Volume 45 Number 2

VEGETABLE SCIENCE

2018

ISSN 0970-6585 (Print)
ISSN 2455-7552 (Online)

VEGETABLE SCIENCE

Volume 45 Number 2 2018

Continued on back cover

Indian Society of Vegetable Science

THE INDIAN SOCIETY OF VEGETABLE SCIENCE

(Registered under the Societies Registration Act XXI 1860)

The Society was founded in 1973 with the following objectives:

i. To promote knowledge and research in vegetable crops and to advance the cause of Vegetable Science in India.

ii. To encourage closer relationship among workers on vegetable crops.

iii. To encourage the development of vegetable cultivation and seed production based on scientific and technical knowledge.

iv. To hold conferences, symposia and meetings from time to time for exchange of ideas and discussion of advances in knowledge of vegetable crops.

EXECUTIVE COUNCIL

President	Dr DP Ray, Bhubaneswar
Immediate Past President	Dr G Kalloo, Varanasi
Vice President	Dr AK Singh, New Delhi
	Dr KV Peter, Chennai
	Dr Brahma Singh, New Delhi
	Dr Nazeer Ahmad, Srinagar
	Mr Suresh O Agrawal, Jalna
Secretary	Dr B Singh, Varanasi
Joint Secretary	Dr Major Singh, Varanasi
Treasurer	Dr RN Prasad, Varanasi

COUNCILLORS

Dr NC Gautam, Chitrakoot	Dr SNS Chaurasia, Varanasi
Dr ML Chadha, Hisar	D. Nirmla Devi, Thrissur
Dr Balraj Singh, Jodhpur	Dr Jitendra Singh, Raipur
Dr AK Pandey, Passighat	Dr M Vijaya, Hyderabad
Dr AK Singh, Ranchi	Dr V Kanthaswamy, Karaikal
Dr AS Dhatt, Ludhiana	Dr SK Tripathi, Nuziveedu Seeds
Dr KB Kathiria, Anand	Dr JC Rajput, Nirmal Seeds
Dr BS Tomar, New Delhi	Dr RP Gupta, Nasik
Dr Pritam Kalia, New Delhi	Dr SK Malhotra, New Delhi
Dr PM Singh, Varanasi	Dr Ranvir Singh, New Delhi
Dr Arup Chattopadhyay, Mohanpur	Sh Vimal Chawada, VNR Seeds

EDITORIAL BOARD

Editor	Dr AB Rai, Varanasi
Joint Editor	Dr Nagendra Rai, Varanasi
Board Members	Dr Jagdish Singh, Varanasi
	Dr AT Sadashiva, Bengaluru
	Dr DR Bhardwaj, Varanasi
	Dr BK Singh, Varanasi
	Dr. Sanjeet Kumar, AVRDC, Taiwan
	Dr Satya S Narina, Peterberg, USA

Life membership fee (India) is Rs. 5000.00 and Life membership fee (overseas) is $ 100.00.

Vegetable Science is an official publication of the society and is published twice in a year. Annual subscription rate is Rs. 5000.00 (online/soft copy) and Rs. 10000.00 (Hard copy) for Indian institutions, and $ 200 (online/soft copy) for overseas institutions. Communication regarding membership and other business matters should be addressed to the Secretary, Indian Society of Vegetable Science, Indian Institute of Vegetable Research, Post Bag No. 01, PO- Jakhini (Shahanshahpur), Varanasi-221305, UP, India; Tel. 91-542-2635236/37; Fax: 91-05443-229007; E-mail: secretary.isvs@gmail.com

Vegetable Science (2018) 45(2) : 149-153

Genetic analysis and identification of molecular marker linked to the gene for fruit skin colour in eggplant (*Solanum melongena* L.)

Bhanushree N[1], Partha Saha[1*], BS Tomar[1], YA Lyngdoh[1], Gopala Krishnan S[2], Bishal Gurung[3], RD Meena[1], AD Munshi[1], ND Saha[4] and Chandrika Ghoshal[1]

Received: January 2019 / Accepted: January 2019

Abstract

Eggplant or brinjal is one of the most important Solanaceous crop cultivated widely throughout the country. The dark purple coloured fruit is preferred by consumer due to high anthocyanin content. The degree of pigmentation is unstable, possibly due to influence of environment, growth stage of fruit, etc. The present investigation was carried out to know the genetics of fruit colour and also to identify SSR marker linked to the trait. Cross was successfully attempted between Pusa Safed Baingan 1 (white coloured fruit) × Pusa Uttam (dark purple coloured fruit) to develop F_1. A single F_1 plant was selfed to develop 168 F_2 plants and also backcross (36 BC_1P1, 33 BC_1P_2) progenies developed. The skin colour of parents, F_1, backcross and F_2 plants was evaluated at edible maturity stage and compared with RHS colour chart. Bulk segregant analysis (BSA) was carried out to identify SSR marker linked to the gene for fruit skin colour. Segregation of fruit colour was analyzed by Chi square ($ë^2$) test for goodness of fit. The fruit of F_1 plants was intermediate revealed incomplete dominance. Out of 168 F_2 plants, 125 were purple coloured, 31 green and 12 white which clearly segregated into 12:3:1 (P:G:W) ratio suggesting dominant epistasis with $ë^2$ value of 0.28 (P=0.80-0.90). The BC_1P_1 (Pusa Safed Baingan 1 backcrossed with F_1) showed 15 purple coloured, 11 green coloured and 10 white coloured which segregated in 2:1:1 ratio. Among the 18 parental polymophic SSR markers, only one marker ($emg21I17_{165/200}$) was found to be polymorphic in BSA. This marker is segregated in 1:2:1 ratio suggesting co-segregation and linked with the gene for fruit skin colour. The result will be very useful in designing breeding strategies for developing dark purple coloured variety in eggplant and also the identified SSR marker will be useful in marker assisted breeding.

Keywords: Eggplant, fruit skin colour, SSR marker, MAS

Introduction

Eggplant or brinjal (*Solanum melongena* L.; 2n = 2x = 24), an important member of Solanaceae family, is cultivated globally and accompanied with divergent shapes and colors of skin. It is herbaceous plant grown as annual or biennial with erect, semi-spreading or spreading habits. It is mainly self-pollinated, but due to the presence of heterostyly and tip pore anther dehiscence, cross pollination occur and known as often cross pollinated crop. Wide variation is observed for shape, size and skin colour in different parts of India (Prasad et al. 2015, Chattopadhyay et al. 2009). It is used in ancient medicine due to presence of various desirable phenolic compounds. The main phenolic compound is chlorogenic acid (CGA) which has antioxidants, anti-carcinogenic, anti-inflammatory, anti-obesity, anti-diabetic (type 2) effects (Plazas et al. 2013). The purple skin colour in eggplant is due to polyphenolic anthocyanin and present in the vacuoles of cell in the fruit epicarp (skin) (Helmja et al. 2007; de Pascual Teresa and Sanchez-Ballesta 2008). The most common anthocyanin is nasunin which helps in neutralizing free radicals (Chaudhary and Mukhopadhyay, 2012), fighting cancer (Salem et al. 2013), and also has anti-aging activity (Mai et al. 2012). Therefore, brinjal stands among the top ten vegetables for oxygen radical absorbance capacity (Hanson et al. 2006).

Fruit color is a component that was affected mostly during eggplant domestication. It is very important characteristic for consumer preference as well as

Bhanushree et al.: Identification of molecular marker linked to the gene for fruit skin colour in eggplant

[1]Division of Vegetable Science, [2]Division of Genetics, [4]CESCRA ICAR-Indian Agricultural Research Institute, New Delhi 110012

[3]ICAR-Indian Agricultural Statistics Research Institute, New Delhi 110012

*Corresponding author, Email: hortparth@gmail.com

breeders point of view which display wide range of variations. As eggplant has gained an important component in human daily diet and is being given concern in research, the breeding of brinjal varieties with high purple pigmentation is an effective method to increase the daily intake of these antioxidants. In the recent past, the genetics of fruit skin colour have been reported and many QTLs, genes have been detected or cloned in various crop species (Huang and Hsieh 2015 and Dou et al. 2018). In eggplant the information on genetics of fruit colour is contradictory wherein presence and absence of is under monogenic dominant control (Daunay et al. 2004). Some QTLs for colour development in eggplant fruit have been mapped (Doganlar et al. 2002, Nunome et al. 2001). But, understanding the genetics of skin colour in eggplant is lagging behind than other Solanaceae crops (Paran and Van der Knaap 2007). Molecular markers are powerful tool for tagging and mapping of useful genes in different crop species (Michelmore et al. 1991). The known genetics of skin colour and identification of molecular markers linked to the gene of fruit skin colour is a useful strategy for breeding eggplant varieties with high anthocyanin content. Therefore, the study was undertaken to know the genetics of fruit skin colour and association with SSR markers.

Materials and Methods

Plant materials: The cross was attempted between Pusa Safed Baingan 1 (white skin colur) × Pusa Uttam (dark purple skin colour). The F_1 fruit was light purple (intermediate) in colour. Both the parents were backcrossed with F_1 to develop BC_1P_1 [(Pusa Safed Baingan 1 × Pusa Uttam) × Pusa Safed Baingan 1)] and BC_1P_2 population [(Pusa Safed Baingan 1 × Pusa Uttam) × Pusa Uttam)]. A single F_1 plant was selfed to develop F_2 progeny. The line Pusa Safed Baingan 1 was derived from an indigenous material collected from West Garo Hills, Meghalaya, India. Pusa Uttam was progeny selection of cross GR x 91-2. In the *Kharif* season of 2017, both the parental lines (20 plants each), BC_1P_1 (36 plants), BC_1P_2 (33 plants) and F_2 (168 plants) were transplanted in July at the research farm of the Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi.

Phenotypic observation of fruit skin colour: Observations were recorded from five randomly selected plants from parents, each from BC_1P_1, BC_1P_2 and F_2 generations at edible maturity stage for fruit skin colour. The colour of skin were visually observed and compared with RHS colour chart (6th Edition) and scoring was done as White: 1, Greenish white: 2, Whitish green: 3, Very pale purple: 4; Pale purple: 5, Very light purple: 6, Light purple: 7, Purple: 8, Dark purple: 9 (Fig. 1). Segregation of fruit colour analyzed by Chi-square (÷2) test for goodness of fit (Panse and Sukhatme, 1967).

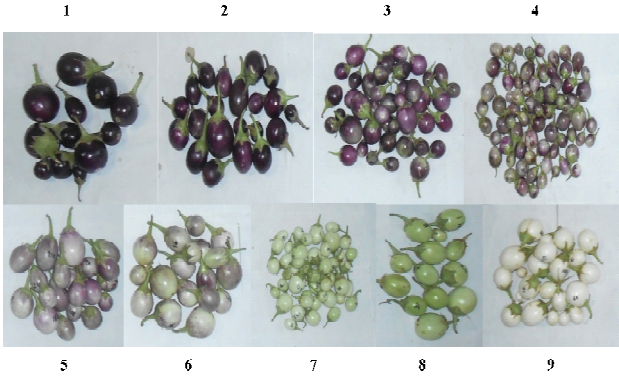

Fig. 1: Scoring of F_2 fruits according to colour where, 1: Dark purple; 2: Pale purple; 3: Light purple; 4: Very light purple; 5: Pale purple; 6: Very pale purple; 7: Whitish green; 8: Greenish white; 9: White

DNA extraction and genotyping of F_2 plants: For the markers analysis only parents and 168 F_2 plants were taken into consideration. DNA was extracted from both the parents and all F_2 plants using CTAB method with modification (Murray and Thompson, 1988). A total of 241 SSR markers were selected from linkage group of Nunome et al. (2009) and used for parental polymorphism between Pusa Safed baingan 1 and Pusa Uttam. DNA bulk was prepared by pooling DNA of ten white fruited plants (B1) and ten dark purple fruited plants (B2) to identify the molecular markers which are putatively linked to the gene for fruit skin colour as per Michelmore et al. (1991). Standard protocol for PCR was followed. The white and dark purple bulks along with parents were screened with polymorphic SSR markers found during parental polymorphism survey. In the gel, different band sizes were present in both the parent and scoring was done accordingly.

Results and Discussion

Genetic analysis of fruit skin colour: The phenotyping of fruit skin colour of parents, F_1, BC_1P_1, BC_1P_2 and F_2 plants is presented in Table 1. Among the parents all the fruits of Pusa Safed Baingan 1 were white in colour whereas fruits of Pusa Uttam were dark purple in colour (Fig. 2). The colour of F_1 fruit was light purple in colour which was intermediate in expression of the parents and this result indicates co-dominance nature of this trait. Similar study was observed by Nunome et al. (2001). A total of 36 BC_1P_1, 33 BC_1P_2 and 168 F_2 plants were phenotyped according to the colour score as

Table 1: Segregation of fruit colour in BC_1P_1, BC_1P_2 and F_2 and inheritance study

Parents/ Progenies	Phenotype of fruit skin colour									Observed plants			Expected ratio	Chi square ($\chi 2$)	probability
	DP	P	LP	VLP	PP	VPP	WG	GW	W	P	G	W			
Pusa Safed Baingan 1									20						
Pusa Uttam	20														
F_1			40												
F_2	18	29	28	18	14	18	17	14	12	125	31	12	12:3:1	0.280	0.80-0.90
BC1P1	0	1	2	1	11	0	9	2	10	15	11	10	2:1:1	1.056	0.50-0.70
BC1P2	7	15	9	2	0	0	0	0	0	33	0	0	-	-	-

DP: Dark purple; P: Purple; LP: Light purple; VLP: Very light purple; PP: Pale purple; VPP: very pale purple; WG: Whitish green; GW: Greenish white; W: White

described in Fig 1. Out of 168 F_2 plants, 125 were purple coloured (dark purple 18, purple 29, light purple 28, very light purple 18, pale purple 14, very pale purple 18), 31 were green coloured (whitish green 17 and greenish white 14) and 12 were white. The segregation of purple: green: white followed 12:3:1 ratio with chi square (÷2) value of 0.28 with probability value of 0.80-0.90 suggesting that the fruit skin colour is governed by dominant epistasis gene action (Table 1). This result is also supported by discrete distribution of fruit colour (data not shown). Our study contradicts the previous report where anthocyanin presence (v/s its absence) is under monogenic dominant control (gene provisionally symbolized A) (Daunay et al. 2004). The observation in BC_1P_1 (Pusa Safed Baingan 1 was backcrossed with F_1) showed 15 purple skinned fruit, 11 green coloured fruit and 10 white coloured fruit which segregated in 2:1:1 ratio with chi square value of 1.056 (P=0.5-0.7). Among BC_1P_2 (Pusa Uttam backcrossed with F_1) plants all the fruits were purple in colour (dark purple 7, purple 15, light purple 9, very light purple 2) and no green or white fruit observed. Our study clearly depicts that purple is dominant over green and white. As in the parental

Fig. 2: Variability for fruit skin colour in parents, F_1, BC_1P_1, BC_1P_2 and F_2 population; P_1: Pusa Safed Baingan 1; P_2: Pusa Uttam; BC_1P_1: [(Pusa Safed Baingan 1 × Pusa Uttam) × Pusa Safed Baingan 1]; BC_1P_2 : [(Pusa Safed Baingan 1 × Pusa Uttam) × Pusa Uttam]

Table 2: Amplification result of the SSR marker $emg21I17_{165/200}$ in 168 F_2 plants

Fruit colour	No of plants	No of plants with target band	No of plants without target band	No of plants without amplification product
Deep purple	18	14	0	4
Purple	29	23	5	1
Light purple	28	23	5	0
Very light purple	18	10	7	1
Pale purple	14	13	1	0
Very pale purple	18	14	4	0
Whitish green	17	10	7	0
Greenish white	14	5	9	0
White	12	8	0	4

lines green colour fruit was not there but in F_2 and BC_1P_1 progenies green colour fruit observed which suggest that there is another gene giving green colour fruit and denoted as *G*. The purple colour gene is denoted as *P*. Both *P* and *G* in recessive form give white fruit coloured fruit (*ppgg*). The green colour fruit is produced when P in recessive and G is in homozygous or heterozygous dominant form *(ppG_)*. The gene dosage effect cannot be over-ruled which give variation in purple/green pigmentation in F_2 and backcross progenies. This is the first study where we clearly demonstrate and symbolize the gene responsible for fruit skin colour in eggplant.

SSR marker linkage analysis: During parental polymorphism survey with SSR markers, 18 were found to be polymorphic. These polymorphic markers were run in BSA (white pool and dark purple pool DNA) along with the parents. Out of 18 markers, only one SSR marker ($emg21I17_{165/200}$) was found to be polymorphic in bulk segregant analysis and selected for genotyping of 168 F_2 plants. The results of single plant analysis and the segregation of marker are presented in Table 2 and Fig. 3. The SSR marker $emg21I17_{165/200}$ amplified a

fragment of 165 bp size in Pusa Safed Baingan 1 and 200 bp size in Pusa Uttam. The specific band of 200 bp was present in the purple pool and dark purple parent (Pusa Uttam), each 10 plants of purple pool and absent in white pool, white parent (Pusa Safed Baingan 1), each 10 plants of white pool. Among 125 purple coloured plants, 22 plants could not amplify the target band specific to Pusa Uttam parent. In 31 green coloured plants, 16 plants were unable to amplify target band. Among12 white fruited plants 8 plants were abled to amplify target band specific to Pusa Safed Baingan 1 whereas 4 plants could not able to amplify any band. The representative gel photograph of F_2 genotyping is presented in Fig. 3. Total 38 plants were not able to amplify target band. The marker was segregated in 1: 2: 1 ratio (165 bp in 37 plants with allele resembles to Pusa Safed Baingan 1 *i.e.* P_1, 62 plants with heterozygous band and 200 bp in 33 plants with allele resembles to Pusa Uttam *i.e.* P_2). This study clearly showed that the SSR marker is co-segregating with the gene of interest. Yi et al. (2009) identified six AFLP markers to be

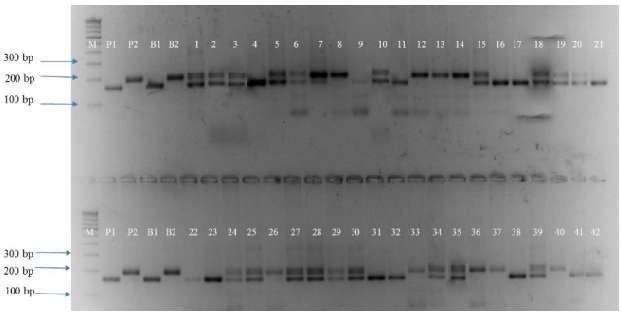

Fig. 3: Genotyping of 168 F_2 plants with SSR emg21I17 marker segregating for fruit colour; M: 100 bp ladder, P1: Pusa Safed Baingan 1; P2: Pusa Uttam; B1: White fruited bulk; B2: Purple fruited bulk; Lane 1-42: 42 F2 plants

associated with peel color of brinjal through bulked line analysis (BLA). Anthocyanin accumulation was found to be determined by a major locus on linkage group 10 which explained as much as 93% (*fap10.1* and *pa10.1*) of the phenotypic variation (Daunay et al. 2004). Nunome et al. (2003) found association of fruit colour with some markers in linkage group 7. They also reported that anthocyanin presence and accumulation are controlled by several different genetic factors in eggplant. In our study we could not find QTLs due to availability of only one polymorphic marker in BSA. The markers developed in this study may be utilized in markers assisted breeding of eggplant improvement. The population will be useful in studying genetics of various traits and trangressive segregants may be identified to develop varieties in future.

सारांश

सोलेनेसी कुल की फसलों में बैंगन पूरे देश में व्यापक रूप से खेती की जाने वाली महत्वपूर्ण फसल है। गहरें बैंगनी रंग के फलों को उपभोक्ताओं द्वारा अधिक पसंद किया जाता है और यह एन्थोसायनिन सामग्री से भरपूर होता है। रंजकता की डिग्री अस्थिर है, जो संभवतः पर्यावरण के प्रभाव, फलों के विकास के चरण आदि के कारण होता है। फल के रंग आनुवंशिकी को ज्ञात करने के लिए और लक्षण से जुड़े एसएसआर मार्कर की पहचान करने के लिए वर्तमान परीक्षण किया गया। संकरों (एफ$_1$) को विकसित करने के लिए संकरणों में पूसा सफेद बैंगन–1 (सफेद रंग का फल) x पूसा उत्तम (गहरे बैंगनी रंग का फल) का प्रयोग किया गया। एक एकल एफ$_1$ पौध से 168 एफ$_2$ पौधों को विकसित किया गया और प्रतीप संकरण (36 बीसी$_1$ पी$_1$, 33 बीसी$_1$ पी$_2$) पूर्वजों को विकसित किया गया। मातृ–पितृ, एफ$_1$, प्रतीप संकरण और एफ$_2$ पौधों की त्वचा का रंग खाद्य परिपक्वता स्तर पर मूल्यांकन किया गया और आरएचएस रंग चार्ट के साथ तुलना की गई। फलों की त्वचा के रंग लिए जीन से जुड़े एसएसआर मार्कर की पहचान करने के लिए थोक अलग–थलग विश्लेषण (बीएसए) किया गया। आवेश की अच्छाई के लिये रूपरेखा तैयार कर परीक्षण द्वारा फलों के रंग के अलगाव का विश्लेषण किया गया। एफ$_1$ पौधों का फल मध्यवर्ती था जिसमें पता चला कि अधूरा प्रभुत्व मौजूद है। कुल 168 एफ$_2$ पौधें में से, 125 बैंगनी रंग के, 31 हरे और 12 सफेद थे जो स्पष्ट रूप से 12:3:1 अनुपात में 0.25 (पीत्र 0.80–0.90) के काई मूल्य के साथ प्रमुख एपिस्टासिस का सुझाव देते हैं। बीसी$_1$पी$_1$ (पूसा सफेद बैंगन–1 को एफ$_1$ के साथ प्रतीप संकरण किया गया था) में 15 बैंगनी रंग का फल, 11 हरे रंग का फल और 10 सफेद रंग का फल पाया गया जिसे 2:1:1 के अनुपात में पाया गया। 18 पैतृक पॉलीमोफिल एसएसआर मार्करों में से केवल एक मार्कर (ईएमजी 21/17165/200) बीएसए में बहरूपी पाया गया। इस मार्कर को 1:2:1 अनुपात में अलग–अलग सह–अलगाव का सुझाव दिया जाता है और फलों की त्वचार के रंग के लिए जीन के साथ जोड़ा जाता है। यह परिणाम बैंगन में गहरे बैंगनी रंग की विविधता विकसित करने के लिए प्रजनन रणनीतियाँ की रूपरेखा तैयार करने में बहुत उपयोगी होगा और साथ ही चिन्हित एसएसआर मार्कर, मार्कर असिस्टेड प्रजनन में उपयोगी होगी।

References

Chattopadhyay DK and Webster DC (2009) Thermal stability and flame retardancy of polyurethanes. Prog Polym Sci 34(10): 1068-1133.

Chaudhary B and Mukhopadhyay K (2012) Induction of anthocyanin pigment in callus cultures of *S melongena* L. in response to plant growth regulators and light. IOSR J Pham 2:76-80.

Daunay MC, Aubert S, Frary A, Doganlar S, Lester RN, Barendse G, van der Weerden, G, Hennart JW, Haanstra J, Dauphin F and Jullian E (2004) Eggplant (*Solanum melongena*) fruit colour: pigments, measurements and genetics. Proc XIIth EUCARPIA meeting on genetics and breeding of Capsicum and eggplant, Netherlands, 17-19 May 2004, pp 108-116.

De Pascual-Teresa S and Sanchez-Ballesta MT (2008) Anthocyanins: from plant to health. Phytochem Rev 7(2): 281-299.

Doganlar S, Frary A, Daunay M, Lester R, Tanksley S (2002) Conservation of gene function in the Solanaceae as revealed by comparative mapping of domestication traits in eggplant. Genetics 161: 1713–1726.

Dou J, Lu X, Ali A, Zhao S, Zhang L and He N (2018) Genetic mapping reveals a marker for yellow skin in watermelon (*Citrullus lanatus* L.). PLoS One 13(9): 0200617.

Hanson PM, Yang RY, Tsou SC, Ledesma D, Engle L and Lee TC (2006) Diversity in eggplant (*Solanum melongena*) for superoxide scavenging activity, total phenolics, and ascorbic acid. J Food Compos Anal 19(6): 594-600.

Helmja K, Vaher M, Gorbatšova J and Kaljurand M (2007) Characterization of bioactive compounds contained in vegetables of the Solanaceae family by capillary electrophoresis. Proc Estonian Acad Sci Chem 56: 172-186.

Huang HY and Hsieh CH (2015) Genetic research on fruit color traits of the bitter gourd (*Momordica charantia* L.). Hort J 86(2): 238-243.

Mai Y and Eisenberg A (2012) Self-assembly of block copolymers. Chem Soc Rev 41(18): 5969-5985.

Michelmore RW, Paran I and Kesseli RV (1991) Identification of markers closely linked to disease-resistance genes by bulked segregant analysis: a rapid method to detect markers in specific genomic regions by using segregating populations. Proc Nat Acad Sci USA 88: 9828–9832.

Murray MG and Thompson WF (1980) Rapid isolation of high molecular weight plant DNA. Nucleic Acids Res 8(19): 4321-4326.

Nunome T, Ishiguro K, Yoshida T and Hirai M (2001) Mapping of fruit shape and colour development traits in eggplant (*Solanum melongena* L.) based on RADP and AFLP markers. Breed Sci 51: 19-26.

Nunome T, Negoro S, Kono I, Kanamori H, Miyatake K, Yamaguchi H and Ohyama A, Fukuoka H (2009) Development of SSR markers derived from SSR-enriched genomic library of eggplant (*Solanum melongena* L.). Theor Appl Genet 119: 143-1153.

Nunome T, Suwabe K, Iketani H and Hirai M (2003) Identification and characterization of microsatellites in eggplant. Plant Breed 122: 256-262.

Panse VC and Sukhatme PV (1967) Statistical Methods for Agricultural Workers, Indian Council of Agricultural Research, New Delhi, 152-162.

Paran I and Van der Knaap E (2007) Genetic and molecular regulation of fruit and plant domestication traits in tomato and pepper. J Exp Bot 58: 3841-3852.

Plazas M, Andújar I, Vilanova S, Hurtado M, Gramazio P, Herraiz FJ and Prohens J (2013) Breeding for chlorogenic acid content in eggplant: interest and prospects. Not Bot Horti Agro 41(1): 26.

Prasad V, Dwivedi VK, Deshpande AA and Singh BK (2015) Genetic combining ability for yield and other economic traits in brinjal (*Solanum melongena* L.). Veg Sci 42(2): 25-29.

Salem MZM, Zeidler A, Böhm M and Srba J (2013) Norway spruce (*Picea abies* [L.] Karst.) as a bioresource: Evaluation of solid wood, particleboard, and MDF technological properties and formaldehyde emission. BioResources 8(1): 1199-1221.

Yi L, Sun BJ, Sun GW, Liu HC, Li ZL, Li ZX, Guo-ping W and Chen RY (2009) AFLP and SCAR markers associated with peel colour in eggplant (*Solanum melongena* L.). Agri Sci China 8(12): 1466-1474.

Vegetable Science (2018) 45 (2) : 154-160

Genetic studies of yield and its component traits using generation mean analysis in summer squash (*Cucurbita pepo* subsp. *pepo*)

Navjot Kaur, Ajmer Singh Dhatt and Mohinder Kaur Sidhu

Received: March 2018 / Accepted: January 2019

Abstract

The present investigation involved the generation mean analysis of six generations (P_1, P_2, F_1, F_2, BC_1P_1 (F_1 × PCK-1) and BC_1P_2 (F1× Lady Godiva) derived from cross of PCK-1(hulled seed) × Lady Godiva (hull-less seed) in summer squash. The pooled analysis of variances revealed highly significant differences among the generation means of different populations for vine length (cm), leaf length (cm), days to 50% flowering, inter-nodal length (cm), peduncle length (cm), polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), fruit yield per plant (kg), number of seeds per fruit and seed yield per fruit (g).The epistasis was absent for node number of 1st female flower, node number of 1st male flower, number of primary branches, leaf width (cm), days to 1st harvest, number of fruits per plant, average fruit weight (kg), fruit shape index and petiole length (cm), where leaf width, number of fruits per plant, and petiole length with highly significant additive genetic variances and partial dominance can be improved through inbreeding and selection. However, over-dominance in the inheritance of node number to first female flower, node number to first male flower, number of primary branches per vine, days to 1st harvest, average fruit weight and fruit shape index suggested use of heterosis breeding for improvement. Six parameter model unveiled the preponderance of dominance and dominant × dominant [*l*] gene interactions for most of the other traits with the inheritance of many dominant genes carrying small and cumulative effects. However, the opposite effects of dominance [*h*] and the estimates of dominant × dominant [*l*] interactions highlighted duplicate type of gene interactions. Therefore, summer squash cross involving PCK-1(hulled seed) × Lady Godiva (hull-less seed) can be used as a source of dominant genes and inter-allelic gene combinations for the expression of yield and related traits that can be exploited in the form of hybrid vigour through heterosis breeding.

Department of Vegetable Science, Punjab Agricultural University, Ludhiana-141004

*Corresponding author: mksidhu@pau.edu

Key words: Summer squash, gene action, six-generation mean, dominant gene effect, additive gene effect

Introduction

Pumpkins and squashes are member of *cucurbitaceous* family and cultivated during summer season in India. It has round fruits with more than 200 seeds interspersed in a net like mucilaginous fibres in the central inner cavity. Its seeds have a malleable, chewy texture and a subtly sweet, nutty flavour. When roasted, pumpkin seeds are delicious and nutritious that can be enjoyed throughout the year. The seeds contain 40 to 50% oil (Jacks et al. 1972) and also source of proteins, fatty acids, antioxidants, carotenoids, tocopherol, and minerals (Lazos 1986, Fu et al. 2006 and Stevenson et al. 2007). Its oil is used for cooking, roasting, preservation and natural therapies due to anti-diabetic, antihypertensive, antitumor, antibacterial, anti-hypercholesterolemia, strong hypo-triglyceridemic and anti-inflammatory properties (Abd EI-Aziz and EI-Kalek 2011, Dhiman et al. 2009, El-Adawy and Taha 2001, Makni et al. 2011, Rajakaruna et al. 2002, Tsaknis et al. 1997 and Wenzl et al. 2002). Hull-less Styrian (mutant) seed summer squash (*Cucurbita pepo* subsp. *pepo* var. *styriaca*), discovered in late 19th Century in South-East of the Astro-Hungarian Monarchy lacks complete lignifications of the testa (Zraidi et al. 2003, Latifi et al. 2012). The middle three layers of total five are collapsed into the hyaline without any trace of lignin in the testa (Stuart and Loy 1983). Although, the first reference on hull-less seeds of *C. pepo* was published in 1934 by an Austrian scientist Techermak-Seysenegg (1934), but breeding efforts were started in early 60's (Winkler 2000). Hull-less seed have evaded expensive decortication process and favored by the oil and nut industries for commercial production (Idouraine et al. 1996). 'Lady Godiva', a vine type selection from European land races was first time released in 1972 by the USDA. This variety was introduced from USA and crossed with bush type variety Punjab Chappan Kaddu-

1 for studying genetics of economically importance traits in summer squash.

Materials and Methods

The present investigation was carried out during spring-summer seasons using six generations *viz* P_1, P_2, F_1, F_2, BC_1P_1 (F_1 × PCK-1) and BC_1P_2 (F_1× Lady Godiva) derived from cross of PCK-1 × Lady Godiva (hull-less) during spring-summer season of 2014 and 2015. The female parent was bush type and light green with globular-round, smooth skinned fruits having creamish-white and hulled seeds. The male parent 'Lady Godiva' was characterized with long and dark green vines, oval-round, attractive fruits and yellowish-green, hull-less seeds. Nursery of all the generations was raised in pro-trays during February and transplanted in the field during first week of March during the spring-summer season of 2014 and 2015. Experiment was planned in randomized block design (RBD) with three replications, wherein, each replication was comprised of 10 plants for each P_1, P_2 and F_1; 60 plants each of BC_1P_1 (F_1 × PCK-1) and BC_1P_2 (F_1× Lady Godiva) and 120 plants of F_2 population. For hull-less seed trait, the plants were randomly selected from all replications in each generation at the end of the season and presence or absence of seed coat was noticed for each. A healthy crop was raised following recommended cultural practices. The data was recorded on various vegetative characters like vine length (cm), inter-nodal length (cm), number of primary branches, leaf length (cm), leaf width (cm), petiole length (cm), node number for 1st female flower, node number for 1st male flower and days to 50% flowering.

For statistical analysis, the presence or absence of seed coat was observed in each plant of each population and the observed frequencies of each were compared with expected frequencies through ÷2 test. For generation mean analysis, the replicated data from individual plants for different traits under investigation was recorded and generation means were worked out by taking the average of all plants in each replication. Pooled data of two years (2014 and 2015) was used for analysis of variances of all the generations. The deviations of means of all possible inbred lines from the cross of parents were estimated and the scaling test suggested by Mather (1949) was applied to test the adequacy of additive-dominance model as well as for detecting the presence of non-allelic interactions. In additive dominance model, the generation means were analyzed to get the information about the additive or dominant genetic variances, which were estimated as *m*, [*d*] and [*h*] parameters. The observed generation means were compared with the expected values through genetic expectations. The genetic expectations of the different generations in the absence of epistasis (three parameter model) and presence of epistatic interactions (six parameter model) were defined as F- metric as given by Mather and Jinks (1982). Epistatic interactions included non-allelic interactions ([*i*], [*j*] and [*l*] parameters) as well as new estimates of *m*, [*d*] and [*h*]. The goodness of fit of additive-dominance model or six-parameter model was tested by ÷2 test as follows:

$$a''^2 = \sum_{i=1} (O_i - E_i)^2 \times W_i \text{ for n-p d.f.}$$

Where, O_i and E_i are observed and expected mean value of i^{th} generation. Degree of freedom was calculated by subtracting the number of generations and number of parameters. Standard errors of the parameters m, [*d*], [*h*], ([*i*], [*j*] and [*l*] were computed from the diagonal elements of the inverted information matrix. The significance of individual parameters was tested by »t¼ test.

The goodness of fit model was tested by chi-square test as described earlier, and the model that showed minimum value of chi-square with maximum number of significant parameters was considered the best fit model. The inferences for additive and dominance gene effects were drawn from the best-fit model, when the non-allelic interactions were significant, but from additive-dominance model, when the interactions were absent.

Results and Discussion

Inheritance of hull-less seed trait: The segregating generations derived from a cross of PCK-1 × Lady Godiva (hull-less) were screened for the presence of hull-less trait. The first generation hybrid of cross had hulled seeds that highlighted the monogenic recessive nature of the trait under investigation. Out of 146, 73 and 66 plants in F2, BC_1P_1 and BC_1P_2 for which the data of seed trait was recorded the seeds of 33, 0 and 27 plants were found hull-less, respectively (Table 1). The generations, F2 and BC_1P_2, followed the Mendelian ratio of 3(hulled):1(hull-less) and 1(hulled):1(hull-less) for the inheritance of hull-less seed trait. It suggested that hull-less seed trait in summer squash was controlled by a single recessive gene. For the improvement of this trait, homozygous recessive plants can be phenotypically identified in the segregating generations. The genetic behaviour of hull-less trait has also been reported by Winkler (2000). Gong *et al* (2008) also reported that four SSR markers closely linked to hull-less locus (*h*) at 1.5–3.6 cM on *LGp9h* that further be used for early screening of the seedlings for hull-less seed trait.

Table1: Goodness of fit test for hull-less seed trait in summer squash

Population	Observed ratio		Expected ratio		χ^2 cal (P=0.05)	χ^2 tab
	Hulled	Hull-less	Hulled	Hull-less		
P_1(PCK-1)	10	-	-	-	-	-
P_2(Lady Godiva)	-	10	-	-	-	-
F_1(PCK-1×Lady Godiva)	10	-	-	-	-	-
F_2 (PCK-1 × Lady Godiva)	113	33	109.5	36.5	0.446	3.84
BC_1P_1(F_1×PCK-1)	73	0	73	0	0	3.84
BC_1P_2 (F_1× Lady Godiva)	39	27	33	33	2.18	3.84

Genetics of quantitative traits: The pooled analysis of variances for vine length (cm), inter-nodal length (cm), leaf length (cm), days to 50% flowering, peduncle length (cm), polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), fruit yield per plant (kg), number of seeds per fruit, seed yield per fruit (g), and average seed weight revealed highly significant differences among the generation means of populations developed from a cross involving hull-less seeded summer squash (Table 2). However, the generation means of six-populations for all the other characters were non-significantly variable.

Occurrence of epistasis: The presence of epistasis for various quantitative traits was observed from the significance of A, B and C scaling test (Table 3). Significant value of B scale and highly significant value of A and C scales for leaf length (cm) and average seed weight (g) indicated the presence of all the three types of non-allelic interactions viz. additive x additive [*i*], additive x dominance [*j*] and dominance x dominance [*l*] for these characters. Also, significant values of A and B scales for vine length (cm), inter-nodal length (cm), days to 50% flowering, peduncle length (cm), polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), fruit yield per plant (kg), number of seeds per fruit and seed yield per fruit (g) marked the presence of all type of epistasis. However, the insignificant A, B and C scales for node number of 1st female flower, node number of 1st male flower, number of primary branches, leaf width (cm), days to 1st harvest, number of fruits per plant, average fruit weight (kg), fruit shape index and petiole length (cm) was an indication for the absence of non-allelic interactions. The results of scaling tests were in accordance with findings of Mohan et al. (2012) in the ash gourd.

Additive dominance model: Additive dominance model given by Mather and Jinks (1952) explained the genetics of characters, where non-allelic interactions were absent. Therefore, three-parameter model elucidated the genetic behaviour of the traits mentioned in Table 4. Additive genetic variances for leaf width, petiole length and number of fruits per plant were high as compared with dominance genetic variances that expressed the presence of partial dominance for these traits. Therefore, further improvement of these traits should be made by accumulation of additive genetic variances through inbreeding and selection. However, other six characters, such as node number to first female flower, node number to first male flower, number of primary branches per vine, days to 1st harvest, average fruit weight, and fruit shape index, with the absence of non- allelic interactions, had significantly greater magnitude of dominant gene effects in the form of over-dominance. There was a substantial contribution of these effects in inheritance of above said characters. As the over-dominance is predominates the expression of these traits,

Table 2: Combined analysis for generation means showing source of variation and MS for different traits

Parameters	Source of variation					Mean Squares
	Years	Reps(year)	Generations	Gen×Year	Pooled error	
Vine length (cm)	2	4	655	655	652	3547.81**
Inter-nodal length(cm)	2	4	655	655	652	13.25**
Days to 50% flowering	2	4	655	655	652	533.05**
Leaf length (cm)	2	4	655	655	652	49.67**
Equatorial diameter (cm)	2	4	655	655	652	95.15**
Polar diameter (cm)	2	4	655	655	652	53.50**
Flesh thickness (cm)	2	4	655	655	652	2.86*
Fruit yield per plant (kg)	2	4	655	655	652	205598.3**
Seed yield per fruit (g)	2	4	655	655	652	36.15*
Number of seeds per fruit	2	4	655	655	652	2095.75**
Average seed weight (g)	2	4	655	655	652	0.0043*

*, ** Significant at 5% and 1% levels, respectively

Table 3: Occurrence of epistasis for different quantitative traits in summer squash

Parameter	Scaling test		
	A	B	C
Node number of 1st female flower	-1.918±3.28	-2.3±1.91	4.5±7.45
Node number of 1st male flower	-0.95±3.21	-1.40±1.86	6.20±6.65
Days to 50% flowering	61.53±12.98**	46.40±7.54**	7.40±24.98
Number of primary branches	-3.26±2.81	-3.30±1.74	1.90±5.37
Leaf length (cm)	18.43±3.63**	9.30±2.31*	-1.30±7.92**
Leaf width (cm)	-3.21±6.38	-2.40±3.93	-2.30±12.18
Vine length (cm)	141.59±58.65*	122.0±40.19**	11.80±73.87
Inter-nodal length(cm)	9.10±2.67**	4.60±1.66**	0.40±4.78
Days to 1st harvest	8.68±28.42	2.10±25.10	7.50±84.29
Equatorial diameter (cm)	19.94±5.78**	24.70±3.43**	0.50±11.72
Polar diameter (cm)	20.18±6.17**	10.80±4.10**	2.0±12.12
Flesh thickness (cm)	4.04±1.87*	2.10±1.11	-0.90±2.65
Fruit yield per plant (kg)	1156.61±609.14*	874.40±320.14**	165.8±1569.45
Number of fruits per plant	0.21±2.63	0.20±1.56	1.0±5.45
Average fruit weight (kg)	-89.94±188.05	-103.50±141.88	-134.30±323.47
Seed yield per fruit (g)	45.28±14.14**	23.20±9.13*	8.00±14.77
Number of seeds per fruit	168.27±65.22**	211.6±68.20**	61.4±188.54
Average seed weight (g)	-0.24±0.07**	-0.1±0.05*	-0.5±0.16**
Fruit shape index	-0.19±1.53	0.1±0.87	-0.2±2.89
Petiole length (cm)	-1.47±12.48	2.60±8.94	-2.90±25.11
Peduncle length (cm)	18.75±4.19**	20.9±2.71**	-2.90±7.23

*, ** Significant at 5% and 1% levels, respectively

the breeding objective should be set towards the development of hybrids for commercial purpose, because, the present cross cannot be exploited for simple selection in its advanced segregating generations with a selection pressure for more number of branches, earliness and bigger fruits. In contrast, Singh et al. (2002) in ash gourd, Ananthan (2002) in ridge gourd, Chandrakumar (2006) in pumpkin, Tewari et al. (1998)) in bitter gourd observed the additive gene effect in controlling the fruit weight and found predominantly dominant genes controlling the number of primary branches. The presence of significant additive genetic variances for fruit weight and fruit yield per plant and high dominant genetic variances for fruit traits has also been reported by Mohan et al (2012) in ash gourd.

Non-allelic interactions: The traits such as vine length (cm), leaf length (cm), inter-nodal length (cm), days to 50% flowering, peduncle length (cm), polar diameter (cm), equatorial diameter (cm), flesh thickness (cm), fruit yield per plant (kg), number of seeds per fruit, seed yield per fruit (g) and average seed weight (g) marked the presence of all type of epistasis (Table 4). Additive dominance model explained the variation among the generation means, but it was inadequate to explain the inter-allelic interactions for the expression of such traits. Therefore, six-parameter model was further used to elucidate the type of epistasis for each character. The estimation of genetic effects according to six-parameter model is given in Table 5. Dominant gene effects were higher as compared to the additive gene effects for all the characters having non-allelic interactions. The pronounced epistasis and over-dominance for all the traits, except number of branches per plant have also been reported by *Mohanty et al. (1999). Epistasis with predominance of dominant gene effects was also reported by* Sirohi and Ghoruri (1993) in pumpkin.

Although all the three type of genetic effects viz; dominance [*h*] effects, additive ×additive [*i*] and dominant × dominant [*l*] were significant for days to 50% flowering, peduncle length (cm), and equatorial diameter (cm), but dominance and interactions of dominant genes had preponderance and additive ×additive [*i*] non-allelic interactions also play some role in the inheritance of these traits. The positive and negative estimates of dominance and dominant × dominant [*l*] interactions clearly highlighted the presence of duplicate epistasis. On the other hand, the estimates of dominant [*h*] effects and dominant × dominant [*l*] interactions were significant for vine length (cm), leaf length (cm), inter-nodal length(cm), polar diameter (cm), flesh thickness (cm) and average seed weight (g), which indicated that the small effects of many dominant genes with inter-allelic interactions were responsible for the inheritance of these traits. The presence of positive dominant gene effects [h] along with negative dominant × dominant [*l*] interactions also indicated the involvement of duplicate type of epistasis in the inheritance of these characters. Significant variances for dominance [*h*] and additive x additive [*i*] inter-allelic interactions in fruit yield per plant (kg) and number of seeds per fruit explained highly significant

Table 4: Estimation of genetic effects of quantitative traits using additive dominance model in summer squash

S. No.	Parameter	M	[d]	[h]	χ^2	Degree of dominance	Genetics effects
1.	Vine length (cm)	75.88±11.10*	3.24±12.18	11.56±19.24**	3.09	-	Epistasis
2.	Inter-nodal length(cm)	2.51±0.61*	0.49±0.62	0.01±1.01	7.14	-	Epistasis
3.	Number of primary branches	1.96±0.82	0.26±0.82	3.16±1.42	1.07	3.49	Overdominance
4.	Leaf length (cm)	9.92±0.95*	1.05±0.95*	1.41±1.72*	11.79	-	Epistasis
5.	Leaf width (cm)	10.27±1.75	1.02±1.75	-0.45±3.24	0.13	0.66	Partial dominance
6.	Petiole length (cm)	15.62±2.67	4.29±2.69	1.22±4.71	0.11	0.53	Partial dominance
7.	Node number of 1st female flower	2.56±0.94	0.22±0.94	1.12±1.71	0.49	2.26	Overdominance
8.	Node number of 1st male flower	2.04±0.76	0.24±0.76	1.00±1.51	0.46	2.04	Overdominance
9.	Days to 50% flowering	22.82±2.10*	2.58±2.10	12.35±5.97**	15.29	-	Epistasis
10.	Days to 1st harvest	75.94±6.73	0.40±6.74	7.39±14.46	0.05	4.30	Overdominance
11.	Peduncle length (cm)	9.96±1.22*	1.10±1.24*	1.43±2.07*	16.09	-	Epistasis
12.	Equatorial diameter (cm)	10.58±1.59**	0.53±1.60*	1.51±2.78*	11.10	-	Epistasis
13.	Polar diameter (cm)	9.33±1.65*	1.06±1.66*	1.70±3.01*	5.21	-	Epistasis
14.	Fruit shape index	1.03±0.36	0.08±0.36	0.13±0.75	0.01	1.27	Overdominance
15.	Flesh thickness (cm)	2.07±0.45**	0.20±0.45*	0.19±0.83*	2.29	-	Epistasis
16.	Average fruit weight (kg)	179.22±81.54	-0.54±83.10	-36.12±117.97	0.25	8.18	Overdominance
17.	Number of fruits per plant	1.80±0.57	0.07±0.58	0.04±1.19	0.02	0.75	Partial dominance
18.	Fruit yield per plant (kg)	347.65±87.76**	15.07±87.91	116.73±143.44*	2.04	-	Epistasis
19.	Number of seeds per fruit	119.32±5.49**	27.51±5.49	41.39±9.44*	3.59	-	Epistasis
20.	Average seed weight (g)	0.22±0.01*	0.11±0.01*	-0.002±0.02*	6.60	-	Epistasis
21.	Seed yield per fruit (g)	12.83±1.67*	2.45±1.68*	5.17±3.23*	4.34	-	Epistasis

M= mean; d =additive variance; h=dominance variance. *, ** Significant at 5% and 1% levels, respectively

Table 5: Estimates of non-allelic gene interactions for expression of quantitative traits in summer squash

S. No.	Parameter	M	[d]	[h]	[i]	[j]	[l]	χ^2	Type of Epistasis
1.	Vine length (cm)	-179.0±191.91	3.8±12.39	777.1±512.13*	251.9±191.51	-	-515.5±326.42*	0.02	duplicate
2.	Inter-nodal length(cm)	-12.0±9.46	0.30±0.63	42.70±22.78*	14.10±9.44	-	-28.70±13.71*	0.93	duplicate
3.	Leaf length (cm)	-19.80±15.52	0.70±0.98	86.50±36.07*	29.01±15.48	-	-56.80±21.23**	1.25	duplicate
4.	Days to 50% flowering	-78.80±47.54	2.20±2.13	312.90±111.10**	100.50±47.50*	-	-208.40±66.12**	0.35	duplicate
5.	Peduncle length (cm)	-33.6±15.10	0.90±1.29	125.5±37.04**	42.50±15.04**	-	-82.20±22.66**	0.05	duplicate
6.	Equatorial diameter (cm)	-34.70±22.71	0.50±1.66	133.0±53.03*	44.1±22.65*	-	-88.6±31.34**	0.15	duplicate
7.	Polar diameter (cm)	-20.5±23.58	0.80±1.71	89.8±55.59*	29.0±23.52	-	-60.0±33.14*	0.52	duplicate
8.	Flesh thickness (cm)	-5.10±5.96	0.10±0.47	20.20±15.22*	7.0±5.94	-	-13.10±9.54*	0.22	duplicate
9.	Fruit yield per plant (kg)	-1533.60±3033.14	8.90±88.65	5869.0±6848.25*	1865.20±3031.84*	-	-3896.20±3911.86	0.04	duplicate
10.	Number of seeds per fruit	-199.6±406.59	27.5±5.49	1057.4±982.42**	318.4±406.55*	-	-698.3±589.79	0.05	duplicate
11.	Average seed weight (g)	0.1±0.34	0.1±0.01	-0.2±0.82*	0.1±0.34		0.3±0.49*	0.44	duplicate
12.	Seed yield per fruit (g)	-48.0±45.58	2.1±1.70	194.0±125.61	60.4±45.55*	-	-128.9±81.14**	0.35	duplicate

M= mean; d =additive; h=dominance; i= additive ×additive; j= additive ×dominance; l= i= dominance×dominance. *, ** Significant at 5% and 1% level, respectively.

expression of dominant genes along with additive x additive [i] gene interactions for the inheritance of these traits. The opposite signs of dominance [*h*] and dominant × dominant [*l*] interactions marked the presence of duplicate gene effects for these traits also. For seed yield per fruit (g), additive x additive [*i*] as well as dominant × dominant [*l*] interactions were significant, but dominance and its interactions played major role in expression through duplicate gene interaction. The preponderance of dominant gene effects can be

substantiated with findings of *Mohanty et al. (1999)*. The duplicate types of digenic non-allelic interactions were found by Mohan et al. (2012) in almost all the crosses for most of the traits except for vine length in ash gourd. The findings of equatorial diameter and polar diameter were in agreement with Bharathi et al. (2006) and Arvindkumar (2004) in muskmelon and Celine and Sirohi (1996) in bitter gourd, respectively. The earlier findings of Singh et al. (2000) in bottle gourd and Sharma and Bhutani (2001) in bitter gourd and Mohanty and Mishra (1999a and 1999b) and Chandrakumar (2006) in pumpkin are also in accord with the present investigation.

The genetic studies highlighted that hull-less seed trait is controlled by single recessive gene and can be identified in segregating generations. The preponderance of dominance and dominant × dominant [*l*] gene interactions for most of the traits having epistasis in the present investigation revealed that the expression of these characters is controlled by many dominant genes with small and cumulative effects. The opposite effects of dominance [*h*] and the estimates of dominant × dominant [*l*] interactions highlighted duplicate type of gene interactions. Due to dominance and epistatic interactions, the isolation of recombinant lines for these traits will not be possible. The results of present study explained that the parental cross involving bush type variety PCK-1 and vine type variety Lady Godiva (Hull-less) was useful source of favourable dominant genes and inter-allelic gene combinations for the expression of these traits in the form of hybrid vigour. Therefore, dominant variances and the epistasis with high magnitude of dominant interactions can only be exploited through heterosis breeding.

सारांश

छप्पन कद्दू में छः पीढ़ियाँ (पी.$_1$, पी.$_2$, एफ.$_1$, एफ.$_2$, बीसी$_1$ पी$_1$ (एफ$_1$ ग पी.सी.के.–1) और प्रतीप संकरण पी.$_2$ (एफ$_1$ ग लेडी गॉडिया) का विश्लेषण किया गया जिनमें पी.सी.के (छिलका युक्त बीज) ग लेडी गॉडिया (छिलका रहित बीज) के आपसी संकरण से प्राप्त हुआ विभिन्न संततियों का प्रयोग किया गया। विभिन्न संततियों की लता लम्बाई (मीटर), पत्ती की लम्बाई (सेन्टी मीटर), 50 प्रतिशत पुष्पन (दिनों में), अन्तर पार्श्व लम्बाई (सेन्टी मीटर), फल वष्न्त की लम्बाई (सेन्टी मीटर), व्यास (सेन्टी मीटर), मध्य व्यास (सेन्टी मीटर), गूदा की मोटाई (सेन्टी मीटर), प्रति पौध फल उपज (किलोग्राम), प्रति फल बीजों की संख्या और बीज उपज प्रति फल (ग्राम) में सार्थक विविधता पाई गई। प्रथम मादा पुष्पन की पार्श्व गाँठ पर विकास, नर पुष्प की पार्श्व गाँठ संख्या, प्राथमिक शाखाओं की संख्या, पत्ती की चौड़ाई (सेन्टी मीटर), कटाई के दिन, प्रति पौध फलों की संख्या, फलों का औसत वजन (किलोग्राम), फल के आकार एवं पर्ण वष्न्त की लम्बाई (सेन्टी मीटर) के लिए एपिस्टासिस सूचकांक अनुपस्थित पाया गया तथा पत्ती की चौड़ाई (सेन्टी मीटर), प्रति पौध फलों की संख्या और पर्ण वष्न्त की लम्बाई (सेन्टी मीटर) का अत्यधिक महत्वपूर्ण योगात्मक अनुवांशिक प्रसरण पाया गया और आंशिक प्रभाव के साथ अन्त प्रजनन अवनयन के लिए चयन प्रक्रिया के माध्यम से उन्नत किया जा सकता है। हालांकि प्रथम मादा पुष्प की पार्श्व गांठ संख्या, प्रथम नर पुष्प की पार्श्व गांठ संख्या, प्रति लता प्राथमिक शाखाओं की संख्या, प्रथम कटाई के दिन, फल का औसत वजन एवं फल के आकार पर प्रभाव के सूचकांक में उन्नयन के लिए प्रजनन ओज का उपयोग करने का सुझाव प्रस्तुत किया गया है। छः प्राचाल प्रतिमान ने अन्य लक्षणों के प्रभाव हेतु प्रभाविता और प्रभावी ग प्रभावी (एल) जीन के आपसी प्रक्रिया का अनावरण स्पष्ट होता है जिसमें छोटे और संचयी प्रभाव वाले कई प्रमुख वंशाणुओं की एकरूपता दिखती है। हालांकि प्रभाव के विपरीत प्रभाव (एच), प्रभावी ग प्रभावी (एल) क्रिया प्रभाव के अनुमानों में अनुलिपि प्रकार के वंशाणु का प्रभाव स्पष्ट होता है इसलिए पी.सी.के (छिलका युक्त बीज) x लेडी गॉडिया (छिलका रहित बीज) से युक्त छप्पत कद्दू के संकरण में उपज की अधिकता और सम्बन्धित लक्षणों के प्रमुख वंशाणु और वंशाणुओं के आपसी प्रक्रिया संयोजन के स्रोत के रूप में उपयोग किया जा सकता है जिनमें ओज प्रजनन के माध्यम से संकर ओज की क्षमता प्राप्त की जा सकती है।

References

Abd EI-Aziz AB and EI-Kalek A (2011) Antimicrobial proteins and oil seeds from pumpkin (*Cucurbita moschata*). Nature Sci 9: 105-119.

Anantham M, Balakrishnamoorthy G and Natarajan S (2002) Genetic variability in ridge gourd (*Luffa cucutangula*). South Indian Hort 53: 326-328.

Aravindkumar J S (2004) Genetics of yield and yield components in muskmelon (*Cucumis melo* L.). Ph. D. (Hort.) Thesis. University of Agricultural Sciences, Bangalore.

Bharathi LK, Naik G and Dora DK (2006) Studies on genetic variability in spine gourd (*Momordica cochichinensis*). Indian J Hort 63(1): 96-97.

Celine VA and Sirohi PS (1996) Heterosis in bitter gourd (*Momordica charantia* L.). Veg Sci 23(2): 180-185.

Chandrakuma NL (2006) Genetics of growth, yield and quality parameters in pumpkin (*Cucurbita moschata* Duch. Ex. Poir). M.Sc. (Hort.) Thesis, University of Agricultural Sciences, Dharwad.

Dhiman AK, Sharma KD and Attri S (2009) Functional constituents and processing of pumpkin: a review. J Food Sci Tech 46: 411-117.

Edelstein M, Paris HS and Nerson H (1989) Dominance of bush growth habit in spaghetti squash (*Cucurbita pepo*). Euphytica 43: 253-257.

El-Adawy TA and Taha KM (2001) Characteristics and composition of watermelon, pumpkin and paprika seed oils and flours. J Agric Food Chem 49: 1253-1259.

Fu CL, Shi H and Li QH (2006) A review on pharmacological activities and utilization technologies of pumpkin. Plant Foods Human Nutr 61:70-77.

Gong L, Stift G, Kofler R, Pachner M and Lelley T (2008) Microsatellites for the genus *Cucurbita* and an SSR-based genetic linkage map of *Cucurbita pepo* L. Theo Appl Genet 117: 37–48.

Idouraine A, Kohlhepp EA, Weber CW, Warid A and Martinez-Tellez JJ (1996) Nutrient constituents from eight lines of naked seed squash (*Cucurbita pepo* L.). *J Agric Food Chem* 44: 721–724.

Jacks TJ, Hensarling TP and Yatsu LY (1972) Cucurbit seeds: I. Characterizations and uses of oils and proteins. A review. Econ Bot 26:135-141.

Lazos ES (1986) Nutritional, fatty acid and oil characteristics of pumpkin and melon seeds. J Food Sci 51:1382-1383.

Latifi M, Barimavandi A, Sedaghathoor S and Lipayi SR (2012). Sowing date and plant population effects on seed yield of *Cucurbita pepo*. Inter J Agric Biol 14: 641-644.

Makni M, Fetoui H, Gargouri NK, Garouri EM, Zeghal N (2011) Anti-diabetic effect of flax and pumpkin seed mixture powder: Effect on hyperlipidemia and antioxidant status in alloxandiabetic rats. J Diabetes Complicat 25:339-345.

Mather K (1949) Biometrical Genetics. Methuen and Company, London, pp 162.

Mather K and Jinks JL (1982) Biometrical Genetics. Chapman and Hall, London.

Mohan NB, Madalageri MB, Mulge R, Adiger S and Kencharaddi HG (2012) Genetics of vine yield and yield contributing traits in ashgourd (wax gourd) . Plant Arch 12: 731-136.

Mohanty BK, Mohanty SK and Mishra RS (1999) Genetics of yield and yield components in pumpkin (*Cucurbita moschata).* Indian J Agric Sci 69: 781-783.

Mohanty BK and Mishra RS (1999a) Studies on heterosis for yield and yield attributes in pumpkin (*Cucurbita moschata* Duch. Ex. Poir.). Indian J Hort 56: 173-178.

Mohanty BK and Mishra RS (1999b) Variation and genetic parameters of yield and its components in pumpkin (*Cucurbita moschata*). Indian J Hort 56: 337-342.

Rajakaruna N, Harris CS and Towers GHN (2002) Antimicrobial activity of plants collected from serpentine outcrops in Sri Lanka. Pharmaceutical Bio 40: 235-244.

Sharma NK and Bhutani RD (2001) Genetic analysis of yield and fruit number in bitter gourd (*Momordica charantina*). Haryana J Hortic Sci 28: 88-91.

Singh KP, Panda PK and Singh AK (2002) Variability, heritability and genetic advance in ash gourd. Haryana J Hortic Sci 31: 139-140.

Singh P, Kumar JC and Sharma JP (2000) Genetic estimates in long fruited bottle gourd (*Lagenaria siceraria*). Veg Sci 27: 162-164.

Sirohi PS and Ghoruri S (1993) Gene effects of certain quantitative characters in pumpkin (*Cucurbita moschata*). Veg Sci 20: 158-162.

Stevenson DG, Eller FJ, Wang L, Jane JL, Wang T and Inglette GE (2007) Oil and tocopherol content of pumpkin seed oil in 12 cultivars. J Agric Food Chem 55: 4005-4013.

Stuart SG and Loy JB (1983) Comparison of testa development in normal and hull-less seeded strains of (*Cucurbita pepo* L.). Bot Gazette 144: 491-500.

Tewari D Harihar Ram and Jaiswal H (1998) Gene effects for various horticultural traits in bitter gourd (*Momordica charantia* L.). Veg Sci 25: 159-161.

Tsaknis J, Lalas S and Lazos ES (1997) Characterization of crude and purified pumpkin seed oil. Grasas Y Aceites 48:267-272.

Tschermak-Seysenegg E (1934) Der kurbis mit schalenlosen samen, eine beachtenswerte Olfruct. Wiener Landwirts Zeit 84: 7-15.

Wenzl T, Prettner E, Schweiger K and Wagner FS (2002) An improved method to discover adulteration of Styrian pumpkin seed oil. J Biochem Biophysics Meth 53:193-202.

Winkler J (2000) Breeding of hull-less seeded pumpkins *(Cucurbita pepo*) for the use of the oil. Seed Sci Res 510:123-28.

Zraidi N, Pachner M and Lelley T (2003) On the genetics and histology of hull-less character of Styrian oil-pumpkin (*Cucurbita pepo* L.). CGC Report 26: 57-61.

Vegetable Science (2018) 45 (2) : 161-165

Variability and character association studies for horticultural and quality traits in garden pea (*Pisum sativum* L. var. hortense)

Jyoti Devi[1]*, SK Sanwal[1,2], Tanmay K Koley[1,3], RK Dubey[1], PM Singh[1] and B Singh[1]

Received: September 2018 / Accepted: January 2019

Abstract

The present study was conducted to examine the variability, heritability and correlation of important yield and quality traits and to determine the relative importance of primary and secondary traits as selection criteria to improve productivity in garden peas. Twenty-two diverse genotypes were grown in Randomized Complete Block Design with three replications during 2015-16. The data was collected on ten horticultural and four quality traits. Significant variations existed in all the traits. High value of PCV and GCV (e"20) were recorded for days to 50% flowering, plant height, average pod weight, number of pod per plant**,** 100-green seed weight, green pod yield per plant and for quality traits viz., total phenolics contents, total flavonoids contents, CUPRAC and FRAP activities. This indicates that selection can be applied on the traits to isolate more promising line. High heritability (e"80%) and high genetic advance (e"50) were noticed for plant height, number of pod per plant, total phenolics contents, total flavonoids contents, CUPRAC and FRAP activities which indicated the role of additive gene action for the inheritance of these traits and are likely to respond better to selection. However, green pod yield per plant revealed moderate heritability and genetic advance. Correlation studies for green pod yield per plant showed a positive and significant correlation with days to 50% flowering, average pod weight and number of pod per plant suggesting improvement of yield by giving special focus to these traits. However, total phenolics and flavonoids contents were found negatively correlated with pod yield.

Keywords: Garden pea, heritability, genetic advance, pod yield and antioxidants activities

[1]ICAR-Indian Institute of Vegetable Research, Post Box 1, Jakhini, Varanasi–221 305

[2]ICAR- Central Soil Salinity Research Institute, Karnal- 132 001

[3]ICAR-Research Complex for Eastern Region, Patna-800014

*Corresponding author, Email: jyoti17iivr@gmail.com

Introduction

Garden peas (*Pisum sativum* var. *hortense* L.) is an Old World legume first cultivated 10,000 years ago, and referred as most economically important domesticated crop till date. Being high in nutritive value and its growing acreage, it has attained a status of primary pulse (FAO 2004) and serving as a major source of protein (23-33%) and nutrients in the vegan diet (Devi et al. 2018). It is low in fat but high in fiber, protein, ascorbic acid, ß-carotene, thiamine, riboflavin and iron (National Food Administration 2002). Its non-nutritive biologically active components include alkaloids, flavonoids, glycosides, isoflavones, phenols, phytosterols, phytic acid, protease inhibitors, saponins, and tannins that have been reported to contribute to its anti-carcinogenesis properties (Rungruangmaitree and Jiraungkoorskul 2017). In India, garden pea covers 0.5 m ha area with 4.81 mt of production and stands second in total green pea's production after China, sharing 24% of world production. However, insight into area and production data for last two decades showed surprising facts that although the area under green peas production has crossed double from 0.2 m ha since 1993 to 0.5 m ha in 2016, a decreasing trend in productivity has been observed from 13.3t/ha to 9.7t/ha. This might be due to multiple challenges raised by various biotic and abiotic stresses and stagnation in yield performances of newly bred cultivars. Therefore, there is an indispensable demand for varietal improvement in such situation. Yield is a complex trait, dependent on many other component traits that are further interacting with environment. Therefore, to breed the new cultivars, success of any breeding programme depends on the existing genetic variability in the base population that could lead to effective selection to obtain high yielding progenies. A comprehensive knowledge on genetic variability, heritability and genetic advance are pre requisite for improvement of any crop for selection of superior genotypes and improvement of any trait. Similarly,

information on character association in peas is important for effective and rapid selection in crop improvement. It is important to highlight that though reports on variability studies for various horticultural traits in garden peas are available, genetic information on quality traits such as total phenolics, total flavonoids and antioxidants activities is limited. In line with this, the objective of the study was to examine the existence of genetic variability, heritability, genetic advance in 22 diverse accessions of garden peas for various yield and quality traits and to determine the relative importance of primary and secondary traits as selection criteria to improve productivity.

Materials and Methods

Twenty-two diverse genotypes of green-pea that differs in maturity group, plant-height, flower-color, seed-shape and mature seed coat color comprised the basic experimental materials. These genotypes were evaluated for various horticultural and quality traits at Experimental Farm of ICAR- Indian Institute of Vegetable Research, Varanasi, located at 82°52'37'' E and 25°18'21'' N at an elevation of 83 m above the mean sea level (AMSL). Field evaluation of genotypes for yield and yield contributing traits was carried out in Randomized Block Design (RBD) with three replications during *Rabi*, 2015-16. Each genotype was grown in plot size of $3m^2$ by keeping the row-to-row and plant-to-plant spacing at 30 × 10 cm. The standard agronomical practices were adopted to raise the healthy crop.

The observations were recorded on randomly taken ten plants of each genotype for yield and its contributing traits viz., days to 50% flowering, plant height (cm), pod length (cm), pod width (cm), seeds per pod, 100-green seed weight; number of pod per plant, average pod weight (g), yield per plant (g) and shelling percentage. The quality traits include total phenolics and total flavonoids contents, and their antioxidant activities through two different methods viz., Cupric Reducing Antioxidant Capacity (CUPRAC) and Ferric Reducing Antioxidant Power (FRAP). Fresh green-pea pods at the edible stage were randomly selected for total phenolic, total flavanoids and antioxidants estimation. Further, mature green-seeds were used for each biochemical trait and analysis of each sample was done in triplicates. TPC estimation was performed spectrophotometrically using Folin-Ciocalteau reagent (Singleton et al. 1999) whereas; total flavonoids content was evaluated using aluminium chloride method (Zhishen et al. 1999). CUPRAC assay was performed as described by Apak et al. (2005) and FRAP was estimated as described by Benzie and Strain (1996).

Mean, standard deviation, standard error, and coefficient of variation (CV) of each trait were calculated by subjecting the data on yield and related component traits to the analysis of variance (Gomez and Gomez 1983). The genotypic and phenotypic coefficient of variations (GCV and PCV) and heritability (broad sense) were estimated by following method of Burton and De Vane (1953). Genetic advance (GA) was calculated as per Burton and De Vane (1953) and Johnson et al. (1955). Coefficients of correlation were calculated as suggested by Al-Jibouri et al. (1958). Statistical analysis was performed using Windostat version 8.5 (http://www.indostat.org). Limits used for categorizing the magnitude of different parameters adopted from Devi et al. (2015) as GCV and PCV values are high (More than 20); moderate (10-20) and low (Less than 10); heritability values are high (More than 80); moderate (50-79) and low (Less than 50) and genetic advance are high (More than 50), moderate (25-49) and low (Less than 25).

Results and Discussion

Genetic variability: Crop genetic diversity treated as wealth of the breeders as adequate variability provides options from which selections are made for improvement and possible hybridization for novel recombinants. Analysis of variance revealed significant differences (P = 0.05) among genotypes for all the fourteen traits studied. The estimates of mean, range, genotypic and phenotypic coefficient of variations for various traits are presented in Table 1. Selection within the genotypes for a particular trait is effective when magnitude of variations in the breeding population is good enough. The genotypes showed highest diversity for the trait viz., total phenolics contents (10 folds over the minimum value) followed by plant height, green pod yield per plant, days to 50% flowering and total flavonoids contents indicating that these traits have more scope for genetic improvement. Contrary to these, least variation was observed for the traits viz., pod width, pod length, seeds per pod and average pod weight in the experimental materials used.

Furthermore, estimates of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) ranged from 5.90 -96.88 and 8.69-97.98, respectively. High value of PCV and GCV (e"20%) were recorded for days to 50% flowering, plant height, average pod weight, number of pods per plant**,** 100-green seed weight, green pod yield per plant and for quality traits viz., total phenolics contents, total flavonoids contents, CUPRAC and FRAP activities. It indicates that selection can be applied on these traits to isolate more promising lines. High PCV and GCV values

Table 1: Estimates of variability for different horticultural and quality traits in twenty-two genotypes of garden pea

Traits	Range		Mean ± SE(m)	GCV (%)	PCV (%)	h² (%) (bs)	GA as % of Mean
	Minimum	Maximum					
Horticultural traits							
Days to 50% flowering	32.33	76.67	53.88±1.81	27.52	28.13	95.7	29.88
Pod length (cm)	6.31	9.97	8.11±0.31	13.37	14.94	80.1	24.65
Pod width (cm)	0.97	1.66	1.21±0.03	13.63	14.38	89.8	26.60
Plant height (cm)	46.43	170.23	84.35±4.92	31.49	33.07	90.7	61.76
Average pod weight (g)	2.49	7.87	5.43±0.46	23.67	27.84	72.4	41.51
Number of pod per plant	7.17	21.07	11.42±0.99	28.99	32.71	78.6	52.95
Seeds per pod	5.17	9.10	7.24±0.35	11.38	14.14	64.8	18.88
100-green seed weight (g)	34.7	76.2	56.91±2.30	21.36	22.49	90.3	41.8
Green pod yield per plant (g)	22.67	86.00	56.49±5.80	25.65	31.22	67.5	43.40
Shelling percentage	41.67	55.72	50.90±1.88	5.90	8.69	46.0	8.24
Quality traits							
Total phenolics content (mg GAE/100 g fw)	12.63	128.63	32.76±1.79	85.65	86.17	98.8	175.38
Total flavonoids content (mg CE/100 g fw)	4.61	45.84	13.44± 1.23	73.43	75.13	95.5	147.84
Antioxidant Activities							
CUPRAC (µmol TE/g fw)	3.20	27.79	7.47±0.61	80.92	82.17	97.0	164.15
FRAP (µmol TE/g fw)	0.41	11.70	2.29±0.19	96.88	97.98	97.8	197.34

GCV: Genotypic coefficient of variation; PCV: Phenotypic coefficient of variation, h²: heritability; GA: genetic advance; CUPRAC: Cupric ion antioxidant reducing capacity; FRAP: ferric reducing/antioxidant power

for plant height, number of pod per plants and 100-green seed weight were also observed by Davendra et al. (2013) and for days to 50% flowering, plant height, pod weight and 100- seed weight by Selvi et al. (2014). On the other side, moderate values were observed for pod length, width and seeds per pod suggested that these traits can be improved only by applying vigorous selection. Higher phenotypic coefficient of variation than genotypic coefficient of variation indicated that most of the yield attributes were under the influence of environment. Further, phenotypic coefficient of variation also had similar trend as genotypic coefficient of variation and there was a close correspondence between genotypic and phenotypic coefficient of variation for all the recorded traits. It showed that these characters less influenced by the environment.

Heritability and genetic advance: High heritability estimates (e"80%) were observed for days to 50% flowering, pod length, pod width, plant height, 100-

Table 2: Phenotypic and genotypic correlation coefficients for pod yield and quality traits in garden peas

Traits → ↓		Pod length	Pod width	Plant height	Average pod weight	Number of pod per plant	Seeds per pod	Shelling percentage	100- green seed weight	Green pod yield Per Plant
Days to 50% flowering	P	0.018	-0.073	0.358**	-0.420 **	0.494 **	-0.025	-0.330 **	-0.395**	0.235
	G	0.042	-0.053	0.390**	-0.501**	0.569**	-0.082	-0.502**	-0.431**	0.318**
Pod length	P	1.000	0.509 **	-0.456 **	0.309 *	-0.250 *	0.379 **	-0.164	0.302 *	0.131
	G	1.000	0.545**	-0.523**	0.439**	-0.372**	0.512**	-0.194	0.322**	0.109
Pod width	P		1.000	-0.282 *	0.232	-0.220	-0.013	-0.468 **	0.431 **	0.131
	G		1.000	-0.310*	0.292*	-0.270*	0.065	-0.742**	0.469**	-0.016
Plant height	P			1.000	-0.643 **	0.414 **	-0.279*	-0.279 *	-0.518 **	-0.139
	G			1.000	-0.827**	0.461**	-0.302*	-0.360**	-0.568**	-0.016
Average pod weight	P				1.000	-0.489 **	0.044	0.130	0.644 **	0.402**
	G				1.000	-0.541**	0.068	0.296*	0.814**	0.336**
Number of pod per plant	P					1.000	0.021	-0.042	-0.523**	0.542**
	G					1.000	0.036	-0.153	-0.622**	0.585**
Seeds per pod	P						1.000	0.213	-0.271 *	0.026
	G						1.000	0.306*	-0.309*	0.046
Shelling percentage	P							1.000	0.030	0.008
	G							1.000	-0.020	0.017
100-green seed weight	P								1.000	0.071
	G								1.000	0.085

*Significant at 5% level of significance and **Significant at 1% level of significance

green seed weight, total phenolics contents, total flavonoids contents, CUPRAC and FRAP activities. Johannsen (1909) stressed that for estimating the actual effects of selection, heritability alone could not be the sole guideline for improvement since high heritability does not mean high expected genetic advance. Hence, prediction on the basis of both the estimates could be more useful. The characters those exhibit maximum heritability and high genetic advance as percentage of mean could be used as powerful tool in selection process such characters are controlled by the additive genes and less influenced by the environment (Panes and Sukhatme1995). In this context, high heritability and high genetic advance (e" 50) were noticed for plant height, number of pod per plant, total phenolics content, total flavonoids contents, CUPRAC and FRAP activities which indicated the role of additive gene action for the inheritance of these traits and are likely to respond better to selection. High heritability along with high genetic advance for the traits viz., days to 50 % flowering, number of pod per plant and 100 -seed weight (Barcchiya et al. 2018); number of pod per plant and total phenol content (Kumar et al. 2015); plant height and number of pod per plant (Thakur et al. 2016) and days to 50% flowering and 100-seed weight (Iqbal et al. 2015) were also reported in their respective experiments. High heritability with moderate genetic advance was observed for the traits viz., days to 50% flowering, pod width, average pod weight and 100- green seed weight. Number of seed per pod and shelling percentage exhibited moderate and low heritability, respectively along with low genetic advance. A similar observation was also made by Sharma and Sharma (2013) in garden peas however, in contrary, Thakur et al. (2016) reported high heritability and genetic advance for these two traits.

Correlation coefficients: Understanding the magnitude and direction of correlations can assist the breeders in selection decisions. Such studies in selection programmes are appreciable when highly heritable traits are associated with the important trait like yield (Kaswan et al. 2018). Estimate of the phenotypic and genotypic correlation coefficients among the ten horticultural traits of garden pea genotypes are presented in Table 2. The correlation studies indicated the greater magnitude of genotypic correlations with pod yield than the phenotypic ones in majority of cases, thus revealing the inherent relationship among these traits. However, genotypic correlation coefficient of average pod weight was less than its corresponding estimates of phenotypic correlation which indicated significant role of environment in the expression of this trait. Correlation study for pod yield showed a positive and significant

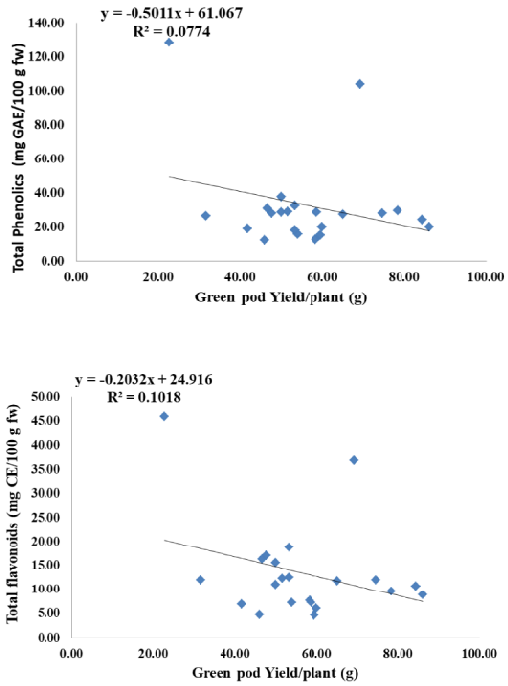

Fig 1: Linear correlation of total phenolics (a) and flavonoids contents (b) with green pod yield per plant

correlation with days to 50% flowering (*rP*=0.235** and *rG*= 0.318**), average pod weight (*rP*=0.402** and *rG*= 0.336**), and number of pod per plant (*rP*=0.542** and *rG* =0.585**), suggesting improvement of yield by giving special focus to these traits through indirection selection (Table 2). High positive correlation of number of pod per plant with pod yield have also been reported by Kumar et al. (2015) and Thakur et al. (2016). Figure 1(a) showed linear correlation of total phenolic with green pod yield per plant (Correlation coefficient, r = -0.278* and coefficient of determination, R^2 = 0.077, significant at the 0.05 level) whereas Figure 1(b) showed linear correlation of total flavonoids with green pod yield per plant (Correlation coefficient, r = -0.319** and coefficient of determination, R^2 = 0.101, significant at the 0.05 level). Thus, both the traits were found negatively correlated with yield. Kumar et al. (2015) also found a negative correlation of total phenol with pod yield in peas.

From the results of the present study, it could be concluded that direct selection can be done for traits viz., days to 50% flowering, plant height, number of pod per plant, total phenolics contents, total flavonoids contents and antioxidant activities since these traits exhibited high genetic variability, heritability and genetic advance. Correlation study revealed positive and significant correlation of green pod yield with days to 50% flowering, average pod weight and number of pod per plant. This showed that selection for these traits

would lead to indirect selection for green pod yield. Further, direct selection for a genotype with high pod yield, phenolics and flavonoids contents is difficult to achieve, due to negative association of above traits, however, genotype with high phenolics contents and high yield could be identify and utilized in crossing programme to incorporate better antioxidant potential along with higher yield traits through pedigree selection from segregating populations.

सारांश

सब्जी मटर में वर्तमान अध्ययन उपज एवं गुणवत्ता वाले लक्षणों की परिवर्तनशीलता, आनुवांशिकता और सहसंबंध की जांच करने तथा उत्पादकता में सुधार के लिए चयन मापदंड के रूप में प्राथमिक एवं माध्यमिक लक्षणों के सापेक्ष महत्व के निर्धारण हेतु किया गया। परीक्षण हेतु वर्ष 2015–16 के दौरान सब्जी मटर के 22 विविध प्रभेदों का यादृच्छिक सम्पूर्ण प्रखण्ड आकार (रैन्डमाईज्ड कम्प्लीट ब्लॉक डिजाइन) में तीन बार प्रतिकृति कर मूल्यांकन किया गया। सभी लक्षणों हेतु सार्थक भिन्नताएं पायी गयी। मटर में 50 प्रतिशत पुष्पन की अवस्था, पौधों की ऊँचाई, औसत फली वजन, प्रति पौध फलियों की संख्या, 100 हरे बीजों का वजन, प्रति पौध फली की उपज और फली गुणवत्ता वाले अन्य लक्षणों जैसे– गुल फेनोलिक्स, फ्लेवोलिक्स, क्यूप्रैक और फ्रैप के लिए बाह्यदृश्य प्रारूप विविधता गुणांक और अनुवांशिक विविधता गुणांक के लिये उच्च मापदंड पाया गया। उच्च आनुवांशिक और उच्च आनुवांशिक उन्नति, पौधों की ऊँचाई, प्रति पौध फल संख्या, कुल फ्लेवोनाइड, क्यूप्रैक और फ्रैप के लिए पाया गया जो चयन प्रक्रिया के लिए महत्वपूर्ण घटक हैं। हालांकि प्रति पौध हरी फलियों की उपज मध्यम आनुवांशिकता और आनुवांशिक उन्नति को प्रकट करती है। कुल फेनोलिक्स एवं फ्लेवोनोइड की मात्रा प्रति पौध फल उपज के साथ नकारात्मक संबंध पाया गया। प्रति पौध हरी फलियों की उपज के लिए सहसंबंध 50 प्रतिशत पुष्पन, औसत फली वजन और प्रति पौध फलियों की संख्या के साथ सकारात्मक और महत्वपूर्ण सहसंबंध पाया। उपरोक्त घटक लक्षणों को आधार मानकर सब्जी मटर के चयन प्रक्रिया सुधार लाया जा सकता है।

References

Al-Jibouri HA, Millar PA and Robinson HF (1958) Genotypic and environmental variances and covariances in an upland cotton cross of interspecific origin. Agron J 50: 632-636.

Apak R, Guclu K, Zyurek MO, Karademir SE, Altun M (2005) Total antioxidant capacity assay of human serum using copper (II)-neocuproine as chromogenic oxidant: The CUPRAC method. Free Radical Res. 39: 949–61.

Barcchiya J, Naidu AK, Mehta AK and Upadhyay A (2018) Genetic variability, heritability and genetic advance for yield and yield components in pea (*Pisum sativum* L.). Inter J Chem Stud 6: 3324-3327.

Benzie IF and Strain JJ (1996) The ferric reducing ability of plasma (FRAP) as a measure of ''antioxidant power'': the FRAP assay. Anal Biochem 239: 70–76.

Burton GW and De Vane EH (1953) Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. Agron J 54: 478-481.

Davendra K, Sunil M, Singh SK, Mukesh K (2013) Genetic Variability, heritability and genetic advance for seed yield and yield components in garden pea (*Pisum sativum* L.). Inter J Plant Res 26(2):182.

Devi J, Mishra GP, Sanwal SK, Dubey RK, Singh PM, Singh B (2018) Development and characterization of penta-flowering and triple flowering genotypes in garden pea (*Pisum sativum* L. var. hortense). PLoS ONE 13, e0201235. doi. 10.1371/journal.pone.0201235.

Devi J, Sharma A, Singh Y, Katoch V and Sharma KC (2015) Genetic variability and character association studies in French bean (*Phaseolus vulgaris* L.) under North-Western Himalayas. Leg Res 38: 149-156.

FAOSTAT (2016) http://www.fao.org/faostat/en/#home (Accessed on 12th April, 2018).

Gomez AA and Gomez KA. Statistical procedure for agriculture research, second Ed. John Willey and Sons, Inc. New York; 1983. pp 357–427.

Johannsen WL (1909) Elemente der exaktenErblickkeitslehre, Fisher, Jewa.

Johnson HW, Robinson HF and Comstock RE (1955) Estimation of genetic and environmental variability in soybean. Agron J 47: 314-318.

Kaswan V, Kaushik A, Devi J, Joshi A and Maloo SR (2018) Genetic association studies for yield and yield contributing traits in *Plantago ovata* Forsk. Electron J Plant Breed 9: 51-59.

Kumar R, Kumar M, Dogra RK and Bharat NK (2015) Variability and character association studies in garden pea (*Pisum sativum* var. hortense L.) during winter season at mid hills of Himachal Pradesh. Leg Res 38: 164-168.

National Food Administration (2002) Food composition database ver. 02.2, code 1155, Uppsala, Sweden.

Panes VG and Sukhatme PV (1995) Statistical methods for agricultural workers. 3rd Edition, ICAR, New Delhi pp 58.

Rungruangmaitree R and Jiraungkoorskul W (2017) Pea, *Pisum sativum*, and its anticancer activity. Phcog Rev 11:39-42.

Selvi BS, Rajangam J and Muthuselvi R (2014) Genetic variability and heritability studies for quantitative traits in pea (*Pisum sativum* L.). Plant Archives 14: 955-959.

Sharma BB and Sharma VK (2013) Genetic variability, heritability and genetic advance studies in garden peas under mid hill condition of Garhwal Himalaya. Environ and Eco 31: 296-301.

Singleton VL, Orthofer R and Lamuela-Raventos RM (1999) Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol 299:152–178.

Thakur S, Thakur R and Mehta DK (2016) Genetic variability and association studies for green pod yield and component horticultural traits in garden pea under high hill dry temperate conditions of Tabo valley of Spiti district of Himachal Pradesh. Inter J Sci Environ Tech 5: 1987 -1992.

Zhishen J, Mengcheng T and Jianming W (1999) The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem 64: 555-559.

Vegetable Science (2018) 45 (2) : 166-172

Screening of tetraploidy induction methods using anti-microtubule agent colchicine in watermelon (*Citrullus lanatus* (Thunb.) Matsum & Nakai)

Barinder Kaur*, Rajinder Singh and Dilbag Singh

Received: November 2018 / Accepted: January 2019

Abstract

Three distinct watermelon genotypes (Sugar Baby, California Sweet and 5255-1-3-1) were subjected to anti-microtubule agent, colchicine with three different doses (0.1%, 0.2% and 0.3%) to induce tetraploidy using three methods viz. shoot apex, seed soaking and inverted hypocotyl. The experiment was carried out at Vegetable Research Farm and Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana during the period 2013-2015. The observations were recorded on chloroplast count, palynological and phenotypic traits to confirm the tetraploidy. California Sweet showed the highest rate of efficiency of generating putative tetraploids (6.12%). Amongst the various methods and concentrations of colchicine for induction of tetraploids, 0.2% and 0.3% concentrations of colchicine by inverted hypocotyl and shoot apex method was comparatively more effective. The highest frequency of putative tetraploids (11.55%) was recorded with inverted hypocotyl method @ 0.3% colchicine.

Keywords: Watermelon, Tetraploid, Induction, Colchicine, Chloroplast count

Introduction

The genus *Citrullus* of the family *Cucurbitaceae* encompasses four diploid species that thrive in Africa, Asia and the Mediterranean (Levi et al. 2001). Among these, *Citrullus lanatus* (Thunb.) Matsum &Nakai is commercially exploited. Presently, seedless watermelons are becoming more preferred because of sweetness and absence of hard seeds (Marr and Gast 1991). Kihara (1951) pioneered the production of triploid seedless hybrid watermelon by crossing a tetraploid (4n) and a diploid (2n) line. To produce the triploid watermelons, development of stable tetraploid breeding line(s) with adequate fertility is a pre requisite (Mohr 1986). The tetraploidy can be induced variously by applying aqueous colchicine solution to the growing apex of diploid seedlings or by soaking diploid seeds in colchicine solution prior to germination (Jaskani et al. 2007, Gaikwad et al 2007, Pradeepkumar 2010-2011) or at hypocotyl portion of diploid germinating seeds (Noh et al.2012, Sheikh et al 2013).The techniques generally used in determining the ploidy level are chromosome count, chloroplast count and phenotypic traits identification. Chromosome counting is difficult in watermelon due to its small chromosome size. The alternative method of counting the number of chloroplasts per guard cell pair of fully expanded leaves using a leaf peel under the microscope (Fassuliotis and Nelson 1992) has been successfully reported in watermelon (McCuistion and Elmstrom 1993). The plant morphological traits such as leaf and flower size, size of the pollen grains and the number of colpi (4 versus 3) are also good indicators for the characterization of ploidy (Rhodes and Zhang 1999). Colchicine treatments induce only 4-6% pure tetraploids in watermelon (Jaskani et al.2004). The major limiting factors in the induction of tetraploids are selection of suitable diploid varieties and induction method with high frequency percentage. Keeping in view, the present study was planned to evaluate the different methods and concentrations of colchicine treatments for tetraploid plants induction in diverse genotypes.

Materials and Methods

The distinct watermelon genotypes *viz.* Sugar Baby (SB), California Sweet (CS) and one advanced breeding line 5255-1-3-1 (5255) were selected to induce tetraploid lines with the different concentrations of colchicine (0.1%, 0.2% and 0.3%) with shoot apex (SA), seed soaking (SS) and inverted hypocotyl (IH) methods. For the shoot apex method (SA 0.1%, SA 0.2% and SA 0.3%), the seeds of each genotype were planted in the polythene bags having mixture of soil and farmyard

Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab

*Corresponding author, Email: barinder-vs@pau.edu

manure in 1:1. One drop of each colchicine solution was applied to the shoot apex of seedlings at the true leaf stage for three consecutive days, in the morning and evening hours. In the seed soaking method (SS 0.1%, SS 0.2% and SS 0.3%), firstly seeds were soaked in water for 24 hours to soften the seed coat. After that, the seeds were soaked in the respective colchicine solution and kept in the dark for 24 hours at room temperature. The treated seeds were rinsed gently in clean water twice and then sown in the polythene bags with similar ratio of soil and farmyard manure. In the Inverted hypocotyl method (IH 0.1%, IH 0.2% and IH 0.3%), seeds of each genotype were kept in petri dishes for germination in incubator at 28^0 C. Germinated seeds were then placed at inverted angle position when radicle became 2 cm long in glass tubes. All the respective colchicine solution was applied to the hypocotyl portion. Colchicine treated seeds were covered tightly with thin plastic film and kept in dark for 15 hours inside an incubator at 28^0 C (Noh et al. 2012). After treatments, the seeds were rinsed gently in clean water 2 times and planted in polythene bags having soil and farmyard manure. This experiment was carried out in randomized complete block design with three replications during 2013-2015 at Department of Vegetable Science, PAU, Ludhiana.

The observations were recorded for the chloroplast count, palyonological (pollen colpi and pollen viability), vegetative (leaf length, leaf width, internode length), flowering (number of days to first female flower), fruiting (number of days to first picking, total soluble solids, fruit weight, rind thickness) and seed (seed number per fruit, developed seeds per fruit, undeveloped seeds per fruit, seed length, seed width, seed thickness, 100 seed weight) traits. Chloroplast count in each side of guard cells of stomata was calculated at 3-5 true leaves stage. The lower epidermis was removed by piercing the leaf with hand and placed on the glass slide after putting a one drop of distilled water and stained with (1%) of Gram's Iodine solution (Fassuliotis and Nelson 1992). The number of chloroplasts was scored and photographed under the light microscope, Leica (LEC Image Analyser) at 40x10 magnifications. Ten microscopic fields of guard cell pairs were examined per leaf from each plant. The chloroplasts per guard cell pairs thus identified, were grouped as diploid (d" 8), tetraploid (11-12) and higher ploidy level (> 12) (McCuistion and Elmstrom 1993). Among the palyonological observations, pollen colpi was calculated in the diploid and tetraploid plants from ten freshly opened staminate flowers, placed on a drop of water on a glass slide. Pollen grains were observed and photographed under the microscope Leica (LEC Image Analyser) at 40x10 magnifications. Several random microscopic fields all over the slide were counted and average worked out. The pollen viability (%) was recorded by dusting pollen on a slide and stained with acetocarmine (1%) under the light microscope, Leica (LEC Image Analyser) magnified by 10 x 10. The averages of ten freshly opened staminate flowers per replication were taken in the morning time. Those pollen grains which were not stained and appeared to have no content were regarded as being abortive. For determining the pollen viability, the number of stained and well filled pollen grains and unstained shriveled pollen grains per unit area were counted in five microscopic fields taken at random and from the average, pollen viability was calculated. Vegetative traits such as leaf length (cm) and leaf width (cm) was recorded from the longitudinal distance from leaf base to leaf apex and the horizontal distance at the widest ends of the leaf by taking three leaves from 7th, 9th and 11th node of five plants per replication using hand held measuring scale, respectively. The first three internodes were taken for the measurement of internode length (cm) from the main vine of five plants per replication using hand held measuring scale. In addition to this, the number of days taken from date of transplanting to date of appearance of first female flower was counted on five plants per replication. Among the different fruiting traits, the number of days taken by the fruit to mature from the date of transplanting was recorded from five plants per replication to determine the days to first picking. The TSS content (^{0}brix) of fruits was determined by putting a drop of juice from five fruits per replication on the hand held refractometer and the freshly harvested fruits were weighed on an electronic balance to measure the fruit weight (kg). The rind thickness (cm) was measured at the middle portion of the fruit after making longitudinal section into two equal halves using Verniers' Calliper. The average rind thickness was calculated from five fruits per replication. After that, seeds were extracted manually and counted with seed counter. The average seed number per fruit, developed seeds per fruit (%) and undeveloped seeds per fruit (%) was taken from five fruits per replication. Seed length (mm) and seed width (mm) was calculated from the longitudinal distance and horizontal distance at widest ends of ten well filled and fully mature seeds taken at random from five fruits per replication, using digital Vernier's Caliper (Mitutoyo Inc., Japan), respectively. Also, the seed thickness (mm) was measured at mid portion of seeds using digital Verniers' Caliper (Mitutoyo Inc., Japan) on the same ten well filled and fully mature seeds selected randomly per replication. 100 seed weight (g) was recorded from 100 well developed seeds counted with

seed counter from five fruits per replication by using an electronic balance and average was taken. Analysis of variance was conducted for various quantitative traits by using WINDOWSTAT 9.3 software and the percentage data were arc sine-transformed.

Results and Discussion

Chloroplast count and palyonological traits: The tetraploids were identified on the basis of number of chloroplasts per guard cell pair, they were grouped as diploid (d" 8.00), tetraploid (11.00-12.00) and higher ploidy level (> 12.00) as described in earlier reports (McCuistion and Elmstrom 1993, Jaskani et al.2005a). The data in Table 1 exhibited that California Sweet had the highest number of chloroplasts per guard cell pair (8.20) and at par with 5255-1-3-1 (8.10), which was significantly different from Sugar Baby. The variation in number of chloroplasts might be due to their genetic make-up. Compton et al. (1996) found genotypic variation with respect to chloroplast guard cells that Royal Sweet had the highest number of chloroplasts per guard cell pair (11.30) and at par with Mickylee (11.00) of watermelon. Among the different methods of colchicine application, treatments SA 0.3%, SA 0.2%, IH 0.3% and SS 0.2% revealed presented significant increase in number of chloroplasts per guard cell pair as compared to other treatments. The interaction between the genotypes and methods of colchicine application revealed that the highest number of chloroplasts (12.00) was significantly recorded in California Sweet with SA 0.2% and statistically at par with California Sweet IH 0.3% and SA 0.3%, Sugar Baby with SA 0.3% and IH 0.3% and 5255-1-3-1 with SA 0.3%, SA 0.2% and SS 0.2% treatments and were putative tetraploids. The rest of the treatments as well as control had significantly lower number of chloroplasts per guard cell pair. Similar results were corroborated by Noh et al.(2012), who treated the five diploid inbred lines of watermelon by applying two concentrations of colchicine with three different methods of application and reported that mean chloroplast count was (18.00) or (19.00) in tetraploids and (12.00) in diploids. The increase in chloroplast count might be due to the fact that cells with a larger complement of chromosomes grow larger to maintain a constant ratio of cytoplasmic to nuclear volume. This increase in size may translate to an increase in plant and its organs (Amiri et al. 2010).

The palyonological observations (pollen colpi and pollen viability) were also recorded (Table 1) to distinguish the effect of different doses of colchicine on watermelon genotypes. The data pertaining to pollen colpi in showed that number of pollen colpi (4.00) were at par in putative tetraploids namely Sugar Baby with SA 0.3% and IH 0.3%, California Sweet with SA 0.2%, SA 0.3% and IH 0.3%, 5255-1-3-1 with SA 0.2%, SA 0.3% and SS 0.2% treatments. These results agreed with the work of Jaskani et al. (2005a) that tetraploids had (4.00) and diploids had (3.00) pollen colpi in watermelon. The increase in number of pollen colpi might be due to the increased cell size. However, pollen viability was the highest in Sugar Baby (75.37%) and highly significant over the other genotypes. Similarly, genotypic variations were studied by Gok et al.(2007) that the highest pollen viability rates (97.40% and 97.36%) in accessions 70 and 71, and the lowest rates (49.65% and 61.08%) were observed in accessions 25 and 24 in the 2,3,5-Triphenyl Tetrazolium Chloride (TTC) test in watermelon. In case of different methods of colchicine application, the

Table 1: Effect of different doses of colchicine on chloroplast count and palynological traits (i.e. pollen colpi and pollen viability) of watermelon genotypes

Treatments (T)		Chloroplast count				Pollen colpi				Pollen viability (%)			
		Genotypes (G)				Genotypes (G)				Genotypes (G)			
		SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean
SA	0.1%	6.67	7.00	7.00	6.89	3.00	3.00	3.00	3.00	78.92	79.32	79.73	79.32
	0.2%	7.00	12.00	11.33	10.11	3.00	4.00	4.00	3.67	79.70	57.62	49.28	62.20
	0.3%	11.67	11.33	11.67	11.56	4.00	4.00	4.00	4.00	58.19	58.19	53.85	56.75
SS	0.1%	6.00	6.00	6.33	6.11	3.00	3.00	3.00	3.00	79.73	79.43	79.72	79.63
	0.2%	6.33	6.67	11.33	8.11	3.00	3.00	4.00	3.33	79.79	78.99	58.79	72.53
	0.3%	6.33	6.33	6.00	6.22	3.00	3.00	3.00	3.00	79.57	79.46	79.85	79.63
IH	0.1%	7.00	7.00	7.00	7.00	3.00	3.00	3.00	3.00	79.79	79.36	79.59	79.58
	0.2%	7.00	7.00	6.67	6.89	3.00	3.00	3.00	3.00	79.87	79.30	79.76	79.65
	0.3%	11.67	11.67	7.00	10.11	4.00	4.00	3.00	3.67	58.24	55.09	79.93	64.42
Diploid		7.00	7.00	6.67	6.89	3.00	3.00	3.00	3.00	79.87	79.76	79.95	79.86
Mean		7.67	8.20	8.10	7.99	3.20	3.30	3.30	3.27	75.37	72.65	72.04	73.36
C.D. 5%		G-0.42	T- 0.77	GxT- 1.33		G- 0.03	T- 0.06	GxT- 0.10		G- 0.54	T- 0.99	GxT- 1.71	

treatments SS 0.2% (72.53%), IH 0.3% (64.42%), SA 0.2% (62.20%) and SA 0.3% (56.75%) showed significant decrease in pollen viability as compared to other treatments and control. It is conspicuous from interaction that the lowest pollen viability was recorded in putative tetraploids of 5255-1-3-1 (49.28%) with SA 0.2%, followed by SA 0.3% while the highest pollen viability was recorded in diploids of 5255-1-3-1. Sheikh et al. (2013) also observed that pollen dust was noticeably more abundant in diploids than in tetraploids in the five cultivars of watermelon. It might be due to various factors such as the instability of chromosome number during an abnormal meiosis (Evans and Rahman 1990) or laggards and bridges due to the higher number of multivalent formation at metaphase I (Darlington 1965).

Vegetative and flowering traits: Slow growth rate and delayed emergence of shoots with rosette-like appearance of first leaves was observed in colchicine treated seedlings of watermelon. Earlier studies by Suying et al.(1995) in watermelon and Jaskani et al.(1996) in citrus, reported that colchicine application had a negative effect on the regeneration of plants. The effect of different doses of colchicine on the vegetative and flowering traits of watermelon cultivars was recorded and is presented in (Table 2). Leaf length, leaf width and internodal length showed significant differences among genotypes and ploidy. Among the different genotypes, California Sweet produced significantly the highest leaf length (13.98 cm) and leaf width (14.96 cm) over the other genotypes. The different methods of colchicine application showed wide range in leaf length and leaf width. The treatments SS 0.2%, SA 0.2%, IH 0.3% and SA 0.3% exhibited significantly more leaf length and width than other treatments and control. The highest leaf length (14.67 cm) and leaf width (16.11 cm) was significantly recorded in the treatment SA 0.3%. It is vivid from the interaction that the highest leaf length (16.67cm) and leaf width (19.97 cm) was recorded in California Sweet with IH 0.3% and at par with SA 0.3% and SA 0.2% treatments. The increase in size of leaf size of tetraploids was the result of increase in the size of cells and the stomata. Similar trend of increase was recorded by Jaskani et al. (2005b) that tetraploid plants had more leaf area (298.90 cm^2) than diploid plants (208.40 cm^2) of watermelon.

However, the data presented in (Table 2) revealed that internode length was the longest in Sugar Baby (5.54 cm) and significantly better than other genotypes. The variation in internode length might be due to their genetic differences. Also, Jaskani et al. (2005b) reported that the highest internode length (119.70 mm) in SS-11 while the lowest (97.20 mm) in NH3 tetaploid line of watermelon. Among different methods of colchicine application, the treatments SS 0.2%, SA 0.2%, IH 0.3% and SA 0.3% attainted shorter internode length as compared to other treatments and control. The shortest internode length (4.08 cm) was significantly recorded in the treatment SA 0.3%. It is vivid from interaction that the shortest internode length (4.00 cm) was found in tetraploids of Sugar Baby with IH 0.3% and statistically at par with SA 0.3%. Sheikh et al. (2013) also reported that internode length was shorter in tetraploids (6.40 cm) than in diploids (6.50 cm) of five cultivars of watermelon treated with three different methods of colchicine application. The decrease in internode length of putative tetraploids might be due to the slow cell divisions of larger cells with more chromosomes (Noggle 1946). Besides this, first female flower appeared late in tetraploids of California Sweet with SA 0.2% (37.33 number of days) and statistically at par with SA 0.3% and IH 0.3% treatments (Table 2). Similarly, delayed flowering was observed by Chopra and Swaminathan (1959) in Asahi Yamato and Farrukhabadi tetraploids of watermelon by 10-15 days. It might be due to various factors such as prolonged vegetative phase, or relatively lower transport of manufactured food from the site of production to the place of utilization (Biswas 1998).

Fruit traits: Similarly, tetraploids had significantly the longest period to first picking (72.50 days) in California Sweet with IH 0.3% followed by SA 0.2% and SA 0.3% treatments (Table 3). Similarly the tetraploids of Sugar Baby had longer period to first picking with IH 0.3% and SA 0.3% and in 5255-1-3-1 with SA 0.3%, SS 0.3% and SA 0.2% treatments. Pradeepkumar (2010-2011) reported the (134.00) and (147.00) days to harvest in plants of Sugar Baby of watermelon with 0.1% colchicine seed and 0.5% colchicine seedling treatment method, respectively and (82.00) days in diploids. It might be due to the slow cell divisions of larger cells with more chromosomes (Noggle 1946). Variation in TSS content of fruits was recorded in different cultivars of watermelon. The perusal of data in (Table 3) recorded the highest TSS content (11.00^0 brix) in diploids of Sugar Baby while the lowest (8.87^0 brix) in tetraploids of 5255-1-3-1 and Sugar Baby with SS 0.2% and SA 0.3%, respectively. However, the TSS content (9.93° brix) of tetraploids in California Sweet with IH 0.3% was statistically at par with diploid fruits when harvested on delayed maturity (*i.e.* 72.50 days after sowing). Chopra and Swaminathan (1959) reported that TSS content was (8.00%) in the fruits of both diploid and tetraploids of Asahi Yamato and Farrukhabadi of watermelon. The

Table 2: Effect of different doses of colchicine on vegetative and flowering traits of watermelon genotypes

Treatments (T)		Leaf length (cm)				Leaf width (cm)				Internode length (cm)				No. of days to first female flower			
		Genotypes (G)				Genotypes (G)				Genotypes (G)				Genotypes (G)			
		SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean
S A	0.1%	11.47	12.93	12.00	12.13	11.73	13.43	11.37	12.18	5.94	5.35	5.62	5.64	23.33	26.67	21.33	23.78
	0.2%	11.40	16.18	13.60	13.73	11.73	18.17	15.30	15.07	5.92	4.15	4.05	4.71	23.33	37.33	29.00	29.89
	0.3%	13.77	16.43	13.80	14.67	14.50	18.17	15.67	16.11	4.07	4.14	4.03	4.08	31.66	36.67	30.00	32.78
S S	0.1%	11.41	13.00	12.13	12.18	11.67	13.37	11.43	12.16	5.91	5.34	5.58	5.61	22.67	26.67	21.67	23.67
	0.2%	11.40	12.93	14.73	13.02	11.60	13.23	15.87	13.57	5.95	5.32	4.52	5.26	23.00	26.00	29.00	26.00
	0.3%	11.43	12.90	11.97	12.10	11.70	13.20	11.40	12.10	5.90	5.33	5.52	5.58	22.00	26.33	21.33	23.22
IH	0.1%	11.47	12.90	12.00	12.12	11.73	13.27	11.43	12.14	5.92	5.36	5.53	5.60	22.33	26.67	21.67	23.56
	0.2%	11.43	12.93	11.90	12.09	11.90	13.23	11.43	12.19	5.90	5.34	5.55	5.59	22.00	27.67	21.33	23.67
	0.3%	13.80	16.67	11.93	14.13	14.93	19.97	11.47	15.46	4.00	4.02	5.62	4.55	31.00	37.00	21.33	29.78
Diploid		11.43	12.97	12.00	12.13	11.90	13.57	11.43	12.30	5.95	5.39	5.64	5.66	23.00	27.00	22.00	24.00
Mean		11.90	13.98	12.61	12.83	12.34	14.96	12.68	13.33	5.54	4.97	5.16	5.23	24.43	29.800	23.867	26.03
C.D. 5%		G- 0.27 T-0.48 GxT- 0.84				G- 0.29 T-0.53 GxT- 0.91				G-0.12 T-0.22 GxT- 0.39				G- 0.55 T-1.00 GxT- 1.74			

Table 3: Effect of different doses of colchicine on fruit traits of watermelon genotypes

Treatments (T)		No. of days to first picking				TSS (^{0}brix)				Fruit weight (kg)				Rind thickness (cm)			
		Genotypes (G)				Genotypes (G)				Genotypes (G)				Genotypes (G)			
		SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean
S A	0.1%	63.00	66.67	63.33	64.33	10.97	10.17	10.60	10.57	2.24	2.26	2.14	2.22	0.90	0.87	0.89	0.89
	0.2%	63.33	69.67	69.67	67.56	11.00	9.37	8.99	9.79	2.21	0.88	1.03	1.37	0.89	1.02	1.02	0.97
	0.3%	69.67	70.00	70.33	70.00	8.87	9.17	8.90	8.98	0.88	0.93	0.95	0.92	0.99	0.99	0.99	0.99
SS	0.1%	62.00	63.67	63.67	63.11	10.97	10.15	10.63	10.58	2.21	2.26	2.13	2.20	0.89	0.86	0.87	0.87
	0.2%	63.33	64.00	69.33	65.56	10.33	10.15	8.87	9.98	2.19	2.25	0.78	1.74	0.87	0.86	0.97	0.90
	0.3%	62.00	63.00	63.33	62.78	11.00	10.15	10.60	10.58	2.22	2.25	2.13	2.19	0.87	0.85	0.88	0.87
IH	0.1%	62.33	64.67	64.00	63.67	10.97	10.16	10.60	10.57	2.23	2.23	2.123	2.19	0.90	0.87	0.88	0.88
	0.2%	63.67	64.33	63.33	63.78	10.67	10.14	10.57	10.46	2.24	2.23	2.12	2.19	0.87	0.88	0.88	0.88
	0.3%	69.33	72.50	63.67	68.50	8.95	9.93	10.60	9.83	0.86	0.88	2.13	1.29	1.02	1.20	0.89	1.03
Diploid		63.00	64.00	64.00	63.67	11.00	10.17	10.70	10.62	2.26	2.27	2.15	2.23	0.91	0.88	0.89	0.89
Mean		64.17	66.25	65.47	65.29	10.53	9.95	10.11	10.19	1.96	1.84	1.77	1.86	0.91	0.93	0.91	0.92
C.D. 5%		G- 0.42 T-0.76 GxT- 1.32				G- 0.20 T-0.37 GxT 0.64				G- 0.04 T- 0.07 GxT- 0.12				G- 0.04 T-0.07 GxT- 0.11			

lower activity of metabolites (Joshi and Verma 2004) and vigorous increase of vegetative growth in the later stages of development (Talukdar 2010) decreases the TSS content of tetraploid fruits. Also, the lowest fruit weight (0.79 kg) was significantly obtained from the putative tetraploids of 5255-1-3-1 with SS 0.2% followed by SA 0.2% and SA 0.3% treatments (Table 3). The analysis of variance presented significant differences for rind thickness in ploidy but non-significant among genotypes. Tetraploids had significantly the highest rind thickness (1.20 cm) in California Sweet with IH 0.3%, followed by SA 0.2% and SA 0.3% treatments (Table 3).

Seed traits: Seed number accounted in both ploidy fruits differed significantly. It is vivid from (Table 4) that tetraploid fruits of all the three cultivars recorded in SA 0.2%, SA 0.3%, SS 0.2% and IH 0.3% treatments produced lower seed number per fruit as compared to other treatments and control. The lowest seed number per fruit (127.67) was recorded in putative tetraploids of Sugar Baby with SA 0.3%. However, as a percentage the number of developed seeds in tetraploid fruits was much lower than the percentage of developed seeds in the diploid fruits (Table 4). The lowest percentage of developed seeds (52.72%) was significantly recorded in Sugar Baby with SA 0.3%. This indicates that tetraploid plants had lower fertility due to the unbalanced number of chromosomes during meiosis. Sheikh et al. (2013) reported that tetraploid fruits had less developed seeds (51.50) than the diploid fruits (110.00) in watermelon. Although the tetraploid fruits inherited larger seeds over their diploids. The highest seed length (11.59 mm) and seed width (7.15 mm) was recorded in the putative tetraploids of California Sweet with SA 0.3% and SA 0.2% treatments, respectively (Table 5). Similarly, the highest seed thickness (2.17 mm) and 100 seed weight (8.30 g) was observed in California Sweet with SA 0.3% (Table 5). Kumari et al. (2014) reported that tetraploid watermelon had the highest seed width in three varieties, Arka Muthu (6.81 mm) followed by IIHR-14 (5.61 mm) and Sugar Baby (4.58 mm) as compared to their respective control.

Table 4: Effect of different doses of colchicine on seed traits of watermelon genotypes

Treatments (T)		Seed number per fruit				Developed seeds per fruit (%)				Undeveloped seeds per fruit (%)			
		Genotypes (G)				Genotypes (G)				Genotypes (G)			
		SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean
SA	0.1%	539.67	603.00	455.00	532.56	81.17	80.05	80.39	80.54	8.83	9.95	9.60	9.46
	0.2%	539.00	171.30	144.33	284.89	81.29	55.45	55.19	63.98	8.71	34.54	34.81	26.02
	0.3%	127.67	177.00	148.33	151.00	52.72	56.45	57.45	55.54	37.27	33.55	32.55	34.46
SS	0.1%	539.67	602.67	455.33	532.56	81.40	79.87	80.66	80.65	8.59	10.13	9.34	9.35
	0.2%	538.00	603.00	151.67	430.89	81.27	79.96	55.90	72.38	8.72	10.04	34.09	17.62
	0.3%	539.00	602.33	454.33	531.89	81.07	79.77	80.39	80.41	8.93	10.23	9.61	9.59
IH	0.1%	538.67	602.67	454.67	532.00	81.28	79.77	80.52	80.53	8.72	10.22	9.48	9.47
	0.2%	539.00	603.33	455.00	532.44	81.07	79.87	80.52	80.49	8.93	10.13	9.48	9.51
	0.3%	148.67	173.33	455.33	259.11	55.25	55.01	80.66	63.64	34.74	34.99	9.34	26.36
Diploid		540.33	603.67	456.00	533.33	81.07	79.88	80.28	80.41	8.92	10.12	9.72	9.59
Mean		458.97	474.23	363.00	432.07	75.76	72.61	73.19	73.86	14.24	17.39	16.80	16.14
C.D. 5%		G- 11.98	T-21.87	GxT- 37.88		G-0.25	T- 0.46	GxT- 0.79		G-0.25	T- 0.46	GxT- 0.79	

Table 5: Effect of different doses of colchicine on seed traits of watermelon genotypes

Treatments (T)		Seed length (mm)				Seed width (mm)				Seed thickness (mm)				100 Seed weight (g)			
		Genotypes (G)				Genotypes (G)				Genotypes (G)				Genotypes (G)			
		SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean	SB	CS	5255	Mean
SA	0.1%	8.24	10.42	7.98	8.88	4.85	5.19	4.66	4.90	1.76	1.65	1.72	1.71	4.62	6.12	4.29	5.01
	0.2%	8.22	11.53	8.81	9.52	4.84	7.15	5.76	5.92	1.78	1.95	2.06	1.93	4.62	7.05	4.98	5.55
	0.3%	8.92	11.59	8.67	9.73	5.65	6.98	5.54	6.05	2.01	2.17	2.03	2.07	5.13	8.30	5.01	6.14
SS	0.1%	8.20	10.43	7.97	8.87	4.83	5.19	4.65	4.89	1.78	1.64	1.72	1.71	4.60	6.10	4.29	5.00
	0.2%	8.22	10.41	8.85	9.16	4.84	5.18	6.05	5.35	1.76	1.67	2.16	1.86	4.62	6.09	5.00	5.24
	0.3%	8.21	10.42	8.01	8.88	4.82	5.19	4.67	4.89	1.76	1.65	1.72	1.71	4.60	6.09	4.27	4.98
IH	0.1%	8.20	10.44	7.97	8.87	4.84	5.17	4.65	4.89	1.78	1.64	1.73	1.72	4.63	6.12	4.28	5.01
	0.2%	8.21	10.43	8.02	8.88	4.83	5.18	4.67	4.89	1.78	1.65	1.72	1.72	4.62	6.12	4.29	5.01
	0.3%	8.88	11.42	7.97	9.42	5.69	7.09	4.65	5.81	2.33	2.25	1.71	2.10	5.11	7.85	4.28	5.75
Diploid		8.23	10.45	8.01	8.89	4.84	5.20	4.66	4.90	1.77	1.66	1.72	1.72	4.63	6.13	4.30	5.02
Mean		8.35	10.75	8.23	9.11	5.01	5.75	4.99	5.25	1.85	1.79	1.83	1.82	4.72	6.59	4.50	5.27
C.D. 5%		G-0.14 T- 0.25 GxT- 0.43				G- 0.09 T-0.16 GxT- 0.29				G- 0.03 T- 0.06 GxT- 0.10				G- 0.09 T-0.17 GxT- 0.29			

Putative tetraploids (%): The present results (Table 6) illustrate that California Sweet had the highest efficiency of generating putative tetraploids (6.12%) and was significantly better over the other genotypes. The variable response of genotypes to colchicine indicated that optimal colchicine concentrations may vary in treating diverse watermelon genotypes. Among the various methods of colchicine application, the treatments SA 0.2%, SA 0.3%, SS 0.3% and IH 0.3% resulted into the putative tetraploids as compared to other treatments. However, the treatment IH 0.3% had the highest frequency of generating putative tetaploids (11.55%) and SS method was least effective. The highest percentage of putative tetraploids (16.43%) was recorded in the Sugar Baby with IH 0.3% treatment. Similarly, the California sweet had higher efficiency of putative tetraploids (14.17 %) with IH 0.3% treatment.

Table 6: Effect of different doses of colchicine on the percentage of putative tetraploids

Treatments (T)		Putative tetraploids (%)			
		Genotypes (G)			
		SB	CS	5255	Pooled
SA	0.1%	4.05	4.05	4.05	4.05
	0.2%	4.05	10.51	5.73	6.76
	0.3%	6.96	8.13	6.96	7.35
SS	0.1%	4.05	4.05	4.05	4.05
	0.2%	4.05	4.05	5.73	4.61
	0.3%	4.05	4.05	4.05	4.05
IH	0.1%	4.05	4.05	4.05	4.05
	0.2%	4.05	4.05	4.05	4.05
	0.3%	16.43	14.17	4.05	11.55
Diploid		4.05	4.05	4.05	4.05
Mean		5.58	6.12	4.68	5.462
C.D. 5%		G- 0.16 T- 0.30 GxT- 0.52			

सारांश

तरबूज में त्रिगुणित (टिट्राप्लोइडी) प्रेरणा के लिए एक उपयुक्त विधि की छँटनी करने के लिए, तीन अलग–अलग प्रभेदों (शुगर बेबी, कैलिफ्रोर्निया स्वीट और 5255–1–3–1) का मूल्यांकन अघुलनशील प्रतिकारक–कोल्चीसिन का प्रयोग तीन अलग मात्रा (0.1 प्रतिशत, 0.2 प्रतिशत और 0.3 प्रतिशत) और विधियाँ (प्ररोह शीर्ष, बीज भिगोना और उलटा बीजपत्राधार प्ररोह) के साथ कियाग या। यह प्रयोग वर्ष 2013–15 के दौरान सब्जी अनुसंधान और प्रयोगशाला वनस्पति

विज्ञान विभाग, पंजाब कृषि विश्वविद्यालय, लुधियाना (पंजाब) में किया गया त्रिगुणिता की पुष्टि करने के लिए हरितलवक गणना, परागाणु और प्ररूपी लक्षणों पर अवलोकन दर्ज किया गये। तरबूज के विभिन्न प्रभेदों कैलिफ्रोर्निया स्वीट में अनुमानित त्रिगुणित उत्पादन क्षमता (6.12 प्रतिशत) पायी गयी। त्रिगुणिता प्रेषित करने के लिए कोल्चीसिन के विभिन्न तरीकों और सांद्रता में उल्टा बीजपत्राधर और प्ररोह शीर्ष विधि द्वारा कोल्चीसिन की 0.2 प्रतिशत और 0.3 प्रतिशत सांद्रता तुलनात्मक रूप से अधिक प्रभावी पाया गया। अनुमानित त्रिगुणित (11.55 प्रतिशत) की उच्चतम आवृत्ति उल्टा बीजपत्राधर 0.3 प्रतिशत के साथ प्राप्त हुई।

References

Amiri S, Kazemitabaar SK, Ranjbar G and Azadbakht M (2010) The effect of trifluralin and colchicine treatments on morphological characteristics of Jimsonweed (*Datura stramonium* L.). Trakia J Sci 8: 47-61.

Biswas SC (1998) Cytogenetic evaluation of induced variations through mutations and polyploidy in *Lathyrus sativus* L. and varietal diversities. Ph.D. dissertation, University of Kalyani, Kalyani.

Chopra VL and Swaminathan MS (1959) Induction of polyploidy in watermelon. Proc Indian Acad Sci 51: 57-65.

Compton ME, Gray DJ and Elmstrom GW (1996) Identification of tetraploid regenerants from cotyledons of diploid watermelon cultured in vitro. Euphytica 87: 165-172.

Darlington CD (1965) Recent advances in cytology. J & A Churchill Ltd London.

Evans GM and Rahman MM (1990) The basis of low grain yield and infertility in autotetraploid barley (*Hordeum vulgare*). Heredity 64: 305-313.

Fassuliotis G and Nelson BV (1992) Regeneration of tetraploid muskmelons from cotyledons and their morphological differences from two diploid muskmelon genotypes. J Am Soc Hortic Sci 117: 863-866.

Gaikwad K J, Jambhale N D and Bhave S G (2007) Detection of induced tetraploids in watermelon cultivars. Asian J Hort 2: 253-55.

Gok P, Yetisir H, Solmaz I, Sari N and Eti S (2007) Pollen viability and germination rates of 45 watermelon genotypes. Acta Hort 731: 99-102.

Jaskani MJ, Khan IA and Husnain S (1996) Morphological description of citrus colchiploids. Proc Intl Soc Citriculture 1: 130-132.

Jaskani MJ, Kwon SW, Koh GC, Huh YC and Ko BR (2004) Induction and characterization of tetraploid watermelon. J Kor Soc Hort Sci 45: 60-65.

Jaskani MJ, Kwon SW and Kin DH (2005a) Flow cytometery of DNA contents of colchicine treated watermelon as a ploidy screening method at M1 stage. Pak J Bot 37: 685-696.

Jaskani MJ, Kwon SW and Kim DH (2005b) Comparative study on vegetative, reproductive and qualitative traits of seven diploid and tetraploid watermelon lines. Euphytica 145: 259-268.

Jaskani MJ, Kwon SW, Hussain Z and Khan IA (2007) Breeding polyploidy watermelon: induction, identification and seed germination of tetraploids. Proc Intl Sym on Prospects of Horticultural Industry in Pakistan. Institute of Horticultural Sciences, University of Agriculture, Faislabad, pp 274-282.

Joshi P and Verma RC (2004) High frequency production of colchicine induced autotetraploids in Faba bean (*Vicia faba* L.). Cytologia 69: 141-147.

Kihara H (1951) Triploid watermelons. J Amer Soc Hort Sci 58: 217-230.

Kumari TV, Ashok P, Rao ES and Sasikala (2014) Studies to improve seed germination in tetraploids watermelon (*Citrullus lanatus Thunb*.). Int J Sci Res Publ 4: 1-3.

Levi A, Thomas E, Keinath P and Whener TC (2001) Genetic diversity among watermelon (*Citrullus lanatus and Citrullus colocynthis*) accessions. Genet Resour Crop Evol 48: 559-566.

Marr CW and Gast KLB (1991) Reactions by consumers in a 'farmers' market to prices for seedless watermelon and ratings of eating quality. Hort Technol 1: 105-106.

McCuistion F and Elmstrom GW (1993) Identifying polyploids of various cucurbits. Proc Fla State Hortic Soc 106: 155-157.

Mohr HC (1986) Breeding Vegetable Crops. AVI Publishing Company, Westport.

Noh J, Sheikh S, Chon HG, Seong MH, Lim JH, Lee SG, Jung GT, Kim JM, Ju HJ and Huh YC (2012) Screening different methods of tetraploid induction in watermelon. Hort Environ Biotech 53: 521-529.

Noggle GR (1946) The physiology of polyploidy in plants. I Rev of Literature. Lloydia 9: 153-173.

Pradeerkumar T (2010-2011) Characterization of M1 generation of polyploids in watermelon variety Sugar Baby. Cucurbit Genetic Coop Rep 33-34: 44-46.

Rhodes B and Zhang XP (1999) Hybrid seed production in watermelon. J New Seed 1: 69-88.

Sheikh S, Noh J, Seong MH, Jung GT, Kim JM, Ju HJ and Huh YC (2013) Phenotypic markers for tetraploid watermelon following parental exposure to colchicine in T_0 generation. Hort Environ Biotechnol 54: 524-530.

Suying T, Xiuqiang H, Jiwei L and Wenge L (1995) Raising the frequency of inducing tetraploid watermelon by treating of colchicine. Acta Hort 402: 18-22.

Talukdar D (2010) Cytogenetic characterization of induced autotetraploids in grass pea (*Lathyrus sativus* L.). Caryologia 63: 62-72.

Vegetable Science (2018) 45 (2) : 173-179

Genetic variability, heritability and genetic advances analysis for quantitative traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] genotypes

Sachin S Chikkeri, DS Duhan*, VPS Panghal and Rajesh Kumar Arya[1]

Received: October 2018 / Accepted: January 2019

Abstract

Thirty-one genotypes of bottle gourd were evaluated at CCS Haryana Agricultural University, Hisar to find out the genetic variability, heritability and potential for screening suitable genotypes for future improvement programmes. Considerable amount of variability was noticed for various traits. The maximum phenotypic and genotypic coefficient (PCV and GCV) was observed for diameter of fruit (26.06 and 27.10 cm), number of primary branches (24.48 and 27.24), nodes to first male flower (22.77 and 24.87) and weight of 100 seeds (20.12 and 21.25), while moderate values were estimated for number of fruits per vine (19.21 and 20.82), nodes to first female flower (18.58 and 21.48), vine length at the time of final harvest (14.69 and 17.34), fruit yield per vine (14.56 and 15.66) and fruit yield per hectare (15.51 and 16.55). High heritability coupled with high genetic advance as percent of mean was observed for diameter of fruit, length of fruit, nodes to first male flower and weight of 100 seeds indicating that these traits were under the strong influence of additive gene action. Moderate heritability and low genetic advance values were observed for the characters days to first male flower opening, days to first female flower opening, days to first fruit harvest and days to 50% flowering. The promising genotypes giving high fruit yield were GH 30 and GH 32 and early maturing were IC 092414 and GH 34.

Keywords: Bottle gourd, variability, GCV, PCV, heritability and genetic advance

Introduction

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] or white flowered gourd is one of the most important cucurbitaceous crop belongs to the family cucurbitaceae with 2n=2x=22. Appearance of first pistillate flower at lower node is the indication of earliness of the variety. On the other hand, higher the node number for the position of first pistillate flower, the maximum would be the production of the pistillate flower. Thus, shorter interval between the appearance of first staminate and first pistillate flower indicates shorter life of a plant. Its tender fruits are rich source of carbohydrates, protein, fat and vitamin C, which are used as a vegetable or for making pickles and sweets, *e.g.*, *halva*, *kheer*, *petha* and *burfi*. Its juice could be prepared without adding any chemical preservative in it with minimal thermal processing because during this processing the minimum and maximum loss of ascorbic acid blend juice have been recorded 22.97% at 80ºC for 5 minutes and 47.70% at 95ºC for 30 minutes, respectively (Gajera and Joshi 2014). In addition, the seeds and seed oil are edible. Generally, the mineral composition of seed is found to be relatively high as compared to its fruit, except for calcium, zinc, cobalt and chromium. Composition also indicates the seed to be a good source of dietary fibers. Bottle gourd seeds are the potential source of protein, lipid, macro- and micronutrients, and if utilized properly, its seeds can solve the problem of malnutrition and serve as raw material for agro-based industries (Hassan et al. 2008). The role of genetic variability in a crop is of paramount importance in selecting the best genotypes for making rapid improvement in yield and related characters as well as to select most potential parents for making the hybridization programme successful (Singh et al. 2014). Therefore, it is necessary to obtain adequate information on the magnitude and type of genetic variability and their corresponding heritability. This is because selection of superior genotypes is proportional to the amount of genetic variability present and extent to which the traits are heritable. The selection efficiency is increases, if the traits are selected based

Department of Vegetable Science, [1]Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar-125004, Haryana

*Corresponding author; Email: dharamveer_duhan@rediffmail.com

on high heritability coupled with high genetic advance over the mean value. The magnitude of such estimates also suggests the extent to which improvement is possible through selection. Keeping the above facts in view, the present study was undertaken to estimates the component of variance, heritability and genetic advance over mean in different bottle gourd genotypes.

Materials and Methods

The present study was conducted at research farm of the Department of Vegetable Science, CCS, Haryana Agricultural University, Hisar (India) during Spring-Summer season, 2015. The experimental materials consist of seed of thirty one genotypes of bottle gourd viz., GH 28, GH 29, GH 30, GH 31, GH 32, GH 33, GH 34, GH 35, GH 36, GH 37, GH 38, GH 9, GH 20, GH 27, HBG 34 and HBG 36 procured from Department of Vegetable Science, CCSHAU, Hisar; IC 042345, IC 092363, IC 092371, IC 092372, IC 092404, IC 092414, IC 092420, IC 092424, IC 092426, IC 092428, IC 092436, IC 092462 and IC 092465 from Indian Institute of Vegetable Research, Varanasi; and two commercial varieties Pusa Naveen and Pusa Summer Prolific Long from IARI, New Delhi. The experiment was sown in Randomized Block Design with three replications with a plot size of 2.5 m x 3.3 m and 2.5m x 60 cm spacing in third week of March 2015. Half dose of nitrogen fertilizer along with full dose of phosphorus and potassium was applied at the time of land preparation and the remaining half dose of nitrogen was top dressed 30 days after sowing. Before sowing, the seed was treated with captan @ 3 g per kg seed. After sowing, the field was irrigated lightly. Other agronomic practices and plant protection measures were undertaken as per package of practices for vegetable crops for Haryana state. The observations were recorded on fourteen quantitative characters *viz*., days to 50% flowering, number of primary branches, days to first male flower opening, days to first female flower opening, nodes to first male flower, nodes to first female flower, days to first fruit harvest, length of fruit (cm), diameter of fruit (cm), vine length at the time of final harvest (m), weight of 100 seeds (g), number of fruits per vine, fruit yield per vine (kg) and yield per hectare (t). The statistical analysis of data was carried out by OPSTAT (http://14.139.232.166/opstat/index.asp) statistical software developed by CCSHAU, Hisar, Haryana (Sheoran 2010).

Results and Discussion

Growth and phonological parameters: Significant differences were recorded among the genotypes with respect to days to 50% flowering, which ranged from 7.00 (GH 9, GH 28, GH 32 and GH 36) to 11.67 (IC 042345) days, with overall mean 8.91 days (Table 1). The number of primary branches per plant ranged from 4.00 to 12.33 with a mean of 8.82 at the time of final harvest. The maximum number of primary branches per plant was observed in genotype HBG 34 and minimum was in IC 092428. Other genotypes with above ten primary branches per plant were GH 30, GH 38, IC 092428,GH 35, GH 20 and GH 9, whereas, the remaining genotypes were having 4 to 9 branches per plant. The variation in days to 50 % flowering and number of branches per vine might have been due to its own genetic makeup, seed vigour and due to vine length, internodal length, hormonal factor and environmental factor confirming to Sharma and Sengupta (2013) for all the characters in bottle gourd crop. Day to opening of first male flower was recorded in between 40.67 and 52.00 days. The genotype GH 37 took minimum days (40.67) followed by GH 33(41.33) and GH 32 (41.67) days. The genotype IC 042345 and IC 092372 took maximum days (52.00) to first male flower, while the average number of days taken to first male flower of thirty-one genotypes was 45.71 days. The genotypes differed significantly with regard to first female flower opening. The genotype GH 37 took least number of days to female flowering (42.33) followed by GH 32 (45.00), IC 092363 (45.00), GH 9 (45.33), GH 20 (45.67) and IC 092420 (46.33) days. However, the maximum number of days for female flower opening was taken by genotype IC 092428 and IC 042345 (58.33) followed by IC 092404 (56.33), IC 092372 (56.00) and IC 092414 (55.67) days. The number of days from sowing to first appearance of female flower is an important character that indicates earliness or lateness of the crop in general. The variation in first appearance of male and female flower might have been due to internodal length, number of internodes, genetic nature, environmental factor and vigour of the crop. Similar results have been reported by Husna et al. (2014) in bottle gourd.

Significant differences were noticed with regard to the nodes to first male flower among the different genotypes studied. The genotype IC 092404 recorded the highest nodes (13.33) to first male flower production followed by GH 27 (12.33), PSPL (12.00), IC 092462 and IC 092465 (11.00). The lowest number of nodes (5.67) was observed in GH 33 followed by GH 34 (6.00), IC 092414 (6.00) and GH 35 (6.33). Earliness is one of the main attribute, which is measured in terms of node to first female flower appearance. Among the genotypes, the range of variation was observed from 6.3 to 16.00 with mean value of 10.70 for node number of flowers per plant. The genotype IC 092414 differed significantly

with respect to number of nodes up to first female flower and recorded female flower at earliest node (6.30), which was followed by GH 34 (7.00) and GH 33 (7.70). The highest nodes for first female flower was recorded in IC 092404 (16.00) followed by IC 092428 (14.70) and GH 27 (13.70). The variation in node number at which first male and female flower appears might have been due to specific genetic makeup of different hybrids and prevailing environmental conditions. These results are in close conformity with the finding of Mangala et al. (2015) for node number at first female flower in bottle gourd. Days to first fruit harvest ranged from 54.00 to 79.00 days and all the varieties differed significantly for this trait. The first fruit was harvested significantly earlier in two genotypes GH 37 (54.00) and GH 9 (54.33) days followed by IC 092462 (56.00) and GH 32 (56.67) days. The genotype IC 042345 took maximum number of days (79.00) to reached harvesting stage, while the genotype IC 092428 (75.33), IC 092372 (72.33) and IC 092414 (69.67) were the next in order. The variation in days to first fruit to harvesting might have been due to genetic factor, environmental factor, hormonal factor and vigour of the crop. These results are in close conformity with the finding of Bhardwaj et al. (2013) in bottle gourd.

Fruit number, size and yield parameters: A wide variation was found among the bottle gourd genotypes for the number of fruits per vine, which significantly varied from 3.4 to 7.7 among the genotypes with an overall mean of 5.71 (Table 1). The genotype IC 092428 recorded minimum number of fruits per vine and GH 30 recorded the maximum number of fruits per vine.

Table 1: Mean values of coefficient of variation for growth and yield character in bottle gourd

Genotypes	Days to 50% flowering	Number of primary branches	Days to first male flower opening	Days to first female flower opening	Nodes to first male flower	Nodes to first female flower	Days to first fruit harvest
GH 28	7.00	7.00	45.67	50.00	9.67	11.0	63.00
GH 29	7.67	10.33	46.33	50.00	10.33	11.3	64.33
GH 30	9.00	12.00	47.00	49.67	7.67	9.7	60.67
GH 31	8.67	8.00	44.33	49.00	8.00	10.0	59.33
GH 32	7.00	11.00	41.67	45.00	7.00	9.7	56.67
GH 33	8.67	10.33	41.33	50.00	5.67	7.7	58.00
GH 34	7.33	9.33	46.00	51.00	6.00	7.0	62.00
GH 35	10.00	11.33	44.33	49.00	6.33	10.3	68.33
GH 36	7.00	10.00	46.00	50.67	8.67	10.7	57.00
GH 37	9.00	8.33	40.67	42.33	6.00	8.7	54.00
GH 38	9.00	11.67	44.00	47.00	7.33	11.3	62.33
IC 042345	11.67	5.00	52.00	58.33	10.67	11.7	79.00
IC 092363	8.00	9.00	43.00	45.00	6.67	8.0	59.33
IC 092371	9.00	5.33	45.33	52.33	8.00	11.3	61.00
IC 092372	10.67	7.33	52.00	56.00	7.67	8.0	72.33
IC 092404	9.33	10.00	49.67	56.33	13.33	16.0	64.33
IC 092414	11.33	11.33	50.33	55.67	6.00	6.3	69.67
IC 092420	8.33	8.33	44.00	46.33	9.00	10.0	60.33
IC 092424	10.67	6.33	49.33	55.00	8.67	10.7	66.00
IC 092426	9.33	5.67	44.67	49.00	9.33	11.3	58.00
IC 092428	11.00	4.00	51.33	58.33	11.67	14.7	75.33
IC 092436	8.33	9.00	42.67	48.67	10.33	11.7	57.00
IC 092462	8.67	6.67	45.00	49.00	11.00	12.0	56.00
IC 092465	9.33	7.33	47.00	50.33	11.00	12.7	63.33
GH 9	7.00	10.67	42.67	45.33	7.67	9.3	54.33
GH 20	10.33	11.00	46.00	45.67	8.00	11.3	58.00
GH 27	8.33	7.00	44.00	49.33	12.33	13.7	61.33
HBG 34	8.67	12.33	45.00	49.67	8.00	10.3	59.67
HBG 36	10.00	8.00	47.33	53.67	9.67	12.0	64.00
P.N.	8.00	10.67	44.00	47.00	10.33	11.3	63.67
PSPL	8.00	9.00	44.33	48.67	12.00	12.0	67.00
General Mean	8.91	8.82	45.71	50.11	8.84	10.70	62.43
SE(d)	0.736	0.861	1.041	1.576	0.722	0.942	1.779
CD at 5%	1.477	1.727	2.087	3.161	1.448	1.888	3.568
CV (%)	10.080	11.961	2.789	3.850	10.005	10.778	3.491

Per se performance of genotypes contd...

Genotypes	Length of fruit (cm)	Diameter of fruit (cm)	Vine length at the time of final harvest (m)	Weight of 100 seeds (g)	Number of fruits per vine	Fruit yield per vine (kg)	Yield (t/ha)
GH 28	25.4	8.2	4.15	10.0	5.7	5.00	28.60
GH 29	24.7	7.9	5.10	12.3	6.9	4.80	30.00
GH 30	24.7	8.0	5.47	14.2	7.7	5.43	32.80
GH 31	31.7	8.0	4.55	11.1	6.2	4.23	24.47
GH 32	34.6	8.1	5.63	13.6	7.3	5.03	31.20
GH 33	26.5	7.5	5.34	14.5	6.7	4.53	29.20
GH 34	34.8	7.2	4.81	13.4	6.2	4.87	27.20
GH 35	26.7	8.0	5.96	14.0	7.1	4.90	29.40
GH 36	22.3	8.4	5.32	13.9	6.2	4.10	24.60
GH 37	33.6	8.7	4.96	15.5	6.6	5.10	26.80
GH 38	31.9	9.7	4.95	16.6	7.5	4.47	30.60
IC 042345	18.5	16.6	3.65	20.6	3.6	3.40	18.22
IC 092363	30.0	6.8	5.28	17.6	5.6	3.57	21.40
IC 092371	31.2	7.6	3.64	15.6	3.9	3.50	20.61
IC 092372	12.5	10.0	4.32	24.5	4.3	3.54	21.22
IC 092404	29.1	7.5	5.14	15.6	5.6	3.93	23.60
IC 092414	7.8	12.2	5.71	17.7	5.2	3.93	22.50
IC 092420	23.1	7.4	4.88	16.4	5.0	4.67	26.30
IC 092424	29.7	7.3	4.30	16.8	5.1	4.38	27.99
IC 092426	27.7	7.1	4.17	18.0	5.3	4.38	25.38
IC 092428	30.6	8.7	3.63	22.7	3.4	3.01	17.80
IC 092436	28.5	3.1	4.71	22.0	5.6	4.60	25.20
IC 092462	31.7	6.3	3.80	15.3	5.3	4.20	27.22
IC 092465	30.5	7.1	4.44	15.0	4.8	3.93	23.60
GH 9	32.2	8.3	5.32	14.5	6.2	4.00	24.00
GH 20	31.3	7.9	4.74	12.5	6.1	5.03	28.80
GH 27	23.0	7.9	4.35	15.7	4.5	3.43	20.57
HBG 34	32.1	7.1	6.20	19.8	7.1	4.83	29.40
HBG 36	27.5	8.0	4.28	15.6	4.9	3.13	18.80
P.N.	21.0	8.7	3.50	15.2	6.2	4.10	24.60
PSPL	36.2	6.2	3.70	13.9	5.4	3.86	22.10
General Mean	27.46	8.11	4.71	15.94	5.71	4.26	25.30
SE(d)	1.978	0.490	0.354	0.887	0.374	0.200	1.189
CD at 5%	3.967	0.983	0.710	1.778	0.750	0.402	2.385
CV (%)	8.823	7.406	9.206	6.813	8.014	5.765	5.757

The other genotypes ranging above 7 number of fruits per vine were GH 32, GH 35, GH 38, and HBG 34. Seventeen genotypes recorded number of fruits per plant lower than the general mean and the remaining 14 were above general mean. The number of fruits per vine is one of the major factors for deciding the fruit yield of the crop. The variation in number of fruits per vine might have been due to sex ratio, fruit set percentage, genetic nature and their response to varying environmental conditions. Variation in number of fruits per vine was also reported by Mangala et al. (2015) in bottle gourd. There was significant difference among the genotypes for length of fruit. It was ranged from 7.8 to 36.2 cm with a mean of 27.46 cm. The less fruit length was recorded by the genotype IC 092414 and more by PSPL. The other genotypes showed more fruit length above the mean beside PSPL were GH 34, GH 32, GH 37, GH 9 and IC 092462. The diameter of fruit ranged from 3.1 to 16.6 cm and the general mean for diameter of fruit was 8.11 cm. The highest diameter was recorded with genotype IC 042345 (16.6 cm), followed by genotype IC 092414 (12.2 cm) and IC 092372 (10.0 cm), whereas, the minimum fruit diameter was observed in genotype IC 092436 (3.1 cm). The variation in fruit length and diameter might have been due to genetic nature, environmental factor and vigour of the crop Mangala et al. (2015) has reported similar findings in bottle gourd. The genotype IC 092372 recorded significantly higher 100 seeds weight (24.5 g) followed by IC 092428 (22.7 g) and IC 092436 (20.58 g). The lowest weight (10.0 g) of 100 seeds was recorded in GH 28 followed by GH 31 (11.1 g), GH 29 (12.3 g), GH 20 (12.5 g) and GH 34 (13.4 g). The grand mean vine length observed at the time of final harvest was 4.71 m. It ranged from 3.50 to 6.20 m. The maximum vine length (6.20 m) was recorded in genotype HBG 34 and the lowest vine length (3.50 m) in Pusa Naveen Other varieties with vine length above five meter were GH 29, GH 30, GH 32, GH 33, GH 35, GH 36, IC 092363, IC 092404, IC 092414 and GH 9.

Vine length of remaining genotypes was below five meter. The higher fruit length results in to higher fruit weight. The longest fruit length in HBG 34 and highest seed weight in IC 092372 might be due to its hybrid vigour and adoptability to Hisar agro-climatic conditions confirming to finding Mangala et al. (2015) for fruit length in bottle gourd.

The fruit yield per vine of bottle gourd varied significantly among the 31 genotypes from 3.01 kg to 5.43 kg, with general mean value 4.26 kg. The maximum fruit yield per plant was recorded in genotype GH 30 and minimum fruit yield per vine was recorded in genotype IC 092428. The most promising genotypes having fruit yield high than general mean were GH 28, GH 29, GH 30, GH 32, GH 33, GH 34, GH 35, GH 37, GH 38, IC 092420, IC 092424, IC 092426, IC 092436, GH 20 and HBG 34. Sixteen genotypes showed yield less than the general mean. The bottle gourd genotypes studied in the present investigation showed a wide range of variation, *i.e.*, from 17.80 to 32.80 t/ha, with a mean value of 25.30 t/ha. The genotype GH 30 (32.80 t/ha) was the highest yielder among the genotypes under study. The genotypes GH 32 (31.20 t/ha), GH 38 (30.60 t/ha), GH 29 (30.0 t/ha), GH 35 (29.40 t/ha) and HBG 34 (29.40 t/ha) were the next in order. The lowest fruit yield was obtained in IC 092428 (17.80 t/ha) followed by IC 042345 (18.22 t/ha), HBG 36 (18.80 t/ha), GH 27 (20.57 t/ha) and IC 092371 (20.61 t/ha). The variation in fruit yield per vine might have been due to fruit set percentage, fruit length, number of fruits per vine, fruit weight, fruit width, genetic nature, environmental factor and vigour of the crop. These findings are in close conformity with findings of Bhardwaj et al. (2013) for yield per plant, Sharma and Sengupta (2013) for all the characters and Mangala et al. (2015) for yield per vine in bottle gourd.

Components of variation and genetic parameters: The results with regard to PCV (phenotypic coefficient of variation), GCV (genotypic coefficient of variation), heritability broad sense (h^2), genetic advance (GA) and genetic advance as per cent of mean (GAM) for fourteen characters are furnished in Table 2.

Higher values for phenotypic coefficient of variability were obtained than that of genotypic coefficients of variability values, indicating the influence of environment variation on these traits. The days to 50% flowering followed by nodes to first female flower, number of primary branches, vine length at the time of final harvest and nodes to first male flower had larger differences between PCV and GCV values, as these were most influenced by the environment. The remaining characters recorded have smaller difference between PCV and GCV values, as they were less influenced by the environment, indicating reliability of selection based on these traits. The genotypic and phenotypic variances in terms of unit of their expression were observed high for length of fruit (39.76 and 45.63) followed by days to first fruit harvest (33.06 and 37.80). The genotypic and phenotypic variances were observed lowest in fruit yield per vine (0.38 and 0.44), vine length at the time of final harvest (0.48 and 0.67), number of fruits per vine (1.20 and 1.41) and days to 50% flowering (1.13 and 1.19). The moderate genotypic and phenotypic variance was observed in yield per hectare (15.40 and 17.52), days to first female flowering opening (14.80 and 18.52) and weight of 100 seeds (10.29 and 11.47). In general, the magnitude of phenotypic variance and coefficients of variation was higher than their respective genotypic estimates, indicating the environment influence on the expression of these characters. Similar, to this study high GCV for length of fruit and days to first fruit harvest was reported by Singh et al. (2002) in bottle

Table 2: Components of variation and estimates of genetic parameters for various characters in bottle gourd

Characters	Components of variance		Coefficient of variation		h2 (%)	Genetic advance	Genetic advance % of mean
	Genotypic	Phenotypic	Genotypic (%)	Phenotypic (%)			
Days to 50% flowering	1.41	2.22	13.28	16.67	63.44	1.95	21.79
Number of primary branches	4.66	5.77	24.48	27.24	80.72	3.99	45.30
Days to first male flower opening	8.59	10.21	6.41	6.99	84.09	5.54	12.11
Days to first female flower opening	14.80	18.52	7.68	8.59	79.94	7.09	14.14
Nodes to first male flower	4.31	5.09	22.77	24.87	83.81	3.80	42.94
Nodes to first female flower	3.95	5.28	18.58	21.48	74.82	3.54	33.11
Days to first fruit harvest	33.06	37.80	9.21	9.85	87.44	11.08	17.74
Length of fruit (cm)	39.76	45.63	22.49	24.16	86.66	11.84	43.13
Diameter of fruit (cm)	4.47	4.83	26.06	27.10	92.53	4.19	51.65
Vine length at final harvest (m)	0.48	0.67	14.69	17.34	71.80	1.21	25.64
Weight of 100 seeds (g)	10.29	11.47	20.12	21.25	89.72	6.26	39.26
Number of fruits per vine	1.20	1.41	19.21	20.82	85.18	2.09	36.53
Fruit yield per vine (kg)	0.38	0.44	14.56	15.66	86.45	1.19	27.89
Yield per hectare (t)	15.399	17.52	15.51	16.55	87.89	7.58	29.96

gourd. Bhardwaj et al. (2013) revealed high GCV for node number at which first male and female flower appeared and length of fruit in bottle gourd. Whereas, Pandit et al. (2009) noted moderate GCV for days to first female flower opening, fruit length, fruit weight and weight of 100 seed and fruit yield in bottle gourd.

High estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded for diameter of fruit (26.06 and 27.10%), number of primary branches (24.48 and 27.24%), nodes to first male flower (22.77 and 24.87%) and weight of 100 seeds (20.12 and 21.25%), indicating that a greater amount of genetic variability was present for these characters. Moderate value for PCV and GCV was estimated for number of fruits per vine (19.21 and 20.82%), nodes to first female flower (18.58 and 21.48%), yield per hectare (15.51 and 16.55%), vine length at the time of final harvest (14.69 and 17.34%) and fruit yield per vine (14.56 and 15.66%), indicating that a moderate amount of genetic variability was present in these characters, which provided average scope for selection. The lowest estimates of PCV and GCV were observed for traits like days to first male flower opening (6.41 and 6.99%), days to first female flower opening (7.68 and 8.59%) and days to first fruit harvest (9.21 and 9.85%), indicating limited scope for improvement among these traits. These results corroborate the findings of Singh et al. (2014) and Muralidharan et al. (2014) in bottle gourd. High heritability estimates were observed for diameter of fruit (92.53%), weight of 100 seeds (89.72%), yield per hectare (87.89%) days to first fruit harvest (87.44%), length of fruit (86.66%), fruit yield per vine (86.45%), number of fruits per vine (85.18%), days to first male flower opening (84.09%) and nodes to first male flower (83.81%). However, moderate heritability estimates were recorded for number of primary branches (80.72), days to first female flower (79.94%), nodes to first female flower (74.82%), vine length at the time of final harvest (71.80%) and days 50% flowering (63.44%). However, none of the characters under study reported for low heritability estimates. High and moderate estimates of heritability for these traits advocate that the selection based on phenotypic performance of these characters would be more effective. High genetic advance as per cent of mean was observed for diameter of fruit (51.65%), number of primary branches (45.30%), length of fruit (43.13%) and nodes to first male flower (42.94%); moderate for weight of 100 seeds (39.26%), number of fruits per vine (36.53%), nodes to first female flower (33.11%), yield per hectare (29.96%), vine length (25.64%) and days to 50% flowering (21.79%); and low for days to first male flower opening (12.11%), days to first female flower opening (14.14%) and days to first fruit harvest (17.74%). The results of the present investigation are also in agreement with previous studies carried out on bottle gourd by several workers like Yadav and Kumar (2012), Sharma and Sengupta (2013) and Mangala et al. (2015). Thus, the material assessed possessed ample scope of their improvement through selection and utilization in breeding for higher yield and quality.

सारांश

लौकी की 31 प्रभेदों में परपम्पर आनुवांशिक विविधता संकलन वंशागतित्व और भावी सुधार कार्यक्रम के तहत इन प्रभेदों की छँटनी करने के लिए यह प्रयोग चौधरी चरण सिंह हरियाणा कृषि विश्वविद्यालय, हिसार में किया गया था । भिन्नता विश्लेषण से स्पष्ट हुआ कि सभी 14 लक्षणों के लिए विविधता की ज्यादा मात्रा पायी गयी। अध्ययन से पता चला कि अधिकतम पितृ और मातृ गुणांक (पीसीवी और जीसीवी) के लिए, फल का व्यास (26.06 और 27.10), प्राथमिक शाखाओं की संख्या (24.48 और 27.24), गांठों में पहले नर पुष्प विन्यास (22.77 और 24.87) और 100 बीज के वजन के लिए (20.12 और 21.25) सबसे अधिक मात्रा के संयोजन पाये गये जबकि मध्यम पितृ ओर मातृ गुणांक के लिए फलों की संख्या प्रति बेल (19.21 और 20.82) प्रथम मादा पुष्पन (18.58 और 21.48) के पार्श्व गांठ प्रति हेक्टेयर फल उपज (15.51 और 16.55), अंतिम तुड़ाई के समय लता की लंबाई (14.69 ओर 17.34) और प्रति लता फल की उपज (14.56 और 15.66) के लिए बीच के संयोजक थे। उच्च वंशागतित्व के साथ उच्च अनुवांशिकता मिलकर फल का व्यास, फल की लंबाई, प्रथम नर पुष्प क्यू पार्श्व गांठ पर 11 भास और 100 बीजों के वनज के लिए अनुकूल एवं प्रभावशाली पाये गये। यह अध्ययन दर्शाता है कि ये लक्षण योगात्मक जीन प्रतिक्रिया के मजबूत प्रभाव में थे। मध्यम विरासत और कम अनुवांशिक अग्रिम मूल्यों को वर्णों के दिनों के पहले नर पुष्प खिलन, पहले मादा फूलों के खिलने के दिन प्रथम बार फूल की लंबाई के दिन और 50 प्रतिशत अंकुरण के दिनों के लिए उत्तम पाया गया। उच्च फल उपज देने वाले उत्कृष्ट प्रभेदों जीएच 30 और जीएच 32 थे और प्रभेद में पाया गया।

References

Bhardwaj DR, Singh A and Singh U (2013) Genetic variability of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] by multivariate analysis. Proc. of National Symposium on Abiotic and Biotic Stress management in Vegetable Crops. Indian Society of Vegetable Science, pp 370.

Gajera RR and Joshi DC (2014) Processing and storage stability of bottle gourd (*Lagenaria siceraria*) base blend juice. Agri Engineering Intel 6(2): 103-107.

Hassan LG, Sani NA, Dangoggo SM and Ladan MJ (2008) Nutritional value of bottle gourd (*Lagenaria siceraria*) seeds. Global J Pure Appl Sci 14(3): 301-306.

Husna AM, Maih A, Begum S, Shilpi, SZ and Islam MR (2014) Genetic variability, correlation and path coefficient analysis based on vegetative characters in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). Advan Agri Biol 2(1): 8-12.

Mangala T, Mandal J and Dhangrah VK (2015) Studies on genetic variability and trait inter relationship in bottle gourd (*Lagenaria siceraria* (Mol.) Standl). Hort Flora Res Spec 4(1): 34- 38.

Muralidharan BV, Kanthaswamy B, Sivakumar S, Kumar R and Magalingam V (2014) Genetics and variability in bottle gourd (*Lagenaria siceraria* M.). Trends Biosci 7(22): 3736-3740.

Pandit MK, Mahato B and Sarkar A (2009) Genetic variability, heritability and genetic advance for some fruit character and yield in bottle gourd. Acta Hort 809: 221-225.

Sharma A and Sengupta SK (2013) Genetic diversity, heritability and morphological characterization in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). The Bioscan 8(4): 1461-1465.

Sheoran OP (2010) Online Statistical Analysis (OPSTAT), A software developed by CCSHAU, Hisar, Haryana. http:// *www.hau.ernet.in/opstat.html*.

Singh DK and Kumar R (2002) Studies on the genetic variability in bottle gourd. Prog Hort 34(1):99-101.

Singh SP, Singh B, Mohan M, Rao S and Soni S (2014) Genetic variability for some quantitative traits in bottle Gourd [*Lagenaria Siceraria* (Molina) standl.]. Annals Hort 8(1): 113-115.

Yadav YC and Kumar S (2012) Studies on genetic variability, correlation coefficient and path analysis in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]. Annals Hort 5(1): 80-89.

Vegetable Science (2018) 45(2) : 180-184

Elucidation of correlation and path coefficient analysis for various morphological attributes in elite genotypes of bitter melon (*Momordica charantia* L.)

Durga Prasad Moharana*, MM Syamal, Anand Kumar Singh and KK Gautam[1]

Received: January 2019 / Accepted: January 2019

Abstract

Bitter gourd or bitter melon is undoubtedly one of the most significant members of the cucurbitaceous vegetable crops. Through the exploitation of this highly potential crop, novel mechanisms and strategies can be developed that will open the wide arrays for further improvement. Keeping this objective in mind, a field investigation was conducted with twenty genotypes of bitter gourd at Vegetable Research Farm of Banaras Hindu University to estimate the character association as well as direct and indirect effects of different yield traits on average yield per plant through correlation and path coefficient analysis. The data demonstrated that the positive and significant interrelationship with average yield per plant was obtained by various traits, viz., node number of first staminate flower (0.375), node number of first pistillate flower (0.54), vine length (0.417), fruit length (0.356), fruit circumference (0.79), average fruit weight (0.768), fruits per plant (0.637), and internodal length (0.3) while negative significant correlation was followed by days to anthesis of first staminate flower (-0.331) and days to first harvest (-0.355). The average fruit weight (0.572) had highest direct positive effect on average yield per plant followed by traits like days to fifty per cent flowering (0.296), number of fruits per plant (0.274), and number of primary branches per plant (0.259) whereas maximum direct negative effect was recorded by days to anthesis of first staminate flower (-0.263) followed by internodal length (-0.162) and days to first harvest (-0.152). The traits with high positive direct effect should be more prioritised for effective selection of promising genotypes for further crop improvement programmes.

Keywords: Bitter gourd, path coefficient analysis, yield contributing traits

Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi, UP

[1]ICAR-Indian Institute of Vegetable Research, Varanasi, UP

*Corresponding author, Email: dpmhort03@gmail.com

Introduction

Cucurbits possess a distinctive place among different groups of vegetable crops. There are about 100 genera and 750 species almost equally divided between new and old world tropics in the family of Cucurbitaceae (Yamaguchi, 1983). Cucurbits can extensively be found in every part of India as well as in other tropical and sub-tropical parts of the world. It is grown extensively throughout India and other tropical and sub-tropical regions of the world. Among the cucurbits, *Momordica charantia* L. (Bitter gourd or bitter melon or balsam pear) is one of the major commercial crops in India which is suitable for hot and humid areas although it is well adapted to a wider range of climatic variations. It is basically a warm season, climbing annual of fast growing nature. In comparison with other cucurbits, bitter gourd has got a very high nutritive status due to its enrichment in various vitamins like retinol, thiamine, riboflavin, and ascorbic acid; and minerals like iron, calcium, potassium, phosphorous, etc. A range of pharmacological properties, viz., antidiabetic, antioxidant, antimicrobial, antiviral, antihepatotoxic, etc. have been credited to the crop (Behera et al. 2010). The understanding of correlation coefficient points out the interrelationship between two characters and forms a basis in the selection of the desirable plant type whereas is simply a standardized partial regression coefficient and measures the direct influence of one variable upon another and permits the partitioning of the correlation coefficient into components of direct and indirect effects. Path coefficient can be defined as "the ratio of the deviation when all causes are constant, except one in question, the variability of which kept in changed". In agriculture, plant breeders use the assistance of correlation and path coefficient analysis in order to ascertain the characters of high importance as selection criteria targeting to improve the crop yield

(Wright 1921; Dewey and Lu 1959). Path coefficient analysis provides a vivid idea about the contribution of individual independent parameter on the dependant one, i.e., yield. Although bitter gourd is an important member of cucurbitaceous vegetable group, adequate information is not readily available regarding these aspects. Hence, an investigation was carried out to estimate the character association among various quantitative as well as the direct and indirect effects of different independent characters on yield in elite genotypes of bitter gourd.

Materials and Methods

The investigation was planned and carried out at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University during kharif season of 2014. The experimental material consisted of twenty diverse genotypes of bitter gourd, viz., Jharli, Special Bolder Ucha, Meghna No. 2, Vikas, Improved Kathai, Arola-D, Dhanraj, NBR-Noble Katahi, Jaunpuri (Special), Preethi, PF Uchia, Karola Gor, G. Uchia, IC-085608, IC-085609, IC-085610, IC-085611, IC-085612, IC-085613, and IC-085615 collected from ICAR-Indian Institute of Vegetable Research, Varanasi (Uttar Pradesh) and Bidhan Chandra Krishi Viswavidyalaya, Mohanpur (West Bengal). The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications and the unit plot size was 5 m^2 (2.5 m × 2 m). There is random allocation of the genotypes to a unit plot in each replication. To maintain a healthy crop stand, good cultural practices were precisely followed and plant protection measures were taken care of as per the requirement. The biometrical observations were recorded on five randomly selected plants excluding the border plants considering fourteen quantitative characters, viz., node number of first staminate flower, node number of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to fifty per cent flowering, days to first harvest, number of primary branches per plant, vine length (m), internodal length (cm), fruit length (cm), fruit circumference (cm), average fruit weight (g), number of fruits per plant, and average yield per plant (kg). The data have been collected and subjected to correlation coefficient (Al-Jibouri et al. 1958) and path coefficient analysis according to the method suggested by Dewey and Lu (1959).

Results and Discussion

Correlation coefficient briefs about the relationship among various traits under study and path coefficient analysis gives an insight for partitioning of correlation coefficient into direct and indirect effects of different independent characters on the dependent one, i.e., yield. Path coefficient analysis delivers an effective method of revealing the direct and indirect causes of association and puts forth a critical analysis of the specific forces acting to generate a given correlation and estimates the relative relevance of each causal factor. The correlation coefficient and path coefficient analysis of different characters on genotypic basis in twenty diverse genotypes of bitter gourd are furnished in Table 2 and Table 3, respectively. The Analysis of variance for all the characters was found to be highly significant (Table 1) thus indicating wide variation among the twenty genotypes taken in the study.

Table 1: Analysis of variance for 14 quantitative characters in 20 bitter gourd genotypes

Character	Mean sum of square		
	Replications (df = 2)	Treatments (df = 19)	Error (df = 38)
Node number of first staminate flower	1.3705	19.850*	0.9431
Node number of first pistillate flower	1.1599	26.729*	2.2793
Days to anthesis of first staminate flower	1.2667	72.978*	3.933
Days to anthesis of first pistillate flower	0.8167	55.705*	4.0447
Days to fifty per cent flowering	11.4098	73.223*	7.2618
Days to first harvest	5.0544	87.080*	8.0219
Number of primary branches per plant	0.3086	5.480*	0.8262
Vine length (m)	0.0337	0.418*	0.0367
Internodal length (cm)	0.0389	0.973*	0.0570
Fruit length (cm)	5.5660	11.935*	1.9721
Fruit circumference (cm)	0.7674	11.209*	1.0539
Average fruit weight (g)	33.1271	406.399*	16.3435
Number of fruits per plant	2.8376	44.339*	5.7600
Average yield per plant (kg)	0.0019	0.1936*	0.0103

* Significant at p d" 0.05

The node number of first staminate flower showed significant and positive correlation with node number of first pistillate flower (0.770), fruit length (0.499), average fruit weight (0.476), vine length (0.342), and days to fifty per cent flowering (0.306); and demonstrated direct negative effect towards average yield per plant (-0.228) level while with respect to indirect effect, this trait exhibited highest positive effect towards average yield per plant via days to anthesis of first pistillate flower (0.009) and showed highest negative effect via node number of first pistillate flower (-0.181).

The node number of first pistillate flower was positively and significantly correlated with fruits per plant (0.667), average fruit weight (0.520), vine length (0.487), fruit circumference (0.386), days to fifty per cent flowering

(0.296), and fruit length (0.262). The trait exerted direct negative effect (-0.389) towards average yield per plant while considering the indirect effect, maximum positive indirect effect towards average yield per plant was recorded via number of primary branches per plant (0.049) and highest negative indirect effect was exerted via node number of first staminate flower (-0.309). Days to anthesis of first staminate flower showed positive and significant association with days to first harvest (0.980), days to anthesis of first pistillate flower (0.997), days to 50% flowering (0.910), number of primary branches per plant (0.416), fruit length (0.315) and internodal length (0.273). A direct positive effect (8.844) was recorded by the days to anthesis of first staminate flower towards average yield per plant. Regarding to indirect effect, this trait unveiled highest positive (8.818) and negative (-3.747) effect towards average yield per plant via days to anthesis of first pistillate flower and fruit circumference, respectively.

Days to anthesis of first pistillate flower recorded positive and significant correlation with days to 50% flowering (0.971), days to first harvest (0.774), number of primary branches per plant (0.281), and fruit length (0.255). A direct negative effect (-2.889) towards average yield per plant was recorded by days to anthesis of first pistillate flower. Regarding to indirect effect, highest positive indirect effect towards average yield per plant was exhibited via fruit circumference (0.95) and highest negative indirect effect was recorded via days to anthesis of first staminate flower (-2.88).

The days to fifty per cent flowering showed positive and significant correlation with days to first harvest (0.859), number of primary branches per plant (0.552) and fruit length (0.434); and demonstrated direct negative effect (-5.534) towards average yield per plant. Considering the indirect effect, this trait recorded highest positive indirect effect towards average yield per plant via fruit circumference (2.236) and maximum negative indirect effect via days to anthesis of first pistillate flower (-5.376).

The days to first harvest was positively and significantly correlated with number of primary branches per plant (0.392) and internodal length (0.254). The trait under study exhibited direct negative effect towards average yield per plant (-1.805). Regarding to indirect effect, highest positive indirect effect towards average yield per plant was demonstrated via fruits per plant (0.845) and highest negative indirect effect was shown via days to anthesis of first staminate flower (-1.77).

The number of primary branches per plant was positively and significantly correlated with internodal length (0.529), vine length (0.44), and fruit length (0.389); and had direct positive effect towards average yield per plant (2.336). Regarding to indirect effect, this trait exhibited highest positive effect towards average yield per plant via days to fifty per cent flowering (1.288) while highest negative effect was exhibited via fruit circumference (-1.069). Vine length was positively and significantly correlated with fruit length (0.353), fruits per plant (0.403), and average fruit weight (0.307). A direct negative effect (-2.948) was recorded by the vine length towards average yield per plant. With consideration of indirect effect, this trait revealed highest positive indirect effect towards average yield per plant

Table 2: Genotypic correlations among various yield and yield attributing traits in bitter gourd

Characters	NNFSA	NNFPA	DAFSF	DAFPF	DFPF	DFH	NPBP	VL	IL	FL	FC	AFW	FP	AYP
NNFSA	1.000	0.770*	0.004^{NS}	-0.037^{NS}	0.306*	0.067^{NS}	0.077^{NS}	0.342*	-0.341**	0.499**	0.123^{NS}	0.476**	0.145^{NS}	0.375**
NNFPA		1.000	0.016^{NS}	0.141^{NS}	0.296*	0.012^{NS}	-0.149^{NS}	0.487*	-0.707**	0.262*	0.386**	0.520**	0.667**	0.536**
DAFSF			1.000	0.997**	0.910*	0.980*	0.416*	-0.313*	0.273*	0.315*	-0.424**	-0.079^{NS}	-0.420**	-0.331**
DAFPF				1.000	0.971**	0.944**	0.380**	-0.184^{NS}	0.236^{NS}	0.356**	-0.329*	-0.044^{NS}	-0.256*	-0.237^{NS}
DFPF					1.000	0.859**	0.552**	-0.001^{NS}	0.166^{NS}	0.434**	-0.404**	0.036^{NS}	-0.227^{NS}	-0.097 ^{NS}
DFH						1.000	0.392**	-0.395**	0.254*	0.232^{NS}	-0.419**	-0.137^{NS}	-0.468**	-0.355**
NPBP							1.000	0.44*	0.529**	0.389**	-0.457**	-0.109^{NS}	-0.372**	-0.024 ^{NS}
VL								1.000	-0.115^{NS}	0.353**	0.085^{NS}	0.307*	0.403**	0.417**
IL									1.000	-0.041^{NS}	-0.785**	-0.636**	-0.629**	0.301**
FL										1.000	0.158^{NS}	0.662**	-0.127^{NS}	0.356**
FC											1.000	0.652**	0.631**	0.79**
AFW												1.000	0.216^{NS}	0.768**
FP													1.000	0.638**
AYP														1.000

Residual effect=0.0561; NS = Nonsignificant, ** = p d" 0.01, * = p d" 0.05

N.B., NNFSF=Node number of first staminate flower, NNFPF=Node number of first pistillate flower, DAFSF=Days to anthesis of first staminate flower, DAFPF=Days to anthesis of first pistillate flower, DFPF=Days to fifty per cent flowering, DFH=Days to first harvest, NPBP=Number of primary branches per plant, VL=Vine length (m), IL=Internodal length (cm), FL=Fruit length (cm), FC=Fruit circumference (cm), AFW=Average fruit weight (g), FP=Fruits per plant, and AYP=Average yield per plant.

Table 3: Direct (bold faced) and indirect effects of genotypic path coefficient for various traits on average fruit yield in bitter gourd

Characters	NNFSF	NNFPF	DAFSF	DAFPF	DFPF	DFH	NPBP	VL	IL	FL	FC	AFW	FP	Correlation with AYP
NNFSF	-0.228	-0.181	-0.001	0.009	-0.07	-0.015	-0.018	-0.078	-0.108	-0.114	-0.028	-0.109	-0.033	0.375**
NNFPF	-0.309	-0.389	-0.012	-0.053	-0.12	-0.006	0.049	-0.187	-0.122	-0.093	-0.138	-0.195	-0.248	0.536**
DAFSF	0.036	0.261	8.844	8.818	8.049	8.671	3.676	-2.769	-1.852	2.787	-3.747	-0.696	-3.71	-0.331**
DAFPF	0.107	-0.39	-2.88	-2.889	-2.806	-2.726	-1.098	0.532	0.307	-1.029	0.95	0.128	0.74	-0.237^{NS}
DFPF	-1.693	-1.706	-5.036	-5.376	-5.534	-4.755	-3.052	0.009	-0.819	-2.401	2.236	-0.199	1.257	-0.097^{NS}
DFH	-0.121	-0.026	-1.77	-1.704	-1.551	-1.805	-0.708	0.713	0.276	-0.42	0.757	0.247	0.845	-0.355**
NPBP	0.18	-0.294	0.971	0.888	1.288	0.916	2.336	1.027	0.894	0.909	-1.069	-0.255	-0.869	-0.024^{NS}
VL	-1.009	-1.416	0.923	0.543	0.005	1.165	-1.296	-2.947	-1.938	-1.041	-0.251	-0.906	-1.189	0.417**
IL	0.414	0.275	-0.183	-0.093	0.129	-0.133	0.334	0.573	0.872	0.383	-0.109	0.315	0.001	0.301**
FL	1.166	0.561	0.736	0.833	1.014	0.543	0.91	0.825	1.026	2.337	0.368	1.546	-0.297	0.356**
FC	-0.579	-1.668	1.995	1.549	1.903	1.974	2.154	-0.4	0.588	-0.742	-4.709	-3.072	-2.973	0.79**
AFW	0.8	0.842	-0.132	-0.075	0.06	-0.23	-0.184	0.517	0.607	1.113	1.097	1.681	0.364	0.768**
FP	0.852	3.751	-2.465	-1.505	-1.335	-2.751	-2.187	2.371	0.007	-0.746	3.71	1.272	5.877	0.638**

Residual effect=0.0614; NS = Nonsignificant, ** = p d" 0.01, * = p d" 0.05

N.B., NNFSF=Node number of first staminate flower, NNFPF=Node number of first pistillate flower, DAFSF=Days to anthesis of first staminate flower, DAFPF=Days to anthesis of first pistillate flower, DFPF=Days to fifty per cent flowering, DFH=Days to first harvest, NPBP=Number of primary branches per plant, VL=Vine length (m), IL=Internodal length (cm), FL=Fruit length (cm), FC=Fruit circumference (cm), AFW=Average fruit weight (g), FP=Fruits per plant, and AYP=Average yield per plant.

via days to fifty per cent flowering (1.288) and highest negative indirect effect via fruit circumference (-1.069).

Regarding direct effect, the internodal length had positive effect towards average yield per plant (0.872) whereas for indirect effect towards average yield per plant, maximum positive effect via vine length (0.573) and highest negative effect via days to anthesis of first staminate flower (-0.183) were recorded. Fruit length is positively and significantly correlated with average fruit weight (0.662) and towards average yield per plant, the fruit length (cm) exerted direct positive effect (2.337) while with respect to indirect effect, maximum positive indirect effect via average fruit weight (1.546) and highest negative indirect effect via fruits per plant (-0.297) were recorded towards average yield per plant.

Fruit circumference is positively and significantly correlated with average fruit weight (0.652) and fruits per plant (0.631); and showed direct negative (-4.709) effect towards average yield per plant. The trait unveiled highest positive indirect effect towards average yield per plant via number of primary branches per plant (2.154) and highest negative indirect effect via average fruit weight (-3.072). The average fruit weight had direct positive effect towards average yield per plant (1.681). The trait recorded highest positive indirect effect towards average yield per plant via fruit length (1.113) while maximum negative indirect effect was recorded via days to first harvest (-0.23). The number of fruits per plant demonstrated direct positive effect towards yield (5.877). This trait exhibited highest positive indirect effect towards average yield per plant via node number of first pistillate flower (3.751). Highest negative indirect effect via days to first harvest (-2.751) was recorded. These findings are in conformity with Singh et al. (2016), Kumari et al. (2018), Singh et al. (2014), Tyagi et al. (2018), Kumar et al. (2018), Yadav et al. (2013), Singh et al. (2015), and Janaranjani and Kanthaswamy (2015).

Critical investigation of results revealed that characters like node number of first staminate flower (0.375), node number of first pistillate flower (0.540), vine length (0.417), fruit length (0.356), fruit circumference (0.790), average fruit weight (0.768), fruits per plant (0.637), and internodal length (0.300) are positively and significantly correlated with yield while days to anthesis of first staminate flower (-0.331) and days to first harvest (-0.355) are negatively and significantly correlated with average yield per plant. The average fruit weight had maximum direct positive effect on average yield per plant followed by traits like days to fifty per cent flowering, number of fruits per plant, and number of primary branches per plant whereas highest direct negative effect was exhibited by days to anthesis of first staminate flower followed by internodal length and days to first harvest. These findings are in accordance with Sundaram (2010), Singh et al. (2012), Pandey et al. (2012), Dalamu and Behera (2013), and Rani et al. (2015). The traits with high positive direct effect should be given more emphasis as these can be used as effective selection criteria in order to advance the further crop improvement programme.

सारांश

करेला निसंदेह कद्दूवर्गीय सब्जियों में एक महत्वपूर्ण सब्जी है। इस फसल में उत्कृष्ट तंत्रों एवं रणनीतियों को अपनाकर भविष्य में और अधिक उन्नयन की गति को बढ़ाया जा सकता है। इस उद्देश्य को ध्यान में रखकर 20 प्रभेदों को सम्मिलित कर सब्जी अनुसंधान प्रक्षेत्र, कषि विज्ञान संस्थान, काशी हिन्दू विश्वविद्यालय में गुणों का संबंध तथा उपज व उपज घटकों के प्रत्यक्ष व अप्रत्यक्ष प्रभाव तथा पथ गुणांक विश्लेषण के लिए प्रक्षेत्र परीक्षण किया गया। आंकड़ों से स्पष्ट हुआ कि प्रति पौध औसत उपज के साथ अन्य गुणों जैसे प्रथम नर पुष्प विकास की गांठ संख्या (0.375), प्रथम मादा पुष्प विकास की गांठ संख्या (0.54), बेल की लंबाई (0.417), फल की लंबाई (0.356), फल की परिधि (0.79), फल की औसत (0.768), प्रति पौध फल संख्या (0.637) व पार्श्व गांठ की लम्बाई (0.3) का सकारात्मक और महत्वपूर्ण अन्तः संबंध प्राप्त हुआ जबकि प्रथम नर पुष्प का पुष्पन (–0.331) व प्रथम तुड़ाई के दिन (–0.355) के लिए नकारात्मक और महत्वपूर्ण सहसंबंध था। औसत फल भार (0.572) का प्रति पौध औसत उपज हेतु सबसे अधिक प्रत्यक्ष प्रभाव पाया गया और उसके बाद अन्य गुणों जैसे– 50 प्रतिशत पुष्पन के दिन (0.296), प्रति पौध फलों की संख्या (0.274) और प्रति पौध शाखाओं की संख्या (0.259) का रहा जबकि अधिकतम नकारात्मक प्रतयक्ष प्रभाव नर पुष्प के पुष्पन के दिन (–0.263) का था और इसके उपरान्त पार्श्व गांठ की लम्बाई (–0.162) व प्रथम तुड़ाई के दिन (–0.162) का रहा। उच्च सकारात्मक प्रत्यक्ष प्रभाव वाले गुणों की ज्यादा प्राथमिकता देना चाहिए जिसके माध्यम से उत्कष्ष्ट प्रभेदों का चयन किया जा सके और चयनित प्रभेदों को आगे फसल उन्नयन में उपयोग हो सके।

References

Al-Jibouri HA, Millar PA and Robinson HF (1958) Genotypic and environmental variances and co-variances in an upland cotton cross of inter-specific origin. Agron J 50: 633-636.

Behera TK, Behera S, Bharathi LK and Joseph JK (2010) Bitter gourd: Botany, horticulture and breeding. In: Janick J (ed.) Hort. Reviews, Wiley Blackwell, pp 101–141.

Dalamu and Behera TK (2013) Character association and path coefficient analysis of indigenous and exotic bitter gourd (*Momordica charantia* L.) germplasm. Indian J Agri Sci 83(5): 525-528.

Dewey DR and Lu KH (1959) A correlation and path co-efficient analysis of components of crested wheat grass and seed production. Agro J 51: 515-518.

Janaranjani KG and Kanthaswamy V (2015) Correlation studies and path analysis in bottle gourd. J Hort 2(1): 1-4.

Kumar D, Kumar S, Meena ML, Meena RK and Kumar P (2018) Correlation and characters association studies in bitter gourd (*Momordica charantia* L.). J Pharma Phyto 7(2): 3510-3514.

Kumari A, Singh AK, Moharana DP, Kumar A and Kumar N (2018) Character relationship and path coefficient analysis for yield and yield components in diverse genotypes of cucumber (*Cucumis sativus* L.). The Phar Inno J 7(5): 33-38.

Pandey P, Singh VB and Achila S (2012) Correlation and path analysis of yield and yield contributing traits for higher yield and better marketable traits in sponge gourd (*Luffa cylindrica* L Roem.). Prog Hort 44(1): 126-129.

Rani KR, Raju CS and Reddy KR (2015) Variability, correlation and path analysis studies in bitter gourd (*Momordica charantia* L.). Agri Sci Dig 35(2): 106-110.

Singh B, Pandey VP and Kumar S (2012) Genetic variability, correlation and path coefficient analysis in bitter gourd (*Momordica charantia* L.). New Agri 23(2): 239-244.

Singh HK, Singh VB, Kumar R, Barnawal DK and Ray PK (2015) Character association, heritability and path analysis for yield and its contributing traits in bitter gourd (*Momordica charantia* L.). Prog. Agri. 15(1): 41-47.

Singh MK, Bhardwaj DR and Upadhyay DK (2014) Genetic architecture and association analysis in bitter gourd (*Momordica charantia* L.) landraces. The Bioscan 9(2): 707-711.

Singh P, Moharana DP, Kurrey V, Bara S, Minz R and Anand PK (2016) Path Coefficient analysis among quantitative and qualitative traits in pointed gourd (*Trichosanthes dioica* Roxb.) in Chhattisgarh region. Prog Res-An Inter J 11(Special-IV): 2146-2148.

Sundaram V (2010) Studies on character association in bitter gourd (*Momordica charantia* L.) under salt stress. The Asian J Hort 5(1): 99-102.

Tyagi N, Singh VB and Maurya PK (2018) Character association and path coefficient analysis of bitter gourd (*Momordica charantia* L.) genotypes. J Pharma and Phyto 7(2): 2419-2422.

Wright S (1921) Systems of mating. Parts I–V. Genetics 6: 111-178.

Yadav M, Pandey TK, Singh DB and Singh GK (2013) Genetic variability, correlation coefficient and path analysis in bitter gourd. Indian J Hort 70(1): 144-149.

Yamaguchi M (1983) World Vegetables. AVI, Westport

Vegetable Science (2018) 45(2) : 185-190

Selection parameters for yield and quality traits in Bhut Jolokia (*Capsicum chinense* Jacq.) under poly-house condition from North East India

Ephilo Mena[1], SD Warade[1], RK Dubey[2], Mohd Talha Ansari[1]*and Md. Ramjan[1]

Received: October 2018 / Accepted: January 2019

Abstract

Sixteen genotypes of Bhut Jolokia were evaluated in polyhouse with three replications at vegetable research farm, CHF, CAU, Pasighat, Arunachal Pradesh. Correlation and path analysis were carried out to study the character association and contribution, respectively. Correlation There was a great deal of significant variation for all the characters among the genotypes. In the present investigation, Correlation studies revealed that characters like weight of ripe fruit (0.966, 0.874), fruit length (0.622, 0.503), weight of dry fruit (0.905, 0.805), dry fruit yield per plant (0.903, 0.875) and capsaicin content (0.458, 0.393) was observed significant positive correlation with fruit yield per plant both at genotypic and phenotypic level. However, at genotypic level, weight of ripe fruit had maximum positive direct effect on fruit yield per plant (1.025) followed by dry fruit yield per plant (0.865), fruit length (0.236), ascorbic acid content (0.203). The findings of present study confirmed that, weight of ripe fruit, fruit length, weight of dry fruit, dry fruit yield per plant and capsaicin content were the important characters for selection and chilli breeding programme.

Key words: Bhut Jolokia, King chilli, correlation, path analysis, genotypic, polyhouse

Introduction

Bhut Jolokia or King chilli or Habanero chile (*Capsicum chinense* Jacq.) is a species of chilli that is native to Amazon basin. The Dutch botanist, Nikolaus Joseph von Jacquin, erroneously named the species as *chinense* in 1776 as he believed that the species originated in China. The species varies greatly in appearance and characteristics of plant growth, flowering, fruit morphology, taste and pungency, which makes very difficult to identify (Singh et al. 2012). Yield is a complex character controlled by large number of contributing characters and their interaction. It is not only influenced by a number of related characters which are governed by few numbers of genes, but is also influenced to a greater extent by environment. The study of correlation coefficients will helps in simultaneous selection for more than one character (Vidya et al. 2018). Chilli is an often cross pollinated crop with high natural cross pollination and this also contributes to its variability, the aim of any breeding program depends on genetic diversity, characters association and direct and indirect effects on yield and its component character (Pandiyaraj et al. 2017). A phenotypic correlation is usually estimated by the product moment correlation (simple correlation). The genotypic correlation in its true sense may be interpreted as the correlation of breeding values (additive genetic). Therefore, selection made for one trait influenced the other linkage or pleotropically affected traits. Correlation between yield and its components and their relative contribution to the yield have a great importance in planning effective breeding programmes and selection of hybrids and parents. Correlation provides information on relationship and does not give any idea about their direct and indirect contribution. Consequently, this information is sometimes misleading with respect to identification of yield components. Path coefficient analysis is one such method which partitions correlation into direct and indirect effects (Wright, 1921 and Dewey and Lu, 1959). Path coefficient analysis helps for sorting out the total correlations into direct and indirect effects and useful in selecting high yielding genotypes available (Yatung et al. 2014a). Correlation simply measures the association between yield and other traits, whereas path coefficient analysis permits the separation of correlation into direct effects and indirect effects (Shweta et al. 2018). Therefore, sixteen King chilli genotypes were collected from different parts of the country and an attempt was made to study interrelationships among important characters and their

[1]College of Horticulture and Forestry, Central Agricultural University, Pasighat-791102 Arunachal Pradesh

[2] ICAR-Indian Institute of Vegetable Research, Varanasi-221305, Uttar Pradesh

*Corresponding author, Email: ansari.talha0@gmail.com

direct and indirect effects on fruit yield by path coefficient analysis.

Materials and Methods

The experiment was carried out in poly-house complex at College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh during 2015-2016. The experiment was laid out with sixteen genotypes (Table1) in randomized completely block design (RCBD) with three replications with spacing (60 x 50 cm). Correlation and path analysis was studied for characters *viz.*, plant height (cm), number of branch per plant, days to 50% flowering, days to first picking, weight of ripe fruit (g), fruit length (cm), number of fruit per plant, fruit yield per plant (Kk), weight of dry fruit (g), dry fruit yield per plant (Kg), ascorbic acid content (mg/100g), capsaicin content (%) and pigment analysis.

Genotypic (v_g) and phenotypic (v_p) correlation coefficients were estimated according to the formulae given by Al-Jibouri et al. (1958). The significance of phenotypic and genotypic correlation coefficient was compared with table r values, as given by Fisher and Yates (1963) at n-2 degree of freedom where 'n' denotes number of genotypes. The path coefficient analysis was done to calculate direct and indirect contribution of different characters towards yield. The direct and indirect effects were calculated by solving the following set of simultaneous equations proposed by Dewey and Lu (1959).

Table 1: List of Chilli genotypes with their sources of collection

Genotype	Source
CHFKC-1	Along , Arunachal Pradesh (A.P)
CHFKC-2	Palin (A.P.)
CHFKC-3	Yazali (A.P.)
CHFKC-4	Kurungkumey (A.P.)
CHFKC-5	Mebo (A.P.)
CHFKC-6	Pasighat (A.P.)
CHFKC-7	Kiyit (A.P)
CHFKC-8	Imphal (Manipur)
CHFKC-9	Tseipama (Nagaland)
CHFKC-10	Daporijo (A.P)
CHFKC-11	Mariyang (A.P)
CHFKC-12	Pasighat (A.P)
CHFKC-13	Dimapur (Nagaland)
CHFKC-14	Mariyang (A.P)
CHFKC-15	Pasighat (A.P)
CHFKC-16	Along (A.P)

Results

Genotypic and phenotypic correlation: The phenotypic and genotypic correlation coefficients among different characters were worked out in all possible combinations (Table 2). The genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the characters; indicated strong association between the two characters genetically. Correlation studies revealed that characters like weight of ripe fruit (0.966, 0.874), fruit length (0.622, 0.503), weight of dry fruit (0.905, 0.805), dry fruit yield per plant (0.903, 0.875) and capsaicin content (0.458, 0.393) had significant positive correlation with fruit yield/plant both at genotypic and phenotypic level. However, negative association of fruit yield/plant was illustrious with plant height (-0.079, -0.111), number of branch/plant (-0.161, -0.315), ascorbic acid content (-0.255, -0.207), â-Carotene (-0.284, -.0233) and á-carotene (-0.272, -.0261) both at genotypic and phenotypic level, respectively.

Path coefficient analysis: Upon the assessment of apparent relationship between yield and yield components, it was felt necessary to partition the direct and indirect effects of each character on yield to understand the association more realistically (Table 3). At phenotypic level, path coefficient analysis showed that weight of ripe fruit had maximum direct positive effect on fruit yield per plant (0.716) followed by dry fruit yield per plant (0.511), days to first picking (0.314), number of fruits/plant (0.158), shelf life at ambient temperature (0.117), capsaicin content (0.115), â-carotene content (0.046) and ascorbic acid content (0.023). While, maximum negative direct effects on fruit yield/plant were recorded for days to 50% flowering (-0.287) followed by weight of dry fruit (-0.157), fruit length (-0.147), á-carotene content (-0.117), plant height (-0.051) and number of branch/plant (-0.027) (Table 3). At genotypic level, weight of ripe fruit had maximum positive direct effect on fruit yield/plant (1.025) followed by dry fruit yield/plant (0.865), fruit length (0.236), ascorbic acid content (0.203), á-carotene content (0.104) shelf life at ambient temperature (0.061) and days to first picking (0.048). However, maximum negative direct effect on fruit yield per plant were observed by weight of dry fruit (-1.012) followed by days to 50% flowering (-0.253), plant height (-0.171), number of fruit/plant (-0.159), number of branch/plant (-0.106), â-carotene content (-0.069) and capsaicin content (-0.0124) (Table 3).

At phenotypic level, the weight of dry fruit imposed high positive indirect effect on fruit yield per plant was recorded through weight of ripe fruit (0.630), followed by dry fruit yield/plant through weight of ripe fruit (0.517), weight of dry fruit through dry fruit yield/plant (0.440), fruit length through weight of ripe fruit (0.380), weight of ripe fruit through dry fruit yield/plant (0.369),

Table 2: Phenotypic and genotypic correlation coefficients among the yield and its contributing characters

Character	Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Plant height	P	1.000	0.055	-0.231	-0.216	-0.000	-0.007	-0.172	0.041	-0.017	0.188	0.210	-0.353*	-0.027	0.008	-0.111
	G	1.000	0.367*	-0.149	-0.099	-0.024	0.024	-0.214	0.073	0.044	0.496**	0.371**	-0.443**	-0.032	0.053	-0.079
Number of branch/plant	P		1.000	0.018	0.064	0.025	-0.341*	-0.144	-0.047	-0.097	-0.088	0.324*	-0.062	0.285*	0.198	-.031
	G		1.000	-0.385**	-0.229	0.077	-0.501**	-0.584**	-0.037	-0.2456	-0.479**	0.326*	-0.142	0.401**	0.301*	-0.161
Days to 50% flowering	P			1.000	0.945**	-0.019	0.250	-0.027	0.036	0.033	0.127	0.143	-0.026	-0.336*	-0.314*	0.014
	G			1.000	0.942**	0.005	0.359*	-0.372**	0.054	-0.098	-0.037	0.087	-0.082	-0.429**	-0.351*	-0.122
Days to first picking	P				1.000	0.083	0.376**	-0.008	0.090	0.081	0.025	0.090	0.000	-0.349*	-0.366*	0.114
	G				1.000	0.157	0.531**	-0.320*	0.143	0.008	-0.182	0.024	-0.052	-0.442**	-0.426**	0.032*
Weight of ripe fruit	P					1.000	0.531**	-0.299*	0.880**	0.722**	-0.280	-0.233	0.398**	-0.259	-0.229	0.874**
	G					1.000	0.564**	-0.542**	0.900**	0.818**	-0.279	-0.240	0.416**	-0.295*	-0.250	0.966**
Fruit length	P						1.000	-0.050	0.502**	0.470**	-0.106	-0.369**	0.341*	-0.596**	-0.597**	0.503**
	G						1.000	-0.060	0.517**	0.547**	-0.148	-0.471**	0.374**	-0.631**	-0.674**	0.622**
Number of fruit/plant	P							1.000	-0.266	0.219	0.002	0.002	-0.031	0.096	-0.078	0.133
	G							1.000	-0.506**	-0.264	0.060	-0.025	0.065	0.222	-0.067	-0.293*
Weight of dry fruit	P								1.000	0.8609**	-0.1561	-0.1980	0.2596	-0.3941*	-0.0261	0.8059**
	G								1.000	0.9694**	-0.1459	-0.2171	0.2621	-0.4290**	-0.0496	0.9055**
Dry fruit yield/plant	P									1.000	-0.138	-0.158	0.209	-0.334	-0.074	0.875**
	G									1.000	-0.142	-0.207	0.279*	-0.396**	-0.076	0.903**
Shelf life at ambient temperature	P										1.000	-0.048	-0.453**	-0.204	0.077	-0.221
	G										1.000	-0.204	-0.613**	-0.243	0.081	-0.286*
Ascorbic acid content	P											1.000	-0.303*	0.460**	0.142	-0.207
	G											1.000	-0.338*	0.521	0.181	-0.255
Capsaicin content	P												1.000	-0.101	-0.172	0.393**
	G												1.0000	-0.1081	-0.1922	0.4587**
β-Carotene	P													1.000	0.362*	-0.233
	G													1.000	0.373**	-0.284
α- Carotene	P														1.000	-0.261
	G														1.000	-0.272
Fruit yield/plant	P															1.000
	G															1.000

*= Significant @ 0.05 probability, **= significant @ 0.01 probability *P= Phenotypic, G=Genotypic

days to 50% flowering through days to first picking (0.297), capsaicin content through weight of ripe fruit (0.285), fruit length through dry fruit yield/plant (0.241), fruit length through days to first picking (0.118), number of fruit per plant through dry fruit yield/plant (0.112) and capsaicin content through dry fruit yield per plant was observed (0.107) (Table 3). However, negative indirect effect on fruit yield/plant were showed by days to first picking through days to 50% flowering (-0.271) followed by number of fruit/plant through weight of ripe fruit (-0.2143), shelf life at ambient temperature through weight of ripe fruit (-0.201), â-carotene content through weight of ripe fruit (-0.186), â-carotene content through dry fruit yield/plant (-0.1710), ascorbic acid content through weight of ripe fruit (-0.167), á-carotene content through weight of ripe fruit (-0.164), weight of ripe fruit through weight of dry fruit (-0.136), dry fruit yield/plant through weight of dry fruit (-0.135) and á-carotene content through days to first picking (-0.115) (Table 3). At genotypic level, weight of dry fruit imposed high positive indirect effect through weight of ripe fruit (0.923) followed by dry fruit yield/plant through weight of ripe fruit (0.839), weight of dry fruit through dry fruit yield/plant (0.838), weight of ripe fruit through dry fruit yield/plant (0.708), fruit length through weight of ripe fruit (0.578), number of fruit/plant through weight of dry fruit (0.531), fruit length through dry fruit yield/plant (0.473), â-carotene content through weight of dry fruit (0.434), capsaicin content through weight of ripe fruit (0.427), capsaicin content through dry fruit yield/plant (0.241) and days to first picking through weight of ripe fruit (0.162) (Table 3). However, in the case of negative indirect effect, high negative indirect effect was exerted by dry fruit yield/plant through weight of dry fruit (-0.981), followed by weight of ripe fruit through weight of dry fruit (-0.912), number of fruit/plant through weight of ripe fruit (-0.556), fruit length through weight of dry fruit (-0.523), â-carotene content through dry fruit yield/plant (-0.343), shelf life at ambient temperature through weight of ripe fruit (-0.286), capsaicin content through weight of dry fruit (-0.265), á-carotene content through weight of ripe fruit (-0.257), ascorbic acid content through weight of ripe fruit (-0.247), days to first picking through days to 50% flowering (-0.238), number of branch/plant through dry fruit yield/plant (-0.212) (Table 3).

Discussion

In the present investigation, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the characters; indicated strong association between the two characters genetically. Correlation studies revealed that characters like weight of ripe fruit, fruit length, weight of dry fruit, dry fruit yield/plant and capsaicin content had significant positive correlation with fruit yield/plant both at genotypic and phenotypic level. Similar results were also reported by Datta and Jana (2010), Ullah et al. (2011), Kumar et al. (2012), Krishnamurthy et al. (2013), Amit et al. (2014) and Dubey et al. (2015) in their experiments. However, negative association of fruit yield per plant was illustrious with plant height and number of branch/plant both at genotypic and phenotypic level, indicated that fruit yield and plant height and number of branch/plant could not be improved simultaneously through selection and suggested that, this character should not be emphasized for direct selection of high yielding genotype. So, independent selection for this trait could be made to get improved population.

In the present investigation at genotypic level, fruit yield per plant was taken as dependent variable and other 14 traits were considered as causal variables. Weight of ripe fruit had maximum positive direct effect on green fruit yield/plant followed by dry fruit yield/plant and fruit length at genotypic level; indicated that these are the real independent characters and have maximum contribution towards increase in fruit yield per plant. These observations were conformity with Kumari et al. (2011), Vikram et al. (2014) and Yatung et al. (2014a). The high positive direct effect of weight of ripe fruit on fruit yield per plant was counter balanced by its positive indirect effect *via* plant height, days to first picking, fruit length, weight of dry fruit, dry fruit yield/plant and capsaicin content. However, high positive direct effect of dry fruit yield/plant on green fruit yield per plant was counter balanced by its positive indirect effect *via* number of branch per plant, days to 50% flowering, days to first picking, weight of ripe fruit, fruit length, number of fruit per plant and capsaicin content. Negative direct effect on fruit yield per plant was imposed by weight of dry fruit (both at phenotypic and genotypic level), days to 50% flowering (both at phenotypic and genotypic level), plant height (both at phenotypic and genotypic level), number of branch/plant (both at phenotypic and genotypic level), number of fruit/plant (genotypic level). High negative indirect contribution of dry fruit yield/plant via weight of dry fruit followed by weight of ripe fruit through weight of dry fruit, number of fruit/plant through weight of ripe fruit, fruit length through weight of dry fruit, â-carotene content through dry fruit yield/plant, shelf life at ambient temperature through weight of ripe fruit, capsaicin content through weight of dry fruit, á-carotene content through weight of ripe fruit, ascorbic acid content

Table 3: Direct (diagonal) and indirect effects of fruit yield components on fruit yield per plant at phenotypic (P) and genotypic (G) level in King chilli

Character		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Plant height (1)	P	-0.051	-0.002	0.011	0.011	0.000	0.000	0.008	-0.002	0.000	-0.009	-0.010	0.018	0.001	-0.000
	G	-0.170	-0.062	0.025	0.017	0.004	-0.004	0.036	-0.012	-0.007	-0.084	-0.063	0.075	0.005	-0.009
Number of branch/plant (2)	P	-0.001	-0.026	-0.000	-0.001	-0.000	0.009	0.003	0.001	0.002	0.002	-0.008	0.001	-0.007	-0.005
	G	-0.039	-0.106	0.041	0.024	-0.008	0.053	0.062	0.004	0.026	0.051	-0.034	0.015	-0.042	-0.032
Days to 50% flowering (3)	P	0.066	-0.005	-0.286	-0.271	0.005	-0.072	0.007	-0.010	-0.009	-0.036	-0.041	0.007	0.096	0.090
	G	0.037	0.097	-0.252	-0.238	-0.001	-0.090	0.094	-0.013	0.025	0.009	-0.022	0.020	0.108	0.088
Days to first picking (4)	P	-0.067	0.020	0.296	0.313	0.026	0.118	-0.002	0.028	0.025	0.008	0.028	0.000	-0.109	-0.115
	G	-0.004	-0.011	0.045	0.047	0.007	0.025	-0.015	0.006	0.000	-0.008	0.001	-0.002	-0.021	-0.020
Weight of ripe fruit (5)	P	-0.000	0.018	-0.014	0.060	0.715	0.380	-0.214	0.630	0.516	-0.200	-0.167	0.285	-0.186	-0.164
	G	-0.025	0.079	0.005	0.161	1.025	0.578	-0.556	0.923	0.838	-0.286	-0.246	0.426	-0.303	-0.256
Fruit length (6)	P	0.001	0.050	-0.036	-0.055	-0.078	-0.147	0.007	-0.074	-0.069	0.015	0.054	-0.050	0.087	0.088
	G	0.005	-0.118	0.084	0.125	0.133	0.236	-0.014	0.122	0.129	-0.035	-0.111	0.088	-0.149	-0.159
Number of fruit/plant (7)	P	-0.027	-0.022	-0.004	-0.001	-0.047	-0.008	0.158	-0.042	0.034	0.000	0.000	-0.005	0.015	-0.012
	G	0.034	0.093	0.059	0.051	0.086	0.009	-0.159	0.081	0.042	-0.009	0.004	-0.010	-0.035	0.010
Number of fruit/plant (8)	P	-0.006	0.007	-0.005	-0.014	-0.138	-0.079	0.041	-0.157	-0.135	0.024	0.031	-0.040	0.062	0.004
	G	-0.074	0.037	-0.055	-0.145	-0.911	-0.523	0.513	-1.012	-0.981	0.147	0.219	-0.265	0.434	0.050
Dry fruit yield/plant (9)	P	-0.008	-0.049	0.017	0.041	0.369	0.240	0.112	0.440	0.511	-0.070	-0.080	0.106	-0.171	-0.038
	G	0.038	-0.212	-0.085	0.006	0.707	0.473	-0.229	0.838	0.864	-0.123	-0.179	0.241	-0.342	-0.066
Shelf life at ambient temp. (10)	P	0.022	-0.010	0.015	0.003	-0.032	-0.012	0.000	-0.018	-0.016	0.117	-0.005	-0.053	-0.023	0.009
	G	0.030	-0.029	-0.002	-0.011	-0.017	-0.009	0.003	-0.008	-0.008	0.061	-0.012	-0.037	-0.014	0.005
Ascorbic acid content (11)	P	0.004	0.007	0.003	0.002	-0.005	-0.008	0.000	-0.004	-0.003	-0.001	0.022	-0.006	0.010	0.003
	G	0.075	0.066	0.017	0.004	-0.048	-0.095	-0.005	-0.044	-0.042	-0.041	0.203	-0.068	0.105	0.036
Capsaicin content (12)	P	-0.040	-0.007	-0.003	0.000	0.045	0.039	-0.003	0.029	0.024	-0.052	-0.035	0.115	-0.011	-0.019
	G	0.005	0.001	0.001	0.000	-0.005	-0.004	-0.000	-0.003	-0.003	0.007	0.004	-0.012	0.001	0.002
β-Carotene (13)	P	-0.001	0.013	-0.015	-0.015	-0.011	-0.027	0.004	-0.017	-0.015	-0.009	0.020	-0.004	0.045	0.016
	G	0.002	-0.028	0.030	0.030	0.020	0.044	-0.015	0.030	0.027	0.017	-0.036	0.007	-0.069	-0.026
α- Carotene (14)	P	-0.001	-0.023	0.036	0.042	0.026	0.069	0.009	0.003	0.008	-0.009	-0.016	0.020	-0.042	-0.116
	G	0.005	0.031	-0.036	-0.044	-0.025	-0.069	-0.007	-0.005	-0.008	0.008	0.018	-0.019	0.038	0.103
Fruit yield/ plant (15)	P	-0.111	-0.031	0.014	0.114	0.874	0.503	0.133	0.805	0.875	-0.221	-0.207	0.393	-0.2331	-0.2610
	G	-0.079	-0.161	-0.122	0.032	0.966	0.622	-0.293	0.905	0.903	-0.286	-0.255	0.458	-0.284	-0.272

through weight of ripe fruit, days to first picking through days to 50% flowering, number of branches/plant through dry fruit yield per plant. These results were in concurrence with the results of Vikram et al. (2014) and Yatung et al. (2014a & 2014b)

Conclusion

On the basis of correlation association analysis, it could be concluded that the selection criteria based on weight of ripe fruit, weight of dry fruit, fruit length, and dry fruit yield/plant can provide better results for the improvement of fruit yield in Bhut Jolokiai. With an eye to the future, King chilli may soon gain more repute for their health benefits as antioxidant becomes an everyday word to consumers than they have in the past. The genetic basis of the different traits needs to be assessed in order to ascertain their constancy in population with the application of DNA markers linked to the respective traits for molecular characterization of these genotypes of *Capsicum chinense.*

lkjk'k

भूत जोलोकिया/किंग मिर्च के सोलह प्रभेदों का मूल्यांकन पॉलीहाउस में तीन प्रतिकृतियों के साथ सब्जी अनुसंधान फार्म, सीएचएफ, सीएयू, पासीघाट (अरूणाचल प्रदेश) में किया गया जिसमें क्रमशः गुण सम्बन्ध योगदान को ज्ञात करने के लिए सहसंबंध और पथ विश्लेषण किया गया। आपसी सहसंबंध प्रभेदों के बीच सभी गुणों के लिए महत्वपूर्ण भिन्नता पायी। सहसंबंध अध्ययनों से यह पता चला कि परिपक्व फल का भार (0.966, 0.874), फल की लंबाई (0.622, 0.503), सूखे फल का भार (0.905, 0.805) का वजन, प्रति पौध सूखे फलों की उपज (0.903, 0.875) और कैप्सेकिन सामग्री (0.458, 0.393) के मध्य सार्थक धनात्मक सह–सम्बन्ध उपज के लिए अनुवांशिक एवं बाह्यदृश्य रूप के स्तर पर पाया गया। हालांकि, अनुवांशिक स्तर पर, पके हुए फल के वजन पर प्रति पौधे (1.025), सूखे फलों की पैदावार (0.865), फलों की लंबाई (0.236), एस्कॉर्बिक एसिड की मात्रा (0.203) के बाद फल के उपज पर अधिकतम सकारात्मक प्रत्यक्ष प्रभाव देखा गया। वर्तमान अध्ययन के निष्कर्षों से पुष्टि होती है कि परिपक्वव फल, फल की लंबाई, सूखे फल का वजन, पौधें और कैप्सैकिन की मात्रा के सूखे फल के उपज का चयन और मिर्च प्रजनन कार्यक्रम के लिए महत्वपूर्ण घटक हैं।

References

Al-Jibouri HA, Miller PA and Robinson HF (1958) Genotypic and environmental variances and covariance in an upland cotton cross of inter specific origin. J Agron 50 (10):633-636.

Amit K, Ahad I, Kumar V and Thakur S (2014) Genetic variability and correlation studies for growth and yield characters in chilli (*Capsicum annuum* L.). J Spices Aromatic Crops 23 (2):170–177.

Datta S and Jana JC (2010) Genetic variability, heritability and correlation in chilli genotypes under Terai zone of West Bengal. SAARC J Agri 8(1):33-45.

Dewey JR and Lu KH (1959) A correlation and path coefficients analysis of crested wheatgrass seed production. J Agron 51: 515-518.

Dubey RK, Singh V, Upadhyay G, Pandey AK and Prakash, D (2015) Assessment of phytochemical composition and antioxidant potential in some indigenous chilli genotypes from North East India. Food Chem 188: 119–125.

Fisher RA and Yates F (1963) Statistical tables for biological, agricultural and medical research. Oliver and Boyd. Ltd, pp 63.

Krishnamurthy SL, Reddy MK and Rao MA (2013) Genetic variation, path and correlation analysis in crosses among Indian and Taiwan parents in chilli. Veg Sci 40(2): 210-213.

Kumar D, Bahadur V, Rangare SB and Singh D (2012) Genetic variability, heritability and correlation studies in chilli (*Capsicum annuum* L.). HortFlora Res Spect 1(3):248-252.

Kumari SS, Jyothi KU, Reddy VC, Srihari D, Sankar AS and Sankar CR (2011) Character association in paprika (*Capsicum annuum* L.). J Spices Aromatic Crops 20 (1):43–47.

Pandiyaraj P, Lakshmanan V, Yadav RK, Vijay SK and Prasanth KN (2017) Genetic correlation and path coefficient analysis in chilli germplasm. Res Environ Life Sci 10(5): 425-428.

Shweta B, Satish HR, Jagadeesha D, Hanachinmani RC and Dileepkumar AM (2018) Genetic correlation and path coefficient analysis in chilli (*Capsicum annuum* L.) genotypes for growth and yield contributing traits. J Pharmac Phytochem 7(2): 1312-1315.

Singh BK, Pathak KA and Ngachan SV (2012) IC-590813: a primitive line of King chilli (*Capsicum chinense* Jacq.). SAARC AgriNews 6(2): 9.

Ullah MZ, Hasan MJ, Saki, AI, Rahman MA and Biswas PL (2011) Association of correlation and cause-effect analysis among morphological traits in chilli (*Capsicum frutescens* L.). Intl J Bio Res 10(6):19-24.

Vidya C, Jagtap VS and Santhosh N (2018) Correlation and path coefficient analysis for yield and yield attributing characters in chilli (*Capsicum annuum* L.) genotypes. Intl J Current Microbio Applied Sci 7(1): 3265-3268.

Vikram A, Warshamana IK and Gupta M (2014) Genetic correlation and path coefficient studies on yield and biochemical traits in chilli (*Capsicum annuum* L*).* Intl J Farm Sci, 4(2):70-75.

Wright S (1921) Correlation and causation. J Agric Res 20(7): 557-585.

Yatung T, Dubey RK, Singh V, Upadhyay G and Pandey AK (2014a) Selection parameters for fruit yield and related traits in chilli (*Capsicum annuum* L.). Bangladesh J Bot 43(3): 283-291.

Yatung T, Dubey RK, Singh V and Upadhyay G (2014b) Genetic diversity of chilli (*Capsicum annuum* L.) genotypes of India based on morpho-chemical traits. Australian J Crop Sci 8(1): 97-102.

Vegetable Science (2018) 45(2) : 191-196

Genetic variability studies in tomato (*Solanum lycopersicum* L.) under eco-friendly management

Vijayakumar Chabbi*, Rakesh Kumar Gupta, Sanjeev Kumar and Manoj Kumar

Received: September 2018 / Accepted: January 2019

Abstract

Twenty genotypes of tomato were evaluated for yield, quality and other traits under eco-friendly management. Analysis of variance revealed that highly significant differences among genotypes for all the traits. High magnitude of phenotypic coefficients of variation and genotypic coefficients of variation were observed for traits including fruit yield per plant, plant height and number of fruits per plant. High heritability coupled with high genetic advance estimates were observed for number of fruits per plant, plant height and fruit yield per plant. Fruit yield/plant had positive and highly significant correlation with number of fruits/ plant, fruit weight, fruit shape index and number of primary branches/plant indicating these traits are important yield components. Whereas, negative and significant association with days to 50% flowering, leaf curl and fruit borer incidence, ascorbic acid content and pericarp thickness. Maximum positive and direct effect towards fruit yield/plant was exerted by average fruit weight, number of fruits per plant, leaf curl incidence and plant height. Few genotypes with high yield and other useful traits were identified for future under eco-friendly management.

Keywords: Tomato, Variability, Heritability, Correlation, Path analysis and Eco-friendly

Introduction

Tomato (2n= 24) is an important vegetable of the world and now commonly used in all households. It contains red color pigment called lycopene (a carotenoid formed during ripening) and its presence in plasma has been related in reducing prostate cancer (Giovannucci et al. 1999). It is being grown on 4.8 m ha area in world with annual production of 182.3 mt (Anonymous 2017). In northern plains of India, productivity of main season crop is relatively poor when compared with other productive regions since growing period coincides with harsh summer, uneven rains and heavy incidence of diseases and insect-pests. Therefore, evaluation of germplasm is imperative to understand the genetic background and breeding value for genetic improvement of tomato both under normally sown and eco-friendly managed conditions. Genetic variability is primary requirement for development of suitable varieties or hybrids for various horticultural traits. The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and environment. The genetic variance of quantitative traits is composed of additive variance (heritable); non-additive variance (non-heritable); dominance and epistasis (non-allelic interaction). Therefore, it becomes important to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation besides heritability and genetic advance. Genetic advance can be used to predict the efficiency of selection. The information on heritability in conjunction with genetic advance is needed for effective selection (Johnson et al. 1955). Correlation coefficient analysis help to know the association between yield and other yield contributing traits, which could be effectively exploited to formulate selection strategies for improving yield components. Path coefficient analysis reveals direct and indirect contribution of character towards yield. On the basis of these studies the quantum importance of individual characters is marked to facilitate the selection programme for better gains. Hence, the present study was carried out to estimate the genetic variability; degree of association among various yield components and their direct and indirect effect on yield in 20 diverse genotypes in early planted tomato crop under eco-friendly management for genetic improvement of tomato.

Division of Vegetable Science and Floriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu– 180009, India

*Corresponding author, E-mail: vijaykumarc234@gmail.com

Materials and Methods

The experimental material comprised of 20 diverse tomato genotypes collected from different parts of the country (Table 1). The seeds were sown in nursery beds in the month of September and transplanting was done in October 2017-18 under open as an early planted crop using RBD with 3 replication at spacing of 90 cm x 60 cm using eco-friendly practices with preceding crop - marigold. The experiment was laid out at experimental farm of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, (India) (longitude 74º58' E and latitude 32º 40'N with altitude 332 m above MSL and mean annual rainfall between 1000-1200 mm). The experimental site experiences hot dry summer, hot and humid rainy season and cold winter months where maximum temperature goes up to 45°C or even more during summer (May to June) while minimum temperature falls to 1°C during winters (December to January).

For eco-friendly management, all the cultural practices were adopted as per Dar (2011) and modifications (including FYM @ 25 tonnes/ha, mustard cake @ 2 t/ha and vermicompost @ 5 t/ha; Neem oil @ 1.0%; Pheromone traps and low cost ecofriendly protected structures). Data was recorded for traits viz. days to 50% flowering, plant height (cm), number of primary branches per plant, number of flowers per cluster, number of fruits per truss, number of fruits per plant, average fruit weight (g), fruit shape index, fruit yield per plant (kg), pericarp thickness (mm), number of locules per fruit, total soluble solids (°B), ascorbic acid (mg/100 g), leaf curl incidence (%), wilt incidence (%) and fruit borer incidence (%).The phenotypic and genotypic coefficient of variance was estimated as per Burton and De Vane (1953). The estimates of heritability in broad sense and genetic advance were calculated as per Allard (1960).The genotypic and phenotypic correlation coefficients were calculated as per Al-Jibouri et al. (1958). Path coefficients analysis was carried out to determine relationship among yield components and for calculating direct and indirect contribution of characters towards yield (Dewey and Lu 1959).

Results and Discussion

Analysis of variance showed significant differences among genotypes for all the traits in early planted crop raised in open under ecofriendly management (Table 2). The comparison of mean performance of 20 genotypes for 16 traits using critical differences revealed existence of very high level of variability in the used genotypes. A wide ranges of variations in mean performance of genotypes were observed for all the traits such as days to 50% flowering (23.67 days in Arka Rakshak to 31.67 days in Palam Pride), plant height (65.60 cm in PKM-1 to 178.77 cm in BSS-488), number of primary branches per plant (4.78 in DVRT-2 to 8.41 in Arka Rakshak), number of flower per cluster (3.66 in Pusa Ruby to 8.66 in BSS-488), number of fruits per truss (1.66 in DVRT-2 to 4.08 in Arka Rakshak), number of fruits per plant (12.92 in PKM-1 to 42.25 in Hawaii-7998), average fruit weight (26.03 g in Hawaii-7998 to 85.52 g in DVRT-2), fruit shape index (0.67 in PKM-1 to 1.07 in Arka Rakshak), number of locules per fruit (3.11 in Hawaii-7998 and Arka Rakshak to 5.44 in DVRT-2), total soluble solids (3.93 ^{0}B in Selection-2 to 5.90 ^{0}B in Marglobe), ascorbic acid (23.32 mg in Marglobe to 33.91 mg in Arka Rakshak), pericarp thickness (3.62 mm in Marglobe to 6.05 mm in BSS-488), fruit yield per plant (0.59 kg in PKM-1 to 2.52 kg in Arka Rakshak), fruit borer incidence (1.44% in Arka Rakshak to 10.33% in Arka Abha), leaf curl incidence (0.00% in Arka Rakshak to 46.67% in PKM-1) and wilt incidence (3.33% in BWR-5 to 26.67% in Arka Abha).

Table 1: List of tomato genotypes used for present study along with their source

Sl. No.	Genotype	Source	Growth habit
1.	PKM-1	TNAU, Coimbatore	Determinate
2.	ArkaAbha	IIHR, Bengaluru	Semi-determinate
3.	ArkaAlok	IIHR, Bengaluru	Indeterminate
4.	ArkaSourabh	IIHR, Bengaluru	Semi-determinate
5.	ArkaVikas	IIHR, Bengaluru	Indeterminate
6.	Pusa Ruby	Durga seeds co.	Indeterminate
7.	Palam Pink	CSKHPKV	Indeterminate
8.	Hawaii-7998	CSKHPKV	Indeterminate
9.	BWR-5	CSKHPKV	Determinate
10.	CLN-2670- B1	CSKHPKV	Indeterminate
11.	Palam Pride	CSKHPKV	Indeterminate
12.	CLN-2123-A1 Red	CSKHPKV	Indeterminate
13.	DVRT-2	SKUAST-J, Chatha	Determinate
14.	KH-105	Khan hybrid seeds co.	Indeterminate
15.	Marglobe	IARI, New Delhi	Indeterminate
16.	BSS-48	AICRVIP	Indeterminate
17.	Bhagya	AICRVIP	Indeterminate
18.	ArkaRakshak	IIHR,Bengaluru	Indeterminate
19.	Selection-2	AICRVIP	Determinate
20.	S-22	Local selection	Determinate

The genotypic coefficients of variation (GCV) and phenotypic coefficients of variation (PCV) presented in Table 3 under that PCV were higher in magnitude than the corresponding GCV for all the characters studied. The differences between GCV and PCV were less in majority of the cases which shows that environmental factors had played less influence on the expression of these characters. Coefficients of variation varied in magnitude (low to high) which indicating that there was

Table 2: Analysis of variance for 16 horticultural traits in tomato

Traits	Replication	Treatments	Error	CV	CD
Degree of freedom	2	19	38	-	-
Days to 50% flowering	32.11	3892.54*	78.841	7.945	14.674
Plant height (cm)	0.45	13.911*	0.854	3.225	1.527
Number of primary branches/plant	0.24	2.752*	0.338	9.428	0.961
Number of flowers per cluster	0.52	5.55*	0.321	10.165	0.937
Number of fruits per truss	0.05	1.422*	0.121	12.891	0.574
Number of fruits per plant	1.19	164.17*	1.984	5.845	2.238
Average fruit weight (g)	27.96	647.265*	21.368	7.908	7.639
Fruit shape index	0.00	0.031*	0.001	3.412	0.048
Number of locules per fruit	0.07	1.189*	0.135	8.759	0.608
Total soluble solids (Bº)	0.20	0.951*	0.073	5.661	0.448
Ascorbic acid (mg/100g)	4.95	17.176*	2.824	6.485	2.777
Pericarp thickness (mm)	0.04	1.907*	0.066	5.606	0.425
Fruit borer incidence (%)	1.28	17.732*	1.699	11.544	2.646
Leaf curl incidence (%)	81.67	361.404*	65.877	18.847	9.279
Wilt incidence (%)	38.45	104.825*	19.590	19.935	6.585
Yield per plant (kg)	0.01	0.694*	0.017	10.417	0.215

* significant at 5% level of significance

a great diversity in the experimental materials (genotypes) used. High estimates of phenotypic as well as genotypic coefficient of variation were observed for wilt incidence (55.43% and 42.64%), leaf curl incidence (48.08 % and 37.22 %), fruit borer incidence (43.85% and 38.20%), fruit yield per plant (39.40 % and 38.00%), plant height (32.88% and 31.04%) and number of fruits per plant (31.06% and 30.51%). The high estimates of PCV and GCV for these characters were reported under natural sown condition by Rai et al. (2016), Sherpa et al. (2014) and Rath and Math (2001). Moderate GCV and PCV were observed for number of flowers per cluster, number of fruits per truss, average fruit weight and pericarp thickness. These results are in agreement with the earlier findings of Bhandari et al. (2017). Low GCV and PCV were observed for days to 50% flowering, total soluble solids, fruit shape index and ascorbic acid. These results are in accordance with the findings of Singh et al. (2017) and Prashanth et al. (2015). Low GCV and moderate PCV were observed for number of primary branches per plant and number of locules per fruit. These results are in conformity with earlier work of Bhandari et al. (2017) under normal sown conditions.

Heritability (H^2) estimates ranged from 59.19% to 96.46%. High heritability was recorded for number of fruits per plant, plant height, fruit yield per plant, fruit shape index, average fruit weight, pericarp thickness, number of flowers per cluster and days to 50%

Table 3: Mean, range and parameters of variability for selected characters of tomato genotypes

Observations/Traits	Mean	Range	Coefficients of variation		Heritability (%)	Genetic advance	Genetic gain
			PCV	GCV			
Days to 50% flowering	28.65 ± 0.75	23.67 - 31.67	7.96	7.28	83.61	3.93	13.72
Plant height (cm)	111.76 ± 7.25	65.60 - 178.77	32.88	31.90	94.16	71.27	63.77
No. of primary branches/plant	6.17 ± 0.47	4.78 - 8.41	17.34	14.55	70.42	1.55	25.15
Number of flowers per cluster	5.58 ± 0.46	3.66 - 8.66	25.76	23.67	84.43	2.50	44.81
Number of fruits per truss	2.70 ± 0.28	1.66 - 4.08	27.64	24.45	78.24	1.20	44.55
Number of fruits per plant	24.10 ± 1.15	12.92 -42.25	31.07	30.51	96.46	14.88	61.73
Average fruit weight (g)	58.46 ± 3.77	26.03 - 85.52	25.94	24.71	90.71	28.34	48.48
Fruit shape index	0.85 ± 0.02	0.67 - 1.07	12.42	11.94	92.45	0.20	23.65
Number of locules per fruit	4.20 ± 0.30	3.11 - 5.44	16.61	14.11	72.18	1.04	24.69
Total soluble solids (Bº)	4.79 ± 0.22	3.93 - 5.90	12.63	11.29	79.92	1.00	20.80
Ascorbic acid (mg/100g)	25.91 ± 1.37	23.32 - 33.91	10.65	8.44	62.88	3.57	13.79
Pericarp thickness (mm)	4.58 ± 0.21	3.62 - 6.05	17.99	17.09	90.28	1.53	33.45
Fruit borer incidence (%)	6.05 ± 1.06	1.44 - 10.33	43.85	38.20	75.88	4.15	68.55
Leaf curl incidence (%)	26.67 ± 6.63	0.00 - 46.67	48.08	37.22	59.93	15.83	59.35
Wilt incidence (%)	12.50 ± 3.61	3.33 - 26.67	55.43	42.64	59.19	8.45	67.58
Yield per plant (kg)	1.25 ± 0.11	0.59 - 2.52	39.40	38.00	93.01	0.94	75.49

Table 4: Genotypic (G) and phenotypic (P) correlation coefficients among various traits in tomato

Traits		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	(G)	-0.078	-0.296*	-0.204	-0.369**	-0.228	-0.146	-0.056	0.395**	0.065	0.646**	0.316*	0.319*	0.420**	0.149	-0.494**
	(P)	-0.060	-0.234	-0.162	-0.300*	-0.189	-0.159	-0.055	0.312*	0.035	0.436**	0.281*	0.250	0.323*	0.153	-0.449**
B	(G)	-	0.913**	0.705**	0.746**	0.549**	-0.095	0.375**	-0.217	0.558**	-0.605**	-0.345**	-0.490**	-0.523**	-0.473**	0.462**
	(P)	-	0.738**	0.642**	0.656**	0.539**	-0.086	0.352**	-0.143	0.462**	-0.486**	-0.337**	-0.427**	-0.427**	-0.366**	0.447**
C	(G)		-	0.683**	0.700**	0.480**	0.013	0.409**	-0.380**	0.467**	-0.791**	-0.288*	-0.385**	-0.538**	-0.511**	0.512**
	(P)		-	0.559**	0.575**	0.403**	0.040	0.327*	-0.261*	0.370**	-0.462**	-0.273*	-0.355**	-0.345**	-0.409**	0.452**
D	(G)			-	0.560**	0.365**	0.113	0.390**	-0.387**	0.411**	-0.687**	-0.684**	-0.436**	-0.582**	-0.318*	0.443**
	(P)			-	0.600**	0.330*	0.188	0.331**	-0.276*	0.351**	-0.465**	-0.685**	-0.512**	-0.489**	-0.381**	0.457**
E	(G)				-	0.583**	-0.222	0.266*	-0.736**	0.552**	-0.620**	0.193	-0.316*	-0.373**	-0.341**	0.351**
	(P)				-	0.515**	-0.089	0.211	-0.533**	0.441**	-0.415**	0.270*	-0.443**	-0.405**	-0.386**	0.376**
F	(G)					-	-0.326*	0.224	-0.324*	0.367**	-0.602**	-0.317*	-0.688**	-0.598**	-0.144	0.590**
	(P)					-	-0.310*	0.215	-0.233	0.322*	-0.492**	-0.309*	-0.603**	-0.465**	-0.131	0.586**
G	(G)						-	0.404**	0.168	-0.101	0.228	-0.391**	-0.201	-0.513**	0.222	0.529**
	(P)						-	0.354**	0.147	-0.099	0.121	-0.426**	-0.288*	-0.444**	0.02	0.547**
H	(G)							-	-0.158	-0.216	-0.638**	-0.607**	-0.402**	-0.594**	-0.206	0.526**
	(P)							-	-0.081	-0.155	-0.485**	-0.548**	-0.310*	-0.394**	-0.138	0.478**
I	(G)								-	-0.193	0.587**	0.177	0.263*	0.250	0.423**	-0.099
	(P)								-	-0.131	0.328*	0.093	0.183	0.177	0.203	-0.033
J	(G)									-	-0.108	0.028	-0.309*	-0.194	-0.231	0.215
	(P)									-	-0.027	0.007	-0.244	-0.127	-0.117	0.175
K	(G)										-	0.725**	0.848**	0.954**	0.666**	-0.801**
	(P)										-	0.522**	0.525**	0.539**	0.364**	-0.594**
L	(G)											-	0.654**	0.811**	0.094	-0.629**
	(P)											-	0.663**	0.692**	0.199	-0.639**
M	(G)												-	0.898**	0.351**	-0.785**
	(P)												-	0.740**	0.457**	-0.755**
N	(G)													-	0.125	-0.979**
	(P)													-	0.167	-0.785**
O	(G)														-	-0.011
	(P)														-	-0.126
P	(G)															-
	(P)															-

A = Days to 50% flowering, B = Plant height (cm), C = Number of primary branches / plant, D = number of flowers / cluster, E = Number of fruits / truss, F = Number of fruits / plant, G = Average fruit weight (g), H = fruit shape index, I = Number of locules/ fruit, J = Total soluble solids (ºB), K = Ascorbic acid (mg/100gm), L = Pericarp thickness (mm), M = Fruit borer incidence (%), N = Leaf curl incidence (%), O = Wilt incidence (%) andP = Yield per plant (kg).

flowering. High genetic advance as per cent of mean was observed for plant height, number of fruits per plant and fruit yield per plant. The high estimates of heritability, genetic advance and genetic advance as per cent of mean for these characters were also reported earlier by several workers Singh et al. (2017). High GCV, heritability and genetic gain was observed for plant height, number of fruits per plant and fruit yield per plant, which shows that response to selection can be stable for crops raised under eco-friendly management.

The correlation coefficients among different characters worked out at genotypic and phenotypic levels is presented in Table 4. The values for genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most of the cases, this indicate strong genetic association among characters and less environment effect. Number of fruits/plant (0.590 and 0.586), average fruit weight (0.529 and 0.547), fruit shape index (0.526 and 0.478), number of primary branches /plant (0.512 and 0.452), number of flower/cluster (0.443 and 0.457), plant height (0.462 and 0.447) and number of fruits / truss (0.351 and 0.376) were had positive and significant association with fruit yield per plant both at genotypic and phenotypic levels respectively. These results indicate that the selection for these traits will directly improve the yield. Similar results were earlier reported by Meena et al. (2018) and Ambresh et al. (2017) under normal sown conditions. Significant negative correlation was observed with days to 50 % flowering, ascorbic acid, pericarp thickness, fruit borer incidence and leaf curl incidence. Number of locules per fruit and total soluble solids has no correlation with fruit yield per plant. These results are in accordance with that of Ambresh et al. (2017).

The genotypic correlation coefficient was partitioned into direct and indirect effects through path coefficient analysis (Table 5). Maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight (0.851), followed by number of fruits per plant (0.847) and plant height (0.285). The other traits which showed positive direct effect with fruit yield per plant were fruit shape index (0.095), number of primary branches per plant (0.085), pericarp thickness (0.042), number of locules per fruit (0.0046) and flower per cluster (0.0042). Traits like days to 50% flowering (-0.379), fruit borer incidence (-0.237), number of fruits per truss (-0.207), ascorbic acid (-0.153) and total soluble solids (-0.023) had negative direct effect on fruit yield per plant. These results are in agreement with earlier work of Singh et al. (2018), Naveen et al. (2017) and Prajapati et al. (2015). Number of fruits /truss had maximum positive indirect effect on fruit yield per plant via number of fruits /plant (0.494) followed by fruit borer incidence via leaf curl incidence (0.3506) and fruit shape index via average fruit weight (0.3438). Whereas maximum negative indirect effect on fruit yield per plant via fruits per plant for fruit borer incidence (-0.5828), followed by average fruit weight for leaf curl incidence

Table 5: Estimates of direct and indirect effects of different traits on yield in tomato (Diagonal bold value is direct effect)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	**-0.3787**	-0.0222	-0.0252	-0.0009	0.0763	-0.1928	-0.1246	-0.0053	0.0018	-0.0015	0.0987	-0.0133	-0.0758	0.1641	0.0052	-0.4942
B	0.0297	**0.2825**	0.0777	0.0030	-0.1542	0.4650	-0.0809	0.0358	-0.0010	-0.0131	-0.0925	0.0146	0.1163	-0.2043	-0.0163	0.4623
C	0.1123	0.2581	**0.0851**	0.0029	-0.1447	0.4061	0.0110	0.0391	-0.0018	-0.0109	-0.1209	0.0122	0.0913	-0.2102	-0.0177	0.5119
D	0.0774	0.1992	0.0582	**0.0042**	-0.1159	0.3090	0.0961	0.0373	-0.0018	-0.0096	-0.1050	0.0289	0.1035	-0.2274	-0.0110	0.4430
E	0.1398	0.2107	0.0595	0.0024	**-0.2068**	0.4940	-0.1888	0.0254	-0.0034	-0.0129	-0.0947	0.0082	0.0749	-0.1455	-0.0118	0.3510
F	0.0862	0.1552	0.0408	0.0016	-0.1206	**0.8467**	-0.2773	0.0214	-0.0015	-0.0086	-0.0920	0.0134	0.1634	-0.2334	-0.0050	0.5904
G	0.0555	-0.0269	0.0011	0.0005	0.0459	-0.2760	**0.8507**	0.0386	0.0008	0.0024	-0.0349	0.0165	0.0478	-0.2004	0.0077	0.5293
H	0.0211	0.1058	0.0348	0.0017	-0.0551	0.1896	0.3438	**0.0955**	-0.0007	0.0051	-0.0974	0.0256	0.0954	-0.2321	-0.0071	0.5259
I	-0.1497	-0.0614	-0.0324	-0.0016	0.1521	-0.2748	0.1432	-0.0151	**0.0046**	0.0045	0.0897	-0.0075	-0.0625	0.0976	0.0146	-0.0987
J	-0.0247	0.1578	0.0398	0.0017	-0.1141	0.3109	-0.0858	-0.0207	-0.0009	**-0.0234**	-0.0165	0.0012	0.0733	-0.0758	-0.0080	0.2149
K	0.2446	0.1711	0.0673	0.0029	-0.1282	0.4098	0.1942	0.0609	-0.0027	-0.0025	**-0.1527**	0.0306	0.2013	-0.3725	-0.0230	-0.8010
L	0.1196	0.0976	0.0245	0.0029	-0.0400	0.2688	0.3326	0.0579	-0.0008	-0.0007	-0.1107	**0.0422**	0.1553	-0.3167	-0.0032	-0.6291
M	-0.1209	-0.1383	-0.0327	-0.0019	0.0653	-0.5828	-0.1714	-0.0384	0.0012	0.0072	0.1295	-0.0276	**-0.2375**	0.3506	0.0121	-0.7855
N	-0.1592	-0.1478	-0.0458	-0.0025	0.0770	-0.5060	-0.4365	-0.0567	0.0012	0.0045	0.1457	-0.0343	-0.2132	**0.3905**	0.0043	-0.9786
O	-0.0566	-0.1337	-0.0435	-0.0014	0.0705	-0.1215	0.1890	-0.0197	0.0020	0.0054	0.1017	-0.0040	-0.0833	0.0489	**0.0346**	-0.0115

Residual value: 0.00634

A = Days to 50% flowering, B = Plant height (cm), C = Number of primary branches / plant, D = number of flowers / cluster, E = Number of fruits / truss, F = Number of fruits / plant, G = Average fruit weight (g), H = fruit shape index, I = Number of locules / fruit, J = Total soluble solids (ºB), K = Ascorbic acid (mg/100gm), L = Pericarp thickness (mm), M = Fruit borer incidence (%), N = Leaf curl incidence (%), O = Wilt incidence (%) and P = Yield per plant (kg).

(-0.4365) and leaf curl incidence for ascorbic acid (-0.3725). The residual effect was recorded very low i.e., 0.00634. Various workers like Singh et al. (2018), Naveen et al. (2017) and Prajapati et al. (2015) earlier reported similar direct and indirect effects of various horticultural and quality traits on yield in tomato.

From above results, number of fruits per plant and average fruit weight, fruit shape index and number of primary branches /plant had highly significant positive correlation with fruit yield per plant. Hence these traits can be used as basic parameters of selection for improvement of yield in tomato for similar environment. Path analysis results indicates that direct selection for average fruit weight, number of fruits per plant and plant height in desired direction would be very effective for yield improvement. Among 20 genotypes 'Arka Rakshak, BSS-488, CLN-2123-A1 Red, DVRT-2 & BWR-5' are identified as superior genotypes for yield and other traits under eco-friendly management, which can be grown as early transplanted crop in Jammu region with protection against cold and frost under eco-friendly management.

lkjk'k

टमाटर के बीस प्रभेदों का मूल्यांकन पर्यावरण के अनुकूल प्रबंधन के हेतु उपज, गुणवत्ता और अन्य लक्षणों के लिए किया गया। विचरण के विश्लेषण से पता चला कि सभी लक्षणों के लिए प्रभेदों में अत्यधिक सार्थक अंतर है। बाह्य दृश्य प्रारूप भिन्नता (पीसीवी) के बाह्य दृश्य प्रारूप गुणांक और भिन्नता के आन्तरिक प्रभेद गुणांक (जीसीवी) के प्रति पौधे फल की उपज, पौधे फल की उपज, पौध की ऊँचाई और प्रति पौध फल की संख्या सहित लक्षणों के लिए उच्च परिमाण देखा गया था। उच्च आनुवांशिक अग्रिम अनुमानों के साथ युग्मित उच्च आनुवांशिकता को प्रति पौध, पौध की ऊँचाई और फल की प्रति पौध संख्या के लिए देखा गया। प्रति पौध उपज की संख्या के साथ सकारात्मक और अत्यधिक महत्वपूर्ण सहसम्बन्ध पाया गया। औसत फल भार, फल आकार सूचकांक और इन लक्षणों को निर्धारित करने वाले प्रति पौध प्राथमिक शाखाओं की संख्या अत्यन्त महत्वपूर्ण उपज घटक है जबकि 50 प्रतिशत फूल, पत्ती मरोड़ और फल बेधक एस्कार्बिक एसिड और फल भित्ती मोटाई के साथ नकारात्मक और महत्वपूर्ण सम्बन्ध पाया गया। प्रति पौध फलों की पैदावार के प्रति अधिकतम सकारात्मक और प्रत्यक्ष प्रभाव औसत फल वजन, प्रति पौध फलों की संख्या, पत्ती मरोड़ और पौध ऊँचाई से अधिक था। उच्च उपज और अन्य उपयोगी लक्षणों के साथ कुछ प्रभेदों को पर्यावरण के अनुकूल प्रबंधन हेतु भविष्य में उपयोग किया जा सकता है।

References

Al-Jibouri HA, Miller PA and Robinson HF (1958) Genotypic and environmental variances and co-variances in an upland cotton cross of inter specific origin. Agron J 50: 633-36.

Allard RW (1960) Principles of Plant Breeding, John Wiley and Sons, Inc. New York, pp 485.

Ambresh, Lingaiah HB, Renuka M and Jyothi, K (2017) Phenotypic and Genotypic Correlation Coefficient Studies in Tomato (*Solanum lycopersicum* L.) for Yield and Quality Traits. Int J Curr. Microbiol App Sci 6(11): 2287-2292.

Anonymous (2017) FAOSTAT.http://www.fao.org/faostat/en/#data/QC. Accessed on 18th January 2019.

Bhandari HR, Srivatsava K and Reddy EG (2017) Genetic Variability, Heritability and Genetic Advance for Yield Traits in Tomato (*Solanum lycopersicum* L.). Int J Curr Microbiol App Sci 6(7): 4131-4138.

Burton GW and De Vane EH (1953) Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. Agron J45: 478-81.

Dar AN (2011) Varietal responses in tomato (*Lycopersicum esculentum* Mill.) under eco-friendly management. MSc Thesis, SKUAST, Chatha, Jammu.

Dewey DR and Lu KH (1959) A correlation and path coefficient analysis of crested wheat grass seed production. Agron J 51: 515-18.

Giovanucci E, Ascherio A, Rimm E, Stampfer M, Colditz G and Willet W (1999) Tomatoes, tomato-based products, lycopene, and cancer: review of the epidemiologic literature. J National Cancer Inst 87: 1767-76.

Johanson HW, Robinson HF and Comstock RE (1955) Estimates of genetic and environmental variability in soyabean. Agron J 47: 314-18.

Meena RK, Kumar S, Meena ML and Kumar A (2018) Correlation and Characters Association Studies in Tomato (*Solanum lycopersicum*L.). Int J Pure Appl Biosci 6(1): 1291-1295.

Naveen BL, Saidaiah P, Ravinderreddy K and Geetha A (2017) Correlation and path coefficient analysis of yield and yield attributes in tomato (*Solanum lycopersicum* L.). J Pharmacogn. Phytochem 6(6): 665-669.

Prajapati S, Tiwari A, Kadwey S, Sharma SK and Raghuwanshi O (2015) Correlation and path coefficient analysis of fruits yield and its attributing traits in tomato (*Lycopersicon esculentum* Mill.). Indian Res J Genet Biotech 7: 138-147.

Prashanth SJ, Mulge R, Madalageri BM, Mukhesh L, Chavan LM and Gasti VD (2015) Studies on genetic variability for quality character in tomato (*Lycopersicum ecsulentum* Mill.).J Asian Hort 3(2): 72-74.

Rai AK, Vikram A and Pandav A (2016) Genetic Variability Studies in Tomato (*Solanum lycopersicum* L.) for Yield and Quality Traits. Intl J Agri Environ Biotech 9(5): 739-744.

Rath PC and Math P (2001) Screening of some tomato genotypes for susceptibility to the fruit borer. Veg Sci 24(2): 153-156.

Sherpa P, Pandiarana N, Shende VD, Seth T, Mukherjee S and Chattopadhyay A (2014) Estimation of genetic parameters and identification of selection indices in exotic tomato genotypes. Electronic J Plant Breed 5: 552-562.

Singh AK, Ram CN, Yadav GC, Srivastava RK, Deo C, Gautam DK, Kumar P and Kumar P (2017) Studies on genetic variability, heritability and genetic advance in tomato [*Solanum lycopersicum* (Mill.) Wettsd.]. Int J Pure Appl Biosci 5: 908-12.

Singh AK, Solankey SS, Akhtar S, Kumari P and Chaurasiya J (2018) Correlation and Path Coefficient Analysis in Tomato (*Solanum lycopersicum* L.). Int J Curr Microbiol App Sci 7: 4278-4285.

Vegetable Science (2018) 45(2) : 197-203

Effect of micronutrient foliar application on seed yield and storability of pea cv. Master B

AF El-Aidy[1], NA Hassan[1], YB El-Waraky[2]* and Faten El-Sayed Abu El-Ftooh[2]

Received: September 2018 / Accepted: December 2018

Abstract

Two field trials were carried out during the winter seasons of 2015-16 and 2016-17 at Sakha Horticultural Research Station Farm, Kafr El-Sheikh University, Egypt to examine the response of pea cv. Master B as foliar nutrients application with boron, manganese, and zinc at shooting, flowering, and podding stages. The results showed that foliar application of micronutrient (boron, manganese, and zinc) at all three stages enhanced most vegetative growth characters, shelling ratio, seed yield and its components, seed germination percentage, chlorophyll leaf contents and seed protein content. It was found that the foliar application of boron, manganese, and zinc at three stages of growth seemed to be the best effective treatment for more robust vegetative growth and seed yield and quality enhancement.

Keywords: pea (*Pisum sativum* L.), foliar micronutrients (B, Mn and Zn), growth.

Introduction

Peas (*Pisum sativum* L.), a winter season crop, is one of the most important pulse crops in Egypt, due to high contents of protein, carbohydrates, vitamins, and minerals. It can grow throughout different soil types extending from the light sandy loam to the heavy clay soil. Most pea cultivars are grown for fresh and/or dry seeds yield. Foliar application is an excellent method for amending soil nutrient deficiencies and overcoming the soil's inability to supply nutrients to the plant (Marchener 1995 and Stigler et al. 2010). Nutrition of crops with micro-nutrients is mostly performed either through soil or foliar application. High pH level and calcium carbonate content are known to render the micro-nutrients added to the soil into unavailable from. Therefore, the required small quantities from micro-nutrients are preferably supplied in the form of a dilute spray to enhance plant response to the added micro-nutrients. Also, foliar nutrition is a practiced when nutrient shortages cannot be fixed by nutrient applications to the soil (Sarkar et al. 2007). Another advantage of foliar application is direct application of micronutrient on target plant, so weeds are not benefited (Chaubey et al. 2016). Boron is one of the micro-nutrients that have important roles in the physiological and metabolic processes of plants. Boron, also, facilitates transport of carbohydrates through cell membranes. Apart from boron, manganese plays crucial roles in the metabolism of isoprenoids, chlorophylls, carotenoids, and phenolics. External application of Mn^{2+} increases photosynthesis, net assimilation and relative growth and yield (Lidon and Teixerira 2000, Sultana et al. 2001). Manganese plays a vital role in nitrogen metabolism, photosynthesis, and forms several other compounds required for plant metabolism. Manganese acts as an activating factor in a plant that almost activates 35 various enzymes in the plant (Mengel and Kirkby 2001). Zinc is one of the trace elements which are needed for the regular healthy growth and reproduction of crop plants (Alloway 2004). In addition, the deficiency of zinc is one of the highly significant and prevalent deficiencies of micronutrients in the world which cause the decrease of crop's products (Brown et al. 1993). Zinc is required for chlorophyll production, pollen function, fertilization and germination (Kaya and Higgs 2002, Pandey et al. 2006). Zinc can become inactivated within cells by the formation of complexes with organic legends or by complexes with phosphorus (Brown et al. 1993). Zinc has high phloem movement from leaves to roots, stems and maturing grain and from one root to another (Rengel 2001). Keeping in the view of above mentioned benefits of micronutrient like B, Mn and Zn the present investigation was carried out to examine the influences of time of foliar application of boron, manganese, and zinc on growth, seed yield and seed quality of the pea plants.

[1]Horticulture Dept., Faculty of Agric., Kafr El-Sheikh Univ., Egypt
[2]Veg. Res. Dept., Hort. Res. Inst., Agric. Res. Center, Giza, Egypt
*Corresponding author, Email: yelwaraky@gmail.com

Materials and Methods

This study was carried out at the experimental farm of Sakha Horticultural Research Station Farm, Kafr El-Sheikh University, for two seasons of 2015-16 and 2016-17. The main goals of these trials were to study the influence of stages of micronutrient application (shooting, flowering, and podding stages) and foliar nutrition with boron, manganese and zinc and their interactions on vegetative growth, dry seed yield and their components of pea cv Master B which is an early maturing, determinate and fertilizer responsive cultivar widely grown in Egypt. The soil of the experimental site is clayey in texture (Table 1).

Table-1: Structural, textural, chemical and mineral profile of experimental site.

Season	Mechanical analysis			Texture	pH*	EC** dSm^{-1}	OM (%)	Available elements (ppm)			Soluble cations (meq/L)				Soluble anions (meq/L)		
	Sand (%)	Silt (%)	Clay (%)					N	P	K	Na^+	Ca^{++}	Mg^{+++}	K^+	HCO_3	Cl^-	SO_4^{--}
1st	10.0	40	50.0	Clayey	8.42	4.03	1.68	46	10	250	22.5	5.86	10.75	0.35	4.7	12.0	22.75
2nd	9.5	39.5	51.0	Clayey	8.15	4.01	1.70	48	12	250	23.5	5.90	10.85	0.35	4.7	11.8	22.60

* 1: 2.5 soil: water suspension.
** Soil past extract

Foliar treatment of micronutrients was performed at specific stages only at once at shooting stage, at flowering stage, at podding stage and at all three stages i.e. shooting, flowering and podding stages. Seven foliar treatments of micronutrient consist of only boron, manganese, zinc and in combination of B+Mn, B+Zn, Mn+Zn, and B+Mn+Zn, in addition to the control only with water. The manure sources involved Boron ethanol amen 10% B, manganese EDTA 13% Mn and zinc EDTA 13% Zn. The foliar concentration of boron, manganese, and zinc were 10, 200 and 100 ppm respectively. Few drops of salient film were added to the spraying (480 l/ ha.) as a wetting agent. Plants of the control treatment were sprayed with water. In all treatments, pea seeds were inoculated by an effective Rhizobium strain just before sowing. The sowing was done during 1st week of November in both years. The experiments were performed using the split-plot design in a randomized complete blocks design with four replications. The main plots were devoted for the stages of micronutrient application; whereas, the sub-plots were allocated for boron, manganese and zinc treatments. Each sub-plot contained 5 rows, 5m in long and 0.6 m in wide, comprising an area of 15 m^2. Spacing between plants within rows was 15 cm, and sowing was done on one side of the row.

After the completion of the spraying of nutrients about 60 days from sowing, the following data were recorded: Total chlorophyll content of leaves measured by the SPAD-501, a portable leaf chlorophyll meter (Minolta crop) was used for greenness measurements (Marquard and Timpton 1987) on fully expanded leaves (the fifth from the shoot tip) leaves without destroying them. Vegetative traits such as plant height, leaves number $plant^{-1}$, leaf area $plant^{-1}$ and plant fresh weight were recorded. Shelling ratio was measured by dividing the fresh weight of the green seeds extracted from 30 pods on the total weight of these pods. After harvesting, the yield of dry seed and its components, and germination percentage were determined, the plants of the three middle rows allocated to evaluate the subsequent data, i.e., dry seed yield $plant^{-1}$ and dry seed yield $ha.^{-1}$, weight of seeds pod^{-1}, seed index (weight of 100 seeds), dry seeds protein which measured by a random sample of 100 seeds from each treatment. Store ability of pea crop expressed as seed germination (%), which was recorded from old dry seeds that were stored for one year at room temperature as suggested by Anitha et al. (2001). For seed germination, seeds collected from middle position of pods were placed on filter paper (Whatman No. 1) moistened with distilled water in 155 mm glass Petri dishes. Three replicates of 50 seeds from each treatment were kept in germinator at 25±2 °C. Germinated seeds were counted daily starting from 5th day to till 14th days. Germination percentage, thereafter, was calculated according to ISTA (2012).

Seed samples were oven dried, crashed and digested using sulphoric and salicylic acid and a catalyst mixture method according to Cottenie et al. (1982). Nitrogen in the digested seeds was determined by micro-Kjeldahl method according to Jackson (1958), the nitrogen content of pea seeds was multiplied by a factor of 6.25 to calculate the crude protein content. Soil samples were collected, air dried and finely ground for chemical and mechanical analysis according to Jackson 1958 and Black et al. (1965). The statistical analysis of mean data for the design (RBD) was worked out by using M-stat-C software; and treatment means were compared by Duncan's multiple range test (Duncan 1955).

Results and Discussion

I. Vegetative characters:

a. Effect of growth stages: Data shown in Table-2 indicated that growth parameters viz, plant height, leaves number plant^{-1}, leaf area plant^{-1}, chlorophyll content, plant fresh weight and shelling percentage were significantly affected by micronutrient foliar application at all stages in both the growing seasons. However, there were no considerable variations between application times of foliar application in the first season for chlorophyll content. This attributed to the role of B, Mn, Zn in CO_2 flowing out, vitamin A enhancement and resistant system performances through different stages of growth (Malakoti and Keshavarz 2003, Mahbobeh et al. 2011).

b. Effect of foliar nutrients: Foliar application of (B+Mn+Zn) gave the tallest plants, the highest leaves number, leaf area, chlorophyll content as well as the largest plant fresh weight and shelling percentage in both the seasons, followed by the treatment of (Mn+Zn), whereas the untreated plants produced the lowest value of each character (Table 2). The improving effects of boron may be attributed to the direct action of boron on the development of N-fixing root nodules (Bolanos et al. 1994) and translocation of sugars through cellular membranes (Dugger and Palmer 1983). Manganese acts as an activating factor in a plant that almost activates 35 various enzymes in the plant. In addition, zinc has high phloem mobility from leaves to roots, stems and developing grain and from one root to another (Mengel and Kirkby 2001, Rengel 2001, Texeira et al. 2004). In the same line, Bin Ishage (2002) and El-Waraky et al. (2013) stated that spring pea plants with various concentrations of boron resulted in more vigorous vegetative growth compared with the untreated ones.

c. Effect of growth stages and foliar nutrients interaction: Data tabulated in Table-3 show that foliar nutrient (B, Mn and Zn) at shooting, flowering and podding stages had the high values of plant height, leaf area, chlorophyll content, plant fresh weight and shelling percentage, followed by foliar nutrients with (Mn and Zn) at the same (shooting, flowering and podding stages) and foliar nutrients with (B, Mn and Zn) and /or foliar nutrients with (Mn and Zn) at shooting stage. Thus, compared with those of the foliar nutrients and flowering and/or podding stages. These outcomes were in harmony with Mahbobeh et al. (2011).

Table-2: Effect of growth stages and foliar nutrients on vegetative characters on pea plants in 2015-16 and 2016-17

Treatments	Plant height (CM)		Number of leaves/plant		Leaf area/plant (cm2)		Chlorophyll Content SPAD unit		Plant fresh weight (g)		Shelling ratio (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1s	2nd
Shooting stage	49.2 a	53.9 b	23.9 ab	28.0 ab	832.2 b	1058.3 b	40.02	42.82 ab	94.90 b	106.2 b	70.1 d	71.4 d
Flowering stage	43.8 b	47.3 c	21.3 bc	25.8 b	790.2 c	975.2 c	38.95	41.51 ab	90.61 c	98.90 c	70.3 cd	71.6 cd
Podding stage	41.0 b	44.4 d	19.8 c	23.5 c	755.2 d	931.1 d	38.37	40.67 b	88.60 c	92.60 d	71.2 b	72.1 b
S. + F. + P. stages*	52.2 a	58.0 a	25.2 a	29.6 a	861.0 a	1113.9 a	40.67	43.50 a	98.58 a	110.8 a	71.7 a	72.4 a
F. test	**	**	**	**	**	**	n.s	*	**	**	*	*
Control	36.9 d	40.6 d	18.1 c	20.8 b	720.5 h	871.3 h	37.43 b	39.65 b	84.60 d	87.50 d	68.8 d	0.3 d
B	39.6 c	42.6 d	18.9 bc	21.8 b	731.6 g	897.5 g	37.93 b	40.24 ab	86.38 d	89.30 d	71.8 a	72.6 a
Mn	46.4 b	50.8 c	22.5 ab	27.1 ab	808.1 f	1010.9 f	39.54 ab	42.24 ab	92.83 c	102.20 c	70.0 c	71.3 c
Zn	47.1 b	51.8 c	23.0 a	27.5 ab	816.2 e	1024.7 e	39.71 ab	42.40 ab	93.45 c	103.30 bc	70.1 c	71.4 bc
B + Mn	48.2 b	52.8 c	23.4 a	27.9 ab	826.0 d	1044.1 d	39.86 ab	42.59 ab	94.40 c	104.7 bc	72.0 a	72.7 a
B +Zn	49.0 b	53.6 bc	23.9 a	28.3 ab	835.7 c	1059.9 c	40.01 ab	42.75 ab	95.15 bc	106.50 b	72.1 a	72.7 a
Mn + Zn	52.2 a	57.1 ab	25.3 a	28.9 ab	868.2 b	1115.3 b	40.64 ab	43.41 a	98.50 ab	110.90 a	70.3 bc	71.4 bc
B + Mn + Zn	52.9 a	58.1 a	25.6 a	30.6 a	874.9 a	1133.6 a	40.90 a	43.72 a	99.80 a	112.60 a	72.3 a	72.8 a
F. test	**	**	**	**	**	**	**	**	**	**	*	*

Means designated by the equal letter at each column are not considerably different at the 0.05 level of probability, according to Duncan's Multiple Range Test.
S. + F. + P. stages = Shotting, flowering and podding stages.
B = Boron, Mn = Manganese, Zn = Zinc.

II. Dry seed yield and its components

a. Effect of growth stages: Foliar nutrients application at (shooting, flowering and podding stages) significantly increased average seed yield plant^{-1}, total seed yield ha.$^{-1}$, weight of seeds pod^{-1}, seed index (weight of 100-seeds), dry seed protein content and seed germination percentage in both the seasons (Table-4). The positive effects of micronutrient application on quantity and quality of pea yield might be related to its beneficial

effects on enzymes system activities and vegetative growth characters (Table 2), which probably supplied more photosynthesis and hence might help in increasing yield potential, as mentioned by Mahbobeh et al. (2011). Days to first flowering, single pod weight, weight of seeds per pod, pod length, number of seeds per pod and number of branches per plant also had positive and direct effect on pod and seed yield per plant (Gautam et al. 2017)

b. Effect of foliar nutrients: Data in Table (4) clearly shown that foliar application with boron, manganese, and zinc, gave the highest values for yield components, where they increased average seed yield plant^{-1}, total seed yield ha.$^{-1}$, weight of seeds pod^{-1}, seed index, dry seeds protein and seed germination percentage over the control. However, there were insignificant differences between the foliar application with B and /or (B+Mn) and /or (B+Zn), in both seasons. Similar results were reported by Bin Ishaq (2002), El-Waraky et al. (2013) who found that boron applied at 10 ppm of boron as a foliar spray to pea plants caused a significant increment in pea seed yield and its components.

c. Effect of growth stages and foliar nutrients interaction: The comparisons between the mean values of each character indicated that foliar application with (B, Mn, and Zn) at (shooting, flowering and podding stages) resulted in significant increases in average seed yield plant^{-1}, total seed yield ha.$^{-1}$, weight of seeds pod^{-1}, seed index (weight of 100-seeds), dry seeds protein and seed germination percentage compared with those of all treatment combinations which were treated with only one factor (Table-5) and the control treatment

Table-3: Effect of the interaction between growth stages and foliar nutrients on vegetative characters on pea plants in 2015-16 and 2016-17

Treatments		Plant height (cm)		Number of leaves/plant		Leaf area/plant (cm2)		Chlorophyll Content SPAD unit		Plant fresh weight (g)		Shelling ratio (%)	
growth Stages	Foliar nutrients**	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Shooting stage	Control	36.9 d	40.6 e	18.1	20.8	720.5 e	871.3 f	37.43 f	39.65 f	84.6 f	87.5 f	68.0 e	70.3 f
	B	40.0 cd	43.0 e	19.1	22.1	732.6 e	900.4 f	38.00 e	40.30 ef	87.0 ef	89.5 ef	70.9 cd	72.1 cd
	Mn	48.7 bc	52.5 cd	23.5	28.7	830.4 cd	1040.6 de	40.05 cd	42.86 cd	94.1 de	107.0 cd	68.0 c	70.7 ef
	Zn	49.2 bc	53.6 cd	24.2	29	835.7 cd	1052.5 de	40.20 d	43.05 cd	94.6 de	107.2 cd	68.0 e	70.7 ef
	B + Mn	50.3 bc	55.4 cd	24.6	29.2	847.5 cd	1075.3 cd	40.36 cd	43.30 cd	95.2 d	108.3 cd	70.9 cd	72.3 c
	B +Zn	51.2 bc	56.3 c	25.1	29.5	855.4 bc	1090.7 cd	40.55 cd	43.58 bc	95.6 d	110.5 c	70.9 cd	72.3 c
	Mn + Zn	58.1 ab	64.5 ab	28.2	32.2	909.5 b	1205.3 b	41.65 bc	44.75 abc	103.2 bc	118.4 b	69.5 e	70.7 ef
	B + Mn + Zn	59.0 ab	65.2 ab	28.6	32.8	925.7 ab	1230.4 ab	41.90 ab	45.06 ab	105.4 b	120.8 ab	70.9 cd	72.3 c
Flowering stage	B	39.2 cd	42.1 e	18.9	21.8	730.1e	893.5 f	37.85 e	40.15 ef	86.5 f	89.1 ef	71.4 f	72.3 c
	Mn	43.5 cd	47.9 de	21.3	26.3	795.4d	982.3 de	39.05d e	41.65 de	91.2 de	98.7 de	70.0 d	71.2 de
	Zn	44.3 cd	48.4 de	21.7	26.7	805.2 cd	990.5 de	39.10 de	41.84 de	91.5 de	100.3 de	70.0 d	71.2 de
	B + Mn	45.4 bc	49.1 de	22.1	27.1	811.6 cd	997.6 de	39.25 de	42.00 de	92.1 de	101.4 de	71.4 c	72.3 c
	B +Zn	46.0 bc	49.5 d	22.5	27.5	815.3 cd	1008.4 de	39.40 de	42.05 de	92.5 de	103.6 cd	71.9 bc	72.3 c
	Mn + Zn	47.2 bc	50.2 cd	22.8	28	820.5 cd	1025.7 de	39.65 de	42.20 de	93.0 de	105.0 cd	70.4 d	71.2 de
	B + Mn + Zn	48.1 bc	50.9 cd	23.1	28.3	822.6 cd	1032.5 de	39.86 cd	42.55 cd	93.5 de	105.8 cd	71.9 bc	72.3 c
Podding stage	B	38.5 cd	41.5 e	18.5	21.2	725.4 e	885.2 f	37.70 f	40.05 ef	86.1 f	88.7 ef	71.9 bc	72.9 b
	Mn	41.1 cd	44.2 de	19.6	23.1	746.2 de	920.5 ef	38.25 e	40.60 ef	88.6 ef	90.5 ef	70.4 d	71.7 d
	Zn	41.5 cd	45.1 de	19.8	23.5	751.5 de	935.3 ef	38.45 e	40.72 ef	89.1 ef	91.6 ef	70.4 d	71.7 d
	B + Mn	42.0 cd	45.3 de	20.1	24.2	760.3 de	942.6 ef	38.62 e	40.90 e	89.5 ef	93.4 ef	72.4 b	72.9 b
	B +Zn	42.2 cd	45.6 de	20.5	24.7	771.4 de	950.4 ef	38.70 e	41.00 e	90.0 ef	95.2 ef	72.4 b	72.9 b
	Mn + Zn	42.7 cd	46.1 de	20.8	25.1	780.1 de	967.5 ef	38.85 de	41.10 e	90.3 ef	96.5 de	70.4 d	71.7 d
	B + Mn + Zn	43.0 cd	46.7 de	21.1	25.4	786.5 de	975.7 ef	39.00 de	41.32 de	90.6 ef	97.1 de	72.9 ab	72.9 b
S. + F. + P. stages*	B	40.8 cd	43.9 de	19.1	22.1	738.4 e	910.7 ef	38.15 e	40.45 ef	87.5 ef	90.0 ef	72.9 ab	73.1 ab
	Mn	52.4 b	58.4 bc	25.5	30.4	860.3b c	1100.4 cd	40.80 c	43.86 bc	97.4 cd	112.7 bc	70.4 d	71.7 d
	Zn	53.5 ab	60.1 bc	26.1	30.8	872.5 bc	1120.5cd	41.10 bc	44.00 bc	98.6 cd	114.2 bc	70.4 d	72.1 cd
	B + Mn	55.1 ab	61.2 bc	26.8	31.1	884.6 bc	1160.7 bc	41.20 bc	44.15 bc	100.8 c	115.5 bc	73.3 a	73.1 ab
	B +Zn	56.4 ab	62.8 b	27.3	31.5	900.8 bc	1190.2 bc	41.40 bc	44.37 bc	102.5 b	116.7 bc	73.3 a	73.1 ab
	Mn + Zn	60.8 a	67.4 ab	29.1	34.2	946.5 ab	1262.5 ab	42.40 ab	45.57 a	107.5 ab	123.6 ab	70.9 cd	72.1 cd
	B + Mn + Zn	61.5 a	69.7 a	29.5	35.7	964.7a	1295.6 a	42.85 a	45.94 a	109.7 a	126.5 a	73.3 a	73.5 a
F. test		**	**	n.s	n.s	**	**	**	**	**	**	**	**

Means designated by the same letter at each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.

S. + F. + P. stages = Shotting, flowering and podding stages; B = Boron, Mn = Manganese, Zn = Zinc.

Table-4: Effect of growth stages and foliar nutrients on dry seed yield and its components of pea plants in 2015-16 and 2016-17

Treatments	Dry seed yield				Weight of seeds per pod (g)		Seed index (g)		Dry seeds protein (%)		Seed germination (%)	
	Per plant (g)		Per hectare (ton)									
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Growth Stages												
Shooting stage	26.42 c	32.40 c	2.114 c	2.592 c	1.65 b	1.81 c	18.41 c	19.13 d	21.79 c	22.86 c	79.7 c	80.6 b
Flowering stage	28.04 bc	34.46 bc	2.258 bc	2.758 bc	1.70 b	1.87 bc	18.90 b	19.72 c	22.04 bc	23.07 bc	80.3 c	81.4 ab
Podding stage	29.71 ab	36.58 b	2.378 ab	2.926 b	1.76 ab	1.92 ab	19.17 ab	20.40 b	22.44 ab	23.42 a	81.3 b	82.5 ab
S. + F. + P. stages*	31.45 a	39.40 a	2.806 a	3.122 a	1.93 a	2.01 a	19.56 a	21.14 a	22.82 a	23.65 a	82.4 a	83.3 a
F. test	**	**	**	**	*	*	*	*	*	*	*	**
Foliar nutrients**												
Control	21.40 c	26.57 c	1.716 c	2.126 c	1.45 c	1.61 c	17.36 c	17.73 c	20.87 c	22.08 c	78.1 d	78.6 c
B	32.36 a	40.46 a	2.590 a	3.238 a	1.85 ab	2.05 a	19.88 a	21.37 ab	22.88 ab	23.77 ab	82.6 abc	83.7 ab
Mn	25.51 b	30.84 b	2.042 b	2.467 b	1.87 a	1.77 bc	18.07 c	18.53 bc	21.66 bc	22.72 bc	78.9 d	79.8 c
Zn	25.60 b	31.46 b	2.047 b	2.518 b	1.62 bc	1.79 bc	18.21 c	18.63 bc	21.78 bc	22.81 bc	79.1 cd	80.0 c
B + Mn	33.14 a	40.66 a	2.652 a	3.252 a	1.87 a	2.05 a	20.01 a	21.64 ab	22.95 ab	23.82 a	82.9 ab	84.1 a
B +Zn	33.37 a	41.32 a	2.669 a	3.307 a	1.88 a	2.06 a	20.09 a	21.90 ab	23.03 a	23.90 a	83.1 a	84.4 a
Mn + Zn	26.23 b	32.12 b	2.098 b	2.570 b	1.67 b	1.81 b	18.31 bc	18.81 abc	21.88 bc	22.87 bc	79.3 bcd	80.3 bc
B + Mn + Zn	33.65 a	42.25 a	2.693 a	3.378 a	1.88 a	2.09 a	20.15 a	22.17 a	23.14 a	24.02 a	83.4 a	84.7 a
F. test	**	**	**	**	*	*	*	**	*	*	**	**

Means designated by the same letter at each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.
S. + F. + P. stages = Shotting, flowering and podding stages; B = Boron, Mn = Manganese, Zn = Zinc

Table-5: Effect of the interaction among growth stages and foliar nutrients on yield of dry seed and its components of pea plants in 2015-16 and 2016-17

Treatments		Dry seed yield				Weight of seeds/ pod (g)		Seed index (g)		Dry seeds protein (%)		Seed germination (%)	
growth Stages	Foliar nutrients**	Per plant (g)		Per hectare (ton)									
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Shooting stage	Control	21.40 g	26.57 g	1.716 g	0.886 g	1.45 c	1.61 d	17.36 f	17.73 g	20.87 e	22.08 e	78.1 g	78.6 g
	B	29.90 cd	36.27 de	2.393 d	1.209 de	1.78 b	1.95 bc	19.10 cd	19.87 de	22.35 c	23.31 cd	80.8d e	81.7 de
	Mn	22.50 fg	27.89 g	1.800 g	0.930 g	1.50 c	1.68 cd	17.55 ef	17.95 fg	21.05 de	22.35 de	78.2 g	78.9 fg
	Zn	22.50 fg	28.56 g	1.800 g	0.952 g	1.50 c	1.70 cd	17.67 ef	18.02 fg	21.25 de	22.42 de	78.2 g	79.0 fg
	B + Mn	30.26 cd	36.66 de	2.422 d	1.222 de	1.78 b	1.95 bc	19.15 cd	20.18 de	22.40 c	23.35 c	81.1d e	82.2 de
	B +Zn	30.44 cd	37.05 de	2.436 cd	1.235 de	1.78 b	1.95 bc	19.29 cd	20.80 de	22.50 bc	23.39 bc	81.4d e	82.5 d
	Mn + Zn	23.56 fg	28.73 fg	1.884 fg	0.958 g	1.55 c	1.70 cd	17.75 ef	18.08 fg	21.36 de	22.45 de	78.3f g	79.1 fg
	B + Mn + Zn	30.79 cd	37.44 de	2.462 cd	1.248 de	1.79 ab	1.95 bc	19.46 bc	20.72 d	22.53 bc	23.50 bc	81.6d e	82.8 cd
Flowering stage	B	31.14 cd	38.80 cd	2.491 cd	3.103 cd	1.80 ab	2.00b c	19.65 bc	20.93 cd	22.57 bc	23.55 bc	81.8 d	83.1 cd
	Mn	24.80 ef	29.93 fg	1.985 fg	2.395 fg	1.60b c	1.75 cd	17.88 ef	18.17 fg	21.42 de	22.51 de	78.4 fg	79.3 fg
	Zn	24.80 ef	30.28 fg	1.985 fg	2.422 fg	1.60b c	1.75 cd	18.05 e	18.35 fg	21.56 de	22.57 de	78.5 fg	79.5 fg
	B + Mn	32.20 bc	38.80 cd	2.575 cd	3.103 cd	1.84 ab	2.00 bc	20.00 b	21.15 cd	22.60 bc	23.60 bc	82.1 cd	83.4 cd
	B +Zn	32.20 bc	39.20 cd	2.575 cd	3.137 cd	1.84 ab	2.00 bc	20.05 b	21.30 cd	22.68 bc	23.65 bc	82.4 cd	83.6 cd
	Mn + Zn	25.43 ef	31.50 fg	2.035 ef	2.518 f	1.63 bc	1.80 cd	18.10 de	18.56 fg	21.75 cd	22.73 d	78.7 fg	79.8 fg
	B + Mn + Zn	32.38 bc	40.59 c	2.590 cd	3.247 c	1.84 ab	2.05 b	20.05 b	21.54 cd	22.87 bc	23.87 bc	82.6 cd	84.1 bc
Podding stage	B	33.46 bc	41.00 c	2.676 bc	3.281 c	1.88 ab	2.05 b	20.15 ab	21.83 c	23.02 bc	24.01 ab	83.0 c	84.3 bc
	Mn	26.54 e	31.86 ef	2.124 ef	2.549 f	1.68 bc	1.80 cd	18.20 de	18.74 f	22.02 cd	22.86 cd	79.0 fg	80.3 ef
	Zn	26.88 de	32.40 ef	2.150 ef	2.592 f	1.68 bc	1.80 cd	18.25 de	18.86 ef	22.05 cd	23.02 cd	79.3 fg	80.5 ef
	B + Mn	33.65 b	41.41 c	2.693 bc	3.312 c	1.88 ab	2.05 b	20.25 ab	22.05 bc	23.09 bc	24.06 ab	83.5 bc	84.7 bc
	B +Zn	34.20 b	42.84 bc	2.736 bc	3.427 bc	1.90 ab	2.10 ab	20.35 ab	22.35 bc	23.15 b	24.11 ab	83.6 bc	85.1 b
	Mn + Zn	27.37 de	33.30 ef	2.189 de	2.664 ef	1.70 bc	1.85 c	18.42 de	19.07 ef	22.10 cd	23.05 cd	79.7 ef	80.7 ef
	B + Mn + Zn	34.20 b	43.26 bc	2.736 bc	3.461 bc	1.90 ab	2.10 ab	20.40 ab	22.57 bc	23.25 ab	24.16 ab	84.0 bc	85.4 ab
S. + F. + P. stages*	B	34.94 b	45.76 ab	2.796 ab	3.660 ab	1.92 ab	2.20 ab	20.60 ab	22.83 bc	23.58 ab	24.22 ab	84.7 ab	85.7 ab
	Mn	28.21 de	33.67 ef	2.256 de	2.693 ef	1.72 bc	1.85 c	18.65 de	19.24 ef	22.15 cd	23.18 cd	80.0 ef	80.8 ef
	Zn	28.21 de	34.58 e	2.256 de	2.767 ef	1.72 bc	1.90 bc	18.86 cd	19.31 ef	22.25 cd	23.22 cd	80.3 ef	81.1 ef
	B + Mn	36.43 ab	45.76 ab	2.914 ab	3.660 ab	1.98 a	2.20 ab	20.65 ab	23.18 ab	23.70 ab	24.28 ab	84.7 ab	86.0 ab
	B +Zn	36.63 ab	46.20 ab	2.903 a	3.696 ab	1.98 a	2.20 ab	20.70 a	23.46 ab	23.78 ab	24.43 ab	85.1 ab	86.2 ab
	Mn + Zn	28.55 de	34.96 e	2.285de	2.796 e	1.72 bc	1.90 bc	18.95 cd	19.53 ef	22.30 cd	23.26 cd	80.5 e	81.5 de
	B + Mn + Zn	37.22 a	47.70 a	2.978 a	3.816 a	1.98 a	2.25 a	20.70 a	23.85 a	23.90 a	24.56 a	85.4 a	86.5 a
F. test		**	**	**	**	**	**	**	**	**	**	**	**

Means designated by the same letter at each column are not significantly different at the 0.05 level of probability, according to Duncan's Multiple Range Test.
S. + F. + P. stages = Shotting, flowering and podding stages; B = Boron, Mn = Manganese, Zn = Zinc.

(without foliar nutrients application). However, there were insignificant differences between the foliar application with B and /or (B and Mn) and /or (B and Zn) at the three stages. Apparently, the stimulating effects of foliar (B, Mn, and Zn) application pea plants growth were returned on the improved total seed yield and its components. These outcomes are in the same line with those achieved by Mahbobeh et al. (2011). Manimurugan et al. (2017) found increased seed quality with foliar application of 0.1% $MgSO_4$ and increased seed yield and quality with foliar application of 0.1% borax at 30 and 60 days after transplanting in carrot.

Conclusion

The results of this study showed that foliar application at the three stages positively affected the plant height, number of leaves^{-1}, leaf area, chlorophyll content, plant fresh weigh, shelling percentage and seed yield and its components. Application of micronutrients B, Mn and Zn is essential for obtaining the good yield. Foliar application of these elements can be the best alternative to reduce fertilizer consumption and also full fill the plant energy requirement.

सारांश

सब्जी मटर के दो प्रक्षेत्र परीक्षण वर्ष 2015–16 एवं 2016–17 में साखा उद्यान शोध प्रक्षेत्र स्टेशन, इजिप्ट में मटर के प्रभेद मास्टर बी पर बोरान, मैग्नीज व जिंक के पर्णीय छिड़काव का प्रभाव पुष्पन एवं फल विकास पर जानने के लिये किया गया। परिणाम से पता चला कि सूक्ष्म ततवों (बोरान, मैग्नीज व जिंक) के तीन विभिन्न अवस्थाओं में छिड़काव करने से वर्धीय विकास गुणों, छिलका; बीज अनुपात, बीज उपज व उपज घटकों जैसे– बीज जमाव प्रतिशत, पत्तियों में हरित लवक की मात्रा एवं बीज में प्रोटीन की मात्रा को बढ़ाता है। इससे स्पष्ट होता है कि मटर में तीन अवस्था पर बोरान, मैग्नीज व जिंक के पर्णीय छिड़काव से वर्धीय विकास, बीज उपज एवं गुणवत्ता में सुधार लाया जा सकता है।

References

Alloway BJ (2004) Zinc in soils and crop nutrition. 1st Edn., International Zinc Association (IZA), Brussels, Belgium, pp 128.

Anitha P, Sadhankumar PG and Rajan S (2001) Effect of maturity nitrogen fertilization and plant spacing on growth, yield and pod quality of common bean under sandy soil condition. Zagazig J Agric Res 26(2):407-419.

Bin Ishaq MS (2002) Comparisons among the effects of biofertilizer, nitrogen and boron on growth, seed production and seed quality of peas (*Pisum sativum* L.). Ph.D. Thesis, Fac. Agric., Alex. Univ.,Egypt.

Black CA (1965) Methods of Soil Analysis. Amer. Soc. Agron. Madison, Wi, USA

Bolanos L, Esteban E, Lorenzo C, Fernadez M, Felipe M.R, Garate A and Bonilla I (1994) Essentiality of boron for symbiotic dinitrogen fixating in pea (*Pisum sativum* L.) rhizobium nodules. Plant Physiol 104:85-90.

Brown PH, Cakmak I and Zhang Q (1993) Form and function of zinc in plants. In: Zinc in soils and plants (Robson Ed.). Kluwer Academic Publishers, Dord Recht, pp 90-106.

Chaubey T, Manimurugan C, Gupta N, Kumar R, Singh PM and Singh B (2016) Effect of different weed management practices on seed yield and quality of vegetable pea. Vegetable Science 43(1): 142-144.

Cottonie A, Verloo M, Kiekens L, Velghe G and Camerlynck R (1982) Chemical analysis of plant and soils. Laboratory of Analytical and Agrochemistry, State University, Belgium.

Dugger WM and Palmer RL (1983) Effect of boron on the incorporation of glucose into cotton fibers grown in vitro. Plant Physiol 65:266-273.

Duncan BD (1955) Multiple range and multiple F-test. Biometrics, 11:1-42.

El-Waraky YB, Masoud AM and Zanata OA (2013) Effect of biofertilization and boron on growth, seed productivity and seed quality of peas (*Pisum sativum* L.). J. Plant Production, Mansoura Univ 4(3):431-444.

Gautam KK, Syamal MM, Singh AK and Gupta N (2017) Variability, character association and path coefficient analysis of green pod yield and its related traits in pea (*Pisum sativum* L.). Legume Research 40(5):818-823

Hassan HM (1985) Effect of boron, molybdenum and inoculation with rhizobium phaseol on quality and yield of beans (*Phaseolus vulgaris* L.). M.Sc. Thesis, Faculty of Agric., Alex. Univ., Egypt.

ISTA (2012) Seed Testing Rules. International seed Testing Association. CH Switzerland.

Jackson ML (1958) Soil chemical analysis. Nitrogen determination for soils and plant tissue. Prentice Hall, Inc, pp 183-205.

Kaya C and Higgs D (2002) Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. Sci. Hortic., 93:53-64.

Lidon FC and Texerira MG (2000) Rice tolerance to excess Mn: implication in the chloroplast lamellae synthesis of a novel Mn protein. Plant Physiol Biochem 38:969-978.

Mahbobeh SN, Yarnia M and Khoei FR (2011) Effect of zinc and manganese and their application method on yield and yield components of common bean (*Phaseolus vulgaris* L. cv. Khomein). Middle-East J Sci Res 8(5):859-865.

Malakoti MP Keshavarz (2003) Boron place in plant efficient nutrition. 1st Ed., Sana Publication, Iran.

Manimurugan C, Pandita VK, Tomar BS, Gupta N and Singh PM (2017) Effect of plant density and foliar nutrient application on seed yield and quality in Asiatic carrot (Daucus carota). Indian J Agric Sci 87(3):419-424.

Marquard RD and Timpton JL (1987) Relationship between extractable chlorophyll and in situ method to estimate leaf green. Hort Sci 22(6):1327.

Marschner H (1995) Mineral nutritional in higher plants. 2ed. New York, Academic Press Sun Diago, CA, pp: 379-396.

Mengel K and Kirkby EA (2001) Principles of plant nutrition. 5th ed. Dordrecht: Kluwer Academic Publishers, pp: 849.

Pandey N, Pathak GC and Sharma CP (2006) Zinc is critically required for pollen function and fertilization in lentil. J Trace Elem Med Biol 20:89-96.

Rengel Z (2001) Genotypic difference in micronutrient use efficiency in crops. Comm. Soil Sci Plant An 32(7-8):1163-1186.

Sarkar D, Mandal B and Kundu MC (2007) Increasing use efficiency of boron fertilizers by rescheduling the time and methods of application for crops in India, Plant Soil. 301:77-85.

Stigler JC, Michaem LD, Ichrdson R, Dougjas E, Karcher A and Patton J (2010) Foliar nutrient uptake by cool-season and warm-season turf grasses. University of Arkansas research lends insight into understanding turf grass foliar feeding. USGA Sponsored Research. Turf. Lib. Msu.edu/gsr/2010s/2010/100107.

Sultana N, Ikeda T and Kashem M (2001) Effect of foliar spray of nutrient solution on photosynthesis, dry matter accumulation and yield in seawater-stressed rice. Environ Exp Bot 46:129-140.

Txeira IR, Boren AB and Araujo GA (2004) Manganese and zinc leaf application on common bean grown on bean grown on a Cerrado soil. Sci Agric (Braz.) 61:77-81.

Vegetable Science (2018) 45(2) : 204-209

Heterosis for yield and its contributing traits in sponge gourd [*Luffa cylindrica* (Roem) L.]

Yamuna Prasad Singh* and VB Singh

Received: November 2017 / Accepted: January 2019

Abstract

The present study was conducted to estimate heterosis for yield and related traits in 40 hybrids of sponge gourd. The experiment was laid out in RBD with three replications. A wide range of variation in the estimates of heterobeltiosis and standard heterosis in positive and negative direction were observed for all the traits studied. In case of fruit yield per plant, heterobeltiosis ranged from -8.07 to 109.04 % and standard heterosis from -33.06 to 22.07 % in Y_1 and heterobeltiosis ranged from -17.35 to 118.59 % and standard heterosis from -34.47 to 36.73 % in Y_2. Out of 40 crosses, twenty nine F_1's showed significant and positive heterosis over better parent and twelve F_1's showed significant and positive heterosis over standard parent in Y_1 and twenty seven F_1's showed significant and positive heterosis over better parent and twelve F_1's showed significant and positive standard heterosis over standard parent in Y_2 for average fruits yield per plant (kg). The best three F_1's for heterobeltiosis were, NDSG-10 × NDSG-12, NDSG-10 × NDSG-15 and NDSG-4 × Pusa Chikni in both the years while the crosses NDSG-55 × NDSG-11, NDSG-63 × Pusa Chikni and NDSG-24 × Pusa Chikni were found superior over standard variety (Pusa Chikni) in both the years. The study suggested scope of heterosis breeding for improving yield and related traits in sponge gourd.

Keywords: Sponge gourd, standard heterosis, heterobeltiosis, average fruit yield per plant, hybrid

Introduction

Luffa [*Luffa cylindrica* (Roem) L. syn. *L. aegyptica* Mill.] commonly called as sponge gourd, loofah, vegetable sponge or dish cloth. It is one of the important cucurbits, both as rainy and summer season vegetable which is grown throughout world. It belongs to the family Cucurbitaceae with diploid chromosome number 2n = 2x = 26 which includes about 118 genera and 825 species. It originated in subtropical Asian region particularly India (Kalloo 1993). *Luffa cylindrica* (Roem) L. and *L. acutangula* (Roxb) L. are domesticated species. Sponge gourd is an annual and monoeceous cucurbit plant and it has a gelatinous compound luffien. In spite of such a large production, the per capita per day supply of vegetables could not rise above 175 g in the country which is lower than the recommended dietary allowance (RDA) of 350-400 g per capita per day for a balanced diet. The vegetable requirement of our country is estimated to be 220 mt by 2020.This target can best be achieved through use of improved varieties and hybrids technology in combination with superior crop management skills. The inflorescences of staminate flowers are raceme, while pistillate flowers are solitary and long pendunculate and it produces fruits containing a fibrous vascular system with vigorous vine length.

The main goal of research on cucurbitaceous vegetables in India is to improve productivity on sustainable basis through developing biotic and abiotic resistant variety/ hybrid coupled with quality attributes. The nutritive value of sponge gourd fruits per 100 g edible portion (tough skin removed, edible portion 80%) is: water 93.2 g, energy 18 kcal, protein 1.2 g, fat 0.2 g, carbohydrate 2.9 g, fibre 2.0 g, Ca 36 mg, P 19 mg, Fe 1.1 mg, carotene 120 µg, thiamine 0.02 mg, riboflavin 0.06 mg, niacin 0.4 mg and the composition of young leaves per 100 g edible portion is: water 89 g, protein 5.1 g, carbohydrate 4.0 g, fibre 1.5 g, Ca 56 mg, Fe 11.5 mg, carotene 9.2 mg, ascorbic acid 95 mg. It has certain medicinal uses. It is quite useful in asthma, skin diseases, blood circulation and splenic enlargement. It is recommended by doctor to the patients suffering from malaria or other seasonal fevers because cooked fruits are easily digestible and very appetizing. Heterosis breeding depends mainly on choice of superior

Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad-224229, UP

*Corresponding author, E-mail: yamunasingh1947@gmail.com

homozygous parent, for hybridization. In India, little attention has been given for the genetic improvement of sponge gourd, which is evidenced by paucity of adequate sponge gourd hybrids. Therefore, the present study was conducted to estimate heterosis for different yield related traits and identify heterotic hybrids.

Materials and Methods

In the present study 40 F_1's along with fourteen parent (10 lines and 4 testers) were evaluated along in RBD with three replications at the Main Experiment Station, Department of Vegetable Science, NDUAT, Kumarganj, Faizabad (U.P.) under two *Zaid* seasons (February) during 2014 (Y_1) and 2015 (Y_2). Seeds were sown in rows spaced at 2.50 m apart with a plant to plant spacing of 0.50 m. All the recommended agronomical practices, protection measures and recommended dose of manures and fertilizers were applied to raise a good crop. Observations were recorded on all the six plants maintained carefully in each plot for fourteen quantitative characters *viz*., node number of first staminate flower, node number of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, node number of first fruit harvest, days to first fruit harvest, number of primary branches per plant, inter nodal length (cm), vine length (m), fruit length (cm), fruit circumference (cm), average fruit weight (g), number of fruits per plant and average fruits yield per plant (kg).

Results and Discussion

The exploitation of heterosis refers as the superiority of F_1 hybrid over its parent in terms of yield and its attributing traits. The exploitation of heterosis requires an intensive evaluation of germplasm to find out diverse donors with high nicking of genes and further identification of heterotic crosses. In the present study, heterobeltiosis for fruit yield ranged from -8.07 to 109.04% and -17.35 to 118.59% and standard heterosis from -33.06 to 22.06% and -34.47 to 36.73% in Y_1 and Y_2, respectively. Twenty nine showed significant and positive heterosis over better parents and twelve F_1's over standard parents in Y_1 and twenty seven F_1's over better parent and twelve F_1's over standard parent Y_2 showed significant and positive heterosis. The best three F_1's for heterobeltiosis were, NDSG-10 × NDSG-12 (109.04 and 79.07%), NDSG-10 × NDSG-15 (95.58 and 78.55%) and NDSG-4 × Pusa Chikni (81.38 and 88.58%) in both the years while the crosses NDSG-55 × NDSG-11 (22.07 and 33.07%), NDSG-63 × Pusa Chikni (21.99 and 36.73%) and NDSG-24 × Pusa Chikni (19.99 and 29.68%) were found superior over standard variety (Pusa Chikni) in both the years(Table 1 and Table 2). In present study, crosses exhibiting significant and positive estimates of heterosis for one or both types of heterosis for average fruits yield per plant also exhibited significant heterosis for some other important yield and yield attributing traits. However, none of the crosses showed significant and desirable heterosis for all the traits. The above results are in conformity with the findings of Kennedy et al. (1995), Singh et al. (2001), Sadat et al. (2008), Bhatt et al. (2010) and Kumar et al. (2011).

For maturity traits negative heterosis is desirable. Since hybrids with heterosis for earliness produce first fruit earlier as compared to parents, thereby increasing their productivity per day per unit area and as a consequence fetch good prices in the market by early supply of produce. A close examination of heterosis values of six maturity traits *viz*., node number to first staminate and pistillate flower, days to first staminate and pistillate flower opening, node number of first fruit harvest and days to first fruit harvest revealed that the two top hybrids *i.e.,* NDSG-6 × NDSG-15 and NDSG-6 × Pusa Chikni, exhibited significant and desirable heterosis in respect to better parent and standard parent both the years. The top ranked crosses for fruit yield were almost of similar duration for earliness and thereby showing good scope for early high yielding hybrids. Our study further revealed that least one parent (NDSG-18, NDSG-10, NDSG-11, NDSG-4 and NDSG-63) with early days to first fruit harvest was invariably involved in the four top ranked F_1 hybrids for days to first fruit harvest over standard parent in both the years. The top ranked crosses for fruit yield, however, were not significantly early for days to first fruit harvest over better/standard parent. Similar findings were earlier reported by Narasannarvar et al. (2014). The earliness of parents as well as crosses were directly associated with the crosses having high magnitude of heterosis. It may therefore, safely be concluded that either of parents, NDSG-18, NDSG-10, NDSG-11, NDSG-4, NDSG-24 and NDSG-63 or any two of them may be a better choice in any heterosis breeding programme intended to breed high yielding hybrids with considerable earliness. Ram et al. (1997), Maurya et al. (2003) and Sundaram (2008) reported similar findings.

Twenty six crosses over better parent and eleven crosses over standard parents showed significant heterosis during both the years for fruit yield. The improvement in heterosis for yield component may not necessarily be reflected in increased yield. Contrarily, the increased fruit yield will definitely because of increase in one or more component traits. The best performing

Table 1: Lists of crosses with desirable and significant heterosis for 14 characters in sponge gourd (Y_1=2014)

S. N.	Characters	Y_1						
		BP			SV			
		Cross combination	No. of crosses with significant positive heterosis	No. of crosses with significant negative heterosis	Range of heterosis	Cross combination	No. of crosses with significant positive heterosis	No. of crosses with significant negative heterosis	Range of heterosis
1.	Node no. of first staminate flower	NDSG-1 × NDSG-15 (-9.50), NDSG-2 × NDSG15(39.93), NDSG6×NDSG-15(-43.59), NDSG-21 × NDSG-15(-28.37), NDSG-63 ×NDSG-15(-54.58)	12	5	-54.58 to 67.68	NDSG-10 × NDSG-12(27.20), NDSG-10 × NDSG-15(24.80), NDSG10×Pusa Chikni(c) (-15.20)	11	3	-27.20 to 44.80
2.	Node no. of first pistillate flower	NDSG-21 × NDSG-15 (-53.65), NDSG-2 × NDSG-15(-35.77), NDSG-1 × NDSG-11 (-15.53), NDSG-6 × NDSG-15(-31.39), NDSG-10 × NDSG-11(-15.98), NDSG-10 × Pusa Chikni(c) (-21.03), NDSG-18 × NDSG-11(-16.44), NDSG-24 × NDSG-15(-30.38), NDSG-63 × NDSG-15 (-21.11)	7	9	-53.65 to 82.09	NDSG-4 × NDSG-12(-24.79), NDSG-10 × NDSG-12(-23.11), NDSG-18 × NDSG-11(-23.11), NDSG-1 × NDSG-11 (-22.27), NDSG-6 × NDSG-12(-22.27), NDSG-10 × NDSG-11(-22.69), NDSG-10 × Pusa Chikni(c) (-22.69), NDSG-18 × NDSG-12 (-18.91) NDSG-4 × NDSG-11 (-15.13),	5	10	-24.79 to 53.78
3.	Days to anthesis of first staminate flower	NDSG-21 × NDSG-15 (-33.79) NDSG-2 × NDSG-15 (-18.68), NDSG-6 × NDSG-15 (-15.14), NDSG-4 × Pusa Chikni(c) (-12.80),	12	7	-33.79 to 52.37	NDSG-4 × NDSG-11 (-19.16), NDSG-18 × NDSG-11 (-26.25) NDSG-4 × Pusa Chikni(c) (-16.14), NDSG-10 × NDSG-11 (-19.28),	11	6	-26.25 to 23.34
4.	Days to anthesis of first pistillate flower	NDSG-21 × NDSG-15 (-20.64), NDSG-6 × NDSG-12 (-23.52), NDSG-21 × NDSG-15 (-20.64), NDSG-6 × NDSG-15 (-15.69)	10	17	-23.52 to 40.71	NDSG-10 × NDSG-11 (-30.92), NDSG-18 × NDSG-11 (-30.02), NDSG-24 × NDSG-11 (-28.84), NDSG-63 × NDSG-11 (-26.22)	2	21	-30.92 to 14.38
5.	Node no. of first fruit harvest	NDSG-21 × NDSG-15 (-48.20), NDSG-24 × NDSG-15 (-33.97), NDSG-6 × NDSG-15 (-32.37), NDSG-2 × NDSG-15 (-25.31), NDSG-10 × Pusa Chikni(c) (-23.97)	8	12	-48.20 to 84.72	NDSG-10 × Pusa Chikni(c) (-24.28), NDSG-18 × NDSG-11 (-24.28), NDSG-18 × NDSG-12 (-20.58), NDSG-4 × NDSG-12 (-24.28)	13	10	-24.28 to 64.20
6.	Days to first fruit harvest	NDSG-6 × NDSG-15 (-17.40), NDSG-6 × Pusa Chikni(c) (-15.77), NDSG-55 × NDSG-11 (-12.08)	2	5	-17.40 to 25.72	NDSG-55 × NDSG-11 (-25.66), NDSG-21 × NDSG-11 (-22.43), NDSG-24 × NDSG-11 (-20.04), NDSG-6 × NDSG-11 (-19.97), NDSG-10 × NDSG-12 (-22.24), NDSG-10 × NDSG-15 (-21.78)	0	25	-25.99 to 7.11
7	No.of primary branches per plant	NDSG-1 × NDSG-11 (52.46), NDSG-21 × Pusa Chikni(c) (51.64), NDSG-2 × NDSG-11 (50.36), NDSG-1 × Pusa Chikni(c) (50.00), NDSG-21 × NDSG-11 (49.18), NDSG-55 × NDSG-11 (47.33)	17	1	-28.97 to 52.46	---	0	36	-48.36 to 3.69
8	Inter nodal length (cm)	---	32	0	9.44 to 134.58	---	37	0	-.80 to 115.20
9	Vine length (m)	NDSG-63 × NDSG-11 (203.17), NDSG-24 × Pusa Chikni(c) (111.49), NDSG-18 × Pusa Chikni(c) (82.76), NDSG-4 × NDSG-12 (80.85),	19	5	-30.85 to 203.17	NDSG-63 × NDSG-11 (119.54), NDSG-24 × Pusa Chikni(c) (111.49), NDSG-4 × NDSG-12 (95.40), NDSG-18 × Pusa Chikni(c) (82.76), NDSG-24 × NDSG-15 (83.91)	14	9	-25.29 to 119.54
10	Fruit length (cm)	NDSG-6 × NDSG-15 (54.61), NDSG-10 × NDSG-11 (48.74), NDSG-4 × NDSG-15 (43.31), NDSG-2 × NDSG-12 (38.84), NDSG-2 × NDSG-11 (31.42)	23	3	-19.47 to 54.61	NDSG-6 × NDSG-11 (17.90) NDSG-2 × NDSG-11 (13.30)	3	26	-35.91 to 17.90
11	Fruit circumference (cm)	NDSG-1 × NDSG-12 (21.61), NDSG-6 × NDSG-15 (20.90), NDSG-55 × NDSG-12 (20.33), NDSG-10 × NDSG-12 (17.27)	10	0	-8.14 to 21.61	NDSG-6 × NDSG-15 (11.74), NDSG-18 × NDSG-12 (11.36),	3	1	-10.23 to 11.74
12	Average fruit weight (g)	NDSG-55 × NDSG-11 (50.06), NDSG-55 × NDSG-15 (47.58), NDSG-55 × NDSG-12 (25.29), NDSG-10 × NDSG-15 (29.71), NDSG-10 × NDSG-12 (24.70)	22	1	-13.50 to 50.06	NDSG-10 × NDSG-15 (28.28), NDSG-10 × NDSG-12 (15.34)	4	16	-36.32 to 28.28
13	No. of fruits per plant	NDSG-4 × NDSG-12 (83.00), NDSG-10 × NDSG-11 (74.58), NDSG-10 × NDSG-12 (73.24), NDSG-10 × Pusa Chikni(c) (73.24), NDSG-4 × NDSG-15 (72.80)	29	2	-18.68 to 83.00	NDSG-55 × NDSG-11 (36.67), NDSG-55 × Pusa Chikni(c) (35.59), NDSG-1 × NDSG-11 (24.36)	14	10	-34.37 to 52.77
14	Average fruits yield per plant (kg)	NDSG-10 × NDSG-12 (109.04), NDSG-4 × Pusa Chikni(c) (81.38), NDSG-10 × NDSG-15 (95.58), NDSG-4 × NDSG-15 (70.83)	29	0	-8.07 to 109.04	NDSG-55 × NDSG-11 (22.07), NDSG-63 × Pusa Chikni(c) (21.99), NDSG-24 × Pusa Chikni(c) (19.99)	12	12	-33.05 to 22.07

BP=Better Parent, SV= Standard Variety

Table 2: Lists of crosses with desirable and significant heterosis for 14 characters in sponge gourd (Y_2=2015)

S. N.	Characters	Y_2							
		BP				SV			
		Cross combination	No. of crosses with significant positive heterosis	No. of crosses with significant negative heterosis	Range of heterosis	Cross combination	No. of crosses with significant positive heterosis	No. of crosses with significant negative heterosis	Range of heterosis
1.	Node no. of first staminate flower	NDSG-2 × NDSG-15 (-52.84), NDSG-6 ×NDSG15(51.64), NDSG21×NDSG-15 (-41.61), NDSG-63 × NDSG-15 (-63.28)	19	4	-63.28 to 59.22	NDSG-10 × NDSG12(24.59), NDSG-10 × NDSG-15 (-18.03)	15	2	-24.59 to 36.07
2.	Node no. of first pistillate flower	NDSG-6 × NDSG-15(-50.81), NDSG-21 × NDSG-15(-46.44), NDSG-1 × NDSG-11 (-17.55), NDSG-2 × NDSG-15 (-42.33), NDSG-24 × NDSG-15(-29.34), NDSG-18 × NDSG-11(-22.04), NDSG-1 × NDSG-15 (-21.24), NDSG-4 × NDSG-11(-20.82), NDSG-4 × NDSG-15 (-19.85), NDSG-63 × NDSG-15 (-15.17)	11	14	-58.81 to 112.80	NDSG-4 × NDSG-12 (-26.57)	17	1	-26.57 to 68.60
3.	Days to anthesis of first staminate flower	NDSG-2 × NDSG-15 (-17.66), NDSG-4 × Pusa Chikni(c) (-14.21), NDSG-6 × NDSG-15 (-17.37), NDSG-21 × NDSG-15 (-28.32),	15	6	-28.32 to 56.01	NDSG-4 × NDSG-11 (-25.38), NDSG-4 × Pusa Chikni(c) (-16.74), NDSG-10 × NDSG-11 (-24.07), NDSG-18 × NDSG-11 (-28.88), NDSG-24 × NDSG-11 (-19.58)	6	11	-28.88 to 20.35
4.	Days to anthesis of first pistillate flower	NDSG-6 × NDSG-12 (-22.82), NDSG-18 × NDSG-11 (-17.98), NDSG-21 × NDSG-15 (-16.19)	6	10	-22.82 to 42.38	NDSG-18 × NDSG-11 (-39.58), NDSG-10 × NDSG-11 (-30.63), NDSG-63 × NDSG-11 (-30.13), NDSG-6 × NDSG-11 (-27.76)	0	26	-39.58 to 4.89
5.	Node no. of first fruit harvest	NDSG-10 × Pusa Chikni(c) (-29.04), NDSG-18 × NDSG-11 (-11.57), NDSG-21 × NDSG-15 (-46.65), NDSG-6 × NDSG-15 (-41.27), NDSG-24 × NDSG-15 (-31.52)	5	14	-46.65 to 55.00	NDSG-10 × Pusa Chikni(c) (-29.04), NDSG-18 × NDSG-11 (-21.32), NDSG-18 × NDSG-12 (-21.69), NDSG-1 × NDSG-11(-20.22)	5	19	-30.51 to 36.76
6.	Days to first fruit harvest	NDSG-6 × NDSG-15 (-21.82), NDSG-6 × Pusa Chikni(c) (-16.93), NDSG-6 × NDSG-12 (-13.75), NDSG-2 × NDSG-15 (-12.45)	4	7	-21.82 to 16.65	NDSG-4 × NDSG-11 (-28.17), NDSG-6 × NDSG-11 (-26.68), NDSG-55 × NDSG-11 (-30.04), NDSG-63 × NDSG-11 (-25.12), NDSG-18 × NDSG-11 (-24.19)	0	30	-30.04 to 1.93
7	No.of primary branches per plant	NDSG-21 × NDSG-11 (74.11), NDSG-2 × NDSG-11 (69.35), NDSG-21 × Pusa Chikni(c) (68.75), NDSG-2 × Pusa Chikni(c) (57.26)	15	17	-20.33 to 74.11	---	0	39	-10.99 to -53.11
8	Inter nodal length (cm)	NDSG-18 × NDSG-11 (-21.51)	33	1	-21.51 to 111.38	---	36	0	-13.25 to 82.12
9	Vine length (m)	NDSG-63 × NDSG-11 (171.83), NDSG-24 × Pusa Chikni(c) (117.07), NDSG-4 × NDSG-12 (85.39) NDSG-18 × Pusa Chikni(c) (81.71),	19	3	-26.97 to 171.83	NDSG-63 × NDSG-11 (135.37), NDSG-24 × Pusa Chikni(c) (117.07), NDSG-18 × Pusa Chikni(c) (81.71), NDSG-4 × NDSG-12 (101.22), NDSG-24 × NDSG-15 (84.15)	21	3	-20.73 to 135.37
10	Fruit length (cm)	NDSG-2 × NDSG-11 (44.68) NDSG-4 × NDSG-15 (43.80), NDSG-2 × NDSG-12 (41.80), NDSG-10 × NDSG-11 (33.59), NDSG-6 × NDSG-15 (29.74)	27	1	-12.43 to 55.88	NDSG-6 × NDSG-11 (29.58), NDSG-2 × NDSG-11 (26.31), NDSG-4 × NDSG-11 (19.76)	7	14	-28.40 to 29.58
11	Fruit circumference (cm)	NDSG-18 × NDSG-11 (23.50), NDSG-63 × NDSG-11 (20.09), NDSG-55 × NDSG-12 (18.47), NDSG-4 × NDSG-12 (19.57), NDSG-2 × NDSG-12 (18.64)	11	1	-17.88 to 23.50	NDSG-18 × NDSG-12 (10.22)	1	8	-17.88 to 10.22
12	Average fruit weight (g)	NDSG-55 × NDSG-11 (32.85), NDSG-55 × NDSG-15 (30.30), NDSG-55 × NDSG-12 (13.79), NDSG-10 × NDSG-15 (28.87), NDSG-4 × Pusa Chikni(c) (10.85)	27	2	-12.77 to 34.97	NDSG-10 × NDSG-15 (13.71), NDSG-6 × Pusa Chikni(c) (15.31)	2	26	-36.07 to 15.31
13	No. of fruits per plant	NDSG-4 × NDSG-12 (113.23), NDSG-55 × Pusa Chikni(c) (43.68), NDSG-10 × Pusa Chikni(c) (85.21), NDSG-18 × Pusa Chikni(c) (67.16)	31	3	-14.83 to 115.16	NDSG-55 × NDSG-11 (39.52), NDSG-55 × Pusa Chikni(c) (43.68), NDSG-18 × NDSG-12 (39.82), NDSG-55 × NDSG-11 (39.52), NDSG-18 × Pusa Chikni(c) (67.16)	21	6	-31.05 to 72.07
14	Average fruits yield per plant (kg)	NDSG-10 × NDSG-12 (79.07), NDSG-4 × Pusa Chikni(c) (88.58), NDSG-10 × NDSG-15 (78.55), NDSG-4 × NDSG-15 (118.59), NDSG-55 × NDSG-11 (72.18)	27	1	-17.35 to 118.59	NDSG-55 × NDSG-11 (33.07), NDSG-63 × Pusa Chikni(c) (36.73), NDSG-21 × Pusa Chikni(c) (22.38), NDSG-24 × Pusa Chikni(c) (29.68)	12	13	-34.47 to 36.73

BP=Better Parent, SV= Standard Variety

heterobeltiotic F_1 (NDSG-63 × Pusa Chikni) for yield common over seasons and NDSG-18 × NDSG-11 showed significant and top ranked heterobeltiosis for number of fruits per plant in both the seasons. This hybrid also showed significant heterosis for fruit circumference. Likewise, out of forty, twenty one crosses were found significant heterotic over better parent common over both the seasons, best three crosses *i.e.* NDSG-55 × NDSG-11, NDSG-55 × NDSG-15 and NDSG-18 × NDSG-11, and two crosses (NDSG-6 × Pusa Chikni and NDSG-10 × NDSG-15) showed significant standard heterosis. Among top heterotic crosses some of the parents were more frequently involved. As the performance of hybrids depends upon the heterotic capability of parents involved, from economic point of view it will be useful to select and utilize the parental inbreds with strong heterotic capability for important economic traits associated with yield in order to achieve higher gains in F_1 hybrids through exploitation of heterosis. Increased yield in crosses of sponge gourd observed in present investigations are in conformity with the findings of various workers (Rajeswari and Natarajan (1999), Singh et al. (2001) and Naliyadhara et al. (2007), and Karmakar et al. (2013) in ridge gourd.

A perusal of Table 1 and Table 2 which showed best three crosses on the basis of desirable and significant heterobeltiosis for fourteen traits in both the years revealed that common crosses on the basis of better parent heterosis for fruit yield per plant were NDSG-63 × Pusa Chikni, NDSG-55 × NDSG-11, NDSG-24 × Pusa Chikni, NDSG-18 × Pusa Chikni and NDSG-18 × NDSG-11. All of them were common in both the years in respect to better parent heterosis for average fruit yield as well as some other traits like number of fruits per plant, fruit weight and fruit length. Standard heterosis of three best cross combinations had been presented in Table 1 and Table 2. Two crosses showed significant standard heterosis for days to first fruit harvest in both the years for earliness. The extent of heterosis of three best crosses *i.e*. NDSG-63 × Pusa Chikni, NDSG-55 × NDSG-11 and NDSG-24 × Pusa Chikni in year Y_1 (56.51 to 62.22%) and Y_2 (51.71 to 84.43%) for average fruit yield per plant revealed that there was a great scope of realizing higher yield in sponge gourd through heterosis breeding (Sabina et al. 2008). Besides fruit yield per plant, substantial heterosis over better-parent and standard variety was also observed in negative as well as positive direction for remaining characters in both the years. However, the number of crosses showing significant estimates and the range of heterosis varied from one character to another. In general, some crosses showed appreciable and high heterosis for number of traits under study. The existence of wide spectrum of heterosis in either direction with expression of high degree of desirable heterosis by some crosses for number of traits observed in present study is in conformity with the earlier reports of high heterosis for such characters in sponge gourd.

lkjk'k

वर्तमान अध्ययन में चिकनी तोरई के 40 संकरों का मूल्यांकन उपज एवं सम्बन्धित गुणों में संकर ओज ज्ञात करने के लिये किया गया। प्रयोग को यादृच्छिक अभिकल्प में तीन प्रतिकृतियों के साथ किया गया। सकारात्मक एवं नकारात्मक दिशा में सभी गणों के लिये ओजस्विता एवं मानक ओज आंकलन में वृहद् विविधता पायी गयी। प्रति पौध उपज के लिये ओजस्विता सीमा विस्तार– 8.07 से 109.4 प्रतिशत तथा मानक ओज–33.06 से 22.07 प्रतिशत वाई–1 में पाया गया तथा ओजस्विता सीमा विस्तार–17.35–118.59 प्रतिशत व मानक ओज– 34.47–36.73 प्रतिशत वाई–2 में पाया गया। कुल 40 संकरों में 20 संकरों ने सार्थक व धनात्मक ओज उत्तम पितृ एवं 12 संकरों ने सार्थक व धनात्मक ओज उत्तम पितृ वाई–1 तथा 27 संकरों ने सार्थक व धनात्मक ओज उत्तम पितृ तथा 12 संकरों ने सार्थक व धनात्मक मानक ओज मानक पितृ के लिए प्रभेद वाई–2 में प्रति पौध फल उपज (किलोग्राम) के लिए पाया गया। तीन उत्कृष्ट संकरों– एन डी एस जी–10 x एन डी एस जी–12, एनडीएसजी–10 x एनडीएसजी–15 तथा एनडीएसजी–4 x पूसा चिकनी में दोनों वर्ष ओजस्विता अधिक पायी गयी जबकि तीन संकरों एनडीएसजी–55 x एनडीएसजी–11, एनडीएसजी–63 x पूसा चिकनी एवं एनडीएसजी–64 x पूसा चिकनी मानक किस्म पूसा चिकनी की तुलना में दोनों वर्ष उत्तम पायी गयी। अध्ययन से सुझाव मिलता है कि चिकनी तोरई के संकर प्रजनन में उपज सम्बन्धित गुणों में सुधार हेतु ओजस्विता व ओज का ज्यादा योगदान पर ध्यान देना चाहिए।

References

Bhatt MM, Sadhu BB and Acharya RR (2010) Exploitation of hybrid vigour in ridge gourd [*Luffa acuangulata* (Roxb.) L.]. Res Crops 11 (2): 401-403.

Islam S, Munshi AD, Kumar R, Behera TK and Lal SK (2008) Evaluation of sponge gourd hybrids for yield and related traits. Cucurbit Genetics Cooperative 31/32: 34-35.

Kalloo G (1993) Loofah-Luff. Genetic Improvement of Vegetable Crops. pp 265-266.

Karmakar P, Munshi AD, Behera TK, Kumar R, Kaur C and Singh BK (2013) Hermaphrodite inbreds with better combining ability improve antioxidant properties in ridge gourd [*Luffa acutangula* (Roxb.) L.]. Euphytica 191(1): 75-84.

Kumar A, Singh B and Kumar M (2011) Exploitation of hybrid vigour for yield in [*Lagenaria siceraria* (Molina) Standl.] using line × tester analysis. Vegetos 24(2): 45-48.

Maurya SK, Ram HH and Singh JP (2003) Hybrid breeding in bottle gourd. Prog Hort 35: 46-50.

Narasannavar AR, Gasti VD, Shantappa T, Mulge R, Allolli TB and Thammaiah N (2014) Heterosis studies in ridge gourd [*Luffa acutangula* (L.) Roxb.]. Karnataka J Agric Sci 27 (1): 47-51.

Rajeswari KS and Natarajan S (1999) Studies on heterosis for growth, yield and quality parameters in bitter gourd (*Momordica charantia* L.). South Indian Hort. 47: 208-209.

Ram D, Kalloo G and Singh M (1997) Heterosis in bitter gourd (*Mornordica charantia* L.). Veg Sci 24(2): 99-102.

Sadat MA, Uddin MJ and Bhuiyan MSR (2008) Heterosis in pointed gourd. Hort Envi Biotech 49(6): 427-433.

Singh R, Khattra AS and Thakur JC (2001) Studies on heterosis in bitter gourd (*Momordica charantia* L.). Haryana J Hort Sci 30: 224-227.

Sundaram V (2008) Heterosis for yield and attributing traits in bitter gourd. Mysore J Agri Sci 42(2): 297-303.

Vegetable Science (2018) 45(2) : 210-219

Heterosis and potence ratio studies for yield and its contributing traits in cucumber (*Cucumis sativus* L.)

Reena Kumari[1*], Ramesh Kumar[1], Devender Kumar Mehta[1], Rajesh Kumar Dogra[2] and Vikram Banyal[1]

Received: January 2019 / Accepted: January 2019

Abstract

The present experiment was conducted to estimate the heterosis and dominance effects in the inheritance of fruit yield and its contributing traits in cucumber by using nine parents (6 lines and 3 testers) crossed in Line × Tester design. ANOVA for Line × Tester analysis revealed the presence of sufficient genetic diversity for different traits in the experimental material. The mid parent heterosis among different genotypes was obtained in both positive and negative direction for different traits under study. Maximum average heterosis was observed for the yield per hectare followed by the seed vigour index II, number of marketable fruits per plant, severity of downy mildew, average fruit weight, harvest duration, severity of powdery mildew, node number bearing first female flower, fruit length, incidence of fruit fly, fruit breadth, seed vigour index I, total soluble solids, seed germination, days to marketable maturity and days to first female flower appearance. Partial to over dominance effects were involved in the inheritance of the studied traits. Hybrids estimated positive or negative potence ratio with >1 value is the indication of prevalence of over dominance in desirable direction and scope for exploitation *via* heterosis breeding in cucumber. Experimental results revealed that among 18 crosses, five crosses naming LC-1-1 × K-75, LC-1-1 × Poinsette, LC-2-2 × K-75, LC-2-2 × Poinsette and CGN-20515 × Poinsette were found superior on the basis of overall mean performance and heterotic response for most of the traits. These hybrid combinations could be exploited commercially for the development of hybrids/varieties for better yield, quality (TSS), insect-pest & disease resistance and seed traits in cucumber.

[1]Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni-173 230, Solan, HP

[2]Department of Fruit Science, Dr YS Parmar University of Horticulture and Forestry, Nauni-173 230, Solan, HP

*Corresponding author, E-mail: reena.sarma92@gmail.com

Keywords: Mid parent heterosis**,** potence ratio, cucumber, degree of dominance, Line × Tester design.

Introduction

In India, a wide range of variability in vegetative and fruit characters is available for cucumber. Unfortunately, very little attention has been paid for its genetic improvement by using wild genotypes. A speedy improvement can be brought about by assessing the genetic variability and exploitation of heterosis. The exploitation of heterosis is much easier in cross pollinated crops and cucumber being monoecious, provides ample scope for the utilization of hybrid vigour on commercial scale (Singh et al. 2012). Cucumber (*Cucumis sativus* L., 2n=2x=14) belongs to the "gourd" family Cucurbitaceae. It is second most widely cultivated cucurbits after watermelon and important vegetable crop for both internal market and export purpose. It is grown for its tender green fruits during summer and rainy season throughout the country (Kumari et al. 2017). Cucumber is a low energy and high water content (95%) vegetable which makes it diuretic, possessing a deep cleansing action due to the presence of some natural chemical constituents such as glycolic, lactic, and salicylic acids. Currently, very few hybrids have been developed by public sector and the farmers are purchasing hybrid seeds from the private sector companies, who are charging exorbitantly. Stability of genotype is also important for its wider adaptation. To tide over the situation, there is a need to make concentrated efforts to develop F_1 hybrids and making their seed available to the farmers at a reasonable price. Development of F_1 hybrid cultivars offers opportunities for improvement in production, earliness, uniformity, quality and resistance to biotic and abiotic stresses. Maximum heterosis is observed in the F_1, but the superiority of the progeny over their parents is progressively lost in subsequent generations obtained

through successive selfing (Meyer et al. 2004). Relative heterosis (mid parent heterosis/average heterosis) i.e. the superiority of a hybrid over its mid parent value, will help in understanding the genetic status of the yield and its component characters. In spite of presence of heterosis, its exploitation will take practical shape only when their F_1 hybrid seeds are produced at an affordable cost. Hence, knowledge of heterosis along with estimates of potence ratio which shed light about degree of dominance will yield more meaningful results to breeders for practical utility and exploitation of heterosis. So, the present investigations were conducted to exploit hybrid vigour for developing the best suitable combination which can replace the conventional varieties as well as hybrids from private sector and also to make F_1 hybrids seed production cost effective (Dogra and Kanwar 2011).

Materials and Methods

The experiment was conducted at the Experimental Research Farm, Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during rainy season of 2013 and 2014. The experimental material comprised of 6 lines (CGN-20256, CGN-20515, CGN-21585, LC-1-1, LC-2-2 and LC-12-4) and 3 broad based testers (Japanese Long Green, K-75 and Poinsette). Eighteen hybrids were developed by crossing 6 lines and 3 testers fashion during rainy season of 2013 as per Line × Tester design as suggested by Kempthorne (1957). Hybrid seeds were produced by conventional hand emasculation and hand pollination method. During *kharif* 2014, 18 F_1 hybrid crosses along with parents (9) were evaluated in randomized block design with three replications. Recommended agronomic practices and need based plant protection measures were taken. The harvestings were carried out manually. Ten plants of each entry in each replication were randomly selected for recording the observations on yield and its component characters. Data were recorded on days to first female flower appearance, node number bearing first female flower, days to marketable maturity, fruit length (cm), fruit breadth (cm), average fruit weight (g), number of marketable fruits per plant, harvest duration (days), marketable yield per hectare (q), total soluble solids (°B), incidence of fruit fly (%), severity of powdery and downy mildew (%), seed germination (%) and seed vigour index-I and II. The data recorded were used to analyze genetic parameters like Line × Tester ANOVA, mid parent heterosis and potence ratio.

For the total soluble solids (TSS) randomly selected fruits were observed under room temperature with the help of 'ERMA Hand Refractometer' by putting 2-3 drops of juice on prism and the values expressed as TSS content of juice (AOAC, 1970). For the incidence fruit fly, total number of fruits per plant and fruits infested with fruit fly were counted from the randomly selected plants to work out its incidence as per the following formula:

$$\text{Incidence of fruit fly (\%)} = \frac{\text{Number of fruit fly infested fruits}}{\text{Total number of fruits}} \times 100$$

The occurrence and severity of powdery mildew was recorded periodically under natural conditions. Fifteen leaves were randomly selected from different levels of height (from top to bottom) from ten vines of each parent/cross and disease severity for powdery mildew was recorded by adopting the 0-5 scale (Ransom *et al.* 1991). Similarly, the severity of downy mildew was recorded by adopting the 0-4 scale (Reuveni 1983).

As per the ISTA guidelines (Anonymous 1985), seed germination of each genotype was tested under laboratory conditions through blot paper method. Germination percentage of each replication was worked out by using following formula:

$$\text{Seed germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds placed for germination}} \times 100.$$

Seed vigour index was calculated as per the formulae given by Abdul-Baki and Anderson (1973):

Seed Vigor Index-I = Seed germination percentage × seedling length (cm)

Seed Vigor Index-II = Seed germination percentage × seedling dry weight (mg)

Data of all the previously mentioned characters were arranged and statistically analyzed to get ANOVA for Line × Tester analysis as per the model suggested by Kempthorne(1957) using statistical software package SPAR 2.0/ OP stat. Heterosis percentages, relative to the mid-parents, for the different studied characters were calculated using the procedure illustrated by Mather and Jinks (1971) as follows:

$$\text{Mid parent heterosis (\%)} = \frac{F_1 - \text{M.P.}}{\text{M.P.}} \times 100$$

Where; F_1 = mean value of the particular hybrid population and M.P. = mean value of the two parents for that hybrid $(P_1 + P_2)/2$.

Moreover, potence ratio was calculated as per Smith (1952) to determine the degree of dominance as follows:

$$P = \frac{F_1 - \text{M.P.}}{0.5\,(P_2 - P_1)}$$

Where, P: relative potence of gene set, F_1: first generation mean, P_1: the mean of lower parent, P2: the mean of higher parent, M.P.: mid-parents value = $(P_1 + P_2)/2$. Complete dominance was indicated when P = +1; while partial dominance is indicated when "P" is between (-1 and +1), except the value zero, which indicates absence of dominance. Over dominance was considered when potence ratio exceeds ±1. The positive and negative signs indicate the direction of dominance of either parent.

Results and Discussion

Performance of the evaluated genetic populations and hybrids: Results of the mean values of the parental/ hybrid cultivar showed relatively significant wide range of genetic variability for most studied traits. The significant variations were observed for the traits determining the earliness of a variety/hybrid, namely, days to first female flower appearance (parents=52.05-57.99 and hybrids=49.07-61.50), node number bearing female flower (parents=4.20-8.97 and hybrids=3.15-10.28) and days to marketable maturity (parents =58.17-66.13 and hybrids=56.87-67.47). Ample variations with respect to earliness were also reported by Bairagi et al. (2005), Munshi et al. (2007), Hanchinamani et al. (2008), Yadav et al. (2009) and Kumar et al. (2013) in cucumber. All the parents and hybrids also revealed wide variations with respect to yield and yield contributing traits, namely fruit length (parents=12.20-24.17 and hybrids=15.07-22.10 cm) and breadth (parents=3.80-5.60 and hybrids=3.53-6.03 cm), average fruit weight (parents=184.44-312.43 and hybrids=214.33-369.60 g), number of marketable fruits per plant (parents=3.60-8.03 and hybrids=4.03-11.37), harvest duration (parents=15.76-28.17 and hybrids=15.93-36.46 days), marketable yield per hectare (parents=92.19-216.03 and hybrids=104.20-442.50 q, respectively). Similar results with respect to variation among yield and yield contributing traits in monoecious cultivars of cucumber have also been reported earlier by Munshi et al. (2007), Kumar et al. (2008), Hossain et al. (2010), Dogra and Kanwar (2011), Golabadi et al. (2012), Kumar et al. (2013) and Ranjan et al. (2015). The general approach of selecting parental lines based on mean performance does not necessarily give fruitful results (Allard 1960). The disease trait *viz*., incidence of fruit fly (parents=16.86-29.65 and hybrids=10.87-33.71 %), severity of powdery mildew (parents=10.30-20.17 and hybrids=9.47-25.13 %), severity of downy mildew (parents=12.90-35.53 and hybrids=11.30-30.93 %) and quality trait like total soluble solid (parents=2.90-4.03 and hybrids=2.88-4.07 ^{0}B) and seed traits viz., seed germination (parents=66.17-82.00 and hybrids=68-84 %), seed vigour index I (parents=2084.60-2787.77 and hybrids=1947.37-3216.90 %) and seed vigour index II (parents=663.20-1203.47 and hybrids=688.73-1996.00 %). Substantial variations for seed germination (Hamid et al. 2002, Kumar et al. 2013) and seed vigour (Nerson 2007, Kumar et al. 2013) traits had also been reported earlier in different varieties of cucumber. But, none of them had studied the variations for seed vigour traits using hybrid varieties of cucumber. The results of the comparisons among mean performances, heterosis relatives to mid parent, and potence ratios of the tested population for the various studied characters of cucumber are presented in table 2-6. Therefore, before drawing any conclusion, we have determined heterotic potential and potence ratio for all the traits under study.

ANOVA for Line × Tester analysis: Mean squares (Table 1) due to genotypic differences found significant for all the traits studied. This indicated that the experimental material under study had sufficient genetic diversity for different traits. Further, partitioning of sum of squares due to genotypes indicated that the differences among parents and among hybrids were significant for most of the characters under study. While, mean squares due to parents vs. hybrids were significant for days to first female flower appearance (DTFFFA), node number bearing first female flower (NNBFFF), days to marketable maturity (DTMM), fruit length (FL), fruit breadth (FB), average fruit weight (AFW), number of marketable fruits per plant (NMFPP), harvest duration (HD), incidence of fruit fly (IFF), severity of powdery mildew (SPM), severity of downy mildew (SDM), total soluble solids TSS, seed germination (SG), seed vigour index-I (SVI-I) and II (SVI-II) indicating prevalence of heterosis for yield, earliness and its components.

Heterosis percentages (relative to the mid parent): Heterosis breeding provides a chance for achieving unique improvement in yield and its attributing traits in single generation that would be more difficult and time consuming with other conventional breeding approaches (Sherpa et al. 2014). Early flowering, fruit maturity and harvest may also be contributed to quick establishment of hybrid plants and their faster growth and development. Estimates of mid parent heterosis for 16 characters studied is presented in the table 2-6. In case of cucumber, for earliness traits like DTFFFA, NNBFFF and DTMM heterosis in negative direction is desirable to catch early market. Range of the mid parent heterosis was -7.21 to 7.35 for DTFFFA; -46.93 to 45.02 for NNBFFF; -5.92 to 8.41 for DTMM. The cross LC-2-2 × Poinsette (-7.21) showed significantly highest negative heterosis for DTFFFA, LC-1-1 × K-75 (-46.93) for NNBFFF and LC-2-2 × Poinsette (-5.91) for DTMM. Significant desirable negative heterosis over mid parent

Table 1: Analysis of variance for Line × Tester analysis including parents in cucumber (F_1)

Source / Character	Mean Sum of Squares								
	Replications	Treatments	Parents	P vs C	Crosses	Lines	Testers	Line × Testers	Error
Df	2	26	8	1	17	5	2	10	52
Days to first female flower appearance	0.411	23.032*	14.464*	0.400*	28.396*	9.022*	19.347*	31.907*	0.783
Node number bearing first female flower	0.091	12.750*	9.621*	9.221*	14.430*	9.249*	12.591*	5.543*	0.076
Days to marketable maturity	0.460	24.919*	26.861*	12.007*	24.765*	27.257*	30.745*	17.110*	0.533
Fruit length (cm)	2.445	18.285*	32.083*	81.633*	8.065*	10.092*	73.441*	59.325*	0.728
Fruit breadth (cm)	0.019	1.224*	0.773*	0.045*	1.506*	0.473*	1.688*	0.445*	0.027
Average fruit weight (g)	800.375	5,156.048*	3,248.331*	20,916.326*	5,126.722*	1,484.293*	6,960.699*	4,643.784*	176.887
No. of marketable fruits per plant	0.113	12.301*	6.369*	18.808*	14.710*	8.330*	4.338*	0.623*	0.112
Harvest duration (days)	1.561	91.191*	42.663*	95.156*	113.795*	58.051*	24.555*	1.942*	1.817
Marketable yield per hectare (q)	171.574	21,483.740*	4,180.226*	69,880.243*	26,779.716*	6,007.101*	1,431.802*	542.704*	197.115
Incidence of fruit fly (%)	0.196	115.958*	52.258*	2.977*	152.581*	51.213*	61.722*	38.557*	1.263
Severity of powdery mildew (%)	1.228	45.274*	27.680*	7.385*	55.782*	24.749*	31.848*	34.002*	2.414
Severity of downy mildew (%)	0.972	106.762*	169.549*	25.440*	81.999*	147.918*	39.548*	537.707*	1.387
Total soluble solids (°B)	0.005	0.282*	0.337*	0.009*	0.272*	0.525*	0.013*	0.047*	0.009
Seed germination (%)	2.420	50.391*	60.981*	8.451*	47.875*	77.433*	41.444*	17.796*	1.240
Seed vigour index-I	5,146.53	241,214.99*	145,186.80*	7,090.80*	300,176.74*	229,607.47*	1,211.16*	11,034.73*	10,472.30
Seed vigour index-II	7,682.73	284,177.78*	100,183.75*	1,393,857.28*	305,487.95*	153,078.57*	15,508.42*	5,060.32*	8,305.71

*Significant at 5% level of significance

Table 2:. Mean performance of parents for different traits in cucumber

Parents	DTF-FFA	NNB-FFF	DT-MM	FL	FB	AFW	NOM-FPP	HD	MYPH	IFF	SPM	SDM	TSS	SG	SVI-I	SVI-II
Lines																
CGN-20256	52.05	5.17	59.08	12.20	4.83	188.44	7.33	25.21	146.91	26.32	20.17	35.53	3.37	75.67	2084.60	683.09
CGN-20515	52.42	4.20	58.18	14.73	5.60	238.93	8.00	26.08	203.72	21.06	12.43	18.60	2.90	82.00	2420.23	809.20
CGN-21585	52.21	4.40	58.17	15.37	4.43	224.65	7.07	24.47	168.81	24.44	18.82	28.90	4.03	77.67	2170.67	663.20
LC-1-1	52.45	5.00	61.10	17.77	4.90	252.05	8.03	28.17	216.03	17.37	17.27	26.27	3.20	75.33	2581.70	1125.62
LC-2-2	52.86	5.97	61.32	15.70	5.10	231.42	7.43	26.49	183.40	16.86	14.47	16.83	3.10	77.67	2787.77	1203.47
LC-12-4	56.59	8.97	66.13	16.10	4.70	242.28	3.60	15.76	92.19	25.47	15.40	21.53	2.93	66.67	2170.93	865.67
Testers																
K-75	55.31	6.87	61.63	15.47	4.97	222.65	6.50	23.88	154.89	21.28	15.60	13.20	3.10	73.33	2435.01	973.44
JLG*	57.99	8.47	65.85	24.17	3.80	312.43	5.43	20.89	180.89	29.65	16.23	19.33	3.23	79.00	2397.10	838.84
Poinsette	52.91	4.40	59.57	15.73	5.20	237.27	7.83	26.61	198.29	22.43	10.30	12.90	3.17	80.33	2404.50	949.97
Range	52.05 to 57.99	4.20 to 8.97	58.17 to 66.13	12.20 to 24.17	3.80 to 5.60	188.44 to 312.43	5.43 to 8.03	15.76 to 28.17	92.19 to 216.03	16.86 to 29.65	10.30 to 20.17	12.90 to 35.53	2.90 to 4.03	66.67 to 82.00	2084.60 to 2787.77	663.20 to 1203.47
Mean	53.87	59.39	61.22	16.36	4.84	238.90	6.80	24.17	171.68	22.76	15.63	21.45	3.22	76.41	2383.61	901.39

*JLG = Japanese Long Green

Whereas: DTFFFA= Days to first female flower appearance, NNBFFF= Node number bearing first female flower, DTMM= Days to marketable maturity, FL= Fruit length, FB= Fruit Breadth, AFW=Average fruit weight, NMFPP= Number of marketable fruit per plant, HD= Harvest duration, YPH= Yield per hectare, IFF= Incidence of fruit fly, SDM= Severity of downy mildew, SPM= Severity of powdery mildew, TSS= Total soluble solids, SG= Seed germination(%), and SVI-I= Seed vigour index I and II

Table 3: Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for earliness and yield contributing traits in cucumber

Traits(s) / Cross(s)	Days to first female flower appearance				Node number bearing first female flower				Days to Marketable Maturity				Fruit Length (cm)			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	55.80	53.68	3.95*	1.30	8.73	6.02	45.02*	3.19	65.43	60.36	8.41*	3.98	16.37	13.84	18.32*	1.55
CGN-20256×JLG	55.27	55.02	0.45	0.08	8.23	6.82	20.67*	0.85	63.68	62.47	1.95*	0.36	19.50	18.19	7.23	0.22
CGN-20256 × Poinsette	52.93	52.48	0.86	1.05	6.40	4.79	33.75*	4.19	61.80	59.33	4.17*	10.10	15.07	13.97	7.91	0.63
CGN-20515×K-75	52.53	53.87	-2.48	-0.92	6.38	5.54	15.27*	0.63	62.47	59.91	4.28*	1.49	17.60	15.10	16.56*	6.76
CGN-20515×JLG	54.10	55.21	-2.00	-0.40	6.68	6.34	5.45	0.16	61.03	62.02	-1.59	-0.26	18.23	19.45	-6.27	-0.26
CGN-20515×Poinsette	51.87	52.67	-1.51	-3.24	5.70	4.3	32.56*	14.00	60.01	58.88	1.93	1.63	16.70	15.23	9.65*	2.94
CGN-21585×K-75	53.57	53.76	-0.35	-0.12	7.22	5.64	28.13*	1.28	62.90	59.90	5.01*	1.73	18.87	15.42	22.37*	69.00
CGN-21585×JLG	59.10	55.10	7.26*	1.38	8.68	6.44	34.89*	1.10	64.81	62.01	4.52*	0.73	18.37	19.77	-7.08*	-0.32
CGN-21585×Poinsette	52.55	52.56	-0.02	-0.03	3.72	4.4	-15.45*	0.00	57.63	58.87	-2.11*	-1.77	16.67	15.55	7.20	6.22
LC-1-1×K-75	50.66	53.88	-5.98*	-2.25	3.15	5.94	-46.93*	-2.98	58.67	61.37	-4.39*	-10.17	22.10	16.62	32.97*	4.77
LC-1-1×JLG	53.20	55.22	-3.66*	-0.73	7.98	6.74	18.49*	0.72	62.25	63.48	-1.93*	-0.52	19.73	20.97	-5.91	-0.39
LC-1-1×Poinsette	53.03	52.68	0.66	1.52	5.38	4.7	14.47*	2.27	60.88	60.34	0.90	0.71	20.17	16.75	20.42*	3.35
LC-2-2×K-75	51.37	54.09	-5.02*	-2.22	5.02	6.42	-21.81*	-3.11	61.31	61.48	-0.27	-1.06	18.53	15.59	18.90*	25.61
LC-2-2×JLG	58.17	55.43	4.95*	1.07	10.08	7.22	39.61*	2.29	65.28	63.59	2.67*	0.75	19.73	19.94	-1.03	-0.05
LC-2-2×Poinsette	49.07	52.89	-7.21*	-152.6	3.17	5.19	-38.86*	-2.57	56.87	60.45	-5.91	-4.09	19.30	15.72	22.81*	239.0
LC-12-4× K-75	54.83	55.95	-2.00	-1.75	8.10	7.92	2.27	0.17	64.74	63.88	1.35	0.38	17.73	15.79	12.32*	6.17
LC-12-4×JLG	61.50	57.29	7.35*	6.01	10.28	8.72	17.89*	6.24	67.47	65.99	2.24*	10.57	19.27	20.14	-4.30	-0.21
LC-12-4× Poinsette	52.73	54.75	-3.69*	-1.10	4.83	6.69	-27.75*	-0.81	59.65	62.85	-5.09*	-0.98	18.87	15.92	18.57*	15.97
Range	51.37 to 61.50		-7.21 to 7.35	-152.6 to 6.01	3.15 to 10.28		-46.93 to 45.02	-3.11 to 14.00	56.87 to 67.47		-5.91 to 8.41	-10.17 to 10.57	15.07 to 22.10		-7.08 to 32.97	-0.39 to 239
SE(m)±	0.71				0.22				0.60				0.69			
$CD_{(0.05)}$	1.43				0.44				1.19				1.37			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

Table 4:. Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for yield and its contributing traits in cucumber

Traits(s) / Crosses	Fruit Breadth				Average Fruit Weight				Number of Marketable Fruits per Plant				Harvest Duration			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	4.97	4.90	1.43	1.00	235.62	205.55	14.63*	1.76	5.73	6.92	-17.14*	-2.86	20.73	24.55	-15.54*	-5.74
CGN-20256×JLG	3.53	4.32	-18.19*	-1.52	200.03	250.44	-20.13*	-0.81	6.43	6.38	0.78	0.05	22.27	23.05	-3.38	-0.36
CGN-20256×Poinsette	4.73	5.02	-5.68*	-1.54	228.18	212.86	7.20	0.63	8.17	7.58	7.78*	2.36	27.55	25.91	6.33	2.34
CGN-20515×K-75	4.77	5.29	-9.74*	-1.63	243.33	230.79	5.43	1.54	8.10	7.25	11.72*	1.13	27.31	24.98	9.33*	2.12
CGN-20515×JLG	6.03	4.70	28.30*	1.48	319.03	275.68	15.72*	1.18	7.83	6.72	16.60*	0.87	26.28	23.49	11.90*	1.08
CGN-20515×Poinsette	5.73	5.40	6.11*	1.65	277.65	238.1	16.61*	47.65	8.83	7.92	11.56*	10.76	29.03	26.35	10.19*	10.13
CGN-21585×K-75	4.50	4.70	-4.26	-0.74	271.75	223.65	21.51*	48.10	7.13	6.79	5.08	1.21	24.94	24.18	3.16	2.59
CGN-21585×JLG	4.27	4.12	3.77	0.49	235.18	268.54	-12.42*	-0.76	5.67	6.25	-9.28*	-0.71	20.55	22.68	-9.39	-1.19
CGN-21585×Poinsette	5.00	4.82	3.84	0.48	258.57	230.96	11.95*	4.38	10.70	7.45	43.62*	8.55	34.59	25.54	35.43*	8.46
LC-1-1×K-75	5.70	4.94	15.50*	21.86	365.20	237.35	53.87*	8.70	11.37	7.27	56.50*	5.37	36.46	26.03	40.10*	4.86
LC-1-1×JLG	4.00	4.35	-8.05*	-0.64	260.36	282.24	-7.75*	-0.72	6.40	6.73	-4.90	-0.25	22.55	24.53	-8.07	-0.54
LC-1-1×Poinsette	5.23	5.05	3.56	1.20	315.79	244.66	29.07*	9.63	9.40	7.93	18.54*	14.70	30.74	27.39	12.23*	4.29
LC-2-2×K-75	5.60	5.04	11.22*	8.69	311.21	227.04	37.08*	19.20	9.33	6.97	33.96*	5.09	30.48	25.19	21.02*	4.06
LC-2-2×JLG	4.13	4.45	-7.19*	-0.49	261.16	271.93	-3.96	-0.27	4.50	6.43	-30.02*	-1.93	17.23	23.69	-27.27*	-2.31
LC-2-2×Poinsette	5.10	5.15	-0.97	-1.00	315.07	234.35	34.45*	27.60	11.30	7.63	48.10*	18.35	36.27	26.55	36.61*	162.0
LC-12-4× K-75	5.27	4.84	9.00*	3.22	270.72	232.47	16.46*	3.90	6.30	5.05	24.75*	0.86	22.32	19.82	12.61*	0.62
LC-12-4×JLG	3.93	4.25	-7.53*	-0.71	242.57	277.36	-12.54*	-0.99	4.03	4.52	-10.74	-0.53	15.93	18.33	-13.07*	-0.93
LC-12-4× Poinsette	5.47	4.95	10.51*	2.08	302.45	239.78	26.14*	25.02	9.63	5.72	68.50*	1.85	31.28	21.19	47.65*	1.86
Range	3.53 to 6.03		-18.19 to 28.30	-1.63 to 21.86	200.03 to 365.20		-20.14 to 53.87	-0.99 to 48.10	4.03 to 11.37		-30.02 to 68.50	-2.86 to 18.35	15.93 to 36.46		-27.27 to 47.65	-5.74 to 162
SE(m)±	0.13				10.66				0.27				1.09			
$CD_{(0.05)}$	0.27				21.35				0.54				2.17			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

was recorded in five each cross combination for DTFFFA, NNBFFF and DTMM traits respectively. The negative heterosis for these traits also revealed that that the hybrids are early maturing types than their parents. Earlier researchers, namely Kumbhar et al. (2005); Yadav et al. (2008); Kumar et al. (2010); Kushwaha et al. (2011) and Kumar et al. (2017) had also reported the importance of heterosis for earliness using monoecious cultivars of cucumber. For fruit parameters like FL, FB and AFW range of mid parent heterosis was -7.08 to 32.97, -18.19 to 28.30 and -20.13 to 53.87 respectively. Out of eighteen hybrids, significantly higher positive (desirable) heterosis was observed in 10 hybrids for FL, 6 for FB and 11 hybrids for AFW. While significantly highest positive (desirable) heterosis was observed in LC-1-1 × K-75 (32.97) hybrids for FL and same cross for AFW with value (53.87), CGN-20515 × JLG (28.30) for FB. The present findings are in conformity with Sudhakar et al. (2005), Kumar et al. (2010) and Singh et al. (2012) and Kumar et al. (2017). But, these results are in discrepancy with the earlier findings, that is, Kartalov (1966) reported that hybrids of cucumber were intermediate in fruit length; while Singh et al. (1970) observed that all the F_1 hybrids produced smaller fruits as compared to their respective mean of parents. The deviation could be on account of the variation in genotypes used in hybrid combinations and also in environments under which these were evaluated. The magnitude of heterosis over mid parent was highly significant in both the directions for above traits which are the indication of varied degree of dominance involved in the inheritance of above traits. Heterosis over mid parent in F_1 ranged -30.02 (LC-2-2 × Japanese Long Green) to 68.50 (LC-12-4 × Poinsette) for NOMFPP and -27.27 (LC-2-2 × Poinsette) to 47.65 (LC-12-4 × Poinsette) for harvest duration per cent respectively over mid parent. Significant desirable positive heterosis over mid parent was recorded in eleven and ten cross combinations for NMFPP and HD respectively. For yield per hectare heterosis over mid parent ranged from -31.18 to 138.70 percent. The highest estimate of hetersois over average or mid parent was shown by LC-1-1 × K-75 and 12 crosses showed significant estimates of heterosis over mid parent for YPH. However, significant heterosis for fruit yield in cucumber had also been reported earlier by Dogra and Kanwar (2011), Kushwaha et al. (2011), Singh et al. (2012), Airina et al. (2013) and Kumar et al. (2017).

Cucumber is vulnerable to the attack of a number of insect-pest and diseases of which fruit fly, powdery mildew and downy mildew are the most destructive during rainy season in Himachal Pradesh. So keeping in view these points, mid parent heterosis for IFF, SPM and SDM varied between -43.75 to 31.97, -28.41 to 46.02 and -34.07 to 63.09 respectively. Out of 18 crosses 9 crosses for IFF, 2 crosses for SPM and 6 crosses for DM showed significant negative mid parent heterosis. The cross LC-1-1 × K-75 showed significant highest positive (desirable) heterosis over mid parent for TSS and ranged from -5.81 to 14.29. Out of eighteen hybrids, significantly higher positive (desirable) heterosis was observed in 4 hybrids for TSS. Seed viability and vigor helps in emergence and development of normal seedlings in wide environmental conditions. Therefore, use of quality seed material is essential for ensuring higher productivity in any crop. The range for seed germination was -3.36 to 13.01, for SVI-I it was -13.24 to 28.25 and -8.29 to 90.18 for SVI-II. Out of 18 crosses 6 crosses for SG, 3 crosses for SVI-I and 12 crosses for SVI-II exhibited significant positive mid parent heterosis. Hence, these hybrids can be exploited for the genetic improvement of seed vigour and yield traits in cucumber. These similar results were found by Kumar et al. 2018 depicted significantly positive values for all the estimates of heterosis. Hence, these hybrids can be exploited for the genetic improvement of cucumber.

Potence Ratio: The potence ratio exhibited in 18 F_1 crosses are presented in table 2-6. In F_1 hybrids for days to first female flower appearance the potence ratio ranged from -152.6 (LC-2-2 × Poinsette) to 6.01 (LC-12-4 × JLG) with twelve crosses indicating over dominance (>±1) and six combination exhibiting partial dominance, for node number bearing first female flower the potence ratios ranged from -3.11 (LC-2-2 × K-75) to 14.00 (CGN-20515 × Poinsette), with eleven crosses indicated over dominance (>±1) and six indicated partial dominance (-1 to +1) where as in one cross there was absence of dominance (0) in F_1 generation and for days to marketable maturity, in F_1 the potence ratios ranged from -10.17 (LC-1-1 × K-75) to 10.57 (LC-12-4 × JLG) with ten crosses indicated over dominance (>±1) and eight indicated partial dominance (-1 to +1) in the inheritance of days to marketable maturity. These results were similar to the results of El-Tahawey *et al*. (2015) who reported negative estimates of potence ratio for number of nodes to the first female flower and number of days to the first female flower in number of crosses of pumpkin. Kumar et al. (2017) illustrated that all the hybrid combinations have positive nature for all the traits related to earliness. These results reflected over dominance in nine crosses towards lower number of days to first female flower appearance, node number bearing first female flower and days to marketable maturity. On the other hand, absence of dominance was found only in one cross combination, for all the traits related to earliness.

Table 5: Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for yield and insect pest and diseases traits in cucumber

Trait(s) / Cross(s)	Yield per Hectare (q)				Incidence of Fruit Fly (%)				Severity of Powdery Mildew (%)				Severity of Downy mildew (%)			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	144.13	150.90	-4.49	-1.70	25.13	23.80	5.59*	0.53	25.07	17.89	40.17*	3.14	17.27	24.37	-29.12*	-0.64
CGN-20256×JLG	137.10	163.90	-16.35*	-1.58	30.79	27.99	10.02*	1.68	13.03	18.20	-28.41*	-2.62	24.60	27.43	-10.32*	-0.35
CGN-20256 × Poinsette	198.82	172.60	15.19*	1.02	16.72	24.38	-31.41*	-3.94	14.30	15.24	-6.14	-0.19	22.80	24.22	-5.84	-0.13
CGN-20515×K-75	210.14	179.31	17.20*	1.26	18.07	21.17	-14.64*	-28.18	13.73	14.02	-2.03	-0.18	18.20	15.90	14.47*	0.85
CGN-20515×JLG	266.59	192.31	38.63*	6.51	29.20	25.36	15.16*	0.90	17.13	14.33	19.54*	1.47	30.93	18.97	63.09*	32.78
CGN-20515 × Poinsette	261.64	201.01	30.17*	22.33	19.84	21.75	-8.76*	-2.78	9.47	11.37	-16.67	-1.78	16.17	15.75	2.67	0.15
CGN-21585×K-75	206.87	161.85	27.82*	6.47	23.05	22.86	0.83	0.12	25.13	17.21	46.02*	4.92	24.77	21.05	17.67*	0.47
CGN-21585×JLG	142.34	174.85	-18.59*	-5.38	33.71	27.05	24.64*	2.56	20.70	17.53	18.12*	2.45	15.90	24.12	-34.07*	-1.72
CGN-21585×Poinsette	295.21	183.55	60.83*	7.58	16.63	23.44	-29.04*	-6.77	16.57	14.56	13.80	0.47	22.50	20.90	7.66	0.20
LC-1-1×K-75	442.70	185.46	138.7*	8.41	10.87	19.33	-43.75*	-4.32	12.93	16.44	-21.33*	-4.20	15.07	19.74	-23.64*	-0.71
LC-1-1×JLG	177.69	198.46	-10.47	-1.18	29.91	23.51	27.22*	1.04	17.33	16.75	3.46	1.12	26.60	22.80	16.67*	1.10
LC-1-1×Poinsette	316.61	207.16	52.83*	12.34	15.44	19.90	-22.41*	-1.76	13.67	13.79	-0.83	-0.03	18.83	19.59	-3.85	-0.11
LC-2-2×K-75	309.68	169.15	83.09*	9.86	12.80	19.07	-32.88*	-2.84	15.52	15.04	3.23	0.86	17.20	15.02	14.55*	1.20
LC-2-2×JLG	125.35	182.15	-31.18*	-45.25	30.69	23.26	31.97	1.16	16.63	15.35	8.34	1.45	24.03	18.08	32.91*	4.76
LC-2-2×Poinsette	379.81	190.85	99.01*	25.38	16.96	19.65	-13.67*	-0.96	12.27	12.39	-0.93	-0.06	11.30	14.87	-23.98*	-1.81
LC-12-4× K-75	182.03	123.54	47.34*	1.87	18.68	23.38	-20.09*	-2.24	21.73	15.50	40.19*	62.30	17.97	17.37	3.48	0.15
LC-12-4×JLG	104.29	136.54	-23.62*	-0.73	31.29	27.56	13.53*	1.78	16.43	15.82	3.89	1.48	26.37	20.43	29.07*	5.40
LC-12-4× Poinsette	310.80	145.24	113.99*	3.12	22.65	23.95	-5.43	-0.86	12.58	12.85	-2.10	-0.11	14.30	17.22	-16.93*	-0.68
Range	104.29 to 442.7		-31.18 to 138.70	-45.25 to 25.38	10.87 to 33.71		-43.75 to 31.97	-28.18 to 2.56	9.47 to 25.13		-28.41 to 46.02	-4.20 to 62.30	11.30 to 30.93		-34.07 to 63.09	-1.81 to 32.78
SE(m)±	11.33				0.91				1.23				0.97			
$CD_{(0.05)}$	22.69				1.82				2.45				1.94			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

In F_1 for yield traits like fruit length the potence ratios ranged from -0.39 (LC-1-1 × JLG) to 239 (LC-2-2 ×Poinsette) with eleven crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1), for fruit breadth the potence ratios ranged from -1.63(CGN-20515 × K-75) to 21.86 (LC-1-1 × K-75) with ten crosses indicated over dominance (>±1), six indicated partial dominance (-1 to +1) and two crosses indicating complete dominance (1) and for average fruit weight it ranged from -0.99 (LC-12-4 × JLG) to 48.1 (CGN-21585 x K-75) with over dominance (>±1) was recorded by the twelve crosses and partial dominance (-1 to +1) with six crosses in F_1. For number of marketable fruits per plant, potence ratios ranged from -2.86 (CGN-20256 × K-75) to 18.35 (LC-2-2 × Poinsette) in F_1 with twelve crosses indicate over dominance (>±1), six crosses partial dominance (-1 to +1). For the trait harvest duration potence ratios in F_1 ranged from -5.74 (CGN-20256 × K-75) to 162 (LC-2-2 × Poinsette) with fourteen crosses indicate over dominance (>±1), four crosses partial dominance (-1 to +1). Yield per hectare recorded potence ratios ranged from -45.25 (LC-2-2 × JLG) to 25.38 (LC-2-2 × Poinsette) and with seventeen crosses indicating over dominance (>±1) and only one cross (LC-12-4 × JLG) with partial dominance in F_1. Similar results were also found by Kumar *et al*. (2017) revealed positive nature; which reflected over dominance towards longer fruit length, higher fruit breadth and average fruit weight. Abd-Rabou and Zaid (2013) reported over dominance for number of fruits per plant, harvest duration and marketable yield/plant in cucumber and reported that potence ratio of seven cucumber hybrids was higher than one, indicating over dominance of this trait towards the heavy parent. On the contrary, two hybrids showed over dominance and one revealed partial dominance towards the lighter parent. In pumpkin, El-Tahawey et al. (2015) had reported positive estimates of potence ratio in most of the hybrids for average fruit weight.

For incidence of fruit fly, potence ratios ranged from -28.18 (CGN-20515 × K-75) to 2.56 (CGN-21585 × JLG) with thirteen crosses indicating over dominance (>±1), five crosses partial dominance (-1 to +1) , and for severity of powdery mildew in F_1 the potence ratios

Table 6:. Mean performance, mid parent value, heterosis percentage (relative to mid parent value) and potence ratio of 9 parents and their 18 F_1 hybrids for quality and seed traits in cucumber

Traits / Crosses	TSS (%)				Seed germination (%)				Seed Vigour Index -I				Seed vigour Index-II			
	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR	Mean	MP	MPH (%)	PR
CGN-20256 ×K-75	3.13	3.24	-3.25	-0.78	72.00	74.50	-3.36*	-2.14	2261.80	2259.81	0.09	0.01	1128.77	828.27	36.28*	2.07
CGN-20256×JLG	3.47	3.30	5.15*	2.43	77.67	77.34	0.43	0.20	2291.20	2240.85	2.25	0.32	960.50	760.97	26.22*	2.56
CGN-20256×Poinsette	3.08	3.27	-5.81*	-1.90	76.33	78.00	-2.14	-0.72	1947.37	2244.55	-13.24*	-1.86	1203.63	816.53	47.41*	2.90
CGN-20515×K-75	3.10	3.00	3.33	1.00	81.33	77.67	4.72*	0.85	2691.80	2427.62	10.88*	35.75	1358.27	891.32	52.39*	5.69
CGN-20515×JLG	3.03	3.07	-1.14	-0.21	75.00	80.50	-6.83*	-3.67	2432.30	2408.67	0.98	2.04	959.70	824.02	16.47	9.16
CGN-20515×Poinsette	2.88	3.04	-5.11	-1.15	83.33	81.17	2.67*	2.59	2381.17	2412.37	-1.29	-3.97	1249.50	879.59	42.06*	5.26
CGN-21585×K-75	3.45	3.57	-3.23	-0.25	73.67	75.50	-2.42*	-0.84	2203.90	2302.84	-4.30	-0.75	949.50	818.32	16.03	0.85
CGN-21585×JLG	4.07	3.63	12.12*	1.10	78.00	78.34	-0.43	-0.50	2090.20	2283.89	-8.48*	-1.71	688.73	751.02	-8.29	-0.71
CGN-21585 × Poinsette	3.53	3.60	-1.94	-0.16	77.00	79.00	-2.53*	-1.50	2194.80	2287.59	-4.06	-0.79	849.97	806.59	5.38	0.30
LC-1-1×K-75	3.60	3.15	14.29*	9.00	84.00	74.33	13.01*	9.67	3216.90	2508.36	28.25*	9.66	1996.00	1049.53	90.18*	12.44
LC-1-1×JLG	3.12	3.22	-2.95	-6.33	76.33	77.17	-1.08	-0.46	2371.87	2489.40	-4.72	-1.27	1099.80	982.23	11.97	0.82
LC-1-1×Poinsette	3.50	3.19	9.89*	21.00	80.67	77.83	3.65*	1.14	2460.13	2493.10	-1.32	-0.37	1264.20	1037.80	21.82*	2.58
LC-2-2×K-75	2.98	3.10	-3.87	0.00	78.00	75.50	3.31*	1.15	2604.73	2611.39	-0.26	-0.04	1359.20	1088.46	24.87*	2.35
LC-2-2×JLG	3.30	3.17	4.27	2.08	76.67	78.34	-2.13	-2.50	2450.40	2592.44	-5.48	-0.73	1195.50	1021.16	17.07*	0.96
LC-2-2×Poinsette	3.02	3.14	-3.67	-3.29	80.33	79.00	1.68	1.00	2996.27	2596.14	15.41*	2.09	1804.60	1076.72	67.60*	5.74
LC-12-4× K-75	2.97	3.02	-1.49	-0.53	68.00	70.00	-2.86*	-0.60	2077.17	2302.97	-9.80*	-1.71	930.50	919.56	1.19	0.20
LC-12-4×JLG	3.22	3.08	4.55	0.93	73.33	72.84	0.68	0.08	2248.90	2284.02	-1.54	-0.31	1019.37	852.26	19.61*	12.46
LC-12-4× Poinsette	3.03	3.05	-0.66	-0.17	76.00	73.50	3.40*	0.37	2340.43	2287.72	2.30	0.45	1216.03	907.82	33.95*	7.31
Range	2.88 to 4.07		-5.81 to 14.29	-6.33 to 21.00	68.00 to 84.00		-6.83 to 13.01	-3.67 to 9.67	1947.37 to 3216.90		-13.24 to 28.25	-3.97 to 35.75	688.73 to 1996.0		-8.29 to 90.18	-0.71 to 12.46
SE(m)±	0.08				0.90				82.45				73.78			
$CD_{(0.05)}$	0.15				1.79				165.07				147.71			

JLG = Japanese Long Green; MP= Mid Parent; MPH= Mid Parent Heterosis; PR= Potence Ratio, *Significant at 5% level of significance

ranged from -4.20 (LC-1-1 × K-75) to 62.30 (LC-12-4 × K-75) with eleven crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1). And for severity of downy mildew the potence ratios ranged from -1.81 (LC-2-2 × Poinsette) to 32.78 (CGN-20515 × JLG), with seven crosses indicated over dominance (>±1), eleven indicated partial dominance (-1 to +1).

The quality traits estimated for the potence ratios to know their inheritance pattern. In F_1 for the total soluble solid the potence ratios ranged from -6.33 (LC-1-1 × JLG) to 21.00 (LC-1-1 × Poinsette) with nine crosses indicated over dominance (>±1), seven indicated partial dominance (-1 to +1) and one each of hybrid shown complete dominance (=1) and absence of dominance (=0) in the inheritance of fruit TSS. For seed germination the potence ratios ranged from -3.67 (CGN-20515 × JLG) to 9.67 (LC-1-1 × K-75) with eight crosses indicate over dominance (>±1), nine crosses partial dominance (-1 to +1) and one cross combination with complete dominance (=1), for seed vigour index I potence ratios for this trait ranged from -3.97 (CGN-20515 × Poinsette) to 35.75 (CGN-20515 × K-75) in F_1 and with nine each of crosses indicate over dominance (>±1) and partial dominance (-1 to +1). For seed vigour index II it ranged from -0.71 (CGN-21585 × JLG) to 12.46 (LC-12-4 × JLG) and twelve crosses indicate over dominance (>±1), six crosses partial dominance (-1 to +1). No information is available in the literature pertaining to potence ratio estimation for seed vigour traits; however, Kumar et al. (2017) had also reported partial dominance in all top five heterotic hybrids for different seed vigour traits, in cucumber.

Conclusion

The present study illustrated that heterosis breeding is the best possible breeding strategy for improving yield and its contributing traits in cucumber, all of which are governed by non additive gene effects. In the present investigation broader range of mid parent heterosis and potence ratio in both positive and negative direction were observed. We also found that partial to over-dominance effects are involved in the inheritance of fruit yield and other economically important traits. Three parental lines (CGN-20515, CGN-20256, LC-1-1 and K-75) were found to be most promising because they produced the maximum frequency of high-yielding hybrids with desirable traits and appreciable disease tolerance when

crossed either among them or with other parents. We were also able to identify some promising hybrids for particular traits based on their *per se* performance, the level of heterobeltiosis manifested in them, their quality and disease reaction. Two hybrids (LC-1-1 × K-75, LC-2-2 × Poinsette) could compete with the existing commercial hybrids that are available in the tropics, and so may be recommended for commercial.

सारांश

वर्तमान अध्ययन खीरे में 9 पित्रों (6 लाइन एवं 3 टेस्टर्स) को समाहित का वंशक्रम x परीक्षण (लाइन ग टेस्टर) अभिकल्प से फल उपज एवं उपज में सहायक घटकों के ओज वंशागतित्व के प्रभावी प्रभाव को ज्ञात करने के लिये आंकलन किया गया। वंशक्रम ग परीक्षण (लाइन ग टेस्टर) के एनोवा से स्पष्ट हुआ कि अध्ययन सामग्री में गुणों की विविधता ज्यादा है। विभिन्न प्रभेदों में मध्य पितृ ओज सकारात्मक व नकारात्मक दोनों दिशा में पाया गया। अधिकतम औसत ओज कुछ गुणों उपज/हे. के लिए पाया गया तथा इसके बाद बीज ओज सूचकांक–II, प्रति पौध बाजार (योग्य फलों की संख्या, मृदुरोमिल आसिता की उग्रता, औसत फल भार, तुड़ाई अवधि, चूर्णिल आसिता की उग्रता, प्रथम मादा पुष्प विकसित होने वाले पार्श्व गाँठ, फल की लम्बाई, फल मक्खी का प्रकोप, फल की चौड़ाई, बीज ओज सूचकांक–I, कुल विलेय ठोस, बीज जमाव, बाजार योग्य पकाव के दिन तथा प्रथम मादा पुष्प विकास का समय के लिये पाया गया। आंशिक से अति प्रभाविता वंशागतित्व के लिये जिम्मेदार घटक है। सकारात्मक या नकारात्मक संकर आंकलन में क्षमता अनुपात >1 मूल्य यह संकेत देता है कि अति प्रभाविता वांछित दिशा में हैं तथा खीरा में संकर प्रजनन कर ओज को प्राप्त किया जा सकता है। कुल प्रायोगिक 18 संकरणों में 5 संकरण एल सी–1–1 x के–75, एल सी–1–1 x प्वाइनसेट, एल सी–2–2 x के–75, एल सी–2–2 x प्वाइनसेट तथा सी जीएन– 20515 x प्वाइनसेट औसत क्षमता माध्य के अनुसार उत्तम पाये गये और इनमें ओजोस्विता परिणाम ज्यादा था। इन संकर संयोजों को संकर/प्रजाति विकास में व व्यवसायिक रूप से अधिक उपज, गुणवत्ता (कुल विलेय ठोस), कीट व रोग प्रतिरोधिता एवं बीज गुण के लिये अपनाया जा सकता है।

References

Abd-Rabou AM and Zaid NA (2013) Development of high quality cucumber inbred lines and their hybrids for resistance to powdery mildew disease. Egypt J Plant Breeding 17: 15-33.

Abdul-Baki AA and Anderson JD (1973) Vigour germinated in soyabean seed by multiple criteria. *Crop Science* 13: 630-633.

Airina CK, Pradeepkumar T, George TE, Sadhankumar PG and Krishnan S (2013)Heterosis breeding exploiting gynoecy in cucumber (*Cucumis sativus* L.). J Trop Agric 51(1-2): 144-148.

Anonymous (1985) International rules for seed testing. *Seed Science and Technology* 13: 293-353.

Anonymous (2014) *Package of Practices for Vegetable Crops*. Directorate of Extension Education. Dr Yaswant Singh Parmar University of Horticulture and Forestry Nauni, Solan HP.178p.

Allard RW (1960) *Principles of Plant Breeding*. John Wiley and Sons, New York. 485p.

AOAC (1970) *Official Methods of Analysis of the Association of Official Analytical Chemists*. Benjamin Franklin Station, Washington, DC.

Bairagi SK, Ram HH, Singh DK and Maurya SK (2005) Exploitation of hybrid vigour for yield and attributing traits in cucumber. Indian J Hort 62(1): 41-45.

Dogra BS and Kanwar MS (2011) Exploitation of combining ability in cucumber (*Cucumis sativus* L.). Res J Agric Sci 2(1): 55-59.

El-Tahawey MAFA, Kandeel AM, Youssef SMS, Abd El-Salam MMM (2015) Heterosis, potence ratio, combining ability and correlation of some economic traits in diallel crosses of pumpkins. Egypt J of Plant Breeding 19: 419-439.

Golabadi M, Golkar P, Eghtedary AR (2012) Assessment of genetic variation in cucumber (*Cucumis sativus* L.) genotypes. Europian J Exp Biol 2: 826-831.

Hamid A, Baloch J U and Khan N (2002) Performance of six cucumber (*Cucumis sativus* L.) genotypes in Swat-Pakistan. Int J Agric and Biol 4(4): 491-492.

Hanchinamani CN, Patil MG, Dharmatti PR and Mokashi AN (2008) Studies on variability in cucumber (*Cucumis sativus* L.). Crop Res 36(1&3): 273-276.

Hossain MF, Rabbani MG, Hakim MA, Amanullah ASM, Ahsanullah ASM. 2010. Studies on variability, character association and yield performance of cucumber (*C sativus* L.). Bangla Res Pub J 43: 297-311.

Kartalov P (1966) A study of heterosis of cucumber cultured under frames. Plovdiv. 15: 107-115.

Kempthorne O (1957) An Introduction to Genetic Statistics. John Wiley and Sons, NY, London,. pp. 458-471.

Kumar A, Kumar S, Pal AK (2008) Genetic variability and characters association for fruit yield and yield traits in cucumber. Indian J Hort 65: 423-428.

Kumar J, Munshi AD, Kumar R, Sureja AK (2010) Studies on heterosis in slicing cucumber. Indian J Hort 67: 97-201.

Kumar S, Kumar D, Kumar R, Thakur KS and Dogra BS (2013) Estimation of genetic variability and divergence for fruit yield and quality traits in cucumber (*Cucumis sativus* L.) in North-Western Himalayas. Uni J Plant Sci 1: 27-36.

Kumar S, Kumar R, Kumar D, Gautam N, Dogra RK, Mehta DK, Sharma HD and Kansal S (2016) Parthenocarpic gynoecious parental lines of cucumber introduced from Netherlands for developing high-yielding, quality hybrids. J Crop Improv 30: 352-369.

Kumar S, Kumar R, Kumar D, Gautam N, Singh N, Parkash C, Dhiman MR and Shukla YR. 2017. Heterotic potential, potence ratio, combining ability and genetic control of yield and its contributing traits in cucumber (*Cucumis sativus* L.). New Zealand J Crop Hort Sci 45(3): 175-190.

Kumar Sandeep, Kumar Ramesh and Dogra Rajesh Kumar (2018) Heterotic potential, potence ratio, combining ability and genetic control of seed vigour traits for yield improvement in cucumber (*Cucumis sativus* L.). Indian J Agric Sci 88(5): 771-778.

Kumari Reena, Kumar Ramesh and Kumar Sandeep (2017) Combining ability and heterosis for TSS and seed traits in cucumber (*Cucumis sativus* L.). Veg Sci 44(1): 12-17.

Kumari Reena, Kumar Ramesh and Kumar Sandeep (2017) Combining ability studies for yield and yield contributing traits in F_1 and F_2 generations of cucumber (*Cucumis sativus* L). Ind J Ecol 44 Special Issue (6): 852-855.

Kumbhar HC, Dumbre AD, Patil HE (2005) Heterosis and combining ability studies in cucumber (*Cucumis sativus* L.). J Maharashtra Agric Univ 30: 272-275.

Kushwaha M, Yadav LB, Maurya RP (2011) Heterobeltiosis and combining ability in cucumber (*Cucumis sativus* L.) under mid hilly area of Uttrakhand. Prog Agri 11: 103-107.

Mather K and Jinks JL (1971) Biometrical Genetics, 2nd ed. Chapman and Hall Ltd., London, UK.

Meyer RC, Torjek O, Becher M and Altmann T (2004) Heterosis of biomass production in Arabidopsis. Establishment during early development. Plant Physio 134: 1813-1823.

Munshi AD, Panda B, Behera TK, Kumar R, Bisht IS and Behera TK. 2007. Genetic variability in *Cucumis sativus* var. *hardwickii* R. germplasm. Cucurbit Genetics Cooperative 30: 5-10.

Nerson H (2007) Seed production and germinability of cucurbit crops. Seed Sci Biotech 1(1): 1-10.

Ranjan P, Gangopadhyay KK, Bag MK, Roy A, Srivastava R, Bhardwaj R, Dutta M (2015) Evaluation of cucumber (*Cucumis sativus* L.) germplasm for agronomic traits and disease resistance and estimation of genetic variability. Indian J Agric Sci 85: 234-239.

Ransom LM, Briens RGO and Glass RJ (1991) Chemical control of powdery mildew in green peas. Australian Plant Patho 20(1): 16-20.

Reuveni R (1983) Resistance of *Cucumis melo* L. to *Pseudoperonospora cubensis*. Ann Appl Biol 102: 533-537.

Sherpa P, Seth T, Shende VD, Pandiarana N, Mukherjee S, Chattopadhyay A (2014) Heterosis, dominance estimate and genetic control of yield and post harvest quality traits of tomato. J App Nat Sci 6: 625-632.

Singh JP, Gill HS, Ahluwalia KS (1970) Studies in hybrid vigour in cucumbers (*Cucumis sativus* L.). Indian J Hort 27: 36-38.

Singh R, Singh AK, Kumar S and Singh BK (2012) Heterosis and inbreeding depression for fruit characters in cucumber. Indian J Hort 69(2): 200-204.

Smith HH (1952) Fixing transgressive vigor in *Nicotiana rustica*. In: Gowen JW, editor. Heterosis. Ames (IA): Iowa State University Press; p. 161-174.

Sudhakar P, Singh B, Major S, Rai M (2005) Heterosis in cucumber (*Cucumis sativus* L.). Veg Sci 32: 143-145.

Yadav JR, Singh SP, Singh N, Singh PB (2008) Heterosis in cucumber (*Cucumis sativus* L.). Prog Res 3: 87-88.

Yadav YC, Kumar S, Brijpal B and Dixit SK (2009) Genetic variability, heritability and genetic advance for some traits in cucumber. Indian J Hort 66(4): 488-491.

Vegetable Science (2018) 45(2) : 220-225

Effect of date, method of sowing and seed rate on growth, yield and seed quality attributes in garden pea

Sumeet Kumar Singh, Sarita Kumari, BS Tomar*, YS Shivay, Monika A Joshi

Received: October 2018 / Accepted: November 2018

Abstract

The effect of date of sowing (15th October, 5th November and 25th November), method of sowing (Raised bed and flatbed) and seed rate (100, 112.5 and 125 kg/ha) was evaluated on growth, yield and seed quality attributes in garden pea *cv.* Pusa Pragati under field conditions. Date of sowing significantly affected the growth, yield and seed quality parameters. Sowing on 15th October (DOS 1) resulted in earliest emergence and days taken to initiate flowering whereas sowing on 25th November (DOS 3) needed longest duration for both these characters. Plant height and number of primary branches per plant was recorded highest for DOS 1 and the lowest for DOS 3. The yield traits (pods per plant, pod length, seeds per pod and seed yield per plant) and seed quality traits (seed index, germination, seedling length and dry weight, vigour indices) were recorded maximum for DOS 2 (sowing on 5th November) and minimum for DOS 1. Electrical conductivity results also showed that DOS 2 and DOS 3 had better seed quality than DOS 1. Method of sowing could not affect significantly on most of the plant growth parameters except plant height but seed yield/plant and seeds/pod were higher in raised bed method of sowing. Most of the quality parameters were quantitatively higher in raised bed but it was statistically *at par* with flatbed. Seed rate also could not affect the most of the growth, yield attributes and quality traits but seed yield per plant was increased on increasing the seed rate.

Key words: Garden pea, Date of sowing, Seed rate, Seed yield, Seed quality

Introduction

Garden pea (*Pisum sativum* var. *hortense* L.) is one of the most popular vegetable crops grown all over the world, both for fresh market and canning. It is highly nutritive and contains high proportion of digestible protein, carbohydrates, minerals and vitamins (Sharma 2010). It is grown commercially as a winter crop in the northern Indian plains, as an early crop in the mid hills and popular off-season vegetable crop grown in north-western Himalayan region in India (Sharma et al. 2014). India ranks second after China in terms of area and production; however, it occupies third position in the world in productivity, after UK and Egypt. Garden pea is grown in in an area of 4.2 lakh ha with annual productivity of 9.5 t/ha in India. Among the states, Uttar Pradesh contributes about 47 % of the total garden pea production and having highest productivity. Other major garden pea growing states are Madhya Pradesh, Jharkhand, Himachal Pradesh and Punjab. Despite having lot of potential to feed and nourish the increasing population, it has received very less attention compared to other legumes which may be one of the reasons for no improvement in its productivity. High quality seed is essential prerequisite to profitable crop production. Maximum yield can be achieved by adopting optimum plant population. One of the key factors in achieving this optimum population is the use of high quality seed. Field conditions are often sub-optimal and therefore vigour tests provide additional information on the relative performance of seed lots in the fields under wide range of environments. Therefore, optimum sowing date is of primary importance for harnessing potential yield as well as seed quality (Amanullah et al. 2002, Vange and Obi 2006). No systematic research has been done in garden pea to evaluate the effect of sowing dates on quality seed formation and seed yield of different varieties under Delhi conditions. One of the major concerns in seed production of garden pea is optimization of seed rates so that maximum seed yield with high quality can be produced. Garden pea is very sensitive to water logged conditions and the plants of this variety are semi dwarf in nature so proper method of planting may be adopted to avoid the contact of plants and pods to the soil for maximising the seed yield and quality. Keeping these facts in view, the present investigation on vegetable pea, variety Pusa Pragati, was conducted at ICAR-IARI, New Delhi during 2014-15

Division of Vegetable Science, ICAR-IARI, New Delhi
*Corresponding author, Email: bst_spu_iari@rediffmail.com

and 2015-16 to find out the effect of date of sowing, method of planting and seed rate on growth, yield and seed quality attributes.

Material and Methods

Plant Material and Experimental Conditions: The seeds of garden pea variety Pusa Pragati were obtained from the seed production unit of ICAR-IARI, New Delhi. Two field experiments were conducted at the research farm of ICAR-IARI, New Delhi during two successive winter seasons of 2014-15 and 2015-16. The experimental plot was sown in double split (split-split) design with three replications in which date of sowing was main plot, method of planting as sub plot and seed rate was taken as sub-sub plot. Planting was done in three different dates of sowing (15th October, 5th November and 25th November). Two methods of sowing were adopted *viz.* flat bed and raised bed. The plot size was 5 × 2 m^2 with eight rows per plot and row spacing of 25 cm. Paired row sowing was done on raised bed with 5 cm shallow channel space and 30 cm raised bed width having two rows. Three seed rates *viz.* 100, 112.5 and 125 kg/ ha were taken as sub-sub plot treatment. Basal recommended dose of N, K_2O and P_2O_5 in the ratio 20:40:50 kg/ha was applied to each plot.

Growth and yield attributes: Data was recorded on plant height, days to flowering, number of primary branches/plant, number of pods/plant, pod length, number of seeds/pod, seed yield/plant, seed index, seed germination percentage, seedling length, seedling dry weight, vigour index, and electrical conductivity from ten randomly selected plants from each replicate / treatment and their seeds.

Statistical Analysis: The average values were used for the statistical analysis. Statistical analysis was carried out using Statistical Analysis Software version 9.3 (SAS 9.3). Data were subjected to analysis of variance and means were compared. Valid conclusions were drawn only on significant differences between the treatment mean at 0.05 level of probability. The least significant difference test was used to decipher the effect of treatments at 5% level of significance (P=0.05).

Results and Discussion

Effect of date of sowing: Data on growth and yield attributes of garden pea (*cv* Pusa Pragati) under the effect of different dates of sowing are presented in Table 1. Results showed that date of sowing significantly affected the growth, yield and seed quality parameters. DOS 1 resulted in earliest emergence and days taken to initiate flowering whereas DOS 3 needed longest duration for both these characters. Plant height and number of primary branches per plant was recorded highest for DOS 1 and least for DOS 3. The yield traits (pods per plant, pod length, seeds per pod and seed yield per plant) and seed quality traits (seed index, germination, seedling length and dry weight, vigour indices) were recorded maximum for DOS 2 and minimum for DOS 1. Electrical conductivity results also showed that DOS 2 and DOS 3 had better seed quality than DOS 1.

The soil and air temperature during DOS 1 was quite higher which resulted in early emergence of the seedling (6.3 days). As the sowing was delayed, the days to emergence increased up to 11.2 days in DOS 3. Plant height decreased with delay in sowing from 53.7 cm in DOS 1 to 49.6 cm in DOS 3. The optimum temperature for vegetative growth in DOS 1 led to higher plant height, whereas the lower temperature during DOS 2 and DOS 3 decreased the plant height significantly. Primary branches per plant decreased with delay in sowing as the environmental condition during DOS 1 were congenial for vegetative development of plant. Maximum number of primary branches per plant was recorded in DOS 1 (3.8), whereas minimum was recorded in DOS 3 (2.87). The days to flowering increased from 39.9 days in DOS 1 to 45.1 days in DOS 3. The higher temperature during DOS 1 hastened the flowering by 4 to 5 days. Number of pods per plant was significantly affected by date of sowing. Highest number of pods per plant was recorded for in DOS 2 (10.90) which was significantly higher than DOS 1 (8.90). However, no significant difference was observed for pods per plant in DOS 2 and DOS 3. The highest pod length was observed in DOS 2 (8.60 cm) followed by DOS 3 (7.97 cm) and DOS 1 (7.30 cm). The DOS 2 plants gave highest number of seeds per pod (8.40) followed by DOS 3 (7.97) and DOS 1 (5.65). The DOS 2 recorded maximum seed yield per plant (20.50 g) followed by DOS 3 (17.65 g) and DOS 1 (9.90 g).

In our study the days to emergence was significantly affected by the date of sowing. The soil and air temperature during the first date of sowing (15th October) was quite higher which resulted in early emergence of the seedling. As the sowing was delayed, the days to emergence increased up to 11.2 days in third date of sowing (25th November) because of low soil temperature prevailing at that time. Days to flowering also increased because of delay in sowing from first to third date of sowing because of the temperature get lowered towards later date of sowing and hence last November sowing took 45 days for initiation of flowering. Because of congenial environment for growth during first date of sowing the plant height was also better but no significant difference in plant height was observed in second and

Table 1: Effect of date of sowing on growth and yield attributes of garden pea *cv.* Pusa Pragati

Time of sowing	Days to emergence			Days to flowering			Plant height (cm)			Primary branches per plant			Pods per plant			Pod length (cm)			Seeds per pod			Seed yield(g) per plant		
	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
DOS 1 (15 October)	6.20^{C}	6.40^{C}	6.30^{C}	39.70^{C}	40.20^{C}	39.90^{C}	53.10^{A}	54.30^{A}	53.70^{A}	3.88^{A}	3.78^{A}	3.80^{A}	8.80^{B}	9.01^{B}	8.90^{B}	7.40^{C}	7.30^{C}	7.30^{C}	5.66^{B}	5.70^{B}	5.65^{C}	9.50^{C}	10.30^{C}	9.90^{C}
DOS 2 (5 November)	8.90^{B}	8.90^{B}	8.90^{B}	42.40^{B}	42.40^{B}	42.40^{B}	50.95^{B}	52.20^{AB}	51.60^{AB}	3.10^{B}	3.10^{B}	3.10^{B}	11.01^{A}	10.80^{A}	10.90^{A}	8.70^{A}	8.60^{A}	8.60^{A}	8.46^{A}	8.40^{A}	8.40^{A}	20.50^{A}	20.50^{A}	20.50^{A}
DOS 3 (25 November)	11.17^{A}	11.20^{A}	11.20^{A}	45.20^{A}	45.10^{A}	45.10^{A}	49.40^{C}	49.80^{B}	49.60^{B}	2.80^{C}	2.90^{B}	2.87^{C}	10.47^{A}	10.50^{A}	10.50^{A}	7.99^{B}	7.95^{B}	7.97^{B}	7.98^{A}	7.97^{A}	7.97^{B}	17.70^{B}	17.65^{B}	17.65^{B}
LSD @5%	0.36	0.68	0.14	1.45	1.81	0.59	1.12	3.97	2.15	0.19	0.28	0.2	0.69	0.99	0.81	0.6	0.38	0.25	0.66	0.45	0.35	0.75	1.24	0.93

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

Table 2: Effect of date of sowing on seed quality attributes of garden pea *cv.* Pusa Pragati

Time of sowing	Seed index (g)			Germination (%)			Seedling length (cm)			Seedling dry weight (mg)			Vigour index I			Vigour index II			Electrical conductivity (µS/cm/g)		
	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
DOS 1 (15 October)	15.96^{B}	15.90^{B}	15.90^{B}	89.70^{B}	89.80^{B}	89.70^{C}	15.70^{B}	15.80^{B}	15.70^{B}	0.0143^{B}	0.0154^{B}	0.0148^{B}	1408^{C}	1414^{C}	1411^{C}	1.28^{B}	1.37^{B}	1.33^{B}	23.80^{A}	22.93^{A}	23.38^{A}
DOS 2 (5November)	21.78^{A}	21.80^{A}	21.80^{A}	97.90^{A}	97.10^{A}	97.50^{A}	21.90^{A}	21.80^{A}	21.80^{A}	0.0316^{A}	0.0306^{A}	0.0311^{A}	2148^{A}	2116^{A}	2132^{A}	3.09^{A}	2.97^{A}	3.03^{A}	16.86^{B}	17.53^{B}	17.22^{B}
DOS 3 (25 November)	21.09^{A}	21.10^{A}	21.10^{A}	96.20^{A}	95.30^{A}	95.80^{B}	20.70^{A}	20.70^{A}	20.70^{A}	0.0304^{A}	0.0298^{A}	0.0300^{A}	1996^{B}	1972^{B}	1984^{B}	2.91^{A}	2.83^{A}	2.87^{A}	18.26^{B}	18.73^{B}	18.50^{B}
LSD @5%	1.17	0.86	0.94	2.75	1.91	1.36	1.7	1.17	1.43	0.008	0.003	0.005	134.4	104.69	116.28	0.71	0.22	0.42	3.49	1.22	2.2

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

Table 3: Effect of method of sowing on growth and yield attributes of garden pea *cv.* Pusa Pragati

Method of sowing	**Days to emergence (day)**			**Days to flowering (day)**			**Plant height (cm)**			**Primary branches per plant**			**Pods per plant**			**Pod Length (cm)**			**Seeds per pod**			**Seed Yield per plant**		
	Y1	**Y2**	**pooled**	**Y1**	**Y2**	**pooled**	**Y1**	**Y2**	**pooled**	**Y1**	**Y2**	**pooled**	**Y1**	**Y2**	**pooled**	**Y1**	**Y2**	**Pooled**	**Y1**	**Y2**	**pooled**	**Y1**	**Y2**	**Pooled**
Raised bed	8.70A	8.90A	8.77A	42.60A	42.60A	42.60A	51.80^{A}	53.05^{A}	52.40^{A}	3.30^{A}	3.30^{A}	3.28^{A}	10.30^{A}	10.20^{A}	10.30^{A}	8.06^{A}	8.04^{A}	8.05^{A}	7.50^{A}	7.50^{A}	7.50^{A}	16.30^{A}	16.36^{A}	16.30^{A}
Flat bed	8.80A	8.80A	8.80A	42.30A	42.50A	42.40A	50.50^{B}	51.2^{A}	50.80^{B}	3.20^{A}	3.28^{A}	3.25^{A}	9.90^{A}	9.90^{A}	9.90^{A}	7.96^{A}	7.86^{A}	7.90^{A}	7.30^{B}	7.20^{B}	7.20^{B}	15.40^{B}	15.90^{A}	15.70^{B}
LSD @ 5%	0.62	0.43	0.35	1.48	0.99	0.78	1.14	2.04	1.16	0.44	0.16	0.21	0.92	0.52	0.5	0.46	0.34	0.34	0.18	0.21	0.15	0.3	0.98	0.55

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

Table 4: Effect of method of sowing on seed quality attributes of garden pea *cv.* Pusa Pragati

Method of sowing	Seed Index (g)			Germination (%)			Seedling length (cm)			Seedling dry weight (mg)			Vigour Index I			Vigour Index II			Electrical Conductivity (µ S/cm/g)		
	Y1	Y2	pooled	Y1	Y2	Pooled	Y1	Y2	pooled	Y1	Y2	pooled	Y1	Y2	pooled	Y1	Y2	pooled	Y1	Y2	pooled
Raised bed	19.50^{A}	19.68^{A}	19.50^{A}	94.80^{A}	94.10^{A}	94.50^{A}	19.50^{A}	19.45^{A}	19.50^{A}	0.0249^{A}	0.0253^{A}	0.0251^{A}	1863^{A}	1837^{A}	1850^{A}	2.39^{A}	2.40^{A}	2.39^{A}	19.5^{A}	19.95^{A}	19.51^{A}
Flat bed	19.70^{A}	19.54^{A}	19.70^{A}	94.40^{A}	94.04^{A}	94.20^{A}	19.40^{A}	19.40^{A}	19.40^{A}	0.0258^{A}	0.02518^{A}	0.0255^{A}	1838^{A}	1831^{A}	1835^{A}	2.47^{A}	2.39^{A}	2.43^{A}	19.82^{A}	19.52^{A}	18.89^{A}
LSD @ 5%	0.44	0.29	0.28	1.37	1.49	1.2	0.96	0.9	0.89	0.008	0.001	0.003	103.31	88.98	92.16	0.74	0.13	0.33	1.28	1.05	0.99

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

Table 5: Effect of seed rate on growth and yield attributes of garden pea *cv.* Pusa Pragati

Seed rate (Kg/ha)	Days to emergence (day)			Days to flowering (day)			Plant height (cm)			Primary branches per plant			Pods per plant			Pod length (cm)			Seeds per pod			Seed yield (g) per plant		
	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled
100	8.60^{A}	8.70^{A}	8.69^{A}	42.60^{A}	42.60^{A}	42.60^{A}	51.40^{A}	51.90^{A}	51.60^{A}	3.30^{A}	3.33^{A}	3.32^{A}	10.20^{A}	10.15^{A}	10.15^{A}	8.08^{A}	8.03^{A}	8.10^{A}	7.20^{A}	7.20^{A}	7.20^{A}	15.23^{B}	15.66^{B}	15.40^{B}
112.5	8.70^{A}	8.80^{A}	8.80^{A}	42.30^{A}	42.50^{A}	42.40^{A}	51.30^{A}	52.20^{A}	51.80^{A}	3.37^{A}	3.35^{A}	3.36^{A}	10.30^{A}	10.12^{A}	10.19^{A}	7.89^{A}	7.93^{A}	7.91^{A}	7.40^{A}	7.39^{A}	7.40^{A}	16.05^{A}	16.26^{AB}	16.10^{A}
125.0	8.80^{A}	8.90^{A}	8.89^{A}	42.27^{A}	42.60^{A}	42.40^{A}	50.80^{A}	52.20^{A}	51.50^{A}	3.12^{A}	3.15^{A}	3.13^{B}	9.90^{A}	10.05^{A}	9.98^{A}	8.04^{A}	7.90^{A}	7.97^{A}	7.50^{A}	7.44^{A}	7.47^{A}	16.35^{A}	16.52^{A}	16.40^{A}
LSD @ 5%	0.62	0.54	0.35	1.47	1.3	1.04	2.93	3.1	2.47	0.3	0.16	0.18	1.02	0.45	0.57	0.47	0.49	0.33	0.36	0.33	0.25	0.69	0.72	0.52

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

Table 6: Effect of seed rate on seed quality attributes of garden pea *cv.* Pusa Pragati

Seed rate (Kg/ha)	Seed index (g)			Germination (%)			Seedling length (cm)			Seedling dry weight (mg)			Vigour index I			Vigour index II			Electrical conductivity (µS/cm/g)		
	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled	Y 1	Y 2	Pooled
100	19.68^{A}	19.61^{A}	19.65^{A}	94.60^{A}	94.10^{A}	94.36^{A}	19.70^{A}	19.60^{A}	19.60^{A}	0.0239^{A}	0.0248^{A}	0.0243^{A}	1873^{A}	1853^{A}	1863^{A}	2.2818^{A}	2.349^{A}	2.3153^{A}	20.06^{A}	19.92^{A}	19.99^{A}
112.5	19.54^{A}	19.6^{A}	19.57^{A}	95.17^{A}	93.70^{A}	94.40^{A}	19.20^{A}	19.30^{A}	19.30^{A}	0.0267^{A}	0.0257^{A}	0.0262^{A}	1842^{A}	1815^{A}	1829^{A}	2.5662^{A}	2.434^{A}	2.5002^{A}	19.74^{A}	20.02^{A}	19.88^{A}
125.0	19.6^{A}	19.62^{A}	19.60^{A}	94.05^{A}	94.40^{A}	94.20^{A}	19.40^{A}	19.35^{A}	19.40^{A}	0.0256^{A}	0.0252^{A}	0.0254^{A}	1836^{A}	1835^{A}	1835^{A}	2.4463^{A}	2.404^{A}	2.425^{A}	19.18^{A}	19.27^{A}	19.22^{A}
LSD @ 5%	0.71	0.44	0.4	1.2	1.22	0.86	0.88	0.76	0.78	0.0054	0.0028	0.0032	82.3	82.02	77.55	0.52	0.24	0.29	1.64	1.12	0.88

Y1: 2014-15; Y2: 2015-16. Values with the same letters in each column are not significantly different (P<0.05)

third date of sowing. The primary branches come out when the vegetative stage temperature is good for branching and therefore the number of branches significantly decreased from first to last date of sowing. Therefore, the soil temperature during sowing, the temperature at vegetative stage strongly affects the growth characteristics of the plant. Yield attributing traits like number of pods per plant, pod length, number of seeds per pod and seed yield per plant was highest in DOS 2 followed by DOS 3. The growth characteristics were good in DOS 1 but the plants could not withstand the lower temperature at pod formation stage and the reproductive growth was highly affected by the lower prevailing temperature. The DOS 3 caused a reduction in the yield and yield attributes because of forced maturity caused by high temperature at the time of maturity which reduces the seed fill duration of the crop.

Data on seed quality attributes of garden pea (*cv* Pusa Pragati) under the effect of different dates of sowing are presented in Table 2. Seed index was found to increase with delay in date of sowing from 15.9 g in DOS 1 to 21.8 g in DOS 2 but further delay did not lead to any significant increase in seed index moreover it decreased insignificantly which may be attributed to forced maturity caused by increased temperature at maturity phase of plants sown on DOS 3. Germination percentage was significantly increased from DOS 1 (89.70 %) to DOS 2 (97.50 %) showing maximum germination followed by DOS 3 (95.80 %), where it decreases but it was more than first date of sowing. Seedling length increased with date of sowing from 15.7 cm in DOS 1 to 21.8 cm in DOS 2. It was recorded maximum in DOS 2 followed by DOS 3 (20.70 cm). Dry weight of seedlings obtained from germination test increased with date of sowing from 0.0148 mg in DOS 1 to 0.0311 mg in DOS 2 but no significant increment was found for DOS 3. Vigour index I was significantly affected by the date of sowing. Maximum vigour index I was observed in DOS 2 (2132) followed by DOS 3 (1984) and DOS 1 (1411). Vigour index II increased up to DOS 2 significantly with maximum vigour index II for DOS 2 (3.03) followed by DOS 3 (2.87) and DOS 1 (1.33). Electrical conductivity was found to decrease significantly with increase of date of sowing from DOS 1 (23.38µS/cm/g) to DOS 2 (17.22µS/cm/g), while no significant change was observed for DOS 3 in comparison to DOS 2.

DOS is an important factor in determining plant stand, flowering and pod filling in garden pea which in turn affects yield (Dapaah et al. 2000) by affecting the amount of radiation and temperature around crop canopy. The seed vigour in garden pea is greatly affected by the time of sowing which was also reported by Castillo et al. (1994). Sharma et al. (2014) also reported that garden pea variety "Arkel" and "Azad P1" gives a higher seed yield towards end of October to first quarter of November under sub humid temperate region. The finding of our study is in one line with the reports of Singh and Singh (2011) which indicates that early sowing dates result in poor seed yield and delayed sowing dates resulted in poor seed yield and quality in garden pea in many varieties

Effect of method of planting: Data on growth and yield attributes of garden pea (*cv* Pusa Pragati) under the effect of different methods of sowing are presented in Table 3. Results showed that method of sowing could not affect significantly most of the plant growth parameters except plant height, seed yield per plant and seeds per pod. However, the plant height was higher in case of raised bed method of sowing (52.40 cm) than flatbed (50.80 cm). Number of seeds per pod was found higher for raised bed method (7.50) than flatbed method (7.20). Similarly, seed yield per plant was higher for raised bed method of sowing (16.30 g) than flatbed method of sowing (15.70 g). Data on seed quality attributes of garden pea (*cv* Pusa Pragati) under the effect of different methods of sowing are presented in Table 4. Seed index, germination, seedling length and dry weight, Vigour indices and electrical conductivity were not significantly affected by method of sowing. However, most of the quality parameters were quantitatively higher in raised bed but it was statistically *at par* with flatbed. As garden pea is very sensitive to water logging and many times pea seeds are killed or damaged by soaking in water and the damage is aggravated by lower temperatures which are also confirmed by above results. Uzun and Esvet (2009) also reported that water logging caused a decrease in pea root mass, penetration depth, plant height, biomass and leaf chlorophyll. The results revealed that the plants sown on raised beds were higher than those sown in flatbed. Among the yield parameters only the number of seeds per pod and ultimately the seed yield per plant was significantly higher in plants grown on raised beds. However, other seed quality parameters were not affected significantly due to different methods of sowing.

Effect of Seed rate: Data on growth and yield attributes of garden pea (*cv* Pusa Pragati) under the effect of different seed rates are presented in Table 5 and the effect on seed quality attributes are shown in Table 6**.** In our study, seed yield per plant was found to increase from 15.40 g to 16.10 g with increase in seed rate from 100 to 112.5 kg/ha but no further increase in seed yield

per plant was observed for 125 kg/ha seed rate. This might be due to lodging of plants in lower seed rate plots reduced the yield therefore the yield increased initially on increasing the seed rate but further increase in seed rates bring the competition factor in role. Seed rate determines the density of the stand which by affecting the micro climate, weed incidence, pod distribution ultimately affects seed yield and quality (Azpilicueta et al. 2012). Lower seed rate resulted in higher number of green pods per plant and *vice versa* that might be attributed to the stronger competition among plants for various factors *viz.* sunlight, water and nutrients (Sharma and Singh, 2002).

It can be concluded that first week of November would be the ideal time of sowing of garden pea under Delhi conditions. Raised bed method of planting can be advised to the farmers in order to get seeds with better quality. The seed rate of 50 kg/acre will be good for seed crop which will yield higher with better seed quality under Delhi conditions making the seed production job profitable and also reducing the price of seed for the farmers.

lkjk'k

सब्जी मटर में वर्ष 2014–15 तथा 2015–16 के रबी मौसम के दौरान अध्ययन किया गया जिसमें बुवाई के समय (15 अक्टूबर, 5 नवम्बर तथा 25 नवम्बर) रोपण पद्धति (उथली क्यारी और समतल क्यारी) एवं बीज दर (100, 112.5 तथा 125 किलोग्राम प्रति हेक्टेयर) का प्रजाति पूसा प्रगति के पौधों की वृद्धि, बीज उपज एवं गुणवत्ता पर पड़ने वाले प्रभावों को देखा गया। अध्ययन में यह पाया गया कि बुवाई की तिथि का पौधों की वृद्धि, बीज उपज तथा गुणवत्ता पर प्रभाव पड़ता है। पहली बुवाई (15 अक्टूबर) के फलस्वरूप त्वरित अंकुर उद्भव तथा पुष्पण भी तीव्र पाया गया जबकि तीसरी बुवाई (25 नवम्बर) में इनकी शुरूआत देर से हुई। पौधों की ऊँचाई तथा प्रति पौध प्राथमिक शाखाओं की संख्या पहली बुवाई में सर्वाधिक जबकि तीसरी बुवाई में न्यूनतम दर्ज की गई। उपज निर्धारक गुण (प्रति पौध फलियाँ, फली की लम्बाई, प्रति फली बीज तथा बीज उपज प्रति पौध) तथा बीज गुणवत्ता निर्धारक लक्षण (बीज सूचकांक, अंकुरण प्रतिशत, नवोद्भिद की लम्बाई तथा शुष्क वजन, शक्ति सूचकांक) दूसरी बुवाई की अधिकतम जबकि पहली बुवाई में न्यूनतम दर्ज किया गया। विद्युत चालकता के नतीजों से यह पता चला कि पहली बुवाई की तुलना में दूसरी तथा तीसरी बुवाई में बीज गुणवत्ता बेहतर थी। उथली क्यारियों पर बुवाई से प्रति बीज उपज में सुधार हुआ। बीज की गुणवत्ता वाले मापदण्ड उथली क्यारियों में अधिक पाया गया। बीज दर भी पौध वृद्धि, उपज और बीज गुणवत्ता वाले मापदण्डों को प्रभावित नहीं कर सकी लेकिन बीज दर में वृद्धि करने पर प्रति पौध बीज उपज में बढ़ोत्तरी देखी गई जो प्रति इकाई क्षेत्र में उच्च गुणवत्ता वाले बीज की उत्पादन लागत को कम करने में सहायक सिद्ध हो सकता है। अतः वर्तमान अध्ययन से प्राप्त परिणामों के अनुसार नवम्बर के पहले सप्ताह में बुवाई बीज उत्पादन के लिए सर्वाधिक उपयुक्त पाया गया।

Reference

Amanullah JI, Hayat TF, Khan AI and Khan N (2002) Effect of sowing dates on yield and yield component of mashbean varieties. Asian J Plant Sci 6: 622-624.

Azpilicueta M, Irigoyen I, Lasa B, Muro J, Pedro M and Tejo A (2012) Yield and quality of sugar snap pea in the Ebro Valley: Sowing date and seed density. Scientia Agricola 69(5): 320-326.

Castillo AG, Hampton JG and Coolbear P (1994) Effect of sowing date and harvest timing on seed vigour in garden pea (*Pisum sativum* L.). New Zealand J Crop Hortic Sci 22(1): 91-95.

Dapaah HK, Mckenzie BA and Hill GD (2000) Influence of sowing date and irrigation on the growth and yield of pinto beans (*Phaseolus vulgaris*) in a sub-humid 270 M. Rajin Anwar, B. A. M C Kenzie and G. D. HILL temperate environment. J Agric Sci Cambridge 134: 33– 43.

Sharma A, Sharma M, Sharma KC, Singh Y, Sharma RP and Sharma GD (2014) Standardization of sowing date and cultivars for seed production of garden pea (*pisum sativum var. Hortense l.*) Under north western Himalayas. Leg Res 37(3): 287-293.

Sharma BB (2010) Combining ability and gene action studies for earliness in garden pea (*Pisum sativum* L.). MSc Thesis, GBPUAT, Pantnagar, Uttarakhand.

Sharma RK and Singh R (2002) Firbs-an efficient input usage production technology. Indian Farming 52(3): 25-26.

Singh R and Singh PM (2011) Effect of sowing dates and varieties on yield and quality of garden pea seed. Veg Sci 38(2): 184-187.

Uzun A and AcÝkgoz E (2009) The response of pea genotypes differing in testa color to waterlogging during early germination stages. J Food, Agri Environ 7 (2): 347-351.

Vange T and Obi IU (2006) Effect of planting date on some agronomic traits and grain yield of upland rice varieties at Makurdi, Benue state, Nigeria. J Sust Dev Agric Environ 2(1): 1-9.

Vegetable Science (2018) 45(2) : 226-231

DUS characterization and assessing the diversity of varieties in onion and garlic

Amar Jeet Gupta* and Vijay Mahajan

Received: October 2018 / Accepted: January 2019

Abstract

DUS test (Distinctness, Uniformity and Stability) are essential for registering new varieties under Protection of Plant Varieties and Farmers Rights Act 2001 (PPV&FRA) in our country and 150 crops/ species have been notified for registration including onion and garlic in India. The variety must be clearly distinguishable by one or more essential characters from any other variety, whose existence is a matter of common knowledge at the time when the protection is applied. The variety is deemed uniform if subjected to variation that may be expected from the particular features of its propagation. It should be sufficiently uniform in its relevant characters. DUS test guidelines for onion and garlic were notified by PPV&FRA in 2009 in India with 34 DUS test characters for onion varieties and 32 characters for garlic varieties. All the available short day varieties of onion and garlic are being maintained at DOGR, Rajgurunagar and IARI, New Delhi; long day varieties are maintained at CITH, Srinagar; and multiplier onion varieties are being maintained at TNAU, Coimbatore. Thirty-eight *rabi* onion varieties including land races are being maintained during *rabi* season whereas 10 onion varieties being maintained during *kharif* season. All the 17 garlic varieties including land races being maintained during *rabi* season. To register varieties it needs to be applied to PPV&FR Authority, New Delhi in prescribed format. Certain guidelines were given for registration of onion and garlic and rules for farmers are relaxed and they have equal rights for registration. The candidate variety was tested for DUS characters in two seasons at two locations; whereas farmers' variety was tested only in one season at two locations.

Key words: Variety, DUS Test, Protection, Registration, Farmers and Breeders Rights

Introduction

In order to provide the establishment of an effective system for the protection of plant varieties and to encourage the development of new varieties of plants it has been considered necessary to recognize and to protect the rights of the farmers' and plant breeders in respect of their contributions made at any time in conserving, improving and making available plant genetic resources for the development of new plant varieties. The Government of India enacted "The Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, 2001" adopting *sui generis* system. Indian legislation is not only in conformity with International Union for the Protection of New Varieties of Plants (UPOV) 1978, but also have sufficient provisions to protect the interests of public/ private sector breeding institutions and the farmers. The legislation recognizes the contributions of both commercial plant breeders and farmers in plant breeding activity and also provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions as well as resource-constrained farmers. To implement the provisions of the Act the Department of Agriculture and Cooperation, Ministry of Agriculture established the Protection of Plant Varieties and Farmers' Rights Authority on 11th November, 2005.

In India, about sixty onion and twenty garlic varieties have been released from different public organizations and their number is expected to increase in future. Onion and garlic varieties attain acceptance when the farmers get genetically pure seeds/ cloves of high standards as well as their yield and quality performance. For this purpose, each onion and garlic variety should be properly defined with suitable descriptors so as to maintain its identity during seed/ bulb production through field inspection and certification. Apart from this,

ICAR-Directorate of Onion and Garlic Research, Rajgurunagar-410 505, Pune, Maharashtra
Corresponding author, E-mail: guptaaj75@yahoo.co.in

characterization of onion and garlic varieties is also required for their protection under Plant Variety Protection (PVP) legislation, because varietal testing for Distinctiveness, Uniformity and Stability (DUS) is the basis for grant of protection of new plant varieties under the PPV&FR Act 2001. The Act has the provision to compare the novel candidate variety with the varieties of common knowledge on a set of relevant characteristics prescribed in the DUS Test Guidelines of onion and garlic (PPV&FR Authority, 2009) and commonly accepted for this purpose at the time of filling of application. The varieties have not so far been extensively described for various heritable morphological traits to enable the identification of these varieties. Thus, the present study was undertaken to characterize the onion and garlic varieties on the basis of morphological characters as prescribed in the DUS Test Guidelines.

Materials and Methods

Present investigation was carried out for successive 3 years during 2011-12, 2012-13 and 2013-14 to carry out characterization of released onion and garlic varieties at the Experimental Farm of ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune, India. The experimental material comprised 38 *rabi* varieties of onion *viz*., Agrifound Rose, Agrifound White, Agrifound Light Red, Arka Bindu, Arka Niketan, Arka Pitamber, Arka Pragati, Bhima Kiran, Bhima Raj, Bhima Red, Bhima Shakti, Bhima Shweta, Early Grano, GWO-1, Hissar-2, Hissar-3, Kalyanpur Red Round, N-2-4-1, NHRDF Red (L-28), NHRDF Red-2 (L-355), NHRDF Red-3 (L-625), Palam Lohit, PKV White, Phule Safed, Phule Samarth, Phule Suwarna, Phursungi Local, Pilipatti Junagadh, Punjab Naroya, Pusa Madhavi, Pusa Red, Pusa White Flat, Pusa White Round, Panchganga ES, Telagi Local, Udaipur-102, Sukhsagar and VL Piaz-3; 10 *kharif* varieties of onion *viz*., Agrifound Dark Red, Arka Kalyan, B-780, Bhima Raj, Bhima Red, Bhima Shubhra, Bhima Shweta, Bhima Super, Bhima Dark Red and N-53; and 17 garlic varieties *viz*., Bhima Omkar, Bhima Purple, G-1, G-41, G-50, G-282, G-323, G-386, GG-2, GG-3, GG-4, Godawari, Ooty Local, Phule Baswant, Rani Bennur Local, Sikkim Local and Silkuei Local were sown in a bed size of 3×2 m with row-to-row and plant-to-plant spacing of 15×10 cm in randomized block design with three replications. A total of 400 plants were accommodated in each plot. All the recommended package of practices was followed to raise a healthy crop. Observations were recorded from 10 randomly selected plants for each character described in the DUS test guidelines.

Table 1: Reference varieties of onion and garlic under maintenance

Name of the Varieties	Source of Varieties
Common Onion (*Allium cepa* L.)	
Pusa Red, Pusa White Round, Pusa White Flat , Pusa Madhavi, Early Grano* and Brown Spanish*	IARI, New Delhi
Arka Niketan, Arka Pitambar, Arka Pragati, Arka Bindu and Arka Kalyan	IIHR, Bangalore
Bhima Super, Bhima Red, Bhima Raj, Bhima Kiran, Bhima Shakti, Bhima Dark Red, Bhima Shweta and Bhima Shubhra	DOGR, Rajgurunagar
VL Piaz-3*	VPKAS, Almora
B-780, Phule Samarth, Phule Safed and Phule Suwarna	MPKV, Rahuri
ADR, ALR, AFW, AFR, NHRDF Red, NHRDF Red-2 and NHRDF Red-3	NHRDF, Nashik
Hissar-2 and Hissar-3	HAU, Hissar
N-2-4-1 and N-53	Agril. Dept., MS
Punjab Naroya	PAU, Ludhiana
PKV White	PDKV, Akola
Udaipur-102	RAU, Udaipur
GWO-1	GAU, Junagadh
Kalyanpur Red Round	CSAUA&T, Kanpur
Palam Lohit*	CSKHPAU, Palampur
Phursungi Local, Sukhsagar, Pilipatti Junagadh and Telagi Local	Farmers' Varieties
Multiplier Onion (*Allium cepa* var. *aggregatum*)	
CO-1**, CO-2**, CO-3**, CO-4** and CO-5**	TNAU, Coimbatore
Garlic (*Allium sativum* L.)	
Bhima Omkar and Bhima Purple	DOGR, Rajgurunagar
VL Garlic-1* and VL Garlic-2*	VPKAS, Almora
GG-2, GG-3 and GG-4	GAU, Junagadh
Godawari and Phule Baswant	MPKV, Rahuri
G-1, G-41, G-50, G-282, G-323, G-386 and Agrifound Parvati*	NHRDF, Karnal
Rani Bennur Local, Sikkim Local, Silkuei Local and Ooty Local	Farmers' Varieties

* Maintained at CITH, Srinagar, ** Maintained at TNAU, Coimbatore

Results and Discussion

ICAR-DOGR is maintaining 38 *rabi* and 10 *kharif* varieties of onion and 17 varieties of garlic (Table 1) which were taken for study. Twenty-five DUS characteristics of common onion and thirty-two characteristics of garlic were recorded in above mentioned varieties of onion and garlic in consecutive three years as per DUS guidelines. All DUS characters recorded in *kharif* onion varieties are given in Table 2 and garlic varieties in Table 3. Gupta et al. (2011) reported that thirty-eight onion varieties and seventeen garlic varieties were maintained as reference varieties under PPV&FRA project.

On the basis of experimental results of onion varieties using 25 DUS characteristics, distinctness of almost all varieties were expressed. Similar attempts for establishment of distinctness were made in soybean (Ravikumar and Narayanswamy 1999), oat (Kumar et al. 2002), rice (Joshi et al. 2007), jute (Kumar et al. 2008) and maize (Yadav and Singh 2010). All DUS descriptors did not show any variation in their states of expression over the three years and less number of off-types was observed. As per DUS test guidelines of onion, to fulfill the criteria of uniformity, the number of off-types should not exceed 4 in 400**,** *i.e.* 1% and if a variety exhibits its uniformity for two consecutive years, the variety is considered as stable. In our present study, the percentage of off-types recorded in each plot over the years was below 1% which is under permissible off-types and indicated the uniformity of the varieties. Expression of each characteristic was also found to be stable in three years for the respective varieties affirming their consistency and stability. Therefore, it may be inferred that all the onion and garlic varieties were uniform and stable. The morphological characteristics studied are stable due to a low genotype-environment interaction in the expression and are controlled by single or two genes with simple dominant or recessive inheritance. Apart from this, during the development of varieties, onion and garlic breeders have purposefully emphasized on the stability and uniformity of these morphological characteristics. Though some onion and garlic varieties were released long back, those are stable even now with regard to these morphological characteristics. The present result confirms the findings of Gupta and Mahajan (2013) and Ahmed et al. (2013). Breeders or farmers who want to register their varieties need to apply to competent authority in the Ministry for registration. Applicant will have to supply minimum 100 g good quality seed of onion/ 1200 bulblets of multiplier onion/ 50 bulbs of male sterile lines of onion/ 2000 viable cloves of garlic per season of each variety along with full details of characters in general and distinct characters in particular. Applicant will have to indicate geographical areas for suitability of candidate variety.

On the basis of above investigation, it can be concluded that onion and garlic varieties can be easily differentiated from one another due to their distinctive, uniform and stable expression of morphological markers over years by DUS testing. Thirty-eight *rabi* onion, ten *kharif* onion

Table 2: DUS characterization of *kharif* onion varieties

S. No.	Entries	1	2	3	4	5	15	16	17	18	19	20	21
		Plant: Number of leaves per pseudo-stem	Foliage: Length (from pseudostem to tip of leaf) (cm)	Bulb: Time of maturity (from date of sowing) (days)	Bulb: Height (cm)	Bulb: Diameter (cm)	Foliage: Attitude	Leaf: Diameter (Max) (cm)	Foliage: Waxiness	Foliage: Intensity of green colour	Foliage: Cranking	Pseudostem: Length (up to last emerged green leaf) (cm)	Pseudostem: Diameter (at midpoint of length) (cm)
1	ADR	Few	Long	Medium	Tall	Medium	Semi-erect	Medium	Present	Medium	Weak	Small	Small
2	Arka Kalyan	Few	Medium	Medium	Medium	Medium	Semi-erect	Small	Present	Medium	Weak	Small	Small
3	B-780	Few	Medium	Medium	Medium	Medium	Semi-erect	Small	Present	Medium	Weak	Small	Small
4	Bhima Dark Red	Few	Long	Medium	Medium	Medium	Semi-erect	Medium	Present	Medium	Weak	Small	Small
5	Bhima Raj	Few	Long	Medium	Medium	Medium	Semi-erect	Medium	Present	Medium	Weak	Small	Small
6	Bhima Red	Few	Long	Medium	Tall	Medium	Semi-erect	Small	Present	Medium	Weak	Small	Small
7	Bhima Shubhra	Few	Long	Medium	Medium	Medium	Semi-erect	Medium	Present	Medium	Weak	Small	Small
8	Bhima Shweta	Few	Medium	Medium	Tall	Medium	Semi-erect	Small	Present	Light	Weak	Small	Small
9	Bhima Super	Few	Long	Medium	Medium	Medium	Semi-erect	Medium	Present	Medium	Weak	Small	Small
10	N-53	Few	Long	Medium	Medium	Medium	Semi-erect	Small	Present	Medium	Weak	Small	Small

Contd... Table 2: DUS characterization of *kharif* onion varieties

S. No.	Entries	22	23	24	25	26	27	28	29	30	31	32	33	34
		Bulb: Thickness of neck (cm)	**Bulb: General shape (in longitudinal section)**	**Bulb: Basic colour of dry skin**	**Bulb: Adherence of skin after harvest**	**Bulb: Thick-ness of rings (mm)**	**Bulb: Fir-mness of flesh (lbf)**	**Bulb: Colour of epider-mis of fleshy scale**	**Bulb : Position of root disc**	**Bulb: Predominant number of axes**	**Bulb: Cross section**	**Bulb: Degree of splitting into bulblet**	**Bulb: Total Soluble Solids (%)**	**Male sterility (under microscope)**
1	ADR	Thin	Flat Globe	Dark Red	Medium	Thin	Strong	Reddish	At surface	Single	Symm.	Medium	Medium	Absent
2	Arka Kalyan	Thin	Flat Globe	Dark Red	Medium	Thin	Strong	Reddish	Exerted	Single	Symm.	Medium	Medium	Absent
3	B-780	Thin	Globe	Dark Red	Medium	Thin	Strong	Purplish	At surface	Single	Symm.	Medium	Medium	Absent
4	Bhima Dark Red	Medium	Flat Globe	Dark Red	Medium	Thin	Strong	Purplish	Exerted	Single	Symm.	Medium	Medium	Absent
5	Bhima Raj	Thin	Globe	Dark Red	Medium	Thin	Strong	Purplish	Exerted	Multiple	Symm.	Medium	Medium	Absent
6	Bhima Red	Thin	Globe	Light Red	Medium	Thin	Strong	Reddish	At surface	Single	Symm.	Medium	Medium	Absent
7	Bhima Shubhra	Medium	Globe	White	Medium	Thin	Strong	Whitish	At surface	Multiple	Symm.	Medium	Medium	Absent
8	Bhima Shweta	Thin	Globe	White	Medium	Thin	Strong	Whitish	At surface	Single	Symm.	Medium	Medium	Absent
9	Bhima Super	Medium	Globe	Light Red	Medium	Thin	Strong	Reddish	Exerted	Single	Symm.	Medium	Medium	Absent
10	N-53	Thin	Flat Globe	Dark Red	Medium	Thick	Strong	Reddish	At surface	Single	Symm.	High	Medium	Absent

Symm. = Symmetrical

Table 3: DUS characterization of garlic varieties

S. No.	Entries	1	2	3	4	5	6	7	8	9	10	11
		Plant: Density of Leaves	**Plant: No. of Leaves per pseud-ostem**	**Foliage: Attitude**	**Leaf: Intensity of Green Colour**	**Leaf: Waxiness**	**Leaf: Length (Longest Leaf) (cm)**	**Leaf: Width (Widest Leaf) (cm)**	**Leaf: Shape in cross section**	**Pseudostem: Length up to 1st emerged green leaf (cm)**	**Pseud-ostem: Width of base (cm)**	**Pseudostem: intensity of anthocyanin colouration at base**
1	Bhima Omkar	Dense	Medium	Erect	Dark	Present	Medium	Narrow	Slightly concave	Medium	Narrow	Present
2	Bhima Purple	Dense	Few	Semi-erect	Dark	Present	Short	Narrow	Strongly concave	Medium	Narrow	Present
3	G-1	Dense	Medium	Erect	Dark	Present	Medium	Narrow	Strongly concave	Medium	Narrow	Present
4	G-282	Sparse	Few	Semi-erect	Light	Present	Medium	Narrow	Strongly concave	Medium	Narrow	Present
5	G-323	Medium	Few	Semi-erect	Medium	Absent	Short	Narrow	Strongly concave	Medium	Narrow	Present
6	G-386	Dense	Medium	Erect	Dark	Absent	Medium	Narrow	Slightly concave	Long	Narrow	Present
7	G-41	Medium	Medium	Erect	Dark	Present	Medium	Narrow	Slightly concave	Medium	Narrow	Present
8	G-50	Medium	Medium	Semi-erect	Dark	Present	Short	Narrow	Slightly concave	Medium	Narrow	Present
9	GG-2	Medium	Few	Erect	Dark	Present	Short	Narrow	Strongly concave	Medium	Narrow	Present
10	GG-3	Sparse	Medium	Semi-erect	Light	Present	Short	Narrow	Slightly concave	Medium	Narrow	Present
11	GG-4	Medium	Few	Semi-erect	Dark	Present	Short	Narrow	Slightly concave	Medium	Narrow	Present
12	Godawari	Medium	Few	Erect	Dark	Present	Medium	Narrow	Slightly concave	Medium	Narrow	Present
13	Ooty Local	Medium	Few	Semi-erect	Dark	Absent	Short	Narrow	Slightly concave	Medium	Narrow	Present
14	Phule Baswant	Dense	Few	Semi-erect	Medium	Present	Medium	Narrow	Strongly concave	Medium	Narrow	Present
15	Rani Bennur Local	Sparse	Few	Semi-erect	Medium	Present	Medium	Narrow	Strongly concave	Medium	Narrow	Present
16	Sikkim Local	Sparse	Few	Semi-erect	Light	Present	Short	Narrow	Strongly concave	Medium	Narrow	Present
17	Silkuei Local	Medium	Few	Erect	Dark	Present	Medium	Narrow	Slightly concave	Medium	Narrow	Present

Contd... **Table 3:** DUS characterization of garlic varieties

S. No.	Entries	12	13	14	15	16	17	18	19	20	21	22
		Flowering Stem	Flowering stem: Curvature	Flowering Stem: Length	Flowering stem: Bulbils	Time of bulb maturity	Bulb: Size (Diameter) (cm)	Bulb: Shape in longitudinal section	Bulb: Shape in cross section	Bulb: Position of cloves at tip of bulb	Bulb: Position of root disc	Bulb: Shape of base
1	Bhima Omkar	Absent	Absent	Nil	Absent	Early	Medium	Elliptic	Elliptic	Inserted	At surface	Flat
2	Bhima Purple	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Elliptic	Inserted	At surface	Flat
3	G-1	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Elliptic	Inserted	At surface	Recessed
4	G-282	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Circular	Inserted	At surface	Flat
5	G-323	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Circular	Inserted	Exerted	Flat
6	G-386	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Circular	Inserted	At surface	Recessed
7	G-41	Absent	Absent	Nil	Absent	Early	Medium	Circular	Circular	Inserted	At surface	Flat
8	G-50	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Circular	Exerted	At surface	Flat
9	GG-2	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Elliptic	Inserted	At surface	Flat
10	GG-3	Absent	Absent	Nil	Absent	Early	Medium	Circular	Circular	Inserted	Inserted	Recessed
11	GG-4	Absent	Absent	Nil	Absent	Early	Medium	Ovate	Elliptic	Inserted	At surface	Flat
12	Godawari	Absent	Absent	Nil	Absent	Early	Medium	Elliptic	Elliptic	Inserted	Exerted	Recessed
13	Ooty Local	Absent	Absent	Nil	Absent	Early	Small	Ovate	Elliptic	Inserted	At surface	Flat
14	Phule Baswant	Absent	Absent	Nil	Absent	Early	Medium	Elliptic	Elliptic	Exerted	At surface	Flat
15	Rani Bennur Local	Absent	Absent	Nil	Absent	Early	Medium	Circular	Circular	Inserted	At surface	Flat
16	Sikkim Local	Absent	Absent	Nil	Absent	Early	Medium	Circular	Circular	Inserted	At surface	Flat
17	Silkuei Local	Absent	Absent	Nil	Absent	Early	Small	Elliptic	Elliptic	Exerted	Exerted	Flat

Contd... **Table 3:** DUS characterization of garlic varieties

S. No.	Entries	23	24	25	26	27	28	29	30	31	32
		Bulb: Compactness of cloves	Bulb: Ground colour of dry external scales	Bulb: Anthocyanin stripes on dry external scales	Bulb: No. of cloves	Bulb: Distribution of cloves	Bulb: External cloves	Bulb: Skin adherence of dry external scales	Clove: Size (Diameter) (cm)	Clove: Colour of scale	Clove: Colour of Flesh
1	Bhima Omkar	Compact	White	Present	Medium	Non-radial	Absent	Strong	Medium	White	White
2	Bhima Purple	Compact	Purple	Present	Medium	Non-radial	Absent	Strong	Small	Purple	White
3	G-1	Medium	White	Absent	Medium	Non-radial	Absent	Medium	Medium	White	White
4	G-282	Compact	White	Absent	Medium	Radial	Absent	Medium	Medium	White	White
5	G-323	Medium	White	Absent	Medium	Non-radial	Absent	Medium	Medium	White	Yellow
6	G-386	Compact	Purple	Present	Medium	Non-radial	Absent	Strong	Small	Purple	Yellow
7	G-41	Medium	White	Absent	Medium	Non-radial	Absent	Medium	Small	White	Yellow
8	G-50	Medium	White	Absent	Medium	Non-radial	Absent	Medium	Medium	White	White
9	GG-2	Medium	White	Present	Medium	Non-radial	Absent	Medium	Medium	White	Yellow
10	GG-3	Compact	White	Absent	Medium	Radial	Absent	Strong	Medium	White	White
11	GG-4	Medium	White	Absent	Medium	Non-radial	Absent	Medium	Medium	White	White
12	Godawari	Medium	Purple	Present	Medium	Non-radial	Absent	Medium	Small	Purple	Yellow
13	Ooty Local	Compact	White	Absent	Medium	Non-radial	Absent	Strong	Medium	White	White
14	Phule Baswant	Medium	Purple	Present	Medium	Non-radial	Present	Medium	Small	Purple	Yellow
15	Rani Bennur Local	Compact	Purple	Present	Medium	Non-radial	Absent	Medium	Small	Purple	White
16	Sikkim Local	Compact	White	Absent	Medium	Radial	Absent	Strong	Small	White	White
17	Silkuei Local	Medium	Purple	Present	Medium	Non-radial	Absent	Medium	Small	Purple	Yellow

and 17 garlic varieties have been characterized as per DUS test guidelines which is essential for protection through PPV&FR Authority in India. It was also noted that each variety has specific traits and found diverse to each other.

lkjk'k

हमारे देश में पौध किस्म और कृषक अधिकार संरक्षण अधिनियम 2001 (पीपीवी और एफआरए) के तहत नई किस्मों को पंजीकृत करने के लिए डीयूएस परीक्षण (विशिष्टता, एकरूपता और स्थायित्व) आवश्यक है तथा भारत में पजीकरण के लिए 150 फसलों/जातियों

को अधिसूचित किया गया है जिसमें प्याज और लहसुन फसलें भी शामिल हैं। प्रजाति में जन्म दर एकरूपता बनी रहनी चाहिए तथा उसमें विविधता प्रदर्शित नहीं होनी चाहिए। प्रजाति सम्बन्धित गुणों में पर्याप्त एकरूपता होनी चाहिए। प्याज एवं लहसुन के लिए डीयूएस परीक्षण दिशा–निर्देशों में पीपीवी और एफआरए द्वारा भारत में प्याज की किस्मों के लिए 34 डीयूएस परीक्षण विशेषताओं और लहसुन की किस्मों के लिए 32 परीक्षण विशेषताओं को अधिसूचित किया गया है। राजगुरूनगर, पुणे में प्याज और लहसुन के लिए डीयूएस परीक्षण करने के लिए नोडल केन्द्र के रूप में काम कर रहा है। प्याज और लहसुन की सभी उपलब्ध अल्प दिन वाली किस्मों को भा.कृ.अनु.प. –प्याज एवं लहसुन अनुसंधान निदेशालय, राजगुरूनगर और भा.कृ. अनु.प.–भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली में अनुरक्षण किया जा रहा है जबकि भा.कृ.अनु.प.– केन्द्रीय शीतोष्ण बागवानी संस्थान, श्रीनगर में लंबे दिन वाली किस्मों का अनुरक्षण किया जा रहा है। तमिलनाडु कृषि विश्वविद्यालय, कोयंबटूबर में मल्टीप्लायर प्याज की किस्मों का अनुरक्षण किया जा रहा है। रबी मौस में कृषक प्रजातियों सहित 38 प्याज की किस्में, खरीफ मौसम में 10 प्याज की किस्में एवं रबी में 17 लहसुन की किस्मों का अनुरक्षण किया जाता है। प्याज एवं लहसुन के प्रजातियों के पंजीकरण के लिए दिशा–निर्देश दिए गए है जबकि किसानों के प्रजातियों के पंजीकरण के लिए नियमों में छूट दी गई है और उन्हें पंजीकरण का समान अधिकार है। प्रत्याशी किस्म को दो मौसमों में दो स्थानों पर जबकि किसानों की किस्मों को केवल एक मौसम में दो स्थानों पर डीयूएस परीक्षण किया जाता है।

Reference

Ahmed N, Khan SH, Afroza B, Hussain K, Qadri S and Nazir G (2013) Morphological characterization in onion (*Allium cepa* L.) for preparation and implementation of plant variety protection (PVP) legislation and DUS testing under temperate conditions of Kashmir. African J Agric Res 8(14):1270-1276.

Gupta AJ and Mahajan V (2013) Maintenance and protection of onion and garlic varieties through PPV&FR Act. *In:* National Conference on Agro-biodiversity Management for Sustainable Rural Development" at NAARM, Hyderabad on 14-15 October, 2013, pp. 25.

Gupta AJ, Mahajan V and Lawande KE (2011) Extant varieties of onion and garlic in India. *In:* National Symposium on Alliums: Current Scenario and Emerging Trends, 12-14 March, 2011. ISA, DOGR, Pune, pp. 159.

Joshi MA, Sarao NK, Sharma RC, Singh P and Bharaj TS (2007) Varietal characterization of rice (*Oryza sativa* L.) based on morphological descriptors. Seed Res 35: 188-193.

Kumar D, Agarwal RC and Begum T (2008) Analysis for identification of distinct and uniform extant jute (*Corchorus olitorius* L. and *C. capsularis* L.) varieties. Seed Res 36: 121-134.

Kumar Y, Ram H and Gulia SK (2002) Varietal identification in oat based on field parameters. Forage Res 28: 73-76.

PPV&FR Authority (2009) Guidelines for the conduct of test for distinctiveness, uniformity and stability on garlic (*Allium sativum* L.) pp 21.

PPV&FR Authority (2009) Guidelines for the conduct of test for distinctiveness, uniformity and stability on onion (*Allium cepa* L.) pp 26.

Ravikumar M and Narayanswamy S (1999) Identification of soybean varieties based on seed morphological characters. Curr Res 28: 50-52.

Yadav VK and Singh IS (2010) Comparative evaluation of maize inbred lines (*Zea mays* L.) according to DUS testing using morphological, physiological and molecular markers. Agric Sci 1: 131-142.

Vegetable Science (2018) 45(2) : 232-237

Combining ability analysis for yield and quality traits in ridge gourd (*Luffa acutangula* L. Roxb.)

Akshay Chittora*, RA Kaushik and KD Ameta

Received: September 2018 / Accepted: December 2018

Abstract

The investigation was carried out to study combining ability in ridge gourd through line × tester analysis in which 11 lines were crossed with 3 testers to get 33 F_1 hybrids. These 33 F_1s along with 14 parents were evaluated in Randomized Block Design with three replications under four environments consisting of two locations and two seasons during 2016-17. The parents DRG-3, DRG-5, DRG-15 and Konkan Harita were good general combiners for fruit yield, fruit quality and yield attributing traits and therefore, these are proposed for their further utilization in hybrid breeding programme. Hybrids DRG-15 × Konkan Harita and DRG-3 × Konkan Harita exhibited good specific combining ability for yield per plant and yield contributing characters like number of fruits per plant, fruit weight and fruit diameter. These superior combinations can be further promoted to be utilized as hybrids.

Key words: Combining ability, GCA, SCA, Ridge gourd, Yield

Introduction

Ridge gourd (*Luffa acutangula* L. Roxb.) is an important cucurbitaceous vegetable crop of tropical and subtropical parts of the world. It belongs to genus *Luffa* of Cucurbitaceae family and has chromosome number 2n = 26 and is native to India. It is popularly known as Kalitori in hindi and also called as angled gourd, angled loofah, Chinese okra, silky gourd and ribbed gourd. Tender green fruits are used in soups and curries or cooked as vegetable. It contains a gelatinous compound called 'luffein'' which has medicinal importance (Swarup 2005). The cultivated species of ridge gourd are monoecious in nature but different sex forms *viz.,* androecious, gynoecious, gynomonoecious, andromonoecious and hermaphrodite plants are also reported. Apart from possessing a wide range of genetic variability in terms of growth and yield characters, it is a cross-pollinated crop which envisages its improvement through heterosis breeding. But in hybrid breeding programme the breeder often faces the problem of selecting parents and crosses. At this juncture information on combining ability may be of great value to the breeder.

Combining ability analysis is one of the powerful tools available in crop breeding to identify the best combiners and utilize them in hybridization, either to exploit for heterosis or to combine favourable fixable genes. The concept of combining ability in terms of genetic variation was first given by Sprague and Tatum (1942) using single crosses in maize. Combining ability of inbred lines is the ultimate factor determining the future usefulness of the lines for hybrids. The common approach of selecting parents on the basis of *per se* performance does not necessarily lead to fruitful results since phenotypically superior lines may not lead to expected degree of heterosis. Thus selection of the best parents for hybridization has to be based on the complete genetic information. Sprague and Tatum (1942) defined the term 'general combining ability' (GCA) as the average performance of a strain or genotype in a series of hybrid combinations and 'specific combining ability' (SCA) as the performance of a parent in a specific cross which indicates the deviation of a particular cross from the general combining ability. The estimation of GCA helps the breeders to select suitable parents for hybridization whereas SCA aids in the identification of superior cross combinations. Griffing (1956) elaborated the hypothesis of Sprague and Tatum (1942) and developed the technique to work out GCA and SCA effects along with their variances. General combining ability is due to additive genetic variance and additive x additive epistasis whereas specific combining ability is due to dominance genetic variance and all the three types of epistasis (additive × additive, additive × dominance and dominance × dominance). The knowledge of types of

Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

*Corresponding author: akshaychittora@gmail.com

gene action controlling various traits is important in deciding a proper breeding programme. Thus, proper understanding of combining ability of the parents and nature of gene effects governing yield and their component traits could be of great help in selecting parents for the hybridization programme and formulating suitable breeding method for improvement of the crop. Keeping these points in mind, present investigation was carried out to obtain information about the GCA and SCA of parents and hybrids, respectively in ridge gourd.

Materials and Methods

The present investigation was carried out in four environments comprising of two locations *viz.*, Horticulture farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) and Krishi Vigyan Kendra, Chittorgarh (Rajasthan) and two seasons *viz.*, summer-2017 and *kharif*- 2017. The experimental material used for the study comprised of eleven genetically diverse inbred lines *viz.,* VRS-7 (L_1), VRS-24-2 (L_2), VRS-27 (L_3), VRS-25/10 (L_4), VRS-2/10 (L_5), VRS-7/10 (L_6), IC-571716 (L_7), DRG-3 (L_8), DRG-4 (L_9), DRG-5 (L_{10}), DRG-15 (L_{11}), three testers *viz*., Swarna Manjiri (T_1), Arka Sujath (T_2), Konkan Harita (T_3), 33 F_1 hybrids and 3 checks *viz.*, Pusa Nutan, Pusa Nasdar and Kaveri (total entries 50). These 33 F_1 hybrids were obtained by crossing 11 inbred lines and 3 testers in line × tester mating fashion during *kharif*- 2016. All genotypes were evaluated in randomized block design (RBD) with three replications in four above mentioned environments. The experimental material was planted in rows of 2.0 m apart with a spacing of 0.5 m between plants. All cultural practices were followed as per the recommended package of practices. Observations were recorded from five randomly selected plants in each replication on twenty growth, yield and quality traits *viz.,* days to anthesis of first male flower, days to anthesis of first female flower, node to first female flower, days to first harvest, number of branches per vine, internodal length (cm), vine length (cm), number of male flowers per vine, number of female flowers per vine, number of fruits per vine, fruit length (cm), fruit diameter (cm), fruit weight (g), rind thickness (cm), flesh thickness (cm), number of seeds per fruit, fruit yield per vine (g), TSS (%), ascorbic acid (mg/100g) and total sugar (%). The pooled data of all four environments for above characters were subjected to statistical analysis for estimation of general and specific combining ability effects according to the model suggested by Kempthrone (1957).

Results and Discussion

Results revealed that the mean squares due to lines, testers and line × tester were significant for all the characters under study (data not shown) which indicated the importance of both additive and non-additive genetic components. Similar results were also reported by Niyaria and Bhalala (2001), Lodam et al. (2009) and Muthaiah et al. (2017). The estimates of negative significant GCA effects for days to anthesis of first male flower and days to anthesis of first female flower were exhibited by parents L_{11} (-3.72 and -3.61), L_8 (-1.90 and -2.13) and T_2 (-0.70 and -0.69) indicating their good general combining ability for these traits. The parental lines L_{11} (-2.80), L_8 (-1.22) and L_1 (-0.87) were recorded to be good general combiners for node to first female flower. L_{11} (-3.91), L_8 (-2.06) and T_2 (-0.87) were good general combiners for days to first harvest (Table 1) which indicated their superiority in transmitting desirable genes for earliness. Significant GCA effects in negative direction for earliness were also reported by Ahmed et al. (2006) in ridge gourd and Naliyadhara et al. (2010) in sponge gourd.

The study revealed that four lines *viz.,* L_{11} (2.36), L_8 (1.38), L_4 (0.62) and L_{10} (0.52) and one tester *viz.,* T_3 (0.61) exhibited positive significant GCA effects for number of fruits per vine (Table 1). Similarly, four lines *viz.,* L_{11} (3.24), L_{10} (2.65), L_8 (2.47) and L_5 (2.04) and one tester *viz.,* T_3 (1.55) exhibited positive significant GCA effects for fruit length (Table 2). For fruit diameter, L_{11} (0.81), L_4 (0.37) and L_{10} (0.32) and T_3 (0.24) were good general combiners. For fruit weight and fruit yield per vine, three lines *viz.,* L_{11} (13.66 and 471.52), L_8 (7.09 and 266.59) and L_{10} (7.03 and 137.47) and one tester *viz.,* T_3 (3.81 and 126.55) exhibited significant positive GCA effects (Table 2) which showed their genetic worth in using them as general combiners for these important traits. These findings are in agreement with the findings of Hedau and Sirohi (2004), Purohit et al. (2007) and Lodam et al. (2009) in ridge gourd. Number of parental lines *viz.,* L_5, L_7, L_8, L_{10} and L_{11} were good general combiners for number of branches per vine while L_4, L_6, L_8, L_{11} and T_3 were good general combiners for vine length. For internodal length, L_1, L_8 and L_{11} exhibited negative significant estimates of GCA effects (Table 1). Narasannavar et al. (2015) also reported positive significant GCA effects for number of branches per vine and vine length. The estimate of negative significant GCA effect for number of male flowers per vine was exhibited by parental line L_{11} only while for number of female flowers per vine positive significant estimates of GCA effects were exhibited by L_3, L_8, L_{11} and T_3. Similar findings for sex ratio have also been reported by Tyagi et al. (2010) in ridge gourd. Parents L_7, L_8, L_{11} and T_3 were good general combiners for rind thickness and flesh thickness while L_1, L_9, L_{11}

Table 1: GCA and SCA effects for different traits in ridge gourd

S. No.	Genotype	Days to anthesis of first male flower	Days to anthesis of first female flower	Node to first female flower	Days to first harvest	Number of branches per vine	Internodal length	Vine length	Number of male flowers per vine	Number of female flowers per vine	Number of fruits per vine
1	T1	0.76**	0.89**	0.59**	1.22**	-0.04	0.25*	-6.68	3.35*	-0.49*	-0.40**
2	T2	-0.70**	-0.69**	-0.32	-0.87**	-0.03	-0.22	-1.86	-0.49	0.03	-0.21
3	T3	-0.06	-0.20	-0.27	-0.36	0.06	-0.03	8.55*	-2.86	0.46*	0.61**
4	L1	-0.32	-0.38	-0.87**	-0.54	-0.61**	-1.05**	-37.43**	1.41	0.21	-1.22**
5	L2	0.72*	0.98*	1.29**	1.22**	-0.70**	0.10	-31.97**	4.52	-0.41	-1.10**
6	L3	1.01**	0.84*	1.11**	1.59**	-0.41**	0.49*	6.70	9.87**	1.44**	-1.28**
7	L4	-0.18	-0.10	-0.07	0.16	-0.05	0.61**	16.56**	-3.61	-1.25**	0.62**
8	L5	1.10**	1.08**	-0.47	1.35**	0.45**	0.55*	-26.91**	1.21	-1.73**	0
9	L6	1.05**	0.88*	0.36	0.55	0.17**	0.80**	18.27**	5.74*	-0.53	-0.32
10	L7	1.10**	1.20**	0.90**	0.73	0.66**	-0.31	-1.03	3.88	-1.14**	-0.69**
11	L8	-1.90**	-2.13**	-1.22**	-2.06**	0.32**	-0.71**	26.71**	-4.08	1.55**	1.38**
12	L9	1.64**	1.61**	1.25**	1.56**	-0.18**	0.02	-17.81**	-0.91	-0.23	-0.27
13	L10	-0.52	-0.37	0.53	-0.66	0.22**	0.60**	-11.67	-1.67	-0.20	0.52*
14	L11	-3.72**	-3.61**	-2.80**	-3.91**	0.13*	-1.09**	58.58**	-16.37**	2.31**	2.36**
15	L1 × T1	0.47	0.43	-0.30	0.41	-0.37**	-0.48	1.20	-5.29	-1.01	-0.15
16	L2 × T1	-0.93	-0.85	-0.10	-0.75	0.42**	-0.24	-2.59	-3.69	1.75*	0.17
17	L3 × T1	-0.98	-0.88	-0.83	-1.08	-0.02	0.14	-1.42	-4.56	1.54*	0.87
18	L4 × T1	-0.49	-0.33	-0.50	-0.58	-0.32**	0.43	-10.41	4.05	-0.46	-0.52
19	L5 × T1	-0.50	-0.55	0.03	-0.69	0.60**	-0.68	-8.13	1.49	0.29	-0.08
20	L6 × T1	-0.18	0.03	1.06	0.59	-0.19	-0.41	-28.59*	-5.37	-0.06	0.05
21	L7 × T1	-0.03	-0.25	-1.02	-0.23	0.22	-0.25	50.34**	6.30	0.34	1.18*
22	L8 × T1	1.76*	1.90*	0.98	1.77	-0.02	1.16**	12.2	10.02	-2.22**	-1.48**
23	L9 × T1	-0.70	-0.69	-0.40	-0.86	0.33**	0.15	7.55	4.04	0.64	1.37**
24	L10 × T1	0.69	0.47	-0.34	0.51	0.01	-0.59	-2.40	-8.35	-0.01	-0.62
25	L11 × T1	0.89	0.72	1.41*	0.92	-0.67**	0.76	-17.74	1.35	-0.79	-0.78
26	L1 × T2	-1.48*	-1.75*	-1.06	-3.00**	0.41**	0.10	-2.24	0.88	0.34	0.58
27	L2 × T2	0.73	0.67	0.30	0.86	-0.10	0.19	14.51	7.13	-1.57*	-0.10
28	L3 × T2	0.35	0.18	-0.50	0.39	-0.03	-0.56	6.59	4.30	-0.37	-0.19
29	L4 × T2	-1.12	-1.48	-0.42	-1.46	0.35**	-0.33	28.59*	-3.20	1.86*	1.57**
30	L5 × T2	0.90	0.94	0.22	0.88	-0.32**	0.84	16.06	-8.49	-1.19	0.21
31	L6 × T2	0.14	-0.22	-1.31*	-0.01	0.11	-0.34	-22.80	-2.01	0.67	-0.39
32	L7 × T2	0.46	0.54	1.25*	0.16	0.30*	0.28	-21.85	-8.85	0.13	-0.95*
33	L8 × T2	1.01	1.19	0.44	1.73	-0.44**	0.26	-68.45**	1.98	0.83	-0.19
34	L9 × T2	1.27	1.07	1.04	1.80	-0.51**	-0.85*	27.23*	3.42	-0.64	-0.54
35	L10 × T2	-1.75*	-0.94	0.33	-1.03	-0.13	0.31	28.12*	4.35	0.67	0.58
36	L11 × T2	-0.52	-0.20	-0.28	-0.32	0.36**	0.11	-5.77	0.49	-0.73	-0.59
37	L1 × T3	1.01	1.32	1.36*	2.59**	-0.04	0.38	1.04	4.40	0.66	-0.43
38	L2 × T3	0.20	0.18	-0.21	-0.11	-0.32**	0.05	-11.91	-3.44	-0.18	-0.07
39	L3 × T3	0.62	0.70	1.34*	0.69	0.05	0.42	-5.17	0.26	-1.17	-0.68
40	L4 × T3	1.61*	1.81*	0.92	2.04*	-0.04	-0.10	-18.18	-0.85	-1.40	-1.04*
41	L5 × T3	-0.40	-0.39	-0.25	-0.19	-0.29*	-0.16	-7.93	7.00	0.90	-0.14
42	L6 × T3	0.04	0.18	0.26	-0.58	0.08	0.75	51.40**	7.38	-0.60	0.34
43	L7 × T3	-0.44	-0.29	-0.23	0.07	-0.52**	-0.02	-28.49*	2.55	-0.47	-0.23
44	L8 × T3	-2.77**	-3.09**	-1.41*	-3.49**	0.46**	-1.42**	56.25**	-11.99*	1.40	1.68**
45	L9 × T3	-0.57	-0.38	-0.64	-0.95	0.18	0.70	-34.78**	-7.47	0	-0.83
46	L10 × T3	1.07	0.48	0.01	0.52	0.13	0.29	-25.72*	4.00	-0.65	0.04
47	L11 × T3	-0.36	-0.51	-1.14	-0.60	0.31*	-0.88*	23.50	-1.84	1.52*	1.36**

*, ** Significant at 5 and 1%, respectively

and T_1 were good general combiners for number of seeds per fruit (Table 2). For TSS content, three parents *viz.*, L_8, L_{11} and T_3 had good range of positive GCA effects. L_7, L_8, L_{11} and T_3 were good general combiners for ascorbic acid content while L_8, L_{11} and T_3 were good general combiners for total sugar content (Table 2). Karmakar et al. (2013) also reported significant GCA effects for ascorbic acid content in ridge gourd.

A perusal of SCA effects with regard to days to flowering revealed that three hybrids *viz.*, $L_8 \times T_3$ (-

Table 2: GCA and SCA effects for different traits in ridge gourd

S. No.	Genotype	Fruit length	Fruit diameter	Fruit weight	Rind thickness	Flesh thickness	Number of seeds per fruit	Fruit yield per vine	TSS	Ascorbic acid	Total sugar
1	T1	-1.65**	-0.35**	-4.31**	-0.05**	-0.06**	-6.41**	-101.52**	-0.07**	-0.25	-0.04
2	T2	0.10	0.10	0.50	0.01	0.02	3.59*	-25.03	-0.03	-0.06	-0.06*
3	T3	1.55**	0.24**	3.81**	0.04*	0.04*	2.82	126.55**	0.10**	0.31*	0.10**
4	L1	-4.86**	-1.32**	-18.21**	-0.21**	-0.24**	-27.72**	-338.98**	-0.38**	-1.51**	-0.23**
5	L2	-1.16*	-0.21	-4.75**	-0.03	-0.01	-0.40	-186.79**	-0.12**	-0.18	-0.04
6	L3	-0.15	0.10	-2.01	-0.05	-0.07*	2.80	-185.45**	-0.51**	-0.74**	-0.31**
7	L4	-1.00*	0.37*	-1.04	-0.02	-0.08*	9.04**	51.79	0.02	0.41	0.08
8	L5	2.04**	-0.10	0.56	-0.03	-0.03	18.07**	-3.26	-0.08	-0.02	-0.18**
9	L6	-0.41	-0.22	-3.18*	0.01	-0.01	2.54	-85.79**	-0.17**	-0.43	-0.23**
10	L7	-0.37	0.02	1.15	0.08*	0.08*	12.89**	-79.89*	-0.06	0.61*	-0.08
11	L8	2.47**	0.27	7.09**	0.12**	0.14**	8.55**	266.59**	0.43**	1.85**	0.28**
12	L9	-2.44**	-0.04	-0.29	-0.02	0.04	-16.91**	-47.22	-0.02	-1.03**	-0.03
13	L10	2.65**	0.32*	7.03**	0.03	0.04	8.45**	137.47**	-0.05	-1.40**	-0.02
14	L11	3.24**	0.81**	13.66**	0.12**	0.15**	-17.32**	471.52**	0.94**	2.42**	0.76**
15	L1 × T1	0.61	0.35	1.23	0.03	0	5.01	13.63	-0.14	-0.63	-0.13
16	L2 × T1	0.48	-0.19	-1.61	-0.02	-0.06	-0.44	14.27	0.12	0.07	-0.07
17	L3 × T1	1.00	-0.29	0.98	0.05	0.05	-7.48	124.46	0.08	1.04*	0.03
18	L4 × T1	-0.21	-0.08	4.31	0.01	0.03	-6.68	-10.89	-0.10	0.08	-0.07
19	L5 × T1	1.25	0.40	4.18	0.15*	0.17*	1.16	48.00	0.10	-0.39	0.24**
20	L6 × T1	-1.32	0.27	2.08	0.06	-0.02	-5.36	36.27	-0.34**	-0.48	-0.23**
21	L7 × T1	0.90	-0.19	0.67	-0.05	-0.08	2.49	159.28*	-0.13	-0.78	-0.24**
22	L8 × T1	1.44	-0.17	-4.56	-0.08	0.06	11.13*	-253.51**	-0.12	-0.29	0.01
23	L9 × T1	0.21	0.39	-1.38	0	-0.02	-8.68	146.57*	0.01	1.27*	0.01
24	L10 × T1	-2.59*	-0.28	-3.19	-0.07	-0.06	9.87	-121.46	0.08	-0.23	0.18*
25	L11 × T1	-1.78	-0.21	-2.71	-0.09	-0.08	-1.02	-156.61*	0.43**	0.34	0.27**
26	L1 × T2	0.52	0.25	2.70	0	-0.05	-3.55	98.38	0.27**	0.81	0.32**
27	L2 × T2	0.38	-0.08	-0.96	0.01	0.01	-1.59	-21.10	-0.19*	-0.41	-0.03
28	L3 × T2	1.04	0.83**	5.27*	0.08	0.07	8.87	32.10	0.05	0	0.04
29	L4 × T2	-0.63	-0.56	-4.01	0	0.08	-5.43	136.56*	0.03	0.42	0.06
30	L5 × T2	-0.48	0	-0.52	-0.05	-0.04	-1.12	23.16	0.56**	0.31	0.19*
31	L6 × T2	-0.33	-0.71*	-1.81	-0.06	-0.02	-3.91	-59.49	0.08	0.28	0.09
32	L7 × T2	-1.36	0.58	-3.31	0.04	0.05	-7.33	-152.32*	-0.22*	-0.28	-0.06
33	L8 × T2	-1.99*	-0.41	-0.68	-0.01	-0.13*	12.96*	-35.95	-0.16	-0.07	-0.16
34	L9 × T2	0.72	-0.08	1.03	0.02	0.02	17.85**	-40.55	0.22*	0.20	0.15
35	L10 × T2	1.91	0.36	2.73	0.01	0.01	-17.69**	107.65	-0.07	-0.18	-0.23**
36	L11 × T2	0.22	-0.19	-0.44	-0.04	0	0.93	-88.44	-0.56**	-1.07*	-0.37**
37	L1 × T3	-1.14	-0.59	-3.92	-0.04	0.05	-1.46	-112.01	-0.13	-0.19	-0.19*
38	L2 × T3	-0.86	0.27	2.58	0.01	0.05	2.03	6.83	0.08	0.35	0.10
39	L3 × T3	-2.04*	-0.53	-6.25*	-0.13*	-0.11	-1.39	-156.57*	-0.13	-1.04*	-0.07
40	L4 × T3	0.84	0.63*	-0.30	-0.01	-0.11	12.11*	-125.67	0.07	-0.50	0
41	L5 × T3	-0.77	-0.40	-3.66	-0.10	-0.13	-0.03	-71.16	-0.67**	0.09	-0.43**
42	L6 × T3	1.65	0.43	-0.27	-0.01	0.03	9.27	23.22	0.26**	0.21	0.15
43	L7 × T3	0.46	-0.40	2.63	0.01	0.03	4.84	-6.96	0.35**	1.06*	0.30**
44	L8 × T3	0.54	0.58	5.24*	0.09	0.07	-24.09**	289.46**	0.28**	0.35	0.15
45	L9 × T3	-0.93	-0.31	0.36	-0.02	0	-9.17	-106.02	-0.23*	-1.48**	-0.16
46	L10 × T3	0.68	-0.08	0.45	0.06	0.04	7.82	13.81	-0.02	0.41	0.05
47	L11 × T3	1.56	0.39	3.15	0.13*	0.08	0.09	245.05**	0.13	0.73	0.10

*, ** Significant at 5 and 1%, respectively

2.77), $L_{10} \times T_2$ (-1.75) and $L_1 \times T_2$ (-1.48) exhibited the negative significant SCA effects for days to anthesis of first male flower while two hybrids *viz*., $L_8 \times T_3$ (-3.09) and $L_1 \times T_2$ (-1.75) exhibited the negative significant SCA effects for days to anthesis of first female flower. For node to first female flower, two hybrids *viz*., $L_8 \times T_3$ (-1.41) and $L_6 \times T_2$ (-1.31) were good specific combiners. Out of 33 hybrids, only two hybrids *viz*., $L_8 \times T_3$ (-3.49) and $L_1 \times T_2$ (-3.00) exhibited the negative significant SCA effects for days to first harvest (Table 1) which indicated that these crosses were good specific combiners for earliness. These results are in agreement

with those of Ahmed et al. (2006) and Muthaiah et al. (2017) in ridge gourd and Naliyadhara et al. (2010) in sponge gourd. The estimates of significant positive SCA effects for number of fruits per vine were observed in five hybrids (Table 1) with minimum value in $L_7 \times T_1$ (1.18) and maximum value in $L_8 \times T_3$ (1.68). Significant positive SCA effects for fruit diameter were observed in two hybrids *viz*., $L_3 \times T_2$ (0.83) and $L_4 \times T_3$ (0.63) while $L_3 \times T_2$ (5.27) and $L_8 \times T_3$ (5.24) exhibited the significant positive SCA effects for fruit weight. For fruit yield per vine, five hybrids exhibited the positive significant SCA effects (Table 2) with minimum value in $L_4 \times T_2$ (136.56) and maximum value in $L_8 \times T_3$ (289.46). Similar findings have been reported by Mole et al. (2001), Ahmed et al. (2006), Purohit et al. (2007) and Narasannavar et al. (2015) in ridge gourd and Ram et al. (2007) in sponge gourd.

The estimates of significant positive SCA effects for number of branches per vine were observed in nine hybrids with minimum value in $L_7 \times T_2$ and maximum value in $L_5 \times T_1$. For vine length, six crosses were observed to be good specific combiners while three hybrids were good specific combiners for internodal length (Table 1). Narasannavar et al. (2015) also reported similar results for these traits. The study revealed that only one hybrid $L_8 \times T_3$ exhibited significant negative SCA effect for number of male flowers per vine while four hybrids *viz*., $L_4 \times T_2$, $L_2 \times T_1$, $L_3 \times T_1$ and $L_{11} \times T_3$ exhibited the positive significant SCA effects for number of female flowers per vine (Table 1). Similarly, Tyagi et al. (2010) and Muthaiah et al. (2017) also recorded significant SCA effects for sex ratio in ridge gourd. Two hybrids *viz.,* $L_5 \times T_1$ and $L_{11} \times T_3$ were good specific combiners for rind thickness while only one hybrid $L_5 \times T_1$ was noted to be good specific combiner for flesh thickness (Table 2). For number of seeds per fruit, two hybrids *viz.,* $L_8 \times T_3$ and $L_{10} \times T_2$ exhibited the negative significant SCA effects. Among 33 crosses, seven crosses exhibited the positive significant SCA effects for TSS with the highest value in $L_{11} \times T_1$. However, three hybrids *viz*., $L_3 \times T_1$, $L_9 \times T_1$ and $L_7 \times T_3$ exhibited the positive significant SCA effects for ascorbic acid while six hybrids exhibited the positive significant SCA effects for total sugar (Table 2). Karmakar et al. (2013) also recorded positive significant SCA effects for ascorbic acid content in ridge gourd.

The results indicated that the GCA effects were mostly reflected in the SCA effects of the cross combinations as it is obvious that in almost all the hybrids which showed the best SCA effects, the parents involved were either one or both of the parents with good GCA effect for the particular trait. This indicated that there was strong tendency of transmitting the favourable alleles from parents to off-springs. However, the crosses exhibiting high SCA effects did not always involve parents with high GCA effects, there by suggesting the presence of interallelic gene interactions. These results are in conformity with the result of Narasannavar et al. (2015). However, good general combiners could not always produce best specific combiners for all the traits. Better performance of hybrids involving poor × poor or average × poor general combiners indicated dominance × dominance (epistasis) type of gene action. The crosses involving both parents with good general combining ability effects can be exploited effectively by conventional breeding procedure like pedigree method. However, the crosses with one good combiner and other average or poor combiner could produce desirable transgressive segregators in subsequent generations if additive genetic system was operative in good combining parents and epistatic effects also act in the same direction (Narasannavar et al. 2015).

Overall, combining ability revealed that the parents L_8 (DRG-3), L_{10} (DRG-5), L_{11} (DRG-15) and T_3 (Konkan Harita) were good general combiners for fruit yield and most of them were also good or average general combiners for other component characters like number of fruits per plant, number of branches per vine, fruit weight, fruit diameter and fruit length. These parents could be included in hybrid breeding programme of ridge gourd for developing promising hybrids. Similarly, the best performing hybrids $L_{11} \times T_3$ (DRG-15 × Konkan Harita) and $L_8 \times T_3$ (DRG-3 × Konkan Harita) for total yield per plant also exhibited significantly higher SCA effects for yield contributing characters like number of fruits per plant, fruit weight and fruit diameter which culminated into higher total yield. These superior combinations can be tested for promotion of F_1 hybrids in ridge gourd.

सारांश

प्रस्तुत अन्वेषण नसदार तुरई में वंशक्रम ग परीक्षक विश्लेषण द्वारा संयोजन क्षमता का अध्ययन करने के लिए किया गया जिसमें 11 वंशक्रमों का 3 परीक्षकों के साथ संकरण करके 33 संकर प्राप्त किये गये। इन 33 संकरों का उनके 14 पैतष्कों के साथ वर्ष 2016–17 के दौरान यादषच्छिक खण्ड अभिकल्पना के अंतर्गत तीन पुनरावषत्तियों में चार वातावरणों के अंतर्गत जिनमें दो मौसम और दो स्थान सम्मिलित थे, का विश्लेषण किया गया। पितष डीआरजी–3, डीआरजी–5, डीआरजी–15 और कोंकण हरिता वांछित फल उपज, फल गुणवत्ता व

उपज में सहायक गुणों के लिए अच्छे संयोजक पाए गये, अतः इन्हें भविष्य की संकर प्रजनन योजना में उपयोग हेतु प्रस्तावित किया गया। संकर डीआरजी–15 ग कोंकण हरिता तथा डीआरजी–3 ग कोंकण हरिता ने उपज प्रति पौध तथा उपज में सहायक लक्षणों जैसे फल संख्या प्रति पौध, फल भार व फल व्यास के लिए अच्छी संयोजन क्षमता का प्रदर्शन किया। इन उच्च संयोजनों को संकर के रूप में उपयोग के लिए आगे बढ़ाया जा सकता है।

References

Ahmed MA, Reddy IP and Neeraja G (2006) Combining ability and heterosis for fruit yield and yield components in ridge gourd [*Luffa acutangula* (Roxb.) L.]. J Res ANGRAU 34(1): 15-20.

Griffing JB (1956) Concept of general and specific combining ability in relation to diallel cropping systems. Aus J Biol Sci 9: 463-493.

Hedau NK and Sirohi PS (2004) Combining ability for yield and its contributing characters in ridge gourd. Prog Hort 36: 91-93.

Karmakar P, Munshi AD, Behera TK, Kumar R, Kaur C and Singh BK (2013) Hermaphrodite inbreds with better combining ability improve antioxidant properties in ridge gourd [*Luffa acutangula* (Roxb.) L.]. Euphytica 191: 75-84.

Kempthorne O (1957) An Introduction to Genetical Statistics. John Willey & Sons Inc., NY, pp 323-331.

Lodam VA, Desai DT, Khandelwal V and Patil PP (2009) Combining ability analysis in ridge gourd (*Luffa acutangula* L.). Veg Sci 36(1): 113-115.

Mole TJ, Devi SN, Rajan S and Sadhankumar PG (2001) Heterosis and combining ability in ridge gourd (*Luffa acutangula* Roxb.). Veg Sci 28(2): 165-167.

Muthaiah K, Gasti VD, Mallesh S, Arindam DAS and Mangi V (2017) Combining ability studies for early and yield traits in ridge gourd [*Luffa acutangula* L. Roxb.]. Intl J Agric Sci 9: 4319-4321.

Naliyadhara MV, Dhaduk LK, Barad AV and Mehta DR (2010) Combining ability analysis in sponge gourd [*Luffa cylindrica* (Roem.) L.]. Veg Sci 37(1): 21-24.

Narasannavar A, Gasti VD, Sridhar Malaghan S and Kumara BR (2015) Combining ability studies in ridge gourd [*Luffa acutangula* (L.) Roxb.]. Indian J Ecol 42(2): 382-387.

Niyaria R and Bhalala MK (2001) Heterosis and combining ability in ridge gourd. Indian J Plant Genet Resour 14: 101-102.

Purohit VL, Mehta DR, Dhaduk LK and Gajipara NN (2007) Combining ability for fruit yield and its attributes in ridge gourd [*Luffa acutangula* (Roxb.) L.]. Veg Sci 34(1): 84-85.

Ram D, Kumar V, Rai M, Singh TB, Kumar A and Chaubey T (2007) Combining ability studies of quantitative traits in sponge gourd (*Luffa cylindrica* Roem L.). Veg Sci 34(2): 170-172.

Sprague GF and Tatum IA (1942) General versus specific combining ability in single crosses in corn. J Am Soc Agron 34: 923-932.

Swarup V (2005) Vegetable science and Technology in India, Kalyani Publishers, New Delhi, pp 426-431.

Tyagi SVS, Sharma P, Siddiqui SA and Khandelwal RC (2010) Combining ability for yield and fruit quality in *Luffa*. Int J Veg Sci 16(3): 267-277.

Vegetable Science (2018) 45(2) : 238-243

Comparative production performance of vegetable crops in the country vis-à-vis Eastern India

Nasim Ahmad*, DK Sinha, KM Singh and RR Mishra

Received: November 2018 / Accepted: January 2019

Abstract

The present study was conducted to analyze the comparative production performance of vegetable crops in eastern India and India. In this study compound growth rates of vegetable crops and major vegetables like potato, tomato, onion, brinjal, cabbage, cauliflower, okra and pea were calculated by fitting exponential function to variables like area, production and productivity and tabular analysis was done to arrive at meaningful results. The study was based on macro framed data collected through different published secondary sources like Horticultural statistics of India and Agricultural statistics at a Glance, Ministry of Agriculture and Farmers Welfare, Government of India. The results pointed out positive growth trends in area, production and productivity of vegetable crops in the region and country during the last 16 years. Considering remarkable growth trends, vegetable crops may be taken as pathway for income enhancement of farming communities. Being good sources of healthy dietary requirements, nutritional security of the region in particular and nation in general can be addressed. Some limiting factors like pre and post harvest losses, storage facilities, lack of refrigerated vans and transportation and farmer's friendly marketing facilities restrict arrival of the actual quantity of vegetable to the consumers and in fetching remunerative prices of the produce. Hence, there is a need to improve pre and post harvest technologies, provide suitable transport and marketing facilities. Appropriate policy to tackle the abrupt price fluctuations during good harvest and scarce period is also needed to protect both the producers and the consumers. Shifting Indian farming from rural setup to urban setup and linking cultivators to super markets particularly for vegetables grower will be a key drivers in improving financial conditions of the farming community of country.

Key words: Vegetables, Compound growth rates, Nutritional Security Pre- and post-harvest technologies

Department of Agricultural Economics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur-848 125, Bihar

*Corresponding author, E-mail: nasim.rau@gmail.com

Introduction

Horticultural development had not been priority until recent years in our country. The era of Green Revolution in the country and thereafter, the emphasis was to enhance production and productivity of the food grains. Many schemes related to enhancement of food grains were launched during different five year plans. Horticultural development got attention in the post 1993 period through an enhancement of plan allocation and knowledge based technology. The need for diversification to horticulture sector was acknowledged by the Government of India in mid-eighties by focusing its attention on investment in this sector. National Horticultural Mission was launched in April 2005 as centrally sponsored scheme to promote holistic growth of horticultural sector through an area based regionally differentiated strategies The foreign trade policy in 2004-09 emphasized the need to boost agricultural exports, growth and promotion of exports of horticultural products. Presently horticulture has established its credibility in improving income through increased productivity, generating employment and in enhancing exports. Resultantly, horticulture has come out from rural confines to commercial front. Vegetables are one of the important components of horticulture sector of the Nation in particular and of the agriculture in general. India ranks second in vegetable production and vegetables and fruits accounts for 90% of the total horticultural produce. Various factors have catalyzed the growth in area and production of the vegetable crops in the country. The productivity of vegetable crops has been continuously increasing during the last many years. The factors like urbanization, increasing per capita income, health consciousness, increasing working women and shifting of farmers in growing higher value vegetables due to higher return have increased the annual growth rate of vegetable in India. Favourable income-elasticity of demand has also contributed in rising trend of vegetable production in the country (Choudhary and Kundal 2015, Verma et al. 2016).

In a study conducted in Andhra Pradesh by Reddy et al. (2010) has emphasized the value chain and retailing of fresh vegetables in the present emerging markets. It has been offering greater opportunities to the farmers who are growing vegetables and fruits can reap larger chunk of financial and economic benefits out of the cultivation of fruits and vegetables. The use of hybrid seeds in cultivation of vegetables has a huge impact over the farm incomes of the farmers growing vegetables by adopting commercial hybrid seeds (Sudha et al. 2006). In their study it was observed that use of commercial hybrid seeds resulted tremendous increase in production of Okra and tomato. This has helped the farmers to boost their income up to a great margin. A study on green pea production was carried out by Singla *et al.,* (2006) in Punjab. The results revealed that productivity of green peas was more for small farms than to medium and large farms. Thus, cultivation of green peas helps the small farmers in augmenting their earning. Agriculture is the backbone of Indian economy. The growth of this sector has strong linkage with other sectors and has striking effect on poverty and unemployment (Mohapatra et al. 2017). It has also been pointed out that per capita income in agriculture sector was just one third of the per capita income in the country thereby creating huge income disparity between primary agriculture vis-à-vis other sectors of the economy. The gap has been continuously widened showing alarming unrest among the farming community across the different states (Sarial 2016). As per NSSO 70th round data 53 per cent of farm households earn income lesser than poverty level income and 52 per cent of the farmers were reported under indebtedness. Most of them were marginal farmers and agricultural labourers. There is absence of efficient supply chain and value realization of agricultural produces. The ups and downs in prices during low harvest and good harvest keep the cultivators almost in same income level.

The eastern region of India comprising the states of Bihar, Jharkhand, Odisha and West Bengal is one of the most backward regions (32.10% below poverty line population and maximum number of economically most backward districts (69 out of 150 at national level) of the nation. This region occupies about 21.85 per cent of geographical area and supports 34 per cent of the population of the country. The population density is 1.91 fold higher in Eastern states to national average. Agriculture is the mainstay of economy in this region. The net sown area is 29.17 million hectare with cropping intensity of 150 per cent in the region. The average rainfall varies from 1091 to 2477 mm with an average of 1526 mm in the region which is sufficient to grow a variety of crops. However, the irrigated area is the eastern region is about 39% as against 45% of the country's average. About 67% of the cultivators belonged to marginal group and over 75% of their earnings are utilized to ensure food security. Eastern India is endowed with natural resources (145.12 BCM annual groundwater availability, groundwater draft is only 36%). Despite the rich natural resources (fertile land, abundant ground water), the pace of agricultural development is very slow (Ahmad et al. 2018). There is lot of scope to accelerate farmer's income by improving productivity and including high value crops like vegetables in cropping pattern of the region (Chand et al. 2008). Horticulture development is currently facing different constraints like poor marketing facilities. The gap between price received by producer and those paid by urban consumers is large, showing thereby inefficient marketing arrangements. Vegetables produced by farmers is collected by market agents, who sell it in organized markets, these markets are unfortunately controlled by a few traders and operate on highly nontransparent ways. The net result is poor realization of income by the farmers.

Many studies at abroad found that as farming shifts from rural lifestyle to an agribusiness sector with a supply chain mentality is the key driver for industrialization of agriculture (Martin 2001). Galanopoulos et al. (2009) found that Mediterranean countries are traditional growers of fruits and vegetables, but are struggling to remain competitive in the global market. In India, area under cultivation of vegetable crops was 10289.84 thousand ha with production of 175007.87 thousand tonnes and in the eastern region of India comprising the states of Bihar, Jharkhand, Odisha and West Bengal the area and production of vegetables stood 3469.28 thousand hectares and 56074.49 thousand tonnes during 2016-17 (Horticultural Statistics at a Glance 2017). The share of area under vegetable crops in eastern India to total area under vegetable crops of the country was computed to be 33.72% with production share of 32.04% during 2016-17. The same documentation has also reflected the wide potentiality of vegetable production and further flourishing on large scale to become a leader on global basis. In the present paper, an attempt has been made to study the comparative trends in area production and productivity of major vegetable crops in India and Eastern India and to find out the annual compound growth rates (CGR) of area, production and productivity of different vegetables in the country as well as in eastern India and to suggest measure to enhance the income of the vegetable growing farmers.

Materials and Methods

In the perspective of specific objective of the present investigation, the time series data from 2001-02 to 2016-17 pertaining to area, production and productivity was obtained from Horticultural Statistics, Govt. of India websites. Compound annual growth rates of area, production and productivity was computed for the period 2001-02 to 2008-09 and 2009-10 to 2016-17 and for overall period 2001-02 to 2016-17 for India and eastern India. The compound growth rate refers to the percentage change of a specific variable within specific period, given certain context. The growth model is given as under:

$Y_t = AB^t$

Where, Y_t = area/production/ productivity of vegetables for the year 't'

A = constant

B = growth coefficient

Log transformation of the above equation

$\log Y_t = \text{Log } A + t \log (B)$

Growth rate (%)= {antilog(b)-1}x100; Where b =log (B).

Results and Discussion

The comparative view on area, production and productivity of vegetables in India and Eastern India (Bihar, Jharkhand, Assam, Odisha and West Bengal) has been shown in Table 1. The compound growth rates for these variables for three periods i.e. 2001-02 to 2008-09, 2009-10 to 2016-17 and overall period 2001-02 to 2016-17 is presented in Table 2. The data presented in Table 1 revealed that the production of vegetables in India increased by about 1.96 times and that of eastern India approximately 1.38 times during study period. The increase in production of vegetables was due to increase in area during the investigation. The productivity also enhanced by around 1.20 times in India and 1.13 times with respect to eastern India. Average productivity of the region was found lower than that of the national average. The reason may be that majority cultivators of this region are poor and could not afford the input costs. The reason may be unavailability better linkage between production centre and marketing centre i.e. infrastructure development and lack of proper marketing facilities.

Compound growth rate: Compound annual growth rate of area depicted significant growth in area at 1.61 percent per annum in the country as well as 1.08 percent per annum in eastern India. The overall growth rates of productivity were found significantly increasing for both India and eastern India. The enhancement in productivity may due to technological changes of production and also due to increasing demand of vegetables from the health awareness during the period under investigation.

Annual compound growth rates of major vegetables grown in the country and Eastern India is presented in Table 3. The results revealed that area of potato increased with significant CAGR of 2.39, 1.05, 1.44 per cent in India and 1.05, 0.81, 0.78 percent in eastern India during different period under study. Production depicted significant growth during 2009-10 to 2016-17 and for overall period (2001-02 to 2016-17 in the country but in eastern India production showed negative trend during 2001-02 to 2008-09 and 2009-10 to 2016-17 but for overall period it was found positive. Productivity for overall period for the country and eastern India was found positive. Compound annual growth rates of area, production and productivity of other vegetables like tomato, onion, cauliflower, cabbage, brinjal, Okra and pea were assessed positive and significant increase for eastern India and country as a whole. In the first period (2001-02 to 2008-09) growth rate of productivity for cabbage was estimated negative in eastern India. The reason may be pest and disease attack during that period. In second period i.e. 2009-10 to 2016-17 annual compound growth rates of the area, production of tomato, productivity of cauliflower, area, production and productivity of brinjal, area of okra and productivity of pea only in eastern India were computed negative. But overall the trends in area, production and productivity were observed increasing in eastern India and India as a whole.

Table 1: Area, production and productivity of vegetables in India and Eastern India, for different triennium during 2001-02 to 2016-17

Period	Area (000ha)		Production (000 tonnes)		Productivity (t/ha)	
	India	Eastern India	India	Eastern India	India	Eastern India
TE-2004	6110.00	2851.13	87257.00	40605.80	14.28	14.24
TE-2007	7179.33	3215.02	109212.67	46464.37	15.21	14.45
TE-2010	7938.00	3323.62	130421.33	52243.87	16.43	15.72
TE-2013	8896.33	3390.48	155022.00	55202.14	17.43	16.28
TE-2017	9979.45	3478.58	171183.34	56078.58	17.15	16.12

Table 2: Compound growth rate of area, production and productivity of vegetables in India and Eastern India (%)

Period	Area		Production		Productivity	
	India	Eastern India	India	Eastern India	India	Eastern India
2001-02 to 2008-09	1.99*	1.32*	2.93*	1.91*	0.93*	0.59**
2009-10 to 2016-17	1.48*	0.37**	1.48*	0.38	0.0003*	0.01
2001-02 to 2016-17	1.61*	0.61*	2.27*	1.08*	0.65*	0.47*

*,** indicate significant at 1% and 5% of probability level, respectively.

The results pointed out that despite of flourishing urbanization in the country as well as in the region under investigation, the area under production vegetables was observed accelerating for both India and Eastern India. The area under vegetables increased from 6110 thousand hectares during TE-2004 to 9979.45 thousand hectares in TE-2017. Similarly in eastern India it increased from 2851.13 thousand hectares in TE-2004 to 3478.58 thousand hectares in TE-2017. India harvested 171183.34 thousand tonnes of vegetables from 9979.45 thousand area during TE-2017(Anonymous 2017). This was possible only due to constant research efforts along with new production and protection technologies developed by agricultural scientists. But real credit goes to the farming community who adopted and implemented the technologies to boost up the production of vegetables. Paradoxically the post production facilities as well as marketing and handling system are inadequate in the country and the region under study. Consequently the quantity and quality deteriorate as these are perishable in nature. There is an urgent need to strengthen post harvest technologies especially in case of vegetables in order to minimize the percentage losses.

A study on "Vegetable marketing in the hinterlands of Pusa road and Tajpur in Samastipur district of Bihar (Ahmad et al. 2017) was conducted and was assessed that the loss of vegetables on account of attack from pests and diseases, wastage during transportation, driage etc was studied and it was found that on an average 2.90 quintals of vegetables was lost. Out of that larger proportion (42.85%) was lost from cauliflower closely followed by loss from brinjal (37.71%). Other important contributors were cabbage (5.98%) and Parwal (5.17%). These examples emphasized the urgent requirement of technologies and infrastructure which may reduce the losses and lure cultivators for cultivation of vegetables. In addition there is need to promote contract farming of vegetables which generally bridges the gap by provision of quality inputs, management skills, technical guidance and even financial assistance to the resource poor farmers who can't afford the cost of modern inputs and invest more in cultivation of vegetables.

Policy measures: To boost up the income from vegetables, improvement in post-harvest technologies, availability of cooling van, cold storage at accessible distance and installation of processing industries may prove worthy for vegetable growers. Contract farming may be promoted and farmers may be made aware of its benefits. To revolutionize agri-market by ensuring better price discovery and enable farmers to get improved remuneration (E-NAM) has been launch by the government with the mission 'One nation One Market' and The Agricultural Produce and Livestock Marketing Act, 2017 (APLM) has been made for promotion and facilitation of transparent marketing systems. Shifting Indian farming from rural setup to urban setup and linking cultivators to super markets particularly for vegetables grower will be a key drivers in improving financial conditions of the farming community of country. These steps may prove to improve income of the cultivators if strictly implemented in proper manner.

Conclusion

The present investigation has analyzed the trends in area production and productivity of vegetables in India as well as in eastern India. The overall finding suggested that area, production and productivity of the vegetables have increased at national level and also in eastern India over the time. Despite of such large enhancement in area, production and productivity of vegetables, post harvest handling and marketing facilities are inadequate and lack of systematic marketing system induce discouragement in vegetable growers. They are unable to fetch actual profit of their produce. Hence, there is an urgent need to address these lacking so that vegetables grower pay more attention towards better cultivation of vegetables as well as they may get proper income.

सारांश

वर्तमान अध्ययन पूर्वी भारत और भारत में सब्जियों की खेती में हो रहे तुलनात्मक विस्तार के विश्लेषण पर आधारित है। इस अध्ययन में मुख्य सब्जियाँ जैसे आलू, टमाटर, प्याज, बैंगन, पत्ता गोभी, फूल गोभी, भिण्डी और मटर आदि के क्षेत्र, उत्पादन एवं उत्पादकता के चक्रवृद्धि वृद्धि दर के घातांक प्राकार्य का उपयोग कर एवं तालिका

Table 3: Compound growth rates of major vegetables grown in India and Eastern India from 2001-02 to 2016-17

Period	India			Eastern India		
	2001-02 to 2008-09	2009-10 to 2016-17	2001-02 to 2016-17	2001-02 to 2008-09	2009-10 to 2016-17	2001-02 to 2016-17
Potato						
Area	2.39*	1.05*	1.44*	1.05*	0.81*	0.78*
Production	1.13	1.20**	3.08**	-0.80	-0.51	1.15*
Productivity	-1.23	0.15	1.62	-1.83*	-1.31**	0.37
Tomato						
Area	1.72*	1.71***	1.78*	1.15**	-0.18	0.46*
Production	2.65*	3.40*	2.94*	2.05*	-0.17*	1.08*
Productivity	0.92*	1.66*	1.14*	0.89**	0.01	0.61*
Onion						
Area	4.25*	2.37**	3.08*	3.34*	1.12*	1.56*
Production	7.76*	2.97*	4.39*	6.81*	1.67*	3.02*
Productivity	3.37*	0.59	1.27*	3.36*	0.55**	1.43*
Cauliflower						
Area	1.76**	1.26*	1.80*	0.81*	0.16	0.53*
Production	2.01*	1.50*	2.02*	0.90*	0.06	0.68*
Productivity	0.25	0.23	0.22*	0.08	-0.10	0.15**
Cabbage						
Area	0.90	0.87**	1.73*	0.58*	0.37**	0.91*
Production	0.89***	1.12*	1.77*	0.50	0.44**	1.00*
Productivity	-0.01	0.24	0.04	-0.09	0.07	0.08
Brinjal						
Area	1.09*	0.17	1.07*	0.50*	-0.11	0.26*
Production	1.50*	0.77	1.61*	1.06*	-0.13	0.59*
Productivity	0.41**	0.60*	0.54*	0.56*	-0.01	0.33*
Okra						
Area	1.58*	0.46	1.49*	0.40*	-0.04	0.25*
Production	2.03*	0.61	2.13*	0.94*	0.06	0.65*
Productivity	0.45**	0.15	0.63*	0.55*	0.09	0.39*
Pea						
Area	0.46	2.30*	1.67*	-0.79***	1.76**	0.61**
Production	2.25*	2.89*	2.93*	1.27	0.10	1.75*
Productivity	1.79**	0.57	1.24*	2.08	-1.63**	1.14*

*,** and *** indicate significant at 1% , 5% and 10% of probability level, respectively.

विश्लेषण कर किया गया है। यह अध्ययन सहायक आंकड़ा, जो सरकार द्वारा प्रकाशित विभिन्न स्रोतों से एकत्र कर किया गया है जैसे– हॉर्टिकल्चरल स्टेटिस्टिक्स, एग्रीकल्चरल स्टेटिस्टिक्स जो भारत सरकार के कृषि एवं किसान कल्याण मंत्रालय द्वारा प्रकाशित किया जाता है के 1 वर्षों के आंकड़ों को विश्लेषण कर मुख्य सब्जियां के क्षेत्र, उत्पादन और उत्पादकता में आ रहे परिवर्तन को जानने की कोशिश की गई है। परिणामतः इन सब्जियाँ के क्षेत्र, उत्पादन और उत्पादन में हो रहे सकारात्मक वृद्धि को दर्शाता है जिससे पूर्वी भारत और भारत के किसानों की आमदनी को बढ़ाने में एक सकारात्मक कदम के रूप में अपनाया जा सकता है। सब्जियाँ स्वास्थवर्धक भोजन का एक मुख्य स्रोत है जो पूर्वी भारत एवं भारत के कुपोषण को कम करने में भी मददगार साबित हो रही हैं। इन सब्जियों के कटाई उपरान्त नुकसान, रख–रखाओं के उचित प्रबंधन प्रशीतित वैन, अच्छी यातायात सुविधा और सुविधाजनक बाजार प्रदान कर किसानों की आमदनी को बेहतर किया जा सकता है। कीमतों के उतार–चढ़ावों को नियंत्रित कर कृषकों एवं उपभोगकर्त्ताओं को हो रही नुकसानों को बचाया जा सकता है। इसके लिये सरकार को उचित नीतियों को लाना होगा ताकि कृषि को ग्रामीण परिवेश से लाभदायक सुपर मार्किट के परिवेश में लाया ज सके। यह नीति कृषकों के वित्तीय स्थिति को सुदृढ़ करने में एक अच्छी पहल हो सकती है।

References

Ahmad Nasim, Mishra RR, Sinha DK and Singh KM (2017) Price Spread and Vegetables Marketing in the Hinterlands of Pusa and Tajpur Blocks of Samastipur District of Bihar (India). Intl J Advan Agric Sci Tech 4(10): 54-66.

Ahmad Nasim, Sinha DK and Singh KM (2018) Growth and instability in pulses: A spatiotemporal analysis in eastern India. J Agri Search 5(1): 67-76.

Anonymous (2017) Horticulture Statistics (2017). National Horticulture Board, Ministry of Agriculture and Farmers Welfare, Government of India.

Chand Ramesh, Raju SS and Pandey LM (2008) Triggering Agricultural Development through Horticulture crops. Ind J Agri Econ 63: 299-309.

Choudhary K and Kundal R (2015) A study in the area, production and productivity of tomatoes in India from 2002-2011. Intl J Advance Res Comp Sci Manage Studies 3(7): 90-94.

Galanopoulus K, Nilsson, Fk OL Wajnblom, Emma; Surry Y (2009) Fruit and vegetable production in the new millennium: Will Mediterranean production satisfies increasing European demand? Outlook Agri 38(3): 11-19.

Martin MA (2001) The future of the world food system. Outlook Agri 30(1): 11-19.

Mohapatra S, Mohapatra U and Mishra RK (2017) Diversification towards vegetable: A good option for doubling the farmer's income. J Experi Agri Intl 18(4):1-17.

Reddy GP, Murthy MRK and Meena PC (2010) Value chain and retailing of fresh vegetables and fruits, Andhra Pradesh. Agric Res Rev 23: 455-460.

Sarial AK (2016) Doubling farmers' income: A model for hilly mountainous region. Himachal J Agric Res 42(2): 101-114.

Singla R, Chahal SS and Kataria P (2006) Economic production of green peas (*Pissum sativam* L.) in Punjab. Agric Res Rev 19: 237-250.

Sudha M, Gajanana TM and Murthy DS (2006) Economic impact of commercial hybrid seed production in vegetables in farm income, employment and farm welfare- A case of tomato and okra in Karnataka. Agric Res Rev 19: 251-268.

Verma VK, Jha AK, Chaudhuri P, Singh BK and Roy A (2016) Comparative analysis of production and profitability of seasonal vegetable, tuber and spice crops under the mid-hills of Meghalaya. Veg Sci 43(1): 87-90.

Vegetable Science (2018) 45(2) : 244-248

Nutritive values, dietary antioxidant and seed protein profile of some under-utilized seeds and nuts from ethnic sources

Kandarpa Kalita

Received: January 2019 / Accepted: January 2019

Abstract

Study with seven unrelated and diverse type of non-conventional seeds and nuts, viz. *Trapa natans*, *Nymphaea nouchali, Euryle ferox, Castanopsis argentea, Artocarpus heterophyllus, Nelumbo nucifera* and *Gnetum gnemon* revealed that they are rich in nutritive values and high in calorific values. Crude protein content varied from 4.40-32.08%; carbohydrate content varied from 38.66-77.50%. With calorific values in the range of 317.78 Kcal/100g to 376.62 Kcal/100g, these are high calorie food with low lipid in the range of 0.93% to 6.74%. They are also rich in dietary antioxidant phenolics which varied widely from 1.0-17.6 mg/g. The free amino acid content varied from 4.0-10.66 mg/g. Present study show that that non-conventional seeds and nuts are very rich in nutrient content

Key words: Nutritive value, seeds and nuts, phenolics, non-conventional food plants

Introduction

Edible non-conventional seeds and nuts and their consumption is a centuries old ethnic practice in different tribal areas as well as among rural communities in India and many other countries. These are mostly seasonal supplementary food, while some others are popular delicacy and some others are used as scarcity food at time of famine (Arora and Pandey 1996, Singh et al. 2013). Some non-conventional seeds and nuts like Jackfruit (*Artocarpus heterophyllus)*, Lotus (*Nelumbo nucifera*), Makhana (*Euryle ferox*), Chestnut (*Castanopsis argentea*), Water chestnut (*Trapa natans* var. *bispinosa*), Mokua (*Nymphaea nouchali*), Gnetum (*Gnetumgnemon*), etc are sold in rural as well as urban market as low cost food item. This is an indication of their consumer acceptance and popularity. Unlike conventional food plants like paddy, wheat, pulses etc they do not come from organized cultivation; rather they are collected from wild, semi-wild habitat, while few are grown in backyard of rural household and hence considered as non-conventional food plants. Although they are part of traditional knowledge and ethnic culture, yet scientific scrutiny about them are scarce. In the absence of scientific scrutiny there is a general tendency to look them down as nutritionally poor and unimportant with little or no contribution to food security system. In the backdrop of growing awareness about bio-resources and growing fear of food crisis, it is important to assess such little known non-conventional seeds and nuts for their nutritive and other values including characterization. This is likely to widen our food base and contribute to our food basket.

Nalbari College, Nalbari, Assam
Corresponding author's Email: kandarpanc@gmail.com

Materials and Methods

Non-conventional seeds and nuts of seven different and diverse plant species were collected from their natural habitat for the present study. These are– *Trapa natans* (Water chestnut or Pani singhara, Trapaceae)- a free floating aquatic herb with blackish or purple coloured triangular nut with soft, white, fleshy kernel inside. *Nymphaea nouchali* (Mokua, Nymphaeaceae)- an aquatic herb with globose fruit that contain numerous blackish seeds embedded within pulpy mesocarp that constitute the edible part. *Castanopsis argentea* (Chest nut, Fagaceae)- a tall tree growing at an altitude of about 5000 ft. in Meghalaya and Nagaland. The nuts, little bigger than pea, is covered with soft spine at growing stage but fall off after maturity. The local tribals roast the mature nuts following which it become completely free of the spiny structures and the surface become smooth. It is popularly referred to as groundnut substitute for its similarity in taste with groundnut. *Artocarpus heterophyllus* (Jackfruit, Moraceae) is an evergreen tall

tree. Jackfruit seeds are consumed as delicacy and as potato substitute. *Nelumbo nucifera* (Lotus, Nympheaceae)– well known aquatic plant, known as India's national flower. *Gnetum gnemon* (Gnetum, Gnetaceae)– a rare type of gymnosperm and perennial shrub that grow as undergrowth in forest. All these seeds and nuts are sold in local market and road side. Moreover, for the present study they were collected from their natural habitat.

Nutritive values were analysed in terms of major nutritional components (AOAC 1975). Freshly collected seeds or nuts were manually dehusked, cleaned and cut into fine pieces. The samples were dried overnight at room temperature and then dried in hot air oven at a constant temperature of 60 °C till constant weight was recorded. The dried samples were grounded into fine powder in a mortar and pestle. Crude protein was estimated by microkjeldahl method (Bagchi at el. 2004). Total carbohydrate was estimated by anthrone method outlined by Clegg (1956). Total soluble sugar from the sample was extracted with warm 80% ethanol. Subsequently ethanol was removed by evaporation and the residual extract was dissolved in distilled water. Estimation was made as per the anthrone method. Lipid content was determined by extracting the sample with petroleum ether for eight hours in Soxhlet apparatus and then removing the solvent by fractional distillation (Bagchi at el. 2004). Crude fibre in the sample was determined as per the protocol of Sadasivam and Manickam (1992). Total mineral in the form of ash content was determined by ashing the sample at 60^0C for three hours (Bagchi at el. 2004). The data were recorded as percentage of dry weight and calorific values were computed using the formula of Sherman (1952). Free amino acids were extracted with 80% warmethanol and quantified by spectroscopic method (Gopalan et al. 1995). Total phenolics were estimated spectroscopically using Folin-Ciocalteu as chromogenic reagent and gallic acid as standard (Gopalan et al.1995). Seed protein profile was analysed by the standard SDS-PAGE technique outlined by Laemmli[7] using 12% separating gel and 4% stacking gel. For Lotus, Jackfruit and Water-chestnut seed protein was extracted with 0.3M tris-HCL (pH 6.5) and for the rest 0.2M phosphate buffer (pH 7.5) was used as extraction buffer. The extraction buffers were selected by trial and error process. For determination of molecular weight, standard protein maker (PMW-M, Bangalore Genei) was co-electrophoresed.

Results and Discussion

Wide variation has been observed for protein content among the species *T. natans* which is a popular delicacy and fetch reasonable price in the local market has 10.04% protein which is reasonable. Jack fruit seed is traditionally used as potato substitute or potato equivalent and it has 15.0% protein which is far more superior to potato which has only 4.0 – 6.3% protein(8). Nuts of *C. argentea* and seeds *G. gnemon* are popular in hilly states of North-East India as a delicacy like roasted groundnuts. While *C. argentea* nut has poor level of protein with 4.4%, *G. gnemon* has a reasonable amount of proteins with 14.78%. But lotus seeds are most outstanding with 32.08% which is higher than any pulse grain except Soyabean. It is noteworthy that except *T. natans* and *N. nouchlai* seeds and nuts can be stored for long time with proper drying which brighten the prospect of organized cultivation of those underutilized seeds and nuts. All the seeds and nuts can be eaten raw or after cooking or roasting except Jackfruit whose seeds are consumed only after cooking. Like protein, total carbohydrate and total soluble sugar also exhibited wide variation. Among them *T.natans* is characterized by high level of total carbohydrate (70%) and as well as total soluble sugar (6.0%). Soluble sugar mostly comprises of monosaccharide which are readily utilized by body and hence are advantageous from nutritional view point. Jackfruit seed contains high amount of lipid (6.74%) which is thehighest in the present study. On the other hand popular delicacy water-chestnut has very low lipid content with 0.93%. Lotus seed however, contain reasonable amount of lipid (3.86%). Compared to others *N. nouchali* has much higher amount of crude fiber with 10.32% which is remarkable considering that most conventional seed and nuts contain low level of crude fiber (Table 1). Lotus seed also had reasonable amount of crude fiber (4.075%). Crude fiber is not a constituent of food in the true sense since it is not digested. Importance crude fibre in human nutrition is well known (Ladizinsky and Hymowitz 1997). In fact, a daily intake of 40g dietary fiber is recommended by Indian Council of Medical Research. In the present study except *N.nouchali* and lotus, others are poor in crude fiber. Lotus seed has been found to have a high level of total mineral in the form of ash content with 4.19% which is remarkable. By contrast conventional food grains contain much lower ash content compared to lotus seeds (Ladizinsky and Hymowitz 1997). Except *E.ferox* (0.35%) others have reasonable amount of ash content. Calorific values have been found to be high and impressive in the range of 317.78 Kcal/100gm in lotus to 376.62/100gm in Jackfruit seed with the exception of *N.nouchali* with 274.22 Kcal/100g (Table 1, Fig 1). Therefore these seeds and nuts can be considered as energy food with low fat which should be ideal for changing urban food habit. Like soluble sugar free amino

Table 1: Major nutritional components (% Dry Weight Basis) and Calorific Values of non-conventional seeds and nuts (± standard error of mean)

Common name	Crude protein (% dry wt.)	Total Carbohydrate (% dry wt.)	TSS (% dry wt.)	Lipid (% dry wt.)	Crude fibre (% dry wt.)	Ash content (% dry wt.	Calorific value (Kcal/100g)
T. natans (Water chestnut)	10.04 ±0.017	70 ±0.513	6 ±0.106	0.93 ±0.020	1.75 ±0.063	1.3 ±0.041	328.56
N. nouchali (Mokua)	9.62 ±0.036	51.66 ±0.038	0.9 ±0.020	3.23 ±0.073	10.32 ±0.166	1.37 ±0.35	274.22
E. ferox (Makhana)	11.57 ±0.134	70.5 ±0.620	1.2 ±0.017	1.9 ±0.041	0.35 ±0.018	0.35 ±0.028	345.4
C. argentea (Chestnut	4.4 ±0.149	77.5 ±0.416	1.55 ±0.066	2.63 ±0.064	1 ±0.02	1.14 ±0.026	351.32
A.heterophyllus (Jackfruit)	15 ±0.089	64 ±0.0655	5.06 ±0.090	6.74 ±0.120	2.6 ±0.044	1.42 ±0.040	376.62
N. noucifera (Lotus)	32.08 ±0.018	38.66 ±0.066	2.7 ±0.036	3.87 ±0.081	4.08 ±0.071	4.2 ±0.056	317.78
G.gnemon	14.78 ±0.0444	66.87 ±0.121	1.6 ±0.026	1.63 ±0.028	1.41 ±0.032	1.1 ±0.0.0330	341.3
CD at p=0.05	0.241	1.584	2.202	0.289	0.335	0.129	
CD at p=0.01	2.202	0.289	0.335	0.129	0.053	0.33	

acids can be considered as an index of nutritive value since it is readily absorbed and metabolized by body. Lotus seeds have been found to be best in the present study with 10.6 mg/gm. Among the rest *C.argentea* and *G.gnemon* also contain impressive amount of free amino acid with 8.0 and 8.2 mg/g respectively. Good amount of free amino acid is also reported for some underutilized crop seeds (Laemmli 1970). Dietary antioxidants which among others include phenolics are gaining increasing importance in recent times for their ability to scavenge free radicals (Naik and Kole 2002). They serve as exogenous non-enzymatic anti-oxidants as dietary components to reduce the risk of cancer, diabetes, coronary heart diseases and age associated oxidative stress (Prakash et al. 1988, Sherman 1952). There are reports that life style changes, mental stress, alcoholism, nicotinism, pollution, radiation etc. also increase free radical generation in the body (Tiwary 2002). In the present study, impressive amount phenolics have been recorded for *N. nouchali* (17.6 mg/g) and *G.gnemon* (11.1 mg/g). Lotus seed also contained reasonable amount of phenolics with 7.0 mg/g. Subhasree et al. (2009) working with four leafy vegetables and Guleria et al. (2011) working with 16 herbs with medicinal values reported very impressive amount of antioxidants, phenolics and flavonoid and their efficacy were confirmed by in vitro assay. The findings of the present study are in conformity with theses earlier reports and substantiate the veracity of traditional knowledge. Hence, such impressive amount of dietary antioxidants imparts nutraceutical value to these nuts and seeds.

Table 2: Protein profile of seeds and nuts of seven species resolved in 12% acrylamide gel

Species	Total proteins	Individual Protein with molecular weight (Kd)
T. natans	10	91.2, 74.0, 61.8, 54.7, 43.7, 41.0, 32.6,26.5, 22.0, 19.5
		No prominent band found
N. nouchali		No protein band could be resolved
E. ferox	3	95.5, 66.0, < 14.3
		Most prominent band <14.3
C. argentea	6	75.5, 66.0, 53.2, 41.2, 21.7 <14.3
		Most prominent bands 21.7 and <14.3
A. hetrophyllus	5	51.2, 41.8, 34.5, 23.0, 19.5
		Most prominent bands 23.0 and 19.5
N. nucifera	20	> 99.0 > 99.0 , 99.0, 92.5, 71.0, 66.0, 54.7, 44.3, 43.0, 41.0, 37.5
		31.7, 26.5, 23.8, 22.4, 20.4, 19.0, <14.3, <14.3,<14.3
		Most prominent bands 92.2, 71.6 and 31.7
G. gnemon	4	92.2, 71.6, 61.4, 31.4
		Most prominent band 31.4

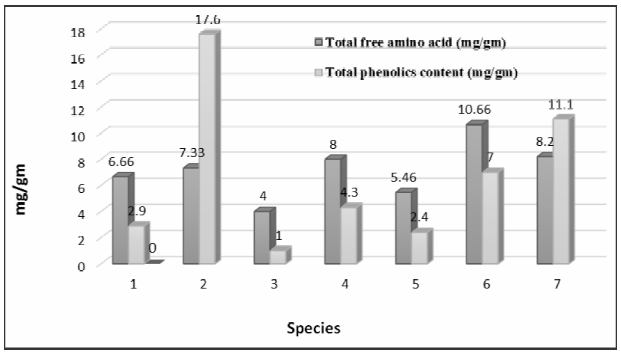

Figure: 1. Bar diagram showing Total free amino acid and Total Phenolics 1. T. natans 2. N. nouchali 3. E. ferox 4. C. argentea 5. A. heterophyllus 6. N. nucifera 7. G. gnemon)

Seed protein profile is widely recognized as a reliable tool for plant germplasm characterization for their stability and reproducibility (Yildrim et al. 2000) and can reveal intraspecific and interspecific variation that help to resolve taxonomic and evolutionary problems. Seed protein profile was found to be highly heterogenous. Highest polymorphism was found in lotus with 20 proteins in the size range of >99.0 to <14.3 Kd with the one of 31.7 Kd being most prominent. *T. natans* also exhibited considerable polymorphism with 10 proteins in the range of 91.2 to 19.5 Kd (Table 2). The remaining four exhibited low degree of polymorphism in the range of 3 to 6 protein bands. No protein band was visible in *N. nouchali*. Probably, the extraction buffer used was ineffective. The protein profile shows that no two species have any close similarity. However all the species in the present study were unrelated phylogenetically from classical taxonomic view. Molecular analysis in terms of seed protein profile also corroborates this (Table 2).

Present study shows that contrary to general belief, non-conventional seeds and nuts are nutritionally very rich with high calorific value. Particularly lotus seeds are outstanding with 32.08% which is possibly second highest next to Soybean among seeds and seed grains. The dried powder of Lotus seed therefore can be blended with processed food to enhance their nutritive values. Lotus is famous for being India's national flower but with rich nutritive and nutraceuticals value of its seed particularly high protein content; it can be added to our food basket. Jackfruit seed, which is essentially a by-product and popular as potato substitute, is in fact superior to potato with 15.0% protein. All the seeds and nuts in the present study are low in fat content which fits well with modern urban trends and requirements for low fat consumption. Being rich in free amino acids and particularly dietary antioxidants phenolics, they possess remarkable nutraceutical value. Thus nonconventional seeds and nuts should give priority in research and developmental activities.

सारांश

वर्तमान अध्ययन में सात असंबंधित एवं विविध प्रकार के गैर पारम्परिक बीज व गिरी जैसे– *ट्रापा नाटान्स, निम्फिया नौचाली, यूरीली फेराक्स, कैस्टानोप्सीस अरजेन्टिया, आर्ट्रोकारपस हेटेरोफिलस, निलम्बो न्यूसीफेरा* तथा *ग्नेटम ग्नीमोन* को सम्मिलित किया गया, जिनमें पोषक मूल्य व उष्मीय मान अधिक होता है। इनमें अपक्व प्रोटीन की विविध मात्रा 4.40–32.08 प्रतिशत तथा कार्बोहाइड्रेट की विविध मात्रा 38.66–77.50 प्रतिशत पाया गया। उष्मीय मान सीमा 317.78 केसीएल/100 ग्राम से 376.62 केसीएल/100 ग्राम तथा लिपिड सीमा 0.93 से 6.74 प्रतिशत पाया गया। इनमें खाद्य आक्सी–प्रतिकारक फिनोलिक की विविधता 1.0–17.6 मिग्रा./ग्राम पाया गया। इसके अलावा इनमें मुक्त एमिनो एसीड की मात्रा सीमा 4.0–10.66 मिग्रा0/ग्राम पाया। वर्तमान अध्ययन से स्पष्ट होता है कि गैर पारंपरिक बीजों एवं गिरी में पोषक तत्वों की मात्रा अधिक होती है।

Reference

AOAC (1975) Official Methods of Analysis 2nd Edition. Association of Official Analytical Chemists, Washington DC

Arora RK and Pandey A (1996) Wild Edible Plants of India: Diversiity, Conservation and Use. National Bureau of Plant Genetic Resources, New Delhi

Bagchi D, Sen CK, Bagchi M and Atalay M (2004) Anti-angiogenic, antioxidant and anticarcinogenic properties of a novel anthocyanin rich berry extract formula. Biochem 69: 75-80

Clegg M (1956) The application of anthrone reagent to the estimation starch in cereals. J Food Sci Agric 7: 40-44

Gopalan GB, Rama Sastry V and Balasubramanium SC (1989) ,Nutritive Values of Indian Foods. National Institute of Nutrition, Hyderabad.

Guleria S, Tiku AK, Singh G and Rana S (2011) Characterization of antioxidant activity of twenty selected medicinal plants growing in North Western Himalaya. Indian J Agric Biochem 24(2): 117–122.

Handique AK (2003) Nutritive values of some non-conventional leafy vegetables from ethnic sources of North East India. Crop Res 26(2): 361-364.

Kaplan M, Mutlu EA, Benson M, Fields JZ, Banan A and Keshavarzian A (2007) Use of herbal preparations in the treatment of oxidant mediated inflammatory disorder. Theor Med 15(3): 207–216.

Ladizinsky G and Hymowitz J (1979) Seed protein electrophoresis in taxanomy and evolutionary studies. Theor Appl Genet 54: 145 – 151

Laemmli UK (1970) Cleavage of structural proteins during the assembly of head of bacteriophage T 4. Nature 227: 680-685.

Naik BS and Kole C (2002) Inheritance of seed protein expression in mungbean, Indian J Genet 62(1): 79-80.

Prakash D, Jain RK and Mishra PS (1988) Amino acid profile of some under-utilised seeds. Plant Food Human Nutri 38: 235-241.

Sadasivam S and Manickam A (1992) Biochemical Methods for Agricultural Science. Wiley Eastern Ltd New Delhi

Sherman HC (1952) Chemistry of Food and Nutrition. The Macmillan Company, New York.

Singh BK, Pathak KA and Ramakrishna Y (2013) Underutilized vegetable crops and spices of Mizoram: need exploration and utilization. In: Developing the Potential of Underutilized Horticultural Crops of Hill Regions (Prakash N, Roy S S, Sharma P K and Ngachan S V Eds.). Today & Tomorrow's Printers and Publishers, New Delhi, pp 217-232.

Subhasree B, Baskar R, Laxmi Keerthana R, Lijina Susan R and Rajasekaran P (2009) Evaluation of antioxidant potential in selected green leafy vegetables. Food Chem 115: 1213-1220.

Tiwary AK (2001) Imbalance in antioxidant defense and human disease: Multiple approach of natural antioxidant therapy. Curr Sci 81: 1179-1187.

Wang ZY (2005) Impact of anthocyanin from *Malva sylvestris* on plasma lipid and free radical. J Forest Res 16: 228-232.

Yildrim A, Mavi A, Oktay M, Kara AA, Algur OF and Bilalogu V (2000) Comparison of antioxidant and antimicrobial activities of tilia (*Tilia argentea* Desf Ex DC), sage (*Saliva triloba* L.) and black tea (*Camelia sinensis*) extracts. J Agric Food Chem 48: 5030-5034.

Vegetable Science (2018) 45(2) : 249-253

Effect of exogenous application of phytohormones and fungicides on yield, quality storability and economics of garlic (*Allium sativum* L.)

Munshi Ram, Satesh Kumar*, Sandeep Chopra, Manoj Kumar and RK Gupta

Received: October 2018 / Accepted: January 2019

Abstract

In garlic, compactness, firmness and healthy state are important quality attributes that determine market value and consumer preference. Phytohormones (cycocel and ethrel) and fungicides (carbendazim and benomyl) are known to play important role in checking post-harvest losses like physiological weight in loss (PLW), rotting, sprouting etc in long stored crops. Main aim of the study was to investigate the effects of their preharvest application on growth, yield, quality and storability of garlic cv. Agrifound Parvati. Results suggested that exogenous application of CCC at 1000 ppm applied at 90 days (bulb development stage) and 150 days (50% neck fall stage) significantly increased growth and yield related parameters in garlic. This hormone maintained higher levels of sulphur content after harvest, which proved helpful in reducing PLW of bulbs significantly during ambient storage period of 4 months. Economically, cost benefit ratio in this treatment was high, both at harvest and after storage as compared to other treatments and control. Fungicides on the other hand, had more or less similar effect on growth and yield parameters but showed significant effect on post-harvest losses of garlic as compared to control. Hence, application of CCC at critical stages of alliums can be tried for reducing post-harvest losses during long periods of ambient storage.

Key words: Garlic, phytohormones, fungicides, yield, quality, storability, economics**.**

Introduction

India produced 16.93 lakh MT of garlic over an area of 3.2 lakh ha during 2016-17 (Anonymous 2018). J&K state has a commendable area under Allium production but in spite of that, per capita availability of garlic is quite low because of post-harvest losses which account for about 25% to 30% of production as per ICAR Vision 2030. Besides, quality of a sizable quantity of produce also deteriorates by the time it reaches the consumer. This is mainly because of perishable nature of the produce which requires maintaining the quality and extending the shelf-life, if consumption is not meant immediately after harvest. Due to excessive post-harvest losses, the farmers are forced to sell garlic immediately after harvest which results in low price realization. Garlic bulbs are normally stored at ambient temperatures after harvest (April-September) and there is a sequence of physiological and biochemical changes occurring in the bulbs during this period. These months experience high temperatures and relative humidity which cause heavy damage and physiological loss in weight at rapid rates. To check these losses, phytohormones like CCC and ethrel can improve/ modify the growth of plants and help in maintaining biochemical and physiological state of the bulbs at harvest and during storage (Grossman 1990 and Moore 1980). These hormones are organic substances, which are produced naturally in plants, synthesised in one part and usually translocated to other part where in every small quantity affect the growth and other physiological function of the plants (Thimone 1948).Exogenous application of growth hormones have shown good results in other crops with respect to growth, yield and storage (Prakash et al. 2003 and Memane et al. 2008).

Long storage of bulbs also promotes storage rots, surface moulds caused by *Aspergillus* and *Penicillium* spp. (Gubb and MacTavish 2002). Fungicides like carbendazim and benomyl have greatly facilitated the maintenance of bulb quality in storage with respect to sprouting and rot losses. These chemicals are often used to control fungal infections in vegetable seeds and other crop seeds during storage. Keeping in view the above mentioned problems, the present study was conducted to observe and evaluate the effect of some pre-harvest treatments of phyto-hormones and fungicides in

Division of Vegetable Science and Floriculture, SK University of Agricultural Sciences and Technology, Jammu Main Campus, Chatha-180 009, J&K

*Corresponding author, Email: sks.vegetable@gmail.com

increasing yield, quality and storage life of garlic bulbs under subtropical conditions.

Materials and Methods

The present investigation was carried out at Advanced Centre for Horticultural Research, Udheywalla, SKUAST, Jammu during 2015-16.The area falls in subtropical zone of Jammu and Kashmir $32^0 40^1$ North Latitude and 74^0 58^1 East longitudes at an elevation of 332 m above mean sea level. Pre-harvest sprays with two fungicides and two growth regulators, each at different levels, were applied to garlic variety Agrifound Parvati (G-313). Sowing of cloves was done at a spacing of 15x10cm in a plot size of 2.0m×2.0m. Plant hormone solutions were prepared fresh and sprayed twice i.e., at 90 days (bulb development stage) and 150 days (50% neck fall) during morning hours for effective absorption. Fresh stock of cycocel (1200 ppm) and ethephon (3000 ppm) were prepared by diluting the required quantity of each hormones i.e. CCC (3.6 ml) and ethephon (6 ml) in 3 liters of distilled water twice at two different sprays. Hormone CCC was first dissolved in 5 ml acetone (99%) and then diluted as per the concentration. In control plots only distilled water was used.Tween-20@ 1ml/litre of plant hormone was added for sticking purpose. There were total thirteen treatment combinations such as T1 (Carbendazim@800 ppm), T2 (Carbendazim @1000 ppm), T3 (Carbendazim @1200 ppm), T4 (Cycocel @800 ppm), T5 (Cycocel @1000 ppm), T6 (Cycocel @1200 ppm), T7 (Ethrel@ 1000 ppm), T8 (Ethrel@ 2000 ppm), T9 (Ethrel @3000 ppm), T10 (Benomyl@ 1000 ppm), T11(Benomyl@ 1200 ppm), T12 (Benomyl @1500 ppm), and T13 (Distilled water spray as control). The experiment was conducted in RBD design in three replicates with 13 number of treatments and data with respect to growth, yield, quality and storability was tabulated and analyzed as suggested by Gomez and Gomez (1984).

Results and Discussion

Growth and yield parameters: Plant height ranged between 31.42 to 37.72 cm among 13 treatments (Table 1) which was highest (37.72cm) in treatment having T_3 (Carbendazim @1200 ppm) and was statistically at par with T_{13} (37.58 cm), T_{10} (36.99cm), T_2 (36.80cm), T_5 (36.48cm), T_{11} (36.04cm), but was statistically superior to T_7 (33.84cm), T_8 (33.07 cm) and T_9 (31.42 cm). Reduction in plant height in all the ethrel treatments might be due to slowing down of cell division and reduction in cell expansion. Ethrel (2-chloroethyl phosphonic acid) helps in promoting epinasty, inhibit growth and retard transverse cell division particularly in cambium which is the zone of meristematic activity at the base of internode (Grossman 1990). Similar reports have been quoted by Deotale and Sorte (1996), Mehetre and Lad (1995), Garai and Dutta (2003) in green gram.

The leaf is considered as an important functional unit which contributes to yield through its functional activity. In the present experiment, number of leaves per plant ranged between 11.33-14.22 (Table 1). It was recorded highest (14.22) with cycocel 1000 ppm (T_5)which was statistically at par with cycocel @800ppm (14.13) (T_1), Cycocel @1200ppm (T_6) (13.93), Benomyl @1200 ppm (T_{11}) (13.42), but was statistically superior to rest of the treatments. This might be due to ability of growth retardant cycocel to delay senescence by arresting the chlorophyll degradation and protease activity and promoting the synthesis of soluble protein and photosynthetic enzyme. Canor and Prado (1983), Srivastava and Goswami (1988) also reported that application of cycocel @500 ppm increased the number of leaves in green gram. Lakshmi Narasimhan (2002), Prakash et al (2003), and Hanchinamath (2005) reported increase in the number of leaves by growth regulators in black gram, cluster bean and sun flower. In the present investigation, maximum weight of bulbs (36.66g) with highest yield per hectare (110.60 q/ha) in significantly more number of days after sowing (196.66) was obtained with (T_5) cycocel 1000 ppm (Table 1). This treatment was statistically at par with cycocel @800 ppm (T_4) (36.46 g and 109.5q/ha), cycocel 1200 ppm (T_3) (36.35g and 108.7q/ha) but was statistically superior to rest of the treatments as well as control. The production of large sized bulbs may be mainly attributed to the fact that CCC remained physiologically more active to build up sufficient food reserves which ultimately led to increased total yields (Memane et al., 2008). Similar findings regarding yield accelerating properties of cycocel have also been reported by Rahim and Fordam (1994) in garlic.

Quality Parameters: Generally, the pyruvate levels of garlic bulbs increased continuously after harvesting although the bulbs are dormant during storage period thereby changing its flavour quality. In the present experiment, sulphur content remained significant and recorded low value with cycocel (1000 ppm) treated bulbs(T_5) (Table 2). This might be attributed to the encouraging effects of cycocel on the utilization of minerals in the leaf metabolism (Pandita and Hooda 1979). Similar results were recorded by Ganie and Solanki (2010). There was a gradual increase in total sugar content in all the treatments during the storage period. The maximum total sugar content of onion has

Table 1: Effect of pre-harvest treatment of phytohormones and fungicides on morphological and yield parameters of garlic

Notation	Treatments	Plant height (cm)	Number of leaves per plant	Days to harvest	Average bulb weight (g)	Yield per ha (q)	B: C ratio
T_1	Carbendazim@800 ppm	36.48	13.12	192.00	33.90	92.40	2.66
T_2	Carbendazim @1000 ppm	36.80	13.02	192.00	33.57	90.20	2.57
T_3	Carbendazim @1200 ppm	37.72	13.25	192.33	33.03	86.70	2.43
T_4	Cycocel @800 ppm	34.89	14.13	194.00	36.46	109.50	3.26
T_5	Cycocel @1000 ppm	33.97	14.22	196.66	36.63	110.60	3.28
T_6	Cycocel @1200 ppm	33.64	13.93	192.66	36.35	108.70	3.19
T_7	Ethrel@ 1000 ppm	33.84	11.80	186.00	30.83	72.00	1.72
T_8	Ethrel@ 2000 ppm	33.07	11.60	181.33	29.25	61.50	1.22
T_9	Ethrel @3000 ppm	31.42	11.33	180.66	27.55	50.20	0.73
T_{10}	Benomyl@ 1000 ppm	36.99	13.18	192.66	33.01	86.60	2.42
T_{11}	Benomyl@ 1200 ppm	36.04	13.42	193.33	33.61	90.50	2.56
T_{12}	Benomyl @1500 ppm	35.33	13.27	192.66	33.93	92.70	2.64
T_{13}	Distilled water spray (control)	37.58	13.33	193.33	33.68	91.00	2.62
	SEM±	0.93	0.39	0.83	1.14	2.24	-
	CD(P = 0.05)	2.74	1.13	2.43	3.36	7.61	-

Table 2: Effect of pre-harvest treatment of phytohormones and fungicides on quality parameters of garlic

Notation	Treatments	Dry matter (%)	Sulphur content (μ moles pyruvate/g of tissue)	TSS (°B)	Total sugars (%)
T_1	Carbendazim@ 800 ppm	50.50	76.62	28.43	11.34
T_2	Carbendazim@ 1000 ppm	51.42	77.38	28.49	11.06
T_3	Carbendazim@ 1200 ppm	50.70	76.79	28.87	11.00
T_4	Cycocel@@ 800 ppm	51.32	79.62	29.00	12.30
T_5	Cycocel @1000 ppm	50.60	80.39	28.80	12.78
T_6	Cycocel @1200 ppm	50.74	80.12	28.66	12.59
T_7	Ethrel@ 1000 ppm	51.18	74.04	29.26	13.10
T_8	Ethrel@ 2000 ppm	50.43	73.19	28.53	13.53
T_9	Ethrel@ 3000 ppm	51.04	73.17	29.90	13.74
T_{10}	Benomyl@ 1000 ppm	51.44	76.72	28.36	11.47
T_{11}	Benomyl@ 1200 ppm	50.15	76.86	29.33	11.28
T_{12}	Benomyl@ 1500 ppm	50.81	76.85	28.20	11.06
T_{13}	Distilled water spray(control)	51.15	74.42	28.83	11.51
	SEM±	0.46	0.44	0.71	0.61
	CD (P = 0.05)	N.S.	1.31	2.16	1.27

been reported to be positively correlated with the ratio of sucrose to monosaccharaides and keeping quality of bulbs during storage (Patil and Kale 1989). Islam et al. (2007) and Dhotre (2009) reported that as bulb weight and diameter loss increased cumulatively, the garlic bulb TSS, pungency and dry matter content decreased, which reduced its quality with decreased shelf life. However, the present study showed contrary results, thus established positive links of CCC with quality parameters of garlic.

Storage Parameters: In the present investigation, sprouting, rotting and physiological loss in weight showed significant values. The minimum loss in weight of garlic during storage is considered one of the most desirable factors to increase storage life. In the present investigation, lowest physiological loss in weight was recorded with cycocel 1000 ppm (T_5) (Table 3). The highest physiological loss in weight was recorded in control. The highest physiological loss in weight in control may be attributed to more respiration and transpiration. In case of sprouting, lowest value was recorded with ethrel 3000 ppm treated bulbs (T_9) which might be due to more integrity and less moisture loss from bulbs. The highest sprouting in control might be attributed to more aeration and wide fluctuation in storage temperature. Chope et al. (2006) reported significant changes during storage of onions and concluded that ratio of monosaccharide to disaccharides and concentrations of zeatin riboside are important factors in discriminating between sprouting and pre sprouting of bulbs. Stage of bulb development, premature defoliation, and skin integrity conditions during growth, maturation, harvesting, curing and storage are main factors contributing to quality of bulbs in postharvest

Table 3: Effect of pre-harvest treatment of phytohormones and fungicides on sprouting loss, rot loss and PLW of garlic

Notation	Treatments	Sprouting loss (%)	Rot loss (%)	PLW (%)
T_1	Carbendazim@ 800 ppm	12.53	9.96	17.61
T_2	Carbendazim@ 1000 ppm	11.96	9.07	17.37
T_3	Carbendazim@ 1200 ppm	12.02	9.25	16.93
T_4	Cycocel @800 ppm	12.16	11.69	15.35
T_5	Cycocel @1000 ppm	11.40	10.75	14.52
T_6	Cycocel @1200 ppm	11.31	10.88	14.93
T_7	Ethrel @1000 ppm	9.46	12.24	17.41
T_8	Ethrel@ 2000 ppm	9.35	14.03	16.99
T_9	Ethrel@ 3000 ppm	9.16	15.66	16.79
T_{10}	Benomyl@ 1000 ppm	14.27	10.27	18.78
T_{11}	Benomyl @1200 ppm	13.74	9.20	18.40
T_{12}	Benomyl@ 1500 ppm	11.49	9.48	18.73
T_{13}	Distilled water spray(control)	16.15	12.86	22.75
	SEM±	0.79	0.23	0.04
	CD (P = 0.05)	2.29	0.68	0.88

Note: Cumulative data after125 days (4 months) of storage under ambient conditions

storage. Rotting is another aspect in pre-harvest storage of garlic and among the pre harvest treatments lowest rotting loss in weight was recorded with carbendazim 1000 ppm(T_2) which was at par with cycocel 1000 ppm (T_5). The highest rotting was recorded in control (T_{13}). The least rotting in pre-harvest carbendazim treatment may be attributed to anti- fungal properties of carbendazim in reducing rotting.

Economics: In the present investigation, highest cost benefit ratio of 3.28 was recorded with cycocel treatment at 1000 ppm (T_5) which resulted in highest yield per hectare (110.60 q/ha) (Table 2). The possible reason for higher yield is directly correlated with increased bulb weight and possibly of reduced rotting of bulbs in the field. During storage, a significant effect of pre-harvest application of growth hormones and fungicides was recorded with respect to the reduction of storage losses of bulbs (Table 4). The sale rate of garlic at the time of sowing had been almost double as compared to the rates, when it is harvested. Hence, CCC proved significantly helpful in the saving of precious propagating material of garlic for next sowing with a sale rate of Rs/150.00 per kg. Among all the treatments tested,CCC @ 1000 ppm application (T_5) recorded less post-harvest losses resulted in saving of 63.33% of the bulbs after 4 month of ambient storage as compared to 42.24% in control (T_{13}). By this treatment, an additional benefit in terms of returns per rupee spent was recovered (1.54) as compared to control (1.18) (Table 4).The findings of Abdul, 1988 are inconformity with the present study.

Table 4: Economics of pre harvest treatments of phytohormones and fungicides on stored bulbs of garlic

Particulars	Treatments												
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}
Cost of pre harvest spray (Rs)	5.84	6.92	8.63	30.68	37.97	46.37	108.33	253.66	466.14	15.66	17.17	20.97	0.00
Cost of bulbs per quintal (Rs)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
Cost of storage per quintal (Rs)	50	50	50	50	50	50	50	50	50	50	50	50	50
Cost of handling per quintal (Rs	20	20	20	20	20	20	20	20	20	20	20	20	20
Cost of marketing per quintal (Rs)	50	50	50	50	50	50	50	50	50	50	50	50	50
Total expenditure (Rs)	6125.8	6126.90	6128.60	6150.60	6157.90	6166.30	6228.30	6373.60	6586.10	6135.60	6137.10	6140.90	6120.00
Total saleable bulbs (kg)	59.9	61.60	61.80	60.80	63.33	62.88	60.89	59.63	58.39	56.68	58.66	60.30	48.24
Gross returns @ 150/kg	8985.0	9240.0	9270.00	9120.00	9499.50	9432.00	9133.50	8944.50	8758.50	8502.00	8790.00	9045.00	7236.00
Net Returns (Rs)	2859.2	3113.1	3141.40	2979.40	3341.60	3265.70	2905.20	2570.90	2172.40	2366.40	2661.90	2904.10	1116.00
B:C ratio	1.46	1.50	1.51	1.48	1.54	1.53	1.47	1.40	1.33	1.39	1.43	1.47	1.18

Note: Rate of carbendazim = Rs 520/kg, Cycocel =Rs 700/100ml, Ethrel= Rs1300/100 ml, Benomyl=Rs1080/kg

सारांश

लहसुन में कसावट, दृढ़ता और स्वस्थ अवस्था महत्वपूर्ण गुणवत्ता घटक हैं जो बाजार मूल्य और उपभोक्ता वरीयता निर्धारित करते हैं। पादप वृद्धि कारकों (साइक्लोसेल और एथ्रेल) और कवक नाशकों (कार्बेन्डाजिम और बेनोमाइल) को फसल के बाद नुकसान की जाँच में महत्वपूर्ण भमिका निभाने के लिए जाना जाता है जैसे नुकसान (पी.डल्लू.एल.), लम्बे समय से संग्रहित फसलों में फटना, सड़ना आदि। अध्ययन का मुख्य उद्देश्य लहसुन (किस्म एग्रीफाउंड पार्वती) की वृद्धि, उपज, गुणवत्ता और भण्डारण क्षमता पर उनके खुदाई पूर्व प्रयोग के प्रभवों की जाँच करना था। परिणामों से स्पष्ट हुआ कि 90 दिनों (कंद विकास अवस्था) और 150 दिनों (50 प्रतिशत ग्रीवा के गिरने की अवस्था) पर 1000 पीपीएम सीसीसी के बहिर्जात प्रयोग से लहसुन में वृद्धि और उपज संबंधी मापदंडों में काफी वृद्धि होती है। इस पादप वृद्धि कारक ने फसल के बाद गन्धक सामग्री के उच्च स्तर को बनाए रखा, जो 4 महीने की परिवेशी भण्डारण अवधि के दौरान कंदों के पी.एल.डब्लू. को कम करने में मददगार साबित हुआ। अन्य उपचारों और नियंत्रण की तुलना में आर्थिक रूप से, इस उपचार में लागत लाभ अनुपात, दोनों कटाई और भण्डारण के बाद अधिक था। दूसरी ओर कवकनाशकों का विकास और पैदावार मापदंडों पर कमोबेश समान प्रभाव था लेकिन नियंत्रण की तुलना में लहसुन की फसल के बाद के नुकसान पर महत्वपूर्ण प्रभाव दिखा। इसलिए, लम्बी अवधि के भण्डारण के दौरान फसल कटाई के बाद के नुकसान को कम करने के लिए लहसुन के महत्वपूर्ण धरणों में सीसीसी 1000 पीपीएम के प्रयोग की कोशिश की जा सकती है।

References

Anonymous (2018) National Horticulture Database. Ministry of Agriculture and Farmers Welfare Government of India, Institutional Area, Gurugram-122015, Haryana.

Abdul RYI (1988) The effect of pre-harvest foliar spray with maleic hydrazide and postharvest curing period on storage losses of onion (*Allium cepa* L.) stored at different temperature. PhD Thesis, University of Agricultural Sciences, Bangalore.

Canor P and Prado MR (1983) Effect of mepiquat chloride on the cotton plant (*Gossypium hirsutum* L). Agriculture Tecnica on Mexico 9: 35-44.

Chope GA, Terry LA and White PJ (2006) Effect of controlled atmosphere storage on abscisic acid concentration and other biochemical attributes of onion bulbs. Postharvest Biotech 39: 233–242.

Deotale RD and Sorte N D (1996) Effect of TIBA and B-9 on growth parameters, biochemical aspects and yield of soybean. J Soils Crops 6(1): 89-93.

Dhotre M (2009) Studies on genetic diversity and influence of nitrogen sources on performance of Kharif onion (*Allium cepa* var. *cepa* L.). MSc Thesis, UAS, Dharwad-580 005.

Garai AK and Datta JK (2003) Effect of phosphorus sources and cycocel spray on green gram (*Vigna radiata* (L.) Wilczek). Leg Res 26 (1): 15-19.

Ganie NA and Solanki RB (2010) Quality characters of kharif onion as affected by concentration of cycocel, intra row spacing and levels of nitrogen. Intl J Agric Sci 6(1): 46-47.

Gomez KA and Gomez AA (1984) Statistical Procedures for Agricultural Research. 2nd edition, John Wiley and Sons, New York, pp 84-129.

Grossman K (1990) Plant retardants as tools in physiological research. Physio Plantarum 78: 642-648.

Gubb IR and MacTavish HS (2002) Onion pre and postharvest considerations. In: Currah, H.D. and Rabinowitch, L. (eds.). Allium Crop Science: Recent advances. CAB International, Wallingford, pp 233-265.

Hanchinamath PV (2005) Effect of plant growth regulators, organics and nutrients on growth physiology and yield in clusterbean (*Cyamopsis tetragonoloba* L). MSc Thesis, UAS, Dharwad, Karnataka.

Islam MK, Alam MF, Islam AKMR (2007) Growth and yield response of onion (*Allium cepa* L.) genotypes to different levels of fertilizers. Bangladesh J Bot 36(1): 33-38.

Lakshmi Narasimhan HP (2002) Influence of growth regulators and boron to enhance seed yield andquality in sunflower hybrid. MSc Thesis, UAS, Dharwad, Karnataka.

Moore TC (1980) Biochemistry and physiology of plant hormone. Naroja Publishing House, New Delhi, pp 107-13.

Mehetre SS and Lad SK (1995) Effect of foliar application of growth substances on growth and yield. Soybean Genet News Letter 22: 132-134.

Memane PG, Tomar RS, Kakade DK, Kulkarni GU and Chovatia RS (2008) Effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum* L.) cv. GG-3. The Asian J Hort 3(1):82-86.

Pandita ML and Hooda RS (1979) Effect of cycocel on growth yield and quality of potato cultivar Kufri Chandramukhi. Haryana J Hort Sci 8: 139-142.

Prakash M, Kumar JS, Kannan K, Kumar MS and Ganesan J (2003) Effect of plant growth regulators on growth physiology and yield of black gram. Leg Res 26(3):183 187.

Patil RS and Kale PN (1989) Screening of onion cultivars for storage quality. Veg Sci 16(1): 56-61.

Rahim MA and Fordham R (1994) Control of bulbing in garlic. Acta Hortic 358: 369-374.

Srivastava GC and Goswami BK(1988) Influence of benzyl adenine on leaf senescence and photosynthesis in sunflower. J Agron Crop Sci 164(1): 23-29.

Vegetable Science (2018) 45(2) : 254-257

Effect of different growing methods and integrated nutrient management systems on yield and yield contributing traits of broccoli [*Brassica oleracea* (L.) *var. italica*]

Rajeev Kumar[1] and Manish Kumar Sharma

Received: November 2018 / Accepted: January 2019

Abstract

Field experiment was conducted in two consecutive summer seasons of year 2016 and 2017 to evaluate effect of different growing methods and integrated nutrient management systems on yield and yield contributing traits of broccoli (*Brassica oleracea var. italica*). Studies employed two growing methods (flat bed & ridges), three biofertilizers levels (No biofertilizers application, *Azospirrillum* spp. & *Psedomonas fluorescence*) and three level of recommended doses of NPK (50%, 75 % & 100 %). Results revealed that ridge method of cultivation, seedling treatment of *Azospirrillum* spp and 100 % recommended dose of NPK has significant direct positive effect on number of leaves, diameter of head, weight of head and yield per ha Interaction effect revealed that ridge method of cultivation, seedling treatment of *Azospirrillum* spp. and 100 % recommended dose of NPK was also statistically at par with the highest treatment combinations for head weight and yield per ha during year 2016 and 2017.

Key words: Broccoli, biofertilizers, higher hills, HP, INM

Introduction

Broccoli [*Brassica oleracea* (L.) *var. italica* Plenck] is an economically important member of family Brassicaceae. It is one of the popular cole crops in Europe, USA and Australia. It is becoming popular among rich people in India because of its low-fat content, high vitamin C and good source of vitamin A, B2 and Calcium Sanwal and Yadav (2005). It also contains Indole 3 carbinol, a chemical which boost DNA repair in cells and appear to block the growth of cancer cells. Due to climatic similarities with European countries, its cultivation is done successfully in the higher hills of tribal districts of Himachal Pradesh. It is cultivated either during main growing season i.e. May to July or after harvesting of Peas during second growing season i.e July to September. Farmers earn remunerative price through contract farming due to its high demand in big cities, luxury hotels and tourist resorts. Flood irrigation is common practice of irrigation in the region. Flat bed method of cultivation results water lodging condition in the field due to flood irrigation. On the other hand, ridge method of cultivation facilitates easy irrigation through furrow channels. Consistent and indiscriminate use of chemical fertilizers had caused serious damage to soil and ecology. Soil micro-organisms play a significant role in regulating the dynamics of organic matter decomposition and the availability of plants nutrient. It is well recognized that microbial inoculants constitute an important component of Integrated Nutrient Management. Biofertilizers are the carrier-based preparations containing beneficial microorganisms in viable state intended for seed, seedling or soil applications. These microbes help to fix atmospheric nitrogen, solubilize and mobilize phosphorus, translocate minor elements like Zinc, copper etc. to the plants, produce plant growth promoting hormones, vitamins and amino acids and control plant pathogenic fungi, thus helping to improve the soil health and increase crop production. Therefore, comparative effect of flat and ridge method of cultivation along with integrated nutrient management was planned to find out its effect on yield and yield contributing traits in broccoli.

Materials and Methods

The present experiment entitled "Effect of different growing methods and integrated nutrient management systems on yield and yield contributing traits of Broccoli (*Brassica oleracea* (L.) *var. italica*)" was carried out at experimental farm of Dr Y S Parmar University of Horticulture and Forestry Krishi Vigyan Kendra Lahaul

Dr YS Parmar University of Horticulture and Forestry, Krishi Vigyan Kendra, Lahaul & Spiti-II, HP

*Corresponding author, Email: rajeev2287@gmail.com

& Spiti-II H.P. during the Year 2016 and 2017. The experiment was laid out in Factorial Randomised Block Design with 18 treatment combinations replicated thrice. The individual plot size was 3 X 1 m having a spacing of 45 X 45 cm. Pusa KTS-1 variety of Broccoli was taken for the trial. Treatment combination comprises of two levels of growing method (flat bed and ridge method), three levels of biofertilizers (No use of biofertilizers, *Azospirrillum*, *Pseudomonas fluorescens*) and three levels of chemical fertilizers (100 % RDF, 75 % RDF and 50 % RDF). The detail of treatment combination is given in Table 1. Seedling dip method of biofertilizers was given at the time of transplanting. Observation were recorded on parameters days taken to head initiation, days taken to marketable maturity, plant height (cm), number of leaves, diameter of head (cm), weight of head (g) and Yield per ha (qt). The data regarding above mentioned characters were averaged and subjected to analysis of variance prescribed by Fisher and Yates (1963).

Table 1: Treatment combinations of fertilizer doses, biofertilizers application and growing method

Treatment combinations	Detail of treatment combinations
F1B0GM1	100% Recommended Dose of NPK + No biofertilizers + Flat Beds
F1B1GM1	100% Recommended Dose of NPK + *Azospirillum* + Flat Beds
F1B2GM1	100% Recommended Dose of NPK + *Psedomonas fluorescence* + Flat Beds
F1B0GM2	100% Recommended Dose of NPK + No biofertilizers + Ridges
F1B1GM2	100% Recommended Dose of NPK + *Azospirillum* + Ridges
F1B2GM2	100% Recommended Dose of NPK + *Psedomonas fluorescence* + Ridges
F2B0GM1	75% Recommended Dose of NPK + No biofertilizers + Flat Beds
F2B1GM1	75% Recommended Dose of NPK + *Azospirillum* + Flat Beds
F2B2GM1	75% Recommended Dose of NPK + *Psedomonas fluorescence* + Flat Beds
F2B0GM2	75% Recommended Dose of NPK + No biofertilizers + Ridges
F2B1GM2	75% Recommended Dose of NPK + *Azospirillum* + Ridges
F2B2GM2	75% Recommended Dose of NPK + *Psedomonas fluorescence* + Ridges
F3B0GM1	50% Recommended Dose of NPK + No biofertilizers + Flat Beds
F3B1GM1	50% Recommended Dose of NPK + *Azospirillum* + Flat Beds
F3B2GM1	50% Recommended Dose of NPK + *Psedomonas fluorescence* + Flat Beds
F3B0GM2	50% Recommended Dose of NPK + No biofertilizers + Ridges
F3B1GM2	50% Recommended Dose of NPK + *Azospirillum* + Ridges
F3B2GM2	50% Recommended Dose of NPK + *Psedomonas fluorescence* + Ridges

Results and Discussion

Direct Effect: Data presented in Table 2 reveal that plant height (cm), number of non-wrapper leaves, diameter of head (cm), weight of head (g) and yield per ha (q) decreased with decrease in fertilizer dose. 100 % recommended dose of NPK recorded maximum values of plant height (47.02 & 45.22 cm), number of leaves (17.57 & 17.50), diameter of head (16.13 & 14.56 cm), weight of head (286.55 & 229.07 g) and yield per ha (141.51 & 113.12 q) during both the years. The probable reason of maximum plant height, maximum number of non-wrapper leaves and yield parameters with highest dose of fertilizer may be due to higher uptake of nitrogen and increased nutrient transport from root to aerial parts and increased rate of photosynthesis and transport of photosynthates. Similar finding of maximum plant height, maximum number of non-wrapper leaves, head diameter, head weight and head yield were observed in cabbage with 100 % recommended doses of fertilizers by Verma et.al. (2014). Among biofertilizers application, significant direct effect was found on all the parameters. Days taken to head initiation (79.42 & 77.48 days) and days to marketable maturity (96.47 & 95.64 days) was earliest with the application of biofertilizer *Pseudomonas fluorescence* during both the years. However, application of biofertilizer *Azospirrillum* spp. recorded maximum values for plant height (47.32 & 45.47 cm), number of non-wrapper leaves (17.96 & 17.74), diameter of head (16.21 & 14.79 cm), weight of head (292.14 & 246.47 g) and yield per ha (144.26 & 121.71 q) during both the years. The microbial inoculants might have accelerated to complete the vegetative growth earlier due to certain growth promoting substances secreted by the microbial inoculants, which in turn, might have to be better root development, better transportation of water, uptake and deposition of nutrients. These results are in close agreement with the findings of Kumari et al. (2015). Growing method has significant effect on days to marketable maturity and number of leaves during both the years. However, its direct significant effect was found on days taken to head initiation during year 2016 and on diameter of head (cm), weight of head (g) and yield (q) during year 2017. Days taken to marketable maturity were earliest (97.10 & 96.20 days) in ridge method of cultivation. Ridge method of cultivation also recorded maximum number of non-wrapper leaves (17.57 & 17.35) during both the years. Same cultivation method was earliest to days taken to head initiation (80.07) during year 2016 and recorded maximum value of diameter of Head (14.30 cm), weight of head (221.05 g) and yield (109.16 q) during year 2017.

Table 2: Direct effect of different growing methods, biofertilizers and doses of chemical fertilizers on yield contributing traits in broccoli var. KTS-1 (2016 & 2017)

Treatment	Days taken to head initiation		Days taken to marketable maturity		Plant height (cm)		No of leaves		Diameter of head (cm)		Weight of head (g)		Yield per ha (q)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Fertilizer Doses														
F1	81.01	79.41	97.91	96.99	47.02	45.22	17.57	17.50	16.13	14.56	286.55	229.07	141.51	113.12
F2	80.94	78.51	97.94	97.01	45.76	44.09	16.28	16.97	14.76	13.72	241.14	212.45	119.08	104.91
F3	80.11	78.61	97.17	96.41	45.92	43.81	17.08	15.82	14.04	12.42	228.65	177.25	112.91	87.53
$CD_{(0.05)}$	NS	NS	NS	NS	0.94	0.95	0.89	0.93	0.93	0.91	29.94	23.68	14.78	11.70
Biofertilizers														
B0	82.25	80.43	99.15	98.22	45.43	43.64	16.36	16.14	14.11	12.71	229.68	179.41	113.42	88.60
B1	80.39	78.62	97.39	96.55	47.32	45.47	17.96	17.74	16.21	14.79	292.14	246.47	144.26	121.71
B2	79.42	77.48	96.47	95.64	45.96	43.99	16.63	16.41	14.63	13.19	234.52	192.89	115.81	95.25
$CD_{(0.05)}$	1.18	1.30	1.15	1.14	0.94	0.95	0.89	0.93	0.93	0.91	29.94	23.68	14.78	11.70
Growing Method														
GM1	81.30	79.37	98.24	97.40	45.89	44.49	16.40	16.18	14.63	12.83	240.51	191.46	118.77	94.55
GM2	80.07	78.32	97.10	96.20	46.58	44.25	17.57	17.35	15.33	14.30	263.71	221.05	130.23	109.16
$CD_{(0.05)}$	0.96	NS	0.94	0.93	NS	NS	0.73	0.76	NS	0.75	NS	19.34	NS	9.55

F1= 100% Recommended Dose of NPK F2= 75% Recommended Dose of NPK F3=50% Recommended Dose of NPK; B0= No biofertilizers B1= *Azospirillum* spp. B2= *Psedomonas fluorescence*; GM1= Growing Method 1 Flat Beds GM2= Growing Method 2 Ridges

Table 3: Interaction effect of different growing method, biofertilizers and doses of chemical fertilizers on yield and yield contributing traits in broccoli var. KTS-1 (2016 & 2017)

Treatment combination	Days taken to head initiation		Days taken to marketable maturity		Plant height (cm)		No of leaves		Diameter of head (cm)		Weight of head (g)		Yield per ha (q)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
F1B0GM1	83.27	81.23	99.67	98.83	45.50	45.73	16.84	16.76	14.50	12.47	231.91	190.86	114.52	94.25
F1B1GM1	79.33	77.43	96.33	95.44	48.00	45.33	17.24	17.10	17.67	15.47	319.73	255.77	157.89	126.30
F1B2GM1	79.50	77.57	96.50	95.61	47.17	46.00	17.43	17.40	16.17	14.03	284.19	232.05	140.34	114.59
F1B0GM2	82.60	81.53	99.60	98.50	46.80	43.40	19.29	19.26	15.80	14.90	304.72	231.97	150.48	114.55
F1B1GM2	81.67	80.33	98.67	97.78	47.00	46.33	18.78	18.64	16.00	14.87	306.15	246.35	151.18	121.65
F1B2GM2	79.67	78.33	96.67	95.78	47.67	44.50	15.87	15.81	16.67	15.60	272.61	217.42	134.62	107.37
F2B0GM1	83.63	81.50	100.63	99.44	42.00	42.73	12.82	16.40	11.00	9.93	158.67	128.70	78.36	63.55
F2B1GM1	83.33	81.27	100.33	99.39	47.33	45.00	17.64	17.79	16.33	15.27	294.70	258.82	145.53	127.81
F2B2GM1	82.33	79.33	99.33	98.44	44.67	42.47	14.69	16.46	13.67	12.73	184.69	179.51	91.21	88.65
F2B0GM2	82.33	79.67	99.33	98.56	48.00	44.00	16.61	15.91	17.00	15.93	293.72	239.28	145.05	118.16
F2B1GM2	78.00	75.67	95.00	94.11	48.23	44.33	18.32	17.71	17.23	16.17	301.12	272.24	148.70	134.44
F2B2GM2	76.00	73.67	93.00	92.11	44.33	46.00	17.63	17.55	13.33	12.27	213.94	196.12	105.65	96.85
F3B0GM1	78.67	77.33	95.67	94.89	45.33	45.67	16.50	12.66	13.33	10.73	205.19	129.44	101.33	63.92
F3B1GM1	81.00	79.67	98.00	97.44	45.67	45.83	17.87	17.00	13.67	14.27	231.91	231.64	114.52	114.39
F3B2GM1	80.67	79.00	97.67	97.12	47.33	41.67	16.54	14.02	15.33	10.53	253.61	116.33	125.24	57.44
F3B0GM2	83.00	81.33	100.00	99.11	44.93	40.33	16.08	15.85	13.00	12.27	183.88	156.22	90.81	77.15
F3B1GM2	79.00	77.33	96.00	95.11	47.67	46.00	17.89	18.18	16.33	12.73	299.23	213.97	147.76	105.66
F3B2GM2	78.33	77.00	95.67	94.78	44.60	43.33	17.62	17.19	12.60	14.00	198.05	215.89	97.80	106.61
$CD_{(0.05)}$	2.89	NS	2.93	2.78	2.30	2.33	2.18	NS	2.28	2.24	73.33	58.01	36.21	28.65

F1= 100% Recommended Dose of NPK F2= 75% Recommended Dose of NPK F3=50% Recommended Dose of NPK; B0= No biofertilizers B1= *Azospirillum* spp. B2= *Psedomonas fluoresence* ; GM1= Growing Method 1 Flat Beds GM2= Growing Method 2 Ridges

Indirect Effect: Data presented in Table 3 reveal that treatment combination has significant effect on all the parameters except days taken to head initiation and number of non-wrapper leaves during year 2017. Days taken to head initiation during year 2016 and market maturity during year 2016 and 2017 was earliest with the treatment combination 75% recommended doses fertilizer + *Psedomonas fluoresence* application + Ridge method of cultivation. The maximum number of days taken head initiation during year 2016 and marketable maturity was observed with 75% recommended doses fertilizer + No use of biofertilizers + Flat method of

cultivation. Ealry head initiation and marketable maturity may be achieved due to cumulative effect of balanced use of fertilizers with bioinnoculents and ridge method of cultivation. Plant height was recorded highest in treatment combination (F2B1GM2) and (F1B1GM2) during year 2016 and 2017 respectively. Both treatment combinations were statistically at par with each other during both the years indicating the assimilative effect of optimum dose of fertilizers with bioinnoculants and ridge method of cultivation on plant height. Diameter of head (cm), weight of head (g), yield per ha (q) were recorded highest in treatment combination (F1B1GM1) and (F2B1GM2) during year 2016 and 2017 respectively. Treatment combinations were found statistically at par with treatment combination (F1B1GM2) during both the years. Based on the direct and indirect effect, treatment combination of 100 % RDF along with seedling treatment with *Azospirrillum* spp. and ridge method of cultivation was found most effective on yield and yield contributing characters. Thus, the study concludes that judicious combination of biofertilizers with recommended doses of fertilizers and ridge method of cultivation may be helpful in increasing the broccoli productivity.

सारांश

ब्रोकली में उपज तथा उपज घटकों पर विभिन्न उगाने के तरीके का प्रभाव तथा एकीकृत पोषक तत्व प्रबंधन पर वर्ष 2016 तथा 2017 में प्रक्षेत्र प्रयोग किया गया। प्रक्षेत्र प्रयोग में दो तरह के उगाने के तरीके (समतल बिस्तर तथा नाली–बरहा रिज), तीन जैव उर्वरक स्तर (बिना जैव उर्वरक के एजोस्पाइरिलम स्पीशीज तथा स्यूडोमोनास फ्लुओरेसेंस) तथा अनुमोदित नत्रजन, फॉस्फोरस तथा पोटाश के तीन स्तर (50 प्रतिशत, 75 प्रतिशत तथा 100 प्रतिशत) के उपचार संयोजकों का प्रयोग किया गया। परिणाम से स्पष्ट है कि नाली–बरहा विधि से उगाने, पनीरी का एजोस्पाइरिलम स्पीशील से उपचार तथा 100 प्रतिशत अनुमोदित नत्रजन फॉस्फोरस तथा पोटाश का पत्तियों की संख्या, ब्रोकली के ग्रीव का व्यास, शीर्ष का वजन तथा पैदावार प्रति हेक्टेयर पर सीधा व महत्वपूर्ण सकारात्मक प्रभाव पड़ा। पारस्परिक प्रभाव में भी ब्रोकली के शीर्ष का वजन तथा पैदावार प्रति हेक्टेयर के लिए वर्ष 2016 तथा 2017 में नाली–बरहा विधि से उगाने, पनीरी का एजोस्पाइरिलम स्पीशीज से उपचार तथा 100 प्रतिशत अनुमोदित नत्रजन, फॉस्फोरस तथा पोटाश का उपचार संयोजक अधिकतम मूल्य वाले उपचार संयोजक के बराबर पाया गया।

References

Fisher RA and Yates F (1963) Statistical Tables for Biological, Agricultural and Medical Research. Sixth Edn. Long Man Group Limited, London.

Kumari C, Mankar A, Karuna K, Solankey SS and Singh VK (2015) Effect of different levels of nitrogen and microbial inoculants on yield quality of cabbage (*Brassica oleracea* var *capitata*) cv Pride of India. Indian J Agric Sci 85(4): 515-518.

Verma R, Maurya BR and Meena VS (2014) Integrated effect of bio-organics with chemical fertilizer on growth, yield and quality of cabbage (*Brassica oleracea* var *capitata*). Indian J Agric Sci 84(8): 914-919.

Sanawal SK and Yadav DS (2005) Broccoli-A highly nutritive and profitable crop. Intensive Agriculture 36: 28-29.

Vegetable Science (2018) 45(2) : 258-261

Bioefficacy and phytotoxicity study of Fosetyl Al 80 WP on tomato seedlings against the damping off disease

Nagendran K*, Sujoy Saha[1], Shweta Kumari, RM Rai, AB Rai and B Singh

Received: October 2018 / Accepted: January 2019

Abstract

Damping-off is a widely distributed and devastating disease causing severe seedling damage to nursery grown vegetable crops. The present study was undertaken to evaluate different doses of fosetyl-Al 80 WP against damping-off disease of tomato under field conditions in two consecutive seasons *i.e.,* 2014-15 and 2015-16. The pooled data indicated that fosetyl-Al 80 WP @ 3g/l provided the best disease control (85.37%) amongst all the treatments against untreated control. In addition, it has increased the dry root mass and plant height by 39.1 and 64.86%, respectively above the untreated control. Application of fosetyl-Al 80 WP was not phytotoxic on tomato seedlings up to the dose of 12g/l.

Key words: Bioefficacy, phytotoxicity, Fosetyl Al 80, damping off disease

Introduction

Tomato (*Solanum lycopersicum*) an important vegetable crop gained a considerable importance due to its acid sweet taste and unique flavour in global market. Tomato provides nutrient components like vitamins, carbohydrates, minerals, protein, water and roughages, which is essential for a balanced diet. In addition, it also helps to forestall prostate cancer due to the presence of a tetraterpene 'lycopene' (Lee et al. 2011). In India, 18.73 million tonnes of tomatoes are produced from an area of about 0.77 million ha during 2015-16 (Anon 2017a). However, the productivity of tomato suffered due to the onslaught of several biotic factors. 'Damping off' of tomato seedlings, at the nursery stage, caused by a pathogen complex of *Pythium*, *Fusarium* and *Rhizoctonia* (Lucas et al. 1997) is widely distributed throughout the world. Among them *P. aphanidermatum* is a predominant cause of the disease as it thrives under warm conditions (Saha et al. 2011). Phosphonates, esters of phosphonic acid, generally are known to control plant diseases caused by *Phytophthora* spp. (Vawdrey et al. 2004; Panicker et al. 1999) and downy mildew pathogens (Panicker et al. 1999). Their efficacy against *Pythium* spp. (Abbasi et al. 2005) also has been described. Various salt-based formulations of phosphorus acid and its esters have been used as agricultural fungicides. One such fungicide, fosetyl-Al (also known as efosite aluminum) was registered in 1977 (Guest et al. 1991) and is reported to be effective against *Phytophthora* spp. when used as a soil drench (El-Hamalawi et al. 1995; Farih et al. 1981). However, there is no published record on their use as a soil drench against damping off in tomato. The objective of this study was to investigate the efficacy of fosetyl-Al as a soil drench treatment to control damping-off of tomato under field conditions.

Materials and Methods

The trial was conducted in nursery conditions at ICAR-Indian Institute of Vegetable Research at Varanasi, Uttar Pradesh, India for two consecutive kharif seasons (2014-15 and 2015-16) during first fortnight of October. Five treatments includes fosetyl Al 80% WP @ 2 g/L, 2.5 g/L and 3 g/L, an untreated control and a standard check fungicide, mancozeb 75% WP @ 3 g/L. Five replications of each treatment were maintained in the randomized block design (RBD). In each of the sick plots 100 seeds of tomato of variety Kashi Vishesh treated with 0.01% $HgCl_2$ (mercuric chloride) were sown. Nursery soil drenchings twice were done *viz*. the first one seven days after germination and the second one at fourteen days after first application. The plants were at 4-5 leaf stage. The untreated control plot was drenched with water only. Observations on number of infected seedlings, healthy seedlings, plant height and dry root mass of tomato were taken ten days after second drench

ICAR-Indian Institute of Vegetable Research, Varanasi– 221 305, Uttar Pradesh
[1]ICAR-National Research Centre for Grapes, Pune– 412 307, Maharashtra
*Corresponding author, Email: krishnagendra@gmail.com

at the time of transplanting. For plant height and root mass of tomato seedlings, twenty five plants were selected randomly from each replication. Mean of each parameter was observed and pooled mean of the same were taken for a logical conclusion. All the data obtained were statistically analyzed. For phytotoxicity observations, the tomato seedlings were treated with the fosetyl-Al @ 2.5, 3.0, 6.0 and 12g/l doses. Observations on phytotoxicity such as malformation, leaf injury, wilting, necrosis, epinasty and hyponasty were recorded from each plot at 0, 1, 3, 5, 7 and 10 days after application (DAA). The maximum and minimum temperature were 37.8°C and 21.5°C respectively while the relative humidity and total rainfall recorded were 79.2% and 70.2 mm respectively during the period of trial.

Results and Discussion

Damping-off disease occurs primarily in moist soils in the field where young seedlings of direct-seeded crops were killed before or soon after they emerge. It is a major constraint for nursery grown vegetable crops. In the trial conducted, all chemical treatments (Fosetyl Al 80 WP and mancozeb 75 WP) were significantly superior to untreated control. Fosetyl-Al 80 WP manifested an increased control of the disease as compared to untreated check at all the doses. Ten days after the second drenching, the test fungicide gave the best control @ 3g/L where the pooled mean number of infected seedlings per 100 cm^2 was 14.22 as compared to untreated control value of 44.65 and the corresponding pooled mean number of healthy seedlings per 100 cm^2 were 56.02 and 36.22 respectively (Table 1). Fosetyl-Al 80 WP @ 2.5g/L gave the second best control which was at par with the check fungicide mancozeb 75 WP@ 3g/L. Thus, fosetyl-Al 80 WP @2.5 and 3g/L manifested a percent disease control of 56.39 and 68.15 respectively over untreated control. The plant height and dry root mass of fosetyl-Al 80 WP treated plants were also superior to that of untreated control. A plant height of 21.35 cm and 20.4 cm were observed in case of fosetyl-Al 80 WP @ 3g/L and 2.5g/L, respectively, while the corresponding values for dry root mass were 12.7g and 11.6 g, respectively (Table 2). The plant height and dry root mass of untreated control were 17.15 cm and 9.13 g, respectively.

Fungicides of the benzimidazole group *viz*. thiophenate methyl and carbendazim have been reported to control damping-off of tomato but the disease was predominantly caused by *Rhizoctonia solani* (Jiskani et

Table 1: Effect of different treatments of fosetyl-Al 80 WP on number of infected seedlings and healthy seedlings with damping off of tomato

Treatments	Dose (g/L)	Mean number of infected seedlings				Mean number of healthy seedlings			
		2014-15	2015-16	Pooled mean	Percent decrease over control	2014-15	2015-16	Pooled mean	Percent increase over control
Untreated control	-	39.3	50	44.65	-	23.7	36.75	30.22	-
Fosetyl Al 80 WP	2.0	16.7	35	25.85	42.10	36.0	52.75	44.37	46.82
Fosetyl Al 80 WP	2.5	12.7	26.25	19.47	56.39	46.0	58.5	52.25	72.90
Fosetyl Al 80 WP	3.0	11.7	16.75	14.22	68.15	48.3	63.75	56.02	85.37
Mancozeb 75 WP	3.0	16.7	26.25	21.47	51.91	36.7	52.75	44.75	48.08
CD (0.05%)		1.29	2.88		-	2.54	3.62	-	-
SEm ±		0.43	1.01		-	0.85	1.27	-	-
CV		7.52	12.48			7.24	8.73		

Table 2: Effect of different treatments of Fosetyl-Al 80 WP on dry root mass and plant height of tomato

Treatments	Dose (g/L)	Mean dry root mass (g) per 25 seedlings				Mean plant height (cm)			
		2014-15	2015-16	Pooled mean	Percent increase over control	2014-15	2015-16	Pooled mean	Percent increase over control
Untreated control	-	9.23	9.03	9.13	-	12.7	13.2	12.95	-
Fosetyl Al 80 WP	2.0	11.2	9.75	10.47	14.67	17.1	17.2	17.15	32.43
Fosetyl Al 80 WP	2.5	12.8	10.4	11.6	27.05	21.2	19.6	20.4	57.52
Fosetyl Al 80 WP	3.0	13.7	11.7	12.7	39.10	21.5	21.2	21.35	64.86
Mancozeb 75 WP	3.0	11.4	11.13	11.26	23.32	16.5	17.8	17.15	32.43
CD (0.05%)		0.77	0.34			1.19	0.63		
SEm ±		0.26	0.12			0.40	0.22		
CV		2.73	4.29			3.46	4.65		

*all the readings in Table 1 and 2 were noted ten days after the second drenching

al. 2007). Copper oxy chloride also was effective in controlling the *Rhizoctonia solani* incited damping-off of tomato (Satija and Hooda 1987). Dimethomorph treated seeds and soil was also able to ward off this disease in tomato caused by *Phytophthora nicotianae* var. *nicotianae* (Washington and McGee 2000) but the information regarding the role of phosphonates and salts of phosphoric acid in the control of the disease was lacking. Abbasi and Lazarovits (2006) reported that treatment of cucumber seeds with AG3 phosphonate solution significantly enhanced their survival compared with untreated controls when planted into a *Pythium aphnidermatum*-infested peat-based mix or a muck soil naturally infested with *Pythium* spp. and the efficacy of phosphonate seed-soak was better than that of phosphonate post-planting drench. In this study, soil drenching with fosetyl-Al 80WP at different doses such 2.5, 3.0, 6.0 and 12.0 g/l did not produce any kind of phytotoxicity on tomato seedlings. Although application of phosphonates through seed treatment is easy and cost effective, phytotoxicity to seeds of individual plant species can occur and the mode of action of phosphonates in seed application is yet to be understood. Soil drenching of fosetyl-Al @2.5-3g/L in the present study gave a good control against damping-off disease infected tomato seedlings and it corroborates to the findings of Farih et al. (1981) where it gave a good control of citrus root rot when applied as a soil drench. The mode of action of phosphonates is unknown (Anon, 2017b) but induction of plant defense responses have not been ruled out (Guest et al. 1990, 1991). The plant height and dry root mass of treated tomato plants were also higher than untreated control and the increase in weights of tomato plants was probably due to disease control as experienced in case of cucumber (Abbasi and Lazarovits 2006). From this study it is inferred that, fosetyl-Al 80WP is effective in managing the damping off disease in tomato.

Conclusion

Fosetyl-Al@ 2.5-3 g/L as a soil drench manifested significantly higher per cent control of damping off of tomato, and may be recommended for the management of the disease in tomato with subsequent inclusion in the Good Agricultural Practices (GAP) of tomato.

Acknowledgment

Authors are thankful to the M/s. Bayer Crop Science Pvt. Ltd for the supply of chemicals used in this study.

सारांश

नर्सरी में पौध तैयार कर उगायी जाने वाली सब्जियों में पद गलन ज्यादा स्तर पर विनाशकारी बीमारी लगती है। वर्तमान अध्ययन टमाटर में पद गलन बीमारी के लिये फोसेटिल– एएल 80 घुलनशील पाउडर का प्रयोग प्रक्षेत्र दशा में लगातार दो वर्षों 2014–15 व 2015–16 में किया गया। समूहीकृत आंकड़ों से संकेत मिलता है कि फोसेटिल एएल 80 घुलनशील पाउडर की 3 ग्राम/लीटर मात्रा के प्रयोग से सभी शोधनों व अशोधित नियंत्रक की तुलना में बीमारी नियंत्रण (85.37 प्रतिशत) पाया गया। इसके अतिरिक्त इससे शुष्क जड़ भार व पौध ऊँचाई 39.1 व 64.86 प्रतिशत अशोधित नियंत्रक की तुलना में पाया गया। फोसेटिल एएल 80 घुलनशील पाउडर के 12 ग्राम/लीटर के छिड़काव से टमाटर के नर्सरी पौधों पर नुकसानदायक प्रभाव नहीं पाया गया।

References

Anonymous (2017a) Horticultural Statistics at a Glance, Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi. 151pp. http://nhb.gov.in/statistics/Publication/Horticulture%20At%20a%20Glance%202017%20for%20net%20uplod%20(2).pdf (Accessed 5 September 2018).

Anonymous (2017b) FRAC Code List2017: Fungicides sorted by mode of action (Including FRAC Code numbering) 12pp.

Abbasi PA and Lazarovits G (2005) Effects of AG3 phosphonate formulations on incidenceand severity of *Pythium* damping-off of cucumber seedlings under growth room, microplot, and field conditions. Can J Plant Pathol 27: 420-429.

Abbasi PA and Lazarovits G (2006) Seed Treatment with Phosphonate (AG3) Suppresses Pythium damping-off of cucumber seedlings. Plant Disease 90(4): 459-464.

El-Hamalawi ZA, Menge JA and Adams CJ (1995) Methods of fosetyl-Al applicationAnd phosphonate levels in avocado tissue needed to control stem canker caused by *Phytophthora citricola*. Plant Disease 79: 770-778.

Farih A, Menge JA, Tsao PH and Ohr HD (1981) Fungitoxic activity of efosite aluminum for control of *Phytophthora gummosis* and root rot on citrus. Plant Disease 65:654-657.

Gowsalya A, Ponnusami V and Sugumaran KR (2014) Isolation of bacteria from soil sample for exo-polysaccharide production. Intl J Chem Tech Res 6(5): 2925-2928.

Guest DI and Bompeix G (1990) The complex mode of action of phosphonates. Australasian Plant Pathol 19: 113-115.

Guest DI and Grant B (1991) The complex action of phosphonates as antifungal agents. Biol Rev 66: 159-187.

Jiskani MM, Pathan MA, Wagan KH, Imran M and Abro H (2007) studies on the control of Tomato damping-off disease caused by *Rhizoctonia solani* Kuhn. Pak J Bot 39(7): 2749-2754.

Lee ST, Wong PF, Cheah SC and Mustafa MR (2011) Alpha-tomatine induces apoptosis andinhibits nuclear factor-kappa B activation on human prostatic adenocarcinoma PC-3 cells. PLOS One 6(4): e 18915.

Panicker S and Gangadharan K (1999) Controlling downy mildew of maize caused by *Peronosclerospora sorghi* by foliar sprays of phosphonic acid compounds. Crop Protec 18: 115-118.

Saha S, Naskar I, Nayak DK and Sarkar MK (2008) Efficacy of seed dressing agents in the control of damping off disease of chilli caused by *Pythium aphanidermatum*. J Mycopathol Res 46(1): 121-123.

Saha S, Rai AB and Pandey S (2011) Efficacy of seed dressing agents against damping off disease of chilli. Indian J Agric Sci 81(1): 92-93.

Satija DV and Hooda I (1987) Influence of farmyard manure in the efficacy of fungicides in controlling damping-off of tomato and chilli. Veg Sci 14: 58-64.

Vawdrey LL, Grice KE, Peterson RA and De Faveri J (2004) The use of metalaxyland potassium phosphonate, mounds, and organic and plastic mulches, for the management of Phytophthora root rot of papaya in far northern Queensland. Australasian Plant Pathol 33: 103-107.

Washington WS and Patricia McGee (2000) Dimethomorph soil and seed treatment of potted tomatoes for control of damping-off and root rot caused by *Phytophthora nicotianae* var. *nicotianae*. Australasian Plant Pathol 29: 46-51.

Wilkinson CJ, Holmes J M, Tynan KM, McComb JA, Colquhoun IJ, McComb JA, St. J Hardy GE and Dell B (2001) Ability Of phosphite applied in a glasshouse trial to Control *Phytophthora cinnamomi* in five plant species native to Western Australia. Australasian Plant Pathol 30: 343-351.

Vegetable Science (2018) 45(2) : 262-268

Management of root- knot nematode *Meloidogyne incognita* in tomato with liquid bioformulations

Manjunatha T Gowda*, C Sellaperumal[1], B Rajasekhar Reddy, AB Rai and B Singh

Received: August 2018 / Accepted: January 2019

Abstract

Root-knot nematodes are one of the major plant parasitic nematodes in tomato (*Solanum lycopersicum* L.). Considering its damage potential, a field experiment was piloted for the management of root-knot nematode, *Meloidogyne incognita* in tomato. For this study, *Bacillus subtilis* (1% A.S) and *Bacillus amyloliquefaciens* (1% A.S) liquid bioformulations were evaluated. The liquid bioformulations were evaluated in two delivery mechanisms such as nursery drench (5 ml/litre of water) and soil application of bioformulations (5 l ha^{-1}) enriched with FYM (20 t ha^{-1}) individually and in combination and their nematicidal efficacy compared with carbofuran 3G (1 kg a.i. ha^{-1}) and combined application of carbofuran 3G (1 kg a.i.ha^{-1}) with FYM (20 t ha^{-1}). Among the bioformulations, integrated application of *B. amyloliquefaciens* (1% A.S) (nursery drench and soil application of enriched FYM) consistently exhibited greater nematicidal activity by resulting maximum percent reduction of nematode population in soil 77.1, 61.5 and 74.6 during 2015-16, 2016-17 and 2017-18, respectively. Therefore, we able to harvest marketable yield of 24.0, 22.5 and 31.1 t ha^{-1} during 2015-16, 2016-17 and 2017-18, respectively which was next to combined application of carbofuran 3G (1 kg a.i.ha^{-1}) with FYM (20 t ha^{-1}). Subsequently, it was followed by *B. subtilis* 1% A.S (nursery drench and soil application of enriched FYM) found promising and recorded percent reduction of nematode population in soil 52.5, 55.8 and 70.4 with marketable yield of 20.0, 22.0 and 30.4 t ha^{-1} during 2015-16, 2016-17 and 2017-18, respectively. The present findings indicate that, liquid bioformulations of *B. amyloliquefaciens* (1% A.S) and *B. subtilis* (1% A.S) with its delivery mechanisms can be considered as a component under integrated nematode management of *M. incognita* infecting tomato under field condition.

ICAR- Indian Institute of Vegetable Research, Varanasi-221305
[1]ICAR- Indian Institute of Spices Research, Kozhikode-673012
Corresponding author*, Email: goudru9@gmail.com

Key words: Root-knot nematode, *Meloidogyne incognita*, tomato, biological control, *Bacillus amyloliquefaciens*, *Bacillus subtilis*

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular, extensively grown vegetable crops in India. It is generally considered as poor man's apple because of its appearance and nutritive richness (vitamins, minerals and antioxidants). In India, tomato cultivated in 0.809 million hectares with 19.7 million tonnes production and 24.4 t ha^{-1} productivity (Anonymous, 2017). However, the current level of productivity and quality are constrained by the direct interference of plant parasitic nematodes on the plant root system besides several pests and diseases. Plant parasitic nematodes hinder the uptake of nutrients as well as water. Among them, root-knot nematodes (*Meloidogyne* spp.) are the frequently observed and most damaging plant parasitic nematode genera in vegetable ecosystem. In known root-knot nematode species, *Meloidogyne incognita* and *M. javanica* are widely distributed in different parts of the country causing annual yield loss to the tune of 27.2% with an estimated 2204 million rupees of monetary loss in tomato (Jain et al. 2007). Owing to their parasitic activity, the second stage infective juvenile (J_2) of root-knot nematodes infect and feeds plant nutrients by developing feeding sites on root system. The primary symptom of root-knot nematode infection is formation of typical galls on root system. Affected plants express symptoms similar to mineral deficiency such as chlorosis, yellowing of leaves, wilting and stunted growth (Abad et al. 2003) because of reduced uptake and translocation of nutrients form soil to shoot (Patil et al. 2013).

The nematode management largely depends on chemical nematicides. However, their potential negative impact on environment and concerns about human health (Ferraz and Freitas 2004, Anastasiadis et al. 2008) and

phasing out of many effective chemical nematicides necessitated research towards finding alternative strategies for the management of nematodes. In this endevour, biological control agents (BCA) have emerged as eco-friendly and safe and cost effective alternatives to chemical nematicides (Collange et al. 2011, Rao et al. 2015). In past years, several researchers, efforts have been made to identify microbial groups which limit the nematode abundance in soil and are categorized into egg-parasitic fungi, nematode-trapping fungi, filamentous fungi, antagonistic bacteria and polyphagous predatory nematodes (Kerry and Hidalgo-Diaz 2004, Kiewnick and Sikora 2005). Among these, the egg parasitic fungi, *Purpureocillium lilacinum* (*Paecilomyces lilacinus*) and filamentous fungi, *Trichoderma viride, T. harzianum* and plant growth promoting rhizobacteria, *Pseudomonas fluorescens* have been extensively exploited for the suppression of root-knot nematodes *Meloidogyne* spp. (Krishnaveni and Subramanian 2004, Haseeb and Khan 2012). *Bacillus* spp. is another group of bacterial agents has recently been recognized as one of the most promising groups of nematode antagonists of which *Bacillus subtilis*, *B. licheniformis, B. amyloliquefaciens and B. cereus* are increasingly becoming important for effective management of root knot nematodes (Mohammed et al. 2008; Mohamedova 2009; Terefe et al. 2009; Xiao et al. 2013; Rao et al. 2017; Abdel-Salam et al. 2018). Considering this, efforts have been made to evaluate the liquid bioformulation of *Bacillus subtilis* (1% A.S) and *Bacillus amyloliquefaciens* (1% A.S) involving two delivery mechanisms individually and in combination for the management of root-knot nematode *M. incognita* in naturally infested tomato field.

Materials and Methods

The experiment was conducted in tomato (cv. Kashi Aman) at Nematology experimental site (25.1821° N latitude and 82.8770° E longitude) located at ICAR-Indian Institute of Vegetable Research, Varanasi, UP for three consecutive years (2015-16, 2016-17 and 2017-18) during Rabi season. The experimental site comes under the alluvial zone of Indo-Gangetic plain, soils having silt loam soil texture with neutral to slightly alkaline in reaction (pH: 7.34) and electrical conductivity 0.31 dSm^{-1}. The root-knot nematode (*Meloidogyne incognita*) was prevalent in nematology experimental site. Prior to experiment, initial soil population of root-knot nematode populations were assessed using Cobb's sieving and decanting method (Cobb 1918). This site had a resident nematode population of 241.3 ± 8.72, 499.9 ± 9.82, 261.9 ± 5.11 per 250 CC of soil during 2015-16, 2016-17 and 2017-18, respectively.

Nematode identification: Root-knot nematode species from naturally infested nematology experimental site located at ICAR-IIVR, Varanasi was identified using molecular technique. DNA was isolated from newly hatched second stage infective juvenile using standard protocol described by Adam et al. (2007). Further, identity of the root-knot nematode species *M. incognita* was confirmed through specific SCAR marker, Inc-K14-F/ Inc-K14-R (Randig *et al.,* 2002) and also morphologically confirmed by making temporary mounts of perineal pattern of the mature females.

Liquid bioformulations: Liquid bioformulations of *Bacillus subtilis* (1% A.S.) and *Bacillus amyloliquefaciens* (1% A.S.) procured from, Division of entomology and nematology, ICAR-Indian Institute of Horticultural Research, Bengaluru for the present study.

Enrichment of liquid bioformulations: Prior to experiments, each liquid bioformulation (5 l ha^{-1}) was thoroughly mixed with FYM (20 t ha^{-1}) and then covered with poly ethylene sheet by maintaining optimum moisture under shade for 15 days. Further, enriched FYM was applied to respective treatments before 15 days of transplanting.

Field efficacy: To evaluate the nematicidal activity of liquid bioformulations of *B. subtilis* (1% A.S.) and *B. amyloliquefaciens* (1% A.S.) against root-knot nematode, *M. incognita* in field, experiment was laid out in a randomized complete block design (RCBD) with eight treatments including different delivery mechanisms and there were three replicates per treatment. The treatments were as follows; T1: Nursery drench with *Bacillus subtilis* 1% A.S. @ 5 ml/litre of water; T2: Nursery drench with *Bacillus amyloliquefaciens* - 1% A.S. @ 5 ml/litre of water; T3: T1+FYM @ 20 t ha^{-1} enriched with 5L *Bacillus subtilis*; T4-T2+FYM @ 20 t ha^{-1} enriched with 5L *Bacillus amyloliquefaciens*; T5: FYM at 20 t ha^{-1} only; T6: carbofuran 3G @ 1.0 kg 1.0 kg a.i.ha^{-1}; T7: carbofuran 3G @ 1.0 kg a.i. ha^{-1} + FYM @ 20 t ha^{-1} ; T8: control (untreated field). In nursery, coco peat was used as substrate for raising tomato (cv. Kashi Aman) seedlings in portrays. Before sowing, one kg of substrate was treated with (5 ml per litre of water) each bioformulation separately with respective treatment. Healthy seedlings were maintained in portrays up to 21 days and transplanted to main experimental plot. Crop was raised following standard agronomic practices. At the time of harvest, observations were recorded on plant growth parameters such as plant height (cm), root weight (g) (average of 15 plants were selected randomly) and marketable yield (t ha^{-1}). Nematode disease parameters

such as gall index (0-10) scale 0= no knots on roots; 1 = few small knots difficult to find; 2 = small knots only but clearly visible; main roots clean; 3 = some larger knots visible, but main roots clean; 4 = larger knots predominate but main roots clean; 5 = 50% of roots knotted; knotting on parts of main root system; 6 = knotting on some of main roots; 7 = majority of main roots knotted; 8 = all main roots knotted; few clean roots visible; 9 = all roots severely knotted, plant usually die; 10 = all roots severely knotted, no root were recorded (Bridge and Page, 1980). Final soil nematode population was assessed by using Cobb's sieving and decanting method (Cobb 1918). The number of egg masses per root system (average of 15 plants were selected randomly of each treatment) were counted with the help of a magnifying glass. The number of eggs per egg mass was also counted under a stereo microscope.

Statistical Analysis: Analysis of variance (one way ANOVA) was performed for respective year data on plant height, root weight, marketable yield, gall index, number of egg mass per root system, number of eggs per egg mass and final nematode population in soil. The significant ($P < 0.05$) differences among treatments were determined by using Tukey's studentized Range (HSD) test (PROC GLM SAS version 9.2; SAS institute).

Results

In the present study, data on nematicidal efficacy of bioformulations with carbofuran presented in Table 1, 2 ,3 and Fig. 1 evidently indicates that all the treatments were considerably reduced the incidence of *M. incognita* in tomato and enhanced plant growth compared to untreated control. Among the bioformulations, the treatment (T4) involving integration of nursery drench and soil application of *B. amyloliquefaciens* (1% A.S) enriched FYM consistently provided a better protection from *M. incognita* to tomato by resulting maximum percent reduction of final nematode population in soil was of 77.1, 61.5, 74.6, number of egg mass per root system was 69.6, 70.2 and 74.2, number of eggs per egg mass were 68.0, 65.8 and 70.5, lesser root gall index (0-10 scale) of 2.0, 2.0 and 1.5 with maximum marketable yield of 24.0, 22.5 and 31.1 t ha^{-1} during 2015-16, 2016-17 and 2017-18, respectively and which was next to carbofuran 3G @ 1.0 kg a.i. ha^{-1} and combined application of carbofuran 3G (@ 1.0 kg a.i. ha^{-1}) with FYM (20 t ha^{-1}) however, it was statistically at par with carbofuran treatments (Table 1, 2 and 3).

Subsequently, it was followed by the treatment (T3) having integration of nursery drench and soil application

Table 1: Nematicidal efficacy of liquid bioformulation of *Bacillus amyloliquefaciens* (1% A.S) and *Bacillus subtilis* (1% A.S) on *Meloidogyne incognita* infecting tomato

Treatments	RKI (0-10)			Average (Three years)	Final soil population (250 CC) Mean±SE			Average (Three years)
	2015-16	2016-17	2017-18		2015-16	2016-17	2017-18	
T1	4.0^{bc}	4.0^{cd}	3.4^{b}	3.80	422.0^{b} ± 10.4 (-37.7)	700.0^{bc} ± 21.4 (-16.0)	402.0^{b} ± 25.6 (-24.6)	508.0 (-25.4)
T2	4.0^{bc}	5.0^{bc}	3.1^{bc}	4.03	410.6^{b} ± 5.0 (-39.4)	656.3^{c} ± 15.0 (-21.2)	395.5^{b} ± 24.0 (-25.8)	487.5 (-28.4)
T3	3.0^{cd}	3.0^{de}	1.7^{cd}	2.57	321.6^{c} ± 12.1 (-52.5)	368.0^{d} ± 15.0 (-55.8)	157.7^{c} ± 11.0 (70.4)	282.4 (-58.5)
T4	2.0^{d}	2.0^{e}	1.5^{d}	1.83	155.3^{d} ± 8.5 (-77.1)	320.6^{d} ±12.3 (-61.5)	135.5^{c} ± 07.9 (-74.6)	203.8 (-70.0)
T5	5.0^{b}	6.0^{ab}	4.0^{b}	5.00	444.0^{b} ± 16.5 (-34.4)	805.0^{ab} ± 20.1 (-3.4)	453.3^{a} ± 11.3 (-15.0)	567.4 (-16.7)
T6	2.0^{d}	2.0^{e}	1.5^{d}	1.83	155.0^{d} ± 11.6 (-77.1)	290.3^{d} ± 20.1 (-65.2)	133.3^{c} ± 03.1 (-75.0)	192.9 (-71.6)
T7	2.0^{d}	2.0^{e}	1.3^{d}	1.77	155.3^{d} ± 11.9 (-77.1)	256.0^{d} ± 36.0 (-69.3)	102.2^{c} ± 03.6 (-80.8)	171.1 (-74.8)
T8	7.0^{a}	7.0^{a}	5.4^{a}	6.47	677.0 ^{a}± 11.9 (0.0)	833.3^{a} ± 13.2 (0.0)	533.3^{a} ± 17.5 (0.0)	681.2 (0)
Tukey's HSD at 0.05	**1.23**	**1.46**	**1.20**		**68.55**	**122.54**	**91.76**	

Figures presented in parentheses ( ) are percent increase (+) or decrease (-) over control. RKI: Root-knot index; SE: Standard error. Different letters on each column indicate statistically significant difference between treatments at ($P < 0.05$) using Tukey's HSD test. **Treatment details: T1:** Nursery drench with *Bacillus subtilis* 1% A.S. @ 5 ml/litre of water; **T2:** Nursery drench with *Bacillus amyloliquefaciens* - 1% A.S. @ 5 ml/litre of water; **T3:** T1+FYM @ 20 t ha^{-1} enriched with 5L *Bacillus subtilis*; **T4:** T2+FYM @ 20 t ha^{-1} enriched with 5L *Bacillus amyloliquefaciens*; **T5:** FYM at 20 t ha^{-1} only; **T6:** Carbofuran 3G @ 1.0 kg 1.0 kg a.i.ha^{-1}; **T7:** Carbofuran 3G @ 1.0 kg a.i. ha^{-1} + FYM @ 20 t ha^{-1} ; **T8:** Control (Untreated).

of *B. subtilis* (1% A.S) enriched FYM was found promising by recording percent reduction of final nematode population in soil was 52.5, 55.8 and 70.4, number of egg mass per root system was 66.8, 65.9 and 69.9, number of eggs per egg mass were 65.4, 63.5 and 67.2, root gall index (0-10 scale) of 3.0, 3.0 and 1.7 with marketable yield of 20.0, 22.0 and 30.4 t ha^{-1} during 2015-16, 2016-17 and 2017-18, respectively (Table 1, 2 and 3). However, treatment (T3) differed statistically significant with the treatment (T4) *B.* and carbofuran with respect to reduction of final nematode population in soil and yield during first year field trial (Table 1 and 3). Nevertheless, in the present study the yield performance of tomato was little poor during 2015-16 and 2016-17 which may attribute to late sowing and transplanting (second fortnight of November during 2015

Table 2: Nematicidal efficacy of liquid bioformulation of *Bacillus amyloliquefaciens* (1% A.S) and *Bacillus subtilis* (1% A.S) on *Meloidogyne incognita* infecting tomato.

Treatments	Number of egg mass/root system Mean±SE			Average (Three years)	Number of eggs/egg mass Mean±SE			Average (Three years)
	2015-16	2016-17	2017-18		2015-16	2016-17	2017-18	
T1	65.8^{b} ± 1.89 (-17.7)	74.4^{ab} ± 3.89 (-19.7)	50.8^{b} ± 2.45 (-20.9)	63.7 (-18.2)	271.0^{b} ± 6.85 (-11.1)	253.7^{b} ± 9.49 (-15.1)	244.1^{b}±7.81 (-15.9)	256.3 (-14.0)
T2	64.2^{b} ± 3.27 (-19.8)	71.0^{b} ± 6.16 (-23.4)	48.4^{b} ± 1.61 (-24.6)	61.2 (-22.5)	250.9^{b} ± 4.99 (-17.7)	252.1^{b} ± 5.20 (-15.7)	228.7^{b}±9.54 (-21.3)	243.9 (-18.2)
T3	26.6^{c} ± 2.64 (-66.8)	31.6^{c} ± 3.98 (-65.9)	19.3^{c} ± 1.66 (-69.9)	25.8 (-67.3)	105.5^{c} ± 4.43 (-65.4)	109.1^{c} ± 6.42 (-63.5)	95.3^{c}±4.34 (-67.2)	100.0 (-65.4)
T4	24.3^{c} ± 2.37 (-69.6)	27.6^{c} ± 2.14 (-70.2)	16.6^{c} ± 1.50 (-74.2)	22.8 (-71.1)	97.6^{c} ± 3.34 (-68.0)	102.1^{c} ± 5.24 (-65.8)	85.6^{c}±5.78 (-70.5)	95.1 (-68.1)
T5	74.5^{ab} ± 2.59 (-6.8)	85.0^{ab} ± 8.16 (-8.3)	54.8^{ab} ± 2.55 (-14.6)	71.4 (-9.6)	274.3^{ab} ± 6.64 (-10.1)	269.2^{ab} ± 7.64 (-9.9)	262.0^{ab}±8.71 (-9.8)	268.5 (-9.9)
T6	22.3^{c} ± 1.91 (-69.4)	25.3^{c} ± 3.42 (-72.7)	14.2^{c} ± 1.91 (-77.9)	20.6 (-74.0)	95.8^{c} ± 4.91 (-68.6)	98.6^{c} ± 3.02 (-67.0)	80.6^{c}±7.81 (-72.2)	91.7 (-69.2)
T7	20.5^{c} ± 0.64 (-74.4)	22.5^{c} ± 2.12 (-75.8)	12.3^{c} ± 1.19 (-80.9)	18.4 (-76.7)	85.8^{c} ± 3.76 (-71.9)	87.9^{c} ± 4.59 (-70.6)	74.7^{c}±4.38 (-74.3)	82.8 (-72.2)
T8	80.0^{a} ± 2.27 (0.0)	92.7^{a} ± 9.0 (0.0)	64.2^{a} ± 2.23 (0.0)	79.0 (0.0)	305.0^{a} ± 4.71 (0.0)	298.9^{a} ± 5.53 (0.0)	290.4^{a}±7.94 (0.0)	298.1 (0.0)
Tukey's HSD at 0.05	**13.87**	**18.91**	**11.63**		**31.64**	**37.02**	**42.65**	

Figures presented in parentheses ( ) are percent increase (+) or decrease (-) over control. SE: Standard error. Different letters on each column indicate statistically significant difference between treatments at ($P < 0.05$) using Tukey's HSD test.

Table 3: Effect of liquid bioformulation, *Bacillus amyloliquefaciens* (1% A.S) and *Bacillus subtilis* (1% A.S) on yield of tomato infected by *Meloidogyne incognita.*

Treatments	Marketable yield (t/ha) Mean ±SE			Average (Three years)
	2015-16	2016-17	2017-18	
T1	18.4^{cd} ± 0.69 (+12.0)	20.3^{bc} ± 0.40 (+3.4)	28.1^{cd} ± 0.35 (+8.1)	22.3 (+7.6)
T2	18.7^{bcd} ± 0.53 (+14.2)	20.6^{ab} ± 0.44 (+4.8)	28.6^{bcd} ± 0.28 (+9.2)	22.6 (+9.1)
T3	20.0^{bc} ± 0.29 (+21.7)	22.0^{ab} ± 0.31 (+11.9)	30.4^{abc} ± 0.28 (+16.4)	24.1 (+16.4)
T4	24.0^{a} ± 0.45 (+46.1)	22.5^{a} ± 0.27 (+14.5)	31.1^{a} ± 0.34 (+18.7)	25.8 (+24.7)
T5	16.5^{d} ± 0.24 (+0.6)	19.7^{c} ± 0.26 (+0.5)	27.4^{d} ± 0.58 (+4.7)	21.2 (+2.2)
T6	21.4^{ab} ± 0.64 (+30.5)	21.8^{ab} ± 0.32 (+10.9)	31.0^{ab} ± 0.45 (+18.5)	24.7 (+19.2)
T7	24.4^{a} ± 0.37 (+48.6)	22.4^{a} ± 0.35 (+13.9)	31.8^{a} ± 0.53 (+21.7)	26.2 (+26.3)
T8	16.4^{d} ± 0.57 (0.0)	19.6^{c} ± 0.17 (0.0)	26.2^{d} ± 0.27 (0.0)	20.7 (0.0)
Tukey's HSD at 0.05	**2.97**	**1.95**	**2.42**	

Figures presented in parentheses ( ) are percent increase (+) or decrease (-) over control. SE: Standard error. Different letters on each column indicate statistically significant difference between treatments at ($P < 0.05$) using Tukey's HSD test.

and 2016). Moreover, tomato (cv. Kashi Aman) performed better during 2017-18, since the crop was transplanted in first fortnight of October month (Table 3).

Besides nematicidal activity and improved marketable yield, bio agents were also considerably enhanced plant growth by increasing plant height and root weight reliably for three consecutive years 2015-16, 2016-17 and 2017-18. The two bioformulations as well as carbofuran 3G @ 1.0 kg a.i. ha^{-1} with FYM (20 t ha^{-1}) were statistically at par with their plant growth promotion activity and significantly better over carbofuran 3G @ 1.0 kg a.i.ha^{-1} (Fig. 1).

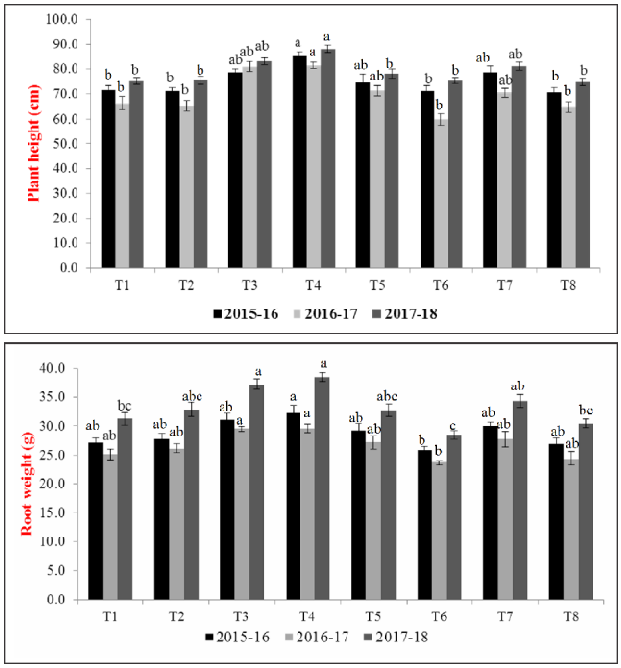

Fig. 1: Effect of liquid bioformulation, *Bacillus amyloliquefaciens* (1% A.S) and *Bacillus subtilis* (1% A.S) on plant growth parameters of tomato.
Means followed by the same letter in top of error bars are not significantly different between treatments at ($P < 0.05$) using Tukey's HSD test.

Discussion

The present investigation indicated that, the liquid bioformulations of *B. amyloliquefaciens* (1% A.S) and *B. subtilis* (1% A.S) gave a good control of *M. incognita* by reducing final soil population, number of egg mass per root system, number of eggs per egg mass, gall index with considerable increase in plant height, root weight and marketable yield in tomato under field condition. The nematicidal activity of these bacterial agents might be attributed to secretion of antimicrobial compounds. Earlier reports revealed that, secretion of various types of antimicrobial metabolites and enzymes from *Bacillus* spp. exhibit strong antagonism against root-knot nematode (Saxena et al. 2000, Ann 2013). Killani et al. (2011) revealed that, the production of five types of antimicrobial compounds such as bacitracin, bacillin, subtillin, subtenolin and bacilonycin from *B. subtilis* are responsible for antimicrobial activity. Similarly, Vinodkumar et al. (2017) identified several antimicrobial peptide genes namely, *ituD, ipa14, bacA, bacD, bamC, sfP, spaC, spaS, alba,* and *albF*, responsible for production of the antibiotics iturin, bacilysin, bacillomycin, surfactin, subtilin, and subtilosin from *B. amyloliquefaciens*.

Furthermore, the success of bio agents with respect to their biocontrol efficacy and consistency relies upon appropriate delivery mechanisms at field condition. Earlier reports revealed that, incorporation of bio agents with organic amendments such as manures or vermicompost or oil cakes will change the soil environment in favour bioagents and provided readily available nutrients to fungal and bacterial antagonists for their survival and development (Singh and Sitramaiah, 1966: Muller and Gooch, 1982; Timper, 2014). In addition, Walker (2004) reported that the activity of bioagents was directly correlated with organic amendments. Subsequently, several researchers demonstrated that, application bio- agents enriched with organic amendments exhibited greater antagonistic activity against root-knot nematodes and many plant pathogens (Latha et al. 2011; Singh 2013; Singh et al. 2014).

Similarly, in our study, nursery drench with soil application of bioformulations enriched FYM was found to be more effective in root-knot nematode control under field condition. This study indicates nematicidal activity of bio agents have direct correlation with FYM and better control might be attributed due to enhanced multiplication and accumulation of their secondary metabolites in amended soil. In addition, our study also agree with previous studies in which they revealed that, the application of enriched organic amendments with bacterial bio agents provided successful control of root knot nematode. For example, *Bacillus cereus* enriched with organic fertilizers exhibited maximum nematicidal activity against root-knot nematodes infecting tomato and muskmelon (Xiao et al. 2013). Similarly, Rao et al. (2017) demonstrated that, soil application of vermicompost enriched with *B. subtilis* had significantly increases yield and reduces the root-knot nematode and soft rot disease complex in carrot under field condition.

In recent years, there has been greater interest in ecologically resistant, environmentally safe methods for controlling root-knot nematodes in vegetable ecosystem.

Since, the application of microbial agents creates an opportunity to cultivate vegetables without nematicides. In this endevour, the present study indicates that, these two nematicidal liquid bioformulations *B. amyloliquefaciens* (1% A.S) and *B. subtilis* (1% A.S) with its delivery mechanism can be considered as a component under integrated nematode management of *M. incognita* infecting tomato under field condition.

Acknowledgements

The authors are thankful to Dr. M.S. Rao, Principal Scientist (Nematology), ICAR-IIHR, Bengaluru for providing liquid bioformulations to conduct present study and AICRP (Vegetable Crops) for financial support.

सारांश

टमाटर में जड़गाँठ सूत्रकृमि हानिकारक परजीवियों में से एक हैं। अतः नुकसान को देखते हुए जड़गाँठ सूत्रकृमि प्रबंधन के लिये *बेसिलस अमीलोलिक्वेफेसीन्स* (1 प्रतिशत ए.एस.) और *बेसिलस सबटिलिस* (1 प्रतिशत ए.एस.) द्रव्य जैवसूत्रीकरण का मूल्यांकन किया गया। द्रव्य जैवसूत्रीकरण को दो विभिन्न वितरण तंत्रों जैसे पौधशाला को भिगोना (5 मिली प्रति लीटर पानी में) और द्रव्य जैवसूत्रीकरण (5 लीटर प्रति हेक्टेयर) के साथ 20 टन खाद प्रति हेक्टेयर से समृद्ध करके मृदा उपचार किया गया। इन उपचारों को सूत्रकृमिनाशक कार्बोफुरन 3 जी (1 किलोग्राम सक्रिय तत्व/हे.) कार्बोफ्यूरान 3 जी. 1 किलोग्राम सक्रिय तत्व/हे. के साथ 20 टन खाद और अनौपचारिक नियंत्रण से तुलना किया गया। द्रव्य जैवसूत्रीकरण उपचार में *बेसिलस अमीलोलिक्वेफासिएस* पौधशाला भिगाने एवं गोबर की खाद से मष्दा उपचार लगातार तीन वर्षों तक जड़गाँठ सूत्रकृमि प्रबंधन करने में बेहतर प्रदर्शन किया और मृदा आबादी में सूत्रकृमि 77.1, 61.5 और 74.6 प्रतशत की कमी होने के साथ ज्यादा से ज्यादा फल उपज 24.0, 22.5 और 31.1 टन प्रति हेक्टेयर 2015–16, 2016–17 और 2017–18 दौरान क्रमशः पाया गया और ये उपचार सूत्रकृमिनाशक (कार्बोफुरन 3 जी 1.0 किलोग्राम सक्रिय तत्व/हे. और कार्बोफुरन 3 जी 1.0 किलोग्राम सक्रिय तत्व/हे. के साथ 20 टन खाद) के साथ तुलनीय था। इसके बाद *बेसिलस सबटिलिस* पौधशाला भिगोने के साथ मष्दा उपचार से मष्दा आबादी में सूत्रकृमि 52.5, 55.8 और 70.4 प्रतिशत कमी होने के साथ 20.0, 22.0 और 30.4 टन प्रति हेक्टेयर 2015–16, 2016–17 और 2017–18 दौरान क्रमशः में फल उपज मिली और जड़गाँठ सूत्रकृमि प्रबंधन के लिये यह उपचार आशाजनक पाया गया। अंत में इस अध्ययन से स्पष्ट होता है कि *बेसिलस अमीलोलिक्वेफासिएंस* (1 प्रतिशत ए.एस.) और *बेसिलस सबटिलिस* (1 प्रतिशत ए.एस.) द्रव्य जैवसूत्रीकरण और उनके वितरण तंत्र का टमाटर में जड़गाँठ सूत्रकषमि प्रबंधन के लिये उपयोग किया जा सकता है।

References

Abad P, Favery B, Rosso MN and Castagnone-Sereno P (2003) Root-knot nematode parasitism and host response: molecular basis of a sophisticated interaction. Mol Plant Pathol 4: 217-224.

Abdel-Salam MS, Hoda HA, Gaziea MS, Elkelany US and Amira MA (2018) Improving the nematicidal potential of *Bacillus amyloliquefaciens* and *Lysinibacillus sphaericus* against the root-knot nematode *Meloidogyne incognita* using protoplast fusion technique. Egypt J Biol Pest Co 28: 1-6.

Adam MAM, Phillips MS and Blok VC (2007) Molecular diagnostic key for identification of single juveniles of seven common and economically important species of root-knot nematode (*Meloidogyne* spp.) Plant Pathol 56: 190 -197.

Anastasiadis IA, Giannakou IO, Prophetou Athanasiadou DA and Gowen SR (2008) The combined effect of the application of a biocontrol agent *Paecilomyces lilacinus*, with various practices for the control of root-knot nematodes. Crop Prot 27: 352-361.

Ann YC (2013) Screening for nematicidal activities of *Bacillus* species against root knot nematode (*Meloidogyne incognita*). Am J Exp Agric 3: 794-805.

Anonymous (2017) Horticulture statistics at a glance. Department of Agriculture Cooperation and Farmers welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India, pp: 151.

Bridge J and Page SLJ (1980) Estimation of root-knot nematode infestation levels on roots using a rating chart. Trop Pest Manage 26: 296-298.

Cobb NA (1918) Estimating the Nema Populations of Soil. USDA, pp. 48 (Technical Circular 1).

Collange B, Navarrete M, Peyre G, Mateille T and Tchamitchian M (2011) Root-knot nematode (*Meloidogyne*) management in vegetable crop production: The challenge of an agronomic system analysis. Crop Prot 30: 1251-1262.

Ferraz S and Freitas LG (2004) Use of antagonistic plants and natural products. In: Chen ZX, Chen, SY and Dickson, DW (ed.) Nematology - Advances and perspectives. Volume II: Nematode management and utilization. Beijing, China and Wallingford UK. Tsinghua University Press, CABI Publishing. pp: 931-977.

Haseeb A and Khan MR (2012) Prospects of *Trichoderma* in nematode management. In: Status and prospects for enhancing the uptake of antagonistic organisms for nematode management in India. Nagesh M, Rajkumar BS, Bhumannavar NK, Krishna Kumar (ed) NBAII (ICAR), Bangalore, India, pp:187.

Jain RK, Mathur KN and Singh RV (2007) Estimation of losses due to plant parasitic nematodes on different crops in India. Indian J Nematol 37: 219-221.

Kerry BR and Hidalgo-Diaz L (2004) Application of *Pochonia chlamydosporia* in the integrated control of root-knot nematodes on organically grown vegetable crops in Cuba. IOBC WPRS Bulletin 27: 123–126.

Kiewnick S and Sikora R (2005) Biological control of the root-knot nematode *Meloidogyne incognita* by *Paecilomyces lilacinus* strain 251. Biol Control 38: 179–187

Killani AS, Abaidoo RC, Akintokun AK and Abiala MA (2011) Antagonistic effect of indigenous *Bacillus subtilis* on root soil borne fungal pathogens of cowpea. Researcher 3: 11-18.

Krishnaveni M and Subramanian S (2004) Evaluation of biocontrol agents for the management of *Meloidogyne incognita* on cucumber (*Cucumis sativus* L.). Curr Nematol 15: 33-37.

Latha P, Anand T, Prakasam V, Jonathan EI, Paramathma M and Samiyappan R (2011) Combining *Pseudomonas*, *Bacillus* and *Trichoderma* strains with organic amendments and micronutrient to enhance suppression of collar and root rot disease in physic nut. Appl Soil Ecol 49: 215-223.

Mohamedova MS (2009) Efficacy of *Bacillus thuringiensis* alone and in combination with oxamyl against *Meloidogyne arenaria* infecting greenhouse tomato. A Sci Tech, 1: 41-44.

Mohammed SH, Anwer M, Saedy El, Enan MR, Ibrahim NE, Ghareeb A and Moustafa SA (2008) Biocontrol efficiency of *Bacillus thuringiensis* toxins against root-knot nematode, *Meloidogyne incognita*. J Cell Mol Biol 7: 57-66.

Muller R and Gooch PS (1982) Organic amendments in nematode control. An examination of the literature. Nematropica 12: 319-326.

Patil J, Miller AJ and Gaur HS (2013) Effect of nitrogen supply form on the invasion of rice roots by the root-knot nematode, *Meloidogyne graminicola.* Nematology 15: 483-492.

Randig O, Leroy F, Bongiovanni M and Castagnone-Sereno P (2001) RAPD characterization of single females of the root-knot nematodes, *Meloidogyne* spp. European J Plant Pathol 107: 639–643.

Rao MS, Kamalnath M, Umamaheshwari, Rajanikanth R, Prabu P, Priti K, Grace, GN, Chaya MK and Gopalakrishnan (2017) *Bacillus subtilis* IIHR BS-2 enriched vermicompost controls root knot nematode and soft rot disease complex in carrot. Sci Hort 218: 56-62.

Rao MS, Umamaheswari R, Chakravarthy AK, Grace GN, Kamalnath M and Prabu P (2015) A frontier area of research on liquid biopesticides: the way forward for sustainable agriculture in India. Curr Sci 108: 1590-1592.

SAS Institute: *SAS version 9.2 System options*. Cary, NC, USA, SAS Institute, USA.

Saxena AK, Pal KK and Tilak KVBR (2000) Bacterial biocontrol agents and their role in plant disease management. In: Upadhyay RR, Mukerji KG and Chamola BP (ed) Biocontrol potential and its exploitation in sustainable agriculture: Crop diseases, weeds, and nematodes. Kluwer Academy Plenum, New York. pp: 25-37.

Singh RS and Sitaramaiah IC (1966) Incidence of root-knot of okra and tomatoes on oil-cake amended soil. Plant Disease Reporter 50: 668-672.

Singh S (2013) Integrated approach for the management of the root-knot nematode, *Meloidogyne incognita*, on eggplant under field conditions. Nematology 15: 747-757.

Singh S, Singh B and Singh AP (2014) Integrated management of root-knot disease of okra caused by root-knot nematode, *Meloidogyne incognita*. Indian J Nematol 44: 172-178.

Terefe M, Terefa T and Sakhuja PK (2009) Effect of a formulation of *Bacillus firmus* on root-knot nematode *Meloidogyne incognita* infestation and the growth of tomato plants in the greenhouse and nursery. J Invertebr Pathol 100: 94-99.

Timper P (2014) Conserving and enhancing biological control of nematodes. J Nematol 46:75-89.

Vinodkumar S, Nakkeeran S, Renukadevi P and Malathi VG (2017) Biocontrol potentials of antimicrobial peptide producing *Bacillus* species: multifaceted antagonists for the management of stem rot of carnation caused by *Sclerotinia sclerotiorum.* Front Microbiol 8: 446.

Walker GE (2004) Effects of *Meloidogyne javanica* and organic amendments, inorganic fertilizers and nematicides on carrot growth and nematode abundance. Nematol Mediterr 32: 181-188.

Xiao TJ, Chen F, Gao C, Zhao QY, Shen QR and Ran W (2013) *Bacillus cereus* X5 enhanced bio-organic fertilizers effectively control root-knot nematodes (*Meloidogyne* sp.). Pedosphere 23: 160–168.

Vegetable Science (2018) 45(2) : 269-271

Short Communication

Punjab Swarna: high yielding tomato variety for naturally ventilated polynet house cultivation

SK Jindal* and MS Dhaliwal

Received: June 2018 / Accepted: January 2019

Tomato (*Solanum lycopersicum* L) is one of the important commercial vegetable grown under protected conditions, where environment is modified to suitable conditions for optimum plant growth which leads to production of quality tomatoes suitable for exports and domestic consumption. Previously, the Punjab Agricultural University has developed and recommended two indeterminate table varieties such as 'Punjab Gaurav' and 'Punjab Sartaj' (Dhaliwal and Jindal 2018a), three cherry tomato varieties viz. Punjab Red Cherry (Dhaliwal and Jindal, 2017); Punjab Sona Cherry and Punjab Kesar Cherry (Dhaliwal and Jindal, 2018b) for commercial cultivation in Punjab. Focusing on breeding for quality in tomato, yellow coloured Punjab Sona Cherry and orange coloured Punjab Kesar Cherry rich in carotene content were developed. The development of these varieties results in creating awareness regarding quality among tomato growers, thus, in turn demand for table tomatoes of other colours specially yellow, orange or pink etc was increased in the state. In view of that, the orange coloured table variety 'Punjab Swarna' was developed and now become available for tomato growers of the state for cultivation under polynet house. The orange fruit colour of 'Punjab Swarna' makes this variety for use where additional flavor or retinoid activity is desired. Stommel et al. (2005) also demonstrated the importance of color on consumer perceptions of fruit quality. Based on the field performance and due to the importance of carotene content in human diet, this variety was released by Punjab State Varietal Approval Committee for commercial cultivation in the state.

The trials were conducted from 2013-14 to 2016-17 at PAU, Ludhiana by taking newly developed tomato cultivar 'Punjab Swarna' along with previously released varieties Punjab Gaurav and Punjab Sartaj; and a commercially grown indeterminate hybrid 'G-600' (from Golden Seeds Private Limited, India) and hybrid 'Heemshikhar' used as checks were evaluated in a naturally ventilated polynet house. During 2015-16, the experiment was conducted at other locations i.e at Krishi Vigyan Kendras (Farm Science Centre of PAU Ludhiana) situated at Sangrur, Bathinda and Jallandhar, in addition to PAU, Ludhiana in completely randomized block design with 3 replications in a naturally ventilated polynet house. During 2016-17, on farm testing (adaptive research trials) was done at 22 locations of the state. The data was recorded for early yield (q/ ha), total yield (q/ ha), fruit weight (g), days to first harvest, number of fruits per cluster, number of clusters per plant, fruit shape index (P/E diameter), pericarp thickness (mm), number of locule per fruit, dry matter (%), total soluble solids (TSS, °Brix), acidity (mg/ 100 ml juice), ascorbic acid (mg/ 100 ml juice), total carotenoids (mg/ 100 g), lycopene content (mg/ 100 g), late blight (% disease index), root gall index (0- 5 scale), leaf curl virus (% incidence), percent fruit damage by *Heliothus armigera*, number of aphid and whitefly population present per 50 leaves. The disease data on late blight, root gall index and leaf curl virus under artificial conditions was recorded as per the method given by Thind et al. (1989), Taylor and Sasser (1978) and Muniyappa et al. (1991), respectively whereas the data on percent fruit damage, number of aphid and whitefly was recorded under open field conditions in non sprayed conditions. However, the performance of 'Punjab Swarna' and checks are based on the overall mean obtained from the 3 levels of evaluation trials under polynet house conditions. The data collected at PAU and other locations were subjected to analysis to calculate least square differences; adaptive trials from 22 locations were averaged. Early yield comprised fruit harvest till the end of March since the

Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab-141004

*Corresponding author, E-mail: saleshjindal@pau.edu

Table 1: Performance of indeterminate tomato varieties/hybrids at On-station research, multilocation and On-farm trials

Variety/ Hybrid	Yield(q/ha)			
	On station research trials (average of 4 years)	Multilocation research trials (average of 4 locations)	On farm trials (average of 22 locations)	Overall mean
Punjab Swarna	2844.67	2769.59	2543.20	2719.15
Punjab Gaurav (Check)	2247.30	2279.33	2206.73	2244.45
Punjab Sartaj (Check)	2112.91	2143.33	2000.64	2085.63
Hybrid G-600 (Check)	1943.74	1932.46	-	1938.10
Hybrid Heemshikhar (Check)	2010.67	-	2067.68	2039.18
CD @ p=0.05	109.19	226.06	111.83	-

normal crop harvest in open starts in April. Fruit weight was recorded by taking mean of ten representative fruits.

Performance for early and total yield: In local research trials, first picking of Punjab Swarna was possible 120 days after transplanting (Table 2) which was at par with Punjab Gaurav (120) and G-600 (119) but 2.65% late than Punjab Sartaj (116 days) and 9% than Heemshikhar (110 days) respectively. Similarly, early yield (harvested till end March) of the hybrid G-600, hybrid Heemshikhar, Punjab Sartaj and Punjab Gaurav was 516.89q ha^{-1} , 465.89 q ha^{-1}, 455.48 q ha^{-1} and 442.85 q ha^{-1} which was 19.59%, 10.78%, 8.74% and 6.14% more than Punjab Swarna (415.65 q ha^{-1}) respectively (Table 2). For total yield, Punjab Swarna recorded average fruit yield of 2844.67q ha^{-1} in local research trials, which was approximately 26% to 46% higher than the checks. In multilocation trials, fruit yield of Punjab Swarna was recorded to be 2769.59q ha^{-1} (Table 1) which was 22% to 43% higher than the checks. Based on the mean performance of 22 on-farm trials, Punjab Swarna out yielded the checks by 15% to 23% (Table 1). Overall, Punjab Swarna recorded an average yield of 2719.15q ha^{-1} which was 21% to 40% more than the checks. Jindal *et al* 2015 and Dhaliwal and Jindal (2018a) also recorded higher early and total yield of tomato hybrids under naturally ventilated polyhouse.

Physical and biochemical traits of fruits: Based on the research trials, average fruit weight (Table 2) of Punjab Swarna was 83.42g which was at par with Punjab Sartaj (83.59g); lower than Punjab Gaurav (90.28) and hybrid G-600 (99.69g) but higher than the hybrid Heemshikhar (73.94g). Punjab Swarna produced more number of fruits per cluster and cluster per plant than the check entries which contributes to its significant higher yield. The fruit shape index of Punjab Swarna was more than unity (Table 2) indicating its oval fruit shape. From checks, Punjab Gaurav was also oval in shape but others were comparable in shape index and were round in shape. The pericarp of Punjab Swarna was thicker than both the check hybrids (5.02mm of G-600 and 4.91mm of Heemshikhar) but thinner than Punjab Gaurav (7.42mm) and Punjab Sartaj (7.12mm). The number of locules of Punjab Swarna (2.59) was 7.17%, 26.21%, 33.07% and 30.93% less than Punjab Gaurav (2.79), Punjab Sartaj (3.51), G-600 (3.87) and Heemshikhar (3.75). Thicker pericarp and lesser number of locules are desirable as these are associated with fruit

Table 2: Performance of indeterminate tomato varieties/hybrids for fruit and quality traits* under poly-net house

Traits \ Variety/ hybrid	Punjab Swarna	Punjab Gaurav	Punjab Sartaj	Hybrid G-600 (Check)	Hybrid Heemshikhar (Check)	CD at p=0.05%
Days to first harvest	119.98	119.80	116.88	119.13	110.03	1.47
Early yield (q/ha)	415.65	442.85	455.48	516.89	465.89	18.20
Fruit weight (g)	83.42	90.28	83.59	99.69	73.94	2.07
Number of fruit per cluster	9.00	8.67	5.79	5.54	6.40	1.08
Number of clusters per plant	13.34	9.84	12.85	10.65	11.90	0.86
Fruit shape index (P/E)	1.16	1.14	0.94	0.92	0.94	0.05
Pericarp thickness (mm)	5.34	7.42	7.12	5.02	4.91	0.35
Number of locules per fruit	2.59	2.79	3.51	3.87	3.75	0.27
Dry matter (%)	4.42	5.23	5.47	4.29	5.59	0.41
TSS (°Brix)	4.06	5.28	5.44	4.44	4.69	0.34
Acidity (g 100 $ml^{-1}$of juice)	0.42	0.38	0.34	0.30	0.44	0.05
Vitamin C (g 100 ml^{-1} of juice)	18.38	23.28	26.24	32.84	29.74	3.02
Lycopene (mg 100 g^{-1} FW)	1.35	5.02	5.25	4.21	4.51	0.30
Total carotenoids (mg 100 g^{-1}FW)	13.86	5.23	5.02	4.84	4.83	1.16

*average of 3 years, FW-Fresh weight

Table 3: Reaction to important diseases (under artificial inoculation conditions) and insect-pests (under natural conditions)*

Variety/Hybrid	Late blight, % disease Index	Root gall index, (0- 5 scale)	Leaf curl virus, % incidence	Percent fruit damage by *Heliothus armigera*	Number of white flies per 50 leaves	Number of aphids per 50 leaves
Punjab Swarna	31.15 (MS)	2.00 (MR)	80.00 (MoI)	17.36	2.52	5.54
Punjab Gaurav (Check)	46.90 (S)	3.10 (MS)	70.00 (MoI)	19.80	1.59	5.92
Punjab Sartaj (Check)	42.75(S)	2.60 (MS)	15.00 (MI)	21.66	2.80	9.50
Hybrid G-600 (Check)	40.50(S)	3.10 (S)	60.00 (SI)	10.50	3.27	14.00
Hybrid Heemshikhar (Check)	43.80(S)	1.55 (MR)	60.00 (MoI)	29.19	2.35	7.79

*average of 2 years,
Where, S-Susceptible, MS-Moderately susceptible, MR-Moderately Resistant, MoI-Moderate infection, MI-Mild infection and SI-Severe infection

firmness. Jindal *et al* 2015 and Dhaliwal and Jindal (2018a) also observed that the genotype having thicker pericarp has longer shelf life, higher fruit firmness and high transportation ability. All the entries were also evaluated for important fruit quality attributes (Table 2). These included dry matter (DM %), total soluble solids (TSS °Brix), acidity (g $100ml^{-1}$), vitamin C (g $100ml^{-1}$), total carotenoids (mg $100g^{-1}$) and lycopene (mg $100g^{-1}$). Dry matter % of Punjab Swarna was (4.42) which was more than G-600 (4.29) but lower than Punjab Gaurav (5.23), Punjab Sartaj (5.47) and Heemshikhar (5.59). TSS content of Punjab Swarna (4.06%), was less than the checks. Acidity content of Punjab Swarna was 0.42g ml^{-1} which was significantly higher than the Punjab Gaurav, Punjab Sartaj and G-600 however, Vitamin C content (Table 2) and lycopene content of Punjab Swarna (18.38 and 1.35) was less than all the test entries. Punjab Swarna (13.86) had significantly higher total carotenoids (which contributes to its orange colour) than check varieties such as Punjab Gaurav (5.23), Punjab Sartaj (5.02) and also from the check hybrids G-600 (4.84) and Heemshikhar (4.83). The orange colour of 'Punjab Swarna' make the fruit more attractive is due to high carotenoid content. Dhaliwal and Jindal (2018a) also developed two cherry tomato varieties with yellow and orange colour having high carotenoids.

Reaction to diseases and insects: Punjab Swarna (31.15%) was moderately susceptible to late blight (Table 3) as compared to other check varieties (46.90% Punjab Gaurav and 42.75% Punjab Sartaj) and check hybrids (40.50% G-600 and 43.80% Heemshikhar). The variety Punjab Swarna (2.00) and check hybrid Heemshikhar (1.55) were moderately resistant to root knot nematodes as compare to other checks which were susceptible. Punjab Swarna and other checks except Punjab Sartaj developed moderate infections to leaf curl disease (Table 3) whereas Punjab Sartaj developed mild tomato leaf curl disease symptoms. The percent fruit damage, number of white flies and number of aphids per 50 leaves were recorded under natural conditions and were found comparable for all the test entries. The variety 'Punjab Swarna' is documented with National Bureau of Plant Genetic Resources, New Delhi having accession code 'IC 624108'.

References

Jindal SK, Dhaliwal MS and Chawla N (2015) Comparative performance of different tomato hybrids under naturally ventilated polyhouse. Intl J Hort 5(14) 1-12.

Dhaliwal MS and Jindal SK (2018a) Punjab Gaurav and Punjab Sartaj: Tomato varieties for polynet house cultivation. Veg Sci 45(1):124-126.

Dhaliwal MS and Jindal SK (2018b) Punjab Sona Cherry and Punjab Kesar Cherry-Varieties of cherry tomato for naturally ventilated polynet house cultivation. Veg Sci 45(1):144-147.

Dhaliwal MS and Jindal SK (2017) Development of cherry tomato variety from interspecific cross (*Solanum lycopersicum* and *Solanum pimpinellifolium*) for protected cultivation. Agri Res J 54: 182-187.

Muniyappa V, Jalikop SH, Saikia AK, Chennarayappa, Shivashankar G, Ishwara Bhat A and Ramappa HK (1991) Reaction of *Lycopersicon* cultivars and wild accessions to tomato leaf curl virus. Euphytica 56: 37-41.

Stommel JR, Abbott JA, Saftner RA and Camp MJ (2005) Sensory and objective quality attributes of ß-carotene and lycopene rich tomato fruit. J Amer Soc Hort Sci 130: 244-251.

Taylor L and Sasser JN (1978) Biology, identification and control of root knot nematodes (*Meloidogyne spp.*). North Carolina State Univ and the US Agency for 1st Div Raleigh, NC.

Thind TS, Mohan C, Sokhi SS and Bedi JS (1989) A detached leaf technique for maintenance and multiplication of *Phytophthora infestans* and evaluation of fungicides. Curr Sci 58:388-89.

Vegetable Science (2018) 45(2) : 272-276

Short Communication

Correlation and path coefficient analysis for growth, yield and its associated traits in sponge gourd [*Luffa cylindrica* (Roem) L.]

Yamuna Prasad Singh*, VB Singh, Pramila, Prince Kumar and Mahendra Kumar Singh

Received: January 2018 / Accepted: December 2018

Sponge gourd is one of the most important cucurbit, both as rainy and summer season vegetable which is grown throughout the country and world. It is an annual and monoeceous cucurbit plant and it has a gelatinous compound luffien. Luffa is domesticated species and commonly called as sponge gourd, loofah, vegetable sponge or dish cloth. It originated in subtropical Asian region particularly India (Kalloo 1993). It belongs to the family Cucurbitaceae with diploid chromosome number 2n = 2x = 26 which includes about 118 genera and 825 species. The nutritive value of sponge gourd fruits per 100 g edible portion (tough skin removed, edible portion 80%) is: water 93.2 g, energy 18 kcal, protein 1.2 g, fat 0.2 g, carbohydrate 2.9 g, fibre 2.0 g, Ca 36 mg, P 19 mg, Fe 1.1 mg, carotene 120 µg, thiamine 0.02 mg, riboflavin 0.06 mg, niacin 0.4 mg and the composition of young leaves per 100 g edible portion is: water 89 g, protein 5.1 g, carbohydrate 4.0 g, fibre 1.5 g, Ca 56 mg, Fe 11.5 mg, carotene 9.2 mg, ascorbic acid 95 mg. It used for scrubbing of body skin as a bath sponge increase blood circulation and also used for utensils purposes. It has certain medicinal uses and recommended to the patients suffering from malaria or other seasonal fevers. Among vegetables, cucurbits are associated with the origin of agriculture and dawn of human civilization. In food crops, cucurbits are largest producer of biological water and easily digestive and recommended even to sick and frail patients. Its flowers are yellow in colour and showy having five petals. It produces fruits containing a fibrous vascular system having vigorous vines with cylindrical ten angle fruits (Whitaker and Davis 1962). To develop a new variety there is need of high magnitude of genetic variability in the base material and the vast of variability for desired characters. Variability in cucurbitaceous crop occurs in the form of land races, traditional cultivars, wild relatives and related non edible wild weedy species. In India little attention has been given for the genetic improvement of sponge gourd by collecting diverse germplasm, their morphological characterization and assessing the variability parameters like coefficient of variation, coefficient of correlation and path analysis (Badade et al. 2001, Islam 2004). Little attention has been given for the genetic improvement of sponge gourd in India.

The experimental materials consisted of 14 promising parental lines of sponge gourd and their F_1 progenies. Out of these advanced breeding parental lines (10 lines and 4 testers) were crossed to get 40 F_1's under Randomized Complete Block Design (RBD) with three replications at main Experiment Station, Department of Vegetable Science, NDUAT, Kumarganj, Faizabad, UP. The treatments were sown in rows spaced 2.50 meters apart with a plant to plant spacing of 0.5 meter. The experiment was sown on 23th February, 2014 (Y_1) and 27th February, 2015 (Y_2). All the recommended agronomic package of practices and protection measures were followed to raise a good crop. Fertilizers and manures were applied as per recommended dose. Observations were recorded on all the five plants maintained carefully in each plot for fourteen quantitative characters *viz*., node number to anthesis of first staminate flower, node number to anthesis of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, node number of first fruit harvest, days to first fruit harvest, no. of primary branches per plant, inter nodal length (cm), vine length (m), fruit length (cm), fruit circumference (cm), average fruit weight (g), number of fruits per plant and average fruits yield per plant (kg). The simple correlations at genotypic (g) and phenotypic (p) levels

Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj-224 229, Faizabad, UP
*Corresponding author, E-mail: yamunasingh1947@gmail.com

Table 1: Estimates of genotypic correlation coefficient among 14 characters for yield and yield traits in sponge gourd during Y_1 and Y_2 (Y_1= 2014 and Y_2= 2015)

S.N	Characters		Node no.to anthesis of first staminate flower	Node no.to anthesis of first pistillate flower	Days to anthesis of first staminate flower	Days to anthesis of first pistillate flower	Days to first fruit harvest	Node no. of first fruit harvest	No. of fruits per plant	Average fruit weight (g)	Vine length (m)	Fruit length (cm)	Fruit circumference (cm)	No.of primary branches per plant	Inter nodal length (cm)	Average fruits yield per plant (kg)
1.	Node no.to anthesis of first staminate flower	Y_1	1.000	0.632	0.586	0.439	0.403	0.602	-0.029	-0.155	-0.046	0.333	0.066	-0.064	-0.228	-0.103
		Y_2	1.000	0.745	0.646	0.422	0.332	0.731	-0.075	-0.071	-0.018	0.283	0.097	-0.083	-0.200	-0.023
2.	Node no.to anthesis of first pistillate flower	Y_1		1.000	0.753	0.551	0.441	0.988	-0.074	-0.041	0.043	-0.100	-0.162	-0.151	0.022	-0.052
		Y_2		1.000	0.719	0.435	0.352	0.968	-0.085	-0.084	0.013	-0.069	-0.034	-0.134	-0.078	-0.061
3.	Days to anthesis of first staminate flower	Y_1			1.000	0.855	0.661	0.747	-0.108	0.108	0.005	-0.044	-0.185	-0.442	0.015	0.089
		Y_2			1.000	0.790	0.661	0.721	-0.103	0.130	0.027	-0.020	-0.022	-0.367	-0.022	0.078
4.	Days to anthesis of first pistillate flower	Y_1				1.000	0.858	0.544	0.030	-0.012	0.055	0.027	0.053	-0.474	-0.182	0.154
		Y_2				1.000	0.791	0.478	-0.003	0.056	0.044	-0.090	0.153	-0.248	-0.074	0.135
5.	Days to first fruit harvest	Y_1					1.000	0.467	-0.016	0.048	0.224	0.161	-0.115	-0.309	-0.520	0.159
		Y_2					1.000	0.411	-0.052	0.144	0.173	0.023	-0.162	-0.105	-0.416	0.120
6.	Node no. of first fruit harvest	Y_1						1.000	-0.125	-0.035	0.061	-0.141	-0.217	-0.191	0.019	-0.108
		Y_2						1.000	-0.128	-0.022	0.063	-0.103	0.040	-0.138	-0.072	-0.063
7.	No. of fruits per plant	Y_1							1.000	-0.635	-0.008	-0.017	0.154	0.154	0.007	0.760**
		Y_2							1.000	-0.482	0.077	0.068	0.181	0.213	-0.010	0.788**
8.	Average fruit weight (g)	Y_1								1.000	-0.178	-0.091	-0.223	-0.139	0.086	0.007
		Y_2								1.000	-0.292	-0.143	-0.173	-0.098	0.182	0.152
9.	Vine length (m)	Y_1									1.000	-0.095	0.183	0.186	-0.100	-0.081
		Y_2									1.000	-0.007	0.160	0.190	-0.080	-0.064
10.	Fruit length (cm)	Y_1										1.000	0.185	0.034	-0.579	-0.022
		Y_2										1.000	-0.004	-0.038	-0.482	0.037
11.	Fruit circumference (cm)	Y_1											1.000	-0.030	-0.041	0.041
		Y_2											1.000	-0.225	-0.034	-0.001
12.	No.of primary branches per plant	Y_1												1.000	0.038	0.056
		Y_2												1.000	0.036	0.163
13.	Inter nodal length (cm)	Y_1													1.000	0.014
		Y_2													1.000	0.052
14.	Average fruits yield per plant (kg)	Y_1														1.000
		Y_2														1.000

Table 2: Direct and indirect effects of various yield characters on yield in sponge gourd at genotypic level during Y_1 and Y_2 (Y_1= 2014 and Y_2= 2015)

Residual effect=SQRT(1- 1.0766) (Y_1) and SQRT(1- 1.0210) (Y_2) Bold values, indicated direct effect

S.N	Characters		Node no.to anthesis of first staminate flower	Days to anthesis of first staminate flower	Days to first fruit harvest	Node no. of first fruit harvest	No. of fruits per plant	Average fruit weight (g)	Vine length (m)	Fruit length (cm)	Fruit circumfer ence (cm)	No.of primary branches per plant	Inter nodal length (cm)	Average fruits yield per plant (kg)
1.	Node no.to anthesis of first staminate flower	Y_1	**-0.132**	0.145	0.005	0.004	-0.037	-0.127	-0.002	0.035	0.004	-0.004	0.006	-0.103
		Y_2	**0.133**	-0.072	-0.264	0.441	-0.096	-0.062	-0.004	-0.010	-0.044	0.007	0.072	-0.023
2.	Days to anthesis of first staminate flower	Y_1	-0.077	**0.247**	0.008	0.005	-0.139	0.089	0.000	-0.005	-0.010	-0.030	0.000	0.089
		Y_2	0.086	**-0.111**	-0.524	0.435	-0.131	0.114	0.006	0.001	0.010	0.031	0.008	0.078
3.	Days to first fruit harvest	Y_1	-0.053	0.163	**0.012**	0.003	-0.021	0.039	0.011	0.017	-0.006	-0.021	0.014	0.159
		Y_2	0.044	-0.073	**-0.793**	0.248	-0.066	0.126	0.040	-0.001	0.073	0.009	0.149	0.120
4.	Node no. of first fruit harvest	Y_1	-0.079	0.185	0.006	**0.007**	-0.161	-0.028	0.003	-0.015	-0.012	-0.013	-0.001	-0.108
		Y_2	0.097	-0.080	-0.326	**0.603**	-0.163	-0.019	0.015	0.004	-0.018	0.012	0.026	-0063
5.	No. of fruits per plant	Y_1	0.004	-0.007	0.000	-0.001	**1.288**	-0.521	0.000	-0.002	0.008	0.010	0.000	0.760
		Y_2	-0.010	0.011	0.041	-0.077	**1.276**	-0.421	0.018	-0.002	-0.081	-0.018	0.004	0.788
6.	Average fruit weight (g)	Y_1	0.020	0.027	0.001	0.000	-0.818	**0.820**	-0.009	-0.010	-0.012	-0.009	-0.002	0.007
		Y_2	-0.009	-0.014	-0.114	-0.013	-0.615	**0.873**	-0.068	0.005	0.077	0.008	-0.065	0.152
7.	Vine length (m)	Y_1	0.006	0.001	0.003	0.000	-0.011	-0.146	**0.051**	-0.010	0.010	0.013	0.003	-0.081
		Y_2	-0.002	-0.003	-0.137	0.038	0.099	-0.255	**0.232**	0.000	-0.072	-0.016	0.028	-0.064
8.	Fruit length (cm)	Y_1	-0.044	-0.011	0.002	-0.001	-0.002	-0.075	-0.005	**0.106**	0.010	0.002	0.016	-0.022
		Y_2	0.038	0.002	-0.018	-0.062	0.087	-0.125	-0.002	**-0.034**	0.002	0.003	0.172	0.037
9.	Fruit circumference (cm)	Y_1	-0.009	-0.046	-0.001	-0.002	0.198	-0.183	0.009	0.020	**0.054**	-0.002	0.001	0.041
		Y_2	0.013	0.002	0.129	0.024	0.231	-0.151	0.037	0.000	**-0.447**	0.019	0.012	-0.001
10.	No.of primary branches per plant	Y_1	0.008	-0.109	-0.004	-0.001	0.198	-.0114	0.009	0.004	-0.002	**0.068**	-0.001	0.056
		Y_2	-0.011	0.041	0.083	-0.083	0.271	-0.086	0.044	0.001	0.100	**-0.084**	-0.013	0.163
11.	Inter nodal length (cm)	Y_1	0.030	0.004	-0.006	0.000	0.009	0.071	-0.005	-0.061	-0.002	0.003	**-0.027**	0.014
		Y_2	-0.027	0.002	0.330	-0.043	-0.013	0.159	-0.018	0.016	0.015	-0.003	**-0.358**	0.052

were estimated according to Searle (1961). For the Path coefficient analysis, Dewey and Lu (1959) method was followed. Fruits yield is not independent variable; it is influenced by all the other independent variables and characters, directly as well as indirectly.

Genotypic correlation coefficients between yield and its components traits: The analysis of correlation coefficient revealed that average fruits yield per plant (kg) *exhibited* highly *significant and positive correlation at genotypic level with* number of fruits per plant (0.760 and 0.788) whereas, days to anthesis of first pistillate flower (0.154 and 0.135) and days to first fruit harvest (0.159 and 0.120) *exhibited significant and positive correlation at genotypic level* in both the years *(Table-1)*. Among other traits, maximum traits showed positive correlation with other traits whereas negative and significant correlation also exhibited with some traits. The present findings are supported by Rajput et al. (1995) in bitter gourd and Shah and Kale (2002) in ridge gourd.

Genotypic *path coefficient analysis: The genotypic path coefficient analysis revealed that the highest positive direct effect towards* average fruits yield per plant (kg) *was observed by* number of fruits per plant (1.228 and 1.276), average fruit weight (g) (0.820 and 0.873) in both the years (table-2), node number of first fruit harvest (0.603) in$Y_{2,}$ days to anthesis of first staminate flower (0.247) in$Y_{1,}$ vine length (m) (0.0232) in$Y_{2,}$ node number to anthesis of first staminate flower (0.133) in$Y_{2,}$ number of primary branches per plant (0.068), fruit circumference (cm) (0.054), days to first fruit harvest (0.012) and node number of first fruit harvest (0.007) in$Y_{1.}$ Almost similar conclusions were drawn by Kumar (2007) and Dey *et al.* (2005). *However* days to first fruit harvest (-0.793), fruit circumference (cm) (-0.447) in$Y_{2,}$ inter nodal length (cm) (-0.027 and -0.358) in both the years, node number to anthesis of first staminate flower (-0.132) in$Y_{1,}$ days to anthesis of first staminate flower (-0.111), primary branches per plant (-0.084) and fruit length (cm) (-0.034) inY_{2} had exerted maximum negative direct effects on average fruits yield per plant (kg). In $Y_{1,}$ node number to anthesis of first staminate flower via days to anthesis of first staminate flower and in $Y_{2,}$ node number to anthesis of first staminate flower via node number of first fruit harvest, days to anthesis of first staminate flower via node number of first fruit harvest, days to first fruit harvest via node number of first fruit harvest, fruit length (cm) via inter nodal length (cm), days to first fruit harvest via inter nodal length (cm), days to first fruit harvest via average fruit weight (g) and days to anthesis of first staminate flower via average fruit weight (g) showed maximum positive indirect effects on average fruits yield per plant (kg) and also in $Y_{1,}$ node number to anthesis of first staminate flower via average fruit weight (g) and in $Y_{2,}$ days to anthesis of first staminate flower via days to first fruit harvest and node number to anthesis of first staminate flower via days to first fruit harvest whereas, number of fruits per plant via average fruit weight (g), node number of first fruit harvest via number of fruits per plant and days to anthesis of first staminate flower via number of fruits per plant had exerted maximum negative indirect effects on average fruits yield per plant (kg). Same result found by Singh et al. (2013).

The correlation coefficients studies revealed that in general an estimate of genotypic correlation coefficient was higher than corresponding phenotypic correlation coefficient, which indicated a strong inherent association among different traits under study. The lower phenotypic values might be due to environmental interactions. Similar observations were noticed in ridge gourd earlier (Karuppaiah et al. 2005). It is concluded that sufficient genetic variability is present for all traits studied. Therefore, crop improvement could be made on the basis of this genetic variability. In view of character association and path coefficients for yield and its contributing characters, it can also be concluded that breeders should give attention on characters like average fruits yield per plant (kg), average fruit weight (g), number of fruits per plant, days to anthesis of first pistillate flower and days to first fruit harvest for high yielding genotypes in sponge gourd.

References

Badade DS, Warade SD and Gaikwad SK (2001) Genetic divergence in bottle gourd. J Maharashtra Agric Univ 26(2): 137-139.

Deway DR and Lu KH (1959) A correlation and path coefficient analysis of component of crested wheat grass seed production. Agron J 51: 515-518.

Dey SS, Behera TK, Pal A and Munshi AD (2005) Correlation and Path Coefficient analysis in bitter gourd (*Momordica charantia* L.). Veg Sci 32:173-176.

Islam MT (2004) Genetic divergence in bottle gourd (*Lagenaria siceraria* Mol. Standl.). Bull Institute Trop Agri Kyushu Univ 27: 19-24.

Kalloo G (1993) Loofah-Luff S.P.P. (ed.). Genetic Improvement of Vegetable Crops. pp 265-266.

Karuppaiah P, Kavita R and Kumar PS (2005) Correlation and path analysis in ridge gourd (*Luffa acutangula* L.). Crop Res Hisar 29:490-494.

Kumar S, Singh R and Pal AK (2007) Genetic variability, heritability, genetic advance, correlation coefficient and path analysis in bottle gourd. Indian J Hort 64(2): 163-168.

Rajput JC, Paranjape SP and Jamadagni BM (1995) Correlation and path analysis studies for fruit yield bitter gourd. J Maharashtra Agri Univ 20(3): 377-379.

Searle (1961) Genotypic and environmental variance and covariance in an upland cotton crops of interpecific origin. Agron J 50:633-636.

Shah SR and Kale PN (2002) Yield component association analysis in ridge gourd . J Mah Agril Univ 27:197-198.

Singh DK, Maurya SK, Jaiswal HR, Singh A and Lohani M (2013) Character association and path coefficient analysis in ridge gourd. Pantnagar J Res 10(2):189-195.

Whitake TW and Davis GN (1962) Cucurbits. Interscience Publ. Inc. New Yark, pp 250.

Vegetable Science (2018) 45(2) : 277-280

Short Communication

Genetic divergence studies in green fruited brinjal (*Solanum melongena* L.)

P Irene Vethamoni*, N Nirmala and Natarajan

Received: June 2018 / Accepted: January 2019

Brinjal (*Solanum melongena* L.) is widely cultivated as one of the most important vegetables in both subtropical and tropical regions of India. It is a popular vegetable in India, China, Turkey, Japan, Syria, Egypt, Indonesia, Philippines, Thailand, France, Italy and USA. It is an important source of fibre (1.3 g/100g), protein (1.4 g/ 100g), vitamin-A (124 I.U) and potassium (200 mg/ 100g) and it is recommended even for patients with diabetes, asthma, cholera and bronchitis. Being primary centre of origin, India has accumulated wide range of variability in this crop. In spite of large number of varieties available in India, only few are promising. This fact draws the attention of plant breeder for its improvement. Any plant breeding programme needs clear understanding of existing genetic divergence in the available population. Genetic diversity plays a very important role for selecting the suitable parents for hybridization programme resulting in superior hybrids and desirable recombinants.The information on genetic divergence of various traits particularly of those that contribute to yield, quality and pest resistance would be of most useful in planning the breeding programme. Brinjal is grown almost in all the districts of Tamil Nadu and extensively in Dindigul, Theni and Madurai districts. In these districts consumers prefer only green coloured fruits than other coloured fruits. To meet the consumers' preference of these districts, it is necessary to develop green fruited variety or hybrids. As a first step of the breeding programme, collection and evaluation of genotype is important to know the yield potential, quality and shoot and fruit borer resistance characters of the selected genotypes. The selected genotypes can be released as a variety otherwise used for further breeding programmes. D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude for divergence between two genotypes under comparison. It considers the variation produced by any character and their consequent effect on other characters.Considering the above point of view, present investigation was undertaken to work out genetic divergence among green fruited genotypes based on twenty two important traits of brinjal, to help the breeders in selecting promising and genetically diverse parents for crop improvement.

The present investigation was carried out at the Department of Vegetable Crops, Faculty of Horticulture, Tamil Nadu Agricultural University, Coimbatore during 2016 which is situated at 11° N latitude and 77° E longitude and at an elevation of 426.6 m above MSL.The experimental materials for the present study consisted of 30 genotypes of green fruited brinjal. Out of 30 genotypes, twelve (IC 261786, IC 354546, IC 111033, IC 090907, EC 316201, EC 315014, IC 249344, IC 354721, IC 383345, IC 454561, IC 310889 and IC 111013) from NBPGR, New Delhi; one (ABSR -2) from IIVR Varanasi; fifteen local types (Notchidaipatti, Namakkal, Karur, Patteswaram, Mathukadipattu, Sathirampatti, Kumbakonam, Kurumbapatti, Devachinnampatti, Swamimalai, Ottanchathiram, Andipatti, Thirchy, Mettupalayam and Musuri) and two (Arka Kusumakar and Arka Shirish) from IIHR, Bangalore were collected and evaluated in a randomized block design with two replications for two seasons. Forty five days old seedlings were transplanted on the ridges adopting a spacing of 60 x 60 cm. Cultural practices were followed as per the package of practices recommended for Tamil Nadu.Twenty five plants were maintained for each hybrid in each replication. The average values were computed as treatment mean under each replication for 22 traits *viz.,* plant height (cm), number of branches per plant, days to first flowering, days to 50 per cent flowering, days to first harvest,

RVS Padmavathy College of Horticulture, Sempatti, Dindigul, Tamil Nadu

*Corresponding author, E-mail: irenevetha17@gmail.com

pedicel length (cm), calyx length (cm), fruit length (cm), fruit girth (cm), single fruit weight (g), number of fruits/ plant, fruit yield per plant (kg), shoot infestation (%), fruit infestation on number basis (%), fruit infestation on weight basis (%), marketable yield per plant (kg), protein content (mg $100g^{-1}$), ascorbic acid (mg $100g^{-1}$), total phenol (mg g^{-1}), total sugars (mg g^{-1}) (FW), polyphenol oxidase (changes in OD min^{-1} $g^{-1}$of sample) and solasodine (%). The genetic divergence was estimated using Mahalanobis' D^2 statistics and genotypes were grouped in clusters according to Tocher's method as described by Rao (1952). The inter- and intra-cluster distances were worked out as per method suggested by Murthy and Arunachalam (1967).

The D^2 statistics has been found as a powerful tool to estimate genetic divergence among populations. Similarly, the diversity of parental material is the basic requirement of any breeding programme. More diverse the parents within a reasonable range, better are the chances of improving economic characters under consideration, in the resulting off springs. The nature and magnitude of genetic distance among the genotypes also serve as an indication for hybridization to exploit maximum heterosis. In the present investigation, based on D^2 analysis thirty genotypes were classified into seven clusters (Table 1). Out of these seven clusters, cluster I had large population of fifteen genotypes followed by cluster II and IV with five genotypes each and cluster VI with two and in remaining clusters *viz.,* cluster III, V and VII had one genotype each.The clustering pattern of genotypes was observed to be random indicating that geographical diversity and genetic divergence were unrelated. Further, it was observed that genotypes belonging to the same origin not only appeared in the same cluster but many of them also distributed in different clusters, which may be due to preferential selection of ideotypes suitable for various vegetable purposes. These findings clearly demonstrated that there was no parallelism between the geographic origin and genetic diversity in brinjal. Therefore, the selection of genotypes for hybridization should be based on genetic divergence rather than geographical diversity. The present results are in accordance with the findings of Shinde et al. (2012) and Krishnapatel et al. (2014).

The absence of relationship between genetic diversity and geographical distance indicates that forces other than geographical origin, such as exchange of genetic stocks, genetic drift, spontaneous variation, natural and artificial selection are responsible for genetic diversity. It may also be possible that causes for clustering pattern were much influenced by environment and genotype x environment interaction resulting in differential gene expression. Another possibility may be that estimates might not have been sufficient to account for the variability caused by some other traits of physiological or biochemical nature which might have been important in depicting the total genetic diversity in the population.The intra- and inter-cluster D^2 values among 30 genotypes presented in Table 2 revealed that cluster VI having lowest intra-cluster D^2value (142.37), whereas, highest intra-cluster D^2 value (215.06) was recorded by cluster IV indicated that genotypes included in this cluster are very diverse and due to natural and artificial selection forces among the genotypes.

Table 1: Clustering pattern of thirty genotypes of brinjal based on D^2 analysis

Clusters	Number of genotypes	Name of the genotypes
I	15	Karur Local, Andipatti Local, IC 383345, Kurumbapatti Local, EC 316201, Namakkal Local, Notchidaipatti Local, Ottanchathiram Local, IC 090907, Musuri Local, IC 454561, Arka Shirish, IC 354721, IC 111013 and IC 310889
II	5	Patteswaram Local, IC 111033, IC 261786, Kumbakonam Local, Swamimalai Local
III	1	Arka Kusumakar
IV	5	Trichy Local, IC 249344, EC 315014, IC 354546 and Mettupalayam Local
V	1	Mathukadipattu Local
VI	2	ABSR-2 and Devachinnampatti Local
VII	1	Sathirampatti Local

Table 2: Average intra (bold) and inter cluster D^2 values for five clusters in thirty brinjal genotypes

Clusters	I	II	III	IV	V	VI	VII
I	179.53	253.73	214.82	274.54	213.12	235.96	242.89
II		186.78	334.32	290.82	273.13	341.73	229.05
III			0.00	237.01	324.25	285.86	275.75
IV				215.06	371.23	381.41	296.33
V					0.00	204.27	293.04
VI						142.37	340.61
VII							0.00

Table 3: Cluster mean for yield and quality traits of thirty brinjal genotypes

Cluster	Plant height (cm)	Number of branches per plant	Days to first flowering	Days to 50% flowering	Days to first harvest	Pedicel length (cm)	Calyx length (cm)	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Number of fruits per plant	Fruit yield per plant (kg)
I	97.42	8.22	45.70	57.31	67.81	3.39	2.54	7.87	10.06	40.03	44.80	1.77
II	91.78	6.66	47.84	60.00	70.74	3.31	2.66	8.08	14.81	65.66	22.45	1.46
III	121.65	7.75	40.95	51.15	63.95	3.40	2.50	10.65	7.15	37.85	57.90	2.19
IV	76.25	6.36	49.07	60.79	70.83	3.38	2.60	7.34	12.88	55.28	25.26	1.45
V	102.55	7.30	45.40	56.75	68.40	2.65	2.10	7.75	10.40	35.45	36.10	1.28
VI	89.50	9.40	41.23	52.15	64.38	2.42	2.08	6.40	9.93	40.00	64.35	2.57
VII	114.75	8.65	43.50	55.55	66.85	3.15	2.75	6.45	10.70	35.10	48.45	1.70

Table 3 continued

Cluster	Shoot infestation (%)	Fruit infestation on number basis (%)	Fruit infestation on weight basis (%)	Marketable yield per plant (kg)	Protein content (mg $100g^{-1}$)	Ascorbic acid (mg $100g^{-1}$)	Total phenol (mg g^{-1})	Total sugars (mg g^{-1}) (FW)	Polyphenol oxidase (changes in OD min^{-1} g^{-1} of sample)	Solasodine (%)
I	11.77	22.56	22.85	1.39	16.02	14.19	1.46	12.45	0.65	0.04
II	13.45	25.22	24.59	1.10	16.34	13.22	1.47	11.54	0.42	0.04
III	13.50	21.84	22.45	1.70	16.56	14.76	1.53	9.50	0.94	0.04
IV	13.45	27.03	28.74	1.07	14.64	13.57	1.48	11.96	0.49	0.03
V	14.80	24.86	21.26	0.96	15.03	12.74	1.45	14.60	0.65	0.04
VI	8.95	15.26	14.04	2.19	16.98	14.79	1.59	7.95	1.12	0.03
VII	11.05	24.89	24.77	1.28	17.11	11.26	1.32	15.30	0.90	0.05

However, the cluster III, V and VII having single genotype had no intra cluster distance.

The minimum inter-cluster D^2 value was observed between the clustersVand VI (204.27) indicated close relationship among the genotypes included in these clusters. Maximum inter-cluster D^2 values was observed between the clusters IV and VI (381.41) followed by cluster IV and V (371.23), cluster II and VI (341.73), cluster VI and VII (340.61) and cluster II and III (334.32) indicated that the genotypes included in these clusters can be used as a parent in hybridization programme to get higher heterotic hybrids from the segregating population. It is suggested that genotypes from more diverse groups and having high yield potential coupled with quality and pest resistance attributes might be useful in breeding programme. Similar results were revealed by Saurabh et al. (2011). Overall inter cluster distances were found to be much higher than that of intra cluster distances, indicating the homogeneous and heterogeneous nature of the genotypes within and between the clusters. The cluster means of thirty genotypes for 22 characters were presented in table 3.The highest mean value are desirable for plant height, number of branches per plant, fruit length, fruit girth, single fruit weight, number of fruits per plant, fruit yield per plant, marketable yield per plant, protein content, ascorbic acid, total phenol, polyphenol oxidase and solasodine, whereas lowest values for days to first flowering, days to 50 % flowering, days to first harvest, pedicel length, calyx length, shoot infestation, fruit infestation on number basis, fruit infestation on weight basis and total sugars.

The cluster VI registered the best cluster mean value for number of branches per plant (9.40), pedicel length (2.42 cm), calyx length (2.08 cm), number of fruits per plant (64.35), fruit yield per plant (2.57 kg), shoot infestation (8.95 per cent), fruit infestation on number basis (15.26 per cent), fruit infestation on weight basis (14.04 per cent), marketable yield per plant (2.19 kg), ascorbic acid (14.79 mg $100g^{-1}$), total phenol (1.59 mg g^{-1}), total sugars (7.95 mg g^{-1}) and polyphenol oxidase (1.12 Changes in OD min^{-1} g^{-1}). The cluster III was identified best for plant height (121.65 cm), days to first flowering (40.95 days), days to 50 per cent flowering (51.15 days), days to first harvest (63.95 days) and fruit length (10.65 cm). The cluster II had highest mean value for fruit girth (14.81 cm) and single fruit weight (65.66 g). Cluster VII recorded the highest mean values for protein content (17.11 mg $100g^{-1}$) and solasodine (0.05 per cent).The information on cluster mean value for brinjal genotypes were also available from the studies of Arun kumar *et al.* (2013), Balaji Lokesh *et al.* (2013) and Vidhya (2015). Among the genotypes spread over seven clusters, the mean values were scored across the clusters for all the twenty two characters. The cluster mean values served as a parameter for selection of parents for recombination breeding. None of the traits in cluster IV and V showed the highest cluster mean values and this might be due less *per se* values of genotypes in these clusters. In

brinjal breeding programme aimed to get higher yield and shoot and fruit borer resistance, the genotypes from cluster VI can be selected as parent for hybridization showing highest fruit yield per plant, yield contributing characters and shoot and fruit borer resistance. The genetic divergence studies in green fruited brinjal using 30 genotypes suggests that intra-cluster distance was the lowest in cluster VI and the highest in cluster IV. The maximum distance at intercluster value was between clusters IV and VI followed by cluster IV and V, cluster II and VI which may serve as a potential genotypes for hybridization programme to get higher heterotic hybrids from the segregating population.The cluster mean for yield and its contributing characters was found to be the highest in cluster VI followed by cluster III. The genotypes having high mean for yield characters and high inter cluster distance may lead to express greater heterotic expression in brinjal.

References

Arun Kumar B, Sunil Kumar SV and Chandra Prakash J (2013) Genetic variability and divergence studies in brinjal (*Solanum melongena* L.) Bioinfolet 10 (2b):739-744.

Balaji Lokesh P, Reddy S and Reddy SK (2013) Genetic divergence in brinjal (*Solanum melongena* L.). J Res ANGRAU 41(1): 79-82.

Krishna Patel, Patel NB, Ahlawat TR, Patel AI, Hetal Rathod and Dharmishta Patel (2014) Study on genetic diversity in brinjal (*Solanum melongena* L.). Trends Biosci 7(19): 2969-2971.

Mahalanobis PC (1936) On the generalized distance in statistics. Proc National Acad Sci (India) 2: 79-85.

Murty BR and Arunachalam V (1967) Computer programmes for some problems in biometrical genetics of Mahalanobis D^2 in classificatory problems. Indian J Genet 27: 60-69.

Saurabh Rathi, Ravinder Kumar, Munshi AD and Verma M (2011) Breeding potential of brinjal genotypes using D^2 analysis. Indian J Hort 68 (3): 328-331.

Shinde KG, Birajdar UM, Bhalekar MN and Patil BT (2012) Genetic divergence in brinjal (*Solanum melongena* L.). Veg Sci 39 (1): 103-104.

Vidhya C (2015) Development of F_1 hybrids in brinjal (*Solanum melongena* L.) with resistance to shoot and fruit borer. PhD (Hort) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Vegetable Science (2018) 45(2) : 281-283

Short Communication

Comparative investigation of genetic diversity in garden pea (*Pisum sativum* var. *hortense* L.) for yield and yield attributing characters

Keshav K Gautam[1]*, DP Moharana[1], MM Syamal, and Vikas Singh[1]

Received: August 2018 / Accepted: January 2019

Pisum sativum var. *hortense* L.*,* the garden pea or green pea, belongs to the legume family, viz., fabaceae It is a cool season vegetable crop cultivated worldwide mainly for its immature seeds and pods for vegetable purpose as well as for various processed products. Being one of the world's oldest crops, it was domesticated over 9000 years ago and has been produced in association with cereals since that time (McPhee 2003). It is being recognized as a pivotal source of numerous nutrients like protein, carbohydrates, fibre, etc. along with vitamin A, B_1, B_2, and C. It is also rich in several non-nutritive biologically active components like phenols, tannins, alkaloids, flavonoids, protease inhibitors, phytic acid, etc. (Rungruangmaitree and Jiraungkoorskul 2017). Being a leguminous crop, it augments the soil nutrient status through the fixation of atmospheric nitrogen as well as acts an effective cover and thus checks soil erosion. With the exploitation of diversity in plant genetic resources, a wide window of opportunity for plant breeders can be opened to develop new and improved cultivars with desirable characteristics vis-à-vis both farmer as well as breeder-preferred traits. As well defined at the Rio de Janeiro Earth Summit, genetic diversity is the key pillar of biodiversity and diversity within species, between species, and of ecosystems (Govindaraj et al. 2015). For initiating any crop improvement program, variation in the existing germplasm is of high requisite. Maximization of genetic diversity among the parental lines is one of the major approaches in order to develop high yielding varieties. This is usually measured by the estimation of morphological and physiological differences. For various applications in plant breeding, knowhow about the patterns and levels of genetic diversity can be considered as an essential aid. In order to accomplish the higher level of productivity, genetic diversity is important as it makes available the genetic building blocks for further development.

Keeping these points in concern, an experiment was designed and conducted at Vegetable Research Farm, Institute of Agricultural Sciences, BHU, Varanasi (UP) during the second fortnight of October 2012-13. The experimental material (seeds) of twenty-four genotypes of garden pea comprised of five commercial cultivars as checks, viz., Arkel, Kashi Mukti, Kashi Nandini, Kashi Shakti, and Kashi Udai; and nineteen germplasm accessions, viz., VRPMR-9, VRPMR-10, VRP-200, VRP-266, VRP-38, VRP-152, VRP-229, VRP-342, VRP-360, VRP-401, VRP-392, VRP-305, VRP-231, VRP-324, PC-531, AP-1, AP-2, VRP- 372, and VRP-4 were collected from ICAR-Indian Institute of Vegetable Research, Varanasi. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each genotype. The unit plot size was 4 m^2 (2 m × 2 m); and the pure and disease free seeds were sown in lines at a spacing of 30 cm × 10 cm. To attain a healthy crop stand, good agricultural practices were followed during the experiment. The observations were recorded from five randomly selected plants per replication for each genotype on various yield and yield contributing traits, viz., days to first flowering, days to 50% flowering, days to first pod initiation, number of pods per plant, average pod weight (g), number of seeds per pod, weight of seeds per pod (g), pod length (cm), pod width (cm), shelling (%), plant height (cm), number of primary branches per plant, TSS (^{0}Brix) and average pod yield per plant (g). Genetic divergence was estimated by using D^2 statistics (Mahalanobis, 1936) and grouping of the genotypes into various clusters was performed following Tocher's method as described by Rao (1952).

Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi, UP

[1]ICAR-Indian Institute of Vegetable Research, Varanasi, UP

*Corresponding author's email: kkgautam008@gmail.com

Selection of genetically diverse parents based on the information about the genetic diversity and variability present in the germplasm is of high requisite for a successful breeding programme. Distribution of twenty-four genotypes of garden pea grouped into four clusters was presented in Table 1. Cluster I has accommodated highest number of genotypes (17) followed by cluster II (5) while cluster III and cluster IV consisted of 1 genotype each. Average intra- and inter-cluster distances for four clusters as presented in the Table 2 revealed that less divergence was there among the genotypes within a cluster while greater divergence was detected among the genotypes belonging to various clusters. The average intra-cluster distance was found to be highest in cluster II (10.25) followed by cluster I (9.08), whereas minimum distance (0.00) was recorded in both cluster III and cluster IV. This information reflected that cluster II which consisted of five genotypes, viz., VRP-4, Arkel, VRPMR-9, VRPMR-10, and VRP-342 was the most divergent.

Table 1: Clustering pattern of 24 genotypes of garden pea on the basis of genetic divergence

Cluster	Number of genotypes	Name of genotypes
I	17	VRP-266, VRP-152, VRP-229,VRP-360,VRP-305,VRP-401, VRP-231, VRP-200, VRP-324, PC-531, AP-1, VRP-38, VRP-392, VRP-372, Kashi Udai, Kashi Shakti, Kashi Mukti
II	5	VRP-4, Arkel, VRPMR-9, VRPMR-10, VRP-342
III	1	Kashi Nandini
IV	1	AP-2

Table 2: Average intra- (bold face) and inter-cluster distance among twenty-four garden pea genotypes

Cluster	I	II	III	IV
I	9.08	17.63	13.69	17.19
II		10.25	22.68	23.55
III			0.00	13.62
IV				0.00

Based on the inter-cluster distance, the maximum diversity was observed in between cluster II and IV (23.55) followed by cluster II and cluster III (22.68) revealing that genotypes belonging to above clusters are more divergent, hence, can be utilized for getting the superior recombinants in segregating generations in the hybridization programmes. From the cluster means of various economic traits (Table 3), cluster I had highest mean value for traits like number of pods per plant (12.8) and average pod yield per plant (69.4 g) whereas cluster II was observed to be superior for five traits, viz., average pod weight (6.3 g), number of seeds per pod (7.1), weight of seeds per pod (2.9 g), pod length (8.4 cm), and pod width (1.5 cm). Cluster III recorded highest values for the traits like days to first flowering (60.7), days to 50% flowering (65.3), days to first pod initiation (69.3), shelling percentage (54.3), and number of primary branches per plant (3.9). Cluster IV showed maximum TSS (^{0}Brix) and plant height (cm) with mean values of 25.33 and 130.33, respectively. The genotypes of cluster I and II can be used as prospective donors for their respective traits. Crosses can also be attempted among genotypes of these clusters for combining desirable traits. Genotypes of any cluster with high mean values can be directly or indirectly utilized for hybridization and/or for further selection. Similar studies on clustering pattern were carried out by Gupta et al. (2017), Kumar and Kumar (2016) and Katiyar and Dixit (2009).

Table 3: Cluster means of 15 quantitative traits in garden pea

Traits	Cluster				
	I	II	III	IV	Overall mean
Days to first flowering	56.88	33.93	60.67	51.00	50.60
Days to 50% flowering	61.10	36.73	65.33	57.33	55.10
Days to first pod initiation	65.18	38.20	69.33	62.00	58.70
Number of pods per plant	12.84	8.72	10.20	10.47	10.60
Average pod weight (g)	5.44	6.32	3.69	5.18	5.20
Number of seeds per pod	6.99	7.14	6.07	5.47	6.40
Weight of seeds per pod (g)	2.89	2.91	2.01	1.87	2.40
Shelling (%)	52.90	47.35	54.29	36.36	47.70
TSS (^{0}Brix)	22.20	20.60	23.33	25.33	22.90
Plant height (cm)	60.51	50.25	101.33	130.33	85.60
Pod length (cm)	8.27	8.38	6.45	8.03	7.80
Pod width (cm)	1.36	1.47	1.33	1.37	1.40
No. of primary branches/plant	2.61	2.05	3.90	1.53	2.50
Average pod yield per plant (g)	69.42	53.31	37.45	53.83	53.50

The contribution of different traits towards the genetic divergence aids in the selection of suitable parents. Amongst the 14 characters studied, the important trait with highest contribution towards genetic divergence is days to first flowering (31.16%) followed by plant height (28.99%), average pod weight (25.72%) and weight of seeds per pod (7.61%) while remaining characters have negligible effect. These results are in accordance with the studies conducted by Singh and Singh (2006) and Gupta and Singh (2006). In conclusion, the maximum inter-cluster distance was observed between cluster II and IV. If crossing attempt was made between the genotypes of these clusters, it

may yield maximum heterosis or desirable segregants. Among the studied traits; days to first flowering, plant height, and average pod weight had the maximum contribution towards genetic diversity while other had negligible contribution towards genetic divergence. Therefore, it is clear that the estimation of genetic diversity can be essential for the selection of most efficient genotypes for developing suitable breeding strategies.

References

Govindaraj M, Vetriventhan M and Srinivasan M (2015) Importance of genetic diversity assessment in crop plants and its recent advances: an overview of its analytical perspectives. Gen Res Int 15: 1-14.

Gupta AJ and Singh YV (2006) Genetic divergence in garden pea (*Pisum sativum* L.). Indian J Genet Pl Breed 66: 341-342.

Gupta A, Singh MK, Kumar M, Singh SK, Katiyar H and Kumar V (2017) Study of genetic divergence in pea (*Pisum sativum* L.) based on agro-morphic traits. Int J Curr Microbiol App Sci 6(11): 3816-3821.

Katiyar PK and Dixit GP (2009) Multivariate analysis for genetic divergence in field pea (*Pisum sativum* L. var. *arvense*) germplasm. Indian J Agr Sci 79: 181-183.

Kumar R and Kumar M (2016) Estimation of genetic divergence in garden pea (*Pisum sativum* var. *hortense* L.) germplasm to facilitate the selection of potential parents for hybridization programme. Leg Res 39(5): 709-712.

Mahalanobis PC (1936) On the generalized distance in statistics. Proc Nat Inst Sci India 2(1): 49-55

McPhee K (2003) Dry pea production and breeding: A mini review. J Food Agri Env 1: 64-69.

Rao CR (1952) Advance Statistical Methods for Biometrical Research. John Wiley and Sons Inc., New York, pp 357-363.

Rungruangmaitree R and Jiraungkoorskul W (2017) Pea, *Pisum sativum*, and its anticancer activity. Pharm Rev 11(21): 39-42.

Singh JD and Singh IP (2006) Genetic divergence in advanced genotypes for grain yield in field pea (*Pisum sativum* L.). Leg Res 29: 301-303.

Vegetable Science (2018) 45(2) : 284-286

Short Communication

GH-22: A new bottle gourd variety

DS Duhan* and NK Sharma

Received: October 2017 / Accepted: July 2018

Bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] belonging to the family cucurbitaceae is cultivated in tropical and subtropical regions of the world though its centre of origin is tropical Africa and Asia. In India, it is cultivated in all parts of the country mainly during spring-summer and rainy season. It supplies carbohydrates, protein, minerals and vitamins in adequate amount. Bottle gourd varieties may be long, round, or oval-oblong fruited. It is grown for its tender fruits, which are consumed either in cooked form or used for making sweets. Its pulp, tender stem and tender leaves are known to have cooling effect and prevent constipation. The green fruits are easily digestible and its juice is considered good for arresting heart problems. Inbreeding in landraces followed by individual plant selection is an effective method of breeding to develop pure line cultivars for cultivation in different agro-ecological zones. Bottle gourd being a cross-pollinated crop does not suffer from inbreeding depression. The goal of bottle gourd breeding is to develop high yielding early variety with more number of fruits, medium fruit weight, high female to male flower ratio, cylindrical green fruits, presence of pubescence sparsely on skin, non-fibrous flesh at edible stage, bitterness free and resistance against insect-pests and diseases. Before sowing, the seed was wrapped overnight in a moist gunny bag, which was sterilized by dipping in 0.2% solution of captan 70% WP. Thereafter, the seed was dried in shade for half an hour. The channels of 45 cm width and 30-40 cm deep were opened in east west direction at a distance of 2.5 to 3 meter for providing uniform sunlight throughout the day to the plants. About one kg mixture of chemical fertilizers and farmyard manure was applied and mixed thoroughly in soil where the seeds were to be sown. Then, two to three seeds were sown on northern side slope of channels where the mixture of fertilizers and farmyard manure was mixed; and retained only one healthy/vigorous seedling per hill, when they became large enough to handle.

Salient characteristics: GH-22 variety has medium long vine (6.6 m) with green leaves, oblong to bottled shaped attractive green fruits, medium size of 28.2 cm length and 7.6 cm diameter, non-fibrous white flesh, medium fruit weight 750-800 g and longer shelf life because of lesser physiological loss in weight (7.43, 3.04 and 2.76%) as compared to Pusa Naveen (11.47, 3.29 and 2.84%) after 8 days of storage in cardboard boxes, polythene bag and cling film packing, respectively (Table-3). The fruits are very good in taste and take lesser time in cooking. It is very early in maturity and fruits become ready for first picking in 55-60 days after sowing in spring-summer and 50-55 days after sowing in *Kharif* season. The average fruit yield is 280 q/ha in a duration of 125-130 days.

Agronomics characters: The variety GH-22 gives more fruits per vine (6.4 and 7.7) than that of Pusa Summer Prolific Long (5.5 and 5.5) and Pusa Naveen (5.7 and 6.3) in spring-summer and rainy season, respectively (Table-1). The average fruit weight is 796 g at edible stage, which is lesser than the average fruit weight of check variety Pusa Summer Prolific Long (1100 g) and Pusa Naveen (950 g). The length and diameter of fruit were recorded 28.2 and 7.6 cm, respectively, which were almost equal to Pusa Naveen but 20% lesser in the fruit length and 10% higher in diameter of Pusa Summer Prolific Long (33.8, 8.5 cm), respectively. The vine length of GH-22 was 659 cm, which was lesser than the check variety Pusa Summer Prolific Long and Pusa Naveen. In agronomical trial, it was revealed (Table 2) that the bottle gourd variety GH-22 gave fruit yield of 297.5 q/ha when sown at 2.50 m x 60 cm spacing and supplied with nitrogen 87.5 kg/ha. Also the crop sown in last week of February with the irrigation frquency of 50 mm CPE recorded maximum fruit yield

Department of Vegetable Science, CCS HAU, Hisar-125004, Haryana

*Corresponding author,
Email: dharamveer_duhan@rediffmail.com

of 341.4 q/ha as compared to other treatments. However, as per the package of practices adopted in Haryana, bottle gourd gives maximum yield when sown in the month of February-March in flat beds or in June-July on raised beds and supplied with farmyard manure 15 tonnes, nitrogen 50 kg, phosphorus 25 kg and potash 25 kg/ha. Farmyard manure is applied at the time of land preparation and one third dose of nitrogen along with full dose of phosphorus and potash is applied at the time of last shallow ploughing. Rest of the nitrogen is applied in two splits, once at the time of vine growth and another at fruiting. A light irrigation is given just after sowing and subsequent irrigations are applied at 4 to 6 days interval depending on season and stages of crop growth and in rainy season as and when required. Irrigation should be applied only up to two third of the channel depth. Applying flood irrigation in summer increases the bottle gourd yield since it keeps the field temperature comparatively low, which promotes femaleness. In initial stages, the field is kept weed free by hoeing and weeding twice or thrice. In summer, the tall weeds are not removed from the field as they will protect the fruits from high light intensity, which may cause injury to the fruits.

Yield and Quality traits: The fruit yield of the bottle gourd variety GH-22 and check varieties are given in Table 1. The fruit yield of GH-22 was 240.7 and 322.3 q/ha under Hisar (Haryana) conditions in spring-summer and rainy season, which was 26.8 and 30.6 percent higher than the check variety Pusa Naveen and 39.7 and 42.0 percent higher than Pusa Summer Prolific Long, respectively (Table-1). In multi-location farmer field trials conducted by various KVK in nine districts of Haryana, the yield was 316.4 q/ha, which was 38.3 percent higher than the check variety Pusa Summer Prolific Long. The results of multilocation trials held by All India Coordinated Varietal Trials revealed that variety GH-22 recorded 256.1 q/ha fruit yield on the average of 20 trial centers conducted over 3 years (2010-11 to 2012-13) and showed 11.1. During these 3 years of testing, GH-22 remained 10 times on top position in IET and AVT-II stages out of 20 trials, indicating the consistency in performance of the variety over locations and years. The ascorbic acid and total soluble solids (Table 3) in fruits of GH-22 (4.0 and 3.37) were more as compared to check variety Pusa Summer Prolific Long (3.2 and 2.03), respectively. It takes less time in cooking than the check variety. The fruits of GH-22 were better in quality traits such as length (medium), colour (green), pubescence (present), taste (good) and flesh texture (medium). The fruits had comparatively longer shelf life.

Disease reaction: The disease reaction is given in Table-4. Based on screening studies of three years trials under natural field conditions, the variety GH-22 showed less severity of *Cercospora* and *Anthracnose* disease (4.0 & 8.0 and 8.7 & 9.8 %) as compared to disease severity on plants of check variety Pusa Naveen (8.9 & 13.4 and 13.0 & 15.0 %) and PSPL (10.9 & 20.9 and 16.5 & 22.9%) in summer and rainy season, respectively. No major incidence of pests was seen in the crop, however, the red pumpkin beetles attacked the crop at

Table 1: Performance of bottle gourd variety GH-22 for fruit yield in station, farmer's field and multi-location research trials

Variety	Number of fruits per vine		Average fruit yield q/ha		Station trials (Av. of four year)	Farmer's field (Av. of two year)	Multi-location (Three years)
	Summer	Rainy	Summer	Rainy	GH-22	Rainy	Summer
GH-22	6.4	7.7	240.7	322.3	281.5	316.4	256.1
Pusa Naveen (NC)	5.7	6.3	184.3	254.2	219.2	-	230.5
PSPL (local check)	5.5	5.5	169.5	230.7	200.1	228.8	-
Percent Increase over checks	-	-	+30.6 +42.0	+26.8 +39.7	+28.8 +40.7	+38.3	+11.1

Table 2: Effect of different nitrogen levels on plant spacing along-with varied date of sowing and irrigation level on fruit yield of bottle gourd variety GH-22

Nitrogen levels (kg/ha)	Plant spacing		Mean	Irrigation level at CPE	Date of Sowing			Mean
	2.5 m x 60 cm	2.5 m x 75 cm			Last week of February	Second week of March	Last week of March	
50.0	246.0	148.0	197.0	50 mm	341.4	335.4	282.8	319.9
62.5	262.0	162.3	212.1	75 mm	329.7	322.9	261.7	304.6
75.0	272.0	173.5	222.8	100 mm	300.0	305.5	243.7	283.0
87.5	297.5	192.5	245.0	Mean	323.7	321.2	262.7	302.5
Mean	269.4	250.6	260.3	CD at 5% level of significance	Date of sowing= 4.2; Irrigation= 4.5; Date of sowing x irrigation= 5.22			
CD at 5% level of significance	Spacing = 6.5; Nitrogen = 14.0; Spacing x nitrogen= 4.8							

Table 3: Physiological loss in weight, decay loss during storage in bottle gourd variety GH 22 at ambient temperature in Hisar

PLW (%) in storage at different (days) interval	Card board box packing			Polythene bag packing			Cling film packing			C.D. at 5%
	GH-22	PSPL (LC)	Pusa Naveen (C)	GH-22	PSPL (LC)	Pusa Naveen (C)	GH-22	PSPL (LC)	Pusa Naveen (C)	
2	3.33	4.14	5.75	0.68	1.03	0.57	0.10	0.60	0.10	0.19
4	5.38	6.38	8.50	1.20	1.67	1.15	0.15	1.08	0.23	0.25
6	6.59	7.61	10.19	2.46	3.22	2.77	1.08	2.77	0.88	0.25
8	7.43	9.07	11.47	3.04	4.75	3.29	2.76	3.26	2.84	0.24

Quality parameters

Variety	Cooking time (minutes)	Juice (%)	TSS (%)	Acidity (%)	Ascorbic acid (mg/100 g)
GH-22	7.3±0.6	69.67±1.53	3.37±0.32	0.075±0.01	4.0±0.35
PSPL (LC)	10.3±0.6	71.33±2.08	2.03±0.12	0.107±0.02	3.2±0.35

Table 4: Performance of bottle gourd variety GH-22 for diseases during rainy seasons at Hisar

Variety	Mosaic (disease reaction)			Cercospora leaf spot (%)			Anthracnose (%)		
	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
GH-22	Mild	Mild	Mild	14.2	7.4	7.9	8.8	7.1	8.1
Pusa Naveen (C)	Mild	Mild	Mild	16.8	13.9	14.4	11.5	13.2	15.5
PSPL (LC)	Mild	Mild	Mild	28.3	18.1	22.4	18.4	17.6	16.7

two to four leaf stage, which was controlled by spraying cypermethrin 25EC 60 ml dissolved in 250 litre of water per acre and applying one litre of chlorpyrephos 20EC through irrigation in starting of crop growth.

Storage studies: After 8 days of storage under ambient room temperature conditions, the physiological loss in weight of GH-22 fruits packed in cardboard boxes, polythene bag and cling film was less (7.43, 3.04 and 2.76%) as compared to the physiological loss in weight of check variety Pusa Naveen (11.47, 3.29 and 2.84%) and Pusa Summer Prolific Long (9.07, 4.75 and 3.26%) fruits, respectively (Table 3). Thus, the GH-22 have better in shelf life than both the check varieties.

Overall, GH-22 variety has medium long vine (6.6 m) with green leaves, oblong to bottled shaped attractive green fruits, medium size of 28.2 cm length and 7.6 cm diameter, non-fibrous white flesh, medium fruit weight 750-800 g and longer shelf life because of lesser physiological loss in weight (7.43, 3.04 and 2.76%) as compared to Pusa Naveen (11.47, 3.29 and 2.84%) after 8 days of storage in cardboard boxes, polythene bag and cling film packing, respectively. The fruits are very good in taste and take lesser time in cooking. It is very early in maturity and fruits become ready for first picking in 55-60 days after sowing in spring-summer and 50-55 days after sowing in *Kharif* season. The average fruit yield is 280 q/ha in a duration of 125-130 days.

References

Anonymous (2011-12) XXXth Annual Report, All India Coordinated Research Project on Vegetable Crops (VC). Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, pp 101-102.

Anonymous (2012-13). XXXIth Annual Report, All India Coordinated Research Project on Vegetable Crops (VC). Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, pp 131.

Anonymous (2012-13) XXXIth Annual Report, All India Coordinated Research Project on Vegetable Crops, (VC). IIVR, Varanasi, Uttar Pradesh, pp 185 (Supplementary).

Anonymous (2016) GH-22 a bottle gourd variety released for Haryana State by Central Variety Release Committee: Gazzette Notification of India dated Dec., 6 2016 by Ministry of Agriculture and Farmers Welfare, S.O. 3666(E), part 3(II) sub section (II), pp 2.

Vegetable Science (2018) 45(1) : 287-290

Short Communication

Field assessment of tinda [*Praecitrullus fistulosus* (Stocks) Pangalo] genotypes under lateritic soils of Eastern India

J Mandal* and S Mohanta

Received: December 2018 / Accepted: January 2019

Tinda or round melon (*Praecitrullus fistulosus* (Stock) Pangalo, 2n=24) is a minor summer grown cucurbitaceous vegetable. The origin of tinda is probably northwestern India, where wild types may still be found. Previously tinda was considered as a distant relative of watermelon and it was classified as *Citrullus lanatus* subsp. *fistulosus* (Stocks) Duthieet J.B. Fuller (Levi et al. 2005). However, the genetic similarity between *Praecitrullus fistulosus* and *Cucumis* or *Citrullus* group was found less than 3%; and it was found more closely related with *Benincasa hispida* than *Citrullus* spp (Levi et al. 2010). It differs to *Citrullus* in the stratification of pollen grains, haploid chromosome number and to some extent in leaf morphology (Tyagi et al. 2017). The tender fruits of tinda are used as a vegetable, canned, rayata preparation and its seeds are roasted and consumed. Tinda is one of the excellent plants, gifted by the nature for its pharmacological activities and traditional uses (Tyagi et al. 2017). It may have good scope for export because it is cultivated only in north India and fruits are available from April to October and good has good storability (Samadia 2007). In the USA, there is an increased interest in using tinda as a commercial vegetable, and possibly as a rootstock for grafting watermelon, melon or cucumber (Levi et al. 2010). Due to its less area coverage and lesser influence in market economy it has yet not receive full attention by the breeders and production scientists. Only little research was carried out on this crop. Munawar et al. (2015) studied the genetic variability, strength and direction of association, and direct/indirect effects of morphological traits on fresh fruit yield of sixteen genotypes of tinda gourd. Samadia (2007) studied genetic variability and elaborate the scope of improvement in tind under hot arid conditions. Commercial cultivation of tinda is restricted only in parts of north western India. In eastern India, tinda is a totally uncommon crop and even not know by the local growers. Tinda is not commercially cultivated in West Bengal (Mandal 2017). Genotype selection is one of the most important factors in any crop production. Thus, a preliminary study on performance of some tinda genotypes under Red and Laterite Zone of West Bengal was tried during summer months to see its suitability of growing in this region and if this crop could commercially be established in future.

The experiment was conducted in the Horticulture Farm, Institute of Agriculture, Sriniketan. The experimental site was situated in the sub-humid, subtropical laterite belt of West Bengal, India. The crop growing area having three seasons, viz. summer season or pre-*kharif* (March to June), wet or rainy season or *kharif* (July to October) and winter or *rabi* season (November to February). The meteorological data pertaining to the crop growing period of this experiment has been presented in Table 1. It was revealed from the data that tinda received a salubrious weather condition during germination and growth. However, crop faced high temperature and relatively low atmospheric humidity during fruiting period.

The soil of the experimental site was loamy sand in texture with 5.8pH and 0.54% organic carbon. The available nitrogen content was 201.6 kg/ha, available phosphorus content was 12.01 kg/ha and available potassium content was 91.57 kg/ha. Five open pollinated (Ludhiana Special, Tinda Dil Pasand, Tinda Ludhiana Special, Mahy Tinda and Golden Tinda) and two F_1 hybrid (Mahy-1 and Chitra) cultivars of tinda were grown during summer 2016 and assessed for various

Department of Horticulture and Post-Harvest Technology, Institute of Agriculture, Visva-Bharati Sriniketan– 731236, West Bengal
*Corresponding author, Email: joydip.mondal@visva-bharati.ac.in

Table 1: Meteorological data recorded during cropping period at Sriniketan.

Month		Temperature (^{0}C)		Total Rainfall (mm)	Relative Humidity (%)	Sunshine (hr)
		Maximum (Average)	Minimum (Average)			
February, 2016	1st fortnight	28.1	15.2	25.0	80.9	5.1
	2nd fortnight	31.8	18.5	6.70	71.9	7.1
March, 2016	1st fortnight	34.0	20.4	0.7	73.0	6.5
	2nd fortnight	31.3	18.5	15.6	57.6	6.8
April, 2016	1st fortnight	39.4	24.6	0.0	54.8	7.9
	2nd fortnight	41.8	26.4	0.0	66.8	8.1
May, 2016	1st fortnight	37.7	24.0	49.4	68.8	8.3
	2nd fortnight	35.6	25.3	65.8	72.5	7.1

Source: India Meteorological Department, Meteorological Office Sriniketan, Birbhum.

growth and yield attributes. All the open pollinated and hybrid cultivars were belongs to private seed companies (Table 2).

The experiment was conducted in Randomized Block Design with three replications. Bed and channel system of planting was followed. Bed width was kept 2.5 m and plant to plant spacing was given 0.5 m. Pre-soaked seeds of each genotype were sown on 6th February 2016 in twenty pits per replication. Four seeds per pit were sown and later only one plant was kept in each pit. FYM (10 t/ha) and fertilizer dose of NPK (90:60:60 kg /ha) were applied to grow the crop. Well decomposed farm yard manure, half amount of nitrogen and potash and full dose of phosphorous were mixed at the time of field preparation as basal application. Rest half amount of nitrogen and potassium fertilizers were applied as top dressing 30 days after sowing. Irrigation was given twice in a week in channels. The data was collected for vine length (cm), number of branches per plant, node to first male and female flower appearance, days to first male and female flower opening, fruit length (cm), fruit circumference (cm), fruit numbers per plant, average fruit weight (g), fruit yield per plant (g) and total soluble solid (TSS; $^{\circ}$Brix). Five plants of each replication were tagged for taking observations for growth and flowering traits. Vine length and number of branches per plant were recorded at 90 days after sowing. Ten freshly harvested fruits were randomly collected from the tagged plants to obtain different fruit traits (average fruit weight, fruit length and circumferences) and TSS. Number of fruits per plant and fruit yield per plant was computed by adding the number of fruits and fruit weight harvested each time. The mean values of various traits thus obtained were subjected to statistical analysis. The total variation for different cultivars was tested for significance by F test using analysis of variance technique. Critical differences were calculated for each trait to the test the significance of difference between means of different genotypes. Correlation has been studied to see the inter-relationship among the studied traits. For statistical analyses Windostat version 8.6 from Indostat service Hyderabad was followed.

Table 2: Tinda genotypes and source of seed materials

Cultivar	Seed source
Chitra (BSS-695)	Kalash Seeds Pvt. Ltd, Jalna, Maharashtra
Mahy-1	Maharastra Hybrid Seeds Company Private Limited (Mahyco), Jalna, Maharastra
Mahy Tinda	Maharastra Hybrid Seeds Company Private Limited (Mahyco), Jalna, Maharastra
Golden Tinda	UPL Limited, c/o Bharathi Bhamha Seeds, Telengana
Ludhiana Special	Doctors Seeds India, Ludhiana, Punjab
Tinda Dil Pasand	Punjab Beej Company, Chowk Baraf Khana, New Delhi
Tinda Ludhiana Special	Rizwan Seed Company, Malerkotla, Punjab

Genotypes recorded significant variation for vine length and number of branches were plant (Table 3). The highest vine length was observed in 'Tinda Dil Pasand'. On the other hand, 'Chitra' and 'Golden Tinda' recorded minimum vine length. Less vine length has considered as desirable trait for dwarf and compact plant type. These types of plants occupy less space and thus, can accommodate more number of plants per unit area. Among the studied genotypes, 'Tinda Dil Pasand' and 'Tinda Ludhiana Special' recorded highest and lowest numbers of branches per plant, respectively. Increased number of branches increases probable fruiting sites and thereby helps to increase yield (Mohanta and Mandal 2016). Variation in growth traits in tinda was reported by Samadia (2007). Length of vine and primary branches per vine showed significant positive association with total fruits per vine (Dahiya et al. 2000).

Monoecious is the major sex form in tinda. In tinda, like others cucurbits, male flowers appears before the appearance of female flowers. The traits such as first female flowering node and days to first female flower opening are related parameters for earliness. Result of this study revealed that flowering traits showed

significant differences among the genotypes for node to first male and female flower appearance and days to first male and female flower opening (Table 3). Among the genotypes, 'Golden Tinda' produced male and female flowers in lowest node. Appearance of flowers (particularly female) at lower nodes and early days often interpreted as early type. Similarly to node numbers, 'Golden Tinda' took minimum number of days to first male and female flower opening. 'Tinda Ludhiana Special' and 'Tinda Dil Pasand' also noted at par with 'Golden Tinda' in days to first male and female flower opening respectively. The appearance of first male and female flower ranged between 22.3 to 31.8 and 35.1 to 43.1 days after sowing respectively. Mohanta and Mandal (2016) reported variation in flowering traits in watermelon.

Among the tinda genotypes significant differences were noted for yield attributing traits, yield and TSS (Table 4). 'Tinda Dil Pasand' produced maximum fruit length, which was noted statistically *at par* with 'Chitra' and 'Mahy Tinda'. 'Tinda Dil Pasand' was also recorded maximum fruit circumference. On the other hand, 'Golden Tinda' was noted minimum fruit length. Fruit diameter of watermelon was studied by Mohanta and Mandal (2016) and Ogwu et al. (2016). Maximum number of fruits per plant was recorded in cultivar 'Golden Tinda'. This cultivar also produce female flower in lower node which was related to early fruit harvest. Munawar et al. (2015) reported that number of fruits per plant had a strong positive association with yield in tinda. Number of fruit per plant is an important character for effective selection of Tinda (Samadia 2007). Fruit weight is an important yield component, which directly contributed to yield per plant and per unit area of land. 'Tinda Dil Pasand' recorded highest average fruit weight in immature stage; whereas 'Tinda Ludhiana Special' showed minimum average fruit weight. Samadia (2007) reported a wide range of variation for fruit weight in tinda (71.4 to 137.5 g). Samadia (2007) reported population mean of 0.89 kg total marketable fruit yield per plant in tinda. 'Tinda Dil Pasand' produced maximum fruit yield per plant which was found superior to other genotypes. The highest Total Soluble Solid (TSS) was recorded in 'Golden Tinda' which was statistically similar to 'Tinda Dil Pasand' and 'MahyTinda'. The genotype Chitra was recorded lowest TSS value. These observed variations may be due to genetic variation among the genotypes. Variation in TSS content in watermelon was reported by Mohanta and Mandal (2016).

Yield is a dependent character and governed by the interaction between genotype and environment. Therefore, for improvement work on any crop, study on its character association with main component is beneficial for formulating the breeding programme. From the correlation study (Table 5) it was noted that

Table 3: Growth and flowering traits of tinda cultivars

Cultivars	Vine Length (cm)	Branch Number	Node to first male flower appeared	Node to first female flower appeared	Days to first male flower opening	Days to first female flower opening
Ludhiana Special	152.6^{d}	4.2^{bcd}	4.3^{bc}	10.9^{c}	29.5^{c}	39.7^{bc}
Tinda Dil Pasand	196.6^{a}	5.5^{a}	4.5^{c}	12.9^{d}	25.0^{b}	37.3^{ab}
Tinda Ludhiana special	149.1^{d}	3.2^{ef}	3.8^{bc}	8.8^{b}	23.5^{ab}	38.8^{b}
Mahy-1	167.5^{c}	4.0^{cde}	4.4^{bc}	13.6^{de}	31.2^{c}	41.6^{cd}
Chitra	136.5^{e}	3.4^{def}	3.9^{bc}	14.0^{e}	31.8^{c}	43.1^{d}
Mahy Tinda	181.7^{b}	4.4^{bc}	3.7^{b}	9.2^{b}	30.1^{c}	42.4^{c}
Golden Tinda	136.7^{e}	5.1^{ab}	2.6^{a}	7.3^{a}	22.3^{a}	35.1^{a}
CV (%)	3.7	12.4	10.0	5.3	3.5	3.6

Note: Same letters in the columns denote the means that are not statistically different.

Table 4: Yield traits, yield and fruit TSS of Tinda cultivars.

Cultivars	Fruit length (cm)	Fruit circumference (cm)	Fruit numbers /plant	Average fruit weight (g)	Fruit yield /plant (g)	TSS ($^{\circ}$Brix)
Ludhiana Special	8.8^{bc}	22.4^{b}	5.8^{b}	99.4^{c}	553.7^{e}	3.30^{bcd}
Tinda Dil Pasand	11.4^{a}	24.4^{a}	5.9^{b}	213.6^{a}	1187.8^{a}	3.80^{ab}
Tinda Ludhiana special	8.5^{bc}	18.4^{e}	4.2^{d}	65.07^{e}	298.1^{g}	3.10^{cd}
Mahy-1	9.2^{b}	20.8^{cd}	4.3^{cd}	100.4^{c}	429.2^{f}	2.93^{d}
Chitra	11.0^{a}	22.7^{b}	3.6^{d}	169.7^{b}	598.7^{de}	2.37^{e}
Mahy Tinda	10.5^{a}	21.9^{bc}	5.2^{bc}	167.3^{b}	873.8^{b}	3.47^{abc}
Golden Tinda	8.0^{c}	20.0^{d}	7.7^{a}	76.8^{cd}	664.6^{cd}	4.03^{a}
CV (%)	6.3	3.8	10.1	3.62	7.1	8.00

Note: Same letters in the columns denote the means that are not statistically different.

Table 5: Correlation coefficients among various traits of tinda genotypes.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000											
2	0.419	1.000										
3	0.301	-0.029	1.000									
4	0.201	-0.081	0.607	1.000								
5	-0.088	-0.307	0.165	0.529	1.000							
6	0.132	-0.296	0.269	0.462	0.579	1.000						
7	0.538	0.231	0.268	0.609	0.286	0.361	1.000					
8	0.433	0.497	0.255	0.542	0.334	0.224	0.616	1.000				
9	-0.002	0.669*	-0.536	-0.549	-0.387	-0.594	-0.305	0.121	1.000			
10	0.566	0.315	0.343	0.521	0.257	0.223	0.817*	0.743*	-0.151	1.000		
11	0.623	0.716*	0.093	0.130	-0.088	-0.171	0.615	0.692*	0.349	0.824*	1.000	
12	0.230	0.597	-0.221	-0.600	-0.526	-0.698*	-0.235	-0.061	0.741*	0.005	0.495	1.000

Note: (1) Vine length, (2) Branch number, (3) Node to first male flower appearance, (4) Node to first female flower appearance, (5) Days to first male flower opening, (6) Days to first male flower opening, (7) Fruit length, (8) Fruit circumference, (9) Fruit number/plant, (10) Average fruit weight, (11) Fruit yield/plant, (12) TSS (°Brix); * means significant at 5% level of significance.

the branch number of tinda was positive and significantly correlated with number of fruits per plant and fruit yield per plant. Munawar et al. (2015) reported that number of vines per plant was positively associated with number of fruits per plant. Fruit length and circumference was positive and significantly correlated with average fruit weight. Average fruit weight and fruit circumference was also positive and significantly associated with fruit yield per plant. Munawar et al. (2015) noted a strong positive association among fruit length, fruit diameter, fruit weight, number of fruits per plant with yield in tinda. Samadia (2007) noted a very strong positive and significant correlation between fruit yield per plant with number of fruits per plant. Dahiya et al. (2000) suggested that selection based on total and number of marketable fruits per vine would be more effective for the improvement of yield in tinda. Days to first female flower opening were negative and significantly correlated with TSS. However, fruit number per plant was positive and significantly correlated with TSS. This study revealed that tinda can be successfully grown under Red and Laterite Zone of West Bengal. 'Golden Tinda' and 'Tinda Dial Pasand' can be tried in this region for commercial cultivation. More numbers of accession /genotypes of tinda should be assessed in future for establishing this crop in this region.

References

Dahiya MS, Baswana KS and Duhan D (2000) Correlation and path coefficient analysis in round melon (*Praecitrullus fistulosus* Pang.). Haryana J Hortic Sci 29(3/4): 211-213.

Khan AQ, Iqbal M, Jilani MS, Ghaffoor A and Waseem K (2001) Effect of different sowing dates on the yield of tinda gourd (*Citrullus vulgaris* var. *fistulosus* under the agroclimatic conditions of DI Khan. J Biol Sci 1: 235-237.

Levi A, Claude ET, Alvin MS and Judy AT (2005) Analysis based on RAPD and ISSR markers reveals closer similarities among *Citrullus* and *Cucumis* species than with *Praecitrullus fistulosus* (Stocks) Pangalo. Genet Resour Crop Evol 52: 465-472.

Levi A, Harris KR, Wechter WP, Kousik CS and Thies JA (2010) DNA markers and pollen morphology reveal that *Praecitrullus fistulosus* is more closely related to *Benincasa hispida* than to *Citrullus* spp. Genet Resour Crop Evol 57(8): 1191-1205.

Mandal J (2017) Tinda: A lesser known vegetable for Eastern India. In: P. K. Chattopadhyay and D. S. Kushwaha (eds.). Issue in Growth and Diverfication in India's Emerging Economy, New Delhi Publishers, New Delhi, pp 89-102.

Mohanta S and Mandal J (2016) Performance of watermelon (*Citrullus lanatus*) in red and laterite zone of West Bengal. J Crop Weed 12(3): 175-177.

Munawar M, Hammad G, Nadeem K, Muzaffar RM andSaleem M (2015) Assessment of genetic diversity in tinda gourd through multivariate analysis. Int J Veg Sci 21: 157-166.

Ogwu MC, Osawaru ME and Aiwansoba RO (2016) Comparative assessment of some physical characteristics of watermelon (*Citrullus lanatus*). Proceedings of NTBA/NSCB Joint Biodiversity Conference, Unilorin, pp 41-46.

Samadia DK (2007) Studies on genetic variability and scope of improvement in round melon under hot arid conditions. Indian J Hort 64(1): 58-62.

Tyagi N, Sharma GN and Shrivastava B (2017) Phytochemical and pharmacological profile of *Praecitrullus fistulosus*: An overview. Int J Ind Herbs Drugs 2(3): 29-35.

Vegetable Science (2018) 45(2) : 291-293

Short Communication

Kashi Bathua-2: A bathua variety for higher nutrient and yield

BK Singh*, Pragya, SNS Chaurasia, B Singh and PM Singh

Received: December 2018 / Accepted: January 2019

Bathua or leafy chenopod (*Chenopodium album* L.) is also known as fat hen, lamb's quarters, goose foot, pigweed, dungweed, melde, etc. Though cultivated in some regions, the plant is also a potentially serious weed in almost all winter-sown crops of the subtropics and tropics. It belongs to family Amaranthaceae, sub-family Chenopodiaceae, genus *Chenopodium*, and species *album* that has almost worldwide distribution and comprises of about 250 species (Risi and Galwey 1984). Some of the other members of this genus are quinoa (*Chenopodium quinoa*), kaniwa (*Chenopodium pallidicaule*), epazote (*Chenopodium ambrosides*) and good king henry (*Chenopodium bonushenricus*). It is originated in the Andean region of Bolivia and Peru; and widely distributed in both the northern and southern hemispheres, occurring in Asia, North America, Europe, India, South Africa, Australia and South America (Brenan and Akeroyd 1993). Now it is being grown/cultivated in various countries like USA, Japan, Chile, Africa, India, Sri Lanka, Pakistan, Bangladesh, etc. Generally, the *Chenopodium* are tolerant to cold, drought and salinity, and have potential for cultivation in marginal lands (Sood 2011). *Chenopodium album* plant is extensively consumed in Northern India as a leafy vegetable as well as animal feed in many Asian countries. The succulent soft leaves of bathua contain appreciable amount of dietary fibre; protein; minerals such as Ca, Fe, P, K, Mg, Zn, Mn, Se and Na; vitamins i.e. vitamin-C, â-carotene, niacin, folic acid and riboflavin; antioxidatns; omega-6-fatty acid; etc (Yadav et al. 2013, Poonia and Upadhayay 2015, Kole et al. 2016, and Singh and Singh 2017). The effect of feeding chenopodium cultivar on blood lipid profile of rats confirmed the hypochloesterolemic effect by lowering total blood cholesterol, LDL, VLDL and triglycerides, and increasing HDL content (Sood 2011). The nutritive value of leaves is comparable to that of spinach, amaranthus and cabbage which can be used as substitute. Usually, the leaves are cooked in form of saag (leafy vegetable), mixed with dal/puri/paratha and also eaten in raw form as salad. The high yielding and nutrient rich variety has very much scope to be used as a potential leafy vegetable, leaf concentrate and dry leaf powder that will eventually help in combating the nutritional deficiency.

A high yielding and nutrient rich variety of bathua or leafy chenopod 'Kashi Bathua-2' (IC0619019 or VRCHE-2) has been released from ICAR-Indian Institute of Vegetable Research, Jakhini, Varanasi, Uttar Pradesh. The leaves of 'Kashi Bathua-2' are green in colour and alternate in orientation having green colored shoots. The plants show luxuriant growth habit and tend to grow

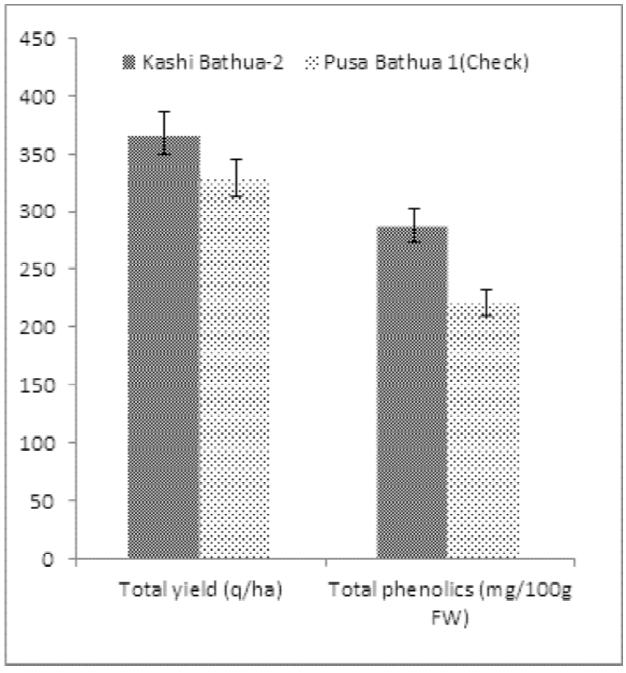

Figure 1: Yield potential and phenolic content in Kashi Bathua-2 and Pusa Bathua-1

ICAR-Indian Institute of Vegetable Research, Jakhini-221305, Varanasi, Uttar Pradesh
*Corresponding author, E-mail: bksinghkushinagar@yahoo.co.in

Table 1: Morphological, yield and quality traits of Kashi Bathua-2 and check

Year	Variety	Plant height (cm)				Total yield (t/ha)	Dry matter (%)	Vitamin C (mg/ 100 g FW)	Total phenolics (mg/100g FW)	Antioxidant activity (CUPRAC µmol/g FW)
		40 DAS	80 DAS	120 DAS	160 DAS					
2013-14	Kashi Bathua-2 (VRCHE 2)	19.7	40.2	122.7	181.6	34.7	15.1	150.4	300.1	41.7
	Pusa Bathua 1(Check)	18.9	36.7	109.7	158.9	30.3	15.6	124.8	218.7	28.4
	% increase over national check	4.2	9.5	11.9	14.3	14.6	-3.2	20.5	37.2	46.8
2014-15	Kashi Bathua-2 (VRCHE 2)	17.8	42.5	129.7	197.6	39.6	15.7	149.3	272.4	44.4
	Pusa Bathua 1(Check)	18.4	40.2	118.0	181.0	34.7	16.3	120.5	215.0	31.6
	% increase over national check	-3.1	5.6	9.9	9.2	14.1	-3.7	23.9	26.7	40.6
2015-16	Kashi Bathua-2 (VRCHE 2)	18.9	37.7	127.2	183.2	35.7	14.9	145.2	289.4	41.9
	Pusa Bathua 1(Check)	18.2	37.5	116.4	170.3	33.6	15.5	121.7	229.5	29.5
	% increase over national check	3.6	0.7	9.3	7.6	6.1	-3.7	19.3	26.1	42.2
Average of three years	Kashi Bathua-2 (VRCHE 2)	18.8	40.1	126.5	187.5	36.7	15.2	148.3	287.3	42.7
	Pusa Bathua 1(Check)	18.5	38.1	114.7	170.1	32.9	15.8	122.3	221.1	29.8
	% increase over national check	1.6	5.3	10.3	10.2	11.5	-3.5	21.2	30.0	43.1
	CD at 5%	ns	ns	9.8	11.5	2.9	0.8	16.6	27.6	8.9

DAS: Days after sowing; FW: Fresh weight

upright, reaching heights of 18.8 cm (17.8-19.7 cm), 40.1 cm (37.7-42.5 cm), 126.5 cm (122.7-129.7 cm), and 187.5 cm (181.6-197.6 cm) at 40 days, 80 days, 120 days & 160 days after sowing, respectively; and showed an average of 10.2% higher plant growth than check during evaluation for three years (Table 1). Total yield potential of this variety was harvested 36.7 t/ha (34.7-39.6 t/ha) which was significantly 11.5% higher than check (Table 1, Figure 1). Further, dry matter content was at par with check which ranged from 14.9-15.7% (15.2%), and vitamin-C (ascorbic acid) content in 100 g fresh weight (FW) was estimated significantly higher (21.2% more) i.e. 148.3 mg (145.2-150.4 mg) in newly released variety 'Kashi Bathua-2' (Table 1, Figure 2).

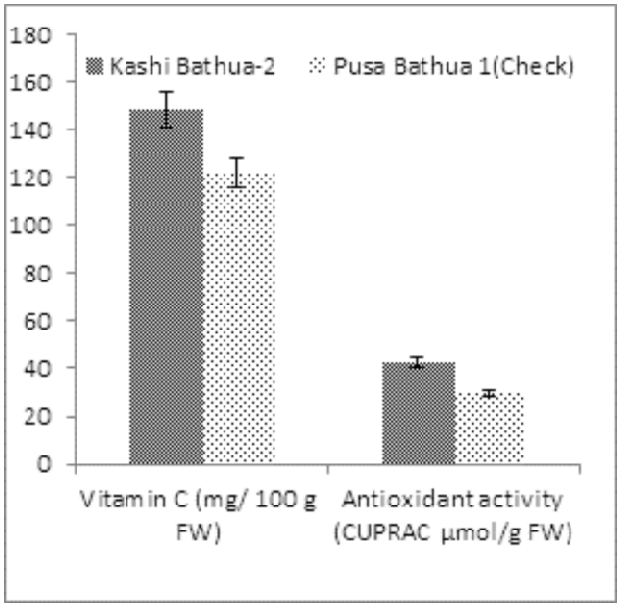

Figure 2: Vitamin-C and antioxidant ability in Kashi Bathua-2 and Pusa Bathua-1

Now-a-days, the importance of phenolics and radical scavenging potential of antioxidants of food items are in discussion because of their wide range of health beneficial properties such as anti-inflammatory, hepato-protective, anti-atherosclerotic, anti-thrombotic, anti-bacterial and anti-carcinogenic. Total phenolics content responsible for antioxidatnts activities was estimated 287.3 mg (272.4-300.1 mg/100 g FW) which was about 30% higher than check variety (Table 1, Figure 1); moreover antioxidant potential in terms of CUPRAC activity (Cupric reducing antioxidant capacity) was quantified 43.1% higher in Kashi Bathua-2 i.e. 42.7 ìmol (41.7-44.4 ìmol/g FW; Table 1, Figure 2).

Kashi Bathua-2, a new variety of bathua (leafy chenopod) having green leaves/shoots and luxuriant growth habit whose yield potential is 36.7 t/ha, and possesses 15.2% dry matter, 148.3 mg/100 g FW of vitamin-C (21.2% higher), 287.3 mg/100 g FW of total phenolics (30.0% higher) and 42.7 ìmol/g FW of CUPRAC antioxidant activity (43.1% higher) that makes variety suitable for preparing saag, leaf concentrate and dry leaf powder.

References

Koley TK, Maurya A, Tripathi A, Singh BK and Singh B (2016) Nutritive vegetables for healthy life. Indian Hort 61(1): 38-41.

Brenan JPM and Akeroyd JR (1993) *Chenopodium* L. In: Flora Europaea Volume 1, Psilotaceae to Platanaceae (Tutin TG et al. eds). 2nd Edition, Cambridge University Press, Cambridge, UK, pp 111-114.

Poonia A and Upadhayay A (2015) *Chenopodium album* Linn: review of nutritive value and biological properties. J Food Sci Technol 52(7): 3977-3985.

Risi J and Galwey NW (1984) The Chenopodium grains of the Andes: Inca crops for modern agriculture. In: Advances in Applied Biololgy (Coaker TH Ed), Academic Press, Landon, pp 145-216.

Singh BK and Singh B (2017) IC0619019 (VRCHE-2): A bathua genotype for higher nutrient and yield. Vegetable Newsletter 4(2): 3.

Sood P (2011) Physico-chemical, nutritional, biological quality evaluation and value addition of chenopodium (bathua) cultivars. PhD Thesis, Department of Food Science and Nutrition, CSKHPKV, Palampur-176062, HP.

Yadav RK, Joshi S, Kumar R, Kalia P, Varshney R and Jain V (2013) Studies on different genotypes of Indian bathua (*Chenopodium album*) for their yield, quality and antioxidant activities. Indian J Agric Sci 83(1): 26–30.

Vegetable Science (2018) 45(2) : 294-296

Short Communication

Evaluation of cherry tomato varieties (*Solanum lycopersicum* var. *cerasiforme*) for growth, yield and quality under naturally ventilated polyhouse

Suni Gyadi and Deepa Borbora Phookan*

Received: June 2018 / Accepted: January 2019

Cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) is a botanical variety of the cultivated tomato. It is a small garden variety of tomato which bears tasty, numerous small sized fruits in clusters along the stems and branches of the plant having chromosome number 2n = 24. It has become more popular all over the world because of a good source of vitamins A and C, TSS content and good taste. It is marketed at a premium to ordinary tomatoes. The demand for tomato, especially cherry tomato (*Lycopersicon esculentum* var.*cerasiforme*) has increased primarily due to the increase in quality (Alarcon et al. 1994). Flavour is generally determined by total soluble solids (TSS) and can be high in cherry tomatoes. Red color is more common, but other varieties such as yellow, green, and black also exist. The cherry tomato is also beneficial to human health because of its high content of antioxidant and phytochemical compounds including lycopene, Beta carotene, flavonoids, vitamin C and many essential nutrients (Rosales et al. 2010). Cherry tomatoes are widely used in salads, as appetizer and for garnishing foods in hotels and restaurants. No research on cherry tomato was done till now and still infancy for farmer's field and as well as for consumption market. In view of this the present experiment was done to see the performance of some cherry tomato varieties in Assam under NV polyhouse condition.

A field investigation was carried out under naturally ventilated polyhouse in the Experimental Farm Department of Horticulture, Assam Agricultural University, Jorhat-785013 during 2017-18. The objective of this investigation was to study the relative performance of cherry tomato varieties under naturally ventilated polyhouse. The experiment was conducted in during rabi season in Randomized Block Design replicated for three times. There were twelve varieties of cherry tomato *viz.,* Roja, Laila, Sheeja, Ruhi, Cherry Tomato Red, Cherry Tomato Yellow, Lara, Sweet Bite, Yellow Pear tomato, Garden's Delight, Pusa Cherry-1 and Meghalaya local in this study. The seedlings were raised in portray containing cocopeat, vermiculite and perlite in the ratio of 3:1:1 volume by volume in the month of October and thirty days old seedlings were planted in the NV Polyhouse in the first week of November. The soil of the polyhouse was prepared to fine tilth and seedlings were plants at a distance of 1 m between rows and 60 cm within rows. Each treatment i.e. variety in each replication was 10 nos of plants. The crop was raised as per package of practices of tomato. Observations on five randomly selected plants were recorded for various growth, yield and quality attributing traits as per standard procedure. Total Soluble Solids (TSS) of the cherry tomato fruits were determined by Zeiss Hand Refractometer. Ascorbic acid content were determined by 2,6 Dichlorophenol indophenols dye visual titration method, carotenoids content was estimated by spectrophotometric method. Sugar and acidity of the fruit juice were determined by adopting the standard methods of AOAC (1990)

Mean plant height ranged from 2.55 m to 5.01 m (Table 1). The maximum plant height was observed in Laila (5.01 m) followed by Cherry Tomato Yellow (4.82 m) and Cherry Tomato Red (4.73 m). The lowest plant height (2.55m) was observed in Sweet Bite. The mean number of primary branches ranged 8.33 to 4.33. The variety Meghalaya Local produced significantly highest number of branches plant^{-1} (8.33) followed by Pusa Cherry -1 (8.00). Significantly lowest branch number

Department of Horticulture, Assam Agricultural University, Jorhat-7685013, Assam
*Corresponding author, Email: deepa.aau@gmail.com

Table 1: Growth and yield attributing characters of cherry tomato varieties

Variety	Plant height(m)	Branch number	Flowers/cluster	Fruit set(%)	Fruiting cluster/plant	Rachis length (cm)
Roja	3.65	5.33	14.63	93.39	24.50	29.72
Laila	5.01	6.00	11.44	96.52	23.10	25.53
Sheeja	3.47	6.33	17.85	94.47	21.40	34.34
Ruhi	4.36	4.67	12.57	88.34	24.20	17.84
Cherry Tomato Red	4.73	5.00	9.87	90.21	10.00	16.53
Cherry Tomato Yellow	4.82	4.33	12.69	75.42	13.00	22.83
Lara	2.93	7.33	11.54	87.78	29.00	25.12
Sweet Bite	2.55	5.67	15.37	97.91	20.00	31.65
Yellow Pear Tomato	2.65	7.00	7.39	50.04	12.00	7.62
Garden's Delight	3.54	7.67	15.56	55.70	13.33	23.2
Pusa Cherry-1	4.51	8.00	44.51	75.21	9.00	38.68
Meghalaya Local	4.25	8.33	7.36	61.46	8.00	16.56
SEm(±)	0.06	0.83	2.84	6.41	0.91	0.11
CD(0.05)	0.14	1.91	6.51	14.67	2.09	0.25

was found in Cherry Tomato Yellow (4.33) followed by Cherry Tomato Red (5.00). The more plant height and branch number might be due to better acclimatization and adaptation to the congenial polyhouse climate coupled with inherent genetic potential of the varieties. Similar results were recorded by Prema et al. (2011), Renuka et al. (2014) in cherry tomato. The mean of number of flowers cluster^{-1} ranged from 7.39 to 44.51. The highest number of flowers cluster^{-1} was observed in the variety Pusa Cherry-1 (44.51) followed by Sheeja (17.85). The mean of number of fruits cluster^{-1} ranged from 3.67 (Yellow Pear Tomato) to 33.33 (Pusa Cherry-1) presented in Table 1. Such variation in flower as well as fruit production might be due to inherent capacity of the varieties and response to the favourable micro climate under polyhouse. Similar results were obtained by Singh et al. (2013) and Renuka et al. (2017) under protected condition. Highly significant differences were noticed among the variety with respect to fruit set percentage.

Table 2: Yield and economics of cherry tomato varieties

Variety	Weight/ fruit (g)	Fruits/ plant	Yield/ plant (Kg)	Yield/ 1000 m^2 (t)	B:C ratio
Roja	16.32	234.87	3.83	6.36	2.16
Laila	15.40	203.83	3.12	5.17	1.57
Sheeja	13.35	256.63	3.44	5.73	1.84
Ruhi	18.33	232.00	4.24	7.06	2.49
Cherry Tomato Red	12.08	76.33	0.91	1.52	-0.25
Cherry Tomato Yellow	12.60	83.33	1.03	1.72	-0.15
Lara	18.80	228.87	4.30	7.16	2.56
Sweet Bite	17.10	183.37	3.13	5.23	1.58
Yellow Pear Tomato	11.00	26.67	0.30	0.52	-0.75
Garden's Delight	23.93	89.00	2.13	3.55	0.76
Pusa Cherry-1	9.11	190.67	1.74	2.87	0.44
Meghalaya Local	12.93	26.00	0.34	0.57	-0.72
SEm(±)	0.29	3.33	0.07	0.014	2.16
CD(0.05)	0.66	7.63	0.16	0.033	1.57

Table 3: Quality parameters of cherry tomato varieties

Variety	TSS (%)	Ascorbic acid (mg)	Acidity (%)	Total sugar (%)	Carotene (µg/g)
Roja	7.10	13.68	0.37	6.12	25.78
Laila	6.42	19.20	0.19	7.27	34.79
Sheeja	6.31	24.48	0.25	5.68	4.55
Ruhi	6.22	21.60	0.28	7.22	23.55
Cherry Tomato Red	5.23	33.60	0.24	6.02	19.55
Cherry Tomato Yellow	6.22	28.80	0.22	5.81	3.43
Lara	6.13	21.60	0.29	7.01	27.14
Sweet Bite	5.72	21.12	0.32	6.45	3.37
Yellow Pear Tomato	4.83	24.72	0.15	5.06	3.43
Garden's Delight	5.53	25.44	0.19	5.27	27.52
Pusa Cherry-1	6.30	31.20	0.23	7.18	27.08
Meghalaya Local	6.25	19.92	0.29	4.65	20.36
SEm(±)	0.08	0.02	0.004	0.04	0.03
CD(0.05)	0.18	0.05	0,01	0.08	0.06

The mean fruit set percentage varied between 50.04 and 96.52. The fruit set percentage was highest in Sweet Bite (97.91%). The increase in number of flowers and fruits cluster^{-1} might be the reason for higher fruit set percentage and similar results were obtained by Singh et al. (2013) and Wahundeniya et al. (2013) in poly house tomato. Apart from other factors, pollen viability is one of the major factors influencing fruit set. The increased fruit set might be due to higher rate of anther dehiscence, higher pollen viability and better response to polyhouse conditions (Omomprasad 2014). The mean number of fruiting clusters plant^{-1} ranged from 8.00 to 23.00. Among the variety, Lara (29.00) had recorded the highest number of fruiting clusters plant^{-1} followed by Roja (24.50). High number of fruiting clusters plant^{-1} might be due to the genetic potentiality of these varieties responding to the favourable micro climate under poly house. Regarding average fruit weight, Table 1 showed

highly significant values among all the cherry tomato variety. Rachis length was found highest in the variety Pusa Cherry-1, this is an important character for fruit number per bunch. The mean fruit weight ranged from 9.11 g to 23.93 g. This variation in average fruit weight might be due to inverse relationship existing between average fruit weight, and number of fruits cluster^{-1}. This was conformity with the findings of Prema et al. (2011). The highest mean fruit yield plant^{-1} was recorded highest in Lara (4.30 kg) followed by Ruhi (4.24 kg) and Roja (3.83 kg). The highest yield of 60.90 t ha^{-1} was recorded in the variety Lara followed by 60.00 t in Ruhi. The cherry tomato varieties Lara, Ruhi and Roja outperformed other varieties in terms of yield when grown under NV polyhouse. Yield is the cumulative effect of number of fruits and fruit size.

The highest TSS (7.10%) was found in Roja followed by Laila (6.42%) while the ascorbic acid content was found highest in Cherry Tomato Red (33.60 mg 100g^{-1}) followed by Pusa Cherry-1 (3.12 mg 100g^{-1}). Higher TSS in Roja and Laila variety might be due to the enhanced deposition of solids and more conversion of organic acids to sugars. Similar result was also reported by Prema et al. (2011) and Islam *et al*. (2012) in polyhouse grown cherry tomato. Significantly the highest ascorbic acid was recorded in the variety Cherry tomato red (33.60 mg 100g^{-1}) followed by Pusa cherry-1 (31.20 mg 100g^{-1}) recorded significantly highest ascorbic acid content. While Roja (13.68 mg /100g^{-1}) followed by Laila (19.92 mg 100g^{-1}) recorded the lowest ascorbic acid content. This significantly varied ascorbic acid content in the present study might be due to immense variation among different cherry tomato cultivars and their genetic makeup of the variety to perform better under protected environmental condition. Acidity percentage ranged from 0.15 to 0.37. The highest titrable acidity was registered from the variety Roja (0.37 %) followed by Sweet Bite (0.32 %) and lowest acidity in the variety Yellow Pear Tomato (0.15 %).The lower acidity in these cultivars might be due to rapid utilization of organic acids in respiration during maturity. Similar results of significant differences among variety were also reported by Prema et al. (2011) and Razzak et al. (2013) in cherry tomato under polyhouse. Sugar content of different variety ranged from 4.65-7.27%, variety Laila had the highest value (7.27%) followed by Ruhi (7.22%). While, Meghalaya Local (4.65 %) followed by Yellow Pear tomato (5.06%) showed least values for total sugars content. Degradation of acids during ripening and senescence in the protected environment may be the causes for sugar content in cherry tomato variety. Similar results were also reported by Razzak et al. (2013) in tomatoes produced under shade net.

In this study the highest benefit cost ratio of 2.56 was obtained in variety Lara. However the varieties Ruhi and Roja are also good performing for various characters taken under study. They could be exploited further in different breeding programs. The promising hybrids can be utilized for the selection to isolate the desirable genotypes in cherry tomato.

References

AOAC (1990) Official Methods of Analysis. Association of Official Analytical Chemist, Arlington, VA, USA

Alarcon J, Bolasin M, Sanchez-Blanco M and Torrecillas (1994) Growth, yield and water relations of normal fruited and cherry tomato cultivars irrigated with saline water. J Hortic Sci 69 (2): 283-288.

Prema G, Indiresh KM and Santhosha HM (2011) Evaluation of cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) genotypes for growth, yield and quality traits. Asian J Hort 6(1): 181-184.

Razzak HA, Ibrahim A, Allah MW and Alsadon A (2013) Response of cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) to pruning systems and irrigation rates under greenhouse conditions. Asian J Crop Sci 5(3): 275-285.

Renuka DM, Sadashiva AT, Kavita BT, Vijendrakuma RC and Hanumanthiah MR(2014) Evaluation of cherry tomato lines (*Solanum lycopersicum* var. *cerasiforme*) for growth, yield and quality traits. Plant Archives 14(1):151-154.

Rosales MA, Cervilla LM, Rodriguez ES, Wilhelmi MR, Blasco B, Rios JJ, Scoriano T, Castilla N, Romero L. and Ruiz JM (2010) The effect of environmental conditions on nutritional quality of cherry tomato fruits evaluation of two experimental Mediterranean greenhouse. J Sci Food Agric 91 (1):649-652

Singh HM and Tiwari JK (2013) Impact of micronutrient spray on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill). Hort Flora Res Spectrum 2(1): 87-89.

Wahundeniya WMKB, Ramanan R, Wicramathunga C and Weerakkody WAP (2006) Comparison of growth and yield performances of tomato varieties under controlled environment conditions. Ann M Veneman Department of Agriculture 8: 251-262.

Vegetable Science (2018) 45(2) : 297-299

Short Communication

Impact of pre-storage seed invigoration in ash gourd [*Benincasa hispida* (Thunb.) Cogn.]

Athmaja S[1], Rose Mary Francies[2], Dijee Bastian[1], Sarah T George[3], Anita Cherian K[4]

Received: September 2018 / Accepted: December 2018

Ash gourd is widely cultivated as a vegetable crop in Kerala. In the state, prolonging seed longevity is a major concern as the prevailing hot humid conditions accelerates deterioration of seeds leading to rapid loss of viability during storage. Seed deterioration due to ageing is indeed inevitable and irreversible phenomenon, the best that can be done is to lower its rate (Coolbear 1995). It is reported that seed priming technology helps in rapid and uniform germination and emergence of seeds and impart a great tolerance to adverse environmental conditions (Heydecker et al. 1973). A study conducted at KAU on the storability of invigorated seeds of ash gourd variety KAU local had revealed that viability of the invigorated seed was maintained above the Indian minimum seed certification standards (IMSCS) for seven months after storage (MAS) under ambient condition (Shobha 2016). Considering all the above, the present study was formulated to elucidate the effect of seed invigoration on viability and quality of seeds stored under ambient and refrigerated environment.

The experiment was conducted at the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Thrissur. The seeds of ash gourd variety KAU Local collected immediately after extraction were invigorated with the respective priming agents (Table 1) in the ratio 1:2 on volume basis for the specified period. The invigorated and untreated seeds were shade dried at room temperature to $\leq$ 8 per cent moisture prior to packing. The seed required for the monthly assessment of seed germination in each of the seven treatments (I_1 to I_7) were packed separately in polyethylene bags of 700 gauge. Three replicates each of the seed thus packed in each treatment were stored under two storage conditions *i.e.*, ambient storage and refrigerated condition. The germination test was carried out in sand medium as per standard procedure (ISTA 2010). Four replicates of 100 seeds each were germinated in a germination room maintained at 25±2°C temperature and 90±3% RH. The number of normal seedlings were counted in each replication at the end of germination period *i.e.,* on the 14th day and the per cent of germination was computed Statistical analysis of the data was performed using OPSTAT and MSTAT-C package for completely randomized design with two factors (storage condition and invigoration treatments).

Germination of seeds under the refrigerated storage during the initial period (up to 3 MAS) was lower than that under ambient conditions. Germination in ambient stored seeds was retained above MSCS of 60 per cent up to 5 MAS (68%) whereas in seeds under refrigerated storage it was retained above MSCS for 13 MAS (61%) (Fig 1). Similar reports on the extension of seed viability

College of Horticulture, Kerala Agricultural University (KAU), Thrissur
[1]Seed Science and Technology, College of Horticulture, KAU, Vellanikkara, Thrissur, Kerala
[2]Department of Seed Science and Technology, College of Horticulture, KAU, Vellanikkara, Thrissur, Kerala
[3]Department of Olericulture, College of Horticulture, KAU, Vellanikkara, Thrissur, Kerala
[4]Department of Plant Pathology, College of Horticulture, KAU, Vellanikkara, Thrissur, Kerala
*Corresponding author, Email: athmajasubhagan@gmail.com

Table 1: Details of treatment

Treatment	Details
I_1	$CaCl_2$ (50 mM for 12 h)
I_2	$CaCl_2$ (50 mM for 24 h)
I_3	Kinetin (Cytokinin) (10 ppm for 12 h)
I_4	Kinetin (Cytokinin) (10 ppm for 24 h)
I_5	KH_2PO_4 (100 mM for 24 h)
I_6	*Pseudomonas fluorescens* ($1x10^6$ cfu.ml^{-1} for 12 h)
I_7	Absolute control (untreated seeds)

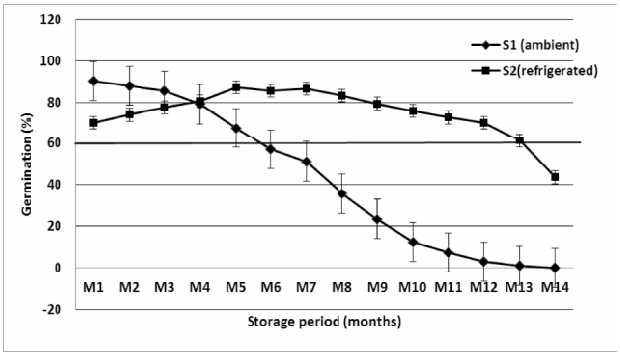

Fig 1: Influence of storage condition on germination (%) in ash gourd

under the cold storage and its advantage over ambient storage were also observed by Dhatt (2016) in pancy, Basavegowda et al. (2016) in pigeon pea, Dhatt et al. (2018) in *Nemesia strumosa.*

Unlike the invigorated seeds which exhibited a germination per cent above 80 after 1 MAS, the germination of the untreated control (I_7) was below the MSCS at 1 MAS and gradually reached a maximum of 84 per cent at 5 MAS. This indicated that priming induced early germination in invigorated seeds (Table 2) and presence of dormancy in untreated control. The finding is in consonance with that of earlier workers (Afzal et al. 2008; Moeinzadeh et al. 2010; Afzal et al. 2012; Shobha 2016). Considering the significant superiority of seeds invigorated with I_1 ($CaCl_2$ 50mM 12 h) and I_2 ($CaCl_2$ 50mM 24 h) with respect to germination in the initial storage period (up to 4 MAS) coupled with retention of germination above MSCS for 8 MAS, priming with $CaCl_2$ 50mM can be advocated.

The interaction between storage condition and invigoration treatment (Table 3) indicated that Bio-primed seeds (*Pf* 1x10^6 cfu.ml^{-1} for 12h; S_2I_6) registered the highest germination (73%) at 13 MAS and was significantly superior to all other treatments. The untreated seeds (S_2I_7) and seeds invigorated with $CaCl_2$ 50mM 12 h (S_2I_1) retained viability above MSCS for 12 MAS only. Under ambient storage, the untreated seeds as well as seeds invigorated with $CaCl_2$ 50mM for 24 h (S_1I_2) had retained viability above MSCS for 7 MAS. The result is in concomitance with that of Meena et al. (2017) and Dorna et al. (2013). The advantage of invigorating seeds of ash gourd with $CaCl_2$ 50mM was also reported by Shobha (2016).

Considering the impact of storage environment and invigoration treatment on seed quality discussed above, it can be concluded that seed invigoration followed by refrigerated storage is advantageous. If only ambient storage condition is feasible, it would be advantageous to invigorate the seeds with $CaCl_2$ 50mM for 12h (I_1) as viability above MSCS is retained for 8 MAS compared to untreated seeds (7 MAS). If provision for refrigerated storage is available, bio-priming with *Pf* 1x10^6 cfu.ml^{-1} for 12 h (S_2I_6) or invigoration with $CaCl_2$ 50mM for 24h (I_2) would be advantageous.

References

Afzal I, Rauf S, Basra SMA and Murtaza G (2008) Halopriming improves vigor, metabolism of reserves and ionic contents in wheat seedlings under salt stress. Plant Soil Environ 54: 382-388.

Afzal I, Hussain B, Basra SMA and Rehman H (2012) Priming with moringa leaf extract reduces imbibitional chilling injury in spring maize. Seed Sci Technol 40(2): 271-276.

Table 2: Effect of invigoration treatment on germination (%) during storage in ash gourd

Invigoration treatment (I)	Storage period (months)									
	1 MAS	2 MAS	3 MAS	4MAS	5 MAS	6 MAS	7 MAS	8 MAS	9 MAS	10 MAS
I_1	89.00^a (74.48)	89.00^a (72.56)	88.00^a (71.00)	84.00^a (67.00)	86.00^a (70.00)	76.00^a (63.03)	72.00^a (59.00)	70.00^a (57.00)	58.00^b (50.00)	51.00^a (45.00)
I_2	86.00^{ab} (69.26)	88.00^a (70.90)	89.00^a (71.00)	89.00^a (71.00)	87.00^a (70.00)	75.00^{ab} (61.00)	75.00^a (61.00)	60.00^b (51.00)	56.00^b (49.00)	51.00^a (45.00)
I_3	82.00^{bc} (66.27)	79.00^b (63.17)	80.00^b (63.00)	75.00^b (60.00)	70.00^{cd} (60.00)	60.00^c (54.00)	57.00^b (52.00)	51.00^c (45.00)	43.00^c (39.00)	38.00^b (31.00)
I_4	81.00^{bc} (68.65)	77.00^b (62.07)	75.00^c (60.00)	66.40^b (54.00)	64.00^d (53.00)	64.00^{bc} (53.00)	55.00^b (48.00)	54.00^{bc} (48.00)	41.00^c (37.00)	39.00^b (34.00)
I_5	80.00^c (64.00)	81.00^b (64.00)	81.00^b (64.00)	87.00^a (70.00)	76.00^{bc} (62.00)	74.00^{ab} (62.00)	70.00^a (58.00)	53.00^{bc} (47.00)	46.00^c (42.00)	40.00^b (36.00)
I_6	84.00^{abc} (70.00)	85.00^a (70.00)	84.00^{ab} (68.00)	83.00^a (66.00)	71.00^{cd} (58.00)	70.00^{abc} (58.00)	73.00^a (60.00)	56.00^{bc} (50.00)	45.00^c (40.00)	43.00^{ab} (37.00)
I_7	56.00^d (48.00)	65.00^c (54.00)	69.00^d (56.00)	71.00^b (57.00)	84.00^{ab} (66.00)	76.00^a (61.00)	77.00^a (61.00)	70.00^a (57.00)	66.00^a (55.00)	44.00^{ab} (40.00)
SEm ±	1.28	1.028	1.144	2.103	2.123	2.515	2.12	1.628	1.228	1.946
CD (0.05)	3.726	2.994	3.33	6.122	6.183	10.30	6.174	4.741	3.575	5.666

Table 3: Interaction effect of Storage condition and Invigoration treatment on germination (%) during storage in ash gourd

Invigoration treatment (I)	Storage period (months)													
	1 MAS	2 MAS	3 MAS	4MAS	5 MAS	6 MAS	7 MAS	8 MAS	9 MAS	10 MAS	11 MAS	12 MAS	13 MAS	14 MAS
S_1I_1	99.00^{a} (85.00)	97.00^{a} (81.00)	94.00^{a} (77.00)	83.00^{abc} (66.00)	77.00^{cd} (61.00)	68.00^{d} (56.00)	62.00^{b} (52.00)	61.00^{c} (51.00)	41.00^{d} (39.00)	37.00.^{d} (37.00)	32.00^{d} (34.00)	11.00^{e} (19.00)	6.00^{d} (14.00)	0.00^{e}
S_1I_2	93.00^{bc} (75.00)	93.00^{b} (75.00)	92.00^{a} (74.00)	88.00^{abc} (70.00)	82.00^{bcd} (65.00)	62.00^{de} (52.00)	63.00^{b} (53.00)	37.00^{d} (37.00)	33.00^{e} (35.00)	25.00^{e} (30.00)	9.00^{e} (17.00)	6.00^{ef} (14.00)	0.00^{e}	0.00^{e}
S_1I_3	93.00^{bc} (74.00)	82.00^{d} (65.00)	81.00^{bcd} (64.00)	64.00^{gh} (53.00)	44.00^{f} (41.00)	33.00^{g} (35.00)	27.00^{d} (31.00)	24.00^{e} (29.00)	10.00^{fg} (18.00)	0.43^{g} (3.00)	2.00^{ef} (9.00)	0.00^{g}	0.00^{e}	0.00^{e}
S_1I_4	98.00^{ab} (83.00)	86.00^{cd} (67.00)	80.00^{cde} (63.00)	60.00^{h} (51.00)	55.00^{e} (48.00)	48.00^{f} (44.00)	27.00^{d} (31.00)	20.00^{e} (26.00)	6.00^{g} (14.00)	3.00^{g} (8.00)	2.00^{ef} (4.00)	1.00^{fg} (5.00)	0.00^{e}	0.00^{e}
S_1I_5	90.00^{c} (72.00)	89.00^{bc} (70.00)	84.00^{bc} (67.00)	93.00^{a} (75.00)	63.00^{e} (53.00)	55.00^{ef} (47.00)	53.00^{c} (47.00)	22.00^{e} (28.00)	13.00^{f} (21.00)	4.00^{fg} (12.00)	0.00^{f}	0.00^{g}	0.00^{e}	0.00^{e}
S_1I_6	98.00^{ab} (83.00)	98.00^{a} (83.00)	93.00^{a} (75.00)	88.00^{ab} (70.00)	62.00^{e} (52.00)	60.00^{de} (51.00)	53.00^{c} (47.00)	24.00^{e} (29.00)	6.00^{g} (14.00)	1.00^{g} (7.00)	0.00^{f}	0.00^{g}	0.00^{e}	0.00^{e}
S_1I_7	58.00^{g} (50.00)	69.00^{f} (56.00)	70.00^{f} (56.00)	73.00^{def} (59.00)	87.00^{abc} (69.00)	71.00^{cd} (57.00)	70.00^{b} (56.00)	58.00^{c} (50.00)	53.00^{c} (46.00)	12.00^{f} (19.00)	4.00^{ef} (11.00)	1.00^{fg} (4.00)	0.00^{e}	0.00^{e}
S_2I_1	79.00^{d} (63.00)	81.00^{d} (64.)	82.00^{bcd} (64.00)	84.00^{abc} (67.00)	95.00^{a} (71.00)	85.00^{ab} (67.00)	82.00^{a} (65.00)	80.00^{b} (63.00)	75.00^{b} (60.00)	65.00^{c} (53.00))	63.00^{c} (53.00)	62.00^{d} (2.00)	52.00^{c} (46.00)	40.00^{cd} (39.00)
S_2I_2	79.00^{d} (63.00)	84.00^{d} (67.00)	86.00^{b} (68.00)	91.00^{ab} (73.00.)	93.00^{a} (75.00)	88.00^{ab} (70.00)	87.00^{a} (69.00)	82.00^{ab} (65.00)	79.00^{b} (62.00)	76.00^{b} (61.19)	74.00^{b} (59.00)	74.00^{ab} (59.00)	60.00^{b} (50.00)	40.00^{cd} (39.00)
S_2I_3	72.00^{e} (58.00)	76.00^{e} (61.00)	79.00^{cde} (63.00)	85.000^{abc} (68.00)	96.00^{a} (79.00)	88.00^{ab} (72.00)	88.00^{a} (72.00)	77.00^{b} (62.00)	76.00^{b} (60.00)	75.00^{b} (60.00)	73.00^{b} (59.00)	73.00^{bc} (58.00)	64.00^{b} (53.00)	43.^{bc} (41.00)
S_2I_4	65.00^{f} (54.00)	69.00^{f} (56.00)	70.00^{f} (57.00)	72.00^{efg} (58.00)	73.00^{d} (59.00)	80.00^{bc} (63.00)	83.00^{a} (66.00)	88.00^{a} (70.00)	77.00^{b} (61.00)	75.00^{b} (60.00)	70.00^{bc} (56.00)	65.00^{d} (54.00)	61.00^{b} (51.00)	57.00^{a} (49.00)
S_2I_5	70.00^{ef} (56.00)	72.00^{ef} (58.00)	78.00^{de} (62.00)	82.00^{bcd} (65.00)	90.00^{ab} (72.00)	93.88^{a} (76.00)	87.00^{a} (69.00.)	84.00^{ab} (66.00)	80.00^{ab} (63.00)	76.00^{b} (61.00))	73.00^{b} (59.00)	68.00^{cd} (55.00)	62.00^{b} (52.00)	41.00^{cd} (39.00)
S_2I_6	70.00^{ef} (56.00)	72.00^{ef} (58.00)	75.00^{e} (60.00)	78.00^{cde} (62.00)	80.00^{bcd} (64.00)	81.00^{bc} (64.00)	92.00^{a} (73.00)	88.00^{a} (70.00)	85.00^{a} (67.00)	85.00^{a} (67.00)	84.00^{a} (66.00)	79.00^{a} (63.00)	73.00^{a} (59.00)	48.00^{b} (44.00)
S_2I_7	53.00^{h} (47.00)	61.^{g} (51.00)	68.00^{f} (56.00)	69.00^{fgh} (56.00)	81.00^{bcd} (64.00)	82.00^{ab} (67.00)	84.00^{a} (66.00)	81.00^{ab} (64.00)	80.00^{ab} (63.00)	76.00^{b} (61.00))	68.^{bc} (55.89)	67.00^{cd} (55.00)	54.00^{c} (47.00)	35.00^{d} (36.00)
SEM ±	1.81	1.454	1.617	2.973	3.003	3.56	2.999	2.302	1.736	2.752	2.719	1.935	1.816	1.962
CD (0.05)	5.2 69	4.234	4.709	8.658	8.744	10.358	8.731	6.704	5.055	8.012	7.917	5.634	5.287	5.682

*Values in parentheses are Arc sine transformed values

**Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Basavagowda, Gururajsunkad AK, Hosamani,BN and Raghu (2016) Effect of commercial cold storage conditions and packaging materials on seed quality of pigeon pea (*Cajanus cajan* (L.) Millisp). Environ Ecol 34 (3): 1262-1266.

Coolbear P (1995) Mechanisms of seed deterioration. Seed Quality-Basic Mechanisms and Agricultural Implications. pp 223-277.

Dhatt KK (2016) Effect of storage conditions and durations on seed viability and germination of pansy (*Viola× wittrockiana*). J Ornamental Horti 19(3): 97-105.

Dhatt KK (2018) Impact of storage temperature and packaging on seed germination and viability of *Nemesia strumosa* Benth. Appl Biolog Res 20(2): 146-153.

Dorna H, Jarosz M, Szopinska D, Szulc I and Rosinska A (2013) Germination, vigour and health of primed *Allium cepa* L. seeds after storage. Acta Scientiarum Polonorum Hortorum Cultus 12(4): 43-58.

Heydecker W, Higgins J and Gulliver RL (1973) Accelerated germination by osmotic seed treatment. Nature 246: 42.

Meena MK, Chetti MB and Nawalagatti CM (2017) Seed quality behavior of soybean (*Glycine max*) as influenced by different packaging materials and storage conditions. Leg Res. 40(6): 1113-1118.

Moeinzadeh A, Zadeh FS, Ahmadzadeh M and Tajabadi FH (2010) Biopriming of sunflower (*Helianthus annuus* L.) seed with *Pseudomonas fluorescens* for improvement of seed invigoration and seedling growth. African J Coop Sci 4(7): 564-570.

Shobha KV (2016) Seed invigoration to overcome dormancy in ash gourd (*Benincasa hispida* (Thunb.)Cogn.). MSc (Ag) Thesis, Kerala agricultural University, Thrissur

Vegetable Science (2018) 45(2) : 300-302

Short Communication

Effect of plastic mulches on performance of brinjal (*Solanum melongena* L.) in temperate Himalaya

AC Mishra

Received: June 2018 / Accepted: January 2019

The brinjal is a very important crop of Indian plains commonly grown throughout the year. A number of high yielding varieties and hybrids have been evolved to increase yield in this crop. In addition to improved cultivars, advances have also been made to develop cop management practices including fertilization, irrigation and weed control for boosting the productivity in this crop. Commercial cultivation of brinjal in hills is confined only to lower hills up to 1000-1200m altitude due to quick fall down of temperature in late Kharif and severe winter at higher altitudes (>15000m). The area under brinjal cultivation in mid hills (1700m-2200m altitude) of Himalayan region is negligible. However, selection of short duration long fruited varieties/hybrids have been found to give economical yield provided seedlings are raised in polyhouse during February-March and transplanted during the month of April. The peculiar feature of this crop in mid hills is that it is free from fruit rot disease and fruit-shoot borer infestation which are severe problems in plains and require frequent spray of long lasting pesticides which lead to health hazard. Such type of disease and insect avoidance in temperate hills opens the opportunity of organic brinjal production which could not be imagined in plains of India. Early fruiting, optimum moisture management during pre-monsoon period and weed management during monsoon are the crucial practices for success of this crop. Sowing of seeds during the month of February in polyhouse may lead to early transplanting of seedlings in the first week of April. Use of plastic mulches can be even more conducive for inducing earliness by increasing soil temperature (Hu et al. 1995 and Ramakrishna et al. 2006) and suppress weed population (Ossom et al. 2001) in addition to conserving soil moisture. With this view, black and white plastic mulches were applied and compared with unmulched control to assess the impact of different mulch treatments on edaphic environment, plant growth and productivity in addition to identify the suitable mulching option for micro-climatic manipulation leading to early and optimum yield by suppression of weed competition in summer-rainy brinjal crop in temperate Himalayas.

The experiments for present investigation were conducted in Vegetable Research Block of Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri Campus, Tehri-Garhwal (2000 m altitude, 30^0 15'N latitude and 78^0 02'E longitude), the rainfed temperate hills of Uttarakhand during summer-rainy seasons of 2014 and 2015. The experiments were laid out in randomized block design with three treatments involving mulching with black polythene (100µm), white polythene (100µm) and without mulching *i.e.* bared soil. All the treatments were replicated six times in the plots of 4.0m x 1.8 m size. The trials were conducted with PPL-74, the F_1 hybrid of brinjal (*Solanum melongena* L.) developed by Sungro Seeds (India) Pvt. Ltd. The seeds were sown in nursery beds in polyhouse during first week of March and seedlings were transplanted in the main field at 60 x 60 cm spacing on 1.2 m wide raised beds with installed drip system as well as plastic mulches as per requirement of the treatments. The drip laterals passed lying close to the plant basin underneath polythene sheet. The soil of experimental field consisted of pH 6.4, organic matter 5.4% and NPK content of 342.7 kg/ha, 31.8 kg/ha and 544.5 kg/ha, respectively. The field was prepared with deep ploughing, clod breaking and mixing compost @ 15.0 t/ha. Prior to transplanting the field was prepared

Department of Vegetable Science, Uttarakhand University of Horticulture and Forestry, Ranichauri Campus, Tehri-Garhwa-249 199, Uttarakhand
Corresponding E-mail: acm24680@gmail.com; and Present Address: Department of Vegetable Science, Banda University of Agriculture & Technology, Banda-210 001, UP

by mixing NPK 80:60:40 kg/ha, respectively in the form of DAP and MoP. The laterals of drip system with online/ flat drippers of 16 mm OD/30 cm/2lph were placed on each row and the system was operates for 45 minutes in each irrigation on alternate day. However, drip system was used up to 15-25 June before onset of the *monsoon*. Later on soil of raised bed resumed sufficient moisture through imbibition of rain water accumulated in furrows between raised beds. The data on soil temperature at 2.0 pm of the day were recorded by inserting thermometer in soil up to 10 cm depth near plant basin in each plot during the month of June, July and August and average soil temperature was worked out for each plot. The data were also recorded for dry biomass of weeds (g /m^2) (Spandl et al. 1999), plant height at first harvest (cm), number of primary branches, days to first harvest (days after transplanting, DAT), number of fruits per plant and fruit yield (q/ha).

The analysed data of two years depicted in tables 1 & 2 revealed that there was significant effect of black and white polythene mulches on soil temperature, dry biomass of weeds, plant growth and fruit yield of brinjal crop in hills. Significantly higher level of mean soil temperature at 10 cm depth was recorded in the plots mulched with white polythene over the years (33.4ºC & 32.8ºC) followed by black polythene (30.6ºC & 28.9ºC). Lowest mean soil temperature was noted in the plots without mulching (24.9ºC & 22.7ºC) which was almost 8ºC and 6ºC lower as compared to that in white polythene and black polythene, respectively. The comparable findings of Duhr and Dubas (1990) also showed an increase of 2.9ºC –3.38ºC in soil temperatures with transparent, photodegradable polythene film mulching. Appreciably high variation in dry biomass of weeds was recorded across the treatments over the years ranging from 4.6 g/m^2 in black polythene mulching to 267.5 g/m^2 in without mulching during first year and 5.9 g/m^2 in black polythene mulching to 234.7 g/m^2 in without mulching during second year. Significantly lower dry biomass of weeds in black polythene mulching was because of non-transmission of sunlight and contrarily, higher dry biomass of weed in white polythene mulching was because of transmission of sunlight across the covering material leading to creation of favourable environment for germination and survival of weeds up to certain extent. From the findings, it was evident that black polythene mulch proved effective for weed suppression. Ossom et al. (2001) also observed significant differences in weed control between mulched and unmulched plots of sweet potato.

The vegetative growth characters *viz*., plant height at first harvest, number of primary branches and days to first harvest were also significantly influenced by mulch materials. Maximum values for plant height at first harvest and number of primary branches were noted in the plots mulched with white polythene *i.e.* 83.5 cm and 6.5, respectively in first year and 79.5 cm and 5.2, respectively in second year; whereas, days to first harvest was minimum in this treatment (40 DAT and 45 DAT in first year and second year, respectively). Similarly, number of fruits per plant and fruit yield were also significantly higher in whit polythene mulching over both the years (25.8 and 446.3 q/ha, respectively in first year and 23.5 and 412.5 q/ha, respectively in second year) followed by black polythene mulching (20.4 and 330.4 q/ha, respectively in first year and 18.3 and 313.8

Table 1: Performance of brinjal hybrid PPL-74 under different plastic mulching in hills during summer-rainy seasons of 2014

Mulching	Mean soil temperature (ºC) at 10 cm depth	Dry biomass of weeds (g/m^2)	Plant height at first harvest (cm)	Number of primary branches	Days to first harvest (DAT)	Number of fruits per plant	Fruit yield (q/ha)
Black Polythene	30.6	4.6	77.6	5.2	45.0	20.4	330.4
White Polythene	33.4	75.06	83.5	6.5	40.0	25.8	446.3
Without mulching	24.9	267.5	56.5	4.5	52.0	8.5	112.2
CV (%)	9.3	16.4	13.2	10.2	8.5	7.5	13.2
CD (0.05)	0.9	75.3	8.6	0.8	4.6	2.6	39.6

Table 2: Performance of brinjal hybrid PPL-74 under different plastic mulching in hills during summer-rainy seasons of 2015

Mulching	Mean soil temperature (ºC) at 10 cm depth	Dry biomass of weeds (g/m^2)	Plant height at first harvest (cm)	Number of primary branches	Days to first harvest (DAT)	Number of fruits per plant	Fruit yield (q/ha)
Black Polythene	28.9	5.9	74.6	4.0	45.0	18.3	313.8
White Polythene	32.8	82.6	79.5	5.2	45.0	23.5	412.5
Without mulching	22.7	234.7	53.8	4.2	50.0	8.9	123.9
CV (%)	11.4	13.2	12.6	8.6	6.0	7.5	16.4
CD (0.05)	1.2	61.8	5.7	0.9	NS	2.6	47.6

q/ha, respectively in second year). Higher mean soil temperature accompanied with better plant growth, early fruiting and higher fruit yield in white polythene mulching was a peculiar finding in this experiment and that was probably because of favourable hydro-thermal regime of soil and low weed competition for nutrient. These findings were in consonance with those of Mahadeen (2014) and Mishra (2017) in squash and Cenobio et al. (2007) and Parmar et al. (2013) in watermelon. In spite of high level of weed suppression in black polythene mulching, fruit yield was noticeably lower as compared to that in white polythene mulching. However, mean soil temperature in black polythene mulching was significantly lower as compared to that in white polythene mulching. It indicated that soil temperature was the main factor for governing the fruit yield in temperate hills particularly in the crops favouring hot climate like brinjal and cucurbits. Drastically lower fruit yield in brinjal crop without mulching (112.2-123.9 q/ha) could be cumulative effect of lower mean soil temperature in rhizosphere (22.4-24.9ºC) and higher weed competition with the crop (234.7-267.5 g/m^2 dry biomass of weeds). On the basis of above results, it could be concluded that application of 100µ thick white polythene as mulch material resulted in 32.8-33.4ºC soil temperature and high level of weed suppression leading to manifold increase in fruit yield in brinjal (412.5-446.3q/ha) as compared to black polythene mulching (313.8-330.4 q/ha) and without mulching (112.2-123.9 q/ha). Therefore, white polythene (100µ) mulching is recommended for brinjal cultivation in temperate hills of western Himalaya during summer-rainy season.

References

Cenobio GP, Inzunza MAI, Mendoza SFM, Sanchez IC and Roman AL (2007) Response of watermelon to colored plastic mulches under drip irrigation. Terra 24: 515-520.

Duhr E and Dubas A (1990) Effect of covering the soil with plastic film on the dynamics of plant development and yield of maize sown on different dates. Prace Komisji Nauk Rolniczych Ikomisji Nauk Lesnych 69: 9–18

Hu W, Duan S and Sui Q (1995) High yield technology for groundnut. Intl Arachis Newsletter 15 (Suppl): 1–22.

Mahadeen AF (2014) Effect of polythene black plastic mulch on growth and yield of two summer vegetable crops under rainfed conditions under semi-arid region condition. Amer J Agric Biol Sci 9: 202-207.

Mishra AC (2017) Effect of irrigation systems and mulching on soil temperature and fruit yield of marrow (*Cucurbita pepo*) in temperate Himalaya of Uttarakhand. Veg Sci 44 (1): 66-70.

Ossom EM, Pace PF, Rhykerd RL and Rhykerd CL (2001) Effect of mulch on weed infestation, soil temperature, nutrient concentration, and tuber yield in *Ipomoea batatus* (L.) Lam. In Papua New Guinea. Trop Agric (Trinidad) 78: 144–151.

Parmar HN, Polara ND and Viradiya RR (2013) Effect of Mulching Material on Growth, Yield and Quality of Watermelon (*Citrullus lanatus* Thunb) cv. Kiran. Universal J Agric Res 1: 30-37.

Ramakrishna A, Tam HM, Wani SP and Long TD (2006) Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Res 95: 115–125.

Spandl E, Kells JJ and Hesterman OB (1999) Weed invasion in new stands of alfalfa seeded with perennial forage grasses and an oat companion crop. Crop Sci 39: 1120–1124.

GUIDELINES TO AUTHORS

General requirements

Full paper must be either reports of original research, critical reviews or interpretive article. The Journal also publishes short communications. Submissions to "Vegetable Science" must not be previously published in or simultaneously submitted to any other scientific or technical journal. The editorial board does not undertake any responsibility to scrutinize regarding the approval of forward of papers by the Head of the Department or Institution or any other competent authority. The responsibility for statements made in the papers whether of fact or opinion, rests entirely with the authors thereof. Authors must be member (Annual or life) of Indian Society of Vegetable Science (ISVS) before article is published in the journal.

Scope

Vegetable science course all aspects of vegetable research & development i.e. genetics, breeding, cytology, genomics, biotechnology, metabolism, physiology, ecology, quality, production technology, disease management, insect management, post harvest management, marketing, extension, etc. Articles reporting research in vegetable crops or reviews or interpretation of such research will be accepted for review as research papers/ review papers. Short articles concerned with experimental techniques, apparatus and observation of unique phenomena will be accepted for review as short communications.

Submission procedures and preparation

All the manuscript should be submitted through on-line submission process of website of the Journal (www.indianjournals.com). For details please visit to website and follow guidelines. Articles sent through surface mail/email will not be entertained.

Text formatting: Manuscripts should be submitted in MS Word format. Use a normal, plain font (e.g. 12-point Times New Roman) for text, italics for scientific name and emphasis, automatic page numbering function to number the pages, tab commands for indents and not the space bar, table function to make tables and save your file in docx format (MS Word 2007 or higher). Please use internationally accepted signs, symbols or units (SI units). Abbreviations should be defined at first mention and used consistently thereafter.

Creating manuscript files: On first page, give the title in sentence case which should include short informative title of the article, the name(s) of the author(s) in title case, affiliation(s) and address(s) of the author(s), and provide email address, telephone and fax number of corresponding author. Please provide an abstract of 150 to 250 words in English and Hindi both. The abstract should not contain any undefined abbreviation or unspecified references. Please provide 4 to 6 keywords which can be used for indexing.

After the title page and abstract, the usual order of section is Introduction, Materials and Methods, Results and Discussion, Acknowledgments (optional) and References followed by Figures, Figure captions and Tables.

***Figures*:** Submit figures in high-resolution (300 or more dpi), TIFFS/EPS/JPG files. Photographs and drawings for graphs and charts should be prepared with good contrast of dark and light. Give care full attention to the width of lines and size and clarity of type and symbols. Figure caption should be brief but sufficiently detailed to tell its own story.

***Tables*:** Prepare tables with the table feature of your word processer, do not use tab spaces or graphics boxes. Each datum needs to be contained in an individual cell. Number the tables consecutively. Table heads should be brief but complete and self-contained. Define all variables and spell out all abbreviations. Tables should be placed at the end of the main text documents.

***Citations and References*:** Cite references in the text by name and year such as by Singh (2015), Singh and Seligman (1996), (Singh 1991, Barakat et al. 1995, Singh and Chaudhary 1995). The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communication and unpublished work should only be mentioned in the text. Do not use foot notes or end notes as a substitute for a reference list. Citations in text and reference list should contain each and every citation. Always use the standard abbreviation of a Journal's name according to the ISSN list of title word abbreviations. Some examples of reference listing are given bellow.

Maenhout S, Baets BD, Haesaert G and Bockstaele EV (2007) Support vector machine regression for the prediction of maize hybrid performance. Theor Appl Genet 115: 1003-1013.

Meuwissen THE, Hayes BJ and Goddard ME (2001) Prediction of total genetic value using genome-wide dense marker maps. Genetics 157(4): 1819-1829.

South J and Blass B (2001) The future of modern genomics. Blackwell, London.

Brown B and Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230-257.

Slifka MK and Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med Doi:10.1007/s001090000086.

Cartwright J (2007) Big stars have weather too. IOP Publishing Physics Web. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007.

Change CC and Lin CJ (2001) LIBSVM: a library for support vector machines. Software available at http://www.csie.ntu.edu.tw/~cjlin/libsvm.

VEGETABLE SCIENCE

ISVS AWARDS

Indian Society of Vegetable Science confers Dr. Biswajit Chaudhary memorial award for outstanding vegetable scientist, Dr. Kirti Singh Life Time award in vegetable science, Dr. Harbhajan Singh Gold Medal for best research paper and Dr. Dwarika Nath Memorial award for best Ph.D thesis.

Published by : Dr D.P. Ray, President, Indian Society of Vegetable Science

army printing press
www.armyprintingpress.com
Lucknow (0522) 656333