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Genetic variability and correlation studies for vegetative, reproductive and yield attributing traits in papaya

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ABSTRACT

An experiment was carried out with 5 parent and 3 hybrid papaya genotypes to study the genetic variability and correlation between different yield attributing traits by evaluating 16 vegetative, reproductive, and fruit yield contributing traits during 2016-2017. The findings indicate that the maximum fruiting zone (129.8 cm) was in PS 3 followed by PS 3 × P-7-9 (128 cm). The hybrid PS 3 × P-7-9 had maximum number of fruits per plant (44.67), minimum fruit weight (1020g) and maximum yield per plant (46.33 kg/plant) among the three hybrids evaluated. The phenotypic coefficient of variation (PCV) is higher than the genotypic coefficient of variation (GCV) for all the traits studied. The genotypic variance and phenotypic variance were high for traits like leaf width, stem diameter and fruit weight. Traits such as leaf length, petiole length, number of fruits per plant, fruit diameter and fruit yield exhibited higher value of GCV and PCV. Heritability for traits ranged from 53.83 to 99.49, of which majority of traits showed very high heritability, except some traits such as inflorescence size and fruit length which showed moderate heritability. Genetic advance (GA) was recorded highest for fruit length (179.13). Traits like fruit yield, petiole length and leaf length exhibited high heritability accompanied by high to moderate genetic advance indicating additive gene action, which suggest that selection may be effective for these traits. The trait, fruit yield was positively associated with plant height at flower initiation and maturity stage, stem diameter, days to flowering, fruiting zone, number of fruits per plant and fruit diameter.

Key words: *Carica papaya*, variability, interelationship genetic advance, heritability.

INTRODUCTION

Papaya (*Carica papaya* L.) belonging to the family Caricaceae, is considered as one of the most important fruit crop cultivated throughout tropical and subtropical parts of the world owing to its high production potential, nutritional and medicinal importance. For an efficient crop improvement programme the two very important steps are, the collection of germplasm and the determination of nature and magnitude of genetic variability and association of traits. High magnitude of variability along with heritability in a population provides the opportunity for selection to evolve a variety having desirable characters. The genotypic and phenotypic coefficient of variations (GCV and PCV), heritability, genetic advance (GA) and correlation coefficients are helpful in exposing and understanding the clear picture of existing variability in the populations and employment of suitable method for improvement. Yield is a complex trait, which is influenced by a number of vegetative, reproductive and yield attributing traits, and by environment. Thus, the variability for these traits is the sum total of heredity effects of the concerned genes and the influence of the environment. Hence, it is very important to partition the total variability into heritable and non-heritable components because only heritable portion of variation is exploitable through selection. GCV along with heritability estimates and GA provides a better picture for the expected amount of genetic gain to be obtained from phenotypic selection (Burton, 3). Heritability coupled with genetic gain proves to be more useful than the heritability values alone as it allows the prediction of the resultant effect for selecting the best individual genotypes (Johnson *et al.*, 8). For predicting the effect of selection, heritability along with genetic advance over means (GAM) is more effective (Ramanjinappa *et al.*, 11). Correlation studies help in finding out the degree of interrelationship among various traits and in evolving breeding method for improvement. The practical utility of selection of a given character as a measure of improving another character depends on the extent to which they are related and this relation depends not only on genotypic correlation but also on phenotypic correlation (Imtiyaz *et al.,* 7). Achieving a superior cultivar with improved yield and good fruit quality is an important objective for further improvement. Thus, the present study was conducted to evaluate genetic variation and correlation among 16 vegetative, reproductive and fruit yield attributing traits.

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MATERIALS AND METHODS

The present study was conducted at the Main Experimental Orchard, Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi during 2015 and 2017. The experimental site is situated at 77º12'E longitude, 28º40 N' latitude and an altitude of 228.6 m above mean sea level. The average maximum temperature ranges between 38.5º to 44.4ºC and the average minimum temperature ranges between 6.1º to 16.9ºC. The experiment was laid out in a randomized block design with four replications. The research material consisted of 5 parent and 3 hybrid papaya genotypes, namely, Red Lady (Selfed) (RL), Pusa Nanha (PN), P-9-5, Pune Sel. 3 (PS 3), P-7-9, Red Lady (selfed) × Pusa Nanha, Red Lady (selfed) × P-9-5 and Pune Sel. 3 × P-7-9, which are maintained at ICAR-IARI, New Delhi and ICAR-IARI, Regional Station, Pune, Maharashtra. Seedlings of parents and F_1 hybrids were planted under uniform field conditions and 12 uniform healthy plants were maintained for each genotype. The plants were raised as per the recommended package of practices for papaya cultivation under north Indian plains.

Each plant was tagged for recording the observations. A total of 8 vegetative and reproductive; and 8 yield attributing traits were recorded on female and hermaphrodite plants of the 8 genotypes. The data obtained for different traits were statistically analyzed to find out the significance of the difference among the papaya genotypes. The mean values of all the traits were evaluated and ANOVA was performed using 'F' test. The significance of the difference among the treatments means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 6). The data was submitted for online http://hau.ernet.in/about/opstat.php) analysis using OP Stat software (Sheoran *et al*., 12). Genotypic and phenotypic variances were derived according to the method suggested by Johnson *et al*. (8). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated as the method suggested by Burton (3). For estimation of the expected genetic advance for different characters under selection was done according to Allard (2). Phenotypic and genotypic correlation coefficients were calculated for the characters by working out the variance components of each character and the covariance components for each pair of characters using the standard procedure suggested by Al-Jibouri *et al*. (1).

RESULTS AND DISCUSSION

Any crop improvement programme for qualitative and quantitative traits demands broad information on level and nature of variation in the available genotypes. Due to predominance of cross pollination and exclusive seed multiplication, higher level of genetic variation was observed in papaya. Data presented in Table 1 revealed significant difference among the parents and hybrids for all 16 vegetative, reproductive and yield attributing traits. Interaction between parents in hybrids showed significant difference for several traits. These results indicated that parents and their hybrids possessed high genetic variation for most of the traits. Plant height at initiation of first flower was highest in P-7-9 and hybrid Red Lady (self) × P-9-5. Plant height at first fruit maturity was highest in hybrid PS 3 × P-7-9. Duration for initiation of first flower was minimum in P-7-9 followed by Pusa Nanha and hybrid Red Lady (self) × Pusa Nanha). Genotype P-7-9 recorded the maximum inflorescence size followed by PS 3 and hybrid P-7-9. Fruiting zone was maximum in PS 3 and hybrid PS 3 × P-7-9. Minimum days to fruit maturity was observed in genotype P-9-5 closely followed by the hybrids Red Lady (self) × P-9-5 and PS 3 × P-7-9. The highest number of fruits per plant, minimum fruit weight and fruit cavity index were recorded in the hybrid PS 3 × P-7-9.

The extent of variability among the genotypes was estimated in terms of genotypic variance, phenotypic variance, GCV, PCV, heritability, GA and GAM as indicated in Table 2. The estimates of phenotypic and genotypic variances were high for fruit weight, stem diameter and leaf width. Whereas, traits like plant height at flower initiation, plant height at first fruit maturity and fruiting zone showed moderate genotypic and phenotypic variances; while, they were low for the remaining traits though it was exceptionally low for traits like inflorescence size and leaf length. Genotypic variance was found highest for fruit weight (14045.08) followed by stem diameter (2303.08) and leaf width (2021.83). Phenotypic variance was recorded highest for fruit weight (26089.39) followed by stem diameter (2366.62) and leaf width (2032.34). The PCV for all the traits were slightly higher than the GCV. Leaf length, fruit yield and number of fruits per plant was recorded with high GCV and PCV. The highest estimate of heritability for vegetative traits was observed for leaf length (99.49), followed by petiole length (99.04) and leaf width (98.78), whereas in case of yield and yield attributing traits, fruit diameter (97.90) followed by fruit yield (95.22) showed highest heritability. GA was found maximum for fruit length (179.13), followed by plant height at first fruit maturity (49.12), petiole length (27.69) and fruiting zone (26.71) whereas GAM% was observed highest for leaf length (46.20) followed by fruit yield (40.50). Leaf length and fruit

Table 1. Performance of papaya parent and hybrid genotypes for vegetative and reproductive traits.

Genotype	Plant ht. at flower initiation (cm)	Plant ht. at first fruit maturity (cm)	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Stem dia. (cm)	Days to flowering	Inflorescence size (cm)	Fruiting zone (cm)	Days to fruit maturity	No. of fruits/ plant	Fruit wt. (g)	Fruit dia. (cm)	Fruit length (cm)	Fruit cavity index (%)	Fruit yield (kg/ plant)
R L (S)	86.5	205.9	83.2	76.1	73.1	12.5	95.8	6.5	117.8	141.8	33.5	1323.8	31.3	24.0	31.7	43.0
P N	63.8	154.0	59.3	48.2	53.9	9.3	82.3	6.5	85.6	138.0	20.6	1160.0	17.9	21.5	30.6	23.8
R L (S) × P N	73.8	179.3	83.2	58.0	64.8	11.0	84.0	6.3	98.0	133.0	34.5	1120.3	24.5	20.5	26.8	38.2
P-9-5	81.0	197.3	96.2	63.3	67.0	12.7	92.3	6.5	120.3	125.5	35.2	1247.0	30.1	25.1	32.4	45.2
R L (S) × P-9-5	93.3	209.5	56.0	35.2	53.5	13.1	95.5	6.5	112.3	126.5	34.7	1123.8	24.5	21.7	34.7	41.4
P S 3	84.0	224.3	70.7	54.0	49.9	13.2	99.5	8.0	129.8	137.0	36.6	1436.3	25.4	18.6	37.6	52.8
P-7-9	96.5	224.0	80.2	55.5	55.5	11.8	81.8	8.5	124.3	144.3	33.9	1199.8	30.1	24.3	34.4	40.4
P S 3 × P-7-9	81.8	227.3	68.7	45.4	56.6	12.5	98.8	7.8	128.0	130.8	44.7	1020.0	21.3	20.9	24.0	46.3
Mean	82.6	202.7	74.7	54.4	59.3	12.0	91.2	7.1	114.5	134.6	34.2	1203.8	25.6	22.1	31.5	41.4
$LSD_{(P=0.05)}$	4.8	11.8	2.0	1.3	1.3	0.9	5.5	1.0	12.3	5.8	2.8	162.5	1.0	1.3	1.5	2.8
CV (%)	3.3	4.3	1.8	1.6	1.4	5.2	4.1	10.0	7.3	3.0	5.4	9.1	2.7	3.8	3.2	4.5

yield exhibited higher heritability along with higher GAM. Higher heritability coupled with higher GA was recorded for petiole length and leaf length. While traits like fruit yield and leaf width exhibited higher heritability with moderate GA.

Traits like fruit weight, stem diameter and leaf width which showed high values of genotypic and phenotypic variance value indicate presence of inherent genetic variance for which selection can be effective. Whereas, traits like inflorescence size, leaf length and fruit length, which were observed with extremely low genotypic and phenotypic variance offers very little or no advantage of genetic improvement through selection. Results revealed that the estimated value of PCV was slightly higher than the value of GCV, which indicates less effect of environment over the traits. The traits like leaf length, fruit yield and number of fruits per plant exhibited high magnitude of GCV and PCV indicating the presence of wide range of genetic variability for these traits and chances for improvement of these traits to be fairly high. The high heritability of the traits like leaf length, petiole length, leaf width, fruit diameter and fruit yield may be due to additive gene effect, suggesting that these traits to likely to respond to direct selection. Similar results regarding fruit yield of papaya and strawberry with high GCV, PCV, heritability and GA was reported by Davamani *et al.* (4) and Mishra *et al.* (10) respectively. High GCV was accompanied with high heritability estimates for leaf length, fruit yield, number of fruits per plant and fruit diameter, which revealed the fact that selection could be more effective for the improvement of these traits. Genetic gain gives an indication of expected genetic progress for a particular trait under suitable selection pressure. Moderate or low heritability estimates with low to medium GA was observed for inflorescence size which might be due to presence of non-additive gene actions. Hence, these traits are not much reliable for effective selection (Deepthi *et al.*, 5). Traits like leaf length and fruit yield exhibited higher heritability along with higher GAM, which indicates the predominance of additive gene action in governing these traits and selection can be done for these traits for further improvement. Traits like fruit length and inflorescence size exhibited low heritability and low GAM, which indicates the predominance of additive and non-additive gene action in controlling these traits. Hence, direct selection for these traits may not be rewarding.

From the correlation matrix for phenotype (Table 3) and genotype (Table 4), significant positive correlations were observed for plant height at flower initiation and maturity stage with stem diameter, inflorescence size, fruiting zone, number of fruits per

Table 2. Genetic parameters of vegetative and reproductive traits of parent and hybrid papaya genotypes.

Trait	Genotypic variance (σ^2g)	Phenotypic variance (σ^2p)	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (%)	Genetic advance	Genetic advance in % of mean
Plant ht. at flower initiation	182.38	184.15	12.50	13.00	92.38	20.43	24.75
Plant ht. at first fruit maturity	149.86	150.64	12.38	13.04	90.26	49.12	24.24
Petiole length	64.61	65.33	18.09	18.17	99.04	27.69	37.08
Leaf length	1.65	2.04	22.49	22.55	99.49	25.15	46.20
Leaf width	2021.83	2032.35	13.34	13.42	98.78	16.49	27.31
Stem dia.	2303.08	2366.62	10.60	11.91	79.28	2.33	19.45
Days to flowering	51.85	65.83	7.89	8.89	78.78	13.17	14.43
Inflorescence length	0.64	1.13	11.33	15.08	56.43	1.24	17.53
Fruiting zone	220.57	289.47	12.97	14.86	76.20	26.71	23.33
Days to fruit maturity	42.88	58.44	4.87	5.68	73.36	11.55	8.58
No. of fruits/ plant	42.41	45.88	19.05	19.81	92.45	12.90	37.73
Fruit wt.	14045.08	26089.39	9.86	10.58	86.98	4.18	18.95
Fruit dia.	21.59	22.06	18.14	18.33	97.90	9.47	36.97
Fruit length	4.74	5.45	9.84	13.42	53.83	179.13	14.88
Fruit cavity index	19.20	20.24	13.90	14.27	94.87	8.79	27.89
Fruit yield	69.48	72.96	20.15	20.65	95.22	16.76	40.50

plant, fruit diameter and fruit yield. At phenotypic and genotypic level, a positive and significant association of petiole length, leaf length and leaf width was observed with fruit weight and fruit diameter. In case of stem diameter, a positive significant phenotypic and genotypic correlation was found for traits like plant height at flower initiation and maturity, days to flowering, fruiting zone, number of fruits per plant, fruit diameter and fruit yield. From the phenotypic and genotypic correlation matrix it was revealed that plant height at maturity, stem diameter, fruiting zone, number of fruits per plant and fruit yield had positive significant association with days to flowering. Traits like fruiting zone, days to fruit maturity, number of fruits per plant and fruit yield exhibited positive significant genotypic correlation with inflorescence size. Phenotypic and genotypic correlation for the trait, fruiting zone was positive and significant with plant height at flower initiation and maturity stage, stem diameter, days to flowering, inflorescence size, number of fruits per plant, fruit diameter and fruit yield. In case of the trait, days to fruit maturity, leaf length and inflorescence size showed positive significant association, whereas, it showed negative association with days to flowering (-0.392). Traits such as, plant height at flower initiation and maturity stage, stem diameter, days to flowering, fruiting zone and fruit yield showed positive significant phenotypic and genotypic correlation with number of fruits per plant. Positive association of fruit weight, fruit length and fruit diameter was observed with leaf length both at phenotypic and genotypic level. A positive significant association was observed for fruit cavity index with fruit diameter and fruit length. Fruit yield was positively and significantly associated with majority of traits such as plant height at flower initiation stage (0.556), plant height at fruit maturity stage (0.790), stem diameter (0.827), days to flowering (0.701), fruiting zone (0.810), number of fruits per plant (0.817) and fruit diameter (0.478) had positive significant association with fruit yield at phenotypic level. Plant height at flower initiation stage (0.595), plant height at fruit maturity stage (0.866), stem diameter (0.955), days to flowering (0.785), inflorescence size (0.476), fruiting zone (0.943), number of fruits per plant (0.836), fruit diameter (0.508) and fruit length (0.457) had positive significant genotypic association with fruit yield.

The genotypic correlation coefficients of vegetative, reproductive, fruit yield and other yield attributing characters were higher as compared to the phenotypic correlation coefficients in almost all cases, indicating that the effects of environment suppressed the phenotypic relationship between these characters. Mir *et al.* (9) also recorded positive and significant correlations for pomegranate yield

Table 3. Phenotypic correlations matrix of vegetative, reproductive, fruit and yield attributing traits in papaya.

Parameter	Plant ht. at flower initiation	Plant ht. at first fruit maturity	Petiole length	Leaf length	Leaf width	Stem dia.	Days to flowering	Inflorescence length	Fruiting zone	Days to fruit maturity	No. of fruits/ plant	Fruit wt.	Fruit dia.	Fruit length	Fruit cavity index	Fruit yield
Plant ht. at flower initiation	1.000															
Plant ht. at first fruit maturity	0.758**	1.000														
Petiole length	0.087NS	0.085NS	1.000													
Leaf length	-0.035NS	-0.046NS	0.792**	1.000												
Leaf width	0.156NS	-0.050NS	0.786**	0.812**	1.000											
Stem dia.	0.669**	0.781**	0.151NS	0.024NS	-0.004NS	1.000										
Days to flowering	0.236NS	0.568**	-0.090NS	-0.027NS	-0.214NS	0.741**	1.000									
Inflorescence length	0.380*	0.548**	-0.030NS	-0.119NS	-0.222NS	0.206NS	-0.021NS	1.000								
Fruiting zone	0.662**	0.889**	0.251NS	0.111NS	0.024NS	0.784**	0.610**	0.421*	1.000							
Days to fruit maturity	0.106NS	0.039NS	0.009NS	0.372*	0.201NS	-0.288NS	-0.314NS	0.366*	0.047NS	1.000						
No. of fruits/ plant	0.496**	0.730**	0.228NS	-0.044NS	0.058NS	0.645**	0.562**	0.323NS	0.662**	-0.269NS	1.000					
Fruit wt.	0.287NS	0.034NS	0.532**	0.455**	0.710**	0.028NS	-0.187NS	-0.122NS	0.131NS	0.091NS	-0.125NS	1.000				
Fruit dia.	0.639**	0.432*	0.732**	0.668**	0.716**	0.495**	0.095NS	0.075NS	0.484**	0.162NS	0.247NS	0.615**	1.000			
Fruit length	0.135NS	0.135NS	0.240NS	0.446*	0.068NS	0.187NS	0.220NS	0.190NS	0.221NS	0.343NS	-0.107NS	0.036NS	0.389*	1.000		
Fruit cavity index	0.435*	0.205NS	-0.066NS	0.018NS	-0.205NS	0.327NS	0.109NS	0.198NS	0.194NS	0.166NS	-0.218NS	0.038NS	0.378*	0.609**	1.000	
Fruit yield	0.556**	0.790**	0.326NS	0.159NS	0.010NS	0.827**	0.701**	0.342NS	0.810**	-0.166NS	0.817**	-0.128NS	0.478**	0.315NS	0.248NS	1.000

*, **Significant at 0.01 and 0.05 levels of probability, NS = Non significant

Table 4. Genotypic correlations matrix of vegetative, reproductive, fruit and yield attributing traits in papaya.

Trait	Plant ht. at flower initiation	Plant ht. at first fruit maturity	Petiole length	Leaf length	Leaf width	Stem dia.	Days to flowering	Inflorescence length	Fruiting zone	Days to fruit maturity	No. of fruits/ plant	Fruit wt.	Fruit dia.	Fruit length	Fruit cavity index	Fruit yield
Plant height at flower initiation	1.000															
Plant height at first fruit maturity	0.844**	1.000														
Petiole length	0.094NS	0.093NS	1.000													
Leaf length	-0.029NS	-0.047NS	0.797**	1.000												
Leaf width	0.158NS	-0.043NS	0.794**	0.819**	1.000											
Stem dia.	0.792**	0.882**	0.167NS	0.023NS	0.011NS	1.000										
Days to flowering	0.338NS	0.625**	-0.108NS	-0.047NS	-0.224NS	0.833**	1.000									
Inflorescence length	0.544**	0.803**	-0.066NS	-0.159NS	-0.304NS	0.353*	0.166NS	1.000								
Fruiting zone	0.750**	0.984**	0.294NS	0.131NS	0.049NS	0.898**	0.672**	0.803**	1.000							
Days to fruit maturity	0.089NS	0.044NS	0.033NS	0.442*	0.229NS	-0.297NS	-0.392*	0.484**	-0.029NS	1.000						
No. of fruits/ plant	0.516**	0.845**	0.235NS	-0.047NS	0.047NS	0.813**	0.681**	0.433*	0.850**	-0.348NS	1.000					
Fruit wt.	0.325NS	-0.021NS	0.576**	0.476**	0.769**	0.013NS	-0.307NS	-0.136NS	0.074NS	0.068NS	-0.114NS	1.000				
Fruit dia.	0.660**	0.452**	0.744**	0.681**	0.728**	0.554**	0.112NS	0.139NS	0.555**	0.205NS	0.276NS	0.668**	1.000			
Fruit length	0.174NS	0.198NS	0.317NS	0.591**	0.069NS	0.388*	0.294NS	0.150NS	0.370*	0.388*	-0.166NS	-0.052NS	0.549**	1.000		
Fruit cavity index	0.467**	0.242NS	-0.073NS	0.015NS	-0.222NS	0.361*	0.105NS	0.274NS	0.283NS	0.221NS	-0.266NS	0.053NS	0.402*	0.824**	1.000	
Fruit yield	0.595**	0.866**	0.331NS	0.162NS	0.008NS	0.955**	0.785**	0.476**	0.943**	-0.210NS	0.836**	-0.132NS	0.508**	0.457**	0.248NS	1.000

*, **Significant at 0.01 and 0.05 levels of probability, NS = Non significant

per plant with traits such as height of plant, fruit weight, fruit diameter, and number of fruits per plant of pomegranate. In case of strawberry also fruit yield per plant was positively and significantly associated with yield attributing traits such as plant height, number of fruits per plant, fruit length, fruit diameter and fruit weight both at phenotypic and genotypic level (Mishra *et al*., 10). From the above discussion, it become clear that use of Pusa Nanha as donor male parents holds immense potentiality for utilization in papaya hybrid development programme. Since, parents have higher fruiting zone and average fruit weight which had subsequently leads the higher fruit yield in parents compare to hybrids.

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Performance of some new apple cultivars for yield and physico-chemical characters under mid-hill conditions of Uttarakhand

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ABSTRACT

An experiment was conducted to evaluate the yield and physico-chemical performance of 18 apple cultivars. The highest fruit yield (46.11 kg/tree), fruit weight (217.33 g), fruit volume (231.67 cc), fruit length (6.98 cm) and fruit diameter (8.22 cm) was recorded in 'Spur Type Red Delicious'. The lowest fruit yield (19.12 kg/tree) and fruit length (4.33 cm) was recorded in 'Chaubattia Anupam'; while, lowest average fruit weight (64.67 g), fruit volume (63.33 cc) and fruit diameter (5.32 cm) was observed in 'Gloster'. The maximum TSS was recorded in 'Skyline Supreme' (14.73°B) and minimum was in 'Chaubattia Princess' (11.26°B). However, the highest titratable acidity was recorded in 'Golden Delicious' (0.66%) and lowest in 'Chaubattia Princess' (0.14%). The cultivar 'Skyline Supreme' possessing highest values for ascorbic acid (8.25 mg/100 g), reducing sugars (9.62%), total sugars (12.42%), total carotenoids (235.73 µg/100 g) and total anti-oxidant activity (41.95 mMTE/L) while 'Prima' exhibited lowest values of ascorbic acid (3.92 mg/100 g) and total sugar contents (6.15%). The lowest values for reducing sugars (5.13%), total carotenoids (79.45 µg/100 g) and total anti-oxidant activity (30.66 mM TE/L) were recorded in 'Gloster', 'Vermont Spur' and 'Stark Spur', respectively. The cultivar 'Golden Delicious' is the most luminous (L^*=84.86) and having the highest yellow colour (b^*= 67.10) and hue angle (h° = 87.41), whereas 'Chaubattia Anupam' showed the highest red colour (a^*= 54.15) and Chroma (C^*= 67.53). From this investigation it can be inferred that the cultivar 'Spur Type Red Delicious' and 'Skyline Supreme' performed better in the region under prevailing climatic conditions.

Key words: *Malus domestica*, physico-chemical, mid hills.

INTRODUCTION

Apple (*Malus domestica* Borkh.) is the most important temperate fruit crop and accounting 30 thousand ha area and 77.5 thousand MT production in Uttarakhand (Anonymous, 1). Monoculture of traditional cultivars since long time led to their genetic degeneration and resulted in low productivity as well as poor quality fruits. The existing cultivars have been found shy bearer, poor in colour development, when grown in the mid hills and marginal areas. The new initiatives like diversification of varieties through introduction and evaluation of promising spur type and high colour strains under mid hill condition gave some promise over traditional varieties (Kumar *et al*., 9). These varieties are spur types, dwarf, prolific bearer and produce fruits of better quality and possess useful traits like less pruning requirements, tolerance to biotic and abiotic stress factors. Apart from spur types, the colour strains develop colour early, with more intensity and have higher yield potential than the existing Delicious groups under relatively warmer conditions, where proper colour development especially in the Delicious group is a major problem (Chadha and Awasthi, 3). Keeping in view, the location specific evaluation of cultivars is essential to identify the suitable cultivars for commercial exploitation. Therefore, the present investigation was undertaken to evaluate the new apple cultivars under mid hill conditions of Uttarakhand under prevailing climatic conditions.

MATERIALS AND METHODS

The present investigation was carried out at ICAR-CITH, Regional Station, Mukteshwar, Nainital (Uttarakhand) during 2015 to 2016 on 18 apple cultivars belonging to Delicious group, spur type and colour strains. Sixteen years old healthy fruit bearing trees of these cultivars planted at a spacing of 6 m × 6 m and trained on modified leader system were selected for the study. Uniform cultural operations were followed during the course of investigation and the fruits were picked after attaining full maturity. The experiment was laid out in randomized block design (RBD) with three replications comprising four trees per replication.

The full bloom period in each cultivar was noted when more than 75-80 per cent of the flowers had opened. Time of fruit harvest was recorded on the basis of total days after full bloom stage to harvest maturity for each replication of each cultivar. At the time of harvest, all the fruits from each replication were

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weighed on pan balance and yield was expressed in kg/tree. The fruit's physical properties in terms of weight (g), volume (cc), size (cm), specific gravity (g/cc) and fruit firmness (lb/in^2) were recorded by calculating the mean of ten fruits at final harvesting stage. The chemical characteristics of the fruits *viz*. TSS, titratable acidity, ascorbic acid, reducing sugars, total sugars, non-reducing sugars and total carotenoids were recorded by using the methods described by Ranganna (13). For estimation of total carotenoids, the samples were extracted in 3% acetone in petroleum ether. Total carotenoids were read colorimetrically using 3% acetone in petroleum ether for baseline correction and the absorbance at 452 nm was recorded against a reagent blank. The total carotenoids were expressed as µg/100 g. Total anti-oxidant activity was recorded by using the method described by Apak *et al*. (2). The antioxidant activity was expressed as m mol Trolox® per litre, or mMTE.

The colour values of different apples cultivars were obtained in terms of L*, a*, b*, C* and h° values using a Lovibond RT series reflectance tintometer. The 'L*' measures luminosity or lightness and varies from zero (black) to one hundred (perfect white). The chromaticity dimension 'a*' measures redness when positive, grey when zero, and greenness when negative. The 'b*' value measures yellowness when positive, grey when zero, and blueness when negative. The 'C*' describes the chroma (saturation) of the colour, a measure of how far from the grey tone the colour is. Hue angle (h°), describes the hue of the colour, *i.e*., colour tonalities (red, green, yellow etc.) as per the method described by Jha *et al*. (6). The statistical analysis was done as per procedure described by Panse and Sukhatme (12).

RESULTS AND DISCUSSION

Data presented in table 1 shows the full bloom in different apple cultivars under study varied from 9th April to 19th April in 2015 and 7th April to 17th April in 2016. The date of full bloom was first noticed in cultivars 'Vermont Spur' and 'Gala Must' (9th April) in 2015 and 'Chaubattia Anupam' and 'Mollies Delicious' (7th April) in 2016, while the cultivars 'Rich-A-Red' (19th April) in 2015 and 'Golden Delicious' (17th April) in 2016 were late to reach the full bloom. The marked differences in full bloom in different cultivars may be attributed to inherent genetic characteristics of the cultivars (Das *et al*., 4 and Sharma *et al*., 14). However, winter precipitation, temperature and ultimate accumulation of chilling

Table 1. Performance of different apple cultivars with respect to flowering traits

Cultivar	Date of full bloom		Days from full bloom to harvest			Date of fruit harvest	
	2015	2016	2015	2016	Pooled mean	2015	2016
Gloster	14/04/2015	11/04/2016	107	106	106.50	30/07/2015	26/07/2016
Vance Delicious	14/04/2015	16/04/2016	116	117	116.50	08/08/2015	11/08/2016
Vermont Spur	09/04/2015	12/04/2016	121	121	121.00	08/08/2015	11/08/2016
Rich-A-Red	19/04/2015	15/04/2016	121	123	122.00	18/08/2015	16/08/2016
Bright-N-Early	15/04/2015	13/04/2016	125	123	124.00	18/08/2015	14/08/2016
Stark Spur	17/04/2015	15/04/2016	130	130	130.00	25/08/2015	23/08/2016
Red Chief	16/04/2015	14/04/2016	121	121	121.00	15/08/2015	13/08/2016
Golden Delicious	11/04/2015	17/04/2016	140	137	138.50	29/08/2015	01/09/2016
Spur Type Red Delicious	17/04/2015	16/04/2016	120	120	120.00	15/08/2015	14/08/2016
Top Red	15/04/2015	13/04/2016	120	121	120.50	13/08/2015	12/08/2016
Skyline Supreme	16/04/2015	15/04/2016	128	125	126.50	22/08/2015	18/08/2016
Chaubattia Anupam	13/04/2015	07/04/2016	103	104	103.50	25/07/2015	20/07/2016
Chaubattia Princess	16/04/2015	08/04/2016	105	112	108.50	30/07/2015	29/07/2016
Mollies Delicious	11/04/2015	07/04/2016	108	107	107.50	28/07/2015	23/07/2016
Starkrimson	14/04/2015	13/04/2016	122	124	123.00	14/08/2015	15/08/2016
Oregon Spur	12/04/2015	16/04/2016	134	131	132.50	24/08/2015	25/08/2016
Gala Mast	09/04/2015	13/04/2016	114	113	113.50	01/08/2015	04/08/2016
Prima	11/04/2015	09/04/2016	111	111	111.00	31/07/2015	29/07/2016
CD at 5%	-	-	4.79	5.76	3.54	-	-

hours are main factors for such drift in flowering (Jindal and Mankotia, 7). The days from the full bloom to harvest were observed minimum (103.50 days) in 'Chaubattia Anupam' resulting into early fruit maturity, whereas the maximum period (138.50 days) from full bloom to harvesting were taken by 'Golden Delicious' ensuing to the late crop maturity. On the basis of date of fruit harvesting all the cultivars can be grouped into early maturing ('Chaubattia Anupam', 'Mollies Delicious', 'Gloster', 'Chaubattia Princess', 'Prima', 'Gala Mast' and 'Vance Delicious'), mid season maturing ('Vermont Spur', 'Top Red', 'Red Chief', 'Bright-N-Early', 'Spur Type Red Delicious', 'Starkrimson' and 'Rich-A-Red') and late maturing cultivars ('Skyline Supreme', 'Stark Spur', 'Oregon Spur' and 'Golden Delicious'). Time and duration of flowering are important traits in classification of apple with respect to their span of flowering under different regions and have been assessed by other workers (Das *et al*., 4 and Sharma *et al*., 14).

A close perusal of data presented in table 2 exhibited significant variation in yield and fruit physical characteristics of different apple cultivars. The highest fruit yield was recorded in 'Spur Type Red Delicious' (46.11 kg/tree) which was statistically *at par* with 'Starkrimson' (45.57 kg/tree) and 'Skyline Supreme' (44.13 kg/tree) but significantly differed with rest of the cultivars. The lowest fruit yield was recorded in 'Chaubattia Anupam' (19.12 kg/tree) followed by 'Gloster' (22.69 kg/tree) and 'Chaubattia Princess' (23.92 kg/tree). The higher fruit yield in 'Spur Type Red Delicious' was primarily due to their bigger size. These results are in conformity with the earlier findings of Dwivedi and Dwivedi (5) and Thakur *et al*. (16). Similarly, fruit weight and fruit volume was also recorded maximum in 'Spur Type Red Delicious' *i.e.*, 217.33 g and 231.67 cc, respectively; while, the minimum fruit weight (64.67 g) and fruit volume (63.33 cc) was observed in 'Gloster'. The highest fruit length was recorded in 'Spur Type Red Delicious' (6.98 cm) followed by 'Vance Delicious' (6.64 cm) and 'Vermont Spur' (6.60 cm) while lowest in 'Chaubattia Anupam' (4.33 cm) which was statistically *at par* with 'Gala Mast' (4.81 cm) and 'Gloster' (4.89 cm). The highest fruit diameter was recorded under 'Spur Type Red Delicious' (8.22 cm) followed by 'Mollies Delicious' (7.73 cm), while lowest in 'Gloster' (5.32 cm). The results obtained in the present investigation are found to be in close conformity with the studies of Kumar *et al*. (9) who also recorded the fruit length and diameter in different apple cultivars varying from 3.62 cm (Top Red) to 6.38 cm (Spur Type Red

Table 2. Comparative data on yield and fruit physical characteristics among different apple cultivars (pooled mean).

Cultivar	Yield (kg/ tree)	Fruit wt. (g)	Fruit vol. (cc)	Fruit length (cm)	Fruit dia. (cm)	Sp. gr. (g/cc)	Fruit firmness (lb/in^2)
Gloster	22.69	64.67	63.33	4.89	5.32	0.92	7.73
Vance Delicious	37.82	159.33	150.00	6.64	7.29	1.06	8.07
Vermont Spur	34.71	167.33	160.00	6.60	7.59	1.05	8.67
Rich-A-Red	38.98	158.67	163.33	6.53	7.45	0.97	6.87
Bright-N-Early	24.03	146.00	160.00	5.97	7.20	0.91	7.23
Stark Spur	32.93	132.00	140.00	6.13	6.85	0.94	7.20
Red Chief	38.56	140.00	141.67	6.41	6.98	0.99	8.17
Golden Delicious	38.13	119.78	133.33	6.03	6.64	0.90	7.41
Spur Type Red Delicious	46.11	217.33	231.67	6.98	8.22	0.94	6.47
Top Red	34.12	144.67	160.00	6.15	7.22	0.90	7.37
Skyline Supreme	44.13	117.33	121.67	5.66	6.78	0.96	7.20
Chaubattia Anupam	19.12	70.90	81.67	4.33	5.88	0.87	5.30
Chaubattia Princess	23.92	100.75	110.00	5.25	6.46	0.91	9.28
Mollies Delicious	28.92	172.52	186.67	6.51	7.73	0.93	7.71
Starkrimson	45.57	168.00	176.67	6.38	7.61	0.95	8.12
Oregon Spur	40.26	151.11	163.33	6.37	7.11	0.93	7.70
Gala Mast	27.16	82.67	83.33	4.81	5.96	0.99	7.60
Prima	37.79	86.00	93.33	5.03	6.02	0.92	4.90
CD at 5%	2.92	22.38	23.55	0.65	0.47	0.04	1.73

Delicious) and 4.20 cm (Tydeman's Early Worcester) to 7.69 cm (Spur Type Red Delicious), respectively. In another study, Dwivedi and Dwivedi (5) measured the variation in different apple cultivars in a range of 6.27 cm (Stark Spur) to 8.36 cm (Silver Spur) in fruit length and 6.84 cm (Stark Spur) to 8.93 cm (Spur Type Red Delicious) in fruit diameter. The variation in fruit size (length and diameter), weight and volume with respect to different apple cultivars are mainly attributed to the inter-varietal differences associated with genetic make-up of the cultivars and governed mainly by the cell size and intercellular spaces of the fruit tissues.

The specific gravity of fruits was recorded highest in 'Vance Delicious' (1.06 g/cc) which was statistically *at par* with 'Vermont Spur' (1.05 g/cc), while lowest was recorded in 'Chaubattia Anupam' (0.87 g/cc). The findings are in agreement with the prior records of Singh (15). The variation in specific gravity may probably be due to corresponding changes in fruit weight and volume. The increase in intercellular spaces in the fruit flesh with the advancement of maturity affects the specific gravity of the fruits. The fruit firmness was found highest in 'Chaubattia Princess' (9.28 lb/in^2) followed by 'Vermont Spur' (8.67 lb/in^2) while the lowest in 'Prima' (4.90 lb/in^2). These findings are in agreement with the prior records of Kumar *et al*. (9) and Dwivedi and Dwivedi (5). A change in fruit firmness is primarily attributed to break down of insoluble protopectins to soluble pectin compounds, which ultimately affect the cell wall consistency and thus varied at different stages of fruit growth and ripeness. The preliminary study indicated that the variability in fruit yield and various physical characteristics of apple cultivars may be due to environmental factors and genetic makeup of the cultivars.

The data pertaining to the chemical characteristics of fruits showed considerable variations among different cultivars of apple (Table 3). From perusal of the data presented in table 3, the highest TSS was found in 'Skyline Supreme' (14.73°B) followed by 'Stark Spur' (14.60°B) and 'Chaubattia Anupam' (14.20°B) while lowest in 'Chaubattia Princess' (11.26°B). The appreciable differences with respect to TSS among different apple cultivars may be explained on the basis of genetic differences with respect to various cultivars, which subsequently affect the synthesis

Table 3. Comparative data on fruit chemical characteristics among different apple cultivars (pooled mean).

Cultivar	TSS (°B)	Titratable acidity (%)	Ascorbic acid (mg/100 g)	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)	Total carotenoids (µg/100 g)	Total anti-oxidant activity (mM TE/L)
Gloster	13.23	0.44	5.42	5.13	6.47	1.28	108.00	36.11
Vance Delicious	12.93	0.40	4.17	7.81	9.14	1.26	155.05	33.36
Vermont Spur	12.20	0.43	4.58	7.99	10.01	1.92	79.45	34.44
Rich-A-Red	13.17	0.27	4.17	5.90	6.72	0.77	116.48	32.77
Bright-N-Early	13.33	0.24	4.00	6.65	7.97	1.26	105.68	30.67
Stark Spur	14.60	0.26	4.42	6.82	7.30	0.46	94.88	30.66
Red Chief	11.93	0.29	4.00	7.09	8.38	1.22	93.73	32.54
Golden Delicious	13.77	0.66	6.25	6.90	9.69	2.65	102.60	33.60
Spur Type Red Delicious	13.83	0.28	4.17	8.07	11.93	3.67	132.68	34.90
Top Red	13.83	0.26	5.42	7.86	10.87	2.86	104.14	36.36
Skyline Supreme	14.73	0.32	8.25	9.62	12.42	2.66	235.73	41.95
Chaubattia Anupam	14.20	0.42	7.45	7.58	9.19	1.30	125.68	36.93
Chaubattia Princess	11.26	0.14	5.96	7.18	9.07	1.80	123.13	34.91
Mollies Delicious	12.73	0.30	6.83	7.83	9.49	1.57	181.00	33.57
Starkrimson	12.00	0.31	6.67	6.26	7.56	1.24	109.16	32.12
Oregon Spur	12.00	0.31	7.08	7.55	8.85	1.23	168.42	36.62
Gala Mast	13.33	0.28	6.67	6.29	7.94	1.57	151.97	31.21
Prima	13.03	0.42	3.92	5.47	6.15	0.65	222.63	34.63
CD at 5%	1.32	0.10	1.20	0.69	1.0	0.72	12.37	3.54

of photosynthates and their further breakdown into simple metabolites. The highest titratable acidity (0.66%) was recorded in 'Golden Delicious' followed by 'Gloster' (0.44%) and 'Vermont Spur' (0.43%) and lowest in 'Chaubattia Princess' (0.14%). The inter-varietal differences in the titratable acidity level of fruits are attributed to the presence of varying amount of organic acids in them. These results obtained in the present investigation are found to be close conformity with the studies of Wu *et al*. (18) and Dwivedi and Dwivedi (5).

The highest ascorbic acid was recorded in 'Skyline Supreme' (8.25 mg/100 g) which was statistically *at par* with 'Chaubattia Anupam' (7.45 mg/100 g) and 'Oregon Spur' (7.08 mg/100 g) while lowest in 'Prima' (3.92 mg/100 g). The synthesis of ascorbic acid in the fruits depends on adequate supply of hexose sugar, which decline at ripening stage might be due to decrease in titratable acidity, which could be attributed to oxidation of ascorbic acid (Mapson, 11). The findings are in agreement with the prior records of Thakur *et al*. (16). The highest reducing (9.62%) and total sugars (12.42%) were recorded in 'Skyline Supreme' which were statistically *at par* with 'Spur Type Red Delicious' *i.e.*, 8.07% and 11.93% respectively, while lowest reducing sugars were recorded in 'Gloster' (5.13%) and total sugars were recorded in 'Prima' (6.15%). The highest non-reducing sugars were recorded in 'Spur Type Red Delicious' (3.67%), while lowest in 'Stark Spur' (0.46%). These results obtained in the present investigation are found to be in close conformity with the studies of Kumar *et al*. (9). Sugar is a vital constituent of fruits which is directly related with sweetness and is fundamental feature of fruit quality (aroma, flavour and texture). The extent of variation in sugars in different apple cultivars may be explained on the basis of leaf: fruit ratio and subsequently on the synthesis of more photosynthates and variable amount of starch in young fruits, which in turn converted into sugars at fruit maturity.

Total carotenoids of fruits were found highest in 'Skyline Supreme' (235.73 µg/100 g) followed by 'Prima' (222.63 µg/100 g) and 'Mollies Delicious' (181 µg/100 g) while lowest in 'Vermont Spur' (79.45 µg/100 g). The results obtained in the present investigation are found to be in close conformity with the studies of Kishor *et al*. (8). The highest total anti-oxidant activity was found in 'Skyline Supreme' (41.95 mMTE/L), while lowest in 'Stark Spur' (30.66 mMTE/L) and 'Bright-N-Early' (30.67 mMTE/L). The results obtained in the present investigation are found to be close conformity with the studies of Lejaa *et al*. (10). The antioxidants are mainly scavengers that reduce the various free radicals serving in the avoidance of cellular injury and other disease. Likewise, fruit antioxidants have ability to produce resistance in tissues against disease and stress conditions. However, plant genotypes may differ in their antioxidant capacity (Lejaa *et al*., 10). In the present study, antioxidant activity was due to presence of high ascorbic acid and total carotenoids contents in fruits of the apple cultivars.

There were significant differences in colour parameters (L^*, a^*, b^*, C^* and h°) among the different apple cultivars (Table 4). The cultivar 'Golden Delicious' was the most luminous (L^*=84.86) followed by 'Stark Spur' (L^*=75.18), while 'Bright-N-Early' was the least luminous (L^*=31.36) followed by 'Skyline Supreme' (L^*=31.69). The ground colour as well as blush depends on sunlight during ripening. Low value of 'L^*' indicates a dark fruit skin. This is in agreement with the lower luminosity value observed in Bright-N-Early which is distinguished by a dark red colour. The cultivar 'Golden Delicious' showed a significant difference in 'L^*' value from all other cultivars. This cultivar is characterized by a greenish yellow colour therefore inducing higher luminosity than the other cultivars. The 'a^*' or red-green values showed a significant differences among the different cultivars studied. The cultivar 'Chaubattia Anupam' showed the highest red colour (a^*=54.15), followed by 'Gala Mast' (a^*=34.76), while the lowest values were shown by 'Golden Delicious' (a^*=3.77) followed by 'Stark Spur' (a^*=4.15). Better red colour in 'Chaubattia Anupam' may be due to its early maturity during which there is more sunshine and less effect of clouds and fog in the region. The 'b^*' or yellow-blue component values were found highest in 'Golden Delicious' (b^*=67.10) followed by 'Stark Spur' (b^*=65.21), whereas the lowest values were shown by 'Red Chief' (b^*=5.82) followed by 'Bright-N-Early' (b^*=5.89). These results agree with the colour of the cultivars, 'Golden Delicious' and 'Stark Spur', characterized by intense yellowish green shades. The Chroma (C^*) values measures colour saturation or intensity. A higher 'C^*' value is indicative of brighter red colour. The cultivars 'Chaubattia Anupam' (C^*=67.53) and 'Golden Delicious' (C^*=67.23) showed the highest 'C^*' value among the different cultivars, whereas the cultivars 'Red Chief' (C^*=14.86) and 'Bright-N-Early' (C^*=18.31) showed the lowest 'C^*' values. The hue angle (h°) that correlates with 'a^*' and 'b^*' values, was a good factor to access changes of the characteristic colour in these cultivars. Lower h° values indicate a redder colour, as exemplified by the cultivars 'Bright-N-Early' (h°=16.84) and 'Skyline Supreme' (h°=19.95), whereas the cultivars 'Golden Delicious' (h°=87.41) and 'Stark Spur' (h°=86.36) showed the highest h° values. Colour is the most important

Table 4. Comparative data on fruit colour characteristics among different apple cultivars (pooled mean).

Cultivar	Skin ground colour				
	L^*	a^*	b^*	Chroma (C^*)	Hue angle (h°)
Gloster	64.11	24.14	38.19	52.51	51.43
Vance Delicious	37.13	31.33	13.98	34.31	24.05
Vermont Spur	39.89	26.09	13.10	29.19	26.67
Rich-A-Red	46.31	20.18	20.64	29.46	45.05
Bright-N-Early	31.36	17.28	5.89	18.31	16.84
Stark Spur	75.18	4.15	65.21	65.34	86.36
Red Chief	33.39	13.90	5.82	14.86	20.41
Golden Delicious	84.86	3.77	67.10	67.23	87.41
Spur Type Red Delicious	38.66	23.20	11.31	26.07	25.05
Top Red	45.63	22.28	20.68	32.38	43.26
Skyline Supreme	31.69	26.59	9.00	26.20	19.95
Chaubattia Anupam	55.98	54.15	40.23	67.53	36.54
Chaubattia Princess	50.55	33.83	28.43	44.75	40.72
Mollies Delicious	59.35	30.68	37.10	48.73	50.14
Starkrimson	39.26	26.23	11.29	28.55	23.14
Oregon Spur	48.16	21.11	41.73	31.85	45.91
Gala Mast	70.63	34.76	44.22	57.03	52.05
Prima	44.82	24.27	27.35	36.56	48.42
CD at 5%	9.50	10.01	18.34	7.78	16.06

indicator of maturity and quality in many fruit species. It is mainly influenced by the concentration and distribution of various anthocyanins in the skin, as well as by other factors, such as light, temperature, ethylene and cultural practices (Usenik *et al*., 17). The results obtained in the present investigation are found to be in close conformity with the studies of Jha *et al*. (6).

The variability in various chemical characteristics of fruits may be due to environmental conditions, harvesting of fruits at different time of maturity/ ripening and genetic variability in genotypes. Thus, it can be inferred that the yield and physico-chemical performance of cultivar 'Spur Type Red Delicious' and 'Skyline Supreme' are better under changing climatic conditions of this region, hence would be popularized in the region.

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Multivariate interpretation of the foliar chemical composition of essential nutrients in mango under Peninsular India

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ABSTRACT

The nutrient concentration vs yield performance data bank was established for *Alphonso* mango grown in Peninsular India to develop multivariate diagnostic norms with high diagnostic sensitivity. Well performing orchards in Ramanagara, Srinivaspur, Chittoor, Krishnagiri, Vengurla and Ratnagiri regions were intensively surveyed to develop the data bank. The diagnostic norms for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and Mo were developed by using compositional nutrient diagnosis (CND) technique. The interactions among different nutrients were elucidated by principal component analysis (PCA). It was evident that wide variation in plant nutrient concentration exists in different geographic locations. The mean N concentration showed wide variations from 1.03% to 2.87%, P from 0.09 to 0.33 % and that of K from 0.78 to 1.35% depending upon the geographic location. Among the micronutrients, Zn concentration showed variation from 14.01 to 24.97 mg kg^{-1} and B from 3.50 to 16.63 mg kg^{-1}. The CND norms showed higher diagnostic precision compared to the bivariate techniques. The application of PCA indicated that as many as eight nutrient elements were found integrated with first principal component in many locations. Involvement of several nutrients in a single principal component indicated that it was not possible to diagnose nutrient imbalance of any particular nutrient in isolation in mango and multi nutrient involvement on governing yield potential. The extent to which a particular nutrient interacting with other nutrients was a function of nutrient in question and geographic location. The nutrient interaction observed for different locations in general mimicked nutrient behaviour reported earlier. There is a need for integration of the all nutrients for diagnosis of nutrient imbalance in high performing fruit crop like mango.

Key words: *Mangifera indica*, nutrient concentration, compositional nutrient diagnosis (CND), principal component analysis (PCA).

INTRODUCTION

The essential nutrient composition of plant tissue is of interest for plant physiology, plant nutrition, fertilization, ecology and environmental protection. Foliar analysis is a common method for assessment of nutrient status in mango like in many other crops, while analysis is often restricted to essential nutrients to evolve management strategies. Since nutrients largely govern plant growth and yield potential in many crops, the optimum ranges have been defined through use of leaf nutrient interpretation techniques in mango (Anonymous, 1). The leaf nutrient interpretation often becomes complex because of interaction among nutrients with in plant (Raghupathi et al. 6). A further step in studying interaction among nutrients is to use multivariate statistical methods.

Several approaches were adopted for developing diagnostic norms and for identification of nutrient imbalance, the recent being compositional nutrient diagnosis-CND (Parent and Dafier 5), which provides undistorted variates amenable to Principal Component Analysis (PCA). There are no or little information in the literature on the use of multivariate nutrient diagnosis in mango. The diagnostic precision increases when a large number of nutrients are included in the interpretation process. Further, a reasoned application of PCA could lead to the greater understanding of the nutrient interaction. The present investigation was carried out to develop multivariate diagnostic norms and to understand multivariate nutrient behaviour in mango grown in Peninsular India.

MATERIALS AND METHODS

The first step in implementing CND is the establishment of the standard values or norms. A data bank of nutrient concentration vs. performance was established based on regional survey carried out in six different potentially mango growing regions viz. Ramanagara, Srinivaspur, Chittoor, Krishnagiri, Vengurla and Ratnagiri regions of Peninsular India. The four to seven-month old leaf along with petiole from the vegetative shoots (non-fruiting terminal, in the middle of the whorl) was collected. Four to five samples were collected depending up on the size of the individual land holding. The information on yield was obtained based on the visual performance of the orchard and interaction with the farmer. The entire data set was included for norms deriving purpose

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although there was difference in performance in individual cropping enterprises.

The foliar samples were dried at 70°C. The samples were wet digested with H_2SO_4 and H_2O_2 and analyzed for N by Kjeldahl method (Jones et al. 3). Another part of the sample was digested with HNO_3: $HClO_4$ (9:4 v/v). The ICP- OES system was used for determining P, K, Ca, Mg, Fe, Mn, Zn, Cu, B and Mo. The soil samples were analyzed for different parameters as out lined by Page *et al.*, 4). The compositional nutrient diagnosis (CND) which has been proposed for nutritional diagnosis includes physiological concept, such as nutrient interaction in plant and also mathematical constraint to a closed system known as bounded sum constraint (Parent and Dafir 5). The full composition array for the nutrient proportions (D) in plant tissues was described by the following simplex (S^D) contained to 100%:

S^D=[(N, P, K,… R) where N+P+K+…+R =100%]

Where, 100% is the dry matter content (i.e., the invariable sum of all the components or the full relative composition of the diagnostic tissues). N, P, K are the nutrient concentrations and R is the filling value between 100% and sum of the nutrient concentrations. The value of R is thus composed of undetermined components as well as experimental error, and was required to linearize compositional data. The bounded sum constraint to 100% of compositional data was alleviated by correcting nutrient concentrations by geometric mean (G) of all the D components including R.

$G = [N \times P \times K \times ….. \times R]^{1/D}$

Row centered log-ratios were generated for V_N to V_{Zn} as follows

V_N = ln (N/G),…..,V_{Zn} = ln (Zn/G)

Expressions such as N/G, Zn/G are multi-nutrient ratios, since each nutrient is divided by geometric means of all the components (the determined nutrients and the filling value). The row -centered log-ratios are linearized (undistorted) estimates of the original components that are fully compatible with PCA. V^*_N to V^*_{Zn} and SD^*_N to SD^*_{Zn} are the CND norms (indicated by asterisks), i.e., mean and standard deviation of each row cantered log-ratios in the high yielding population. The standardized variables (V_N - V_N^*) / SD^*_N to (V_{Zn} - V^*_{Zn}) / SD^*_{Zn} are the CND nutrient indices.

A reasoned application of PCA could lead to the greater understanding of the effect of fertilization treatments on leaf composition. PCA reduces the number of interdependent variables into smaller number of independent PCs that are linear combinations of original variates (Schleppi et al. 9) A PCA was performed on log transformed nutrient concentration data. According to distribution of data, all the measured concentration was transformed to their logarithms prior to statistical computation. It was shown that, the assumption of log normal distribution was reasonable. To be declared significant PCs must have eigen values >100/P, where P is the total number of varieties under diagnosis. Alternatively, PCs showing eigen values <1 were considered non-significant. Only PC loading in eigen vectors having values greater than the selection criterion (SC) are given significance. The selection criterion was computed as: SC = 0.50 / (PC eigen values)$^{0.5}$

RESULTS AND DISCUSSION

The mean N concentration showed wide variations from 1.03 % to 2.87% depending up on the geographic location. Mean N was highest in Konkan region of Maharashtra where in traditionally best mango is grown. The soils were rich in organic carbon level and high nitrogen level in leaf is reflected. There was nearly threefold difference in P concentration in leaf samples of different locations. The P concentration of the Konkan region was higher when compared to the other regions. Potassium being a major dry matter building component showed less variation among different locations when compared to N and P. Calcium concentration was the lowest in Konkan region and the highest in Chittoor region. The soil available Ca also was very high in this region indicating that high levels of Ca in soil is reflected in plant as well. Magnesium concentration showed far less variations compared to Ca. Iron concentration was generally low in most of the places except that of Konkan region. The information on micronutrient levels for Alphonso mango was published earlier (Raghupathi and Bhargava 8). The variation in Zn concentration among different location was not very wide and the lowest concentration of 14.0 mg kg^{-1} was recorded in Krishnagiri and the highest of 24.97 mg kg^{-1} in Vengurla region (Table 1). Boron concentration varied from 3.56 ppm to 16.63 mg kg^{-1} while within the Konkan region mean B concentration showed only marginal differences. Molybdenum concentration although varied considerably among different regions, with in the Konkan region the difference was very narrow.

The CND norms for N (V_N), was higher for Vengurla and Ratnagiri followed by Srinivaspur region (Table 3). The difference in the norm value were not high among different locations for N. Whereas norm value for P (V_P) was particularly high for Konkan region when compared to the norm values developed for Karnataka. Potassium norm (V^*_K) for mango varied narrowly among different regions indicating similar requirement of K for *Alphonso* mango irrespective of the geographic location. As expected the norm value for Ca was far lower for Konkan region when compared the mango

Table 1. Mean concentration of different nutrients in mango leaf under different geographic locations.

Nutrient	Unit	Ramanagara	Srinivaspur	Chittoor	Krishnagiri	Vengurla	Ratnagiri
N	%	1.71	1.74	1.03	1.23	2.87	2.73
P	%	0.11	0.09	0.12	0.13	0.29	0.33
K	%	0.92	0.78	1.13	1.35	0.86	0.94
Ca	%	0.68	0.73	1.34	1.25	0.35	0.35
Mg	%	0.19	0.18	0.31	0.26	0.29	0.28
S	%	0.15	0.15	0.16	0.17	0.17	0.19
Fe	mg kg^{-1}	87.44	78.16	80.53	80.09	260.39	240.10
Mn	mg kg^{-1}	146.70	162.93	68.10	47.23	265.57	227.24
Zn	mg kg^{-1}	19.76	20.96	17.42	14.01	24.97	21.96
Cu	mg kg^{-1}	3.56	3.50	7.57	10.76	5.06	5.97
B	mg kg^{-1}	9.94	9.40	8.47	3.56	16.63	15.59
Mo	mg kg^{-1}	1.33	1.50	1.94	2.28	3.60	2.92

grown in other regions as lateritic soil of the coastal region were low in available Ca (Table 2). Similar was the case with Mg as well indicating in general lower levels of both Ca and Mg for *Alphonso* of Konkan region. Sulphur norm value showed less variation and was independent of the location. The CND norms are multivariate norms with due weight-age for all the other elements including the unmeasured factors. The sum of the tissue components is 100 % and, therefore, the sum of the row centred log ratios including the filling value is zero. The CND norm values developed were difficult to comprehend compared to the nutrient concentration expressed as % or ppm (Raghupathi et al 6). However, the CND norms are having higher diagnostic precision compared to the bi-variate values as in case of diagnosis and recommendation integrated system as outlined by Walworth and Sumner (10).

Among the micronutrients the order of requirement was Mn>Fe>Zn>Cu>B>Mo with the exception in Ramanagara and Srinivaspur region where B requirement was much higher compared to Cu. The variations were observed in diagnostic norms value of Fe in different locations. Although the absolute values for Zn showed marginal difference among different

Table 2. Mean physico-chemical soil properties in different locations.

	Unit	Srinivaspur	Ramanagara	Chittoor	Krishnagiri	Vengurla	Ratnagiri
pH		6.25	6.16	7.16	6.82	6.39	5.76
EC	dSm^{-1}	0.22	0.13	0.19	0.28	0.07	0.11
OC	g kg^{-1}	5.50	8.10	7.90	8.60	22.4	4.40
N	mg kg^{-1}	88.7	131.2	128	139	364	71.3
P	mg kg^{-1}	19.9	22.24	15.5	15.94	9.09	9.49
K	mg kg^{-1}	141	94	133	124	135	163
Ca	mg kg^{-1}	1021	1173	2583	3023	1090	1211
Mg	mg kg^{-1}	222	303	296	361	249	398
S	mg kg^{-1}	44.63	14.46	6.72	4.40	66.1	64
Fe	mg kg^{-1}	28.7	30.3	9.56	8.04	71.32	23.4
Mn	mg kg^{-1}	24.8	37.5	13.04	16.46	18.09	12.0
Zn	mg kg^{-1}	1.1	1.05	1.80	1.76	0.84	1.13
Cu	mg kg^{-1}	2	2.24	2.25	2.80	2.52	4.43
Silt	%	12	14	8	11	14	16
Clay	%	24	26	14	20	34	24
Sand	%	64	60	78	69	52	60

Table 3. CND diagnostic norms for mango for different regions of peninsular India.

CND variate	Ramanagara		Srinivaspur		Chittoor		Krishnagiri		Vengurla		Ratnagiri	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
V_N	3.95	0.27	3.97	0.21	3.31	0.21	3.55	0.24	4.00	0.24	3.98	0.23
V_P	1.18	0.32	1.01	0.22	1.18	0.16	1.34	0.25	1.70	0.24	1.71	0.63
V_K	3.34	0.20	3.11	0.44	3.40	0.23	3.66	0.22	2.81	0.17	2.92	0.20
V_{Ca}	3.04	0.24	3.11	0.15	3.59	0.10	3.57	0.20	1.91	0.13	1.93	0.14
V_{Mg}	1.73	0.24	1.69	0.19	2.11	0.16	1.99	0.24	1.71	0.17	1.72	0.18
V_S	1.49	0.19	1.50	0.21	1.42	0.17	1.56	0.17	1.20	0.19	1.33	0.17
V_{Fe}	-1.43	0.41	-1.47	0.31	-1.49	0.23	-1.52	0.31	-0.79	0.40	-0.83	0.40
V_{Mn}	-1.20	0.83	0.48	0.29	-1.87	0.60	-2.19	0.60	-0.81	0.53	-0.88	0.44
V_{Zn}	-2.81	0.17	0.06	0.01	-3.08	0.19	-3.22	0.21	-3.16	0.46	-3.25	0.44
V_{Cu}	-4.72	0.62	0.01	0.00	-3.94	0.31	-3.58	0.43	-4.66	0.31	-4.49	0.33
V_B	-3.49	0.14	0.03	0.00	-3.86	0.41	-4.63	0.31	-3.45	0.25	-3.49	0.24
V_{Mo}	-5.65	0.53	0.00	0.00	-5.33	0.39	-5.10	0.39	-5.03	0.38	-5.23	0.40

locations, the diagnostic norms value for Zn was far lower for Ratnagiri region. The diagnostic norm value for B was the lowest for Krishnagiri region.

Barring that of Ratnagiri region N was a component of the first PC in all the regions (Fig. 1). As many as eight nutrient elements were found integrated with first PC in many locations. Earlier studies have also indicated that involvement of several nutrients in a single PC and it was not possible to diagnose nutrient imbalance of any particular nutrient in isolation in mango (Raghupathi *et al*., 7). Barring that of Mo all the nutrient elements were having significant loadings in Vengurla region. The contrast indicates a very close association between foliage N and B concentration. However, the relationship between N and B was less conspicuous in Konkan region. Mo was not involved in any significant interaction with any nutrient element in mango except in Ratnagiri region where it was found to have some positive relationship with P. The second PC showed a very significant close association between N and Fe with positive loading and between Ca and Mg with negative loadings (Table 4). The PCs indicated the trend in build-up of nutrients in mango leaf. For example, the first PCs in Ramanagara region indicated that build up in concentration of N, P, K, Mg, Zn and B which resulted in accompanying

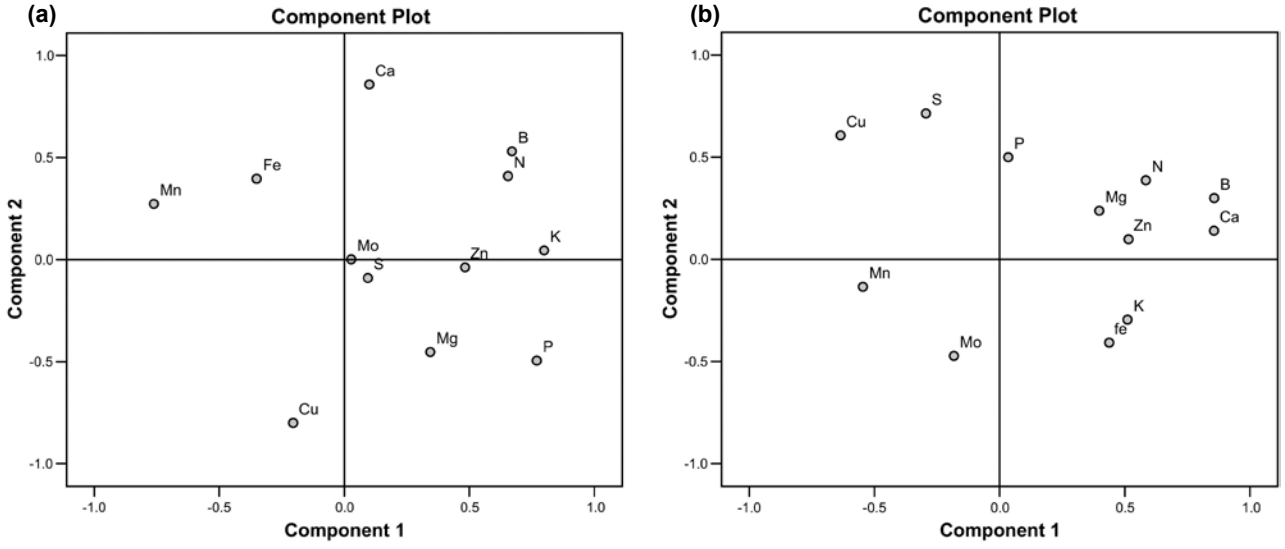

Fig. 1. First two principal components and variable cluster derived from the log transformed nutrient concentration for Ramanagara (a) and Srinivaspur (b).

decrease in concentration of Fe and Mn. The build-up in Ca concentration was found to the central cause for changes in other nutrient concentration. The two eigen values explained about 45 to 51% of the total variance in different regions. The involvement of several nutrients in a single PC indicated multi-nutrient interaction in mango, although some interactions like Zn and K in Ratnagiri region was difficult to explain. The total variance was less effectively captured by PCA in some regions like Ratnagiri when compared to other regions indicating influence of other factors on growth and productivity (Fig. 3). Calcium was excluded from the first PC in both Ramanagara and Chittoor regions (Fig. 2), while N was part of the group with positive loading having close association with P, K, S and Zn. The positively loaded Fe showed a close association

Table 4. Principal component analysis of log transformed nutrient concentrations in mango.

Nutrient	Ramanagara		Srinivaspur		Chittoor		Krishnagiri		Vengurla		Ratnagiri	
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2
N	0.655*	0.410*	0.584*	0.387*	0.204	0.694*	0.507*	0.227	0.344*	0.895*	0.008	-0.050
P	0.770*	-0.495*	0.034	0.500*	0.603*	0.070	0.880*	0.003	0.344*	0.895*	-0.559*	-0.583*
K	0.799*	0.045	0.511*	-0.295	0.716*	-0.223	0.704*	0.172	0.325*	0.080	-0.267	0.478*
Ca	0.100	0.859*	0.856*	0.140	-0.211	0.658*	-0.661*	0.526*	0.843*	-0.074	0.743*	-0.068
Mg	0.344*	-0.453*	0.398*	0.238	-0.128	-0.641*	0.226	0.662*	0.658*	-0.412*	0.636*	0.258
S	0.094	-0.090	-0.294*	0.714*	0.391*	0.538*	-0.157	0.583*	0.569*	-0.657*	0.241	0.314*
Fe	-0.351*	0.397*	0.438*	-0.408	-0.005	-0.127	-0.724*	0.142	-0.641*	-0.192	0.093	0.427*
Mn	-0.762*	0.273	-0.546*	-0.134	-0.538*	0.172	-0.421*	-0.569*	-0.577*	-0.251	0.596*	-0.317*
Zn	0.483*	-0.038	0.515*	0.098	0.623*	-0.049	0.548*	0.469*	-0.565*	0.061	-0.460*	0.444*
Cu	-0.205	-0.800*	-0.635*	0.607	0.668*	-0.390*	0.609*	-0.485*	0.479*	-0.567*	0.048	0.683*
B	0.670*	0.531*	0.857*	0.300	-0.558*	-0.481*	-0.593*	0.214	0.621*	0.188	0.484*	-0.345*
Mo	0.028	0.002	-0.183	-0.473	-0.268	0.238	-0.275	-0.292	-0.068	0.182	-0.230	-0.433*
Eigen Value	3.224	2.519	3.508	1.947	2.630	2.150	3.830	2.060	3.490	2.707	2.264	1.992
% Variance	26.87	47.86	29.23	45.46	21.98	39.95	31.99	49.21	29.12	51.68	18.86	35.47
SC	0.278	0.315	0.267	0.358	0.308	0.341	0.255	0.348	0.268	0.304	0.332	0.354

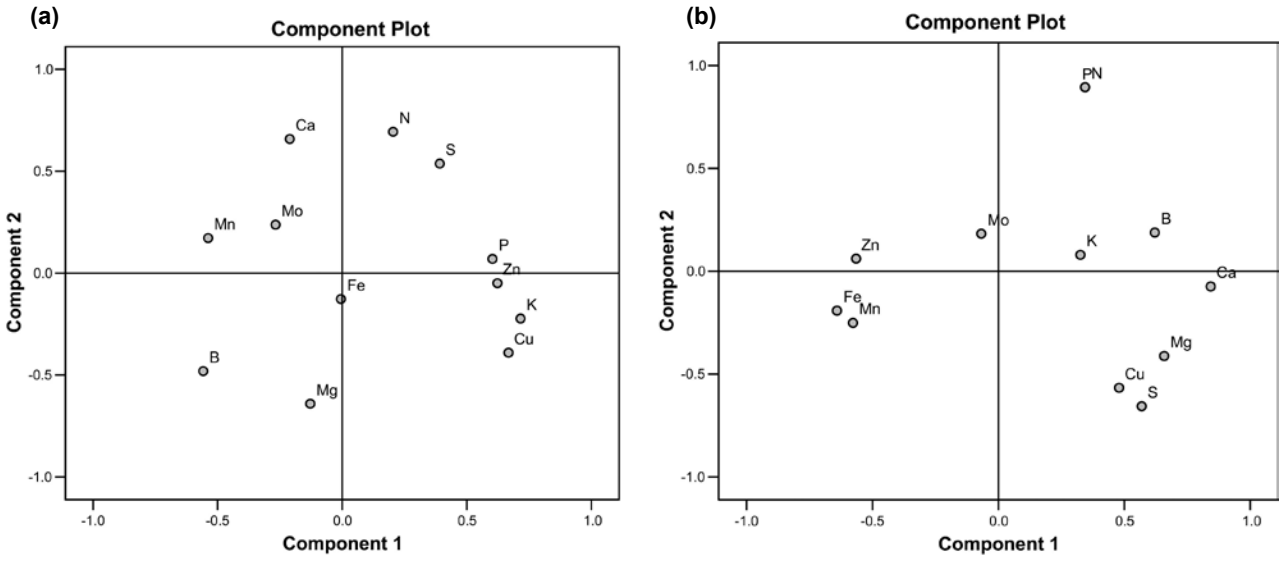

Fig. 2. First two principal components and variable cluster derived from the log transformed nutrient concentration for Chittoor (a) and Krishnagiri (b).

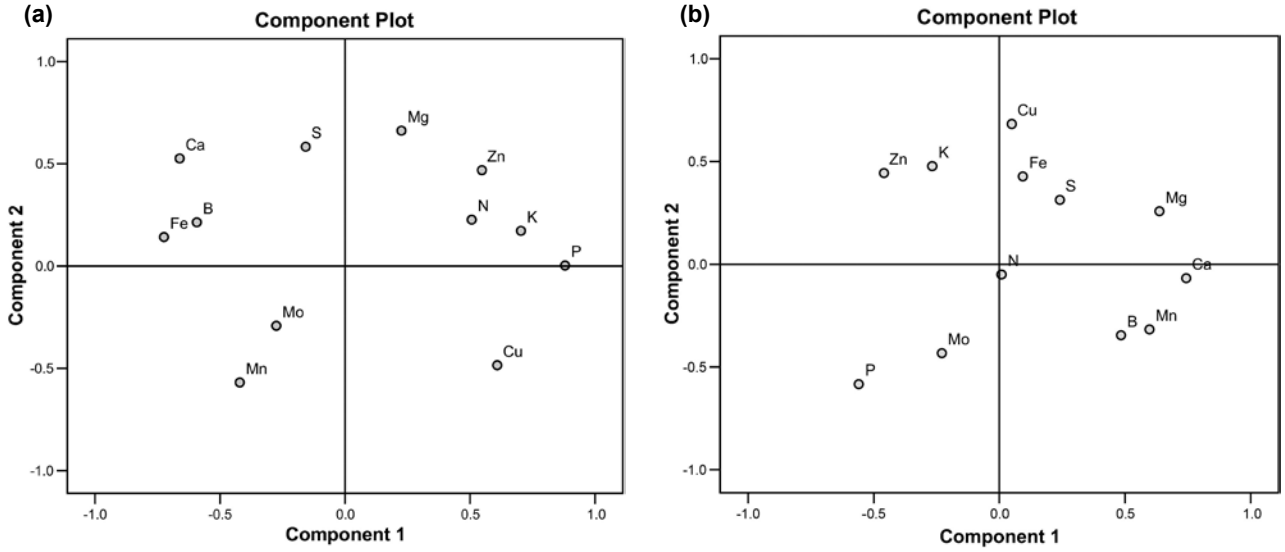

Fig. 3. First two principal components and variable cluster derived from the log transformed nutrient concentration for Vengurla and Ratnagiri.

with K in Srinivaspur region. The positive loading for P and Zn in many locations indicated existence of no antagonistic relations between two as reported in many crops. Notwithstanding twofold higher levels of Fe in Konkan region no accompanying relationship with major nutrient was noticed (Fageria 2). The inclusion of many nutrients elements indicated importance of no single element in growth and production of mango.

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Influence of cultivars, cropping systems and nutrient levels on yield and quality of mango in north India

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ABSTRACT

A field experiment was carried-out on 3-year-old mango trees (6 m × 6 m) during 2011-12 and 2012-13 at New Delhi to study the effect of cultivar, cropping system and nutrient level on yield and quality parameters. The experiment was laid out in a split-split-plot design with three replications. The main plots comprised of four cultivars, *viz*., Pusa Surya, Amrapali, Mallika and Dashehari, sub-plots consisted of four cropping systems, *viz*., vegetable cowpea-Indian mustard, green gram-Indian mustard, blackgram-Indian mustard and sole mango. Sub-sub plots included three fertility levels *viz*., control, 50% recommended dose of NPK fertilizers (RDF) + 50% recommended dose of FYM (RD-FYM), and 100% RDF + 100% RD-FYM to mango. A marked variation in fruit yield and fruit quality was observed among mango cultivars. 'Amrapali' exhibited supremacy over rest of the cultivars for yield and quality parameters. Under vegetable cowpea-mustard system, the mango fruit yield and yield parameters were comparatively higher. However, the physical and biochemical fruit quality parameters showed a non-significant variation among cropping systems. Application of 100% RDF + 100% RD-FYM remaining at par with 50% RDF + 50% RD-FYM produced significantly higher number of fruits/plant (16.5 and 24.3), fruit weight (212 and 223 g) and pulp: stone ratio (5.01 and 5.02) during 2011-12 and 2012-13, respectively over control. Application of 100% RDF + 100% RD-FYM exhibited higher biochemical quality parameters *viz*., TSS, vitamin C, total carotenoids and total sugars during both years over other treatments. Overall, 'Amrapali', vegetable cowpea-mustard cropping system and application of 100% RDF + 100% RD-FYM were the best performing treatments in terms of fruit yield and quality parameters in the current study.

Key words: *Magnifera indica*, cropping systems, fruit quality, intercropping.

INTRODUCTION

Mango (*Mangifera indica* L.) is regarded as national fruit of the country because of its wide edaphic and climatic adaptability, high nutritive value, attractive appearance and popularity among growers. It is a huge-size woody perennial tree, is usually grown on wider spacing and also at juvenile phase the sparse foliage permits required light for the under storey intercrops that makes the microclimate compatible for inter-cultivation (Swain, 14). Thus, long juvenile period of mango plant can be efficiently utilized for different intercrops. Intercropping enables efficient utilization of resources in vertical (space and light) and horizontal dimensions (land, nutrient and moisture). This additional intercropping component provides additional production and farm income by utilizing natural resources and inputs efficiently especially in the initial years of orchard establishment (Swain *et al*., 15). Pulses are preferred intercrops over cereals in fruit based agri-horticultural systems as they have biological N_2 fixation ability vis-à-vis higher N turnover in the soils (Kumar *et al*., 6). Similarly, the application of chemical fertilizers alongwith organic manures in mango orchards may improve the plant growth, fruit yield and quality owing to improved soil physico-chemical and biological properties (Patil *et al*., 8). Thus, a field experiment was conducted to assess the influence of cultivars, legume based cropping systems and nutrient levels on mango yield and quality parameters.

MATERIALS AND METHODS

A field experiment was conducted during 2011-12 and 2012-13 at Todapur Research Orchard, Division of Fruits & Hort. Tech., ICAR-ARI, New Delhi [28°35' N, 77°12' E, 228.61 m amsl, humid subtropical climate]. The soil of experimental site was sandy clay loam, having pH 7.8. Soil had 157.2 kg/ha available N, 12.4 kg/ha available P, 252 kg/ha available K, 0.38% organic carbon and electrical conductivity of 0.36 dS/m. The experiment was carried-out on 3-year-old existing mango orchard (6 m × 6 m), which gave ample space for growing intercrops. The experiment was laid out in a split-split-plot design with three replications. Main-plots treatments consisted of four mango cultivars, *viz*., Pusa Surya, Amrapali, Mallika and Dashehari. Sub-plots consisted of four

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cropping systems, *viz*., CS_1: mango + cowpea (cv. Pusa Komal) for green pods -Indian mustard (cv. Pusa Vijay); CS_2: mango + greengram (cv. Pusa Vishal) for grains - Indian mustard (cv. Pusa Vijay), CS_3: mango + blackgram (cv. Azad Urd 1) for grains - Indian mustard (cv. Pusa Vijay) and CS_4: sole mango (Fig. 1). The sub-sub-plot treatments comprised three nutrient levels in mango, *viz*., F_0: Control; F_1: 50% recommended dose of NPK fertilisers (RDF) + 50% recommended dose of FYM (RD-FYM); and F_2: 100% RDF + 100% RD-FYM (Fig. 1). Natural litter fall of mango and intercrop residues were incorporated uniformly in the soil after threshing/pod picking.

During first year, the recommended dose of FYM and NPK fertilizers consisted of 20 kg FYM, 300 g N, 150 g P_2O_5, 300 g K_2O/plant, while in the succeeding year we gave 30 kg FYM, 400 g N, 200 g P_2O_5, 400 g K_2O/plant. Half of fertilizers (urea, DAP and MOP) were broadcasted under the canopy after mango harvesting (in July) and incorporated upto 15 cm soil depth followed by irrigation when no rain. Remaining doses were applied at flowering. Intercrops were sown 0.50 m away from either side of the trunk; thus, leaving an area of 0.787 m^2 around each tree. Uniform spacing of 0.50 m was left between all the plots, thus; only 8,184.5 m^2 orchard area was available for cultivation on hectare basis. The experimental area was divided into 12 main-plots of 23.5 m × 17.5 m and each plot consisted of 12 mango bearing plants (Fig. 1). Sub-plot and sub-sub-plot treatments were duly randomized, however randomization could not be done for main-plot treatments (cultivars), because same cultivars were already planted in common strip. Drip irrigation was stopped before 21 days to flowering and 10 days before harvest of mango to reduce flower drop and produce larger fruits. Cultural practices were uniformly followed except nutrient management.

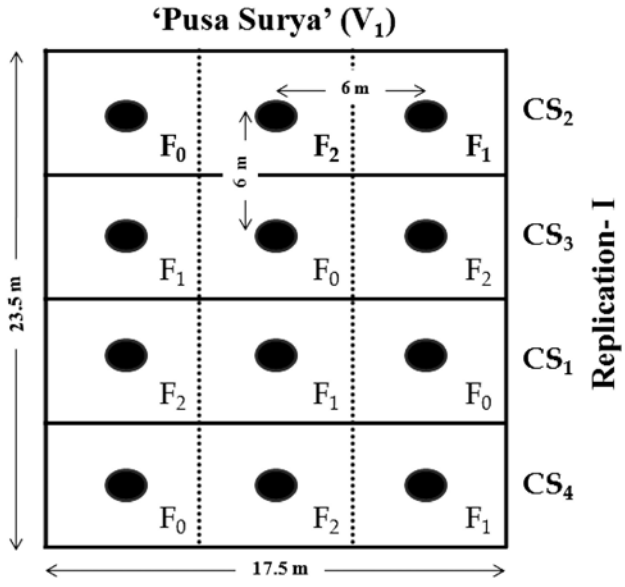

Fig. 1. Layout of one main plot (Mango cultivar), indicating 12 mango plants in a main plant. Sub-plot consists of cropping system (CS_1: Mango + cowpea - Indian mustard, CS_2: Mango + greengram - Indian mustard, CS_3: Mango + blackgram - Indian mustard and CS_4: Sole mango), Sub-sub-plot consists of nutrient management in mango (F_0: Control, F_1: 50% RD of NPK + 50% RD of FYM and F_2: RD of NPK + RD of FYM)

Cowpea, greengram and blackgram were sown in the seed-beds on 17th and 18th July in 2011 and 2012, respectively. Indian mustard was sown on 6th Nov., 2011 and 5th Nov., 2012. Basal dose of 20 kg N, 50 kg P_2O_5 and 40 kg K_2O/ha was given to all the rainy-season crops, while the fertilizer dose for Indian mustard comprised 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha. The recommended package of practices was followed for all intercrops (Rana *et al*., 10). Harvesting of mango was done at full maturity stage. Physico-chemical analysis was done on five randomly selected mature fruits from each plant. Biochemical quality parameters, *viz*., TSS, sugars, total titratable acidity, ascorbic acid and total carotenoides were determined using standard procedures. The data was statistically analysed at 5% level of significance following standard procedures (Rana *et al*., 10).

RESULTS AND DISCUSSION

A marked variation in yield attributes, yield and physical quality parameters of mango fruits was observed among cultivars (Table 1). 'Pusa Surya', 'Amrapali' and 'Dashehari' yielded significantly higher number of fruits/plant over 'Mallika'. Maximum number of fruits/plant were harvested from 'Dashehari' (20.8 and 29.8) followed by 'Amrapali' and 'Pusa Surya' and lowest in 'Mallika' during 2011-12 and 2012-13, respectively. Significantly higher fruit weight was obtained from 'Mallika' over rest of the cultivars. Owing to heavier fruit weight, 'Mallika' produced significantly highest pulp: stone ratio. Average fruit yield per plant and fruit yield ha was significantly influenced amongst mango cultivars. 'Amrapali' with fruit yield/plant of 3.35 and 5.07 kg and fruit yield/ha of 929 and 1407 kg during 2011-12 and 2012-13, respectively showed supremacy over 'Dashehari' and 'Mallika'. 'Amrapali' gave 18.6 and 9.0% higher fruit yield compared to 'Mallika' in 2011-12 and 2012-13, respectively. Though the individual fruit weight of 'Mallika' was higher, but because of significantly lower number of fruits/plant, it registered lowest yield amongst cultivars. The variation amongst cultivars for physical quality and yield parameters of fruit might be

Table 1. Effect of mango cultivars, cropping systems and nutrient levels on yield attributing characters and physical quality parameter.

Treatment	No. of fruits/ plant		Fruit wt. (g)		Fruit yield/ plant (kg)		Estimated fruit yield/ ha (kg)		Pulp: stone ratio	
	2011-12	2012-13	2011-12	2011-12	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Cultivar										
Pusa Surya	14.0	20.8	235	240	3.29	5.00	913	1388	5.40	5.35
Amrapali	18.7	27.2	179	186	3.35	5.07	929	1407	4.02	4.12
Mallika	11.0	17.0	256	274	2.82	4.65	783	1291	6.57	6.36
Dashehari	20.8	29.8	149	163	3.10	4.86	860	1350	3.35	3.48
CD (P = 0.05)	0.41	0.76	7.7	7.3	0.20	0.16	56.4	43.2	0.27	0.24
Cropping system										
Mango + cowpea - mustard	16.2	24.1	207	220	3.18	5.08	882	1412	4.94	4.99
Mango + greengram - mustard	16.2	23.9	206	218	3.16	4.97	878	1382	4.83	4.87
Mango + blackgram - mustard	16.1	23.8	205	215	3.14	4.88	872	1356	4.87	4.81
Sole mango	16.0	23.1	202	210	3.07	4.63	853	1286	4.70	4.65
CD (P = 0.05)	NS	0.57	NS	7.4	NS	0.16	NS	44.1	NS	0.21
Nutrient level										
Control	15.7	22.9	195	204	2.91	4.44	808	1232	4.63	4.58
50% RDF + 50% RD - FYM	16.2	23.9	207	220	3.19	5.04	886	1400	4.86	4.88
100% RDF + 100% RD - FYM	16.5	24.3	212	223	3.31	5.20	920	1445	5.01	5.02
CD (P = 0.05)	0.4	0.5	5.0	5.4	0.12	0.13	33.7	36.5	0.25	0.19

due to variable response of applied inputs, variation in genetic constitution and interaction of various genotypes with the agro-climatic conditions (Singh *et al*., 13; Das, 3).

There were no significant effects of agri-horticultural systems on yield and physical quality parameters of mango fruits during 2011-12, though highest number of fruits/plant, fruit weight, and pulp: stone ratio was recorded from mango + cowpea-mustard system (Table 1). During 2012-13, cowpea-mustard system recorded significantly maximum cumulative number of fruits/plant (24.1), average fruit weight (220 g) and pulp: stone ratio (4.99) over sole mango closely followed by greengram-mustard system. Cropping systems showed non-significant differences in mango yield during 2011-12. During 2012-13, mango yield/ plant was maximum in mango + cowpea-mustard system followed by mango + green gram-mustard and mango + black gram-mustard system and least in sole crop of mango (Table 1). Similar effects of intercropping with legume crops on physical fruit quality and fruit yield of base crop mango has also been advocated by several workers (Singh *et al*., 12; Swain, 14). Better performance of intercropped mango over sole mango may be ascribed to substantial N turnover in the soil *vis-a-vis* improved soil health due to legume intercrops (Bai *et al*., 1). Legume based intercropping systems in mango orchard also efficiently utilized the natural resources like solar radiation, soil moisture and nutrients, thus, adding larger biomass and nutrient recycling which led to better yield and quality of mango fruits (Negi *et al*., 7; Swain *et al*., 15).

Application of 100% RDF + 100% RD-FYM demonstrated significantly higher number of fruits/ plant, fruit weight, fruit yield/plant, fruit yield/ha and pulp: stone ratio during both years over control (Table 1). The 50% RDF + 50% RD-FYM was found to be the second best treatment and statistically as good as 100% RDF + 100% RD-FYM for all the above parameters. There was an increasing trend in yield with successive increase in nutrient levels. This variation may be ascribed to variation in nutrient availability, which differently influenced the growth and yield. Addition of FYM alongwith NPK fertilizers might have helped in improving the soil physico-chemical and biological properties (Paul *et al*., 9), which ultimately improved the plant growth and yield in terms of number of fruits, fruit weight and yield (Singh and Banik, 11).

Biochemical quality parameters were significantly influenced by the mango cultivars (Table 2 and 3). 'Amrapali' was observed as superior cultivar for most of the biochemical quality parameters of fruits exhibiting highest values for total soluble solids (TSS), total carotenoids as well as non-reducing sugars. Significantly least acidity was again recorded in the fruits of 'Amrapali'. However, ascorbic acid (vitamin C) content was significantly lower during both years in the 'Amrapali' fruits. Mallika possessed significantly higher ascorbic acid and reducing sugars among all mango cultivars. It also registered significantly higher total sugars content except 'Amrapali' during second year of study. Significantly higher acidity during respective season was recorded from the fruits of 'Mallika'. Variation in biochemical quality of fruits among cultivars implies intrinsic genetic variability and their interaction with environment (Das, 3; Dixit and Yadav, 4).

The intercrops did not bring significant differences with respect to biochemical fruit quality parameters of mango during both the years of study (Tables 2 & 3). However, mango + cowpea-mustard system recorded superior values of biochemical quality parameters. Improvement in soil fertility due to nitrogen fixation by legumes might have been the reason for improved physical and biochemical quality of fruits (Kumar *et al*., 5; Swain, 14).

Mango plants supplied with 100% RDF + 100% RD-FYM, and 50 % RDF + 50% RD-FYM exhibited significantly better fruit quality parameters over control. Application of 100% RDF + 100% RD-FYM showed marginal supremacy over 50 % RDF + 50% RD-FYM and both the treatments were marked as statistically identical for most of the quality parameters, except for total carotenoids during 2012-13. Application of 100% RDF + 100% RD-FYM resulted in an increase of about 10.5 and 9.8% in TSS, 6.5 and 6.1% in vitamin C, 9.3 and 9.1% in total carotenoids and 12.8 and 13.4% in total sugars during 2011-12 and 2012-13, respectively over control. This variation in quality parameters may be ascribed to variation in nutrient availability and uptake which differently influenced the growth and quality traits (Bai *et al*., 1; Kumar *et al*., 5; Swain *et al*., 15). The acidity was reduced by 3.3 and 3.5% with the application of 100% RDF + 100% RD-FYM, and by 1.4 and 2.0% with 50 % RDF + 50% RD-FYM compared to control during 2011-12 and 2012-13, respectively. Balanced fertilization and organic manures increase the nutrient use efficiency which led to improved fruit quality (Bhargava, 2; Paul *et al*., 9).

Current study inferred that integration of legumes and their biomass incorporation in juvenile phase

Table 2. Effect of mango cultivars, cropping system and nutrient levels on fruit biochemical parameters.

Treatment	TSS (ºBrix)		Acidity (%)		Ascorbic acid (mg/100 g pulp)		Total carotenoids (µg/100 g pulp)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Cultivar								
Pusa Surya	18.6	18.8	0.218	0.195	40.8	41.8	14215	14139
Amrapali	20.5	20.9	0.168	0.168	36.8	39.0	15355	15858
Mallika	19.3	19.5	0.259	0.236	46.2	46.9	9347	9603
Dashehari	18.5	18.9	0.185	0.182	42.3	42.9	7449	8027
CD (*P* = 0.05)	0.53	0.63	0.007	0.007	1.7	1.3	449	330
Cropping system								
Mango + cowpea - mustard	19.5	19.8	0.204	0.192	41.9	43.1	11701	12030
Mango + greengram - mustard	19.3	19.5	0.208	0.195	41.7	42.7	11596	11985
Mango + blackgram - mustard	19.1	19.5	0.209	0.197	41.5	42.6	11562	11906
Sole mango	19.0	19.3	0.210	0.197	41.0	42.2	11508	11706
CD (*P* = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient level								
Control	18.1	18.4	0.211	0.199	40.1	41.2	10996	11291
50% RDF + 50% RD - FYM	19.6	20.0	0.208	0.195	41.8	43.1	11763	12105
100% RDF + 100% RD - FYM	20.0	20.2	0.204	0.192	42.7	43.7	12016	12324
CD (*P* = 0.05)	0.46	0.39	0.004	0.005	0.9	0.7	274	215

Table 3. Effect of mango cultivars, cropping systems and nutrient levels on fruit biochemical parameters.

Treatment	Total sugars (%)		Reducing sugar (%)		Non-reducing sugars (%)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Cultivar						
Pusa Surya	15.6	15.7	4.24	4.33	11.4	11.4
Amrapali	16.7	17.0	4.71	4.76	12.0	12.2
Mallika	17.4	17.3	5.84	5.93	11.6	11.4
Dashehari	14.4	14.7	4.64	4.68	9.8	10.1
CD (P = 0.05)	0.42	0.45	0.11	0.14	0.35	0.35
Cropping system						
Mango + cowpea - mustard	16.3	16.4	4.94	5.00	11.3	11.4
Mango + green gram - mustard	16.1	16.2	4.86	4.95	11.2	11.3
Mango + black gram - mustard	16.0	16.1	4.83	4.91	11.1	11.2
Sole mango	15.9	16.0	4.79	4.84	11.1	11.1
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient level						
Control	14.9	14.9	4.48	4.55	10.4	10.4
50% RDF + 50% RD - FYM	16.5	16.7	4.99	5.05	11.5	11.6
100% RDF + 100% RD - FYM	16.8	16.9	5.09	5.18	11.7	11.8
CD (P = 0.05)	0.54	0.44	0.16	0.14	0.39	0.32

of mango orchard appreciably improved the mango productivity and quality owing to modified soil physico-chemical and biological properties. Overall, 'Amrapali', cowpea-mustard cropping system, and application of 100% RDF + 100% RD-FYM were the best performing treatments with respect to mango yield attributes, fruit yield and quality parameters in the current study.

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Acreage estimation of mango orchards using hyperspectral satellite data

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ABSTRACT

Horticultural crop plays a unique role in India's economy, therefore reliable and timely estimates of area under horticulture crops are of vital importance. Present methods of crop acreage estimation rely heavily on sample survey approach which is time consuming for a diversified and large country like India. Modern space technology with advance tools of Remote Sensing, GIS and GPS may be an alternative option for estimating area under horticultural crops. The advantage of using satellite data is that it provides both synoptic view and the economies of scale, since data over large areas could be gathered quickly from such platforms. This study has been undertaken to estimate the acreage under mango and to map existing orchards of Mango using hyperspectral satellite data. The study was conducted for Meerut district of Uttar Pradesh. The hyperion hyperspectral satellite data was evaluated to estimate the area under all mango orchards. These estimates were compared with actual area under mango orchards measured using Global Positioning System (GPS) and the total area under mango was predicted as 961.88 ha which was 92% close to ground data 889.65 ha. The results indicated the scope of hyperspectral remote sensing in acreage estimation of fruit crops.

Key words: Endmember extraction, ground control point, root mean square error, spectral angle mapper.

INTRODUCTION

Horticultural crops play a significant role in economy, health, food and self-reliance of any country. During past few years, horticulture development has emerged as one of the major thrust area in agriculture sector. Horticultural crops play a unique role in India's economy and nutritional security. It contributes more than 33% to GDP of agriculture (Economic Survey, 2015-16) and among horticultural crops India has been placed at 2nd position in the world for production of fruits and vegetables. The fruit crops solely share 32.19% of total production of major horticultural crops of the country. For optimum utilization of available horticultural land resources on a sustainable basis, timely and reliable information regarding their nature, spatial extent is important which means accurate discrimination of horticultural crops is necessary for giving area under the crop which acts as a vital input for taking valuable decision regarding planning, policy making and exports at national level. Till date usually sample survey techniques are applied for estimating area and production of horticultural crops, which is time consuming, involves lot of field survey and less accurate. With the advancement in space technology and the emergence of modern tools like remote sensing and Geographic Information System it may be easier, quicker and faster to estimate area under horticultural crops which has been explored in the present study.Most of the studies on crop acreage estimation using satellite image also involves the use of multispectral data like Landsat TM (7 bands), LISS II (4 bands), LISS III (4 bands), SPOT 5 (4 bands), MODIS (36 bands) faced difficulties in crop identification. Major limitation of multispectral data is lesser number of bands and mixed pixels which may not be able to discriminate fruit crops. Because of lesser number of bands in multispectral data, it gives a discrete spectrum, which fails to identify minute differences in reflectance pattern of different crops particularly fruit crops. Hyperspectral data has relatively large number of narrow, contiguous bands which lead to continuous spectral reflectance curve, making intricate details visible in the spectrum. There are some research work related to acreage estimation of fruit crops which includes: Gordon and Phillipson (3) first explored the usefulness of Landsat TM sensor data for estimating area of fruit trees in New York State. TM satellite data shows promise in distinguishing fruit trees but the main problem which was encountered was mixing of forests and fruit trees signatures made it difficult to separate forests from fruit trees. Due to low spatial resolution, the orchard rows were not discriminated from the forest.Yadav *et al.* (6) initiated a study to estimate the acreage and production of mango orchards using IRS LISS-II and LISS-III sensor data. They found difficulty in identification of mango orchards due to the mixing

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of different varieties, variation in the age of the fruit trees, mixing of the signature with other plantation crops like coconut, sapota, mixing of signatures of young plantations of mango with that of vegetation.

According to the results, mango acreage estimation using satellite data leads to deviation of 6.32% (LISS-II) and 12.71% (LISS-III) from the actual estimates as released by Department of Horticulture, Government of India. Nagaraja (4) made an attempt to estimate acreage of mango growing areas using IRS 1C LISS-III (23.5 and 70.5 m) and MODIS (250 m., 500 m. and 1000 m.) data for Saharanpur district of Uttar Pradesh. Unsupervised, supervised, decision tree and spectral angle mapping techniques were used for classification and acreage estimation of mango. The study clearly shows the usefulness of IRS 1C LISS-III data for identifying mango orchards and acreage estimation. Decision tree approach was found to be more reliable. Presently estimates of area of fruit crops are obtained through labour-intensive methods using multispectral satellite data, which are less precise and does not give in-depth information about different species. Schupp *et al*. (9) stated that future improvements in orchard production and associated equipment may be done using laser, videos and satellite imaging technologies. Many studies has endorsed the potential of hyperspectral imagery for area estimation, fruit yield estimation and plant stress identification (Tajeda *et al.*, 10; Ye *et al.*, 11) So far, not much work on acreage estimation of fruit crops using hyperspectral satellite data has been attempted. Therefore, this study has been taken with an objective of acreage estimation of mango orchards using hyperspectral satellite data of Meerut district, Uttar Pradesh.

MATERIALS AND METHODS

Part of Meerut district of Uttar Pradesh corresponding to coverage of hyperspectral sensor, Hyperion of EO-1 satellite was consideredfor area estimation of fruit crops. However, ground survey done later confirmed Mango as only dominating fruitcrop in the region. This study area was used for area estimation of mango orchards from hyperspectral satellite data. EO-1-Hyperion image data of 13th April, 2005 with scene centre (Latitude- 29.17^0 and Longitude-77.7^0) has been used for the study.The scene characteristics of EO-1 Hyperion image of Meerut area are listed in the Table 1 below :

A field survey was conducted during 20th January, 2016 confined to Hyperion image coverage area of the Meerut to identify and locate major fruit crops grown in the region. Location co-ordinates were recorded using hand held Trimble GPS (June C). However, field survey revealed the major fruit crop over the site was only mango. During survey 24 mango orchard locations were identified as shown in black dots in Figure 1.a. on google image and green circles in the Hyperion image as shown in Fig. 1.b. Unique identification system was maintained for GPS locations and related fruit orchards throughout the study.

Before acreage estimation, hyperspectral satellite image need to be pre-processed followed by classification using SAM. Finally area was estimated using pixel counting method. The entire methodology for area estimation is explained with the help of flowchart in Fig. 2. and the detail steps for area estimation are elaborated below:

The pre-processing stage can be considered as the first stage to be undertaken to work with the hyperspectral data sets and to collect the valuable information from the data sets. Spaceborne hyperspectral data sets require careful pre-processing

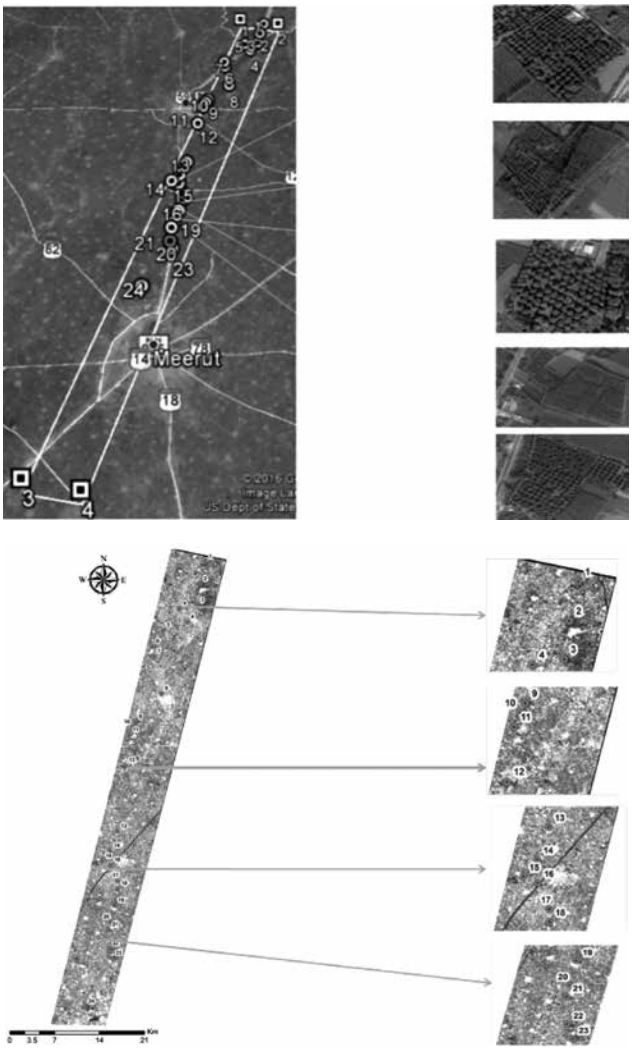

Fig. 1. Location of 24 mango orchards on (a) Google image and (b) Hyperion image of study area.

Table 1. Scene Characteristics of EO-1 Hyperion data of Meerut Area.
(Source: http://edcsns17.cr.usgs.gov/NewEarthExplorer)

Data attribute	Attribute value	Data attribute	Attribute value
entity ID	EO11460402005103110PF_PF1_01	Scene Start Time	2005_103_05:07:05
Acquisition Date	April 13, 2005	Scene Stop Time	2005_103_05:11:25
Site coordinates	29.17, 77.70	Date Entered	April 13, 2005
NW Corner	29.712443, 77.800198	Target Path	146
NE Corner	29.698625, 77.876903	Target Row	40
SW Corner	28.796505, 77.566649	Sun Azimuth	125.40
SE Corner	28.782861, 77.642726	Sun Elevation	59.03
Cloud Cover	0-9%	Satellite Inclination	98.21
Receiving Station	PF1	Look Angle	-2.1523

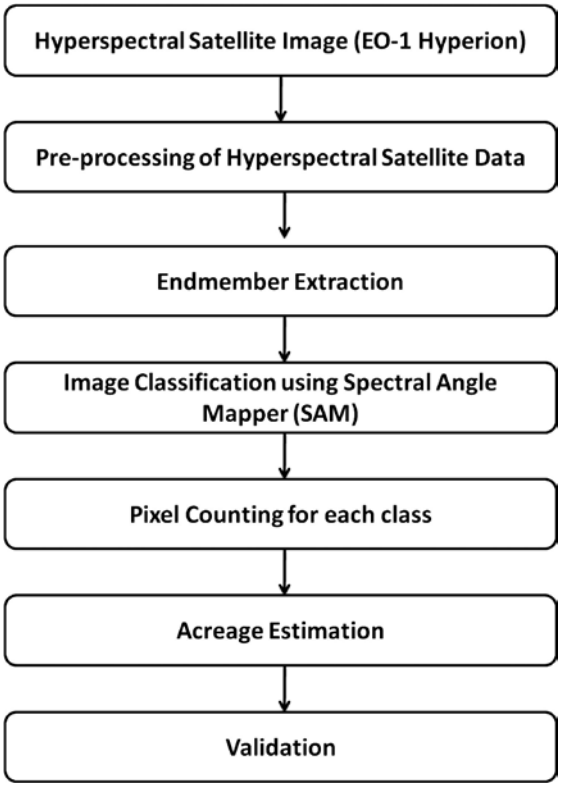

Fig. 2. Methodology for area estimation in mango.

because of their low spatial resolution which causes the mixing of spectral response of features within apixel. As hyperspectral sensors acquire data in narrow wavelength bands of width of the order of 10 nm, data volume is much more than the conventional system. Therefore, different pre-processing techniques applied to the data set in this work are bad band removal, image registration, atmospheric corrections, dimensionality reduction using Minimum Noise Fraction (MNF), purest pixel identification and extraction. Bad bands mean bands which do not provide any information should be removed. These are the water vapour absorption bands, overlapping bands, bands which are not illuminated properly. These bands should be removed because of higher noise level present in these bands. There are a number of corrupted pixels and dark vertical strips in the Hyperion datasets that are caused by calibration differences in the Hyperion detector array and temporal variations in the detectors response (Acito *et al*., 1). The geometric calibration of the image data can be done by the georeferencing. It is the simplest way of linking an image data to a projection system. Geometric correction is undertaken to avoid geometric distortions from a distorted image and is achieved by establishing the relationship between the image co-ordinate system and the geographic co-ordinate system using calibration data of the sensor, measured data of position, the ground control points, atmospheric conditions, etc. (Dobhal, 2). The electromagnetic signals recorded by the airborne or space borne hyperspectral sensors are a combination of the signals from earth's surface, atmospheric constituents and sensor errors. Thus, for quantitative analysis of the earth reflectance, these atmospheric effects need to be removed from the acquired signal and the procedure is called an atmospheric correction. The objective of atmospheric correction is to collect the surface reflectance (that characterises the surface features) from the hyperspectral imagery by removing the effects of atmosphere and it should be done carefully because it determines the usability of the final data. In atmospheric corrections, radiance values are converted into apparent surface reflectance, measuring the fraction of the radiation reflected from the earth surface. FLAASH module of ENVI is used for atmospheric correction of satellite images. In hyperspectral image processing, MNF is commonly used to align the data along the axis of decreasing

the signal to noise ratio (SNR). This technique is applied for removing redundancy and reducing dimensionality from hyperspectral data. It is a linear transformation consist of two separate PCA rotations in which at the first step it reduces the redundancy by creating independent bands which contain complete independent information and in the secondstep we select only first few transformed bands which may represent a very good percentage of information of original bands. The reflected spectrum of a pure feature is called a reference or *endmember* spectrum. Endmember spectra are extracted under idealized laboratory conditions where reflected spectrum is obtained with a spectrometer focused on a single feature. When this is impractical, the endmembers are derived from image manually. The Pixel Purity Index (PPI) is a commonly used algorithm for determining the purest pixels in an input image. The PPI algorithm ranks image pixels based on their pixel purity indices. Then, the pixels with the highest pixel purity values are returned as potential endmembers. The number of endmembers is not determined by this algorithm. It provides an interactive tool for extracting specific pure endmembers. Spectra can be thought of as points in n-dimensional scatter plot, where 'n' is the number of bands. Distribution of these points in n-space is used to estimate the number of spectral endmembers and their pure spectral signatures. It clusters the purest pixels and makes it separate class and then export the selected classes to ROIs and use them as input to classification.Based on the endmembers we classify the image by using Spectral Angle Mapper. SAM computes the spectral similarity betweenan image spectrum and the reference spectrum. If the angle is below a threshold angle (0.1 radian) then this classification procedure classify the pixel into endmembers class. The spectral angle mapper uses an n-dimensional angle to match pixels to reference spectra. The spectra of individual pixels are described as vectors in an n-dimensional space, where 'n' is the number of spectral bands. Each vector has certain length and direction. The length of the vector represents the brightness of the pixel while the direction represents the spectral feature of the pixel.To compare two spectra, such as an image pixel spectrum and a library reference spectrum, the multidimensional vectors are defined for each spectrum and the angle between the two vectors is calculated. Smaller angle means there is a close match to the reference spectrum. Spectral angle values are between 0 and $\pi/2$ and are calculated as

$$\theta = \cos^{-1}\left(\frac{\sum_{i=1}^{n} t_i r_i}{\sqrt{\sum_{i=1}^{n} t_i^2 \sum_{i=1}^{n} r_i^2}}\right) \quad (1)$$

where, n is the number of spectral bands, t is the reflectance of the actual spectrum and**r** is the reflectance of the reference spectrum.After the classification of EO-1 hyperion image of Meerut, total number of pixels in the mango orchards class wasidentified and then area of Mango orchards were obtained by multiplying the number of pixels classified into the mango class with the size of each pixel. Accuracy assessment of area estimation was done by using Google Earth.

RESULTS AND DISCUSSION

Hyperspectral satellite image contain huge volume of data which leads to redundancy and dimensionality problem. Therefore, before doing image classification different pre-processing techniques were applied to remove bad bands and atmospheric noise from the image and to reduce dimensionality in the data. In hyperspectral satellite image of Meerut, only 159 number of bands are found good and rest are bad bands. Those bad bands are removed from the data set before going to further pre-processing techniques (Fig. 3).

To select the Ground Control Point (GCP), permanent features like railway lines, road crossings, built up, etc. which are easy to locate on both map and Hyperion image is used. Root means square error (RMSE) for the geo-corrected image was found 0.43. Geo-correction also involves selection of the transformation projection and the Datum which was taken as Universal Transverse Mercator (UTM) and WGS84 respectively. Presence of atmospheric noise may influence the reflected radiation received by the sensor. So, atmospheric correction of EO-1 hyperion image of Meerut was done by using FLAASH module of ENVI (Fig. 4). In this module only basic information like site location, flight altitude, sensor model, local visibility and acquisition time required are needed

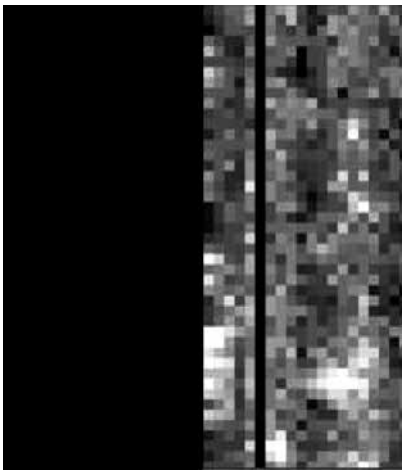

Fig. 3. Bad bands from EO-1 Hyperion image of Meerut.

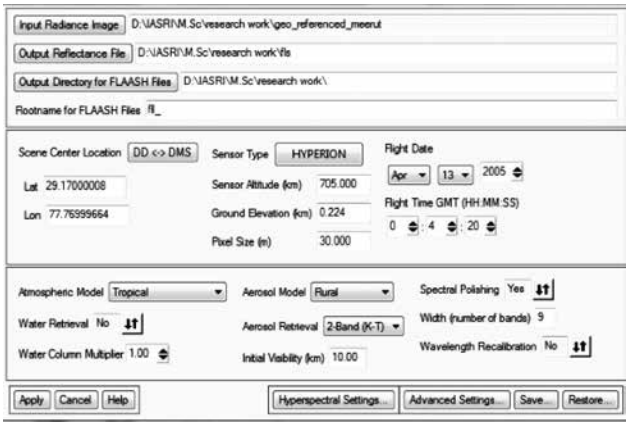

Fig. 4. FLAASH module for Atmospheric Correction.

to perform atmospheric correction. Fig. 5 shows the atmospherically corrected image.

On applying MNF on atmospherically corrected satellite image of Meerut, it was seen that only first 27 transformed bands contain almost 90% of the information of the original bands. Therefore, these 27 bands were selected for creating reduced MNF band image, which was later used for image classification. The MNF transformed image and MNF plot is shown in Fig. 6.

Endmembers were identified and extracted using PPI and n-Dimensional visualizer. This endmembers represent only mango orchards. In Fig. 7, PPI image and n-Dimensional visualizer window are shown. Based on the endmembers spectra of 24 Mango orchards image was classified using spectral angle mapper. The resulted SAM classified image is represented in Fig. 8.

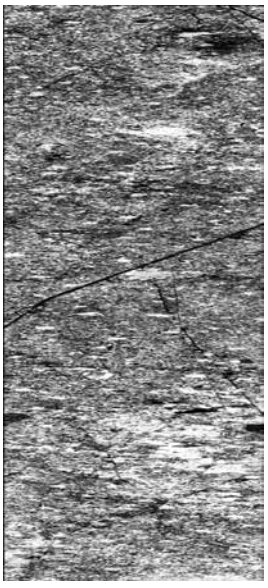

Fig. 5. Atmospherically corrected image of Meerut.

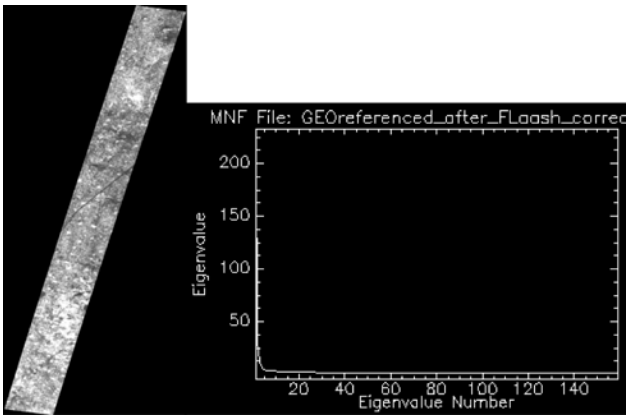

Fig. 6. MNF image and MNF plot of Hyperion image of Meerut.

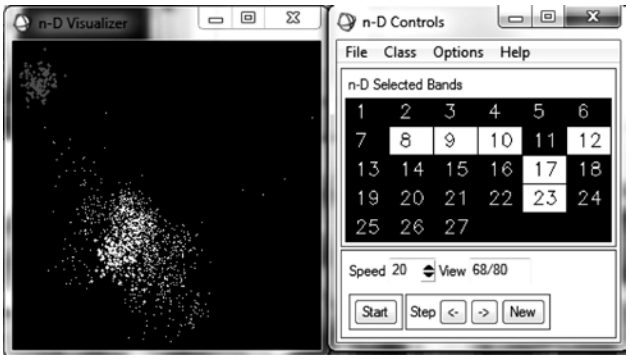

Fig. 7. PPI image and n-Dimensional plot of hyperion image.

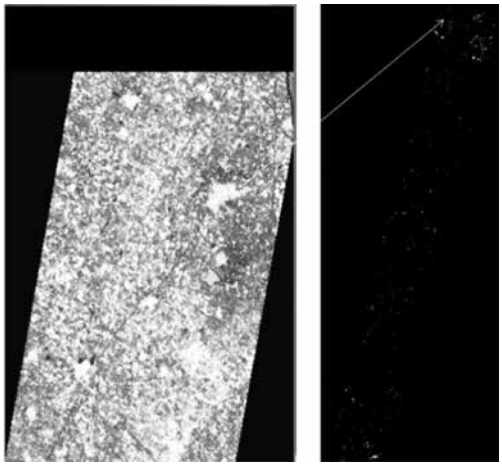

Fig. 8. SAM classified image.

After image classification, total number of pixels in the Mango orchard class were identified. Area of Mango orchards was obtained by multiplying the total number of pixels identified for mango orchard class with the size of each pixel. In the SAM classified image 9885 pixels of mango were identified. Since

the spatial resolution of the sensor is 30 m, the pixels size accounts to (30 × 30 sq. m.). Thus the total area under mango orchard is calculated as (9985 × 30 × 30 = 8896500) sq. meter or 889.65 hectare. Twenty four mango orchards were identified in the image (Paul, 5). The coordinates (latitude & longitude) of these mango orchards were recorded using GPS and are shown in Table 2.

Further, the area of 24 mango orchards was recorded using GPS and the area under these orchards was also obtained from the classified image which is shown in Table 3.

Further, regression analysis was performed assuming the actual area obtained from GPS as independent variable and area obtained using satellite data as dependent variable to predict the area under mango in the satellite image. The area obtained using satellite data was predicted using the constants of this regression equation. The plot of regression is shown in Fig. 9.

Table 2. Coordinates of mango orchards identified in the image.

Mango orchard No.	Mango orchard location	Latitude	Longitude
1	Before Gurukul Bus stop	29.696569°	77.848529°
2	Purquazi	29.665744°	77.841474°
3	BwPurquazi and Abdulpur	29.635641°	77.837343°
4	Mandla	29.612320°	77.823439°
5	Phalouda	29.631335°	77.812551°
6	Near Barla	29.600825°	77.789657°
7	Chhapar	29.578146°	77.775040°
8	Inside Chhapar-	29.563893°	77.776678°
9	Datiyana	29.512227°	77.787255°
10	Mustafabad	29.472328°	77.750959°
11	Mustafabad	29.465019°	77.747105°
12	Bilaspur	29.454020°	77.742200°
13	Salajuddi	29.411451°	77.736787°
14	Above Bhainsi	29.319025°	77.725439°
15	Nh58- Raipur Nagli	29.291349°	77.715821°
16	Phulat	29.277050°	77.704037°
17	Before Khatauli	29.271625°	77.716324°
18	Dhahbazpur Tingai	29.249603°	77.725881°
19	NH-58	29.238746°	77.726012°
20	NH-58	29.215010°	77.721677°
21	Sakoti Rly Stn	29.191875°	77.716030°
22	Near Sakoti	29.180903°	77.713486°
23	NH-58	29.154757°	77.713945°
24	Walidpur	29.140810°	77.718411°

Table 3. Comparison of area under GPS and Hyperion image.

Mango orchard No.	Area GPS (ha)	Area hyperion (ha)
1	3.22143	2.789
2	5.63895	4.891
3	3.85708	3.597
4	1.14708	1.049
5	4.42724	3.869
6	1.32623	0.912
7	1.65727	1.259
8	2.04305	1.987
9	3.08288	2.869
10	6.99187	5.997
11	2.03217	1.731
12	9.34408	8.036
13	0.37959	0.159
14	0.24720	0.259
15	0.30765	0.296
16	1.48500	1.289
17	1.14080	1.057
18	0.26256	0.055
19	0.69852	0.470
20	5.67319	4.865
21	1.36491	1.056
22	1.03190	1.023
23	23.15287	21.568
24	5.78992	4.978

The predicted area under the whole hyperion image was obtained as

$$Y = 1.081 \times (889.65) + 0.1726$$
$$= 961.71165 + 0.1726$$
$$= 961.88 \text{ ha}$$

A similar study was carried out by Panda et al., (7) In that study, fruit and nut crops were evaluated using many multispectral as well as one of the narrow band hyperspectral data and results of the study encouraged used of images for orchard mapping. The results of present study also endorse the use of satellite data for estimation of area under fruit crop. In hyperspectral satellite data, every pixel provides a reflectance spectrum that can be compared to the ground measured spectra. Therefore, the results of present investigation encourage the use of hyperspectral data to estimate acreage of orchards. The results of present study has quite good resemblance with the results of the study carried out by Taylor et al. (8). He also concluded that hyperspectral imagery offers

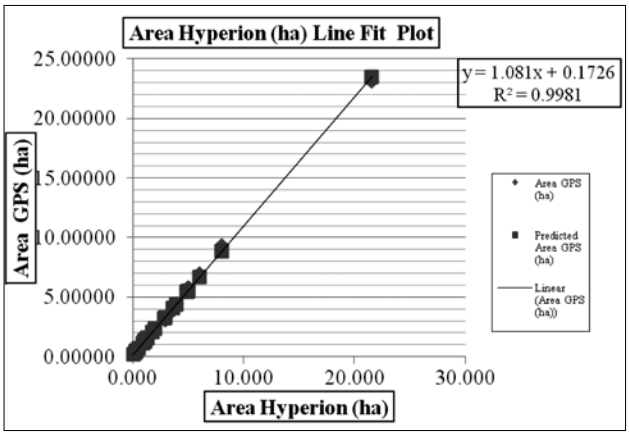

Fig. 9. Line of fit plot based on 24 Mango orchards (GPS points) of Meerut.

better estimation accuracy compared to multispectral imagery.

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Rootstock evaluation for sweet orange cv. Early Gold in arid irrigated region of Punjab

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ABSTRACT

The performance of sweet orange cv. Early Gold on different rootstocks was evaluated at Regional Research Station Abohar, Punjab during 2013-16. The plants budded on different rootstocks were supplied by Punjab Agri Export Corp. Ltd., imported from USA. The data was analyzed in a randomized block design, replicated four times. Fruit yield was significantly higher and comparable in trees raised on Carrizo citrange (39.1 kg/tree) and *Jatti khatti* rootstock (37.7 kg/tree) than other rootstocks. Fruits on Carrizo rootstock registered maximum juice content (48.47%), which was statistically same as observed on *Jatti khatti* and Volkamer lemon. Total soluble solids were also highest on Carrizo. Fruit quality index (TSS:acid ratio) was comparable in Volkamer lemon, *Jatti khatti* and Carrizo citrange rootstocks. The trees raised on commercial *Jatti khatti* rootstock were quite younger but resulted comparable yield and fruit quality to that of Carrizo. Hence, *Jatti khatti* seem to be the most suitable rootstock for raising 'Early Gold' sweet orange in arid irrigated regions of Punjab.

Key words: Leaf nutrient, fruit quality, yield.

INTRODUCTION

Citrus is one of the important crops of tropical, subtropical and Mediterranean regions. In India, Gross annual citrus fruit production during 2014-15 was 11655, 000 MT and hold sixth position among top ten citrus players of world (NHB, 9). At national level, Telangana, Maharashtra, Madhya Pradesh, Andhra Pradesh and Punjab are top citrus growing states and accounts for about 60 and 70 per cent in the total area and production of the country, respectively. The contribution of Punjab alone in country's total area and production of citrus fruit is about 6 and 10 per cent (NHB, 9). Climatic conditions of Southwest regions of Punjab are most suitable for producing high quality citrus fruits.

Kinnow is the most preferred citrus crop of Punjab. Besides being a remunerative crop, its bright coloured citrus fruits are very attractive, rich in vitamin-C and contain high juice content. But, fresh fruits of Kinnow are available in the market during January-March. Hence, there is always a high demand for citrus fruits in the market especially during November and December. In early group, Mosambi is one of the options; however, it could not gain much commercial importance, since a small delay in harvesting may result in occurrence of granulation which drastically affects the fruit quality. Therefore, the replacement of Mosambi with other flawless early sweet orange varieties like 'Early Gold' may prove highly remunerative for citrus growers of this region.

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The use of rootstock plays an important role in profitable orchard management. Tree vigour, yield and physico-chemical characteristics of fruits are markedly influenced by rootstocks (Wutscher, 16). US-1213 and US-1210 rootstocks produced fruits with higher soluble solids than US-1203 and US-1205 (Bowman and McCollum, 4). Al-Jaleel *et al.* (2) also reported variable fruit yield and quality of 'Allen Eureka' lemons grafted on different rootstocks. The findings from earlier rootstock trials have, however, revealed different results owing to local climatic conditions and edaphic factors (Rouphaela *et al.,* 13). Therefore, the outcomes of these trials cannot be replicated as such from one part of the world to another without a thorough local evaluation of rootstocks. With these considerations, performance of 'Early Gold' sweet orange was evaluated on locally most accepted *Jatti khatti* rootstock as well as on some exotic rootstocks.

MATERIALS AND METHODS

A sweet orange cultivar 'Early Gold', budded on Carrizo, C-35, Benton, Volkamer Lemon and 852 rootstocks was supplied by Punjab Agri Export Corporation Limited (PAGREXCO), imported from USA. These stock/scion combinations were planted in the demonstration block of Punjab Agricultural University (PAU) Regional Research Station Abohar, Punjab, India during the year 2005. The plantation was made in pits of size 3 × 3 × 3ft at a spacing 25 × 15 ft. cultivar 'Early Gold' was also budded on local *Jatti Khatti* rootstock and planted in the experimental

field of Regional Research Station Abohar during 2009. All cultural practices were followed as per standard package of practices, Punjab Agricultural University (PAU), Ludhiana.

The study area was located at an altitude of 180 m above mean sea level with a latitude and longitude of 30.14° and 74.20°, respectively. Climate of area has been assigned a nation 'BWh' by Köppen-Geiger system of classification. The experimental soil was sandy loam with 7.85 pH, 0.22 dS/m EC and 0.37% organic carbon. The soil was low in available N, medium in P and high in K content.

Leaf samples were collected as per standard procedure (Kumar and Sharma, 7) and analysed for N, P and K content (Jackson, 6).Trunk girth, tree height and spread were measured during February. Fruit yield was recorded by counting the number of fruits per tree multiplied by fruit weight. Physico-chemical characteristics of fruit were determined only for 2015 and 2016. The fruit weight was determined by calculating mean weight of randomly selected 20 fruits in each combination. The observations on fruit size and peel thickness were recorded with the help of by 'vernier calliper'. 'Hand refractrometer' was used for the estimation of total soluble solid (TSS) content of fruits. Total titratable acidity, ascorbic acid and reducing content of fruits were determined following standard methods as outlined in A.O.A.C. (1).

The data were subjected to analysis using the statistical package SPSS and Microsoft Excel. Treatment means were compared considering least square difference at 5% level of significance.

RESULTS AND DISCUSSION

The data (Table 1) revealed maximum leaf N content in trees budded on Carrizo rootstock (2.90%). The values were statistically at par with Jatti Khatti (2.73%). Benton and Volkamer Lemon exhibited almost similar leaf N content. Higher P was noted on Benton, *Jatti Khatti* and Volkamer rootstocks. Leaf K was higher on Benton (1.8%) which was statistically similar to Carrizo citrange (1.7%). Higher leaf calcium was noticed on Benton, *Jatti Khatti* and Carrizo whereas; magnesium was recorded significantly higher on Carrizo rootstock. Furthermore, trees on Benton registered maximum value for leaf Cu (4.4 ppm), followed by Carrizo (3.8 ppm). Iron content was notably higher on Volkamer lemon (282 ppm). Zinc content was maximum on *Jatti khatti* whereas, higher leaf Mn content was observed on Volkamer Lemon and Benton rootstocks. It is clear from the data that different rootstocks behave differently in terms of nutrient uptake from the soil. These results may be attributable to rootstock/scion combinations which have been supposed to govern water and nutrient uptake by the plants (Lee and Oda, 8; Ruiz *et al.*, 14; Pulgar *et al.*, 11 and Rouphael *et al.*, 12).

The data presented in Table 2 indicate significantly higher tree spread in trees budded on Carrizo rootstock (4.72 m). Minimum spread was observed in trees raised on C-35 (3.63 m). Maximum tree height was achieved on *Jatti khatti* (3.52 m), which was statistically at par with other rootstocks except C-35. Tree canopy volume was significantly highest on Carrizo rootstock (29.1 m^3) followed by *Jatti khatti* (25.4 m^3).

It is also evident from data (Table 2) that trees on Carrizo rootstock asserted maximum fruit number (244) followed by Benton (243) while, lesser number of fruits was noted in C-35 rootstock (201). Heavier fruits were observed in trees budded on *Jatti khatti* (164 g), and Carrizo (160 g). Comparatively, lower fruits weight was noticed in trees raised on Volkamer lemon and C-35 rootstocks. Fruit size (length and breadth), however, was better in Carrizo and C-35 rootstocks but the values were statistically non-significant over other rootstocks. Maximum fruit yield on Carrizo (39.1 kg/tree) which was 3.7% higher than trees raised on *Jatti Khatti* (Table 3). Minimum fruit yield was noted on C-35 rootstock. Seed number was significantly higher in C-35 and Volkamer Lemon rootstocks (Table 2).

Higher tree vigour, fruit weight and more number of fruits in Carrizo and Jatti Khatti rootstocks may

Table 1. Effect of different rootstock on leaf nutrient content*.

Rootstock	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	Cu(ppm)	Fe(ppm)	Zn(ppm)	Mn(ppm)
Benton	2.47	0.18	1.8	3.93	0.59	4.4	242.4	21.0	9.5
Jatti khatti	2.73	0.18	1.4	3.88	0.64	3.2	149.4	24.6	8.6
Carrizo	2.90	0.15	1.7	3.82	0.70	3.8	182.0	22.2	8.4
V. lemon	2.59	0.18	1.4	3.62	0.64	3.0	200.0	21.6	9.8
C-35	2.21	0.16	1.2	3.14	0.54	3.0	166.4	21.5	8.6
$LSD_{0.05}$	0.17	0.01	0.1	0.28	0.04	0.2	16.3	2.0	0.7

*Av. data of 2015 ad 2016

Table 2. Effect of rootstocks tree growth* and physical characteristics of fruits**.

Rootstock	Stock / scion	Tree spread (m)	Tree height (m)	Canopy volume (m^3)	No. of fruits/ tree	Fruit wt. (g)	Fruit length (cm)	Fruit breadth (cm)	Peel thickness (cm)	No. of seed
Benton	1.06	3.76	3.39	22.9	243	150	6.1	6.5	0.52	3.1
Jatti Khatti	1.04	3.87	3.52	25.4	230	164	6.3	6.5	0.56	2.4
Carrizo	1.08	4.72	3.42	29.1	244	160	6.5	6.7	0.53	2.3
V. Lemon	1.10	3.79	3.33	22.2	236	147	6.1	6.6	0.57	3.4
C-35	1.15	3.63	3.19	19.5	201	131	6.3	6.4	0.52	3.4
$LSD_{0.05}$	NS	0.33	0.31	2.3	17.2	12	NS	NS	NS	0.2

*avg. data of 2013-2016, **avg. data of 2015 and 2016

Table 3. Effect of rootstocks on fruit yield.

Rootstock	Fruit yield (kg/tree)				Av.
	2013	2014	2015	2016	
Benton	39.8	28.5	34.3	43.4	36.5
Jatti khatti	31.7	38.1	36.8	44.1	37.7
Carrizo	39.1	43.4	31.7	42.2	39.1
V. lemon	29.3	31.9	34.7	43.0	34.7
C-35	26.3	26.3	23.4	29.2	26.3
$LSD_{0.05}$	2.4	2.5	2.6	2.5	2.5

be ascribed to better absorption of nutrients from the soil (Table 1). Enhanced nutrient uptake and assimilation may have resulted in higher tree growth as reflected by canopy volume. Canopy volume is a measure of source size which directly influences certain critical plant processes like photosynthesis and consequently-the tree response. Anderson (3), Obreza and Rouse (10) and Syvertsen and Lloyd (15) also co-related positively the tree canopy volume with number of fruits, fruit weight and yields in citrus. Furthermore, fruit yield is a function of fruit weight and number of fruits. Better allocation of photosynthates in terms of fruit size and numbers on Benton, C-35 and Carrizo rootstocks may therefore be assumed.

Rootstocks significantly influenced the fruit quality of Early Gold (Fig. 1-2). Fruits juice content was higher and comparable in *Jatti Khatti*, Carrizo and Volkamer Lemon than other rootstocks tried (Fig. 1). Trees raised on Carrizo rootstocks exhibited minimum juice content which was statistically at par with *Jatti Khatti* and Volkamer Lemon. Total soluble solids were also highest on Carrizo which was statistically similar to Volkamer Lemon. The data in Fig. 2 revealed highest fruit quality index (TSS-acidity ratio) in Volkamer Lemon which was statistically at par with *Jatti Khatti* and Carrizo rootstocks. Ascorbic acid content in fruits was found to be significantly

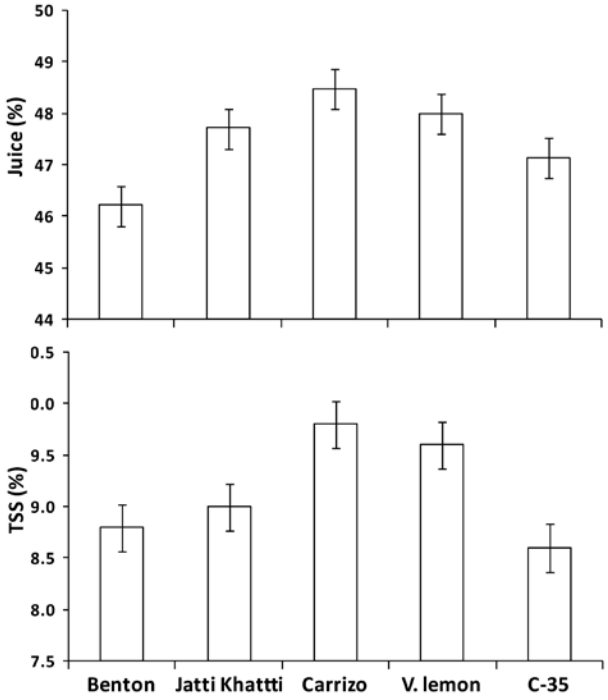

Fig. 1. Juice and TSS content of fruits as influenced by different rootstocks.

higher and comparable between *Jatti Khatti* and Volkamer Lemon rootstocks as compared to other rootstocks (Fig. 2). Reducing sugar and titratable acidity was significantly higher in Carrizo and C-35 rootstocks, respectively (Fig. 3).

Rouphaela *et al.* (13) concluded that rootstock and scion compatibility may induce undergrowth or overgrowth of the scion. This varying growth behaviour may lead to differential water and nutrient flow through the grafted union and consequently variable fruit quality of produce. Castle (5) also reported that in citrus, fruit and juice quality are closely related to rootstock effects on plant water relations. Rootstock also supposed to have bearings

on translocation of photosynthates and synthesis of plant hormones which affect the fruit quality (Lee and Oda, 8).

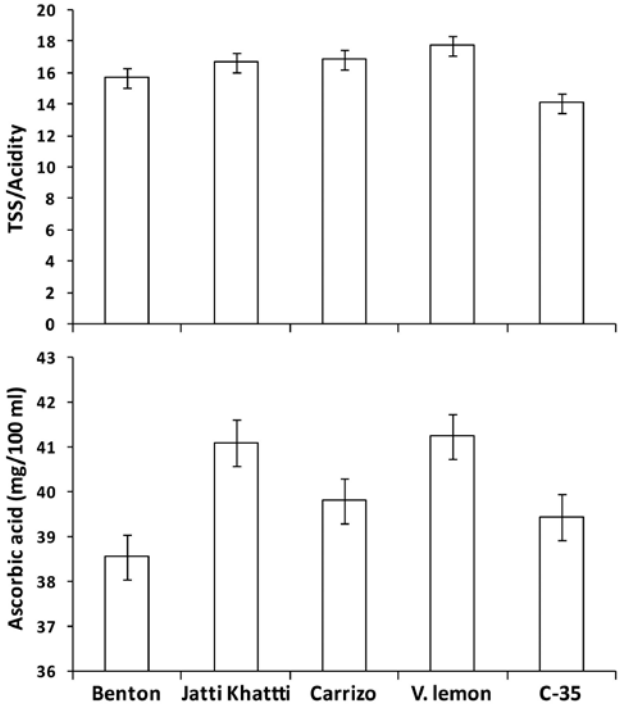

Fig. 2. Chemical fruit quality characteristics of 'Early Gold' on different rootstocks

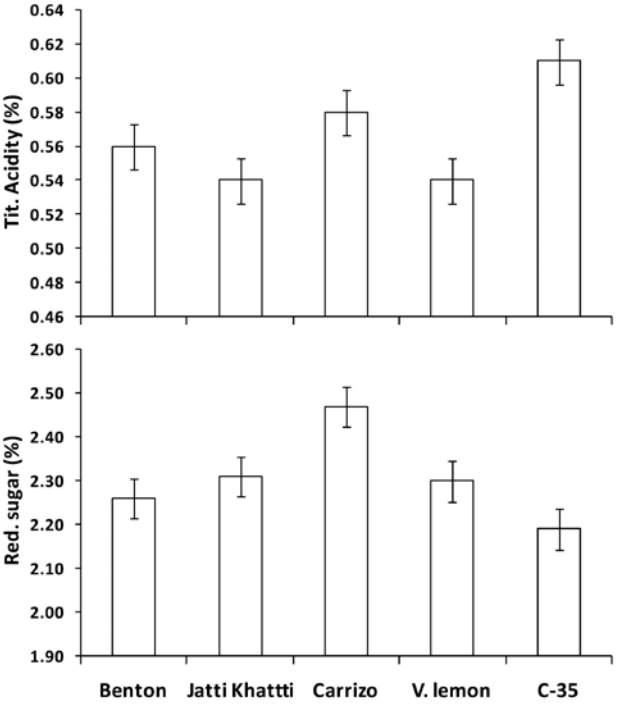

Fig. 3. Influence of rootstock on reducing sugar and titratable acidity of 'Early Gold'.

The results of study clearly demonstrated that a given scion can only perform better on a particular rootstock. Hence, selection of a suitable rootstock seems very crucial for maintaining higher productivity as well as quality of fruits. Carrizo and *Jatti Khatti* maintained higher tree vigour and productivity of sweet orange var. 'Early Gold' with the assurance of good quality fruit. Also, it is worthwhile to mention that trees raised on commercial Jatti Khatti rootstock were quite younger than trees budded on Carrizo rootstock, however, both resulted in comparable yields. This proved the superiority of Jatti Khatti over Carrizo both in terms of tree vigour and productivity of 'Early Gold. Hence, *Jatti Khatti* is considered most suitable rootstock for raising 'Early Gold' sweet orange in arid irrigated regions of Punjab.

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Nutritional status of apple orchards in Kinnaur region of Himachal Pradesh

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ABSTRACT

The nutritional survey of 82 representative orchards was carried out in apple growing blocks of district Kinnaur of Himachal Pradesh. Maximum variation in leaf N, P, K, Ca and Mg contents was recorded in apple orchards of Nichar block. Deficiencies of N, Mg, Zn, B, Mn and Mo were quite common in the orchards of all the three blocks, but Ca and K were deficient in Nichar and Pooh blocks only. However, the deficiency of P was recorded in Kalpa and Pooh blocks only. Leaf analysis showed that 7.3, 7.3, 12.2, 13.4, 25.8, 31.7, 14.6 and 9.7% orchards were deficient in N, K, Ca, Mg, Zn, B, Mo and Mn, respectively. The soils of apple orchards were moderately acidic to slightly alkaline in soil reaction with normal electrical conductivity and rich in organic carbon. Variability in pH, EC, organic carbon (%), N, P, Ca, Mg, Zn, Cu and Mo contents was also observed the highest in the soils of apple orchards located in Nichar block, while K, Fe, Mn and B were found highly variable in orchards of Pooh block only. All the leaf and soil nutrients showed synergetic effect on fruit yield except Cu and Fe.

Key words: *Malus domestica*, soil and leaf nutrients, spatial variability.

INTRODUCTION

Apple is one of the most important fruit of Himachal Pradesh, since it occupies 49 percent of total area under fruit crops with an estimate production of 777 thousands tones over an area of 110.7 thousand hectares (Anonymous, 1). The yield levels of apple (7.02 t/ha) in the state are, however, far below the international standards of (30 t/ha). Royal Delicious is the most popular cultivar of Himachal Pradesh as table fruit due to its shape, colour, quality and marketability but has the disadvantages of low yield per unit area, high production cost, alternate bearing and susceptibility to disease. The low apple productivity as compared to international standards has been ascribed to various factors such as varietal, soil fertility, imbalanced nutrition, topography of land and incidence of pests and diseases. It is therefore, inevitable to consider the analysis assessing the nutritional availability of fruit growing crops with deep and ramified root system (Najar *et al*., 11). Nutritional imbalances in the soil cause nutritional disorders and consequently affect both quality and quantity of fruit. Soil and plant analysis are complimentary to each other, because at a time one component may or may not provide the requisite information. The nutritional analysis of soil and plant thus provides a valuable tool for understanding the nutrient supplying capacity of soil for ascertaining the relationship between available nutrients and leaf nutrient status and therefore predicting the yield levels (Dar *et al.*, 3).

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Like other hilly areas, the economy of district Kinnaur of Himachal Pradesh mainly dependent upon horticulture. The climate of this area due topographical variations and altitudinal differences provide congenial environment for growing high quality apple fruits. The apples of this region possess qualities at par with international standards for export purposes. In spite of increasing importance of apple as a commercial crop in this temperate region, no adequate scientific study concerning leaf diagnostic and soil fertility status had been made so far. Therefore, the study was conducted to carry out the nutritional survey of apple orchards of Kinnaur district through soil and leaf nutrient status andtheir relationship to use such knowledge as a tool in optimizing fertilizers use for better fruit yield and quality.

MATERIALS AND METHODS

The present study was carried out in Kinnaur region which extends from 30°22'40" to 33°12'40"N latitude and 75°47'55" to 79°04'20"E longitude (Fig 1.1 & 1.2). The district has unique climatic conditions having three typical microclimatic zones, *i.e.* Nichar, Kalpa and Pooh (sub-division/ block). Winters are severe with heavy snowfall (5220 mm) causing glaciers and avalanches particularly in some parts of Kalpa and Pooh blocks. Summers are mild with rainy season in most of the Kalpa and Nichar blocks of the district with lighter snowfall. Pooh block of this district forms a part of the 'Indian Cold Desert' and receives scanty rainfall (< 100 mm) but as it falls in rain-shadow zone of Himalayas.

The field surveys were undertaken on apple orchards with cultivar Royal Delicious, which is the widely cultivated in the district. Eighty-two geographical locations spread over three sub-divisions (Nchar-24, Kalpa-31 and Pooh-27) were selected in the district for collecting soil and leaf samples. Selected sites detail has been given in the Table 1. Geo-referenced

Table 1. Details of the selected apple orchards located in three apple-growing blocks of Kinnaur district.

Location	Latitude	Longitude	Elevation (m)
Nichar block			
Bari-I	31° 33' 09" N	077° 56'20.4"E	2195
Bari-II	31° 33'09.6" N	077° 56'32.9" E	2205
Bari-III	31° 33'11.7" N	077° 56'31.3" E	2179
Bari-IV	31° 33'09.7" N	077° 56'37.1"E	2230
Sungra-I	31° 33'28.3" N	077° 56'01" E	2020
Sungra-II	31° 33'16.5" N	077° 56'10.5" E	2089
Sungra-III	31° 33'09.4" N	077° 56'14.6" E	2180
Nichar	31° 33'24.6" N	077° 56'37.4"E	2045
Bara Kamba	31° 34'34.75" N	077° 53'09.1" E	2085
ChhotaKamba-I	31° 34'06.4" N	077° 54'32.9" E	2070
ChhotaKamba-II	31° 34'07.4" N	077° 54'29.2" E	2037
ChhotaKamba-III	31° 34'05.9" N	077° 54'36" E	2100
Chaura	31° 34'09.83" N	077° 51'10.7" E	1735
Nigulsari	31° 33'24.2" N	077° 52'52.16" E	1700
Kafnu	31° 36'48.1" N	078° 01'34.6" E	2447
Huri	31° 36'59.75" N	078° 01'34.81" E	2476
Kafnoo	31° 36'56.7" N	078° 01'27.6"E	2440
Yangpa	31° 36'56.2" N	078° 01'43.6" E	2546
Katgaon	31° 35'34.9" N	078° 02'12.7" E	2254
Chagaon-I	31° 32'08" N	078° 05'31.1" E	2523
Chagaon-II	31° 32'03.5" N	078° 05'28.9" E	2500
Chagaon-III	31° 32'03.36"N	078° 05'28.1"E	2488
Urni	31° 31'44.61"N	078° 07'50.5" E	2288
Urni	31° 31'37.2" N	078° 07'52.18" E	2240
Kalpa block			
Sangla	31° 25'29.25" N	078° 15'41.54" E	2587
Rakchham	31° 23'51" N	078° 20'40.70" E	3000
Batseri	31° 24'13.7" N	078° 18'17.6" E	2829
Sangla	31° 25'46.6" N	078° 16'14.4" E	2780
Kuppa-I	31° 25'59.1" N	078° 14'50.95" E	2578
Kuppa-II	31° 25'57.1" N	078° 14'46.8" E	2572
Kilba	31° 29'19.7" N	078° 08'11.7" E	1836
Purbani	31° 35'13.1" N	078° 17'51.76" E	2435
Talampi	31° 32'56.84" N	078° 18'00.92" E	2270
Tangling	31° 31'34.11" N	078° 16'54.4" E	1972
Barang	31° 30'24.20" N	078° 16'05.65" E	2373
Sharbo-I	31° 32'21.37" N	078° 16'34.81" E	2142
Sharbo-II	31° 32'16.65" N	078° 16'35.4" E	2160
Mebar-I	31° 35'31" N	078° 15'20.5" E	2810
Mebar-II	31° 35'28.2" N	078° 15'24.7" E	2758
Mebar-III	31° 35'29.6" N	078° 15'21.9" E	2795
Rali-I	31° 29'33.58" N	078° 12'24.03" E	2220
Rali-II	31° 29'35.17" N	078° 12'26.35" E	2170
Talangi	31° 33'32.9" N	078° 16'01.8" E	2501
Khwangi	31° 33' 28.7" N	078° 16'25.3" E	2244
Roghi	31° 30' 51.58" N	078° 13'50.84" E	2767
Kalpa	31° 32' 24" N	078° 15'02" E	2871
Duni-I	31° 32' 43.1" N	078° 15'23.5" E	2737
Duni-II	31° 32' 42.1" N	078° 15'25.3" E	2717
Pangi	31° 35' 29.8" N	078° 16'40.5" E	2737
Boktu	31° 34' 41.4" N	078° 16'30.7" E	2530
Kothi	31° 32' 51.9" N	078° 16'08" E	2394
Shaung	31°26' 39.82" N	078° 1155.22" E	2748
Brua	31° 27' 58.47" N	078° 10'43.71" E	2135
Sapni	31° 28' 52.9" N	078° 10'08.30" E	2420
Sudarang	31° 31'17.85" N	078° 15'50.40" E	2325
Pooh block			
Giabong-I	31° 46'31.2" N	078° 26'41.35" E	2891
Giabong-II	31° 46'53.79"N	078° 26'37.1" E	2985
Giabong-III	31° 46'51" N	078° 26'30.9" E	2965
Ropa	31° 47'49" N	078° 25'13" E	3035
Rushkulang	31° 46'11" N	078° 26'55.9" E	2814
Sunnam	31° 45' 40.92"N	078° 27'58.37" E	2823
Shialkhar	32° 00' 31.48"N	078° 34'13" E	3040
Chango	31° 58' 42.66"N	078° 35'43.67" E	3054
Nako	31° 53'32.1" N	078° 37'31.65" E	3459
Leo	31° 53'11" N	078° 35'31" E	2971
Dubling	31° 44'49.54" N	078° 38'01.63" E	2804
Pooh-I	31° 45'39.75" N	078° 35'10.95" E	2587
Pooh-II	31° 45'57.92" N	078° 35'26.3" E	2811
Nesang	31° 38'43.26" N	078° 31'12.97" E	3064
Spello	31° 39'45.88" N	078° 26'16.27" E	2694
Labrang	31° 40'57.31" N	078° 26'36.65" E	2830
Kanam-I	31° 40'33.6" N	078° 27'06" E	2766
Kanam-II	31° 40'34.8" N	078° 27'08.66" E	2805
Moorang	31° 35'54.5" N	078° 26'46.5" E	2475
Thangi	31° 33'23.29" N	078° 28'42" E	2815
Lippa	31° 39'32.4" N	078° 23'07" E	2660
Asrang	31° 40'02" N	078° 19'06" E	3242
Jangi	31° 36'36.2" N	078° 25'40.8" E	2705
Akpa	31° 35'18.8" N	078° 23'09" E	2500
Rarang	31° 36'06.6" N	078° 21'13.7" E	2668
Rispa	31° 34'35.4" N	078° 25'18.3" E	2447
Ribba	31° 35'06.8" N	078° 21'37.6" E	2564

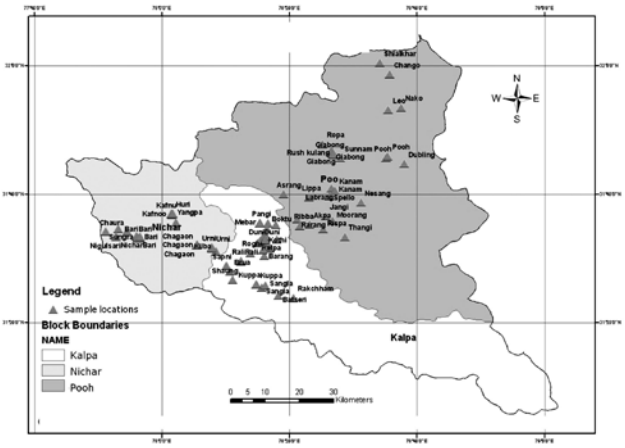

Fig. 1. Geographical location of the study area.

and stratified soil and leaf samples were collected at a grid size varying from 1.0 to 1.5 km^2 depending on the homogeneity of the area from the selected locations/ orchards. Four hundred and ten surface (30 cm) soil samples covering three blocks of district Kinnaur were collected with an auger during first week of November to third week of December. Leave samples (about fifty leaves per tree from middle of terminal shoot growth) were collected from the same tree/ orchard from which soil samples were collected between July 20 and end of the August during the year 2011-12.

The soil samples were ground and passed through 2 mm stainless steel sieve. These samples were analyzed for pH, electrical conductivity (EC), and organic carbon (OC) by standard methods (Jackson, 6). Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 16) and available P by Olsen *et al*., (12). Available K and exchangeable Ca and Mg were extracted using 1N neutral ammonium acetate solution (Jackson, 6) and were estimated using atomic absorption spectrophotometer(AAS Model AA-7000, Lab India).Available Cu, Zn, Fe and Mn were extracted as per the procedure described by Lindsay and Norvell (9) and estimated using atomic absorption spectrophotometer (AAS Model AA-7000, Lab India). Available B and Mo were extracted in hot water and acid ammonium oxalate of pH 3.3 solution and then determined by Carmine (Hatcher and Wilcox, 5) and stannous chloride (Johnson and Arkley, 7) methods, respectively.

The leaf samples were washed and dried as per the method described byKenworthy (8). Total N was determined by micro-Kjeldahl method, P by vanadomolybdate-phosphoric yellow colour method as suggested by Jackson (6). The K, Ca, Mg, Cu, Zn, Fe and Mn in the digest were estimated on atomic absorption spectrophotometer. The leaf B and Mo were determined by carmine (Hatcher and Wilcox, 5) and thiocyanate stannous chloride (Johnson and Arkley, 7) methods, respectively. The data were then categorized as deficient, low, optimum and high (above optimum) in leaf nutrient content in accordance with the working standards for apples (Kenworthy, 8). Orchards found between deficient and optimum range have been categorized as low and those above the optimum range as high (above optimum) in leaf nutrient status. About five to six trees per location was selected to record yield per tree and total fruit yield was estimated, accordingly. The data were analyzed statistically as per Panse and Sukhatme (13) and to establish the relationship between various parameters, the data were subjected to correlation analysis.

RESULTS AND DISCUSSION

The concentration of N, P, K, Ca and Mg in the leaves varied from 1.60-2.60, 0.18-0.33, 0.9-1.80, 0.9-2.10 and 0.24-0.45 percent, respectively (Table 2). The respective mean values for these nutrients were 2.25, 0.24, 1.50, 1.52 and 0.31 percent. The data further revealed that the maximum variation in leaf N, P, K, Ca and Mg contents were found in Nichar block with the highest values of coefficient of variation (12.30, 13.16, 14.82, 20.90 and 18.15%, respectively) followed by Kalpa and Pooh block orchards. Categorization of the leaf samples (Table 3) on the basis of standard concentrations of nutrient elements for foliar analysis of apple, revealed that in the different blocks 3.2-20.8% orchards were found deficient in leaf N, 79.2-96.8% in optimum and 0-11.1% were above optimum range in N (1.81-2.50%) with an overall mean values of 7.30, 89.0 and 3.7% in the district, respectively. Similarly, 0-6.5% orchards in different blocks with an overall mean value of 2.4% were deficient in leaf P, 74.1-93.5% in different blocks with mean value of 85.4% were in optimum range and 12.5-25.9% were above optimum range (0.19-0.28%) in different blocks in leaf P status with an average value of 12.2%. In K status, 7.4-16.7% orchards were deficient and 83.3-92.6% were in optimum range (1.21-1.80%) in different blocks with average values of 7.3 and 92.7%, respectively. However, 7.4-29.2% orchards were found to be in the insufficient range of leaf Ca in different blocks with an average value of 11.0% and 66.6-100% were in optimum range (1.21-1.80%) in different blocks with mean value of 82.9% along with 0-14.8% were in above optimum range in different blocks. While leaf Mg was found deficient in 11.1-16.1% orchards in different blocks with an average value of 13.4% and 66.7-83.9% were in optimum range(0.25-0.36%) in different blocks with mean value of 74.4% and 18.6-20.8% above optimum with an average value

Table 2. Leaf nutrient contents in orchards located in three blocks of Kinnaur district.

Nutrient	Nichar		Kalpa		Pooh		Overall mean	
	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)
				Macronutrient				
N(%)	1.60-2.40 (2.07)	12.30	1.80-2.50 (2.27)	6.42	2.10-2.60 (2.37)	6.50	1.60-2.60 (2.25)	9.80
P(%)	0.20-0.32 (0.25)	13.16	0.18-0.26 (0.22)	9.20	0.21-0.33 (0.26)	12.00	0.18-0.33 (0.243)	13.26
K(%)	0.90-1.70 (1.42)	14.82	1.30-1.70 (1.55)	6.43	1.20-1.80 (1.53)	11.00	0.90-1.80 (1.50)	11.20
Ca(%)	0.90-1.80 (1.40)	20.90	1.30-1.70 (1.52)	6.62	1.20-2.10 (1.62)	15.51	0.90-2.10 (1.52)	15.60
Mg(%)	0.24-0.45 (0.32)	18.15	0.24-0.36 (0.29)	12.0	0.24-0.40 (0.32)	15.54	0.24-0.45 (0.31)	15.80
				Micronutrient				
Fe(ppm)	164-390 (278.60)	25.16	98-337 (216.45)	27.44	98-358 (209.44)	39.80	98.00-390.00 (232.33)	32.90
Mn(ppm)	23-71 (46.67)	28.61	24-78 (47.06)	31.75	29-80 (52.00)	27.64	23.00-80.00 (48.60)	29.51
Zn(ppm)	11-35 (23.42)	28.80	15-45 (27.00)	27.45	15-46 (29.00)	28.85	11.00-46.00 (26.60)	29.30
Cu(ppm)	10-28 (14.03)	29.41	8.50-25 (16.06)	26.06	12.4-24.6 (14.37)	21.40	8.50-28.00 (14.91)	26.12
B(ppm)	17.7-36.5 (27.1)	25.67	24-38 (29.85)	11.00	18-45 (31.06)	19.05	17.70-45.00 (29.46)	16.80
Mo(ppm)	0.48-0.78 (0.61)	17.20	0.48-0.84 (0.59)	15.10	0.44-0.85 (0.63)	18.10	0.44-0.85 (0.61)	16.04

Figure in the parentheses are mean values.

Table 3. Leaf nutrient status of orchards located in three apple-growing blocks of Kinnaur district.

Nutrient	Nichar				Kalpa				Pooh				Overall mean			
	D	L	O	H	D	L	O	H	D	L	O	H	D	L	O	H
N	-	20.8	79.2	-	-	3.2	96.8	-	-	-	88.9	11.1	-	7.3	89.0	3.7
P	-	-	87.5	12.5	-	6.5	93.5	-	-	-	74.1	25.9	-	2.4	85.4	12.2
K	4.2	12.5	83.3	-	-	-	100	-	-	7.4	92.6	-	1.2	6.1	92.7	-
Ca	4.2	29.2	66.6	-	-	-	100	-	-	7.4	77.8	14.8	1.2	11.0	82.9	4.9
Mg	-	12.5	66.7	20.8	-	16.1	83.9	-	-	11.1	70.3	18.6	-	13.4	74.4	12.2
Fe	-	-	-	100	-	-	12.9	87.1	-	37.1	62.9	-	-	-	17.1	82.9
Mn	4.2	12.5	83.3	-	3.2	6.5	90.3	-	-	3.7	96.3	-	2.4	7.3	90.3	-
Zn	16.6	20.8	62.5	-	-	19.4	80.6	-	-	25.9	74.1	-	4.9	20.9	73.2	-
Cu	-	4.2	87.5	8.3	-	3.2	80.7	16.1	-	-	92.6	7.4	-	2.4	86.6	11.0
B	16.7	25.0	58.3	-	-	25.8	74.2	-	3.7	25.9	70.4	-	6.1	25.6	68.3	-
Mo	-	12.5	87.5	-	-	16.1	83.9	-	-	14.8	85.2	-	-	14.6	85.4	-

D = Deficient, L = Low, O = Optimum, H = High (Above optimum).

of 12.2% in the district. Thus, on an average 7.3% of the orchards were below N optimum level because farmers apply nitrogenous fertilizers, 2.4% in P, while 7.3% deficient in K suggesting a need to incorporate of muriate of potash in fertilizer schedule. About twelve percent of the orchards were categorized as low in Ca level because there is abundant leaching of $CaCO_3$in sand rich soils and also Ca has tendency of lesser translocation in plant system from soil, thus suggesting application of Ca based fertilizers and foliar sprays and 13.4% orchards were also deficient in Mg and low Mg status has been explained by antagonistic effect of soil Ca on Mg uptake by plants.

The leaf overall Fe, Mn, Zn, Cu, B, and Mo contents of Kinnaur apple orchards ranged from 98-390, 23-80, 11-46, 8.50-28, 17.7-45 and 0.44-0.85 ppm, respectively (Table 2) and the respective mean values for these nutrient elements were 232.3, 48.6, 26.6,14.91, 29.46 and 0.61 ppm. The data further indicates that the maximum variation in leaf Cu and B contents was observed in Nichar and for Mn in Kalpa block with the highest values of coefficient of variation i.e. 29.4, 25.67 and 31.75%, respectively. However, the variation in leaf Fe, Zn and Mo contents were maximum in Pooh block with highest coefficient of variation values. Regarding the status of leaf Fe content, 12.9-62.9% samples were in optimum range in different blocks with an average value of 17.1% (20.1-50.0 ppm)in the district (Table 3) and in Kalpa and Nicharblocks 87.1 and 100% leaf samples were found in high category, respectively. The leaf Mn status indicated that 0-4.2% samples were deficient, 3.7-12.5% low and 83.3-96.3% were in optimum range (30.1-150 ppm)in different blocks with an average values of 2.4, 7.3 and 90.3%, respectively. Similarly, 0-16.6% samples in different blocks were deficient in leaf Zn with an average value of 4.9%, and 20.8-25.9% was low with mean value of 20.9% and 62.5-80.6% was in optimum range (20.1-50.0 ppm)with an average value of 73.2% in the district. However, 0-4.2% samples were in the insufficient rangewith respect to leaf Cu in different blocks with an average value of 2.4%, 80.7-92.6% samples were in optimum range (10.1-20.0 ppm) in different blocks with mean value of 86.6%, and 7.4-16.1% was in above optimum range with a mean value of 11% in the district. While leaf B was found to be deficient in 0-16.7% samples in different blocks with an overall average value of 6.1%, whereas 25-25.9% samples were in low category with mean value of 25.6% and 58.3-74.2% samples were in optimum range (28.1-50.0 ppm) with an average value of 68.3% in the district. Similarly, 12.5-16.1% samples were low in leaf Mo in different blocks with a mean value of 14.6% and 83.9-87.5% samples in optimum range (0.51-1.50 ppm) in different blocks with an overall average of 85.4% in the apple orchards of the Kinnaur. Thus, on an average 31.7, 26.8, 14.6, 9.7, and 2.4 % samples were deficientwith respect toleaf B, Zn, Mo, Mn and Cu contentsin apple orchards of Kinnaur. This may be partially because orchardistsof area are not well aware of the usefulness of applications of micronutrients, whereas it is a common practice in other districts of the state. All the orchards were adequate in Fe and Cu because their solubility and availability has increased in slightly acidic soil reaction prevalent in these areas.However, based on overall average about 11.0 and 82.9% samples were found in above optimum range for leaf Cu and Fe contents in apple orchards because farmers are applying Fe micronutrient formulations without getting their soil and leaf tested and Cu based fungicides but toxicity symptoms are not recordedany of the orchards under investigations

The soils of the apple orchards surveyed were sandy loam to sandy clay loam in texture (feel method). The soil pH varied from 5.53 to 7.55 in different bocks with an average value of 6.69 (Table 4). Apple trees can thrive well in nearly acidic to slightly alkaline soil environment. These values were within the range for apple crop. The pH values of the district indicate that soil reaction is not a major constraint for obtaining higher yields of apple. The electrical conductivity indicates about salt concentration of soil and it varied from 0.11 to 0.86 dS m^{-1} in apple orchards of the district with an average value of 0.26 dS m^{-1} (Table 4). The EC values were also within the optimum range for the growth of apple crop. The organic carbon content varied from 0.84-5.55% with an average value of 3.25% (Table 4). The higher addition of organic manure mostly FYM during winter months and the continuous mineralization of organic matter in the surface soils may be responsible for higher values of organic carbon.

The perusal of data in table 5 shows that the available N, P, K, Ca and Mg in the soils varied from 250-672 Kg/ha, 14-188 Kg/ha, 168-829 Kg/ha, 570-2090 ppm and 395-1663 ppm, respectively in different blocks of the district Kinnaur. The respective mean values for these macronutrient elements were 508.7 kg/ha, 72.04 kg/ha, 439.2 kg/ha, 1431.6 ppm and 995.9 ppm. The high altitude soils under temperate climate have high contents of macronutrients as compared to the low altitude, warm, humid and sub-tropical climates(Singh and Datta, 15). This can be attributed to reduced rate of mineralization under temperate climate of the region and fertilizer P accumulation in the surface soils because of its low mobility to lower depths. High K status could

Table 4. Soil characteristics of orchards located in three apple-growing blocks of Kinnaur district.

Parameter	Nichar		Kalpa		Pooh		Overall mean	
	Range	CV(%)	Range	CV(%)	Range	CV(%)	Range	CV(%)
pH	5.53-7.19 (6.46)	6.80	5.86-7.14 (6.65)	5.08	6.13-7.55 (6.94)	5.30	5.53-7.55 (6.69)	6.3
EC (dS m^{-1})	0.14-0.86 (0.24)	61.5	0.11-0.62 (0.26)	37.0	0.17-0.51 (0.28)	27.70	0.11-0.86 (0.26)	41.9
OC (%)	1.35-4.50 (2.71)	35.0	0.84-4.73 (3.37)	26.7	1.29-5.55 (3.60)	32.34	0.84-5.55 (3.25)	32.5

Figure in the parentheses are mean values.

Table 5. Available soil macro- and micro-nutrient concentration in orchards located in three apple-growing blocks of Kinnaur district.

Nutrient	Nichar		Kalpa		Pooh		Overall mean	
	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)	Conc.	CV(%)
				Macronutrient				
N(Kg ha^{-1})	250-672 (474.1)	27.9	280-650 (505.1)	19.3	350-652 (543.7)	17.8	250.0-672.0 (508.7)	21.7
P(Kg ha^{-1})	16-183 (73.0)	67.5	21-188 (74.8)	54.9	14-161 (67.9)	61.4	14.0-188.0 (72.04)	60.2
K(Kg ha^{-1})	251-827 (475.5)	32.0	168-826 (480.0)	36.7	177-829 (360.2)	38.2	168.0-829.0 (439.2)	37.5
Ca(ppm)	570-1890 (1258.2)	30.8	650-1920 (1428.4)	22.8	950-2090 (1589.5)	18.2	570.0-2090.0 (1431.6)	24.8
Mg(ppm)	395-1663 (933.5)	33.6	470-1350 (972.4)	23.9	598-1400 (1078.5)	18.1	395.0-1663.0 (995.9)	25.4
				Micronutrient				
Fe(ppm)	7.0-42.2 (22.28)	45.60	3.7-69.7 (32.09)	48.00	2.80-24.70 (11.41)	54.80	2.80-69.70 (22.41)	64.00
Mn(ppm)	13-31 (21.94)	26.12	12-33 (19.70)	28.00	11.50-37.00 (20.87)	35.30	11.50-37.00 (20.74)	30.00
Zn(ppm)	0.50-4.90 (2.29)	50.46	0.9-4.1 (2.62)	35.42	1.0-3.80 (2.17)	41.87	0.50-4.90 (2.37)	42.17
Cu(ppm)	0.90-2.70 (1.53)	30.80	1-2.90 (1.80)	24.36	0.80-2.10 (1.42)	27.00	0.80-2.90 (1.60)	28.50
B(ppm)	0.36-0.80 (0.52)	21.65	0.42-1.00 (0.72)	22.60	0.38-1.70 (0.79)	42.21	0.36-1.70 (0.68)	35.90
Mo(ppm)	0.14-0.39 (0.25)	30.05	0.12-0.36 (0.25)	20.40	0.17-0.40 (0.28)	22.75	0.12-0.40 (0.26)	24.66

Figure in the parentheses are mean values.

be ascribed to the fact that the clay complex of this region is a mixture of muscovite, smectite, vermiculite and kaolinite. The apple orchards of the area are well supplied with available Ca and Mg as the soils are young and there was not much leaching of base cations. The maximum variation in soil N, P, Ca and Mg contents were observed in the apple orchards located in Nichar block with highest coefficient of variation values, i.e. 27.9, 67.5, 30.8 and 33.6% respectively. However, the variation was highest in Pooh block for soil K content, having maximum coefficient of variation value (38.2%). The data in table 5 also revealed that available Fe, Mn, Zn, Cu, B, and Mo contents in the soils ranged from 2.80-

69.7, 11.5-37.00, 0.50-4.90, 0.80-2.90, 0.36-1.70 and 0.12-0.40 ppm, respectively and the respective mean values for these micro nutrient elements were 22.41, 20.74, 2.37, 1.60, 0.68 and 0.26 ppm. The data further indicate that the maximum variation in available Zn, Cu and Mo contents was observed in Nichar block with the highest value of coefficient of variation, respectively. However, the variation in available Fe, Mn and B contents were highest in Pooh block with the maximum values of coefficient of variation.

For comparing soil analysis data with leaf composition values, simple correlation coefficients were worked out (Table 6). Correlation between soils and leaf analysis values showed significant and positive relationship for N, Mg, Mn, Zn, Cu, B and Mo. The other soil nutrient had positive but non-significant correlation with their contents in the leaf. The nitrogen in the soil showed significant and positive relation with leaf P, K, Ca, Mg, Mn, Zn, B and Mo contents. Similarly, soil Ca and Mg showed positive and significant correlation with leaf Mo only. However, Fe content in the soil had negative correlation with most of the nutrients and significant only with P and Mn contents in the leaf. The relationship between soilMn was found positive and significant with leaf Zn contents only. Similarly, available soil Zn showed positive and significant correlation with leaf N, K, Ca, Cu and B content but negative with Mo only. However, Cu content in the soil have negative and significant relationship for most of the nutrients in the leaf except for Ca contents, where it has positive but non-significant correlation. However, B content in the soil had significant and positive correlation with most of the leaf nutrient contents and negative and non-significant only with Fe and Mo. The relationship between soil Mo was found positive and significant with leaf Mg contents only. Similarly, Walker and Mason (17) also reported significant and positive correlation between leaf and soil samples for Ca, K and P in apple orchards.

In the present study, correlations were not perfect for some nutrient elements, which may probably be due to the influence of weather and ion antagonism as observed by Walker and Mason (17). The plausible explanation for this may also be because the nutritional status of the majority of the orchard soil was moderate. In fact, above critical level in the plant only small changes in the plant nutrient contents may occur despite marked increase in the nutrient availability in the soil. On the other hand, several factors other than nutritional status have great influence on leaf composition, *e.g.* atmospheric temperature and moisture conditions etc. Further confirmations for the present findings also come from studies on other fruit orchards such as grapes, apples, pear, and peaches (Azad *et al*., 2).

Statistically highly significant and positive correlation was found with soil organic carbon, available soil N, Zn, B and Mn with fruit yield (Table 7). Singh (14) also reported the positive effects of N on fruit yield. Significant and positive correlations between fruit yield and soil OC, N and Zn have also been reported earlier (Singh, 14; Mamgain, 10). However, other soil nutrients showed positive but non-significant correlation with the fruit yield except Cu and Fe content, which has negative but non-significant relationship. Similarly, leaf N, P, K, Ca, and Mg showed highly significant positive correlation with fruit yield (Table 8). The positive relationship of macronutrients with fruit yields seems to be mediated through their involvement in vital physiological processes of the plants and enhanced photosynthesis (Delvin and Witham, 4). As far as micronutrients

Table 6. Correlation between soil and leaf nutrient contents of apple orchards.

Soil nutrient	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Mo
N	0.770**	0.339**	0.517**	0.577**	0.294**	-0.098	0.381**	0.766**	-0.043	0.359**	0.242*
P	0.113	-0.049	0.001	0.051	0.091	0.021	0.111	0.126	0.053	0.051	-0.121
K	0.073	0.019	-0.002	-0.104	0.119	-0.056	0.046	0.073	0.195	0.092	-0.063
Ca	0.138	0.067	0.072	0.044	0.216	-0.086	0.037	0.097	-0.111	0.138	0.395**
Mg	0.057	0.109	0.001	-0.009	0.258*	-0.067	0.072	0.058	-0.108	0.133	0.397**
Fe	-0.162	-0.368**	0.043	-0.124	-0.211	0.079	-0.219*	-0.145	0.193	-0.124	-0.185
Mn	0.155	0.057	0.068	0.101	-0.087	0.076	0.667**	0.297**	-0.093	0.048	0.058
Zn	0.316**	0.061	0.372**	0.304**	-0.009	0.108	0.208	0.321**	0.223*	0.240*	-0.257*
Cu	-0.146	-0.162	-0.148	0.148	-0.279*	-0.063	-0.327**	-0.236*	0.625**	-0.062	-0.337**
B	0.382**	0.253*	0.289**	0.350**	0.109	-0.008	0.046	0.295**	0.119	0.687**	-0.142
Mo	0.101	0.118	-0.030	0.073	0.281*	-0.046	-0.040	0.118	-0.109	0.163	0.566**

*,**Significant at 1 and 5% levels

Table 7. Correlation of soil characteristics and available nutrients with yield of apple orchards.

Parameter	Yield	Soil macronutrient	Yield	Soil micronutrient	Yield
pH	0.12	N	0.84**	Fe	-0.06
EC	0.14	P	0.13	Mn	0.26*
OC	0.67**	K	0.06	Zn	0.33**
		Ca	0.12	Cu	-0.27*
		Mg	0.05	B	0.36**
				Mo	0.13

*,**Significant at 1 and 5% levels

Table 8. Correlation of leaf nutrients with yield of apple orchards.

Macronutrient	Yield	Micronutrient	Yield
N	0.84**	Fe	-0.09
P	0.44**	Mn	0.40**
K	0.54**	Zn	0.85**
Ca	0.60**	Cu	0.01
Mg	0.31**	B	0.52**
		Mo	0.19

*,**Significant at 1 and 5% levels

are concerned, Zn, Mn, and B showed a significant positive relationship with fruit yield. Zinc and B controls the auxin level and nucleic acid in plants and found closely related to plant growth, differentiation and crop yield.

Thus, the results of the present study amply elucidated variability in soil properties, plant available soil nutrients and leaf nutrient contents in the apple orchards of Kinnaur region. Spatial variability consolidated a strong need and potential for the development of site-specific recommendation for the management of soil fertility and plant health besides improving yield levels for higher quality and sustained productivity of apple in the district. It is important to emphasize here that spatial leaf and soil nutrients database provides a strong reason to develop a more reliable site-specific fertilization programme that involves a consistent reduction in fertilizers in order to avoid economic and potential environmental problems derived from a homogeneous/blanket fertilizer usage in the orchards and useful to apple farmers of the region also.

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Effect of foliar application of nutrients and growth regulators on fruit cracking and quality of Eureka lemon under rainfed conditions

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ABSTRACT

An experiment was laid out in Randomized Block Design with 13 treatments, consisting of foliar sprays of K_2SO_4 (6.0, 8.0 and 10%), $CaCl_2$ (0.5, 0.75 and 1%), 2,4-D (20, 30 and 40 ppm), NAA (20, 30 and 40 ppm) and control (10 ppm GA_3) and each treatment replicated thrice. Among the various treatments, spray of 40 ppm NAA was found to be most effective for minimizing fruit cracking (13.06%) as compared to other treatments and this treatment also recorded maximum fruit length (5.45 cm), fruit breadth (5.22 cm), fruit weight (71.38 g), pulp weight (37.47 g), rind weight (17.55 g), rind thickness (2.64 mm) specific gravity (1.02), Juice content (50.97%), TSS (7.9°Brix), acidity (5.77%) and ascorbic acid (50.76 mg/100 ml). Among the nutrients, minimum fruit cracking (17.96%) was noticed with the application of 10% K_2SO_4 and this treatment also recorded the maximum fruit length (5.42 cm), fruit breadth (5.09 cm), fruit weight (67.10 g), pulp weight (36.20 g), rind weight (16.30 g), rind thickness (2.54 mm), Juice content (48.94%), TSS (7.6°B), acidity (5.67%) and ascorbic acid (50.68 mg/100 ml).

Key words: Eureka lemon, Fruit splitting, plant growth substances, quality.

INTRODUCTION

Lemon is leading acid citrus fruit because of its very appealing colour, odour and flavour, however, the summer crop has been observed to be prone to severe fruit cracking. Lemon has potential to bear in several flushes making it long lasting crop having round-year availability of the fruits. Fruit cracking is a worldwide problem which affects a number of fruits and losses are sometimes high. Cracking is manifested as a meridian fissure of the peel, usually developing from the stylar end and reaching the equatorial zone or even extending beyond that. It has been explained that citrus fruit splitting as one of the most exasperating problems experienced by the citrus fruit growers. Lemon is confronted with a very serious problem of fruit cracking. The disorder causes considerable losses of the marketable fruit which make it inconsumable leading to heavy losses to the growers. Garcia-Luis *et al.* (6) studied the response of application of growth regulators to fruit cracking and found them relevant to splitting as this application markedly affected the rind structure, affecting both cell size and the thickness of the flavedo. Hoffmann (7) explained citrus fruit splitting as one of the most exasperating problems experienced by the citrus fruit growers. Splitting is usually observed when growing conditions become erratic such as imbalance in nutrients. The optimal growing conditions including reasonable cultural practices along with mineral nutrition can significantly reduce the malady of splitting. Singh *et al.* (14) added that the deficiencies of calcium, boron and potassium causes imbalance leading to fruit cracking. The use of foliar feeding of nutrient and growth regulators is a new and innovative approach to check fruit cracking and enhance quality. Keeping in view the seriousness of the problem the present investigation was conducted to find out the most effective treatment in reducing fruit cracking and improving the quality of Eureka lemon.

MATERIALS AND METHODS

The study was carried out at Rainfed Research Sub Station for Subtropical Fruit Crops, Raya, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K, India during 2014-2015. The experiment was laid out in randomized block design with 13 treatments, consisting of foliar sprays of K_2SO_4 (6.0, 8.0 and 10%), $CaCl_2$ (0.5, 0.75 and 1%), 2,4-D (20, 30 and 40 ppm), NAA (20, 30 and 40 ppm) and control (10 ppm GA_3) and each treatment was replicated thrice. All the trees were maintained under uniform cultural schedule before and during the course of investigation. Two sprays of nutrients and growth regulators were given in the month of May at 20 day intervals. First spray was given on 9th May and second on 29th May in seven-year-old Eureka lemon trees. The plants were sprayed during forenoon with the help of foot pump sprayer. Total number of fruits present on the tree were counted when observation

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on total number fruits per tree was recorded. The percentage of cracked fruits was calculated on the basis of total number of fruits initially present on the tree. The observations on fruit length, breadth and peel thickness were measured with Vernier calipers. The weight of ten fruits from each replication of all the treatments was measured with electronic balance. Subsequently, the average fruit weight was calculated and expressed in grams. A random sample of five fruits already taken for weight was hand peeled and weighed with electronic balance. Subsequently, the average rind weight was calculated and expressed in grams. Specific gravity of fruits was measured with water displacement method. Juice percentage was calculated on the weight basis. The chemical characters like TSS, acidity and ascorbic acid were estimated as per standard procedures outlined by Ranganna (11) and AOAC (1) and all the data were subjected to statistical analysis.

RESULTS AND DISCUSSION

The statistical analysis of the data presented in Table 1 showed that there was significant difference between the treatments of nutrients and growth regulators in terms of fruit cracking. Among the growth regulators, the minimum fruit cracking was recorded under treatment T_{12} (NAA 40 ppm), *i.e.* 13.06 percent, which is statistically at par with the treatment T_{11} (NAA 30 ppm), *i.e.* 14.10 per cent and maximum fruit cracking was noticed under the treatment T_7 (2,4-D 20 ppm), *i.e.* 36.21 percent. All the treatments had a profound effect on the fruit cracking percentage and the elastic and plastic properties of the citrus rind are thought to be involved in resistance to puncture. Application of auxins caused enlargement of cells by increasing the elasticity or permeability of cell wall (Cline and Trought, 4). Reduction in fruit cracking may be due to the auxin causing enlargement of cells by increasing elasticity and plasticity of the cell wall. Thus, peripheral tissues of the fruit would have kept pace with growth of cortex resulting in the reduction of fruit cracking, since; one reason for cracking in fruits is differential growth rates of the peripheral and cortex tissues. Peripheral tissues, being senescent and weak, are highly prone to mechanical stress and cracking. The results are in close conformity with the findings of Sandhu and Bal (13) who reported that the treatment NAA is effective for the managing fruit cracking and improving fruit quality. Similar results have been reported by Sandhu and Bal (12) in lemon cv. Baramasi substantially reduced the cracking losses by (94.5%) and resulted in impressive impact on fruit quality. Singh *et al.* (14) also opined that systematic spray of growth regulators before rind splitting helps control cracking as growth regulators influence rind thickness. Garcia-Luis *et al.* (6) found that application of growth regulators markedly influenced rind structure, affecting both cell size and thickness of flavedo, as it is relevant to cracking. Moreover, growth regulators play a

Table 1. Effect of foliar application of nutrients and growth regulators on fruit cracking and quality of Eureka lemon under rainfed conditions.

Treatment	Cracking (%)	Fruit length (cm)	Fruit breadth (cm)	Fruit wt. (g)	Pulp wt. (g)	Rind wt. (g)	Rind thickness (mm)
T_1 = K_2SO_4(6%)	26.05	5.30	4.42	61.71	34.75	16.23	2.36
T_2 = K_2SO_4 (8%)	21.99	5.37	5.02	65.98	35.34	16.29	2.50
T_3 = K_2SO_4 (10%)	17.96	5.42	5.09	67.10	36.20	16.30	2.54
T_4 = $CaCl_2$ (0.5%)	30.11	4.69	4.38	53.61	34.15	16.17	2.24
T_5 = $CaCl_2$ (0.75%)	28.08	4.70	4.41	57.70	35.37	16.20	2.29
T_6 = $CaCl_2$ (1.0%)	24.02	5.20	4.45	60.10	36.41	16.21	2.30
T_7 = 2,4-D (20 ppm)	36.21	4.60	4.26	50.75	32.27	15.93	2.06
T_8 = 2,4-D (30ppm)	34.17	4.61	4.28	51.11	33.25	15.99	2.11
T_9 = 2,4-D (40 ppm)	32.15	4.67	4.35	51.63	33.98	16.16	2.23
T_{10} = NAA (20 ppm)	19.98	4.57	5.06	62.40	35.45	15.89	2.39
T_{11} = NAA (30 ppm)	14.10	5.43	5.19	67.36	36.30	17.38	2.61
T_{12} = NAA (40 ppm)	13.06	5.45	5.22	71.38	37.47	17.55	2.64
T_{13} = GA_3 (10 ppm) (control)	15.93	5.35	5.13	66.19	35.47	16.26	2.53
$CD_{0.05}$	2.00	0.51	0.11	2.94	2.70	0.03	0.10

significant role in peel resistance and plasticity that determine intensity of cracking.

It is clear from the data presented in the Tables 1 and 2 that there were significant differences between the treatments of nutrients and growth regulators on quality of Eureka lemon. The maximum fruit length (5.45 cm) and fruit breadth (5.22 cm) were recorded with application of NAA (40 ppm) as compared to all the treatments. A generally accepted opinion is that increase in fruit size is due to enlargement of the already existing cells, and auxin is presumed to be responsible for this enlargement. Hence, application of NAA caused fruit enlargement by increase in cell size. Fruit elongation and increase in fruit breadth may be due to cell division initially, and cell enlargement in the later stages. The result are in close conformity with the findings of Sandhu and Bal (12) who reported that foliar application of NAA at 40 ppm resulted in comparatively large sized fruits. Similar findings have been documented by Babu *et al*. (3) in Kagzi lime, who also reported increase in fruit size with NAA and GA treatments. Auxin is considered to be responsible for enlargement of cells, thus increase in size of fruit.

In the present study the maximum fruit weight (71.38 g), pulp weight (37.47 g) and rind weight (17.55 g) were noticed with the application of 40 ppm NAA, *i.e.* T_{12} treatment. There are many reports suggesting that application of NAA may raise endogenous auxins levels in the fruit, which favours development of various tissues of the fruit. Thus, increase in fruit size due to auxins application perhaps led to increase in fruit weight due to cell expansion. It is also possible that a developing fruit is an important metabolic sink, into which nutrients and organic substances from leaves and other plant parts flow, thereby accumulating in the fruit. This accumulation of metabolites and water in fruit increases fruit weight. A direct relationship between endogenous gibberellin content in developing fruits of orange with their growth rate has been established. The results obtained in the present investigation are also in consonance with the findings of Babu *et al.* (3), Josan *et al.* (9) and Sandhu and Bal (13). The application of NAA might have favoured the development of various parts of fruit due to increase in endogenous auxin levels. Maximum rind thickness (2.64 mm) was recorded with 40 ppm NAA followed by GA_3, while minimum rind thickness was registered in 20ppm 2,4-D. Singh *et al.* (14) also opined that systematic spray of growth regulators before rind splitting helps control cracking as growth regulators influence rind thickness.The treatments of nutrients and growth regulators had non significant effect on specific gravity of Eureka lemon in the present study.All the treatments of nutrients and growth regulators applied in the presentexperiment produced significant effect on juice content of Eureka lemon. Data clearly depict that fruits harvested from trees sprayed with 40 ppm NAA showed maximum juice content (50.97%), which is statistically at par with 30 ppm NAA and 10 ppm GA_3. Higher moisture content in fruits resulted in higher juice content.

Table 2. Effect of Foliar application of nutrients and growth regulators on quality of Eureka lemon under rainfed conditions.

Treatment	Specific gravity	Juice (%)	Total soluble solids (°Brix)	Titreable acidity (%)	TSS:acid ratio	Ascorbic acid (mg/ ml)
T_1 = K_2SO_4(6%)	1.10	43.63	7.5	5.40	1.38	50.46
T_2 = K_2SO_4 (8%)	1.01	45.71	7.6	5.53	1.38	50.57
T_3 = K_2SO_4 (10%)	1.00	48.94	7.6	5.67	1.36	50.68
T_4 = $CaCl_2$ (0.5%)	1.00	44.78	7.4	5.40	1.37	50.11
T_5 = $CaCl_2$ (0.75%)	1.01	45.69	7.5	5.43	1.34	50.25
T_6 = $CaCl_2$ (1.0%)	1.01	46.25	7.5	5.50	1.37	50.29
T_7 = 2,4-D (20 ppm)	0.99	40.36	7.3	5.10	1.41	49.67
T_8 = 2,4-D (30ppm)	1.00	41.15	7.4	5.20	1.42	49.92
T_9 = 2,4-D (40 ppm)	1.00	43.79	7.4	5.30	1.42	50.07
T_{10} = NAA (20 ppm)	1.01	49.11	7.7	5.70	1.33	50.55
T_{11} = NAA (30 ppm)	1.00	44.20	7.8	5.73	1.35	50.74
T_{12} = NAA (40 ppm)	1.02	50.97	7.9	5.77	1.38	50.79
T_{13} = GA_3 (10 ppm) (control)	1.01	49.11	7.5	5.67	1.43	50.62
$CD_{0.05}$	NS	3.27	0.13	0.18	NS	0.20

Josan *et al* (9) in lemon elucidated similar results. The results are in consonance with the findings of Sandhu and Bal (12) who also reported that 40 ppm NAA yielded highest juice percentage.

The data depicted in Table 2 revealed that the treatments of nutrients and growth regulators had significant effect on total soluble solid, acidity and ascorbic acid of Eureka lemon under rainfed conditions. The Maximum TSS (7.9°B), acidity (5.77%), and ascorbic acid (50.76 mg/ 100 ml) were recorded under treatment T_{12}, *i.e.* 40 ppm NAA. Auxins have been known to be involved in synthesis of α-amylase, which converts starch in sugars and, consequently, increasing osmotic pressure of the cell which results in accumulation of water and other solutes. Another reason may be that sugars get accumulated, or, some insoluble substances like starch are rendered soluble by hydrolysis, and thus increase total soluble solids. Results regarding TSS percentage were found to be in consonance with that of Atawia and El-Desouky (2) and Huang and Huang (8) who reported that by application of growth regulators like auxin and gibberellins, TSS content of citrus species can be significantly increased. Babu *et al*. (3) found an increase in total soluble solids by application of NAA. An increase in TSS could be attributed to higher solutes as a result of enhanced mobilization of carbohydrates in these treatments. It is well known that activity of cytoplasmic sucrose phosphate synthase, a key enzyme regulating the pool size of sucrose in the leaf, had been shown to be stimulated by foliar applications of plant growth regulators and promotes phloem loading.The acid content of juice increased significantly under all treatments of growth regulators. However, maximum acidity (5.77%) in case of growth regulators was found under T_{12} (40 ppm NAA) and the least acidity was found under T_7 (20 ppm 2,4-D). The results of acidity are in close conformity with the findings of Nawaz *et al.* (10) who also reported that 15 ppm NAA results in increase in acidity in Kinnow mandarin. Babu *et al.* (3) reported significant increase in acidity of Pant-lemon with 5 to 10 ppm NAA. The treatments of nutrients and growth regulators had non-significant effect on TSS:acid ratio of Eureka lemon.

It is clear from the data presented in Table 2 that maximum ascorbic acid (50.76 mg/ 100 ml) was recorded under the treatment T_{12} (40 ppm NAA) and minimum under T_7 (20 pm 2,4-D). The increase in ascorbic acid content may also be due to the growth regulators increasing osmotic pressure by cell expansion, thus leading to accumulation of this organic acid. Similar results are documented by Sandhu and Bal (14) who observed that the 40 ppm NAA increases the ascorbic content of lemon. Nawaz *et al.* (10) also observed that 15 ppm NAA showed highest vitamin-C content in Kinnow mandarin. Results regarding this parameter of study were also found to be in agreement with that of Xiao *et al.* (15) who also observed that preharvest application of growth regulators increased vitamin-C contents of the citrus fruits. Farag and Nagy (5) also reported that the application of NAA led to a significant increase in vitamin C relative to the control.

It is concluded from the present investigation that application of nutrients and growth regulators reduce the fruit cracking and enhanced the quality of Eureka lemon. The treatment T_{12} (NAA 40 ppm) recorded least fruit cracking and this treatment also enhanced the fruit quality of lemon cv. Eureka. Among the nutrients 10% K_2SO_4 was found superior in reduction of fruit cracking with improved fruit quality.

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Effect of *Azotobacter* and *Sphingobacterium* species on guava seedlings under nursery conditions

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ABSTRACT

An experiment was planned to study the effect of biofertilizers, namely *Azotobacter* and *Sphingobacterium* species on guava seedlings under nursery conditions. The standard culture of *Azotobacter* and *Sphingobacterium* species was obtained from Department of Microbiology, Punjab Agricultural University, Ludhiana, Punjab, India. The liquid formulations of microbial inoculants were prepared by supplementing 2% PEG in basal medium. The three months old guava seedlings were given dip treatment for 30 mins with liquid microbial inoculants and transplanted in nursery bed and observations were recorded after one year. The treated guava seedlings showed very good response to *Azotobacter* and *Sphingobacterium* species treatment (T_3) followed by *Azotobacter* sp. (T_2). Seedlings inoculated with *Azotobacter* and *Sphingobacterium* species inoculation showed an increase of 4.28 per cent in shoot length, 4.41 per cent in collar diameter, 14.55 per cent in root length, 3.85 per cent in root numbers, 9.33 per cent in number of main branches/plant, 7.95 per cent in number of leaves, 6.95 per cent in fresh weight of shoot, 8.27 per cent in dry weight of shoot, 15.08 per cent in fresh leaf weight, 14.08 per cent in dry weight of leaves, 12.60 per cent in fresh weight of root and 12.69 per cent in dry weight of root over control. The use of biofertilizer offers better options for enhancing the vegetative growth of horticultural crops under nursery conditions in an increasingly eco-conscious world, thus increasing the success rate of vegetative propagation in healthy plants with well developed root and shoot system.

Key words: *Azotobacter*, *Sphingobacterium*, Bio-fertilizers.

INTRODUCTION

Guava is an important fruit of tropical and subtropical area of the world. It is commonly called poor man's fruit. Guava contains maximum vitamin C content per l00g of pulp after amla. It contains antioxidant factors and can control systolic blood pressure. It is good source of roughage and help in removal of constipation. In India, area under guava during the year 1987-88 was 176.8 thousand hectares, which has increased to 234.06 thousand hectares during the year 2011-12. India has made a fairly good progress in production from the year 1987-88 to 2011-12. It increased from 1112.6 thousand tonnes to 2660.76 thousand tonnes. The productivity of guava has increased from 6.3 tonnes to 11.70 tonnes during above period (Kumbhar *et al*., 9). One of the most important factor contributing towards high productivity of fruit crops is quality planting materials. Shortage of planting material is a major problem in the production of horticultural crops. There is an immense scope of employment and income generation through production and supply of quality planting material in horticultural crops.

Perennial fruit crops are heavy feeders of plant nutrients and high yields can only be sustained through the application of optimal doses in balanced proportion. Nutrient management is one of the largest shares of cost with its impact on potential yield and crop quality (Ganeshamurthy *et al*., 7). Chemical fertilizers today are an indispensible part of modern orchard practices (Bala *et al*., 3). Continuous use of chemical fertilization leads to the deterioration of soil health and productivity. In this context, biofertilizers have emerged as an important component of the integrated nutrient supply system and have great potential to improve crop yields through environmentally better nutrient supplies (Das *et al*., 5). They are known to improve fixation of nutrients in the rhizosphere, produce growth stimulants for plants, improve soil stability, provide biological control, biodegrade substances, recycle nutrients, promote mycorrhiza symbiosis and develop bioremediation processes in soils contaminated with toxic, xenobiotic and recalcitrant substances (Rivera-Cruz *et al*., 12). Biofertilizers keep the soil environment rich in all kinds of micro- and macro-nutrients via nitrogen fixation, phosphate and potassium solubilisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Sinha *et al*., 13) providing better nutrient uptake and increased tolerance towards drought and moisture stress. Biofertilizers differ from chemical

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and organic fertilizers in the sense that they do not directly supply any nutrients to crops and are cultures of special bacteria and fungi, relatively simple and having low installation cost (Alam and Seth, 1).

In today's scenario there is an increasing demand of horticultural crops in India. To meet this demand quality planting material is prerequisite. Thus nursery business is flourishing at a fast pace. Keeping in view the economic, environmental and agronomic importance of biofertilizers an experiment was planned for the production of quality planting material for horticultural crop i.e guava. The present experiment was carried out to study the effect of *Azotobacter* sp. and *Sphingobacterium* sp. on vegetative growth parameters of guava under nursery conditions for the development of healthy planting material with well developed shoot and root system for vegetative propagation.

MATERIALS AND METHODS

The study has been conducted to assess the influence of *Azotobacter* and *sphingobacterium* species on vegetative growth and biomass accumulation of guava seedlings under nursery conditions for the production of quality planting material. The standard culture of *Azotobacter* and *Sphingobacterium* species was obtained from the Department of Microbiology, PAU, Ludhiana. Liquid microbial inoculants of individual cultures were prepared by supplementing 2% Polyethylene Glycol (PEG) in basal medium (NaCl 5g/L, Glucose 10g/L, Yeast Extract 3.0g/L). It has a shelf life of three month at ambient temperature and used @ 250ml/acre respectively (liquid microbial inoculants, $1x10^8$ colony forming unit (CFU) per ml). The liquid inoculants for one acre can be diluted in 10-15 liters of water and use accordingly for dip treatment. Both the cultures used in this study are positive for IAA production and Phosphate solubilization. In addition, *Azotobacter* sp. is also positive for NH_3 production. The three month old guava seedlings of uniform vigour and height were collected (10-12 cm of height). The dwarf and bigger seedlings were discarded and the roots of selected seedlings were given dip treatment by dipping in respected liquid biofertilizer culture for 30 mins and transplanted on to the nursery beds of size 2X1m in rows of 15 cm apart. The data on vegetative growth parameters in terms of shoot length (cm), collar diameter (cm), root length (cm), root numbers, number of main branches/ plant, number of leaves and biomass accumulation in terms of fresh and dry weight of shoot (g), fresh and dry weight of leaves (g) and fresh weight and dry weight of roots (g) were recorded after one year of transplanting. There were three treatments, T_1: Control, T_2: *Azotobacter* sp., T_3: *Azotobacter* sp. and *Sphingobacterium* sp. replicated four times with 50 plants/ replication in a randomised block design. Analysis of variance (ANOVA) and the test of mean comparison according to critical difference (CD) were applied. Significance level was accepted at $p \leq 0.05$. The data was analyzed statistically by randomized block design using CPCS1 software as a statistical analysis tool (Cheema and Singh, 4).

RESULTS AND DISCUSSION

Inoculation with microbial inoculants had a significant ($p \leq 0.05$) effect on growth parameters of guava seedlings. The shoot length (125.80 cm) and collar diameter (1.42 cm) was recorded significantly ($p \leq 0.05$) higher from the seedlings treated with *Azotobacter* sp. and *Spingobacterium* sp. (T_3) accounting to about 4.28 per cent increase in shoot length and 4.41 per cent increase in collar diameter over control (T_1). This was followed by treatment with *Azotobacter* sp. (T_2) with 2.48 per cent increase in shoot length and 2.94 per cent increase in collar diameter with respect to control (T_1). An increase in plant height and spread with the application of biofertilizers in guava was also reported by Dutta *et al*. (6). It may be due to enhanced N and P availability to the plant. Apart from its ability to fix atmospheric nitrogen, *Azotobacter* sp. used in this study also synthesize biologically active growth substance such as indole acetic acid whereas *Sphingobacterium* sp. has the ability to solubilize inorganic P from insoluble sources and make available fixed forms of soil P. These properties of the two biofertilizers seemed to have enhanced the availability of both the nutrients (N and P) and benefit the plant. An increase in plant growth might also be due to the improvement in physio-chemical properties of soil; increase in enzymatic activity and microbial population by application of microbial inoculants.

Root length and number of roots of guava plants varied significantly ($p \leq 0.05$) with biofertilizers inoculation. The significantly higher root length of 37.80 cm was recorded from the plants treated with *Azotobacter* and *Sphingobacterium* species (T_3) accounting to about 14.55 per cent increase over control (33.00 cm) (T_1) followed by the treatment with *Azotobacter* sp. (T_2) with 35.88 cm root length. Similarly number of roots also get improved due to dual inoculation of microbial inoculants viz. *Azotobacter* and *Sphingobacterium* species (T_3) accounting to about 3.85 per cent increase over control (35.05 cm) (T_1). An increase in root length due to application of *Azotobacter* and *Sphingobacterium* species could be attributed to their capability to

synthesize biologically active substances like IAA and increased uptake of essential macronutrients like nitrogen and phosphorus due to biological nitrogen fixation and phosphate solubilization. Glick *et al.* (8) also reported that bacterial IAA increases root surface area and length, and thereby provides the plant greater access to soil nutrients. Also, rhizobacterial IAA loosens plant wall and as a result facilitates an increasing amount of root exudation that provides additional nutrients to support the growth of rhizophere bacteria. Rapid establishment of roots is advantageous for young seedlings as it increases their ability to anchor themselves to the soil and to obtain water and nutrients from their environment, therefore enhancing their chances for survival (Subramanian and Satyan, 14).

A significantly (p≤0.05) higher number of branches per plant (8.20) was reported from the plants treated with *Azotobacter* and *Sphingobacterium* species (T_3). An increase in number of branches was 9.33 per cent over the control (T_1). This was followed by the treatment with *Azotobacter* sp. (T_2) with 6.67 per cent (8.00 branches/plant) increase in number of branches over control i.e 7.50 branches/plant (T_1). The increased number of branches might be due to increased number of vegetative buds produced by taller plants. This is attributed to the ability of *Azotobacter* sp. to release IAA, solubilise phosphorus and fix nitrogen (Fig. 1) and phosphate solubilising activity and IAA producing potential of *Sphingobacterium* sp. The number of leaves varied significantly (p≤ 0.05) due to microbial inoculants. The maximum number of leaves per plant (133) was recorded from the plants treated with *Azotobacter* and *Sphingobacterium* species. (T_3) accounting to about 7.95 per cent increase over control (123.20) (T_1) followed by the treatment with *Azotobacter* sp. (T_2) with 129.50 number of leaves per plant. This could also be due to the production of IAA by *Azotobacter* and *Sphingobacterium* species. Naeem *et al.* (11) also reported that the application of IAA increased germination percentage, plant height, number of branches and leaves, total chlorophyll content and dry weight in *Lens culinaris*. IAA exerts influence on plant growth by enlarging leaves and increasing photosynthetic activities in plants. It also activates the translocation of carbohydrates during their synthesis (Awan *et al*., 2).

Biomass can be treated as true indicator of growth. Biomass content of the seedlings treated with biofertilizers inoculants varied significantly (p≤ 0.05). The fresh above the ground biomass (fresh shoot weight and fresh leaf weight) was recorded significantly (p≤ 0.05) higher from the plants treated with *Azotobacter* and *Sphingobacterium* species (T_3) followed by the treatment with *Azotobacter* sp. (T_2) (Fig. 2). An increase in 6.95 per cent in fresh weight of shoot and 15.08 per cent in fresh leaf weight was obtained in plants treated with *Azotobacter* and *Sphingobacterium* species (T_3) over control. If we

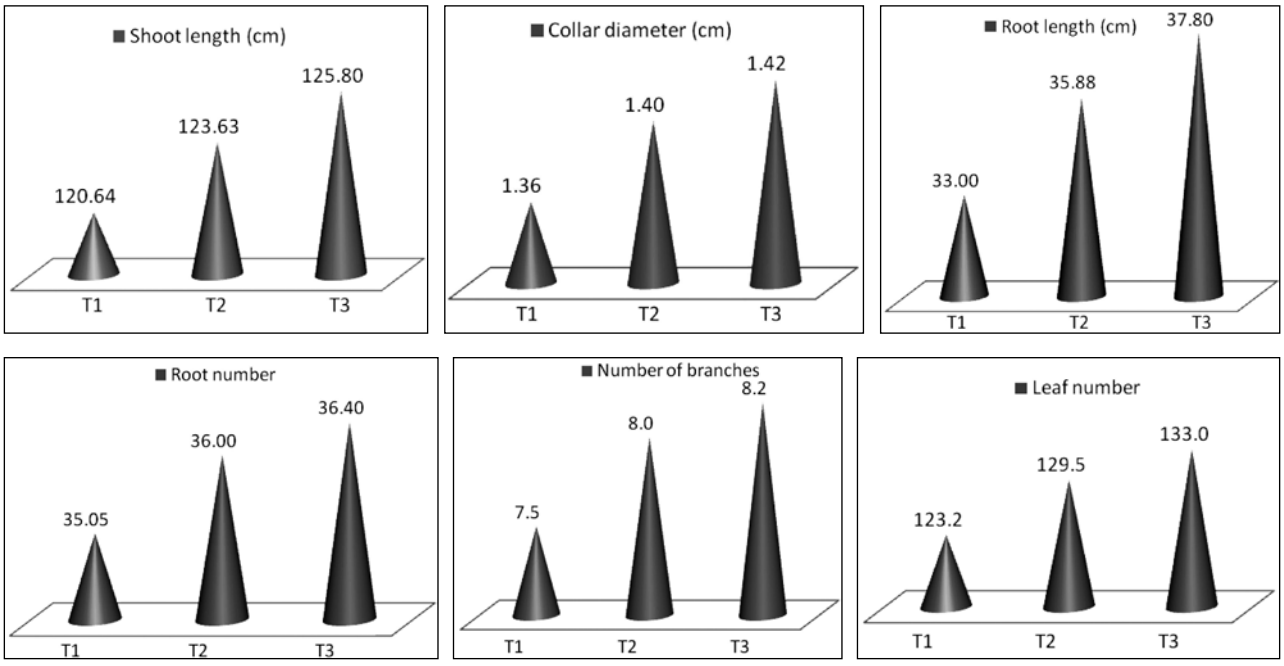

Fig. 1. Effect of microbial inoculants on shoot length, collar diameter, root length, root number, number of branches and leaf number of guava seedlings under nursery conditions.

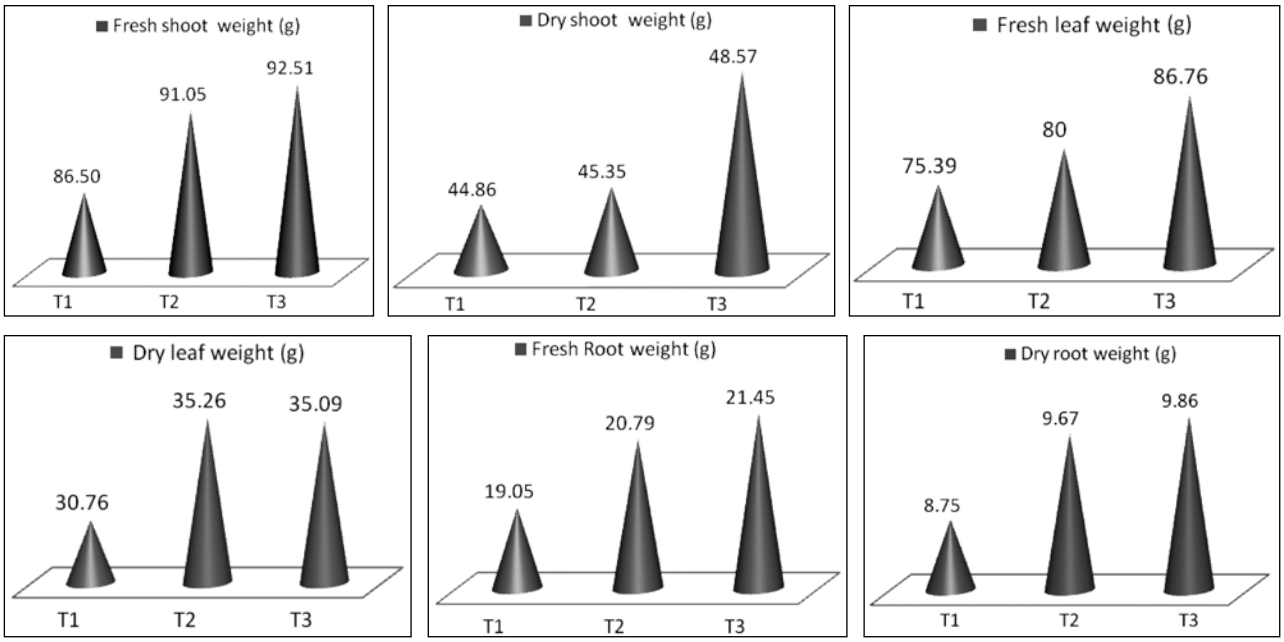

Fig. 2. Effect of microbial inoculants on biomass accumulation of guava seedlings under nursery conditions.

consider dry weight of shoot and leaves (above the ground biomass) again the best performance was given by T_3 (48.57 gm/plant and 35.26 gm/plant respectively) followed by T_2 (45.35 gm/plant and 35.09 gm/plant). An increase in 8.27 per cent in dry weight of shoot and 14.08 per cent in dry weight of leaves was recorded in plants treated with *Azotobacter* and *Sphingobacterium* species (T_3) over control. The fresh root biomass was found maximum in T_3 (21.45 gm/plant), followed by T_2 (20.79 gm /plant) and T_1 (19.05 gm/plant). For dry root biomass, T_3 (9.86 gm/plant) was the best treatment, followed by T_2 (9.67 gm/plant) and T_1 (8.75 gm/plant). The fresh weight of root was 12.60 per cent higher and dry weight of root was 12.69 per cent higher in plants treated with *Azotobacter* and *Sphingobacterium* species over control.

An overall increase in biomass accumulation by application of biofertilizer i.e *Azotobacter* and *Sphingobacterium* species may be due to the nitrogen fixing and phosphate solubilising activities of inoculated biofertilizer. In addition both the cultures (*Azotobacter* and *Sphingobacterium* species) used in this study produced indole acetic acid growth hormone. This hormone stimulates root growth and development. The use of growth stimulating inoculants helps to accelerate uptake of plant nutrients from applied chemical fertilizers by increasing the root growth. Thus, continuous use of bio-fertilizers can enables the microbial population to remain and build up in the soil and helps in maintaining soil fertility contributing to sustainable agriculture (Malik *et al*., 10).

CONCLUSION

The most prominent findings emerged was regarding superiority of seedling bacterization with *Azotobacter* and *Sphingobacterium* species over un inoculated control plants in terms of vegetative growth parameters and biomass accumulation due to atmospheric nitrogen fixing ability of *Azotobacter* sp. and Phosphate solubilizing activity of *Azotobacter* and *Sphingobacterium* species apart from their ability to produce IAA.

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Genetic diversity analysis for fruit quality traits and nutrient composition in different horticultural groups of muskmelon

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ABSTRACT

Sixty seven muskmelon genotypes from three horticultural groups were analysed for 13 fruit quality traits including 9 minerals. The range of variation was about 8-10 times for many fruit quality traits such as total caretonoids, P, K, Ca, Mg, Na, Zn, Mn, Cu and Fe contents, which reflect the high selection prospects for these traits to improve the performance through breeding programme. Sixty seven genotypes were classified into 13 distinct clusters based on 13 fruit quality traits. Cluster I comprised of maximum number of genotypes (26) mostly *inodorous* type and the mean value of this cluster for many quality traits was also high. The second largest cluster XIII consisted of 19 genotypes comprised *cantaloupensis* type and all 6 commercial Indian varieties were grouped together in this cluster. Based on higher genetic distance among clusters and higher mean value of genotypes for quality traits, yield and TSS, DM-31, DM-145, DM-159 and DM-162, DM-56 genotypes from cluster I and Pusa Madhuras, Kashi Madhu and Punjab Sunheri from cluster group XIII could be exploited in breeding programmes as potential donors for developing nutrient-rich muskmelon varieties.

Key words: *Cucumis melo*, *Cantaloupensis*, *inodorous*, quality, variability.

INTRODUCTION

Muskmelon (*Cucumis melo* L.; 2n = 24) is one of important vegetables for summer which is being grown for their edible fruits in most of the frost free regions of the world. Muskmelon is highly relished as dessert because of its attractive and unique aromatic musky flavour, sweet taste and being a rich source of vitamins and nutrients (Munshi and Choudhary, 5). It is often regarded as a health food because of its low calorie content and presence of many vitamins and other phytonutrients. Muskmelon fruits contain about 95% water that keeps body hydrated and acts as diuretic. African continent especially eastern region of south Sahara desert was generally regarded as the centre of origin of muskmelon. However, recent studies showed that both cucumber and muskmelon are of Asian origin and wide diversity of wild species of *Cucumis melo* L. exists in India and China (Sebastian *et al*., 9).

Multivariate analysis of elite genotypes is prerequisite for choosing promising genetically diverse lines for improvement of specific traits. Study of genetic diversity in muskmelon may play significant role in identification of desirable genotypes which will be helpful in development of variety/hybrids and pre breeding lines with higher nutritional content. In the past, limited attempt has been made to estimate genetic divergence in muskmelon genotypes for fruit quality traits and nutritional content. Hence, this study was carried out for assessment of genetic diversity in nutritional composition and other fruit quality traits among different horticultural groups of muskmelon genotypes to indentify genotypes rich in specific nutrient which can be utilized in future breeding programme.

MATERIALS AND METHODS

A total of 67 genotypes from three different horticultural groups including 36 accessions procured through NBPGR New Delhi and six commercially popular Indian varieties, viz., Durgapura Madhu, Kashi Madhu, Pusa Madhuras, Hara Madhu, Arka Jeet and Punjab Sunheri were taken for this study. It comprised of 20 accessions from *C. melo* var. *inodorous*, 45 from *C. melo* var. *cantaloupensis* and 2 from *C. melo* var. *momordica*. This experiment was conducted in a randomized block design with three replications during the Feb-June season of 2014. Seeds were sown on both sides of channels on well prepared hills with a spacing of 2 m in between channels and 60 cm between hills. Twenty plants per genotype in each replication were maintained. Fruits were cut into two halves and flesh from a composite samples of five random fruits were taken for analysis of 9 mineral content (P, K, Ca, Mg, Na, Zn, Mn, Cu and Fe) and 4 other quality traits (TSS, acidity, vit. C and total carotenoids). The samples were dried at 65°C in hot-air oven for 72 h and then grinded for making powder which were used for

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the estimation of nutrient content. Nutrient content was estimated according to standard procedure of analytical methods (AOAC, 1). Phosphorus was determined by vanado-phosphomolybdate yellow colour method using spectrophotometer (Elico-Mini Spec SL 171, India). Potassium and sodium were estimated by using flame photometer (Systronics, India limited). Calcium and magnesium content in fruit samples was determined by atomic absorption spectrophotometer (Model-Analytikjena ZEEnit 760, Germany) according to (Jackson, 3). Different micronutrients copper, iron, manganese and zinc content in fruits were estimated from diacid digested fruit samples by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS (Model NexION 300X, Perkin Elmer, USA). The concentration of all phytonutrients was expressed in mg/100g (dry weight basis). Total soluble solids (TSS, expressed as °Brix) were measured from fruit juice using a digital hand refractometer. Titrable acidity (%) was determined by titration of a fruit juice sample with 0.05 N NaOH, using phenolphthalein as indicator. Total carotenoids were estimated by the method described by (Thomas and Joshi, 10). Statistical analyses like ANOVA, principal component analysis (PCA) were performed using Statistical Analysis Software, Version 9.2 (SAS, 8). The sample similarities were calculated on the basis of pair-wise Euclidean distance and the unweighted pair-group method with arithmetic averaging (UPGMA) algorithm was used for establishing cluster to search natural groupings among the genotypes for nutrient content.

RESULTS AND DISCUSSION

Analysis of variance showed highly significant mean sum of square due to treatments for 13 fruit quality traits including TSS, acidity and mineral contents and fruit yield indicating substantial amount of genetic diversity in the genetic materials used for this study. The range of variation was about 8-10 times for many fruit quality traits such as total carotenoids (16.52-192.93 µg/100 g), P (4.45-28.72 mg/100 g), K (25.80-235.26 mg/100 g), Ca (3.13-29.22 mg/100 g), Mg (3.13-29.22 mg/100 g), Zn (0.15-1.93 mg/100 g), Mn (0.15-1.44 mg/100 g), Cu (0.08-0.85 mg/100 g) and Fe (0.12-1.92 mg/100 g) content, which reflect the high selection prospects for these traits to improve the performance through breeding programme. Total soluble solids (TSS) is one of most important fruit quality traits which range (data is not presented) from 5.50°Brix (IC274026 from *C. melo* var. *momordica*) to 15.67°Brix (DM-56 from *C. melo* var. *inodorous*) with a mean of 10.82, which indicated wide range of diversity for this trait in the population under study as well as presence of large number of genotypes with higher TSS. Snapmelon genotypes (DSM-11, IC 274026) showed the highest level of acidity (0.22%), while lower range was recorded for *C. melo* var. *inodorous* genotypes (DHM-149; 0.06%, DM-56; 0.07%) and it also indicated that variability for acidity was low. The range for total carotenoids was varied more than 10 times from 16.52 µg/100 g (Durgapura Madhu) to 192.93 µg/100 g (DM-162). Fruits with orange coloured flesh were high in carotenoids content while fruits with green or white flesh colour were having lower carotenoids content. The vitamin C content was ranged from 11.2 mg/100 g (DM-54 from *C. melo* var. *cantaloupensis)* to 25.0 mg/100 g (DMDR-1). Potassium (mg/100 g) content ranged from 25.80 mg/100 g (DM-6) to 235.26 mg/100 g (DM-153). The lowest sodium (mg/100 g) content was recorded in DM-31 and the highest ratio of K/Na was also recorded by DM-31. High phosphorus content was recorded in several genotypes, *viz.* DM-7 (28.72 mg/100 g) and DM-12 (27.63 mg/100 g). Calcium (mg/100 g) content was found maximum in genotype DM-147 (29.22 mg/100 g). There was moderate amount of Mg content among the genotypes under study which ranged from DM-2 (7.82 mg/100 g) to DM-31 (26.19 mg/100 g). The genotypes Durgapura Madhu (1.93 mg/100 g), DM-155 (1.9 mg/100 g), DM-36 (1.86 mg/100 g), DM-174 (1.84 mg/100 g) and DM-169 (1.83 mg/100 g) had high value of zinc content. High iron content was recorded in genotypes DM-7 (1.92 mg/100 g), DM-145 (1.75 mg/100 g) and Pusa Madhuras (1.67 mg/100 g). Most of the genotypes recorded lower content of Cu and Mn. The genotypes, DM-7, DM-145 and Pusa Madhuras were found to be superior for iron content, whereas DM-31 was found superior for sodium content. Commercial variety, Durgapura Madhu was found to be superior for zinc, while Arka Jeet was found superior for manganese and DM-45 and Pusa Madhuras for copper content. The values of sodium, zinc, manganese, copper and iron contents obtained in the present study were consistent with the earlier report (Lester, 4).

For an initiation of successful breeding programme, it is desirable to select genetically divergent suitable parents based on information about the genetic variability and genetic diversity present in the available germplasm. Sixty seven muskmelon genotypes were classified into 13 distinct clusters using D^2 statistics based on 13 fruit quality traits. Among 13 clusters (Table 1), Cluster I comprised of maximum number of genotypes (26) and most of them (15) belong to *inodorous* type. The second largest cluster XIII consist of 19 genotypes belong to *cantaloupensis* type and all 6 commercial Indian varieties could be grouped together in this cluster. All other 11 clusters consisted of 2 genotypes in each. Two snapmelon (*C. melo*

Table 1. Clustering pattern of 67 muskmelon genotypes based on fruit quality traits.

Cluster	No.	Genotypes
I	26	DM-31, DM-35, DM-38, DM-54, DM-55, DM-56, DM-145, DM-143, DM-144, DM-146, DM-150, DM-152, DM-147, DM-153, DM-156, DM-159, DM-160, DM-162, DM -163, DM-169, DM-2, DM-3, DM-4, DM-5, DM-6, DM-175
II	2	M-2, DM-172
III	2	DM-10, DM-180
IV	2	DM-20, DM-173
V	2	Ananas, DM-154
VI	2	DM-151, DM-17
VII	2	DM-177, DM-178
VIII	2	DM-170, DM-176
IX	2	DSM-11, IC274026
X	2	DM-16, DM-18
XI	2	DM-19, DM-171
XII	2	DM-148, DM-15
XIII	19	DM-7, DM-8, DM-11, DM-12, DM-13, DMDR-1, DM-14, Kashi Madhu, Hara Madhu, MS-1, ArkaJeet, Punjab Sunheri, DM-46, Durgapura Madhu, Pusa Madhuras, DM-149, DM-155, DM-174, DM-36

Table 2. Contribution of different fruit quality traits towards genetic diversity.

Trait	First rank	Contribution (%)
Total soluble solids (°Brix)	111	5.02
Acidity (%)	58	2.62
Vitamin C (mg/100 g)	26	1.18
Total carotenoids (µg/100 g)	270	12.21
Phosphorus (mg/100 g)	27	1.22
Potassium (mg/100 g)	234	10.58
Calcium (mg/100 g)	97	4.39
Magnesium (mg/100 g)	8	0.36
Sodium (mg/100 g)	36	1.63
Zinc (mg/100 g)	272	12.3
Manganese (mg/100 g)	235	10.63
Copper (mg/100 g)	40	1.81
Iron (mg/100 g)	797	36.05
Total	2211	100

var. *momordica*) genotypes DSM-11, IC274026 could be grouped together in a separate cluster IX. Amongst fruit quality attributes (Table 2), iron content (36.05%), total carotenoids (12.21%), manganese content (10.63%), potassium content (10.58%) and TSS (5.02%) contributed mainly for the genetic divergence. Among the 13 clusters, cluster XIII showed the highest intra cluster distance (41.75) and possessing 19 genotypes followed by the cluster I (37.17) having 26 genotypes (Table 3). It reflected the existence of maximum distance among the genotypes of cluster XIII, which consisted all 6 Indian commercial cultivars and 13 other genotypes from *cantalouensis* group. Based on inter-cluster distance the maximum diversity was observed between clusters XIII and

Table 3. Average intra- (bold face) and inter-cluster distance (D^2) among muskmelon genotypes.

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	**37.17**	32.18	36.65	35.63	36.49	33.98	32.56	31.42	45.52	36.39	31.55	32.85	41.35
II		**8.76**	24.25	14.16	13.29	12.18	20.85	18.05	28.66	19.46	19.96	12.65	41.41
III			**9.60**	21.11	20.57	24.70	26.41	17.93	24.96	25.88	19.06	25.52	46.78
IV				**9.82**	11.53	15.37	23.49	19.21	22.29	18.67	20.68	15.49	44.45
V					**9.94**	12.84	21.69	20.23	20.77	17.30	22.67	15.79	45.55
VI						**9.97**	14.86	17.00	27.09	13.95	22.25	15.04	43.06
VII							**11.23**	18.02	31.91	16.23	24.44	20.20	40.66
VIII								**11.60**	31.41	21.02	14.28	21.07	41.60
IX									**13.82**	23.59	35.43	27.91	53.09
X										**14.30**	27.37	18.88	44.28
XI											**15.46**	22.96	41.34
XII												**16.53**	41.16
XIII													**41.75**

IX (53.09), followed by clusters XIII and III (46.78), clusters XIII and V (45.55), clusters IX and I (45.52) and clusters XIII and IV (44.45), suggesting that the genotypes belonging to above clusters are more divergent, hence, can be undertaken in hybridization programme. Based on fruit quality traits, genotypes from *inodorous, cantaloupensis* and *momordica* could be broadly grouped in distinct clusters. Therefore, cluster analysis was useful in forming core subsets for grouping the genotypes with similar characters into homogeneous categories. Grouping of muskmelon genotypes on the basis of yield traits have been reported by Reddy *et al.* (6), Tomar *et al.* (11) and Rukam *et al*. (7), but grouping based on fruit quality traits could not be found. However, variability of cucumber germplasm for nutrients composition have been reported by Arivalagan *et al.* (2). In general, the genotypes grouped together in one cluster were less divergent for quality traits than those which were placed in different clusters. Further, higher intra-cluster distance indicates high degree of divergence within that cluster. The genotypes of cluster I (Table 4) recorded maximum total soluble solids (11.53˚Brix) followed by cluster XI (11.50˚Brix), cluster VIII (11.35˚Brix), while cluster III (8.18˚Brix) recorded minimum total soluble solids. Cluster IX recorded maximum acidity (0.22%), while cluster I recorded minimum acidity (0.11%); cluster XIII recorded maximum vitamin C (15.15 mg/100 g), while cluster III recorded minimum (12.60 mg/100 g); the higher total carotenoids was found in cluster III (163.52 µg/100 g), while it was lower in cluster IV (71.87 µg/100 g). Cluster XIII recorded the maximum calcium content (15.67 mg/100 g), while cluster V recorded the minimum calcium content (4.19 mg/100 g). The higher and lower sodium content were found in clusters VII (8.69 mg/100 g) and IX (4.30 mg/100 g), respectively. Cluster XIII recorded the maximum zinc content (1.11 mg/100 g), while clusters VI and VIII had minimum zinc content (0.20 mg/100 g); cluster XI recorded the maximum manganese content (0.90 mg/100 g), while cluster × recorded minimum manganese content (0.25 mg/100 g). The higher and lower iron content was found in clusters XIII (0.87 mg/100 g) and cluster VI (0.18 mg/100 g), respectively. In general, no two clusters taken together had the similar pattern for all the traits indicating wide diversity in the experimental material for majority of the traits. For getting better heterosis, the genotypes from higher degree of divergence with high mean performance may be the best combination of parents for improvement of various economic characters. Thus, genotypes from cluster I and XIII consisted of better yield and fruit quality traits may be utilized for heterosis breeding.

Table 4. Cluster means of 13 fruit quality traits in muskmelon.

Cluster	Total soluble solids (°Brix)	Acidity (%)	Vitamin C (mg/100g)	Total carotenoids (µg/100 g)	P (mg/100g)	K (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	Na (mg/100g)	Zn (mg/100g)	Mn (mg/100g)	Cu (mg/100g)	Fe (mg/100g)
I	11.53	0.11	14.82	119.40	10.43	111.18	13.66	14.70	5.48	0.70	0.77	0.22	0.54
II	10.40	0.12	13.40	37.80	7.93	88.74	7.61	11.02	4.48	0.30	0.80	0.14	0.36
III	8.18	0.17	12.60	163.52	7.37	45.26	5.80	9.25	5.04	0.30	0.82	0.15	0.25
IV	9.87	0.16	14.90	35.49	6.41	34.52	10.00	13.39	5.32	0.35	0.78	0.17	0.38
V	8.47	0.14	13.10	39.62	9.17	50.34	4.19	10.95	6.03	0.30	0.70	0.11	0.31
VI	10.28	0.12	14.10	45.11	8.96	72.87	7.30	14.02	6.50	0.20	0.47	0.13	0.18
VII	10.52	0.12	14.40	102.02	11.37	84.53	14.04	17.46	8.69	0.31	0.28	0.14	0.21
VIII	11.35	0.13	15.10	133.53	7.51	61.64	9.27	12.17	4.71	0.20	0.56	0.17	0.22
IX	5.52	0.22	13.08	40.26	7.08	55.23	9.44	11.58	4.30	0.34	0.53	0.11	0.24
X	9.85	0.16	14.70	49.47	7.43	89.55	9.92	15.28	8.15	0.24	0.25	0.14	0.23
XI	11.50	0.12	15.00	138.17	6.67	44.31	6.75	10.81	5.95	0.41	0.90	0.20	0.38
XII	10.00	0.14	13.60	41.24	8.95	86.30	12.44	16.67	6.68	0.30	0.80	0.21	0.48
XIII	11.22	0.12	15.15	99.82	13.52	119.13	15.67	16.59	5.73	1.11	0.64	0.39	0.87

Table 5. Principal component analysis for 67 muskmelon genotypes based on fruit quality traits.

Parameter	PC 1	PC 2	PC 3	PC 4	PC 5
Cumulative Eigen value	4.10	2.70	1.41	1.20	1.08
Explained variation (%)	29.27	19.29	10.06	8.57	7.74
Cumulative explained variation (%)	29.27	48.57	58.63	67.20	74.94
Trait			Eigen value		
Total soluble solids (°Brix)	0.23	0.89	0.23	-0.16	-0.08
Acidity (%)	-0.24	-0.82	-0.07	0.22	-0.08
Vitamin C (mg/100 g)	0.04	0.69	0.36	0.03	-0.46
Total carotenoids (µg/100 g)	0.02	0.42	0.04	-0.17	0.68
Phosphorus (mg/100 g)	0.70	-0.20	0.22	0.39	0.00
Potassium (mg/100 g)	0.66	-0.17	0.39	0.34	0.01
Calcium (mg/100 g)	0.66	-0.23	0.12	-0.39	-0.20
Magnesium (mg/100 g)	0.73	-0.36	0.11	-0.10	-0.13
Sodium (mg/100 g)	0.21	-0.40	0.09	-0.59	0.29
Zinc (mg/100 g)	0.69	0.24	-0.45	0.02	-0.13
Manganese (mg/100 g)	0.11	0.33	-0.46	0.50	0.26
Copper (mg/100 g)	0.86	0.04	-0.29	-0.08	0.02
Iron (mg/100 g)	0.83	0.11	-0.35	-0.05	0.06
Yield per plant (kg)	0.39	-0.01	0.60	0.23	0.41

Principal component analysis was carried out using 14 traits comprising of fruit quality traits including mineral composition and fruit yield per plant to understand the underlying inter relationships in the whole set of nutrient composition data and to select the best linear combination of nutrients that explains the largest proportion of the variation in the data set. Estimation of PCA revealed that the first three principal components (PCs) together governed 58.63% of the total variability (Table 5). PC1 and PC2 individually explained about 29.27 and 19.29 of the total variance, respectively. PC1 showed positive factor loading for phosphorus (0.70), potassium (0.66), calcium (0.66), magnesium (0.73), sodium (0.21), zinc (0.69), manganese (0.11), copper (0.86), iron (0.83) and yield per plant (0.39). PC2 showed highest positive factor loading for total soluble solids (0.89) and vitamin C (0.69). The first component is a measure of the overall nutrient content, since the first Eigen vector showed approximately equal loadings on all nutrients except manganese and sodium, which have less loading. The second Eigen vector has high positive loadings on TSS followed by vitamin C, total carotenoids and manganese content.

Hence, it is clear that iron and copper followed by phosphorus and potassium contributed much towards the total variability among the muskmelon genotypes studied. There was wide diversity among the muskmelon genotypes with respect to phosphorus, potassium, calcium, magnesium, sodium, zinc, manganese, copper and iron contents. On the basis of fruit quality attributes and yield, 7 genotypes, *viz.,* DM-162, DM-159, DM-143, DM-145, DM-31, DM-56 were identified as superior and were group in a single cluster I. Based on higher genetic distance among clusters and higher mean value of genotypes for quality and yield traits, DM-145, DM-159 and DM-162, DM-56 genotypes from *inodorous* group and Pusa Madhuras, Kashi Madhu, Punjab Sunheri and DM-31 from *cantaloupensis* group should be utilized in hybridization programme for developing nutrient rich muskmelon varieties/ hybrids.

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Combining ability and gene action in experimental hybrids of Sweet Corn (*Zea mays* var. *saccharata*)

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ABSTRACT

Combining ability effect was estimated for sixty crosses produced in Line × Tester design using twenty sweet corn parents as female with three sweet corn cultivars as testers. General and specific combining ability for all the traits were found to be significant, suggesting both additive and dominance variance were operating for these traits. Proportionately, the additive variance component was higher in magnitude than dominance component. Based on *per se* and GCA effects the best combiners for more than one trait are IPSA-2710, IPSA-2713 and IPSA-2703. IPSA-2710 was good general combiner for days to tasseling, silking and maturity. For ear weight with husk, without husk and grain yield, the parent IPSA-2713 was found superior, and IPSA-2703 for TSS and cob length. While IPSA-2707 had good GCA for ear weight with husk, without husk, TSS and grain yield. Among the crosses, based on superior *per se* performance and SCA effect, IPSA-2696 × T2 and IPSA-2698 × T1 were superior for 100 kernel weight and grain yield. IPSA-2714 × T3, IPSA-2698 × T1 and IPSA-2700 × T2 were found superior for ear weight with and without husk and grain yield.

Key words: Sweet corn, additive variance, GCA, SCA, dominance variance.

INTRODUCTION

Among cereal crops, maize is uniquely amenable to many diverse uses as different plant parts are used for a various usages. Such uses attract considerable attention in Indian context due to current emphasis on diversification of agriculture and even diversification within each crop. Specialty corns represent important component of diverse uses of maize and constitute majority of the types suitable for direct human consumption. Sweet corn (*Zea mays* var. *saccharata*) is the type of corn with a thin pericarp layer and it is consumed at immature grain stages of endosperm at 18 to 22 days after fertilization. These genotypes accumulate higher amounts of sugars due to gene/genes operating in different stages of starch biosynthesis pathway. Such changes make sweet corn amenable for using as vegetable in many ways (Dagla *et al*., 4). Single cross hybrids in maize are gaining prominence in field corn, the same strategy would be applicable in other specialty corns, including sweet corn improvement (Gadag *et al*., 7). It is widely used in many countries in different forms and, India is emerging as one of the potential sweet corn producing country due to low cost of production and high demand within the country. There is a great potential to earn foreign exchange through export of fresh/canned sweet corn and its processed products. Some efforts towards sweet corn improvement were initiated during couple of years using different approaches (Meena *et al*., 12).

However, further studies with wider and better choice of source material are warranted. Moreover, it is important to study the traits related to green ears, which are more relevant for the marketable product. A better understanding of the magnitude and nature of gene action of such character could help the breeder in identifying and using an appropriate breeding strategy (Kumari *et al*., 11). Therefore, the present investigation was undertaken to determine combining ability and gene action for yield, its component and quality traits. A technique that helps to choose the best parents based on their performance, as well as for selection of promising hybrids, is the line × tester mating design. It also provides information on variances that govern the character in the study (Kempthorne, 8). The combining ability analysis is an important method to know gene actions and it is frequently used by crop breeders to choose the parents with a high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects. Large genotype × environment effects tend to be viewed as problematic in breeding because of lack of a predictable response which hinders progress through selection. The aim of this study was to evaluate twenty sweet corn inbreds for performance *per se* and combining ability for yield and yield components in specific hybrid combinations.

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MATERIALS AND METHODS

The genetic materials used in the present study were twenty sweet corn inbred lines which were used as female lines and three popular sweet corn composites namely Win orange, Madhuri and Priya as male parents. The crosses were made in the line × tester mating design and numbers of total crosses (female x male) were sixty. The total of eighty three entries, comprising of 60 F_1s, twenty parents and three testers were evaluated in two seasons, *Rabi* and *Kharif* 2010 in a Randomized Block Design in three replications at IARI Experimental Farm, New Delhi. The each experimental plot consisted of two rows, each of 5m length with 75 cm inter row and 20 cm plant-to-plant spacing. Standard agronomic practices were followed for raising and maintenance of the crop.

Fifteen traits relating to productivity and quality parameters were recorded. In which data on ear weight, ear length, ear breadth, number of rows and kernels per ear were recorded at fresh harvest stage ie., 20-22 days after pollination as the average of five randomly selected dehusked green ears per plot. For estimation of total soluble solids, kernels from this subsample were cut to full depth, squeezed with a press, and the juice was centrifuged at 5000 rpm for 1 minute just to separate the extract from the debris. Total soluble solids (Brix content, an indicator of sugar concentration) within the supernatant of the juice were measured with refractometer (Pocket Refractometer, Atago Company, India.) (Elayaraja *et al*., 6). The combining ability analysis was done by following the procedure of line x tester given by Kempthorne (8) and Arunachalam (1). Statistical analysis was done using computer software SPAR-I for all statistical and biometrical analysis developed by Indian Agricultural Statistical Research Institute, New Delhi.

RESULTS AND DISCUSSION

Sweet corn genotypes, in general show relatively poor germination, lack early vigour and also plant stand in extreme climatic condition affect field emergence and these factors result in lower yield and nonuniform maturity (Tracy, 15). This emphasizes the importance of stabilization and adaptation of sweet corn germplasm in the different locations and season. As expected the variation in two seasons was significant for all the traits studied. The two traits which have not shown significant difference were number of rows per ear and 100 seed weight (Table 1). It shows that the number of rows per ear was not affected by the season and consistent performance was observed in both seasons. Also the 100 kernel weight in dried sweet corn lines is not expected to vary much across the season this can the possible explanation of insignificant difference in two seasons for this trait. However, these traits have shown highly significant difference between lines and testers as well as in hybrids.

The ANOVA revealed high level of variability for all the traits between lines, testers and hybrids. This shows that the material used for the study is diverse for all the agronomic and quality traits. In realty the sweet corn lines have narrower genetic base than normal corn (Srdic *et al*., 14). As mentioned above the lines in the study are new and diverse which are helpful in broadening the genetic base of available sweet corn germplasm. Parents are significantly different for all the agronomic traits at 1% significance level except for days to maturity which is significant only at 5% significance level. Similar pattern of variation was observed in the female parents that is, highly significant difference for all the agronomic and quality traits except for days to maturity which is significant at 5% significance level. All the testers (male parents) in the present study did not vary significantly for many traits but were highly significant for ear length, TSS and significant for days to silking, plant height, ear placement height, 100 seed weight and grain yield per plant among the agronomical traits. Females vs. males were significant for all the agronomical traits except for ear breadth and TSS. The significant difference between the hybrids suggests the varying performance of cross combinations manifested in the hybrids. Only the days to tasseling and maturity was not significant in hybrids as well in testers. In general, all the sweet corn genotypes may belongs to same maturity group. This suggests that the combination of genes in crosses rendered anthesis and maturity insignificant. Further, sweet corn ears are harvested after specific days of fertilization (18-22days). The parents *versus* hybrids component was also found significant for all the agronomical traits except ear placement height. Similar findings were reported by Kumara *et al*. (10).

Days to tasseling, silking and maturity, these three traits reflecting duration of genotypes have not shown significant GCA (Table 2). The SCA variance component was significant. This suggests a strong non-additive gene action for these traits. The specific cross combination performance is governed by inter and intra allelic interactions like dominance and overdominance and epistasis. Thereby, in the present study, it can be inferred that combination of plus and minus genes in coordination led the days to lesser flowering and maturity differences in hybrids. All the traits including agronomical traits have shown significant GCA and SCA variance, suggesting both

Table 1. GCA effects among the sweet corn parental lines for flowering, yield and related traits (Pooled data).

Parents	Days to tasseling	Days to silking	Days to maturity	Ear wt. with husk (gm)	Ear wt. without husk (gm)	Ear length (cm)	Ear breadth (cm)	No. of rows per ear	No.of kernels per row	Total soluble solids (TSS)	Plant ht. (cm)	Ear Placement ht. (cm)	100 seed weight (g)	Grain yield per plant (g)	Grain yield (kg/ha)
IPSA-2696	0.25	-0.77	-0.70	-2.54	2.53	-0.21	-0.06	0.33	1.55*	-0.98**	8.79**	1.65	0.06	-6.83**	-455.78**
IPSA-2697	0.25	-0.27	-0.86	17.65**	13.79**	-0.02	-0.06	0.17	-0.75	-0.43	8.20**	2.95**	0.54*	4.20**	279.96**
IPSA-2698	0.01	-0.38	0.08	-0.63	3.75	0.06	0.13	-0.28	0.57	-0.45	-4.55**	-6.27**	-0.20	-3.44**	-229.52**
IPSA-2699	-0.55	-0.72	-0.79	0.81	7.24*	-0.32	-0.21**	-0.45*	-1.01	-1.38**	-1.31	-5.47**	1.68**	1.01	67.14
IPSA-2700	0.30	0.12	-0.20	-2.54	-4.44**	-0.35	-0.07	0.35	0.76	-1.27**	-4.84**	-3.38**	-0.99**	-0.81	-54.31
IPSA-2701	-0.16	-0.77	-0.32	1.54	3.49	-0.59**	-0.16	-0.09	-0.34	0.43	4.10**	-5.34**	0.52*	1.60*	106.64
IPSA-2702	-0.38	-0.99	-0.58	-9.54**	-10.06**	0.25	0.06	0.24	-1.40*	-0.50	0.24	-3.76**	-1.09**	-6.81**	-454.15**
IPSA-2703	-0.10	0.17	1.10*	-3.16	0.21	0.49**	-0.28**	-0.22	0.96	2.34**	-3.33*	1.69	0.09	-3.35**	-223.48**
IPSA-2704	1.10*	0.45	0.66	9.22**	13.20**	0.71**	-0.12	0.14	2.22**	0.50	-1.38	2.38*	0.02	2.48**	165.36**
IPSA-2705	-0.46	-0.33	0.21	12.47**	6.03**	-0.02	0.01	0.15	-0.49	1.47**	2.22	4.37**	0.09	1.72*	114.82*
IPSA-2706	0.25	0.47	0.73	-3.06	-3.87*	0.53**	0.04	-0.31	1.13	0.08	-5.86**	-3.56**	0.05	-1.52*	-101.51
IPSA-2707	-0.75	-0.49	-0.64	12.55**	11.34**	-0.39*	0.13	0.27	-0.97	2.81**	1.47	0.72	0.12	4.26**	283.85**
IPSA-2708	0.54	1.08*	0.21	-15.51**	-19.90**	-0.01	-0.15*	0.16	1.35*	-0.05	4.11**	7.43**	-0.66**	-0.06	-3.73
IPSA-2709	0.19	1.23*	0.92	-22.95**	-21.83**	0.98**	0.10	0.25	2.12**	-0.15	2.38	6.34**	0.07	-3.21**	-213.88**
IPSA-2710	-1.49**	-1.23*	-1.14*	14.72**	12.72**	0.06	0.10	-0.43*	-0.62	-1.24**	-4.87**	2.20*	0.67**	6.80**	453.39**
IPSA-2711	0.79	0.54	0.53	-2.92	-5.09**	0.40*	0.29**	0.06	-0.68	0.12	0.01	2.16*	-0.40	-2.28**	-151.79**
IPSA-2712	-0.16	0.17	0.12	-20.44**	-14.51**	-1.42**	-0.17*	0.20	-2.79**	-0.69*	-0.85	-4.62**	-0.41	-0.94	-62.50
IPSA-2713	-1.20*	-1.05*	-1.31*	16.18**	13.57**	-0.59**	0.16*	-0.03	-0.46	1.01**	-2.67	-0.17	-0.03	5.32**	354.87**
IPSA-2714	0.19	0.78	0.08	-0.36	-0.39	0.61**	0.22**	-0.46*	-1.28*	-0.68*	1.36	0.19	0.35	3.65**	243.23**
IPSA-2715	1.38**	2.00**	1.90**	-1.49	-7.79**	-0.17	0.03	-0.05	0.12	-0.94**	-3.23*	0.48	-0.47*	-1.78*	-118.59*
SE	0.51	0.53	0.53	2.24	1.90	0.19	0.07	0.18	0.62	0.27	1.36	0.98	0.21	0.86	57.33
Testers															
T1	0.03	0.15	0.03	-2.55**	-3.42**	-0.22**	-0.04*	-0.06	-0.10	-0.07	1.36**	-0.55	0.10	-0.13	-8.37
T2	0.09	0.11	0.03	3.82**	3.76**	0.32**	0.01	-0.10	-0.01	0.09	-0.35	1.01**	0.23**	1.60**	106.48**
T3	-0.12	-0.25	-0.06	-1.27	-0.34	-0.11	0.03	0.16**	0.11	-0.02	-1.02**	-0.46	-0.33**	-1.47**	-98.11**
SE	0.17	0.17	0.17	0.73	0.62	0.06	0.02	0.06	0.20	0.09	0.44	0.32	0.07	0.28	18.60

* and ** indicate significance level at 5% and 1%, respectively.
T1 - Win orange,T2 - Madhuri and T3 - Priya

Table 2. SCA effects for flowering, yield and related traits in selected experimental crosses of sweet corn (Pooled data).

Crosses	Days to tasseling	Days to silking	Days to maturity	Ear wt. with husk (gm)	Ear wt. without husk (gm)	Ear length (cm)	Ear breadth (cm)	No. of rows per ear	No.of kernels per row	Total soluble solids (TSS)	Plant ht. (cm)	Ear Placement ht. (cm)	100 seed weight (g)	Grain yield per plant (g)	Grain yield (kg/ha)
IPSA-2696 × T2	-0.76	-0.49	-0.42	17.74**	20.21**	0.60*	-0.12	-0.06	0.65	-1.77**	0.52	1.34	1.17**	9.09**	606.14**
	(85.17)	(89.83)	(132.83)	(269.56)	(222.63)	(18.94)	(3.66)	(13.98)	(33.60)	(15.83)	(190.89)	(83.13)	(14.48)	(67.18)	(4479.90)
IPSA-2698 × T1	-0.79	-0.92	-1.36	24.75**	22.16**	0.36	0.01	-0.66*	2.00*	0.98*	1.12	1.62	2.45**	9.02**	601.65**
	(84.83)	(89.83)	(132.67)	(272.11)	(218.62)	(18.44)	(3.93)	(12.81)	(33.88)	(18.94)	(179.86)	(73.93)	(15.36)	(68.78)	(4586.83)
IPSA-2700 × T2	2.02**	2.45**	2.25**	27.12**	34.90**	-0.34	0.47**	-0.50	0.02	0.12	3.50	4.74**	1.13**	5.39**	359.50**
	(88.00)	(93.67)	(136.00)	(278.94)	(230.35)	(17.86)	(4.24)	(13.57)	(32.18)	(17.42)	(180.24)	(81.50)	(13.39)	(69.50)	(4634.73)
IPSA-2701 × T2	1.82*	2.51**	1.87*	29.76**	25.88**	0.82**	0.19	0.31	2.87**	0.30	3.41	3.97**	0.79**	3.31**	221.00**
	(87.33)	(92.83)	(135.50)	(285.66)	(229.26)	(18.78)	(3.87)	(13.93)	(33.93)	(19.31)	(189.09)	(78.76)	(14.55)	(69.83)	(4657.19)
IPSA-2702 × T2	0.04	0.23	0.13	19.59**	23.59**	0.39	-0.30**	0.15	1.27	0.87*	1.07	1.30	0.73*	8.80**	586.72**
	85.33	90.33	133.50	264.41	213.42	19.19	3.60	14.11	31.27	18.95	182.88	77.67	12.88	66.91	4462.12
IPSA-2703 × T1	-1.90*	-2.48**	-1.83*	8.67**	9.10**	0.46	0.00	0.61*	1.34	0.14	-6.41**	-0.11	0.11	6.52**	435.11**
	(83.61)	(88.83)	(133.22)	(253.50)	(202.02)	(18.96)	(3.51)	(14.15)	(33.61)	(20.90)	(173.55)	(80.16)	(13.32)	(66.37)	(4426.33)
IPSA-2705L × T1	-0.49	-0.65	-0.27	19.81**	15.90**	-0.24	-0.31**	0.05	2.54**	0.84*	-3.05	-2.78*	-0.17	5.51**	367.13**
	(84.67)	(90.17)	(133.89)	(280.26)	(214.64)	(17.75)	(3.49)	(13.95)	(33.35)	(20.73)	(182.46)	(80.17)	(13.03)	(70.43)	(4696.64)
IPSA-2706 × T3	2.12**	2.01**	2.19**	13.99**	11.39**	-0.23	-0.10	0.29	0.47	0.60	1.62	-0.14	-0.55	2.56*	170.80*
	(87.83)	(93.22)	(136.78)	(260.20)	(203.31)	(18.42)	(3.79)	(13.97)	(33.12)	(19.15)	(176.67)	(74.98)	(12.19)	(62.89)	(4194.25)
IPSA-2710 × T1	-0.29	0.09	-0.47	13.46**	13.94**	0.63*	0.13	0.24	1.22	-2.05**	-0.56	1.24	0.62*	-0.45	-30.01
	(83.83)	(90.00)	(132.33)	(276.17)	(219.37)	(18.70)	(4.03)	(13.57)	(31.91)	(15.13)	(177.87)	(82.02)	(14.40)	(69.55)	(4638.07)
IPSA-2712 × T2	-0.85	-1.27	-1.57*	-8.82**	-10.70**	-1.07**	-0.06	1.04**	-2.95**	2.69**	-3.00	-3.30*	1.46**	-1.59	-105.70
	(84.67)	(90.00)	(132.50)	(225.11)	(174.67)	(16.06)	(3.60)	(14.96)	(25.65)	(20.58)	(177.73)	(72.22)	(14.30)	(62.40)	(4161.34)
IPSA-2712 × T3	-1.53*	-1.08	-0.53	20.36**	19.73**	0.85**	0.16	-0.08	3.27**	-1.96**	1.48	1.09	0.64*	8.65**	576.83**
	(83.78)	(89.83)	(133.45)	(249.19)	(201.01)	(17.56)	(3.84)	(14.09)	(32.00)	(15.81)	(181.54)	(75.15)	(12.92)	(69.57)	(4639.29)
IPSA-2714 × T3	0.18	1.81*	0.56	29.80**	24.30**	-0.39	-0.01	0.50	0.14	1.62**	-5.54**	-7.76**	0.32	6.03**	402.16**
	(85.83)	(93.33)	(134.50)	(278.71)	(219.71)	(18.35)	(4.06)	(14.01)	(30.38)	(19.41)	(176.73)	(71.11)	(13.37)	(71.53)	(4770.34)
IPSA-2715 × T1	1.17	1.29	0.82	18.79**	19.57**	0.36	0.02	0.60*	1.08	-0.51	7.46**	2.75*	0.74*	9.69**	646.11**
	(88.17)	(94.44)	(136.67)	(265.29)	(204.49)	(18.20)	(3.84)	(14.30)	(32.51)	(16.97)	(187.53)	(81.81)	(13.39)	(71.11)	(4742.21)
SE	0.72	0.75	0.75	3.17	2.68	0.27	0.10	0.26	0.88	0.39	1.93	1.39	0.30	1.22	81.07

* and ** indicate significance level at 5% and 1%, respectively. T1-Win orange,T2- Madhuri and T3- Priya

() values in parenthesis are means of crosses

additive and dominance gene action is operating for these traits. This report is similar to the earlier findings of Sadaiah *et al*. (13) and Azad *et al*. (2). Proportionately, the additive variance component was higher in magnitude than dominance component. This information on these new lines is of much importance in further improving the agronomical and quality traits in future. The predominance of GCA variance suggests that the improvement in the said traits is still possible. The precise phenotyping, high selection intensity and use of elite breeding material with high population mean would give high response to selection. Nevertheless, the results obtained in the study on combining ability suggest that most of the lines used in the study have high *per se* performance than the checks (Win-Orange, Madhuri and Priya). And, the hybrids (Line × Tester) have also shown better performance indicating that the cultivars developed can go for commercial cultivation after multi-location evaluation. Though *per se* performance is important in identifying the superior cross combination or elite lines but, the combining ability effect scores strengthen the strategy to be employed by the breeder to improve upon specific base population.

The combining effects i.e GCA and SCA effects obtained in the analysis were critically scrutinized for identification of some of the best combiners (general or specific or both) *vis-à-vis* mean performance. Based on the GCA effects and *per se* performance some of the best combiners for agronomical traits (comprising of multiple desirable features) were identified as IPSA-2710, IPSA-2713 and IPSA-2703. While IPSA-2710 was found good combiner for days to tasseling, silking and maturity, IPSA-2713 for ear weight with husk, without husk and grain yield, and IPSA-2703 for TSS and cob length (Table 1). The other lines important to consider are IPSA-2699 which are good combiners for 100 kernel weight and IPSA-2707 are good combiner for ear weight with husk, without husk, TSS and grain yield. The IPSA-2707 is good general combiner for important traits of sweet corn. IPSA-2710 showed negative significant GCA for over all duration traits, which is desirable for developing early maturing sweet corn hybrids which is corroborated the report of Dhasarathan *et al*. (5). Many lines have also shown better GCA for yield contributing traits which are highly correlated to the cob weight, which means that increase in cob weight is dependent on cob length, cob diameter, number of kernel rows and kernel rows per ear. Kashiani and Saleh (9) reported that agronomical and quality traits shows quantitative inheritance. Using these identified lines in population improvement programmes will serve as necessary foundation for developing sweet corn inbred lines which may be utilized for hybrid development program in future. Among the testers, mean performance of Priya (T3) was better than other two testers for ear length, ear breadth, number of rows per ear, number of kernel per row, grain yield, but, has shown significant GCA only for number of kernel rows per ear in desirable direction. Madhuri (T2) showed significant positive GCA effect for ear weight with and without husk, ear length, grain yield. Significant GCA effect for ear weight without husk, ear length and grain yield, suggests the role of additive gene action for the expression of these traits. It implies that selection and fixing of favorable alleles for these traits is possible.

Keeping in view the requirement for sweet corn quality traits coupled with yield contributing traits the hybrids with superior *per se* performance and SCA effect are IPSA-2696 × T2 and IPSA-2698 × T1 (Table 2). The other crosses which are found best specifically for green ear usage are IPSA-2714 × T3, IPSA-2698 × T1 and IPSA-2700 × T2. These crosses are found superior for ear weight with, without husk and grain yield. The similar finding was found by Worrajinda *et al*. (16). The crosses IPSA-2714 × T3 and IPSA-2698 × T1 were also found superior for TSS and 100 kernel weight respectively. IPSA-2703 × T1, IPSA-2696 × T2, IPSA-2698 × T1, IPSA-2712 × T3, IPSA-2696 × T3 and IPSA-2715 × T1 crosses were found good specific combining ability effects for grain yield which is similar to findings of Dhasarathan *et al*. (5). The cross IPSA-2712 × T2 has well performed for TSS and 100 kernel weight. Further, these crosses may be advanced to next generation for selecting better segregants with high marketable yield and sugar content. Cartea *et al*. (3) evaluated field corn inbreds as useful source to improve yield, field emergence and agronomic performance. In the present study, the above mentioned cross combinations were good specific combiner for more than one agronomical trait.

Based on *per se* and GCA effects, IPSA-2710 was found as good general combiner for days to tasseling, silking and maturity; IPSA-2713 for ear weight with husk, without husk and grain yield; and IPSA-2703 for TSS and cob length. While IPSA-2707 is good GCA for ear weight with husk, without husk, TSS and grain yield. IPSA-2710 showed negative significant GCA for flowering and maturing traits which is desirable for developing early maturing sweet corn hybrids. The hybrids based on superior *per se* performance and SCA effects, IPSA-2696 × T2 and IPSA-2698 × T1 showing superiority for 100 kernel weight and grain yield. IPSA-2714 × T3, IPSA-2698 × T1 and IPSA-2700 × T2 which were found superior for ear weight with, without husk and grain yield, indicating

their value best for green ear usage. The lines showing high *per se* performance and showing high SCA effects in crosses for yield or yield contributing traits and/or quality traits can be used in further improvement of sweet corn lines.

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Collection and phenotypic characterisation of pole-type common bean (*Phaseolus vulgaris* L.) landraces from Mizoram

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ABSTRACT

Common beans are one of the many important food legumes grown in India. In the hilly regions of north-eastern India farmers mostly grow the pole-type beans by intercropping beans with maize, and in backyards and kitchen gardens. In this study, we characterized a set of 52 pole-type common bean landraces collected from the state of Mizoram for 23 agro-morphological and quality traits. Remarkable variability was observed for almost all the traits. Wide range of variability was found for the traits such as leaf length (7.5-18.0 cm), leaf breadth (6.2-12.8 cm) days to flowering (33-70 days), pods per plant (7.7-24.0), pod length (8.1-14.6 cm), pod yield per plant (61.5-182.3 g), seeds per pod (4.6-8.0), 100-seed weight (23.0-50.1 g) and crude protein content (20-33.8%). Positively significant correlation coefficients were observed between 100-seed weight and days to flowering; number of pods per plant and pod yield per plant. The patterns of morphological variation were assessed using multivariate approaches. Five morphologically distinct clusters were identified within the collected germplasm. The evolutionary grouping of the common bean landraces has been discussed considering the morphological features.

Key words: Climbing bean, genetic characterization, phenotypic diversity.

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) has one of the longest histories of cultivated plants and is an important source of minerals and phyto-chemicals (Dutta *et al*., 3). The crop originated and was domesticated in the New World in two centres of origin (Andes and Mesoamerican), which gave rise to two major gene pools (Andean and Mesoamerican) with racial sub-divisions (Blair *et al*., 2). It is grown in different parts of the world and there are many secondary centres of diversity outside the centres of origin (Zhang *et al*., 13).

In India, common beans, popularly known as *Rajmash*, are grown in about 9.1 mha yield around 3.6 MT (FAO, 5). Information on the dissemination of common bean in India especially in the NE Himalayan region is sparse (Sofi *et al*., 12). Most possibly the common beans introduced to this part of India by English traders in early 16th century and by Chinese through Hindustan Silk Route (Joshi and Mehra, 7). The genetic diversity of Indian common beans resembles European and Chinese beans, which suggests the combination of both Andean and Mesoamerican cultivated gene pools (Angioi *et al*., 1). Mizoram is one of the eight states of NE India with a tribal population of ~95%. Diversity of pole-type common bean landraces in Mizoram is remarkable. Till date, few studies have been conducted with a limited number of landraces of Mizoram (Dutta *et al*., 4; Singh *et al*., 11). In the present study, we undertook phenotypic characterization of common bean landraces collected from Mizoram to assess the extent of variability in phenological, agro-morphological and quality traits.

MATERIALS AND METHODS

A total of 52 common bean landraces of Mizoram were used in this study. Most of the landraces were collected and maintained by the researchers at ICAR Research Complex for North Eastern Hill Region, Kolasib, Mizoram during 2008-13. The landraces were collected from six districts (Kolasib, Aizawl, Serchhip, Lunglei, Lawngtlai and Saiha) of Mizoram (Fig. 1a). The collected germplasm accessions fairly represent the pole-type common bean diversity in the state. The accessions have been sent for long-term storage at ICAR-NBPGR, New Delhi.

Data on the germplasm were recorded during June-October in 2013 and 2014. The plants were grown under screen-house conditions at Kolasib, Mizoram (24.2304° N, 92.6761° E and 722 m altitude). Two seeds per accession were sown in pots filled with 8 kg of soil (two parts of forest soil and one part of fine sand). Potting mixture properties were pH: 6.28 ± 0.17, EC: 0.984 ± 0.016, organic C (%): 1.57 ± 0.25, N (kg/ ha): 166.2 ± 9.41, P (kg/ ha): 52.5 ± 1.33, K

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(kg/ ha): 275.5 ± 19.04, Cu (mg/ kg): 1.12 ± 0.08, Zn (mg/ kg): 2.51 ± 0.11, Mn (mg/kg): 42.1 ± 1.90 and Fe (mg/ kg): 21.9 ± 0.07. A total of ten plants per accession were used to record data on vegetative morphological traits. The plants received adequate irrigation and natural photoperiod throughout the growth cycle. Range of maximum temperature, minimum temperature and RH were 33.8-35.8ºC, 23.5-28.6ºC and 81-87%, respectively during the crop growth period.

Data were recorded on 23 traits based on observations recorded on ten plants per accession following *Phaseolus vulgaris* descriptors published by IBPGR (IBPGR, 6). Data on leaf length (LL), leaf breadth (LB), days to flowering (DF), flower bud per inflorescence (FBI), nodes number at harvest (NH), number of pods per plant (PPP), pod length (PL), pod yield per plant (PYP), number of seed per pod (SPP), 100-seed weight (SW) and crude protein percent (CP) were recorded. Qualitative observations were taken on pod colour (PC), seed coat colour (SCC), colour of freshly opened flower (CFF), pod cross section (PCS), pod curvature (PCV), seed shape (SS), flower bud size (FBS), size of bracteolate (SIB), shape of bracteolate (SOB), bracteolate colour (BC), pod beak position (PBP) and pod beak orientation (PBO). The statistical parameters, *viz.* mean, standard deviation (SD), range, coefficient of variation (CV), and skewness were determined based on 2-year data of quantitative traits with completely randomised design (CRD) of experiment. Pearson's correlation coefficients (r) were calculated for the quantitative traits. The qualitative traits were subjected to frequency distribution. Z scores were used to standardize the data and then used for principal component analysis (PCA). The extracted principal components (PCs) were further used in the Ward's hierarchical clustering to assess the phenotypic diversity in common bean landraces. All the analyses were performed in SPSS.

RESULTS AND DISCUSSION

Seeds were collected mainly from the farm-stores of villages mostly located along the road side, as the terrain is very difficult (Fig. 1a). A wide range of variations were observed in the seed morphology of the collected common bean accessions of Mizoram (Fig. 1b). The descriptive statistics of range of variations recorded for eleven quantitative variables

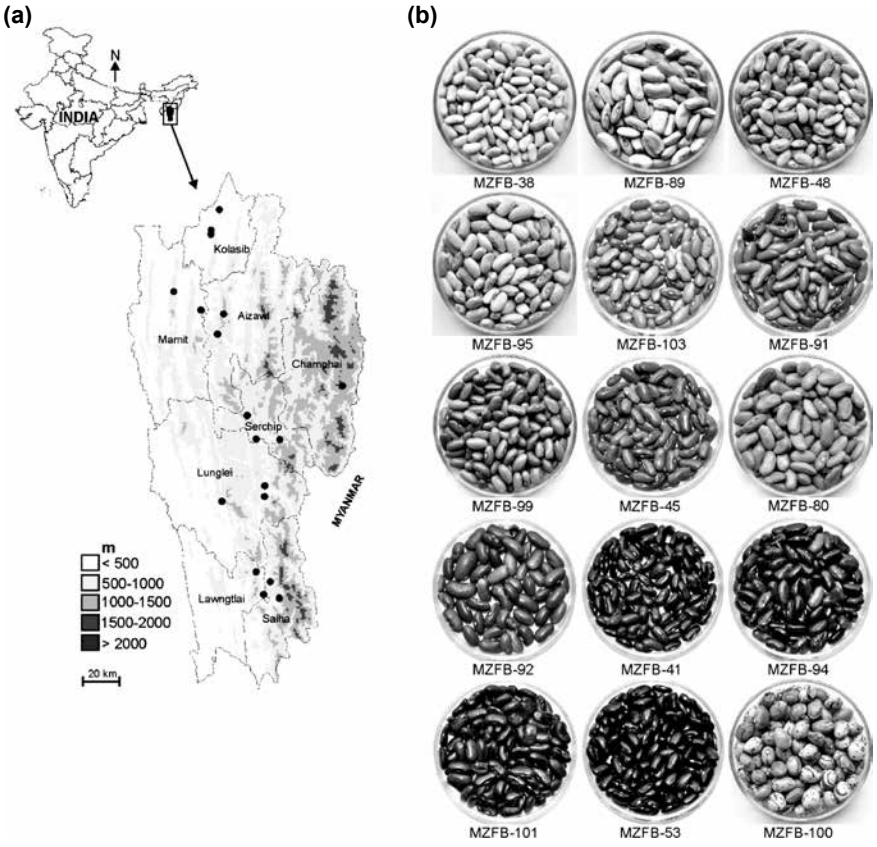

Fig. 1. Pole-type common bean landraces in Mizoram. (a) Collection sites of 52 accessions with altitude ranges indicated by gray shadings; (b) Variability in seed shape and colour in the collected germplasm.

are given in Table 1. The landraces exhibited large variations for PPP, PYP, FBI, LL and SW as appeared from the coefficient of variation values. The earliest flowering landrace was MZFB-50a (33 days) while the longest duration for flowering was observed in MZFB-80 (70 days). PPP ranged from 7.7 (IC0611109) to 24.0 (IC0611107). PYP varied from 61.5 g (IC0611109) to 182.3 g (IC0611107) with a mean value of 107.1 g. A large variation in SW was also observed. It ranged from 22.9 g (IC0611101) to 50.6 g (MZFB-100) with a mean value of 32.0 g. There was a considerable variation in crude protein content within the germplasm. The highest and the lowest CP were recorded in MZFB-81 (19.9%) and IC0611106 (33.8%), respectively. The landraces with >30% crude protein content were IC0611109, IC0611110, MZFB-99, IC0611104, MZFB-82, MZFB-107, MZFB-93 and MZFB-102. Negative skewness exhibited by traits like LB, FBI and NH indicated that most of the landraces had broader leaf, higher number of FBI and higher NH. Characterisation based on qualitative data revealed that majority of the landraces exhibited normal green PC (80.8%), brown, pale to dark SCC (69.2%), white CFF (67.3%), pear shaped PCS (55.8%), slightly curved pods (75%), cuboid seeds (51.9%), medium FBS (75%), medium SB (78.8%), intermediate SOB (61.5%), green bracteolate (63.5%), marginal PBP (59.6%) and upward PBO (40.4%) (Table 2). Considering the seed traits and growth habit, the common beans of Mizoram can be included in the Mesoamerican gene pool. Phenotypic and phonological information based on descriptors is considered as the first step for the assessment, description and classification of germplasm collections to promote the use of crop genetic resources in plant breeding programmes (Raggi *et al*., 9). The phenotypic characterization helps in deciphering the nature and magnitude of genetic divergence among the gene pools for reliable scoring during selection of potential parents for hybridization (Kumar *et al*., 8).

Pearson correlation coefficients between the quantitative agro-morphological characters are given in Table 3. There was a highly significant association ($P < 0.01$) among the traits such as LL and LB, LL and FBI, LB and FBI, DF and SW, PPP and PYP. Significant negative association associations were found between LL and DF ($P < 0.05$), LL and SW ($P < 0.01$), LB and DF ($P < 0.05$), LB and SW ($P < 0.01$), DF and FBI ($P < 0.01$), FBI and SW ($P < 0.01$). Information on the associations between yield and its components is important for improving yield through traditional plant breeding methods because it helps in choosing effective selection criteria

Hierarchical cluster analysis grouped landraces into five clusters based on the 23 agro-morphological traits (Fig. 2a). The mean values of quantitative traits of landraces falling in each cluster are presented in Table 4. The qualitative characters of the landraces in different clusters are presented in Table 5. Number of landraces in cluster varied from 9 (Cluster 1 and 2) to 13 (Cluster 5). Cluster 1 consisted of nine landraces having higher LL (14.7 cm) and PL (12.4 cm). Similarly, cluster 2 grouped nine landraces with higher LB (10.2 cm), FBI (3.6), NH (17.5) and SPP (6.4). Cluster 3 grouped 11 landraces and was characterised by the lowest mean values for all the traits. Cluster 4 comprised of 10 landraces with late flowering habit (55.6 days), bold seeds (highest 100-seed weight, 40.4 g) and maximum CP (27.3%).

Table 1. Variability in the quantitative traits in pole-type common beans.

Trait	Mean ± SD	Min.	Max.	Variance	CV (%)	Skewness
LL	12.8 ± 2.9	7.5	18.0	8.7	23.1	0.23
LB	9.3 ± 1.6	6.2	12.8	2.5	16.3	-0.25
DF	50.8 ± 5.8	33.0	70.0	34.1	11.4	0.49
FBI	2.9 ± 0.7	2.0	4.2	0.5	24.1	-0.04
NH	16.3 ± 1.7	12.6	20.0	2.9	9.8	-0.09
PPP	13.3 ± 3.9	7.7	24.0	14.9	28.6	1.04
PL	11.2 ± 1.6	8.1	14.6	2.6	14.4	0.20
PYP	107.1 ± 26.5	61.5	182.3	699.9	24.6	0.81
SPP	6.1 ± 0.8	4.6	8.0	0.7	13.1	0.50
SW	32.0 ± 6.4	22.9	50.6	40.4	19.6	1.16
CP	26.2 ± 3.3	19.9	33.8	11.1	12.5	0.25

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 2. Frequency distribution of common bean accessions for qualitative traits.

Trait	Morphological class (% landrace)				
PC	Normal green	Purple stripe on green	Dark purple	Pale red stripe on green	
	(80.8)	(5.8)	(11.5)	(1.9)	
SCC	Brown, pale to dark	Pale cream	Black	Maroon	Light brown
	(69.2)	(1.9)	(23.1)	(3.8)	(1.9)
CFF	White	Lilac	White with red stripes	Purple	
	(67.3)	(1.9)	(3.8)	(26.9)	
PCS	Very flat	Pear Shaped	Round elliptic		
	(9.6)	(55.8)	(34.6)		
PCV	Straight	Slightly curved	Curved		
	(3.8)	(75.0)	(21.2)		
SS	Oval	Cuboid	Kidney Shape	Truncate fustigate	
	(3.8)	(51.9)	(40.4)	(3.8)	
FBS	Small	Medium			
	(25.0)	(75.0)			
SB	Small	Medium			
	(21.2)	(78.8)			
SOB	Lanceolate	Intermediate	Ovate		
	(25.0)	(61.5)	(13.5)		
BC	Green	Pale violet	Dark purple		
	(63.5)	(30.8)	(5.8)		
PBP	Marginal	Non marginal			
	(59.6)	(40.4)			
PBO	Upward	Straight	Downward		
	(40.4)	(32.7)	(26.9)		

PC = Pod colour, SCC = Seed coat colour, CFF = Colour of freshly opened flower, PCS = Pod cross section, PCV = Pod curvature, SS = Seed shape, FBS = Flower bud size, SB = Size of bracteolate, SOB = Shape of bracteolate, BC = Bracteolate colour, PBP = Pod beak position, PBO = Pod beak orientation

Table 3. Correlation coefficients of quantitative traits.

	LB	DF	FBI	NH	PPP	PL	PYP	SPP	SW	CP
LL	0.87**	-0.34*	0.53**	0.09	-0.02	0.22	-0.04	0.12	-0.58**	-0.15
LB		-0.29*	0.54**	-0.05	0.08	0.15	0.09	0.05	-0.54**	-0.16
DF			-0.41**	0.05	-0.17	0.20	-0.18	-0.17	0.42**	-0.05
FBI				0.16	0.01	0.00	0.08	0.02	-0.55**	-0.01
NH					-0.03	0.05	-0.12	-0.10	-0.10	-0.01
PPP						-0.15	0.92**	0.05	-0.17	0.11
PL							-0.16	-0.10	0.15	0.12
PYP								0.02	-0.21	0.01
SPP									-0.08	0.21
SW										0.23

*$P < 0.05$ **$P < 0.01$

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 4. Comparison of cluster means for quantitative traits in common bean accessions.

Trait	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
LL	14.7 ± 2.6[a]	14.7 ± 1.8	14.1 ±2.5	9.3 ± 0.9	11.6 ± 2.4
LB	9.9 ± 1.5	10.2 ± 0.7	10.1 ± 0.9	7.4 ± 1.1	8.8 ± 1.6
DF	49.0 ± 4.5	48.9 ± 7.5	48.3 ± 2.5	55.6 ± 5.8	52.0 ± 5.6
FBI	3.4 ± 0.5	3.6 ± 0.4	3.2 ± 0.6	2.3 ± 0.5	2.6 ± 0.8
NH	17.3 ± 0.9	17.5 ± 1.8	14.8 ± 1.1	16.1 ± 1.8	16.3 ± 1.5
PPP	9.9 ± 2.2	13.7 ± 4.9	14.1 ± 3.9	12.0 ± 1.5	15.7 ± 3.6
PL	12.4 ± 1.3	10.8 ± 1.2	10.4 ± 1.2	11.4 ± 1.7	11.2 ± 1.9
PYP	81.6 ± 15.4	107.8 ± 27.5	116.3 ± 24.8	96.9 ± 11.6	124.4 ± 26.7
SPP	5.8 ± 0.6	6.4 ± 0.8	6.2 ± 0.8	6.2 ± 0.8	6.0 ± 1.1
SW	29.8 ± 3.2	27.6 ± 2.9	29.2 ± 3.1	40.4 ± 7.0	32.7 ± 5.5
CP	26.0 ± 3.9	24.9 ± 2.4	26.3 ± 4.6	27.3 ± 2.3	26.3 ± 3.0
No. of accessions	9	9	11	10	13

[a]Values represent mean ± SD

LL = Leaf length (cm), LB = Length breadth (cm), DF = Days to flowering, FBI = Flower bud per inflorescence, NH = Nodes No. at harvest, PPP = No. of pods per plant, PL = Pod length (cm), PYP = Pod yield per plant (g), SPP = No. of seeds per pod, SW = 100-seed weight (g), CP = Crude protein content (%)

Table 5. Comparison of qualitative agro-morphological traits in five clusters derived from Ward's hierarchical clustering.

Trait	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
PC	Normal green	Normal green/ Purple stripe on green	Normal green	Normal green	Normal green/ Purple stripe on green/ Dark purple/ Pale red stripe on green
SCC	Brown, pale to dark	Brown, pale to dark/ Pale cream/ Black	Brown, pale to dark/ Black	Brown, pale to dark/ Maroon/ Light brown	Brown, pale to dark/ Black/ Maroon
CFF	White/ Purple	White/ White with red stripes	White/ White with red stripes/ Purple	White	White/ Purple
PCS	Pear shaped/ Round elliptic	Very flat/ Pear Shaped/ Round elliptic	Pear Shaped/ Round elliptic	Very flat/ Pear Shaped	Very flat/ Pear Shaped/ Round elliptic
PCV	Slightly curved/ Curved	Slightly curved	Slightly curved/ Curved	Slightly curved	Straight/ Slightly curved/ Curved
SS	Cuboid/ Kidney shaped	Cuboid/ Kidney Shape/ Truncate fustigate	Oval/ Cuboid/ Kidney Shape	Oval/ Cuboid/ Kidney Shape	Cuboid/ Kidney Shape/ Truncate fustigate
FBS	Small/ Medium	Small	Small/ Medium	Medium	Small/ Medium
SB	Medium	Small/ Medium	Small/ Medium	Medium	Medium
SOB	Lanceolate/ Intermediate/ Ovate	Lanceolate/ Intermediate	Lanceolate/ Intermediate/ Ovate	Intermediate/ Ovate	Lanceolate/ Intermediate/ Ovate
BC	Green/ Pale violet	Green/ Pale violet	Green	Green	Pale violet/ Dark purple
PBP	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward	Upward/ Straight/ Downward
PBO	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal	Marginal/ Non marginal

PC = Pod colour, SCC = Seed coat colour, CFF = Colour of freshly opened flower, PCS = Pod cross section, PCV = Pod curvature, SS = Seed shape, FBS = Flower bud size, SB = Size of bracteolate, SOB = Shape of bracteolate, BC = Bracteolate colour, PBP = Pod beak position, PBO = Pod beak orientation

Thirteen landraces having the highest PPP (15.7) and PYP (124.4 g) included in cluster 5.

The contribution of individual landraces to the morphological grouping and the relationship between the clusters were assessed by plotting PC1 and PC2 (Fig. 2b). Cluster 1-3 formed a separate group on the biplot and was appeared to be distant from both cluster 4 and 5. Although the accessions from cluster 4 and 5 were belonged to the same major cluster (Fig. 2a), they formed two separate groups on the biplot (Fig. 2b). Both PCA and cluster analysis were found equally effective in grouping the common bean landraces based on their morphological characteristics. Nevertheless, grouping of landraces into homogenous clusters facilitates useful comparison among all possible pair of populations and provides an opportunity for bringing together gene constellation yielding desirable progenies (Rana *et al*., 10).

In conclusion, the current study serves as a baseline study for the analysis of climbing type common beans in Mizoram as well as in NE India. This study showed the predominance of Meso-American gene pools in Mizoram. The results obtained based on various genetic parameters analysed on wide range of traits, especially seed and pod traits, will help plant breeders in selecting diverse germplasm accessions for yield and its contributing

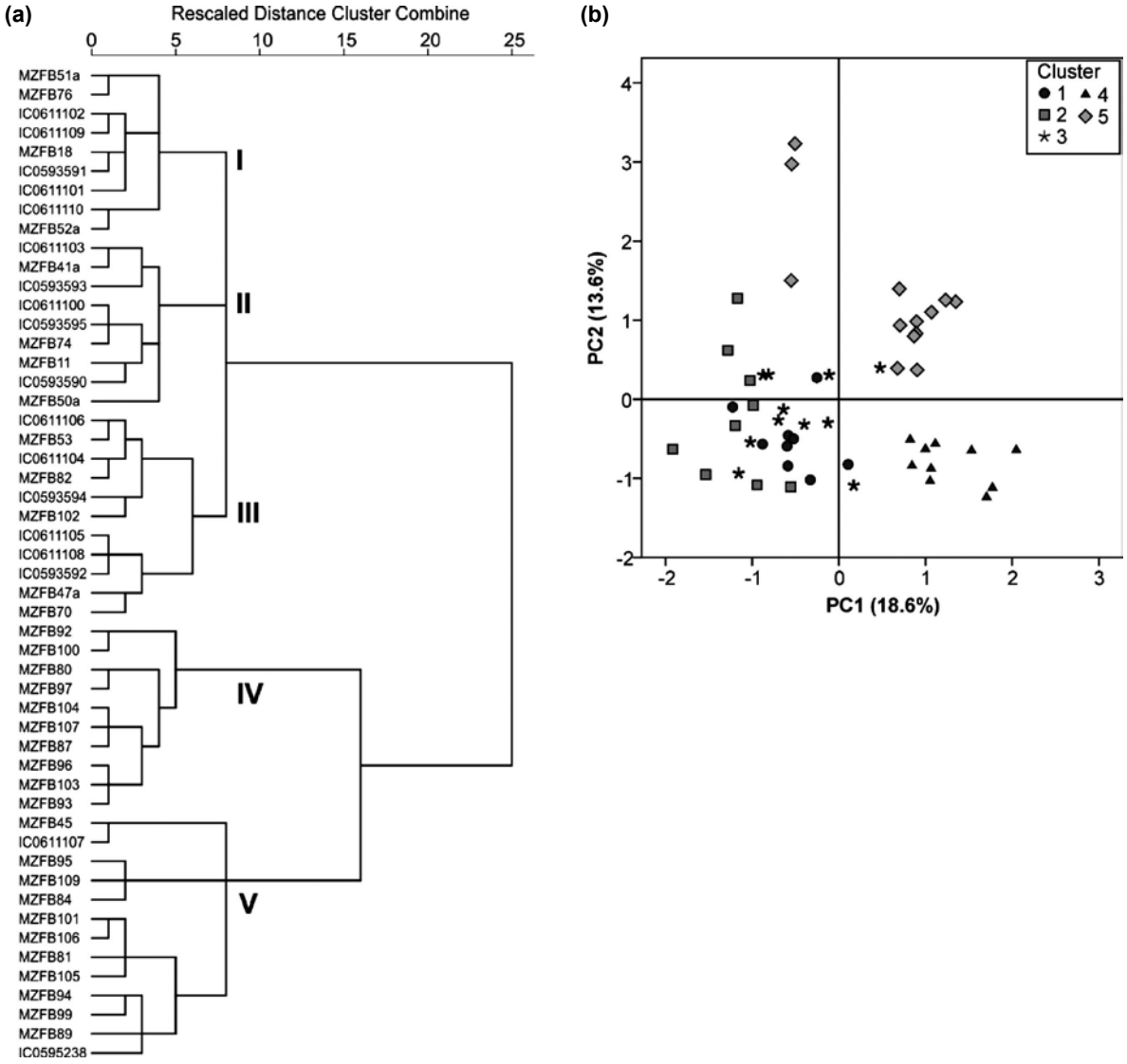

Fig. 2. Grouping of 52 pole-type common bean accessions (a) on the basis of the standardized squared Eulidean distance using Ward's hierarchical clustering method and (b) separation of the common bean landraces in PCA biplot.

traits. The collection and conservation of common bean landraces from various remote locations will safeguard these valuable genetic resources for future use.

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Effect of moisture stress on growth and yield of cucumber genotypes

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ABSTRACT

The experiment was conducted during spring-summer season with twenty five cucumber genotypes subjected to four levels of drought stress (control, 75%, 50% and 25% of recommended irrigation) in the open field experiment using completely randomized design with three replications to assess the effects of drought on vegetative growth and fruit yield. Star flow meter instrument used to measure the amount of irrigation water as calculated to induce an artificial drought stress levels on the plants. ANOVA revealed significant differences amongst genotypes and genotype × drought stress level interaction for all the traits indicating differential response of the genotypes. Decreased amount of water levels resulted in progressive reduction in number of leaves (19.7, 15.3, 12.4 and 9.0), vine length (55.8, 55.4, 46.7 and 41.3 cm) and fruit yield per vine (0.982, 0.645, 0.546 and 0.487 kg), while increased in affected leaves at 18.8, 58.8, 67.2 and 84.6%, respectively in control (100%), 75%, 50% and 25% of recommended irrigation. Thus, these above phenotypic traits appeared to be promising as selection criteria for drought tolerance at morphological level. As a result, the genotypes DGC-1 and WBC-13 observed drought tolerant, whereas DGC-8 and GS-3 were drought susceptible.

Key words: *Cucumis sativus*, drought stress, vegetative growth, fruit yield.

INTRODUCTION

Among abiotic stress, drought is considered as one of the most adverse environmental factors limiting crop productivity. Dry land areas cover more than 40 percent of the world's land surface {CGIAR (http://drylandsystems.cgiar.org/content/worlds-dry-areas)}. Deficit water detrimental effects on crop growth and development in general but varies depending on the severity of stress and the crop growth stage (Aroca, 2). The main consequences of drought in crop plants are reduced in rate of cell division and expansion, leaf size, stem elongation, root proliferation, disturbed stomatal oscillations, plant water, nutrient relations with diminished crop productivity and water use efficiency (WUE) (Yangyang *et al*., 7; Farooq *et al*., 5). One of the most effective approaches to overcome drought stress problems is to use drought tolerant varieties. In this context, breeding efforts should be made to identify genotypes those required minimum amount of water towards crop growth and development. This will not only help to save water but also to improve plant fitness to cope abiotic stresses and thereby minimizes the loss of yield. Plants under drought stress react with alterations in growth, metabolism and production and it depends on the level of plant tolerance which is species and cultivar specific. The degree of this tolerance can be assessed through the analysis of some morphological and yield traits. Extensive research has been done on effects of drought stress on cereals, leguminous crops and some field grown vegetable crops. Though, inter-varietal differences are pronounced with respect to drought tolerance in *Cucumis sativus* (Botia *et al*., 3), yet systematic studies on consequences of drought stress on vegetative growth of cucumber are limited. Understanding effects of drought stress and mechanism of tolerance are essential to breed for drought tolerant cucumber. The best criterion in this regard is to select for higher yield. A reliable and quick method of screening would be necessary for the rapid progress in breeding for drought stress tolerance (Tiwari *et al*., 6). Identifying selection criteria during early growth and vegetative stages is an alternative to reduce time required for screening large number of germplasm. In the present study, the consequences of drought stress on vegetative growth and yield component trait in cucumber were investigated to identify the trait/ criteria important for drought tolerance during early growth and vegetative stages of cucumber.

MATERIALS AND METHODS

The present investigation was carried out at the Division of Vegetable Science, IARI, New Delhi. Twenty five cucumber genotypes, namely, WBC-37, WBC35, WBC17, WBC14, WBC13, WBC10, WBC1, RK40, Pusa Uday, Pahari Barsati, HS-5, HS-1, GS-3, DGC9, DGC-8, DGC7, DGC6, DGC-505, DGC-29, DGC19, DGC-11, DGC1, Barsati, 7026-C and 7026-B-76, previously collected from different parts

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of India, were taken for study. Cucumber seeds were sown in the field in lines with 15 m length, spacing intervals of 50 cm between each line and spacing between each plant was 30 cm. Plants were exposed to four levels of water irrigation which includes three levels of drought stress, *viz*., 100% (control), 75%, 50% and 25% of the recommended irrigation. The water amount has been measured by using the Star flow meter (model No. 6526 E/C, UNIDATA, Australia). The recommended irrigation water amount (100% treatment) was calculated based on crop evapotranspiration calculated using FAO Irrigation and Drainage Paper No. 56 Crop evapotranspiration guidelines for computing crop water requirements (Allen, 1).

Experiment was laid out of completely randomized design (CRD) with three replications and five holes per replication per treatment. Irrigation started normally as 100% of recommended amount of irrigation for all treatments up to 2 weeks till germination completed. After germination, one plant was retained in each hole. At the end of the experiment (60 DAS) when majority of the genotypes started showing wilt symptoms, the observations such as number of leaves, affected leave percentage was recorded. Affected leaves percentage was calculated by recording number of affected leaves out of total leaves. Fruit yield per vine was taken by averaging the total weight of fruits from all the pickings from the surviving vines in each treatment. In order to allow comparisons among genotypes, scoring and ranking on a 1-6 scale procedures was followed as described by (Zeng *et al*., 8). Accordingly, a drought susceptible genotype DGC-8 was chosen susceptible check based on morphological traits and drought tolerance index (DTI), which was estimated and score of 6 was given to this genotype. The DTI was calculated with by using following formula:

All agriculture practices have been followed as recommended and all other environmental factors have been taken care during investigation. Data analysis for RBD was carried out using SAS software.

RESULT AND DISCUSSION

In the present investigation of drought stress, observations were recorded up to 25% of the recommended irrigation, since none of the genotypes survived and yield was severely affected in the crops grown without irrigation. Analysis of variance of the normally distributed data for the percentage, parameters of vegetative growth and fruit yield per vine revealed significant differences among genotype and genotype × drought stress level interaction indicating the existence of considerable genetic variability among the genotypes. The highest mean number of leaves was recorded in WBC-13 (17.8) followed by DGC-1(16.8), which also observed the highest drought tolerance index (1.835 and 1.732) and the highest drought tolerance score (1 and 2) in that order. The lower mean number of leaves was recorded in DGC-8 (9.7) and 'Barsati' (10.0) and these two genotypes had lower drought tolerance index (1.000 and 1.031) and score (6 and 6), respectively. The lowest mean percentage of affected leaves was observed in DGC-1 (0.553) followed by WBC-13 (0.578), while the highest was recorded in DGC-8 followed by GS-3. For per cent affected leaves, the genotypes DGC-1 and WBC-13 had top drought tolerance score of 1, while DGC-8, Barsati and GS-3 recorded the lowest score of 6 (Tables 1 & 4).

Table 1. Effect of different irrigation levels on vegetative growth characters in cucumber genotypes.

Genotype	No. of leaves per vine					Affected leaves (%)					Vine length (cm)				
	Water Irrigation treatment					Water Irrigation treatment					Water Irrigation treatment				
	100%	75%	50%	25%	Mean	100%	75%	50%	25%	Mean	100%	75%	50%	25%	Mean
WBC-37	18.0	13.0	10.5	6.0	11.9	19.5	73.5	80.4	90.3	65.9	37.3	34.0	34.3	31.0	34.1
WBC-35	21.0	17.0	14.0	11.0	15.8	15.3	39.3	53.6	77.4	46.4	85.2	80.3	64.0	51.8	70.3
WBC-17	19.0	16.0	13.5	9.0	14.4	23.0	69.5	75.0	86.4	63.4	45.9	41.3	31.9	35.8	38.7
WBC-14	19.0	14.0	12.5	10.0	13.9	21.9	67.7	74.8	88.4	63.2	39.9	36.0	34.8	33.0	35.9
WBC-13	24.0	19.0	15.0	13.0	17.8	11.0	32.3	44.9	75.7	41.0	102.5	102.9	97.5	74.6	94.4
WBC-10	20.0	16.0	14.0	9.0	14.8	19.2	63.8	68.2	81.6	58.2	51.1	54.1	42.1	41.3	47.1
WBC1	21.0	18.0	14.0	10.0	15.8	22.3	45.0	57.9	81.4	51.6	54.1	54.9	40.9	42.0	48.0
RK-40	18.0	15.0	12.3	7.0	13.1	22.4	67.6	76.1	89.3	63.8	35.9	30.6	36.4	32.0	33.7
Pusa Uday	21.0	17.0	15.0	11.0	16.0	19.3	50.4	58.7	80.4	52.2	55.4	64.8	43.9	44.5	52.1
Pahari Barsati	20.0	17.0	13.0	8.0	14.5	21.2	62.6	70.2	84.7	59.7	48.3	45.9	34.8	36.8	41.4

Genotype	No. of leaves per vine					Affected leaves (%)					Vine length (cm)				
	Water Irrigation treatment					Water Irrigation treatment					Water Irrigation treatment				
	100%	75%	50%	25%	Mean	100%	75%	50%	25%	Mean	100%	75%	50%	25%	Mean
HS-5	19.0	15.0	12.7	9.0	13.9	22.2	71.6	76.3	87.4	64.4	44.0	34.9	32.6	31.9	35.8
HS-1	22.0	17.0	15.0	10.0	16.0	11.1	37.4	50.3	76.3	43.8	96.4	96.3	76.7	59.8	82.3
GS-3	16.0	12.0	7.0	5.0	10.0	23.4	80.3	82.3	95.2	70.3	22.5	22.5	24.7	17.5	21.8
DGC-9	20.0	16.0	13.7	10.0	14.9	20.2	61.5	69.7	85.7	59.3	46.4	43.5	37.0	36.1	40.8
DGC-8	15.0	11.0	7.7	5.0	9.7	26.4	77.6	82.5	97.2	70.9	21.2	22.1	24.3	16.8	21.1
DGC-7	21.0	16.0	13.3	10.0	15.1	16.3	48.6	55.5	78.4	49.7	68.3	74.1	51.3	48.6	60.6
DGC-6	22.0	16.0	16.0	10.0	16.0	12.0	40.5	51.6	77.0	45.3	87.2	89.0	73.5	55.8	76.4
DGC-505	22.0	16.0	13.7	10.0	15.4	17.3	49.2	56.5	78.3	50.3	55.8	71.8	49.3	46.1	55.7
DGC-29	18.0	13.0	8.7	7.0	11.7	19.5	67.3	77.8	91.3	63.9	29.1	26.9	30.2	28.0	28.5
DGC-19	22.0	17.0	14.3	11.0	16.1	11.4	37.0	48.1	75.2	42.9	100.5	101.5	82.8	67.9	88.2
DGC-11	20.0	16.0	14.5	10.0	15.1	19.4	64.4	69.6	84.4	59.4	49.0	51.3	32.9	40.0	43.3
DGC-1	23.0	18.0	14.0	12.0	16.8	10.8	29.7	41.2	75.0	39.2	124.6	117.3	101.7	84.0	106.9
Barsati	16.0	12.5	5.5	6.0	10	19.0	82.6	85.8	93.5	70.2	25.5	24.5	24.0	20.0	23.5
7026-C	19.0	14.0	11.5	8.0	13.1	24.2	73.8	78.4	89.0	66.3	36.1	34.0	34.8	32.5	34.3
7026-B-76	17.0	12.0	7.5	7.0	10.9	22.9	77.9	84.4	92.0	69.3	28.9	26.4	30.4	24.0	27.4
Mean	19.7	15.3	12.4	9.0		18.83	58.845	67.16	84.56		55.8	55.4	46.7	41.3	
$CD_{0.05}$	0.311				0.779	0.274				0.685	2.146				5.364

Table 2. Effect of different irrigation levels on vegetative growth characters in cucumber genotypes.

Genotype	Yield per vine (kg)					Yield reduction (%) over control				No of fruits per vine				
	Water Irrigation treatment					Water Irrigation treatment				Water Irrigation treatment				
	100%	75%	50%	25%	Mean	75%	50%	25%	Mean	100%	75%	50%	25%	Mean
WBC-37	0.865	0.47	0.352	0.308	0.499	45.553	59.263	64.093	56.303	3.33	3.33	2.67	3.33	3.17
WBC-35	1.035	0.802	0.676	0.624	0.784	22.560	34.610	39.673	32.281	4.67	4.33	3.67	3.00	3.92
WBC-17	0.91	0.537	0.427	0.375	0.562	41.080	52.937	58.747	50.921	3.67	3.33	3.33	3.00	3.33
WBC-14	0.87	0.493	0.379	0.338	0.52	43.367	56.397	60.943	53.569	4.33	3.00	4.00	3.33	3.67
WBC-13	1.365	1.149	1.051	0.903	1.117	15.833	22.750	33.677	24.087	8.33	7.33	5.67	5.67	6.75
WBC-10	0.962	0.644	0.553	0.534	0.673	33.180	42.353	44.447	39.993	4.67	4.00	3.67	4.00	4.08
WBC1	1.017	0.711	0.627	0.574	0.732	30.180	38.237	43.500	37.306	4.33	4.33	3.67	3.00	3.83
RK-40	0.84	0.467	0.356	0.309	0.493	44.190	57.490	62.743	54.808	3.67	3.00	3.00	3.67	3.33
Pusa Uday	0.997	0.697	0.616	0.57	0.72	30.120	38.047	42.860	37.009	4.33	4.00	3.33	4.00	3.92
Pahari Barsati	0.908	0.558	0.472	0.479	0.604	38.370	47.783	47.170	44.441	4.33	4.33	3.33	3.33	3.83
HS-5	0.945	0.539	0.415	0.357	0.564	43.100	55.967	62.297	53.788	3.67	3.67	4.00	3.33	3.67
HS-1	1.11	0.874	0.813	0.629	0.856	21.260	26.747	43.343	30.45	6.00	4.67	5.00	4.00	4.92
GS-3	0.828	0.361	0.265	0.248	0.426	56.227	67.760	69.840	64.609	2.67	2.67	2.00	2.00	2.33
DGC-9	0.905	0.541	0.456	0.379	0.57	40.237	49.460	57.920	49.206	3.67	3.67	3.00	2.67	3.25
DGC-8	0.783	0.346	0.263	0.241	0.408	55.643	66.243	69.060	63.649	2.33	2.33	1.67	1.67	2.00
DGC-7	1.02	0.781	0.673	0.615	0.772	23.497	34.000	39.620	32.372	5.00	4.67	3.67	4.00	4.33
DGC-6	1.095	0.854	0.725	0.645	0.83	21.983	34.197	41.040	32.407	5.00	4.33	4.00	4.00	4.33
DGC-505	1.032	0.735	0.645	0.582	0.748	28.787	37.337	43.580	36.568	4.33	4.00	3.33	3.67	3.83

Contd...

Table 2 Contd...

Genotype	Yield per vine (kg)					Yield reduction (%) over control				No of fruits per vine				
	Water Irrigation treatment					Water Irrigation treatment				Water Irrigation treatment				
	100%	75%	50%	25%	Mean	75%	50%	25%	Mean	100%	75%	50%	25%	Mean
DGC-29	0.86	0.451	0.342	0.303	0.489	47.330	60.227	64.330	57.296	3.67	3.00	3.00	3.33	3.25
DGC-19	1.238	0.944	0.946	0.812	0.985	23.673	23.507	34.380	27.187	8.00	5.67	5.00	4.67	5.83
DGC-11	0.928	0.579	0.497	0.503	0.627	37.673	46.147	45.753	43.191	4.33	3.33	3.67	3.67	3.75
DGC-1	1.528	1.295	1.14	0.986	1.237	15.257	25.403	35.467	25.376	8.33	7.33	6.33	6.67	7.17
Barsati	0.813	0.383	0.282	0.252	0.432	52.567	65.003	68.307	61.959	3.00	2.33	2.67	1.67	2.42
7026-C	0.845	0.472	0.364	0.318	0.5	44.060	56.917	62.237	54.404	3.67	3.33	3.67	3.33	3.50
7026-B-76	0.845	0.435	0.307	0.298	0.471	48.340	63.517	64.287	58.714	3.00	2.67	2.67	2.67	2.75
Mean	0.982	0.645	0.546	0.487		36.163	46.492	51.973		4.49	3.95	3.60	3.51	
$CD_{0.05}$	0.018				0.045	1.568			4.525	0.272				0.68

Table 3. Drought tolerance index and score among cucumber genotypes at mean value of drought stress treatments.

Genotype	No. of leaves per vine		Affected leaves (%)		Vine length (cm)		Yield per vine (kg)	
	Index	Score	Index	Score	Index	Score	Index	Score
WBC-37	1.227	5	0.929	6	1.616	6	1.22	6
WBC-35	1.629	2	0.654	2	3.332	3	1.92	4
WBC-17	1.485	3	0.894	5	1.834	5	1.38	5
WBC-14	1.433	4	0.891	5	1.701	5	1.27	6
WBC-13	1.835	1	0.578	1	4.474	2	2.74	1
WBC-10	1.526	3	0.821	4	2.232	5	1.65	5
WBC1	1.629	2	0.728	3	2.275	5	1.79	4
RK-40	1.351	4	0.900	5	1.597	6	1.21	6
Pusa Uday	1.649	2	0.736	3	2.469	4	1.76	4
Pahari Barsati	1.495	3	0.842	5	1.962	5	1.48	5
HS-5	1.433	4	0.908	5	1.697	5	1.38	5
HS-1	1.649	2	0.618	2	3.900	3	2.10	3
GS-3	1.031	6	0.992	6	1.033	6	1.04	6
DGC-9	1.536	3	0.836	5	1.934	5	1.40	5
DGC-8	1.000	6	1.000	6	1.000	6	1.00	6
DGC-7	1.557	3	0.701	3	2.872	4	1.89	4
DGC-6	1.649	2	0.639	2	3.621	3	2.03	3
DGC-505	1.588	3	0.709	3	2.640	4	1.83	4
DGC-29	1.206	5	0.901	5	1.351	6	1.20	6
DGC-19	1.660	2	0.605	2	4.180	2	2.41	2
DGC-11	1.557	3	0.838	5	2.052	5	1.54	5
DGC-1	1.732	2	0.553	1	5.066	1	3.03	1
Barsati	1.031	6	0.990	6	1.114	6	1.06	6
7026-C	1.351	4	0.935	6	1.626	6	1.23	6
7026-B-76	1.124	6	0.977	6	1.299	6	1.15	6
Range	1.000-1.227		0.553-1.000		1.000-5.066		1.00-3.032	
$CD_{0.05}$	0.139		0.074		0.65		0.338	

Table 4. Characterwise score range.

Score	No. of leaves per vine	Affected leaves (%)	Vine length (cm)	Yield per vine (kg)
1	1.768-1.974	0.496-0.580	4.860-5.746	2.690-3.032
2	1.624-1.768	0.580-0.662	4.012-4.860	2.350-2.690
3	1.490-1.624	0.662-0.747	3.149-4.012	2.014-2.350
4	1.345-1.490	0.747-0.834	2.377-3.149	1.670-2.014
5	1.139-1.345	0.834-0.926	1.680-2.377	1.336-1.670
6	1.000-1.139	0.926-1.000	1.000-1.680	1.000-1.338

Vine length decreased as drought stress level was increased. Longest mean vine length was observed in DGC-1 (106.9 cm) Followed byWBC-13 (94.4 cm), whereas, shortest mean vine length was recorded in DGC-8 (21.1 cm) followed by GS-3(21. 3 cm) and Barsati (23.5 cm). From table 3, maximum drought tolerant index (5.066) was observed in DGC-1 with a score of 1 followed by WBC-13, whereas, the lowest drought tolerance index (1) was observed for DGC-8 with lowest drought tolerance score of 6. There was a progressive reduction in fruit yield per vine as drought stress increased in all the genotypes (Table 2). Highest fruit yield per vine average was observed in DGC-1 (1.237 kg) followed by WBC-13 (1.117 kg), whereas, the lowest in DGC-8 followed by GS3, *i.e*. 0.408 and 0.426 kg, respectively. It could be noted that under normal irrigation (100% irrigation treatment) conditions, the fruit yield of DGC-1 and WBC-13 was 1.528 and 1.365 kg, respectively (Table 3). The maximum index of (3.032) was observed in DGC-1 with a score of (1) followed by WBC-13 (2.738) with and score 1. The lowest index (1.0) was observed for DGC-8 and GS-3 whose index was at par with those of Barsati, 7026-B-76, DGC-29, RK40, 7026-C, WBC-37 and WBC-14 with a score of 6. The average fruit yield reduction under different drought stress conditions was 36.16, 46.492 and 51.97 percent at 75%, 50% and 25% of recommended irrigation, respectively (Table 2). Among the genotypes, minimum yield reduction under drought stress was observed in WBC-13 (24.08%) followed by DGC-1 (25.37%) and DGC-19 (27.18%). Further, highest reduction under drought stress was seen in GS-3 (64.6%) followed by DGC-8 (63.64%) and Barsati (61.95%). Results of the present investigation are in agreement with previous findings in melon by Bustan *et al*. (4). Thus, in the present investigation, the traits such as affected leaves and vine length were identified promising as selection criteria for drought tolerance at morphological level in cucumber. The genotypes DGC-1 and WBC-13 appeared to be drought tolerant with high mean values of drought tolerance index and score (1.1 and 1.8) and accordingly both may be included as one of the parents in cucumber breeding programmers for drought tolerance.

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Response of potato to elevated CO_2 under short days: Growth, physiological parameters and tuber yield

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ABSTRACT

An experiment was conducted at ICAR-Central Potato Research Station, Jalandhar during 2014-15 to study the effect of elevated CO_2 concentration (600 ppm) on the physiological parameters, growth and yield of potato under short day conditions. Effects on plant growth and yield was positive with increased stem height (7.5%), stem numbers (18.9%), leaf area (19.4% at 70 DAP), photosynthesis (21% at 40 DAP) and total biomass product (14%). Tuber yield increased by 28% under CO_2 enrichment. Although harvest index did not change, specific leaf area (-2.6%) and stomatal conductance (-19 %) decreased under CO_2 enrichment. The increase in biomass and tuber yield may be due to enhanced leaf area coupled with increased rate of photosynthesis.

Key words: CO_2 enrichment, OTC, photosynthesis, stomatal conductance.

INTRODUCTION

Global climate has never been static. Since 1880, the Earth's temperature has increased at a rate of 0.09 degree per decade, which has increased to 0.29 degree per decade over the past 30 years mainly due to anthropogenic activity which has increased emission of GHGs like CO_2, methane etc. At present concentration of CO_2 in the atmosphere has touched 400 ppm, which is likely to increase to 421-936 ppm by the end of the century which could result in a temperature rise between 1 to 3.7ºC (IPCC, 7).

A general positive effect of CO_2 enrichment on growth and productivity of plants has been reported with C_3 plants responding more favorably to increase in CO_2 concentration compared to C_4 plants (Kimball, 9). Potato is a C_3 plant and has very large sink organs coupled with apoplastic mechanism for phloem loading (Riesmeier *et al.*, 13). Both these factors are favourable for better crop performance under enhanced CO_2 concentrations. Potato is expected to yield 10% higher total tuber for every 100 ppm increase in CO_2 concentration (Miglietta *et al.*, 12). The effect of increased CO_2 concentration on physiological parameters of potato plant, like photosynthetic rate, dry matter accumulation and partitioning, stomatal conductance etc. has been studied and reported (Bunce, 2; Chen and Setter, 3), however, most of these studies were carried out where potato is grown under long-day conditions. No such information is available for potato crop grown under short-day conditions, which is relevant in identifying the germplasm with suitable traits for developing varieties for future climatic scenario as well as for the potato crop growth modeling studies. Keeping these points in view, an experiment was conducted in the open–top chambers (OTCs) to study the effect of elevated CO_2 concentrations on the physiological parameters, growth and yield of potato under short day conditions.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of Central Potato Research Station, Jalandhar, Punjab (India) (31.16° N 75.32° E). The potato crop was raised in a transparent walled open-top chambers (OTCs) during winter season of 2014-15. The OTCs used were square in shape, 3 m long and 2.5 m tall with a 6.25 m square opening on the top. A total of 6 chambers were used in the present study which were 4.0 m apart from each other. Three OTCs were maintained at 600 ppm CO_2 between 8 am and 5 pm while the other three were kept as control (ambient: 400 ppm).

The soil in the OTCs was moderately alkaline in reaction (pH 7.9), low in available N (246 kg/ha) and medium in available P (18 kg/ha) and available K (184 kg/ha). In the present study, potato cultivar Kufri Jyoti was selected, which falls under the medium maturity group. The seed size tubers (50 g) of Kufri Jyoti were planted at 60 cm x 20 cm spacing on 7th October, 2014. The crop was supplied with 175 kg N, 100 kg P and 120 kg K through urea + di-ammonium phosphate, di-ammonium phosphate and muriate of potash, respectively. 50% N and full PK were applied at planting while the remaining N was applied at the time of earthing-up, *i.e.* 35 days after planting. The crop was raised with standard package of practices. The crop was harvested on 5th Jan 2015, *i.e.* 90 days

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after planting for recording the observation on final yield and above-ground biomass.

For morphological observations, ten plants were tagged from each chamber and observations on plant height and number of main stems were recorded at 7 day interval, starting from 15 days of planting till 72 days. Periodical sampling for dry matter partitioning was carried out at 10 days interval, starting from 20 days of planting till 90 days, by uprooting five plants from each chamber. The plants were separated into leaf, stem, root and tubers. Fresh and dry weights of plant parts were taken to study periodic growth and development and dry matter distribution among different plant parts. Fifty leaf discs of known diameter were punched from the leaves of each sample and dried. Leaf area per plant was calculated from the leaf dry weight using dry weight and area of leaf discs. Photosynthesis and stomatal conductance was measured at 40 days using portable photosynthesis system. One elevated CO_2 and one control OTC were left undisturbed for final tuber yield data. Meteorological parameters (minimum and maximum temperature, relative humidity) were recorded daily during the experimentation and depicted in Fig. 1. Statistical analysis: For all physiological parameter as well as fresh and dry weights, values recorded from one plant were considered as a replication. Standard error of mean was calculated and is shown in all the figures.

RESULTS AND DISCUSSION

Maximum and minimum temperature during the crop growth was 33.0/21.5 °C at the time of planting which dropped gradually to 11.8/6.8 °C at the time of haulm cutting. Relative humidity varied between 50 and 86% during this period (Fig. 1). The effects of elevated CO_2 on different plant species have been well documented. In the present study potato cultivar Kufri Jyoti was studied under ambient (400 ppm) and elevated (600 ppm) CO_2. Emergence was not affected by treatments and it took 14 days from planting to 95% emergence.

A 50% increase in CO_2 level showed a significant effect on plant height and stem numbers per plant. In general, a uniform increase in both the parameters was observed from emergence till the maturity of crop. At final stage of crop growth, an increase of 7.5% in plant height and 18.9% in stem number per plant was recorded (Figs. 2, 3). However, in some studies on potato in Europe under long day conditions, elevated CO_2 concentration did not affect or negatively affected plant height (Lawson *et al.*, 10). The stimulatory effect of CO_2 on plant growth includes increase in tiller number in wheat and rice (Allen and Prasad, 1). In potato we report a stimulatory effect of CO_2 on stem number/hill.

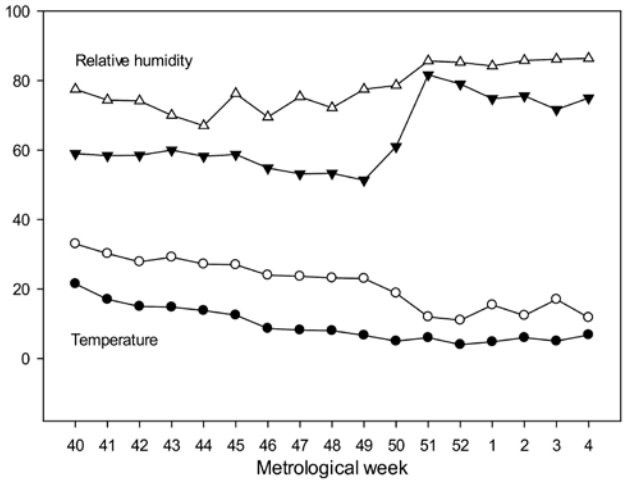

Fig. 1. Weather parameters during the crop season at Jalandhar, Punjab.

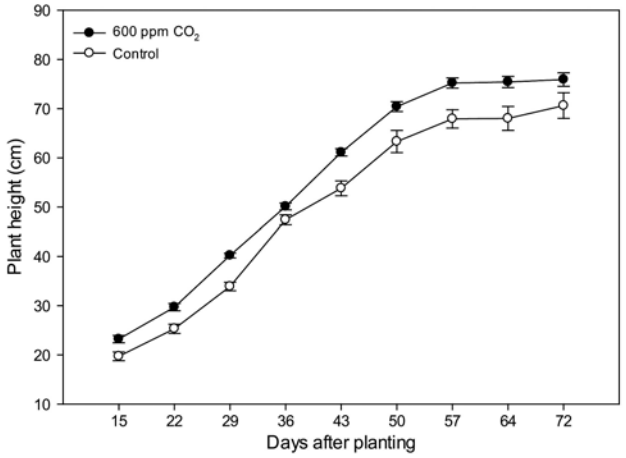

Fig. 2. Plant height in potato during plant development phase.

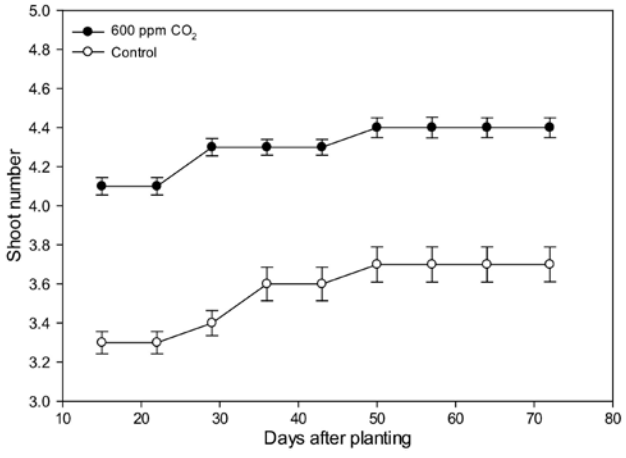

Fig. 3. Number of stems per hill in potato during development phase.

While control plants had an average 3.54 stems/hill, it was 4.28 stems per hill under 600 ppm CO_2.

Leaf Area Index (LAI) is a primary indicator of photosynthetic potentials. In our experiment, leaf area index (LAI) was not affected due to the exposure to elevated CO_2 concentration till 40 days but after that higher LAI was recorded under elevated CO_2 which increased till 80 days and then declined rapidly to 5.5 at harvest. However, in plants raised at ambient CO_2, the LAI achieved the peak at 70 days of planting and declined to 4.05 at harvest (Fig. 4). During early part of growing season, development of leaf area in soyabean was similar under ambient and enriched environments but later increased under elevated CO_2 which also delayed LAI loss (Dermody *et al.*, 4). A faster decline in LAI towards the end of growing season due to remobilization of leaf nitrogen has been reported by Miglietta *et al.* (12).

Specific leaf area or specific leaf mass is a measure of leaf thickness and it tended to increase under ambient CO_2 at 40 days of crop growth and then declined and remained below the crop raised at elevated CO_2 till 70 days (Fig. 5). The average specific leaf weight (SLW) during entire crop growth was lower under elevated CO_2 (3.76 mg/cm^2) than control (3.86 mg/cm^2) indicating faster removal of the photosynthates from the leaves. The results are in conformity with Maillard *et al.* (11). Yin (15) analyzed 170 published data sets from 62 species and showed that in majority of the cases SLW declines as CO_2 increases mainly due to decline in leaf nitrogen.

Photosynthesis is the primary driver of plant growth providing sugars and carbohydrates needed for producing biomass. Net photosynthesis was recorded 40 days after planting. The photosynthesis was 21% higher in forenoon and 27% higher in afternoon under elevated CO_2 (Fig. 6). At atmospheric CO_2 concentrations, C_3 plants like potato lose carbon through photorespiration because of the affinity of ribulose 1-5 bi-phosphate carboxylase/oxygenase (RUBP) to oxygen as well. Therefore under increasing CO_2 concentration more carbon is available at the RUBP site than oxygen leading to reduced photorespiration and increased photosynthesis. Photosynthesis on a leaf area bases is regarded as the most important attribute which can explain the observed yield increase. However, Donnelly *et al.* (5) had attributed tuber yield stimulation to LAI as they did not find elevated CO_2 to increase photosynthetic rate. In our case, LAI and photosynthetic rate both increase significantly and might have contributed together in increasing the potato tuber yield under the CO_2 enriched environment.

The CO_2 enhancement recorded a significant decrease in stomatal conductance. A 19 % decrease

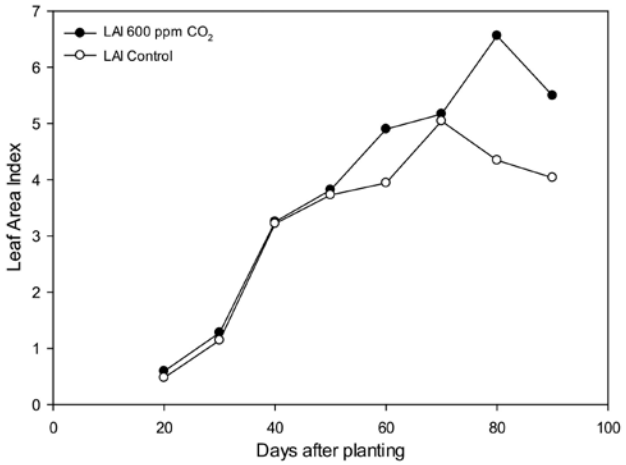

Fig. 4. Leaf area index during crop development in potato.

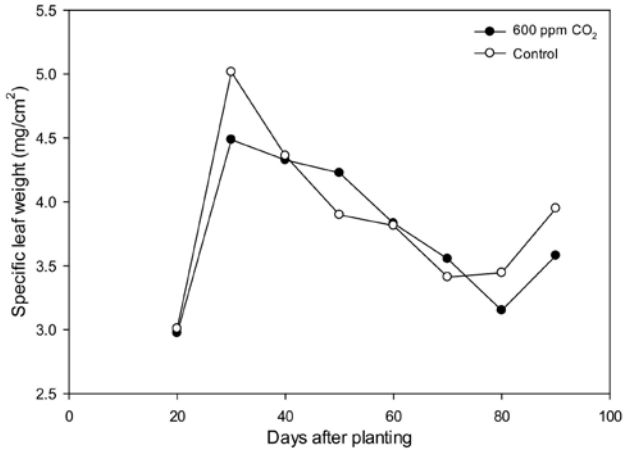

Fig. 5. Specific leaf weight during crop development in potato.

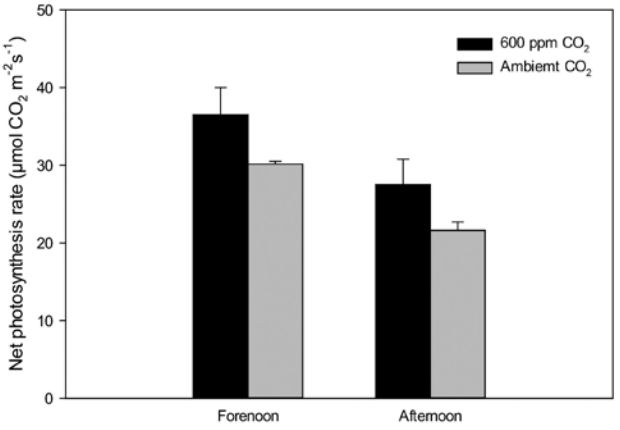

Fig. 6. Net photosynthesis in potato plants 40 days after planting.

in stomatal conductance was observed in the forenoon and 40% in the afternoon at 40 days of planting (Fig. 7). Increased ambient CO_2 leads to partial stomatal closure due to high malate concentration in the apoplast that activates anion channels in the guard cell and many workers have reported a reduction in stomatal conductance up to 700 ppm (Taub, 14).

The increase in Carbon dioxide level caused a significant increase in tuber yield. Final fresh tuber yield obtained in the undisturbed OTC was 3.27 kg/m^2 under elevated CO_2 compared to 2.54 kg/m^2 under ambient conditions which is 28% higher under elevated CO_2 (Fig. 8). Partitioning of dry matter to tubers at 30 days after planting was similar under ambient as well as elevated CO_2. However, as the growth progressed, the higher partitioning of dry matter to tuber was observed under elevated CO_2 condition and the gap widened till the harvesting of crop when the final dry matter portioned to tubers was 94.74 g/plant under elevated CO_2 levels, which was 16% higher over ambient CO_2 at 81.68 g/plant (Figs. 9, 10). A positive response of potato to elevated CO_2 in terms of final tuber yield has been reported by Jaggard *et al.* (8). Tuber dry matter percentage under elevated CO_2 was lower (15.3%) than under control (16.8%). Sink strength is the major determinant of dry matter partitioning and potato has large below-ground sinks for carbon along with apoplastic mechanism of phloem loading and therefore, it is probably the best candidate for a large response to rising atmospheric CO_2 (Miglietta *et al.*, 12). Total plant biomass accumulated during the growth period was 111.48 g/ plant in control at 90 days after planting compared to (130.34 g/ plant) under elevated CO_2. The results are in conformity with the finding of Hogy and Fangmieier (6) who have also recorded an increase in absolute biomass production under elevated CO_2. However, tuber to whole plant dry weight ratio (harvest index) was not affected due to change in CO_2 concentration (72.7 under 600 ppm CO_2 compared to 73.3 for control), showing thereby

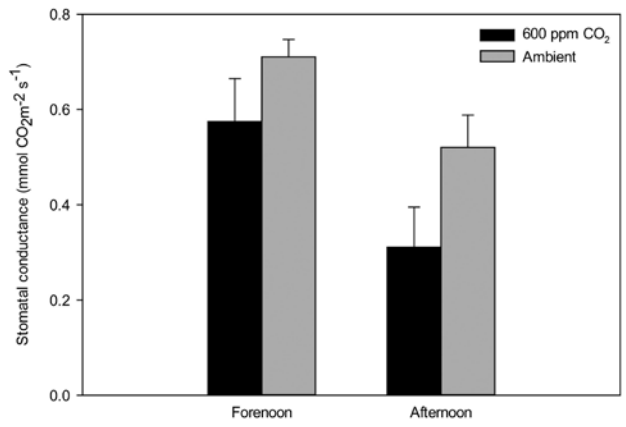

Fig. 7. Stomatal conductance in potato plants 40 days after planting.

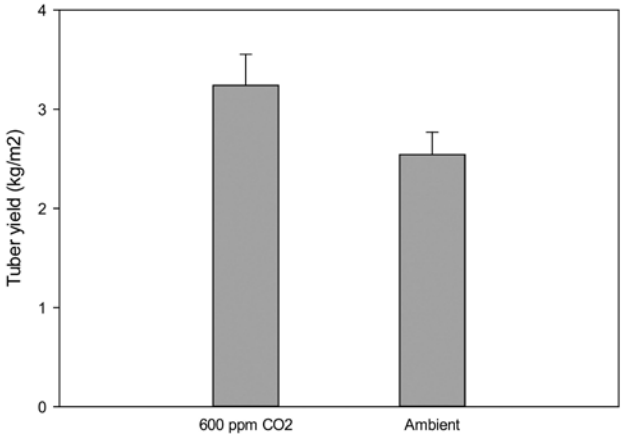

Fig. 8. Tuber yield (kg/m^2) under elevated and ambient CO_2.

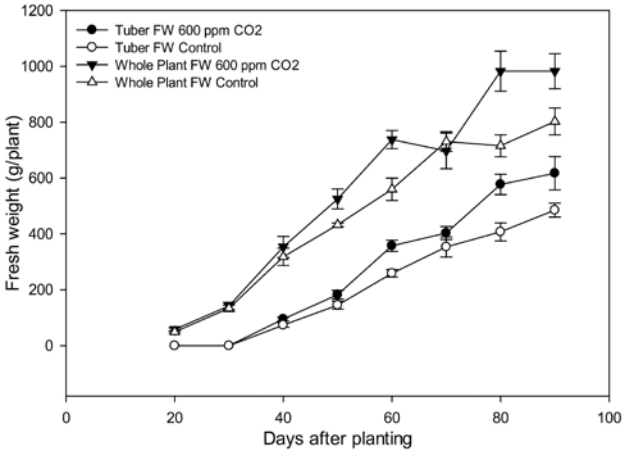

Fig. 9. Tuber fresh weight during crop development in potato.

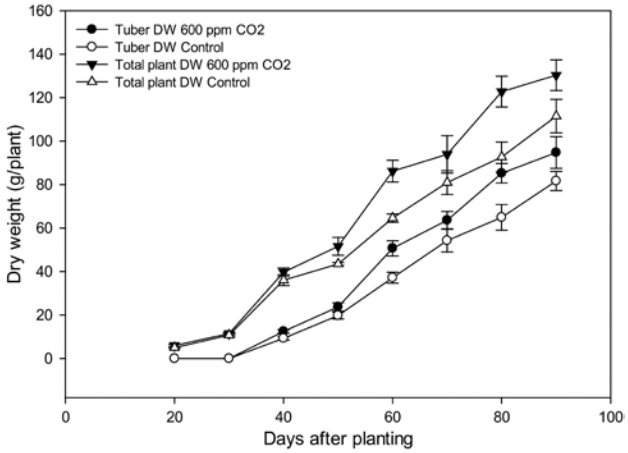

Fig. 10. Tuber dry weight during crop development in potato.

that the CO_2 enrichment did not alter the allocation pattern of dry matter to tubers and above ground biomass. Consistent trend has not been observed for harvest index under elevated CO_2, however Allen and Prasad (1) have reported a decrease in Harvest index in soybean. However, the partitioning of the above ground biomass to leaves and stem was altered due to CO_2 fertilization. A perusal of data on leaf and stem dry weight showed that CO_2 enrichment affected favorably the leaf and stem dry weight. The leaves were benefited more under elevated CO_2 than the stems as the increase in leaf dry matter was more (24.8 g/ plant 38% higher) than stem (9.84 g/ plant 35.9% higher). Higher dry matter partitioning to leaves coupled with lower specific leaf weight explains the increase in leaf area under CO_2 enrichment in potato.

The CO_2 enrichment increased the overall growth of the potato crop under the short day condition. A 200 ppm increase brought about a significant increase in the plant height, stem number and the above ground biomass of the potato crop. The increase in LAI in combination with significantly higher net photosynthetic rate lead to an overall increase in the total tuber yield of potato crop grown under the winter season.

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Effect of soilless growing media and fertigation on capsicum production under naturally ventilated polyhouse in cold desert region of Himachal Pradesh

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ABSTRACT

An experiment on effect of soilless growing media and fertigation on capsicum production under naturally ventilated polyhouse was conducted at Regional Horticulture Research Sub-Station, Dr Y.S. Parmar University of Horticulture and Forestry Tabo, Spiti during year 2015 and 2016. Significant individual effect of growing media and fertigation was found on parameters like harvest duration, plant height, number of fruits per plant, fruit yield per plant, fruit yield per m² and fruit yield per ha during both the years. Interaction effect of growing media and fertigation was found significant for harvest duration, number of fruits per plant, fruit yield per plant, fruit yield per m² and fruit yield per ha. Soilless growing media comprising of vermicompost: sand (2:1) and fertigation @ 250 kg NPK/ha recorded the maximum harvest duration (52 days), fruit yield per plant (621.31 & 585.85 g), fruit yield per m² (4.60 & 4.33 kg) and fruit yield per ha (46.02 & 43.40 MT) during year 2015 and 2016, respectively.

Key words: Bell peppar, cold desert, fertigation, polyhouse, vermicompost.

INTRODUCTION

Capsicum is one of the most important nutritious and highly remunerative vegetable crops grown for its fruits. It is not possible to obtain higher yields of good quality fruits under open conditions in cold desert regions of Himachal Pradesh and therefore protected cultivation offers good scope for production of capsicum in this region. One of the most important cultural inputs involved in greenhouse crop production, perhaps the most important is the type of growing media used. It is well known that soilless culture offers an alternative to soil culture when serious soil and water problems (i.e., soil borne pests, soil and water salinity, chemical residues in soil, lack of fertile soil, water shortage), create difficulties in traditional soil based production. The main advantages of soilless culture are the most accurate control over the supply of water, nutrients, pH, root temperature, etc., increase productivity due to easier and more accurate control of production factors, reduction of labour requirement, no need for soil sterilization and more crops per year Tuzel *et al*. (10).

Soilless culture is widely used to grow plants in greenhouse in many countries at present. Monoculture results in a lot of problems when soil is used as growing media Sevgican (8). Another important component of protected cultivation, which influences productivity and quality of the produce, is application of fertilizers with irrigation water called fertigation. Fertigation also provides opportunity to control the concentration of individual nutrients in the form of soluble fertilizers to meet the crop need slowly according to its stage of development and reduce leaching of nutrient. Therefore, an experiment was conducted to investigate the productivity potential of soil based and soil less growing media along with fertigation treatment for capsicum production under naturally ventilated plastic greenhouses for yield and quality traits.

MATERIALS AND METHODS

The experiment was conducted in a plastic greenhouse with natural ventilation at Regional Horticulture Research Sub Station, Dr YSPUH&F, Tabo Spiti, for two consecutive years. The seeds of capsicum var. Solan Bharpur were sown in polytunels for healthy seedling production. Further, the seedlings were transplanted in three different growing media (soil: vermicompost: sand; 2:1:1 (M_1), 1:2:1 (v/v) (M_2) and vermicompost: sand, 2:1 (v/v) (M_3). Three levels of fertigation, *i.e.* 150 kg NPK/ha (F_1), 200 kg NPK/ha (F_2) and 250 kg NPK/ha (F_3) with water soluble fertilizers 19:19:19 NPK were tested. Fertigation treatment started after three weeks of transplantation and given twice a week. It was stopped 2 weeks prior to expected final harvest. The irrigation regime was kept at 20 kpa with the help of tentiometer. The

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observations were recorded on days to marketable maturity, harvest duration, plant height (cm), number of fruits per plant, fruit length (mm), fruit breadth (mm), average fruit weight (g), fruit yield per plant (g), fruit yield per m^2 (kg) and fruit yield per ha (MT). Plant spacing was 45 cm × 30 cm. All the parameters were recorded through standard procedure and fruit yield per ha (MT) was calculated on the estimation basis of fruit yield per m^2 (kg). The experimental design was two factors completely randomized design with three replications. Data were subjected to analysis of variance (ANOVA) to compare the effects of growing media and fertigation. The differences between the means were compared using the least significant difference test (LSD, $p<0.05$).

RESULTS AND DISCUSSION

Days to first picking was earliest with the lowest level of fertigation F1 (101.77 and 100.78 days) during both the years (Tables 1, 3). Higher dose of fertilizer may lead to more vegetative growth which may delay in early maturity. Maximum harvest duration of 50.00 and 48.67 days was recorded in highest level of fertigation F3 during year 2015 and 2016, respectively. It may be due to higher nutrient availability for plants from maximum dose. Highest fertigation dose also recorded maximum values for number of fruits per plant, fruit yield per plant, fruit yield per m^2 and fruit yield per ha. Similar results of higher yield under fertigation were also reported by Contreras *et al.* (4), Bassiony *et al.* (2) and Brahma *et al.* (3). Among growing media, soilless media comprising of vermicompost: sand (2:1) (M_3) found promising for most of the traits. Maximum harvest duration (47.00 & 48.67 days), fruit length (75.56 & 77.31 mm) and number of fruits per plant (11.16 & 11.83) were recorded in M_1 soilless growing media during both the years, respectively. Vermicompost have a property of good water holding capacity and are also able to drain excess water to come to field capacity which creates congenial root environment. Considering the results, it is noticed that growth characters of capsicum were increased with application of vermicompost treatments. These results may be attributed to the role of macro and micro-nutrients, as well as the improved growing conditions due to vermicompost application, which stimulate metabolic processes and encourage growth, synthesis and accumulation of more metabolites in plant tissues. Several investigators mentioned similar results on different plants such as Kumar and Kohli (5) in capsicum, Natarajan *et al.* (7) in tomato, Bairwa *et al* (1) in Okra. Same growing media also recorded the highest value for fruit yield per plant, fruit yield per m^2 and fruit

Table 1. Effect of growing medium and fertigation on capsicum production under protected conditions during year 2015.

Treatment	Days to 50% flowering	Days to first picking	Harvest duration	Plant height (cm)	Fruit length (mm)	Fruit breadth (mm)	Pericarp thickness (mm)	Av. fruit wt. (g)	No of fruits per plant	Fruit yield per plant (g)	Fruit yield per m^2 (kg)	Fruit yield per ha (MT)
Fertigation												
F1	82.33	101.77	42.33	47.70	70.03	45.62	3.22	35.30	8.55	302.46	2.24	22.40
F2	87.88	116.11	43.77	48.32	73.12	46.69	3.18	41.49	9.80	406.48	3.01	30.11
F3	85.11	109.55	50.00	58.39	71.83	46.97	3.29	39.17	11.25	448.30	3.32	33.21
$CD_{(0.05)}$	NS	7.59	1.04	3.57	NS	NS	NS	NS	0.32	43.05	0.32	3.19
Growing medium												
M1	83.11	105.55	47.00	58.26	75.56	47.49	3.33	41.31	11.16	466.52	3.45	34.56
M2	85.22	109.33	45.33	50.50	70.56	47.73	3.31	39.60	9.48	376.14	2.78	27.86
M3	87.00	112.55	43.77	45.66	68.86	44.05	3.15	35.05	8.95	314.59	2.33	23.30
$CD_{(0.05)}$	NS	NS	1.04	3.57	2.70	NS	NS	NS	0.32	43.05	0.32	3.19

Table 2. Interaction effect of growing medium and fertigation on capsicum production under protected conditions during year 2015.

Treatment combination	Days to 50 % flowering	Days to first picking	Harvest duration	Plant height (cm)	Fruit length (mm)	Fruit breadth (mm)	Pericarp thickness (mm)	Average fruit weight (g)	No of fruits per plant	Fruit yield per plant (g)	Fruit yield per m^2 (kg)	Fruit yield per ha (MT)
M1F1	80.00	98.33	42.00	59.67	71.81	48.22	3.47	38.39	9.08	348.99	2.58	25.85
M2F1	83.00	103.00	43.00	44.00	69.51	45.63	3.44	35.29	8.37	294.46	2.18	21.81
M3F1	84.00	104.00	42.00	39.44	68.80	43.02	3.06	32.24	8.20	263.92	1.95	19.55
M1F2	85.00	108.00	47.00	52.33	77.87	48.77	3.00	41.06	10.47	429.25	3.18	31.80
M2F2	87.67	119.33	43.00	49.31	71.52	47.60	3.25	45.24	9.63	435.13	2.22	32.23
M3F2	91.00	121.00	41.33	43.33	69.99	43.72	3.29	38.18	9.30	355.07	2.63	26.30
M1F3	84.33	110.33	52.00	62.78	77.02	45.50	3.52	44.49	13.94	621.31	4.60	46.02
M2F3	85.00	105.66	50.00	58.18	70.66	49.98	3.26	38.27	10.43	398.84	2.95	29.54
M3F3	86.00	112.66	48.00	54.22	67.81	45.44	3.10	34.75	9.37	324.77	2.40	24.06
$CD_{(0.05)}$	NS	NS	1.80	NS	NS	NS	NS	NS	0.56	74.57	0.55	5.52

Table 3. Effect of growing medium and fertigation on capsicum production under protected conditions during year 2016.

Treatment	Days to 50% flowering	Days to first Picking	Harvest duration	Plant height (cm)	Fruit length (mm)	Fruit breadth (mm)	Pericarp thickness (mm)	Av. fruit wt. (g)	No of fruits per plant	Fruit yield per plant (g)	Fruit yield per m^2 (kg)	Fruit yield per ha (MT)
Fertigation												
F1	80.67	100.78	43.00	46.37	70.95	45.87	3.19	36.15	8.55	309.79	2.29	22.95
F2	83.11	105.33	45.44	49.29	75.04	48.29	3.46	42.27	12.31	520.41	3.85	38.55
F3	87.22	115.56	48.67	53.58	74.32	46.28	3.45	40.85	10.52	435.79	3.22	32.28
$CD_{(0.05)}$	1.73	1.82	1.57	1.82	2.27	NS	0.15	1.59	0.27	19.27	0.14	1.43
Growing medium												
M1	81.89	104.55	48.67	55.07	77.31	48.57	3.59	42.38	11.83	504.67	3.73	37.38
M2	83.44	107.67	45.67	47.39	71.88	47.76	3.38	40.57	9.97	410.19	3.03	30.39
M3	85.67	109.44	42.78	46.78	71.11	44.11	3.13	36.31	9.59	351.13	2.60	26.01
$CD_{(0.05)}$	1.73	1.82	1.57	1.82	2.27	2.46	0.15	1.59	0.27	19.27	0.14	1.43

Table 4. Interaction effect of growing medium and fertigation on capsicum production under protected conditions during year 2016.

Treatment combination	Days to 50% flowering	Days to first picking	Harvest duration (days)	Plant height (cm)	Fruit length (mm)	Fruit breadth (mm)	Pericarp thickness (mm)	Av. fruit wt. (g)	No of fruits per plant	Fruit yield per plant (g)	Fruit yield per m^2 (kg)	Fruit yield per ha (MT)
M1F1	79.00	98.00	43.00	53.67	73.51	49.11	3.40	39.19	9.08	355.79	2.63	26.35
M2F1	81.00	101.33	43.67	43.33	70.07	46.17	3.25	36.15	8.37	302.43	2.24	22.40
M3F1	82.00	103.00	42.33	42.11	69.27	42.32	2.95	33.12	8.20	271.17	2.01	20.08
M1F2	82.00	103.67	51.00	55.56	79.80	50.30	3.76	41.57	13.78	572.37	4.23	42.40
M2F2	82.33	105.33	43.67	48.12	73.42	48.94	3.39	46.07	11.90	547.56	4.05	40.56
M3F2	85.00	107.00	41.67	44.00	71.89	45.62	3.24	39.17	11.27	441.29	3.27	32.69
M1F3	84.67	112.00	52.00	56.00	78.63	46.30	3.64	46.39	12.63	585.85	4.33	43.40
M2F3	87.00	116.33	49.67	50.52	72.16	48.18	3.50	39.51	9.63	380.60	2.82	28.19
M3F3	90.00	118.33	44.33	54.22	72.17	44.37	3.21	36.65	9.30	340.92	2.52	25.26
$CD_{(0.05)}$	NS	NS	2.71	3.16	NS	NS	NS	2.76	0.48	33.37	0.14	1.43

yield per ha. Increase in yield in vermicompost rich medium is also reported by Llaven *et al.* (6) in bell pepper,Sumita Roy *et al.* (9) Uma Maheshwari and Haripriya (11) in hot pepper. Combined effect of soilless growing media and highest level of fertigation (Tables 2, 4) recorded significantly higher values for harvest duration, number of fruits per plant, fruit yield per plant (g), fruit yield per m^2 and fruit yield per ha.

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Effect of integrated nutrient management on growth, yield and quality of turmeric under Nagaland conditions

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ABSTRACT

A field experiment was conducted in two consecutive years during 2013 and 2014 to evaluate the effect of integrated nutrient management on growth, yield and quality of turmeric under Nagaland conditions. Eighteen treatments which include, inorganic fertilizers, organic manures and biofertilizers alone or in combination were included in the experiment. Results revealed that application of different levels of fertilizers, organic manures and *Azospirillum* either alone or in combination significantly increased growth, yield and quality of turmeric as compared to control. The maximum plant height (83.22 cm), number of leaves plant^{-1}(10.45), leaf area (905.73 cm^2), number of tillers clump^{-1} (3.22), chlorophyll content (0.97 mg g^{-1} fresh weight), number of primary fingers clump^{-1}(8.50), number of secondary fingers clump^{-1}(19.50), fresh rhizome yield (48.06 t ha^{-1}), cured rhizome yield (8.22 t ha^{-1}) and curcumin content (6.68%) were recorded in the integrated application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}). Maximum uptake of nitrogen (182.25 kg ha^{-1}), phosphorus (50.80 kg ha^{-1}) and potassium (283.98 kg ha^{-1}) were also observed in the same treatment combination. Thus, integrated application of 50% NPK + 50% poultry manure + *Azospirillum* was found to be the best treatment combination for obtaining higher yield with quality turmeric.

Key words: *Curcuma longa*, biofertilizers, nutrient uptake.

INTRODUCTION

Turmeric (*Curcuma longa* L.) belongs to family Zingiberaceace. It is one of the most important and ancient spice crop of India. The processed and dried underground portion called 'rhizome' forms the basis of commerce which is use in culinary, medicinal, cosmetics and textile industries. India produces turmeric about 1.19 million tonnes from an area of 0.233 million hectares with an average productivity of 5.10 tonnes ha^{-1} (Anonymous, 2). The climatic condition of the North Eastern region is quite conducive to commercial cultivation of turmeric. But inspite of the favourable agro-climatic conditions, production level is low due to lack of proper package of practices. Among various factors responsible for low production of turmeric, nutrition is of prime importance. Turmeric being a heavy feeder and exhaustive crop responds very well to nutrients application. Therefore, to reduce dependency on chemical fertilizers and conserving the natural resources in align with sustainable crop production are vital issues in present time which is only possible through integrated plant nutrient supply system. Besides fertilizers, there are several sources of plant nutrients *viz.* organic manures, biofertilizers etc. to improve soil and crop productivity. Use of organic manures in INM help in mitigating multiple nutrient deficiency. Application of organic manures to acidic soil reduces the soluble and exchangeable Al temporarily by forming complex and provides better environment for growth and development in addition to improvement in physical, chemical and biological properties of soil (Tekaasangla *et al.*, 14). Biofertilizers have also emerged promising components of nutrient supply system. Application of biofertilizers, which is environment friendly and low cost input with organic and inorganic fertilizers as part of an integrated nutrient management strategy and play significant role in plant nutrition. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation (Yeptho *et al.*, 16). The diverse agro-climatic conditions, varied soil types and abundant rainfall under foothills condition of Nagaland enable the favourable cultivation of turmeric. Meagre no information is available on the nutrient management of turmeric in North Eastern region including Nagaland in particular, hence the present study was undertaken.

MATERIALS AND METHODS

An experiment was carried out during 2013 and 2014 at Experimental Farm, Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland, The field lies at the altitude of 304.8 m above mean sea level with geographical location at 20º 45' 43'' N latitude and 93º 53' 04''

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E longitude. The pH, organic carbon, available N, P and K contents of experimental plot were 4.5, 1.5%, 240.86 kg ha^{-1}, 9.68 kg ha^{-1} and 219.43 kg ha^{-1}, respectively. The experiments were laid out in Randomized Block Design with 18 treatments consisted of T_1= Control (without application of manures/ fertilizers/ biofertilizers), T_2 = 100% RDF (80:60:60 kg NPK ha^{-1} Bendangsenla, 2), T_3 = FYM (40 t ha^{-1}), T_4 = Pig manure (30 t ha^{-1}), T_5 = Poultry manure (25 t ha^{-1}), T_6 = Vermicompost (10 t ha^{-1}), T_7 = FYM + *Azospirillum*, T_8 = Pig manure + *Azospirillum*, T_9 = Poultry manure + *Azospirillum*, T_{10} = Vermicompost + *Azospirillum*, T_{11}- 50% NPK + 50% FYM, T_{12} = 50% NPK + 50% Pig manure, T_{13} = 50% NPK+ 50% Poultry manure, T_{14} = 50% NPK + 50% vermicompost, T_{15} = 50% NPK + 50% FYM + *Azospirillum*, T_{16} = 50% NPK + 50% pig manure + *Azospirillum*, T_{17} = 50 % NPK + 50% Poultry manure + *Azospirillum*, T_{18} = 50% NPK + 50% vermicompost + *Azospirillum*) with three replications. The rhizomes were planted at 30 cm × 30 cm spacing and 2.4 m × 2.4 m plot size (64 plants) was maintained. N, P and K were given through urea, SSP and MOP, respectively. Full dose of P and K and half dose of N were applied at the time of planting and remaining half dose of N was given in two equal split doses, *i.e.* 45 and 90 days after planting. Manures *viz.,* FYM, pig manure, poultry manure and vermicompost were incorporated as per treatment in respective plot 20 days prior to planting. *Azospirillum brasilense* (biofertilizer) was inoculated to seed rhizome prior to planting @ 5 kg ha^{-1}. The doses of organic manures were applied equivalent basis. Observations on growth and yield characters were recorded at harvest (180 days after planting). Total chlorophyll content in leaf was estimated spectrophotometrically as described by Ranganna (11) and expressed in mg g^{-1} of fresh weight. Freshly harvested rhizomes were washed to make them free from inert materials and cured to obtain cured yield. The dried powder of rhizomes was used for estimation of curcumin content in turmeric (Sadasivam and Manikam, 12). The dried powder of rhizomes and leaves were used for estimation of macro and micro nutrients content in rhizomes and NPK contents in leaves. Nitrogen was estimated through micro Kjeldahl steam distillation method, phosphorus was estimated through vanadomolybdo phosphoric method, potassium was estimated through flame photometry method and Ca, Mg, S, Fe, Cu, Zn and Mn using atomic absorption spectrophotometer. The nutrient uptake by the plant was worked out by multiplying dry matter yield (kg ha^{-1}) with percent nutrient content in plant. The result thus obtained was expressed in term of kg ha^{-1}. The composite soil samples were collected before and after the experiment from the experimental plots. Soil samples were analysed for pH, organic carbon, available nitrogen, phosphorus and potassium using standard procedure (Jackson, 6). The pooled date of two consecutive years was analysed statistically following the method of Panse and Sukhatme (9).

RESULTS AND DISCUSSION

Integrated application of inorganic fertilizers, organic manures and biofertilizer alone or in combination had significant effect on growth parameters of turmeric (Table 1). Growth behaviour of all the 18 treatments varied considerably. Treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) exhibited the maximum plant height (83.22 cm), which was found significantly superior over other treatments except T_{18} (50% NPK + 50% vermicompost + *Azospirillum*). Minimum plant height (66.25 cm) was recorded in T_1 (control). The additional supply of poultry manure in INM improved physical properties of soil, availability of NPK in soil and well developed root system resulting in better absorption of nutrients and water, due to which plant height might be increased. *Azospirillum* used in INM might have helped in production of growth promoting substances leading to increased plant height. Number of leaves $plant^{-1}$ due to different treatments was found to have significant difference among different treatments. The maximum number of leaves $plant^{-1}$ (10.45) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) whereas the minimum number of leaves $plant^{-1}$ (8.50) was recorded in T_1 (control). Leaves are the main site of photosynthesis as such its effective number per plant is considered an important factor in determining the growth and productivity of crop. The increase in the number of leaves might be due to effective function of biofertilizer which provided bioactive substances having similar effects as that of growth regulators which enhance the number of leaves when applied in combination with poultry manure and inorganic fertilizers. All the treatments showed significant increase in leaf area as compared to control. Like the other growth parameters, treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded significantly higher leaf area (905.73 cm^2) as compared to other treatments. While the lowest leaf area (670.25 cm^2) was recorded in T_1 (control). The added poultry manure and *Azospirillum* in integrated nutrient management might have improved the physical, chemical and biological properties of soil, which helps in better nutrient absorption and utilization by plant and more translocated to the aerial parts for protoplasmic protein and synthesis of other compound resulting better plant growth and thereby

Table 1. Effect of INM on growth, yield and quality of turmeric (pooled data of two years).

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Leaf area (cm^2)	No. of tillers plant^{-1}	Chlorophyll content (mg g^{-1})				No. of primary fingers plant^{-1}	No. of secondary fingers plant^{-1}	Fresh rhizome yield (t ha^{-1})	Cured rhizome yield (t ha^{-1})	Curcumin content (%)
					90 DAP	120 DAP	150 DAP	180 DAP					
T_1	66.25	8.50	670.25	1.61	0.85	1.02	0.70	0.46	4.50	9.83	23.14	4.24	5.70
T_2	71.60	9.78	757.70	2.56	1.11	1.32	1.01	0.73	6.67	16.33	33.85	5.90	6.28
T_3	66.63	9.17	704.40	1.89	0.91	1.14	0.77	0.57	4.67	11.17	29.35	4.94	5.78
T_4	67.53	9.28	713.36	2.11	0.94	1.14	0.82	0.58	5.67	12.17	29.94	5.22	5.82
T_5	68.20	9.39	729.47	2.28	1.01	1.21	0.92	0.59	6.00	14.17	30.60	5.44	6.23
T_6	67.36	9.33	721.47	2.11	0.96	1.17	0.88	0.62	5.83	12.67	30.29	5.24	6.14
T_7	69.26	9.56	737.12	2.33	1.05	1.25	0.96	0.63	6.33	14.17	30.65	5.51	6.19
T_8	71.31	9.56	748.97	2.33	1.07	1.26	0.99	0.65	6.33	14.83	31.05	5.56	6.20
T_9	71.60	9.72	757.22	2.50	1.09	1.29	1.00	0.67	6.33	15.33	32.24	5.81	6.22
T_{10}	71.20	9.67	749.70	2.45	1.08	1.26	0.97	0.67	6.50	15.17	31.61	5.75	6.24
T_{11}	72.08	9.83	760.12	2.61	1.21	1.43	1.10	0.75	6.83	16.50	35.05	6.12	6.34
T_{12}	72.08	9.83	772.50	2.61	1.24	1.46	1.14	0.77	7.17	16.67	37.51	6.21	6.37
T_{13}	73.64	10.06	802.93	2.72	1.29	1.52	1.19	0.87	7.50	17.17	39.39	6.81	6.45
T_{14}	72.14	9.89	777.22	2.67	1.27	1.49	1.17	0.85	7.33	17.17	38.44	6.74	6.41
T_{15}	74.78	10.11	828.01	2.78	1.30	1.52	1.20	0.90	7.83	17.50	40.27	6.89	6.46
T_{16}	78.05	10.22	848.35	2.78	1.33	1.53	1.23	0.91	8.00	18.33	40.32	7.19	6.51
T_{17}	83.22	10.45	905.73	3.22	1.45	1.62	1.34	0.97	8.50	19.50	48.06	8.22	6.68
T_{18}	81.00	10.28	861.42	2.95	1.35	1.55	1.26	0.94	8.17	18.83	44.05	7.35	6.53
$CD_{(0.05)}$	2.30	0.57	5.08	0.45	0.05	0.06	0.05	0.03	0.69	2.07	7.70	1.23	0.21

DAP = Days after planting

increase in leaf area. Number of tillers plant^{-1} was found to have significant difference among different treatments. Maximum number of tillers plant^{-1} (3.22) was obtained under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*), whereas the minimum number of plant^{-1} (1.61) was recorded in T_1 (control). This might be attributed to the release of nitrogen from poultry manure which is readily made available to the plant. Poultry manure also contains uric acid having 60% nitrogen which changes rapidly to ammoniacal form (NH_4^+) and hence efficiently utilized by plants. The possible reason might be because of certain growth promoting substances secreted by the microbial inoculants, which in turn, might have lead to better root development, better transportation of water, uptake and deposition of nutrients leading to more number of tillers. Significant difference on chlorophyll content due to various treatments was observed at all stages of plant growth. There was an appreciable increase in the chlorophyll content up to 120 days after planting, there after declined at later stages. As apparent from the table 1, that treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded the highest chlorophyll content with the value of 1.45, 1.62, 1.34 and 0.97 mg g^{-1} at 90, 120, 150 and 180 days after planting, respectively. This was followed by T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) and T_{16} (50% NPK + 50% pig manure + *Azospirillum*). The minimum chlorophyll content was recorded in T_1 (control). This might be due to the fact that nitrogen is a component of chlorophyll, which cause increase in chlorophyll content. Moreover, higher number of leaves and maximum size of leaves under this treatment may have also attributed to higher chlorophyll content. These results are in accordance with the findings of Padmapriya *et al.* (8) who reported maximum plant height, number of leaves plant^{-1} and leaf area index in turmeric was recorded with treatment combination of 50% NPK + 50% FYM + coir compost + biofertilizer. Earlier, Nanda *et al*. (7) and Yanthan *et al.* (15) reported positive effect of IPM on ginger.

It is revealed from the Table 1 that integrated application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) recorded the significant variation in yield and yield attributing characters. Numbers of

primary and secondary fingers plant^{-1} were found to be significantly different among all the treatments. Maximum number of primary and secondary fingers plant^{-1} (8.50 and 19.50) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment (T_{18}) 50% NPK + 50% vermicompost + *Azospirillum* (8.17 and 18.83) and (T_{16}) 50% NPK + 50% pig manure + *Azospirillum*, *i.e.* 8.00 and 18.33, respectively, which were at par with each other. However, the minimum number of primary and secondary fingers plant^{-1} (4.50 and 9.83) was recorded in T_1 (control). Higher vegetative growth under integrated application of nutrients might have helped in synthesis of greater amount of food material which was later translocated into developing rhizomes resulting in increased healthy primary and secondary fingers. There was a significant difference in fresh rhizome yield among the treatments. The treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded the maximum fresh rhizome yield (48.06 t ha^{-1}) closely followed by yielded 44.05 t ha^{-1} with the treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*). The minimum yield (23.14 t ha^{-1}) was found in T_1 (control). The treatment difference between treatment 50% NPK + poultry manure + *Azospirillum* (T_{17}) and 50% NPK + 50% vermicompost + *Azospirillum* (T_{18}) was found statistically at par. The treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded 41.97% higher fresh rhizome yield over T_2 (80:60:60 kg NPK ha^{-1}). This result indicates positive effects of integrating NPK with organic manures as well as biofertilizer on yield of turmeric. This might be due to favourable effect of integrated application of organic manure, biofertilizer and inorganic fertilizer in supplying all essential nutrients in balanced ratio and improved the fertility status of soil. Biofertilizer inoculant also might have played a vital role in increasing the rhizome yield. This finding has close conformity with Nanda *et al.* (7) who reported the maximum number of primary and secondary fingers, maximum fresh yield and dry yield of turmeric with integrated nutrient management of 75% NPK + 10 t FYM + micronutrients + biofertilizers. Similar results were also reported by Yeptho *et al*. (16) where they revealed that integrated application of 50% NPK + 50% poultry manure + biofertilizers recorded significantly higher yield in tomato under Nagaland condition. As was apparent from the data, the cured yield was found to be significantly different among the treatments. Maximum cured yield (8.22 t ha^{-1}) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with the value of 7.35 t ha^{-1}. However, the minimum cured yield (4.24 t ha^{-1}) was recorded in T_1 (control). This finding has close conformity with Senapati *et al*. (13) on turmeric.

The quality of turmeric is often determined on the basis of curcumin content in cured rhizomes. Though this character is generally considered as varietal and has high genotype × environmental influence (Anandaraj *et al.*, 1) it has also been observed that it is influenced by the nutrient management. The data pertaining to the curcumin content of rhizome has been represented in table 1. The curcumin content in rhizomes were found to be significantly different among the treatments. Maximum curcumin content (6.68%) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with 6.53%, which was at par with each other. However, the minimum curcumin content (5.70%) was recorded in T_1 (control). These results are in accordance with the findings of Nanda *et al.* (7) who reported maximum content of curcumin in turmeric (5.90 %) with the integrated application of 75 % NPK + 10 t ha^{-1} FYM + micronutrient + biofertilizers. Hu *et al.* (5) reported that 1/3rd poultry manure + 2/3rd chemical fertilizer recorded the maximum curcumin content in turmeric.

It is evident from the Table 2 that various treatments showed appreciable impact on enhancing the nutrients concentration in rhizome and leaves over control. The application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) recorded the maximum accumulation of N (1.54%), P (0.44%), K (2.92%), Ca (0.37%), Mg (0.15), Mn (55.17 ppm), Zn (31.83 ppm), Cu (2.75 ppm) and S (0.45 ppm) while the maximum accumulation of Fe (98.17ppm) in turmeric rhizome was recorded the maximum in T_{18} (50 % NPK + 50 % vermicompost + *Azospirillum*). The lowest accumulation of nutrients in turmeric rhizome was observed in T_1 (control). The concentration of NPK in leaves had shown significant difference among the various treatments. The highest concentration of N (1.90%), P (0.53%) and K (2.94%) in leaves was observed under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) which was followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with N (1.84%), P (0.52%) and K (2.84%) The lowest concentration of NPK in leaves was recorded in T_1 (control). The reason for higher content of NPK and micronutrients in rhizome might be due to better vegetative growth under this treatment, which might have attributed increased microbial activities in the root zone which decomposes organic manures and also fixed unavailable form of mineral nutrients into available form in soil which helped in better accumulation of the nutrient in the plant and the rhizome. It might also

Table 2. Effect of INM on nutrients content in rhizome and leaves (pooled data of two years).

Treatment	Nutrient content in rhizome										Nutrients content in leaves		
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	S (ppm)	N (%)	P (%)	K (%)
T_1	1.37	0.31	2.26	0.25	0.09	68.17	32.67	22.83	1.90	0.17	1.14	0.24	2.13
T_2	1.43	0.38	2.51	0.29	0.12	84.17	37.17	25.83	2.39	0.35	1.60	0.42	2.53
T_3	1.38	0.35	2.28	0.26	0.10	81.00	33.00	23.50	2.08	0.19	1.25	0.29	2.16
T_4	1.40	0.33	2.29	0.26	0.11	74.17	33.17	23.83	2.12	0.23	1.30	0.29	2.19
T_5	1.42	0.35	2.32	0.27	0.11	76.67	34.67	24.00	2.13	0.27	1.40	0.32	2.29
T_6	1.41	0.33	2.29	0.27	0.11	79.00	33.83	23.17	2.08	0.26	1.35	0.29	2.21
T_7	1.42	0.36	2.33	0.28	0.11	81.50	35.00	24.50	2.15	0.27	1.44	0.34	2.31
T_8	1.42	0.37	2.42	0.28	0.11	82.83	36.50	24.50	2.18	0.29	1.50	0.35	2.33
T_9	1.43	0.38	2.48	0.28	0.12	83.33	37.00	25.00	2.20	0.35	1.58	0.38	2.47
T_{10}	1.43	0.38	2.46	0.28	0.12	84.00	36.83	24.67	2.18	0.32	1.55	0.36	2.43
T_{11}	1.45	0.38	2.53	0.30	0.12	84.33	37.67	26.50	2.32	0.35	1.65	0.45	2.55
T_{12}	1.46	0.38	2.58	0.30	0.13	84.83	38.00	27.17	2.40	0.36	1.65	0.46	2.58
T_{13}	1.48	0.39	2.71	0.31	0.13	85.50	39.50	28.83	2.48	0.37	1.73	0.47	2.67
T_{14}	1.48	0.39	2.64	0.30	0.13	91.17	38.50	27.50	2.43	0.37	1.73	0.48	2.66
T_{15}	1.49	0.40	2.70	0.31	0.13	93.33	40.00	29.50	2.50	0.39	1.78	0.50	2.72
T_{16}	1.50	0.41	2.75	0.32	0.14	94.00	42.17	31.00	2.63	0.39	1.80	0.51	2.73
T_{17}	1.54	0.44	2.92	0.37	0.15	97.33	55.17	31.83	2.75	0.45	1.90	0.53	2.94
T_{18}	1.51	0.41	2.89	0.33	0.14	98.17	49.50	31.50	2.75	0.41	1.84	0.52	2.84
$CD_{(0.05)}$	0.09	0.10	0.21	0.14	0.13	8.76	3.42	1.76	0.68	0.11	0.05	0.10	0.04

be due to combined application of organic manures, inorganic fertilizers and biofertilizer, which allowed normal carbohydrate utilization to take place, thus ultimately enhanced efficiency of leaves and as a result more photosynthates were translocated to fleshy or storage organ, which caused more yield and more accumulation of nutrients in turmeric rhizomes. Bendangsenla (3) reported increase in nitrogen and potassium concentration in leaf and rhizome significantly in turmeric at 80 kg N ha^{-1} under terrace condition of Nagaland. She also reported that biofertilizer also showed a positive impact in enhancing the concentration of N, P and K in leaf as well as in rhizome.

It is evident from the table 3 that integrated application of inorganic fertilizers, organic manures and biofertilizer alone or in combination significantly influenced the nutrient uptake by plants. Maximum uptake of N (182.25 kg ha^{-1}), P (50.80 kg ha^{-1}) and K (283.98 kg ha^{-1}) was recorded from treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*). This might be due to the supplementation of nutrient into the soil after mineralization that contributes to the availability of the plant nutrients resulting in better uptake by the plant. This finding are in corroboration with the findings of Rajnarayan *et al.* (10). The data in Table 3 showed there was significant increase in available N, P_2O_5 and K_2O due to various treatments over control. Among the treatment, the highest available nitrogen (297.40 ha^{-1}) was recorded in T_2 (80:60:60 kg NPK ha^{-1}), which was followed by treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) and T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with the value of 293.77 and 287.48 kg ha^{-1}, respectively. The lowest available nitrogen (177.22 kg ha^{-1}) was found in T_1 (control). The probable cause of high available nitrogen after harvest in 100% NPK might be due to poor soil physical structure, lack of organic manures and microbial activities, thus resulting in poor utilization of N to plants at its growth stages. As such the applied N could bring about higher residual nitrogen. The highest available P_2O_5 (13.43 kg ha^{-1}) and K_2O (197.25 kg ha^{-1}) in the soil after harvest was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*). The lowest available P_2O_5 and K_2O were found in T_1 (control). The comparative higher level of P_2O_5 and K_2O in soil after harvest under treatment 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) might be attributed to increased microbial activities in

Table 3. Effect of INM on nutrient uptake by plant and nutrient status of soil after harvest (pooled data of two years).

Treatment	Nutrient uptake by plant			Nutrient status of soil after harvest				
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic carbon (%)	pH
T_1	23.51	4.76	44.29	177.22	7.32	149.08	1.41	4.47
T_2	79.33	20.64	126.14	297.40	12.22	188.90	1.93	4.65
T_3	43.19	9.88	74.67	252.88	10.04	167.99	2.28	4.55
T_4	47.01	10.50	79.46	250.78	9.74	163.78	2.17	4.55
T_5	54.55	12.59	89.53	251.15	9.81	174.00	2.27	4.55
T_6	47.46	10.28	78.06	257.27	9.81	165.80	2.21	4.55
T_7	54.94	12.97	88.69	268.49	10.90	178.85	2.40	4.58
T_8	65.31	15.36	102.22	265.61	10.52	173.76	2.33	4.57
T_9	73.97	17.65	116.40	270.70	10.72	179.89	2.34	4.62
T_{10}	67.15	15.61	105.87	268.74	10.60	176.39	2.34	4.58
T_{11}	87.87	23.85	136.19	273.87	11.39	185.49	2.55	4.63
T_{12}	97.11	26.73	152.29	272.06	10.87	182.73	2.45	4.62
T_{13}	110.02	30.12	171.50	276.86	11.28	187.99	2.53	4.63
T_{14}	105.58	29.17	163.50	275.19	11.23	184.55	2.47	4.63
T_{15}	120.18	33.76	185.23	285.03	12.43	192.95	2.66	4.67
T_{16}	132.49	37.48	202.47	283.25	12.21	186.82	2.56	4.63
T_{17}	182.25	50.80	283.98	293.77	13.83	197.25	2.60	4.71
T_{18}	152.92	43.09	237.95	287.48	12.31	190.01	2.58	4.66
$CD_{(0.05)}$	19.01	5.32	29.83	3.34	1.07	2.69	0.06	NS

NS = non-significant

the root zone, which decomposes organic manures and also fixed unavailable form of mineral nutrients into available form in soil thereby, substantiates crop requirements and also further enhances residual P_2O_5 and K_2O. The affects of integrated nutrient management on the general nutrient availability in the soil after harvest is better than those treatments without integration with the exception to application of 100% NPK, which gave the highest available N after harvest. The highest organic carbon content (2.66%) was recorded in treatment T_{15} (50% NPK + 50% FYM + *Azospirillum*). However, there was no significant difference by the various treatments on the pH after harvest. These findings are in corroboration with the findings of Choudhury *et al.* (4) on tomato.

Based on the present findings, it may be concluded that integrated application of 50% NPK + 50% poultry manure + *Azospirillum* is considered the best treatment for getting higher yield and curcumin content in turmeric under Nagaland conditions. By adopting this treatment, 50% chemical fertilizers can be reduced without any adverse effect on yield, quality and fertility of soil.

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Late blight resistance status in wild potato species against Indian population of *Phytophthora infestans*

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ABSTRACT

Late blight caused by oomycete pathogen *Phytophthora infestans* is the most destructive disease affecting potato crop world-wide with losses up to 90% in India. Resistant varieties offers safe and economical mean for management of the disease. Wild species of potato are the reservoirs of resistance against many insect pest and diseases including late blight. In the present study, 539 clones of 91 potato accessions belonging to 18 wild species maintained at CPRI, Shimla were evaluated for presence of durable resistance against late blight. The clones SS 1764-19 (*S. alandiae*), SS 1763-09 and SS 1763-25 (*S. albicans*), SS 1769-04, SS 1769-08 and SS 1770-14 (*S. arnezii*), SS 1784-07 (*S. berthaultii*), SS 1794-07 (*S. brevicaule*), SS 0551-02, SS 0680-06, SS 1671-01 and SS 1671-03 (*S. chacoense*), SS 1835, SS 1846-05, SS 1847-09, SS 1850-0, SS 1850-01 and SS 1850-04 (*S. demissum*), SS 1926-09, SS 1926-10, SS 1926-11 and SS 1926-13 (*S. microdontum*), SS 2615-01, SS 2616-01, SS 2616-02, SS 2655-01, SS 2656-02, SS 2658-01, SS 2658-02 and SS 2658-03 (*S. pinnatisectum*), SS 1664-02 and SS 1724-40 (*S. sparsipilum*), SS 2038-04 and SS 2048-0 (*S. tuberosum* ssp. *andigena*) and SS 2082-0 (*S. vernei*) were found to be most promising having high late blight resistance under laboratory and field testing. Although some difficulties exist in direct utilization of these clones due to ploidy and EBN differences, but these can be overcome through both short and long-term breeding strategies viz., ploidy and EBN manipulation, bridging species, embryo rescue, somatic hybridization and molecular techniques.

Key words: *Solanum tuberosum*, *Phytopthora infestans*, wild species, EBN.

INTRODUCTION

Late blight caused by oomycete pathogen *Phytophthora infestans* is the most destructive disease affecting potato crop and incurs huge expense world-wide in crop losses and control measures (Haverkort *et al*., 4). In India, late blight appears in most of the potato growing regions in varying degree causing losses up to 90% depending upon the variety and control measures adopted (Singh *et al*., 12). The disease is usually managed by applying fungicides but it increases the cost of production and poses environmental hazards. Resistant varieties offer safe and economical mean for controlling the disease. Early potato breeding for *Phytophthora infestans* resistance was based on major gene resistance derived mainly from the Mexican hexaploid species *Solanum demissum* but it proved to be unstable. Attempts have been made to incorporate quantitative resistance but little success is achieved (Bormann *et al*., 2) due to strong linkage between foliage resistance and late foliage maturity (Visker *et al*., 13). The pathogen *Phytophthora infestans* has proved to be notoriously rapid in evolving complex races and matching virulence types and adapting to changing environmental conditions. High genetic uniformity among the varieties released during last century has further made potato cultivation vulnerable to losses from diseases, insect pests *etc*. (Provan *et al*., 7). Wild species of potato have been reported to possess resistance against many insect pests and diseases including late blight which confers broad spectrum resistance and also broaden the genetic base of the future varieties. Late blight resistance genes have been mapped in many wild species like *S. pinnatisectum*, *S. berthaultii*, *S. microdontum etc*. With recent advances in the gene transfer technology, it has become possible to efficiently transfer only the gene of interest either through cisgenesis or transgenesis (Havekort *et al*., 4).

Central Potato Research Institute, Shimla serves as national repository for collection and conservation of potato germplasm in India from all over the world. Every year new accessions are being added to this collection from different sources. Evaluation of these wild species for resistance to different biotic and abiotic stresses affecting potato crop has been a continuous activity (Bhardwaj *et al*., 1; Luthra *et al*., 6). Many wild species maintained in different parts of the world have been evaluated separately

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for resistance to late blight (Douches *et al*., 3) but only a part of the accessions found resistant in one study can be confirmed in other studies owing to differences in the variability of the pathogen, evaluation methodology used or segregation of character expression between different accessions or species. Thus, it becomes essential to evaluate the existing germplasm against the local pathogen population present in the respective countries. The present study was undertaken to evaluate the existing wild species potato germplasm for presence of durable resistance against late blight populations in India.

MATERIALS AND METHODS

The accessions used in the study were imported from Potato Introduction Station, Sturgeon Bay, USA and Institute of Plant Genetics and Crop Plant Research (GLKS), Gross Luessewitz, Germany in true potato seed (TPS) form for evaluation and utilization under Indian conditions. The TPS belonging to different accessions were sown in plastic trays and later transplanted in the pots for converting into tuber form. The tubers obtained from each seedling represent a different clone and these clones were used in the present study. A total of 539 clones of 91 potato accessions belonging to 18 wild species were evaluated for late blight resistance following laboratory screening through detached leaf methodology and field screening under natural epiphytotic condition during 2014 & 2015.

The detached leaf tests were done in 2014 (June to August) and 2015 (July to September) by challenge inoculation of *Phytophthora infestans* under environment-controlled conditions (18 ± 2°C temperature and >90% relative humidity). The *P. infestans* isolate HP10/42 (A2 mating type and races 1.2.3.4.5.6.7.8.9.10.11) was used as inoculum and was multiplied through a tuber-slice method on a R-gene free susceptible potato cultivar, Kufri Chandermukhi. The zoospore concentration was adjusted to a level of 6×10^4 zoospores/ ml using a hemocytometer. The artificial inoculation of this complex race was done in a minimum of six leaflets of top 4-5th leaf from 2-4 plants/clone obtained from the six weeks old crop grown under glass house. Based on lesion area, clones were grouped into highly resistant (lesion area <1.0 cm^2), resistant (lesion area 1.1 to 2.5 cm^2), moderately resistant (lesion 2.51-6.0 cm^2) and susceptible (lesion area >6.0 cm^2) categories. The field evaluations were done during the summer season (April-September) in Shimla (31.10°N, 77.17°E, 2200 m (above mean sea level), Himachal Pradesh, India and the mean temperature and relative humidity during the main cropping season (July to September) ranged from 14.71-24.21°C and 75-93%, respectively with a total rainfall of 1855mm. The data on disease severity were recorded at weekly intervals and used to calculate Area Under Disease Progress Curve (AUDPC) following Shaner and Finney (9). Clones were classified as highly resistant (AUDPC < 50), resistant (AUDPC 50-150), moderately resistant (AUDPC 151-250), susceptible (AUDPC 251-500) and highly susceptible (AUDPC > 500) categories based on the AUDPC values. The laboratory as well as field observations were recorded in three replications for two years and parameters like mean, range, analysis of variance and different interaction effects were estimated following standard statistical procedures.

RESULTS AND DISCUSSION

Out of 539 clones belonging to 18 *Solanum* species screened against late blight, more than 25% belonged to highly resistant or resistant group indicating high proportion of resistant genotypes among the wild species (Table 1). Maximum proportion of highly resistant clones was found in *S. pinnatisectum* (69.2%) followed by *S. chacoense* (23.4%), *S. microdontum* (12.5%) and *S. demissum* (10.3%). Maximum proportion of resistant clones was found in *S. vernei* (54.5%) followed by *S. demissum* (41.4%), *S. cardiophyllum* (33.3%), *S. sparsipilum* (30.8%), *S. berthaultii* (25.9%), *S. arnezii* (25%) and *S. microdontum* (25%). *S. haancabambense* and *S. gourlayii* had only moderately resistant or susceptible clones while *S. cardiophyllum* had only resistant and moderately resistant clones. Thus, clones from the wild species *S. pinnatisectum*, *S. chacoense*, *S. microdontum*, *S. demissum*, *S. cardiophyllum*, *S. sparsipilum*, *S. berthaultii* and *S. arnezii* can be used as donors for late blight resistance genes. The analysis of variance of the late blight resistance of the accessions scored through laboratory testing revealed significant variances among clones which indicated presence of sufficient variability in the experimental material under study (Table 2). The variance due to species was also significant indicating presence of variability among different species for late blight resistance. The variance due to accessions was significant which was expected as each accession represents an individual genotype.

The accessions PI-498089 and PI-568913 (*S. alandiae*), PI-498201 (*S. albicans*), PI-545880 and PI-545958 (*S. arnezii*), PI-473331 and PI-595507 (*S. berthaultii*), PI-473378 (*S. brevicaule*), PI-GLKS-95 (*S. cardiophyllum*), PI-230495, PI-189217, PI-217451, PI-133073 and PI-320285 (*S. chacoense*), PI-GLKS-269, PI-GLKS-306, PI-160208, PI-161169, PI-161366, PI-161719 and PI-175423 (*S. demissum*),

Table 1. Status of late blight resistance in different *Solanum* species under field conditions.

Solanum sp.	Chr No.	EBN	Total clone (s) tested	Late blight status (%)*			
				HR	R	MR	S
S. alandiae	24	2	42	2.4 (1)	16.7 (7)	81.0 (34)	-
S. albicans	72	4	39	5.1 (2)	17.9 (7)	66.7 (26)	10.3 (4)
S. arnezii	24	2	32	9.4 (3)	25.0 (8)	50.0 (16)	15.6 (5)
S. avilesii	24	2	15	-	6.7 (1)	26.7 (4)	66.7 (10)
S. berthaultii	24	2	27	3.7 (1)	25.9 (7)	63.0 (17)	7.4 (2)
S. brevicaule	24	2	10	10.0 (1)	-	70.0 (7)	20.0 (2)
S. cardiophyllum	24	1	15	-	33.3 (5)	66.7 (10)	-
S. chacoense	24	2	17	23.5 (4)	29.4 (5)	41.2 (7)	5.9 (1)
S. demissum	72	4	58	10.3 (6)	41.4 (24)	46.6 (27)	1.7 (1)
S. gandavillasii	24	2	14	-	-	28.6 (4)	71.4 (10)
S. gourlayii	48	4	14	-	7.1 (1)	28.6 (4)	64.3 (9)
S. haancabambense	24	2	14	-	-	85.7 (12)	14.3 (2)
S. microdontum	24	2	32	12.5 (4)	25.0 (8)	46.9 (15)	15.6 (5)
S. pinnatisectum	24	1	13	69.2 (9)	15.4 (2)	7.7 (1)	7.7 (1)
S. sparsipilum	24	2	39	5.1 (2)	30.8 (12)	46.2 (18)	17.9 (7)
S. spegazzinii	24	2	57	-	24.6 (14)	47.4 (27)	28.1 (16)
S. tuberosum ssp. *andigena*	48	4	90	3.3 (3)	8.9 (8)	50.0 (45)	37.8 (34)
S. vernei	24	2	11	9.1 (1)	54.5 (6)	36.4 (4)	-
Kufri Jyoti (check)	48	4	1	-	-	-	S
Total			539	37	115	278	109

Late blight status (%)*: HR = Highly resistant; R = Resistant; MR = Moderately resistance; S = Susceptible
#Figures in parentheses indicate number of clones.

PI-595509 and PI-218224 (*S. microdontum*), PI-275236, PI-347766, PI-275231, PI-230489, PI-275231 and PI-184774 (*S. pinnatisectum*), PI-113531, PI-DA 019 and PI-CGN-17838 (*S. sparsipilum*), PI-CGN-17839 and PI-442686 (*S. spegazzinii*), PI-186178, PI-243361 and PI-243404 (*S. tuberosum ssp. andigena*) and PI-473306 (*S. vernei*) were found to be highly resistant to late blight under laboratory testing.

The response of late blight reaction was almost similar under field and lab evaluations though variable response was observed in few accessions. The lesion expansion rate decrease with decrease in inoculum load and, therefore, the expression of virulence in detached leaf test depend on the inoculum concentration (Sharma and Singh, 10). Though a standardized inoculum load was used under lab evaluations, but the same may vary under field conditions. Similarly, the environmental conditions i.e. temperature and humidity also vary in the field vis-à-vis controlled chambers which together with inoculum load explain aberration in results obtained under both testing methods. The accessions PI-568913 (*S. alandiae*), PI-595507 (*S. berthaultii*), PI-GLKS-95 (*S. cardiophyllum*), PI-133073 and PI-320285 (*S. chacoense*), PI-GLKS-269, PI-GLKS-306 and PI-161169 (*S. demissum*), PI-595509 and PI-218224 (*S. microdontum*), PI-113531 (*S. sparsipilum*), PI-CGN-17839 and PI-442686 (*S. spegazzinii*) and PI-243361(*S. tuberosum ssp. andigena*), that were highly resistant in laboratory testing showed less resistance under field conditions while reverse trend was observed in the accessions PI-545958 (*S. arnezii*), PI-473101 (*S. gourlayii*), PI-320314 (*S. microdontum*), PI-275231 (*S. pinnatisectum*), PI-CGN-17838 and PI-CGN-17839 (*S. spegazzinii*) and PI-243390 and PI-243435 (*S. tuberosum ssp. andigena*). Such variation among late blight reaction in laboratory and field screening can be due to differences in methodology, testing condition, duration of testing, plant age, canopy structure, pubescence of leaves and spatial and temporal variation in pathogen pressure (Rogozina *et al*., 8). It can be safely concluded that the accessions resistant under both laboratory and field conditions are of much breeding value.

Table 2. Late blight status of different potato species based on laboratory testing.

Species name	Accessions (P.I. No.) evaluated#	Lesion area (cm^2)	Promising clone(s)*
S. alandiae	498089 (21), 568913 (21)	0.73 - 4.23	1764-19
S. albicans	365310 (12), 498201 (27)	0.67 - 7.39	1763-09, 1763-25
S. arnezii	545880 (17), 545958 (15)	0.51 - 7.54	1769-04, 1769-08, 1770-14
S. avilesii	498091 (10), 498093 (5)	1.39 - 6.46	-
S. berthaultii	218215 (10), 265857 (1), 265858 (2), 310926 (1), 473330 (3), 473331 (1), 473339 (1), 473340 (1), 498104 (3), 595507 (4)	0.62 - 7.08	1784-07
S. brevicaule	473378 (7), 545971 (3)	0.53 - 7.05	1794-07
S. cardiophyllum	GLKS-95 (3), 283062 (1), 341233 (11)	0.59 - 5.20	-
S. chacoense	230495 (1), 3297 (1), 189217 (1), 113443 (3), WRF-286 (1), 217451 (4), EC 329480 (1), 133073 (4), 320285 (1)	0.53 - 7.06	0551-02, 0680-06, 1671-01, 1671-03
S. demissum	GLKS-221 (1), GLKS-233 (2), GLKS-269 (6), GLKS-306 (1), 160208 (1), 160212 (1), 160220 (3), 160222 (2), 161149 (1), 161169 (3), 161366 (8), 161719 (7), 161729 (17), 175423 (4), 201853 (1)	0.48 - 6.53	1835, 1846-05, 1847-09, 1850-0, 1850-01, 1850-04
S. gandavillasii	265866 (2), 545862 (12)	3.48 - 8.10	-
S. gourlayii	473101 (14)	1.64 - 7.78	-
S. haancabambense	458400 (14)	2.89 - 7.37	-
S. microdontum	218225 (1), 458358 (3), 473170 (8), 595505 (1), 595509 (12), 320314 (6), 218224 (1)	0.58 - 7.44	1926-09, 1926-10, 1926-11, 1926-13
S. pinnatisectum	190115 (1), 275236 (1), 347766 (3), 275231 (1), 230489 (1), 275231 (3), 184774 (3)	0.53 - 7.46	2615-01, 2616-01, 2616-02, 2655-01, 2656-02, 2658-01, 2658-02, 2658-03
S. sparsipilum	113531 (1), DA 019 (2), 310972 (2), CGN-17838 (34)	0.50 - 7.53	1664-02, 1724-40
S. spegazzinii	205407 (2), CGN-17839 (51), 442686 (4)	0.47 - 7.76	-
S. tuberosum ssp. *andigena*	161716 (2), 161683 (1), 186178 (7), 225629 (14), 237208 (7), 243361 (15), 243390 (1), 243404 (4), 243406 (8), 243411 (2), 243435 (3), 243437 (5), 460701 (6), 243443 (4), 243448 (2), 296086 (9)	0.80 - 7.77	2038-04, 2048-0
S. vernei	WAC 4085 (1), 473306 (1), 500062 (9)	0.44 - 5.42	2082-0
K. Chandermukhi (check)	-	6.94 - 9.49	-
CD (5%)			
Clone	0.09	Species	0.15
Accession	0.13	Year	NS
Clones × Year	NS	Species × Year	NS
Accession × Year	NS		

*Clones exhibiting high level of late blight resistance under laboratory conditions as well as in field testing.
#Values in parenthesis indicate the number of clones evaluated in particular accession (P.I. No.).

The clone SS 1764-19 (*S. alandiae*), SS 1763-09 and SS 1763-25 (*S. albicans*), SS 1769-04, SS 1769-08 and SS 1770-14 (*S. arnezii*), SS 1784-07 (*S. berthaultii*), SS 1794-07 (*S. brevicaule*), SS 0551-02, SS 0680-06, SS 1671-01 and SS 1671-03 (*S. chacoense*), SS 1835, SS 1846-05, SS 1847-09, SS 1850-0, SS 1850-01 and SS 1850-04 (*S. demissum*), SS 1926-09, SS 1926-10, SS 1926-11 and SS 1926-13 (*S. microdontum*), SS 2615-01, SS 2616-01, SS 2616-02, SS 2655-01, SS 2656-02, SS 2658-01, SS 2658-02 and SS 2658-03 (*S. pinnatisectum*), SS 1664-02 and SS 1724-40 (*S. sparsipilum*), SS 2038-04 and SS 2048-0 (*S. tuberosum ssp. andigena*) and SS 2082-0 (*S. vernei*) were found to be most promising having high late blight resistance under both laboratory and field conditions. Presence of high level of late blight resistance among clones of potato wild species *S. arnezii*, *S berthaulti*, *S. chacoense*, *S. demissum*, *S. microdontum*, *S. pinnatisectum*, *S. sparsipilum*, *S. tuberosum* ssp. *andigena* and *S. vernei* have also been reported earlier (Hoekstra, 5).

The clones found promising in this study forms excellent material for pre-breeding that can be used later to breed late blight resistant tetraploid germplasm and will also broaden the genetic base of the cultivated potato. Besides, the highly resistant clones from *S. tuberosum ssp. andigena* (SS 2038-04 and SS 2048-0), having endosperm balance number (EBN) and ploidy level same as that of cultivated *S. tuberosum* ssp. *tuberosum* (2n = 48, 4 EBN), can directly be utilised in crossing with cultivated potato varieties. For transferring late blight resistance from the promising clones of hexaploid species (2n = 6x), *viz*., *S. albicans* (SS 1763-09 and SS 1763-25) and *S. demissum* (SS 1835, SS 1846-05, SS 1847-09, SS 1850, SS 1850-01 and SS 1850-04) with 4 EBN to *S. tuberosum*, bridge species like *S. chacoense* and *S. phurja* can be utilised. Diploid 2 EBN germplasm generally crosses more readily with cultivated germplasm than diploid 1EBN germplasm due to 2n gamete formation *via* first division restitution (FDR) and second division restitution (SDR) (Singh *et al.*, 11). By following this breeding strategy, the late blight resistance from the promising clones of diploid species *S. alandiae* (SS 1764-19), *S. arnezii* (SS 1769-04, SS 1769-08 and SS 1770-14), *S. berthaultii* (SS 1784-07), *S. brevicaule* (SS 1794-07), *S. chacoense* (SS 551-02, SS 680-06, SS 1671-01, SS 1671-03), *S. microdontum* (SS 1926-09, SS 1926-10, SS 1926-11 and SS 1926-13), *S. sparsipilum* (SS 1664-02 and SS 1724-40) and *S. vernei* (SS 2082-0) can be transferred to cultivated potatoes.

The promising clones of diploid *S. pinnatisectum* (SS 2615-01, SS 2616-01, SS 2616-02, SS 2655-01, SS 2656-02, SS 2658-01, SS 2658-02 and SS 2658-03) with 1 EBN are difficult to utilize in short term. These can be utilized through long term breeding strategies by adopting various techniques of ploidy and EBN manipulation, utilizing bridging species, embryo rescue and somatic fusion (Zlesak and Thill, 14).

It can be concluded that there is high intra and inter genetic diversity in accessions and species of potato maintained in India. The genetically diverse and most promising clones from different species as identified in this study can be exploited both for short and long-term breeding strategies in terms of deploying different set of genes for different environmental conditions i.e. inoculum load and duration of congenial conditions for development of late blight thus avoiding mono-culture of the host that has resulted in the quick breakdown of resistance in the past globally. Further, these strategies would help to broaden the genetic base of potato gene pool leading to stronger and more durable resistance in the potato cultivars.

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DNA fingerprinting in African marigold (*Tagetes erecta* L.) genotypes using ISSR and URP markers

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ABSTRACT

Genetic diversity of 22 marigold (*Tagetes erecta* L.) genotypes was evaluated with Inter Simple Sequence Repeats (ISSR) and Universal Rice Primers (URP) markers. A total of 31 molecular markers comprising of 19 ISSR and 12 URP markers were utilized for the study. A total of 184 amplicons were amplified using 19 ISSR primers, out of which 171 (92.73%) were polymorphic. The polymorphic information content (PIC) ranged from 0.23 to 0.47 with an average of 0.34. The resolving power (RP) ranged from 7.00 to 16.00 with average of 11.20. The marker index (MI) ranged from 0.77 to 4.83 with an average of 2.93. In case of URP markers, a total of 131 amplicons were amplified of which 122 (93.08%) were polymorphic with 12 URP primers. The polymorphic information content (PIC) ranged from 0.17 to 0.39 with an average of 0.32. The resolving power (RP) ranged from 8.82 to 22.45 with average of 13.75. The marker index (MI) ranged from 0.55 to 5.87 with an average of 3.17. The Jaccard's similarity coefficient ranged from 0.33 to 0.81 in ISSR markers and 0.33 to 0.86 for URP markers which suggests a wide range of genetic divergence for marigold genotypes. UPGMA method was used for cluster analysis which categorised 22 genotypes in two main clusters at 0.44 similarity coefficient in both ISSR and URP markers. The two male sterile lines formed a distinct group as confirmed through both the marker systems.

Key words: *Tagetes erecta*, genetic diversity, DNA markers.

INTRODUCTION

Genus *Tagetes* (Asteraceae) is native of South and Central America, especially Mexico. It is commonly known as marigold and comprises of approximately 50 species. Due to its high adaptability to various agro climatic conditions, it is being grown as a major loose flower crop in many parts of India. Moreover, it ranks first among nation's loose flower area and production. Two species, especially *Tagetes erecta* L. (African marigold), *Tagetes patula* L. (French marigold) are most common in cultivation under Indian scenario for loose flower production. Nowadays, it is also being used as landscape plant as well as a cut flower. Marigold is also rich source of various value added compounds *viz*. essential oils, carotenoid pigments etc. which finds applications in many nutraceutical, pharmaceutical and cosmetic industries.

Estimation of genetic diversity is the prerequisite step for any crop improvement programme as genetically diverse genotypes provides wide gene pool for the isolation of favourable gene combinations through various crop improvement techniques. Inter simple sequence repeats (ISSR) which has been proved useful for detecting polymorphisms among accessions in various crop plants offer enormous potential for resolving intra and intergenomic relationships (Zietkiewicz *et al*., 16). ISSR markers are useful for detecting polymorphism and overcome some limitations of other marker system like low reproducibility of RAPD, high cost of AFLP and the need to know the flanking sequences to develop species specific primers for SSR polymorphism. The reason of high reproducibility of ISSR markers may be due to use of long primers (16-25 mers) as compared to RAPD (10 mers) and high annealing temperature (45-60ºC) which leads to high stringency (Reddy *et al*.,11). Namita *et al*. (7) studied genetic diversity of 15 marigold genotypes with 12 ISSR markers and revealed 60.48% polymorphism. Kumar *et al*. (5) reported 86.48% polymorphism with 23 ISSR markers in 75 genotypes of chrysanthemum. Zeng *et al*. (15) reported that ISSR markers serve as a potential tool to assess the genetic diversity of genus *Tagetes*.

Universal Rice Primers (URP) derived from repeat sequences of rice, was first developed by Kang *et al.* (4) and have been proved to be better DNA markers for diversity analysis across genomes. Dikshit *et al*. (1) studied genetic differentiation of 70 *Vigna* genotypes of genus using five universal rice primers (URP) and recorded 71-100% polymorphism. Jhang *et al*. (3) studied genetic variability in 40 elite indigenous breeding lines of subtropical carrots using 10 universal

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rice primers (URP). In marigold, meager research has been carried on assessing genetic diversity with molecular markers. The present study for the first time added a new marker system, *i.e.* URP for molecular analysis of marigold.

MATERIALS AND METHODS

Plant material comprised of 22 marigold genotypes, *viz*. three male sterile lines (MS-5, MS-7 and MS-8), two varieties, namely, Pusa Narangi Gainda (PNG) and Pusa Basanti Gainda (PBG) and 17 selections (Af.Sel.1, Af.Sel.2, Af.Sel.3, Af.Sel.4, Af.Sel.5, Af.Sel.6, Af.Sel.7, Af.Sel.8, Af.Sel.9, Af.Sel.10, Af.Sel.11, Af.Sel.12, Af.Sel.13, Af.Sel.14, Af.Sel.15, Af.Sel.16, Af.Sel.17). The genotypes were grown and maintained at the research farm, Division of Floriculture and Landscaping, ICAR-IARI, New Delhi. All the uniform cultural practices were undertaken to raise healthy crop. The laboratory work was undertaken at ICAR- National Research Centre on Plant Biotechnology, New Delhi. Genomic DNA from young healthy leaves of marigold seedlings was extracted with CTAB (Cetyl Trimethyl Ammonium Bromide) method with minor modifications (Murray and Thomson, 6; Saghai-Maroof *et al*., 14). Purification of DNA samples was done and further it was quantified and assessed for quality in 0.8% agarose gel electrophoresis. Final concentration of working samples was made 25 ng/µl.

A total of 19 ISSR (Inter Simple Sequence Repeats) and 12 URP (Universal Rice Primers) markers were used for PCR amplification in 22 marigold genotypes. PCR amplification conditions for ISSR primers were: initial extended step of DNA denaturation at 94°C for 4 minutes followed by 35 cycles of denaturation at 94°C for 1 min. primer annealing at 57°C for 1 min. and elongation at 72°C for 2 min., followed by an elongation step at 72°C for 10 min. The reaction products were mixed with 2 µl of 10 × loading dye. The amplification products were separated on 1.5% agarose gels. Electrophoresis was carried out at 120 V for 2.5 h using horizontal gel electrophoresis system (Bio-Rad). A 1kb DNA ladder (Gene Ruler, Fermentas) was run alongside the amplified products for the determination of approximate band size of PCR product. The resolved amplification products were visualized by using UV-transilluminator and gels was photographed under gel documentation system (Flourchem™ 5500, Alpha Innotech, USA). For URP markers, all the PCR amplification conditions were same as used for ISSR markers except that the annealing temperature was set at 55°C.

For data analysis, the scoring of DNA bands was done manually and all amplifications were repeated twice and only reproducible bands were considered for analysis.The presence of bands were recorded (1) and absence were recorded (0) and missing data was denoted by 9 in order to construct a binary matrix. The discriminatory power of markers was calculated by three parameters, *viz*. polymorphic information content (PIC), resolving power (Rp) and marker index (MI). The polymorphic information content (PIC) was calculated as proposed by Roldan-Ruiz *et al*. (13). The resolving power (Rp) of primers was calculated according to Prevost and Wilkinson (10). The marker index (MI) was calculated as proposed by Powell *et al*. (9). Similarity index values for ISSR and URP markers were calculated for all the possible pair wise comparisons using Jaccard's similarity coefficient (Jaccard, 2). The similarity matrix was subjected to cluster analysis by unweighted pair group method for arithmetic average (UPGMA) and a dendrogram was generated. Computation for multivariate analysis was done using NTSYS-pc Version 2.1 (Numerical Taxonomic System) software (Rohlf, 12). The reliability of the node of UPGMA tree was tested by bootstrap analysis using 1000 permutations.

RESULTS AND DISCUSSION

Total 19 ISSR primers generated 184 reproducible amplicons, out of which 171 were found polymorphic (Table 1). The number of amplicons per primer ranged from 6 (ISSR-24) to 13 (ISSR-1, ISSR-5, ISSR-12 and ISSR-16), with an average of 9.68 amplicons per primer. The number of polymorphic amplicons was observed as 9 amplicons per primer. This was in close confirmation with many researchers viz., as 10.4 amplicons per primer in rose (Panwar, 8), 6.75 amplicons per primer by Namita *et al*. (7) in marigold. The percentage of polymorphism in our study ranged from 63 to 100% with average polymorphism of 92.73%, which was higher than obtained by Kumar *et al.* (5) in chrysanthemum (86.48%) and Namita *et al.* (7) in marigold (60.48%). The PIC value ranged from 0.23 (ISSR-27) to 0.47 (ISSR-32) with average of 0.34. High PIC values were also observed for the primers, *viz.* ISSR-9, ISSR-21, ISSR-11, ISSR-17 and ISSR-20. These results are in confirmation with Namita *et al.* (7) in marigold. The RP ranged from 7.00 (ISSR-22) to 16.00 (ISSR-16) with average of 11.20. Other primers having higher RP values were ISSR-15, ISSR-17, ISSR-20, ISSR-5 and ISSR-12. The marker index ranged from 0.77 (ISSR-7) to 4.83 (ISSR-17) with an average of 2.93. The other primers recorded higher marker index values were ISSR-20, ISSR-12 and ISSR-21. These results are in confirmation with Namita *et al.* (7) in marigold. The Jaccard's similarity coefficient for ISSR markers ranged from 0.33 to 0.81.

Table 1. Details of banding pattern and discriminative statistics of ISSR markers.

Primer	Sequence (5'-3')	TB	PB	P(%)	PIC (SD)	RP	MI
ISSR-1	CAC ACA CAC ACA CAC ARG	13	13	100	0.27 (±0.11)	7.18	3.55
ISSR-2	CAC ACA CAC ACA CAC ARC	8	6	75	0.26 (±0.21)	9.91	1.19
ISSR-5	GAG AGA GAG AGA GAG AYG	13	12	92	0.32 (±0.17)	13.55	3.56
ISSR-7	AGA GAG AGA GAG AGA GYC	8	5	63	0.24 (±0.22)	10.73	0.77
ISSR-9	ACA CAC ACA CAC ACA CYG	9	9	100	0.41 (±0.09)	10.45	3.67
ISSR-10	GTG TGT GTG TGT GTG TYC	7	7	100	0.35 (±0.13)	7.82	2.48
ISSR-11	GTG TGT GTG TGT GTG TYG	7	7	100	0.40 (±0.14)	8.55	2.83
ISSR-12	AGA GAG AGA GAG AGA GYG	13	13	100	0.36 (±0.13)	13.45	4.74
ISSR-15	AGA GAG AGA GAG AGA GC	11	9	82	0.32 (±0.19)	15.45	2.32
ISSR-16	AGA GAG AGA GAG AGA GG	13	12	92	0.34 (±0.18)	16.00	3.80
ISSR-17	GAG AGA GAG AGA GAG AT	12	12	100	0.40 (±0.10)	14.09	4.83
ISSR-20	GTG TGT GTG TGT GTG TC	12	12	100	0.40 (±0.14)	13.91	4.76
ISSR-21	TCT CTC TCT CTC TCT CG	10	10	100	0.41 (±0.10)	12.82	4.08
ISSR-22	TCT CTC TCT CTC TCT CC	7	7	100	0.33 (±0.15)	7.00	2.33
ISSR-24	CTC TCT CTC TCT CTC TRG	6	6	100	0.35 (±0.16)	8.73	2.10
ISSR-27	BDB CAC ACA CAC ACA CA	10	8	80	0.23 (±0.21)	10.45	1.49
ISSR-30	HVH TGT GTG TGT GTG TG	9	8	89	0.24 (±0.14)	12.73	1.70
ISSR-31	AGA GAG AGA GAG AGA GVC	9	8	89	0.32 (±0.16)	12.73	2.27
ISSR-32	CCC GTG TGT GTG TGT GT	7	7	100	0.47 (±0.04)	7.27	3.26
Total	19 primers	184	171	92.73	0.34 (±0.16)	11.20	2.93

TB = Total bands, PB = Polymorphic bands, P(%) = Per cent polymorphism, PIC = Polymorphism Information Content, RP = Resolving Power, MI = Marker Index, SD = Standard Deviation

Total 12 URP primers generated 131 reproducible amplicons, out of which 122 were polymorphic (Table 2). The number of amplicons per primer ranged from 5 (URP-25 F) to 16 (URP-9F), with an average of 10.91 amplicons per primer. The average number of polymorphic amplicons per primer was 10.16. The percentage of polymorphism ranged from 73.00 to 100.00% with an average of 93.08%, which was similar to those obtained by Jhang *et al*. (3) in carrot (94.0%) and Dikshit *et al*. (1) in *Vigna* (94.2%). The average PIC value was 0.32 and ranged from 0.17 (URP-25F) to 0.39 (URP-2R). Other primers having higher PIC values were URP-30F, URP-4R, URP-13R and URP-32F. The resolving power ranged from 8.82 (URP-30F) to 22.45 (URP-9F) with average of 13.75. Other primers having higher RP values were URP-6R, URP-1F, URP-17R, URP-2F and URP-2R. Jhang *et al*. (3) reported Rp (6.91) in carrot for URP markers.The marker index ranged from 0.55 (URP-25F) to 5.87 (URP-2R) with an average of 3.17. The other primers recorded higher marker index values were URP-30F, URP-32F, URP-6R and URP-9F. The Jaccard's similarity coefficient for URP markers ranged from 0.33 to 0.86.

The dendrogram generated from the Jaccard's similarity values using NTSYS software based on genotyping data generated by 19 ISSR and 12 URP primers. For ISSR markers at similarity coefficient 0.44 the genotypes were grouped in two main clusters (Fig. 1). The cluster I represent maximum number of genotypes (20), whereas only two genotypes were grouped in cluster II. Further cluster I was divided into two sub-clusters consequently named as cluster IA and cluster IB. The sub-cluster IA consisted of 4 genotypes, namely, Af.Sel.1, Af.Sel.10, Af.Sel.17 and Af.Sel.7, whereas sub-cluster IB consisted of 16 genotypes, namely, Af.Sel.4, Af.Sel.9, Af.Sel.2, Af.Sel.5, Af.Sel.11, Af.Sel.15, Af.Sel.12, Af.Sel.8, Af.Sel.16, Af.Sel.13, Af.Sel.6, Af.Sel.3, PNG, PBG, Af.Sel.14 and MS-5. Cluster II grouped genotypes MS-7 and MS-8.

For URP markers also the genotypes were grouped in two main clusters at similarity coefficient 0.44 (Fig. 2). The cluster I represented maximum number of genotypes (20), whereas only two were represented by cluster II. Further Cluster I was grouped into two sub-clusters, namely, sub-cluster IA and sub-cluster IB. The sub-cluster IA consisted

Table 2. Details of banding pattern and discriminative statistics of URP markers.

Primer	Sequence (5'-3')	TB	PB	P(%)	PIC (SD)	RP	MI
URP-1F	ATCCAAGGTCCGAGACAAC	13	12	92	0.25 (±0.13)	15.45	2.75
URP-2F	GTGTGCGATCAGTTGCTGGG	10	10	100	0.35 (±0.14)	14.64	3.48
URP-2R	CCCAGCAACTGATCGCACAC	15	15	100	0.39 (±0.12)	14.27	5.87
URP-4R	AGGACTCGATAACAGGCTCC	9	9	100	0.37 (±0.10)	12.00	3.32
URP-6R	GGCAAGCTGGTGGGAGGTAC	12	12	100	0.30 (±0.18)	17.36	3.65
URP-9F	ATGTGTGCGATCAGTTGCTG	16	13	81	0.34 (±0.20)	22.45	3.57
URP-13R	TACATCGCAAGTGACACAGG	9	9	100	0.37 (±0.15)	10.45	3.29
URP-17R	AATGTGGGCAAGCTGGTGGT	11	10	91	0.32 (±0.15)	15.18	2.95
URP-25F	GATGTGTTCTTGGAGCCTGT	5	4	80	0.17 (±0.12)	9.00	0.55
URP-30F	GGACAAGAAGAGGATGTGGA	10	10	100	0.38 (±0.13)	8.82	3.79
URP-32F	TACACGTCTCGATCTACAGG	10	10	100	0.37 (±0.11)	12.82	3.67
URP-38F	AAGAAGCATTCTACCACCAC	11	8	73	0.19 (±0.18)	12.55	1.09
Total	12 Primers	131	122	93.08	0.32 (±0.16)	13.75	3.17

TB : Total bands, PB: Polymorphic bands, P(%): Per cent polymorphism, PIC: Polymorphism Information Content, RP: Resolving Power, MI: Marker Index, SD: Standard Deviation

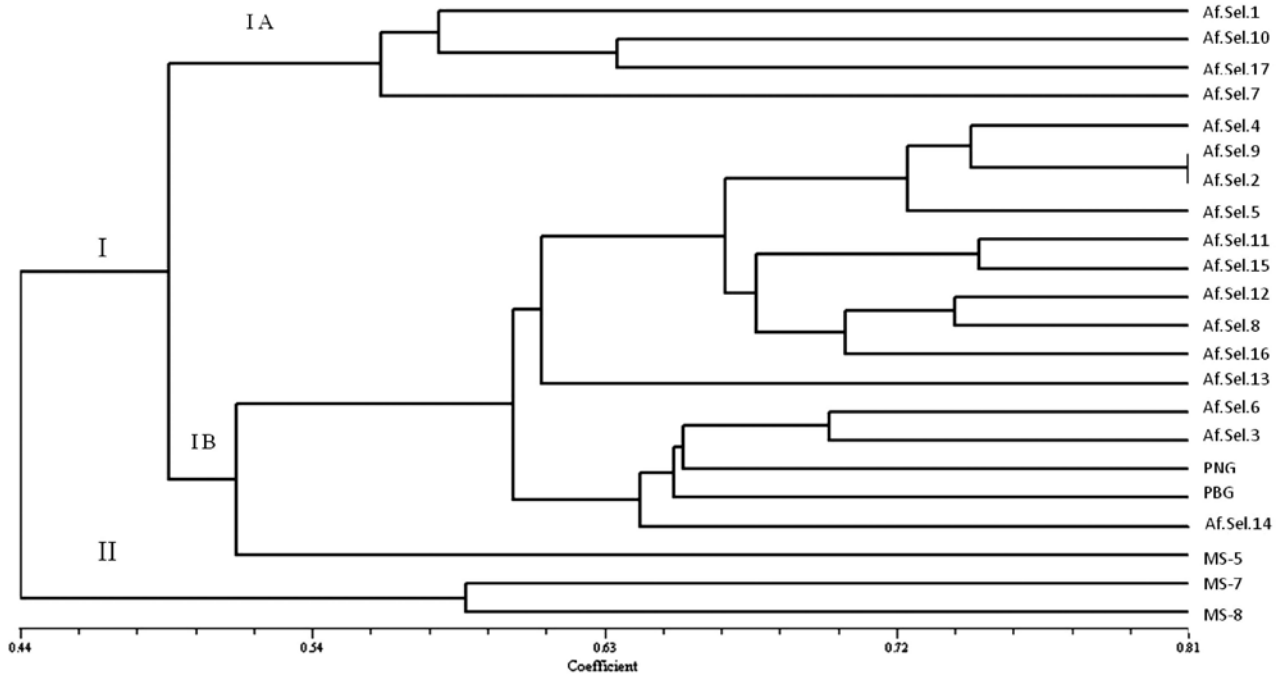

Fig. 1. Dendrogram based on the similarity index values of 22 marigold genotypes using ISSR markers.

of 19 genotypes, namely, Af.Sel.1, Af.Sel.7, Af.Sel.6, PBG, Af.Sel.4, Af.Sel.9, Af.Sel.2, Af.Sel.3, Af.Sel.5, Af.Sel.11, Af.Sel.12, Af.Sel.15, Af.Sel.16, PNG, Af.Sel.8, Af.Sel.14, Af.Sel.13, Af.Sel.10 and Af.Sel.17, whereas sub-cluster IB consisted of one genotype, *i.e.* MS-5. Cluster II consisted of 2 genotypes (MS-7 and MS-8). In both the cases the two male sterile lines MS-7 and MS-8 are represented by separate cluster, which showed their genetic similarity between themselves.

The assessment of different marker systems (ISSR, URP) presented here is useful to evaluate suitability of various marker systems in crop plants. The study provides an additional marker resource by demonstrating use of URP for genotyping of marigold genotypes. Moreover, the genetic diversity analysed

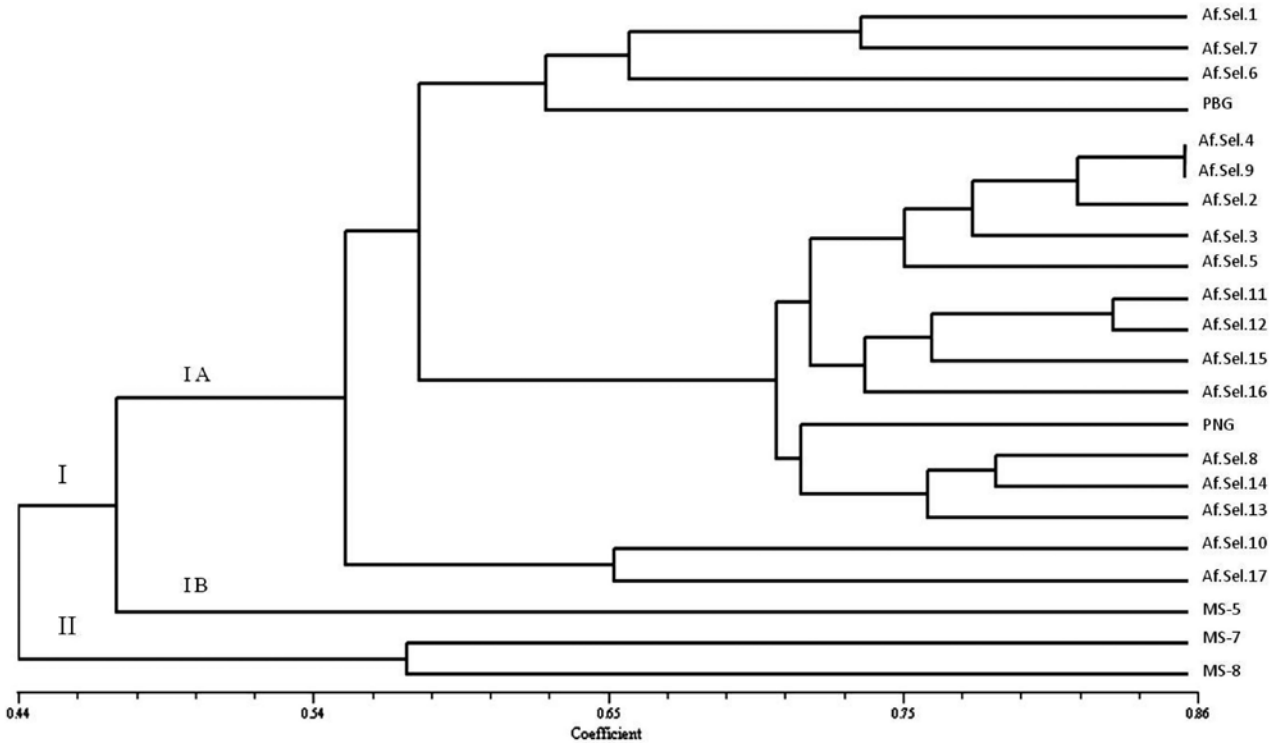

Fig. 2. Dendrogram based on the similarity index values of 22 marigold genotypes using URP markers.

among marigold genotypes will be useful to exploit genetic resources in more effective manner. The high level of genetic variability among the cultivars would be useful for selecting parents in the development of elite marigold varieties which will be further utilized for genome mapping and breeding.

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Influence of storage conditions of marigold flowers on retention of carotenoids and antioxidant activities

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ABSTRACT

The present investigations were carried out to find the effect of different storage temperatures and durations on retention of total carotenoids and antioxidant activities of dried marigold flower petals in varieties Pusa Arpita of *Tagetes patula* L., Pusa Basanti Gainda and Pusa Narangi Gainda of *Tagetes erecta* L. The results revealed that vacuum dried petals of varieties, namely Pusa Arpita, Pusa Narangi Gainda and Pusa Basanti Gainda recorded the highest content of carotenoids (952.78, 1923.94 and 119.75 mg/100 g DW), lutein (220.48, 205.26 and 65.87 µg/g DW), β carotene (14.61, 11.68 and 3.86 µg/g DW), total phenolic content (46.50, 45.48 and 63.34 mg GAE/g DW), total flavonoid content (30.85, 29.32 and 31.28 mg GAE/ g DW) and antioxidant activities {FRAP (430.59, 595.29 and 509.57 µmol $FeSO_4$/g DW) and DPPH (49.28, 59.73 and 51.30%)} after 60 days of storage temperature at -20°C, respectively followed by 4°C and lowest content was observed in dried marigold flower petals stored at ambient temperature. It was also revealed from the studies that carotenoids, total phenolic content, total flavonoids and antioxidant activities were found decreased during storage at all the temperatures. The retention of carotenoids and their antioxidant activities was found to be high in vacuum dried petals stored at -20°C. Among varieties, Pusa Narangi Gainda of African marigold retained better carotenoids and antioxidant activities after 60 days of storage at -20°C.

Key words: *Tagetes* sp., β-carotene, flavonoid, lutein, phenols.

INTRODUCTION

Flower crops are also one of the potential sources of pigments, however, due to lack of awareness it remained as an unexploited area. Among flowers, marigold is one of the economically important loose flower crops which are further used for their diuretic, antiseptic, depurative, insect repellent activities. Since marigold petals are a rich source of carotenoids especially the yellow carotenoids (β-carotenes), xanthophylls (lutein, zeaxanthin) and polyphenols, it is used as food colourant and animal feed. Since these pigments are inherited unstable, highly unsaturated molecules, hence, subjected to isomerisation causing colour loss and oxidation. Carotenoid pigments still bind to proteins and keep their natural state by providing stability to pigment colour and structure during storage. However, the retention of carotenoids during storage is an important aspect to get acceptable end product (Cinar, 7). Carotenoid degradation during storage not only affects colour but also flavour and nutritive value.

Antioxidant activity of the plants also depends upon the composition and content of the phenolic and flavonoid content present in the plants. Storage at different temperatures is also an important factor for retention of carotenoid pigments and their antioxidant activities in fruits, vegetables and flowers (Lee and Kader, 11). Effect of efficient storage techniques on retention of carotenoid content and antioxidant activities of marigold flowers was supported by very few published reports. The time between harvesting and consumption might be long and during this period, biochemical changes could happen that affect the nutraceutical value in marigold, hence, there is need to standardize storage of dry petals at different temperatures and for different durations to recover maximum content of carotenoids and other bioactive compounds and high retention of antioxidant activities of pigments in marigold flowers.

MATERIALS AND METHODS

The plant material utilized for conducting the experiment consisted of two varieties of African marigold (*Tagetes erecta* L.), namely, Pusa Narangi Gainda and Pusa Basanti Gainda and one variety of French Marigold (*Tagetes patula* L.), namely, Pusa Arpita. The features of varieties used in the present investigation are given in Table 1. These were grown and maintained at research farm of the Division of Floriculture and Landscaping and estimation was done in laboratory of the Division of Agricultural Chemicals, ICAR-IARI, New Delhi during 2013-15.

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Table 1. Salient features of marigold genotypes.

Genotype	Flower type	Flower form	Flower size	Flower colour	Species	Flowering time	Source
Pusa Arpita	Semi double	Petalous	Medium	Orange	*Tagetes patula* L.	Mid Dec.,- Mid Feb.,	ICAR-IARI
Pusa Narangi Gainda	Semi double	Petalous	Medium	Orange	*Tagetes erecta* L.	Mid Feb.,- Mid April	ICAR-IARI
Pusa Basanti Ganida	Semi double	Petalous	Medium	Yellow	*Tagetes erecta* L.	Mid Feb.,- Mid March	ICAR-IARI

Fresh marigold flowers were harvested at full bloom stage for drying of petals in vacuum drying oven. The petals were spread uniformly in the trays of vacuum oven, at pressure of 0.08 kP at 60°C till the constant weight was obtained. The dried petals were subjected to different storage temperatures such as ambient temperature, 4° and -20°C for different durations of 0, 20, 40 and 60 days. The dried petals were further used for extract preparation (petroleum ether extract for carotenoids, ethanolic extract for antioxidant, and lutein extract for lutein and β-carotene estimation).

The total carotenoids were extracted and estimated using method given by Ranganna (13) with minor modifications. Sample preparation for Lutein and β-carotene was done using a modification of procedure described by Barba *et al.* (2). Analysis of lutein and β-carotene was carried out using high performance liquid chromatography. Sample was prepared for estimation of phenolic compounds and assessment of antioxidant activity was done using a method described by Uzelac *et al*. (17) with some modifications. Total phenolic content (TPC) was estimated according to procedure given by Singleton and Rossi (14). The colorimetric method described by Abu Bakar *et al.* (1) was used to determine total flavonoid content (TFC). Total antioxidants were estimated using FRAP method as described by Benzie and Strain (3). The antioxidant activity of the extracts was determined using DPPH assay described by Braca *et al.* (5). The data was statistically analyzed in completely randomized design (CRD) using statistical analysis system (SAS) software. All determinations were done in triplicate and were averaged.

RESULTS AND DISCUSSION

The data presented in the Table 2 revealed that there was significantly decreasing trend for carotenoid pigments in vacuum-dried marigold flowers as the storage duration is increased. The rate of depletion of carotenoid pigments and antioxidant activities in petals stored at -20°C temperature was very slow, followed by petals stored at 4°C. Total carotenoids, lutein and β-carotene in petals of French marigold (*Tagetes patula* L.) variety, Pusa Arpita was decreased from 1108.76 mg/100 g DW, 252.51 87 µg/g DW and 17.00 µg/g DW on 0 day to 952.78 mg/100 g DW, 220.48 µg/g DW and 14.61 µg/g DW after 60 day of storage at -20°C temperature, respectively. Highest retention of total carotenoids (85.93%), lutein (87.31%) and β-carotene (85.94%) during storage was observed at -20°C temperature, whereas, only 74.49% of total carotenoids, 73.80% of lutein and 68.70% of β-carotene was retained at ambient temperature after 60 days of storage of dried petals (Fig. 1). In African marigold (*Tagetes erecta* L.) variety, Pusa Narangi Gainda, total carotenoids, lutein and β-carotene content decreased from 2765.76 mg/100 g DW, 295.15 µg/g DW and16.44 µg/g DW on 0 day to 1923.94 mg/100 g DW, 205.26 µg/g DW and 16.44 µg/g DW after 60 days of storage at -20°C, respectively. It is depicted from Fig. 3 that highest retention of carotenoids (69.56%), lutein (69.54%) and β-carotene (71.04%) was observed at -20°C, however, only 61.69% of total carotenoids, 61.68% of lutein and 63.01% of β-carotene was retained after 60 days of storage of dried petals at ambient temperature (Fig. 2). The data revealed that in African marigold, Pusa Basanti Gainda, total carotenoids, lutein and β-carotene were decreased from 144.90

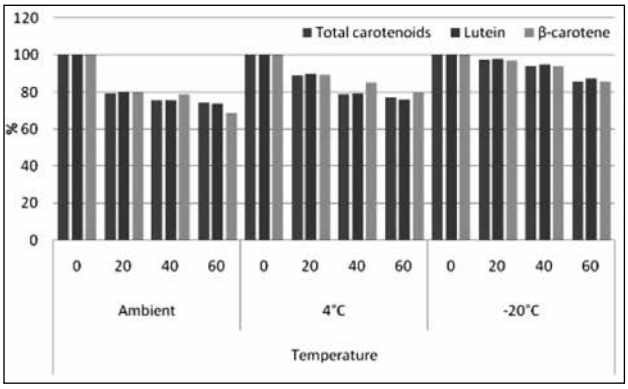

Fig. 1. Carotenoids retention in vacuum dried flowers of French marigold variety Pusa Arpita during storage.

Table 2. Effect of storage temperature and duration on retention of high carotenoid pigments in vacuum dried flowers of marigold.

Variety	Storage temp. (°C)	Duration (days)	Total carotenoids (mg/100 g)		Lutein (µg/g)		β-carotene (µg/g)	
			Mean	SD	Mean	SD	Mean	SD
Pusa Arpita	Ambient	0	1108.76	87.03	252.51	9.43	17.00	0.24
		20	882.85	14.53	202.57	10.37	13.55	0.89
		40	837.33	20.79	191.06	3.44	13.45	1.71
		60	826.00	18.31	186.36	5.28	11.68	0.95
	4	0	1108.76	87.03	252.51	9.43	17.00	0.24
		20	989.35	22.37	226.95	6.03	15.22	0.97
		40	876.33	20.44	200.95	8.61	14.49	1.09
		60	859.24	27.99	191.86	7.46	13.68	1.95
	-20	0	1108.76	87.03	252.51	9.43	17.00	0.24
		20	1081.21	51.70	247.08	5.36	16.51	1.98
		40	1044.58	22.39	240.54	19.01	16.01	1.07
		60	952.78	9.38	220.48	4.01	14.61	1.40
Pusa Narangi Gainda	Ambient	0	2765.76	56.39	295.15	10.38	16.44	1.99
		20	2175.47	108.26	232.10	11.55	13.21	0.66
		40	1830.11	88.72	195.26	9.47	11.11	0.54
		60	1706.34	18.71	182.05	2.00	10.36	0.12
	4	0	2765.76	56.39	295.15	10.38	16.44	1.99
		20	2278.08	31.37	243.05	3.35	13.83	0.19
		40	2026.12	49.64	216.17	5.30	12.30	0.30
		60	1918.33	25.29	204.67	2.70	11.65	0.15
	-20	0	2765.76	56.39	295.15	10.38	16.44	1.99
		20	2292.47	16.71	244.58	1.78	13.92	0.10
		40	2068.31	48.42	220.67	5.17	12.56	0.30
		60	1923.94	25.47	205.26	2.72	11.68	0.16
Pusa Basanti Gainda	Ambient	0	144.90	8.06	79.21	4.40	4.65	0.98
		20	113.60	9.24	62.49	5.08	3.66	0.30
		40	101.56	6.87	55.87	3.78	3.27	0.22
		60	91.10	5.16	50.11	2.83	2.94	0.17
	4	0	144.90	8.06	79.21	4.40	4.65	0.98
		20	126.43	5.90	69.55	3.25	4.08	0.19
		40	120.33	5.86	66.19	3.22	3.88	0.19
		60	114.70	7.75	63.09	4.27	3.69	0.25
	-20	0	144.90	8.06	79.21	4.40	4.65	0.98
		20	131.77	11.70	72.48	6.44	4.25	0.38
		40	125.67	6.90	69.12	3.80	4.05	0.23
		60	119.75	5.73	65.87	3.15	3.86	0.19
$CD_{0.05}$	Variety (A)		20.15**		3.35**		0.46**	
	Temperature (B)		20.15**		3.35**		0.46**	
	Duration (C)		23.27**		3.87**		0.53**	
	Variety × Temp. (A×B)		34.90**		5.81**		0.79^{NS}	
	Variety × Duration (A×C)		40.30**		6.70**		0.91**	
	Temperature × Duration (B×C)		40.30**		6.70**		0.91^{NS}	
	Variety × Temp. × Duration (A×B×C)		69.80*		11.61*		1.58^{NS}	

**,*Significant at 1 and 5% levels

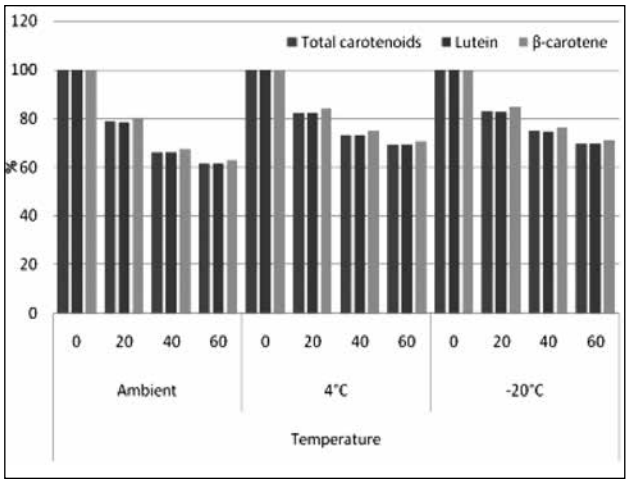

Fig. 2. Carotenoids retention in vacuum dried flowers of African marigold variety Pusa Narangi Gainda during storage.

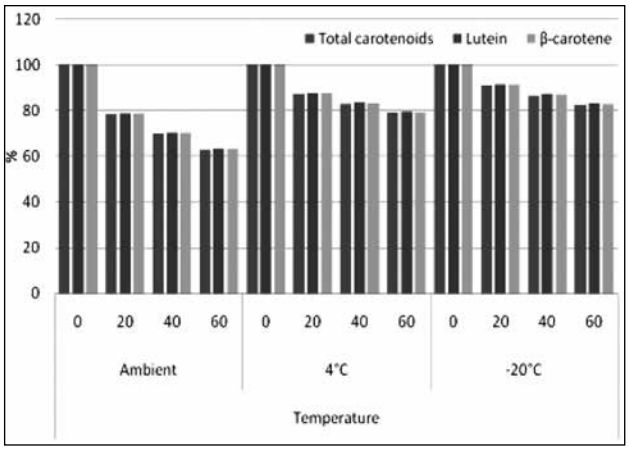

Fig. 3. Carotenoids retention in vacuum dried flowers of African marigold variety Pusa Basanti Gainda during storage.

mg/100 g DW, 79.21 µg/g DW and 4.65 µg/g DW on 0 day to 119.75 mg/100g DW, 65.87 µg/g DW and 3.86 µg/g DW after 60 days of storage at -20°C temperature. Highest retention of total carotenoids (82.64%), lutein (83.16%) and β-carotene (83.01%) was observed at -20°C temperature after 60 days of storage of dried petals (Fig. 3). The interaction between variety × temperature, variety × duration, temperature × duration for total carotenoids and lutein content was significant at 1% level of significance. However, interaction between variety × temperature × duration was significant at 5% level of significance. For β-carotene, interaction between variety × temperature, temperature × duration and variety × temperature × duration was non-significant, whereas, interaction between variety × duration was significant at 1% level of significance. Carotenoids are sensitive to heat, light and oxygen and the major cause of carotenoid destruction during processing and storage is enzymatic or non enzymatic oxidation in carrots (Dutta, 9). The results were also in confirmation with Blessington *et al*. (4) in potato and Siriamornpun *et al.* (15) in marigold.

The data presented in the Table 3 depicts that the phenolic content, flavonoid content and antioxidant activities (FRAP and DPPH) in marigold petals tend to decrease during storage. The storage temperature of -20°C had high retention of phenolic content, flavonoid content and antioxidant activities and the rate of depletion was much faster under ambient temperature. In French marigold variety, Pusa Arpita, total phenolic content (84.24 mg GAE/g DW) and total flavonoids content (47.74 mg GAE/g DW) on 0 day, were decreased to 46.50 mg GAE/g DW and 30.85 mg GAE/g DW after 60 days of storage at -20°C, respectively. Highest retention of total phenolic content (55.20%) and total flavonoid content (49.67%) during storage was observed at -20°C temperature, whereas, only 39.10% of phenolic content and 39.00% of total flavonoid content was retained at ambient temperature after 60 days of storage of dried petals (Fig. 4). The data shows that in African marigold (*Tagetes erecta* L.) variety, Pusa Narangi Gainda, total phenolic content (83.89 mg GAE/g DW) and total flavonoid content (46.61 mg GAE/g DW) on 0 day decreased to 45.48 mg GAE/g DW and 29.32 mg GAE/g DW after 60 days of storage at -20°C temperature, respectively. Highest retention of total phenolic content (54.21%) and total flavonoid content (62.90 %) during storage was observed at -20°C temperature, whereas, only 37.68% of phenolic content and 39.30% of total flavonoids content was retained at ambient temperature after 60 day of

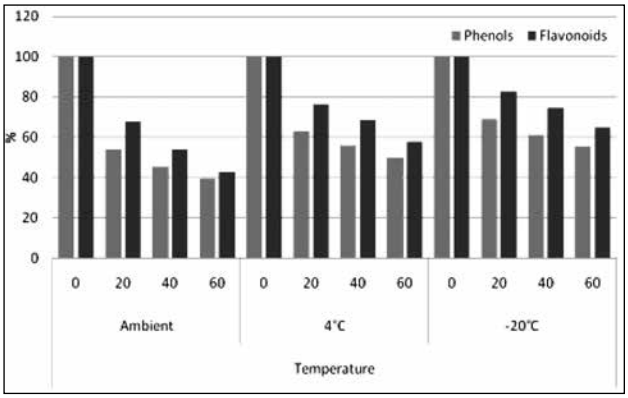

Fig. 4. Retention of Phenolic compounds in vacuum dried flowers of French marigold variety Pusa Arpita during storage.

Table 3. Effect of storage temperature and duration on retention of antioxidant activities, phenolic and flavonoid content in vacuum dried flowers of marigold.

Variety	Storage temperature (°C)	Duration (days)	Total Phenolic content (mg GAE/g)		Total Flavonid content (mg RE/g)		FRAP (µmol $FeSO_4$/g)		DPPH (%)	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pusa Arpita	Ambient	0	84.24	1.99	47.74	1.31	655.75	35.28	76.63	2.70
		20	45.36	6.54	32.37	2.11	538.89	30.26	52.31	1.66
		40	38.16	2.04	25.72	2.23	406.99	45.62	37.62	0.89
		60	32.94	1.48	20.35	2.21	306.98	32.93	29.53	0.85
	4	0	84.24	1.99	47.74	1.31	655.75	35.28	76.63	2.70
		20	52.78	3.24	36.33	3.10	562.28	32.30	58.15	1.87
		40	46.83	1.71	32.59	3.14	440.48	13.12	51.35	2.52
		60	41.85	1.12	27.55	1.91	370.82	65.05	45.69	0.89
	-20	0	84.24	1.99	47.74	1.31	655.75	35.28	76.63	2.70
		20	58.03	1.43	39.44	1.80	594.61	35.38	62.34	1.95
		40	51.28	2.58	35.44	2.90	530.23	20.93	54.28	2.94
		60	46.50	2.15	30.85	1.12	430.59	22.82	49.28	1.94
Pusa Nara-ngi Gainda	Ambient	0	83.89	2.75	46.61	2.00	838.83	27.46	71.99	3.69
		20	43.66	1.04	28.49	1.04	602.44	13.23	54.88	0.63
		40	37.66	0.80	23.41	2.00	461.05	9.54	41.81	1.69
		60	31.61	0.75	18.32	1.23	309.50	13.71	30.39	0.94
	4	0	83.89	2.75	46.61	2.00	838.83	27.46	71.99	3.69
		20	53.33	0.85	36.04	1.63	709.51	21.73	64.98	0.82
		40	46.10	1.55	29.56	1.51	639.20	2.85	58.98	1.79
		60	41.43	0.66	25.63	1.16	524.82	8.19	54.53	0.98
	-20	0	83.89	2.75	46.61	2.00	838.83	27.46	71.99	3.69
		20	57.45	1.68	38.00	0.38	734.92	10.81	67.16	0.77
		40	50.27	1.98	33.97	1.32	677.27	4.59	63.26	0.87
		60	45.48	1.04	29.32	1.56	595.29	11.31	59.73	0.44
Pusa Basanti Gainda	Ambient	0	93.00	2.05	46.61	2.00	716.05	98.44	73.15	0.90
		20	62.45	4.35	29.85	2.45	552.56	89.26	53.49	3.70
		40	51.83	6.36	24.48	2.24	434.03	38.17	41.04	1.38
		60	44.33	5.25	19.47	0.99	347.30	25.58	31.95	1.62
	4	0	93.00	2.05	46.61	2.00	716.05	98.43	73.15	0.90
		20	70.98	2.62	34.47	2.67	623.00	41.09	59.92	1.34
		40	64.06	3.92	30.50	1.11	503.86	27.84	54.16	0.99
		60	58.55	1.61	28.45	2.02	434.48	26.00	48.30	0.93
	-20	0	93.00	2.05	46.61	2.00	716.05	98.43	73.15	0.90
		20	74.09	2.34	38.31	3.75	641.94	40.28	64.45	2.27
		40	68.27	4.06	34.70	1.50	564.27	47.20	57.22	1.08
		60	63.34	7.03	31.28	2.17	509.57	45.44	51.30	1.27
$CD_{0.05}$	Variety (A)		1.40**		0.93**		2.03**		0.92**	
	Temperature (B)		1.40**		0.93**		2.03**		0.92**	
	Duration (C)		1.62**		1.08**		2.34**		1.06**	
	Variety × Temp. (A×B)		2.43NS		1.62 NS		35.16**		1.59**	
	Variety × Duration (A×C)		2.81**		1.87 NS		40.60 NS		1.83**	
	Temperature × Duration (B×C)		2.81**		1.87**		40.60**		1.83**	
	Variety × Temp. × Duration (A×B×C)		4.86 NS		3.23 NS		70.32 NS		3.17 NS	

**,*Significant at 1 and 5% levels

storage of dried petals (Fig. 5). In African marigold (*Tagetes erecta* L.) variety, Pusa Basanti Gainda, total phenolic and flavonoid content decreased from 93.00 mg GAE/g DW and 46.61 mg GAE/g DW on 0 day to 63.34 mg GAE/g DW and 63.34 mg GAE/g DW, respectively, after 60 days of storage at ambient temperature. Highest retention of total phenolic content (68.10%) and total flavonoid content (67.11%) was observed after 60 days of storage at -20°C temperature whereas, only 47.66% of total phenolic content and 41.77% of total flavonoid content had retained in marigold petals stored at ambient temperature (Fig. 6). The interaction between variety × duration, temperature × duration for total phenolic content is significant at 1% level of significance. However, interaction between variety × temperature, variety × temperature × duration are non-significant.

Data with respect to FRAP and DPPH activities showed that the antioxidant activities decreased as the storage temperature and duration increased. It was observed that the FRAP and DPPH values decreased from 655.75 µmol $FeSO_4$/g DW and 76.63% to 430.59 µmol $FeSO_4$/g DW and 49.28% retaining 65.66 and 64.30% reducing power in flowers of variety Pusa Arpita after 60 days of storage at -20°C temperature, respectively (Table 3; and Fig. 7). In vacuum dried flowers of variety Pusa Narangi Gainda, the FRAP and DPPH values decreased from 838.83 µmol $FeSO_4$/g DW and 71.99% to 595.29 µmol $FeSO_4$/g DW and 59.73% retaining 70.96 and 82.96% reducing power in flowers after 60 days of storage at -20°C temperature, respectively (Table 3, Fig. 8). The Table 3 and Fig. 9 exhibited that the FRAP and DPPH values decreased from 716.05 µmol $FeSO_4$/g DW and 73.15% to 509.57 µmol $FeSO_4$/g DW and 51.30% retaining 71.16% and 70.12% reducing power in flowers of variety Pusa Arpita after 60 day of storage at -20°C, respectively. The interaction between variety × temperature and temperature × duration for ferric

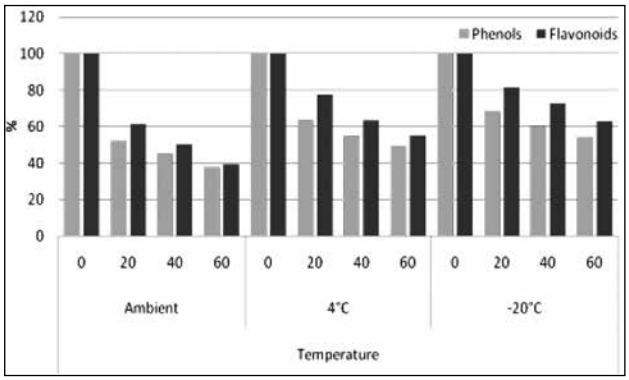

Fig. 5. Retention of Phenolic compounds in vacuum dried flowers of African marigold variety Pusa Narangi Gainda during storage.

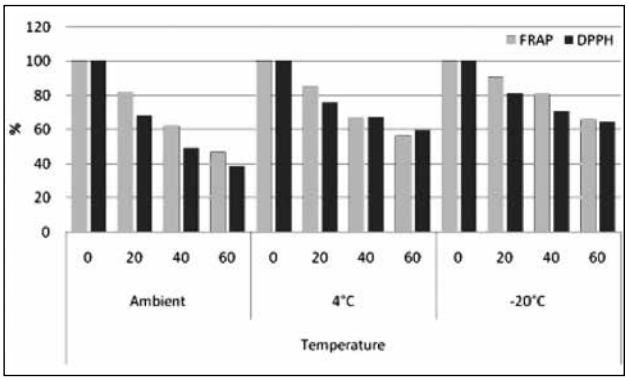

Fig. 7. Retention of antioxidant activities in vacuum dried flowers of French marigold variety Pusa Arpita during storage.

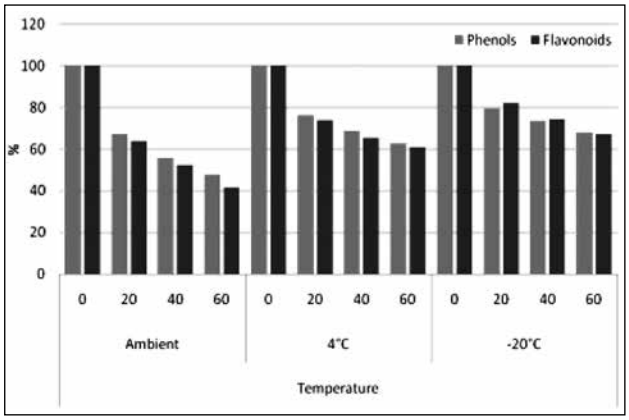

Fig. 6. Retention of Phenolic compounds in vacuum dried flowers of African marigold variety Pusa Basanti Gainda during storage.

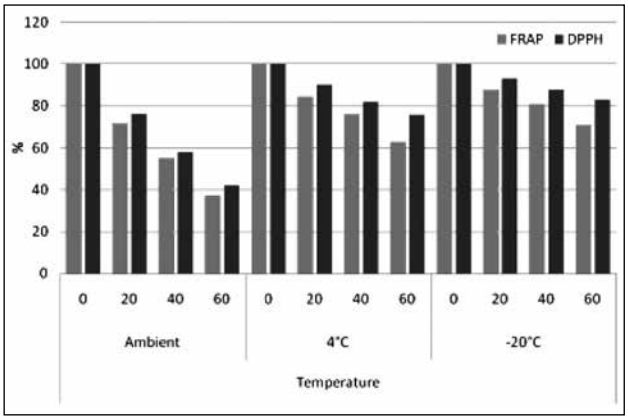

Fig. 8. Retention of antioxidant activities in vacuum dried flowers of African marigold variety Pusa Narangi Gainda during storage

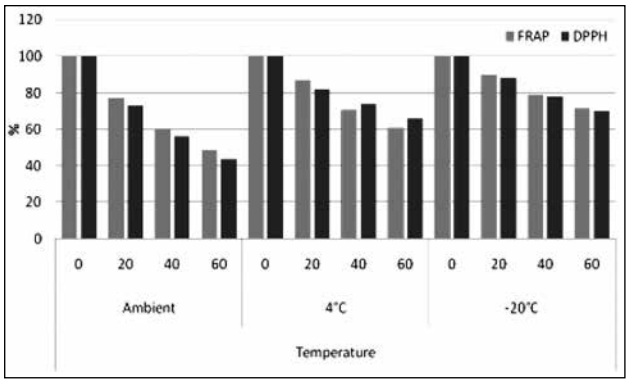

Fig. 9. Retention of antioxidant activities in vacuum dried flowers of African marigold variety Pusa Basanti Gainda during storage.

reducing antioxidant power and DPPH; variety × duration for DPPH were significant at 1% level of significance. However, interaction between variety × duration for FRAP values and variety × temperature × duration for both FRAP and DPPH values were non-significant. Klimczak *et al.* (10) reported the decrease in antioxidant activity of orange juices by 18, 45 and 84% after 6 months of storage at 18, 28 and 38°C, respectively. Similarly, De Ancos *et al.* (8) reported that the freezing process at -20°C during storage produced a decrease of antiradical efficiency in the four cultivars of raspberry ranging between 4 and 26%. Our results are in confirmation with the results of Cao *et al*. (6) who reported that low temperature storage maintained higher content of total phenolics and higher levels of DPPH radical scavenging activity and reducing power in Loquat fruit. Patthamakanokporn *et al.* (12) reported that the antioxidant activity and total phenolic compounds in the homogenised guava decreased significantly during storage at -20°C for 2 week and continued to decrease during 3 month of storage. Similar results were obtained by Siriamornpun *et al.* (15) in marigold and Tavarini *et al.* (16) in kiwifruit cultivar Hayward.

It was concluded from the investigations that among varieties, Pusa Narangi Gainda of African marigold retained more carotenoids, lutein and β-carotene content and antioxidant activities. The storage of vacuum dried petals at -20°C temperatures was found suitable for higher retention of bioactive compounds.

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Integrated use of NPK fertilizer with FYM influences growth, floral attributes, soil fertility and nutrient uptake of gladiolus in an Inceptisol of semi-arid tropics

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ABSTRACT

Various combinations of farmyard manure (FYM), nitrogen (N), phosphorous (P) and potassium (K) were evaluated to optimize their levels for growth, yield and nutrient uptake of *Gladiolus hybridus* Hort. cv. Trader Horn grown under open field conditions. The field trials were conducted during two cropping seasons (2013-14 & 2014-15) in a randomized block design with three replications. The treatments consisted of three levels of FYM (0, 5 and 10 t ha^{-1}); four levels, each of N (0, 100, 200 and 300 kg ha^{-1}), P and K (0, 40, 80 and 120 kg ha^{-1}), respectively. The results showed substantial improvement in morphological and floral characteristics of gladiolus with increasing levels of FYM and NPK dosage. The nutrient consortium, FYM 10 t ha^{-1} and 300, 120 and 120 kg NPK ha^{-1} (T_1) were found to be most effective in enhancing plant height (142.0 cm), number of leaves (8.9), spike length (115.1 cm), rachis length (72.0 cm), florets per spike (17.4) and spike yield m^{-2} (19.1). These experiments also showed that balanced application of N, P and K significantly promoted the soil fertility and plant nutrient uptake.

Key words: *Gladiolus* hybrids, manure, floral traits, plant nutrient uptake.

INTRODUCTION

Gladiolus (*Gladiolus hybridus* Hort.) is one of the most commercially exploited open field grown bulbous cut flower, where soil nutrient status and its management through fertilizer and manures play a major role in quality spike production. Among the bulbous ornamentals, *Gladiolus* is one of the leading geophytes in international cut flower trade for its fascinating spikes in various forms and sizes with markings and blends of elegant colours (Mukhopadhyay, 13). It is widely used as a cut flower, for garden display, flower arrangements, bouquets and does quite well in pots. In spite of considerable acreage under gladiolus (11,160 ha) with a production of 54.6 lakh cut spikes, a meagre 13 ha area (Saxena *et al*., 17) is under nutrient supervision, where mining of nutrients from soil operating a disturbance in soil sustainable strategy. As, gladiolus is heavy feeder of primary nutrients and responds positively to the applied nutrients (Kumar and Misra, 10), soil reserves alone are not sufficient thus making it necessary to supply the deficit quantity through external sources. Apart from chemical fertilizers, organic manures like FYM are good complementary sources of nutrients, which improves the efficiency of the applied mineral nutrients and enrich physical and biological properties of soil (Goulding *et al*., 6). A judicious and combined use of these organic and inorganic sources of plant nutrients is essential to maintain soil health, augment the nutrient use efficiency and to economize the use of costly fertilizer inputs. Hence, the present investigation was aimed to come out with an optimized site specific nutrient dose for cut flower production in gladiolus.

MATERIALS AND METHODS

The experiment on gladiolus was carried out during 2013-14 and 2014-15 at research farm of ICAR-IARI, New Delhi. Seventy-two plots were laid out with each gross plot size of 4 × 2.5 m^2 and quality grade corms (3.5-4.0 cm dia.) were dibbled at a spacing of 50 × 15 cm. Initial soil samples from several spots (0-15 cm soil depth) were collected from the experimental field before start of the experiment. Composite soil sample was processed and analyzed for various physico-chemical properties.

The experiment was laid out in a randomized block design with 24 treatments and three replications. Selected combinations of FYM (0, 5 and 10 t ha^{-1}) and NPK fertilizers each at four levels (0, 1, 2 and 3) corresponds to 0, ½ RDF, RDF, 1 ½ RDF (where recommended dose of fertilizers (RDF) equals to

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200, 80 and 80 kg N, P and K ha^{-1}) respectively, were randomized in each plot before dibbling of corms. Well decomposed FYM (at moisture content 30%, total N - 0.4%, total P - 0.2% and total K - 0.5%), half dose of N and entire dose of P and K were added as a basal dose while the remaining N was applied in three splits, *i.e.* at 3rd leaf, spike emergence and harvesting stages as per the treatment combinations. The fertilizer sources were urea, di-ammonium phosphate, single superphosphate and muriate of potash to meet the requirements of different treatment combinations. All the recommended cultural operations were carried out throughout the crop growth period. Soil samples were collected from each treatment after crop harvest and analyzed for alkaline $KMnO_4$-N, Olsen's-P and NH_4OAc-K. Total N, P and K content in plant tissue was analyzed as per the standard procedures of (Jackson, 8); and nutrient uptake (kg ha^{-1}) by the crop was computed by multiplying tissue nutrient concentration with dry weight.

Data on various parameters like plant height, number of shoots per plant, number of leaves per shoot, spike and rachis length, diameter of 3rd fully open floret, duration of flowering, number of florets per spike and spike yield were recorded. Data of both the years were pooled, analyzed and presented in tabular form. Statistical analysis was performed using SAS 9.3 (SAS, 17). The treatment differences were determined by ANOVA procedure in a randomized block design (P≤0.05).

RESULTS AND DISCUSSION

The soil of experimental site was sandy loam in texture and taxonomically categorized under the great group typic Haplustepts (old alluvium). The initial soil had $pH_{1:2.5}$ 8.13, $EC_{1:2.5}$ 0.32 dSm^{-1}, 179 kg ha^{-1} alkaline $KMnO_4$-N, 20.4 kg ha^{-1} Olsen's P, 167 kg ha^{-1} NH_4OAc-K and 0.46% organic carbon. DTPA-extractable micronutrients were in sufficiency range. The data presented in Table 1 clearly indicate that different treatment combinations of FYM and NPK fertilizers significantly influenced the vegetative characters studied. A composite dose of FYM 10 t ha^{-1} and 300, 120 and 120 kg N, P and K ha^{-1} (T_1) was found to be more effective in enhancing the vegetative attributes like plant height, number of shoots per plant and leaves per shoot.

All the treatments improved the plant height in comparison to control (127.1 cm). However, T_1 ($F_{10}N_3P_3K_3$) was found to be the highest (142.0 cm) and was on par with $F_{10}N_3P_2K_3$ (T_5) and $F_{10}N_3P_2K_2$ (T_8). The increased plant height at higher doses may be attributed to stimulatory action of sufficient supply of plant nutrients in terms of cell division and cell enlargement. The least determined height in control could be because of the unavailability of sufficient nutrients at critical crop stages for its luxuriant growth. Similar results in gladiolus were reported earlier (Khan and Ahmed, 9).

Number of shoots per plant (1.4) failed to show statistical disparity beyond 200, 80 and 80 kg NPK ha^{-1} irrespective of FYM dose. It may be probably due to the cumulative effect of optimistic dose on the process of cell division, assisted in assured emergence of more shoots per mother corm up to a certain level. These findings are in accordance with (Gupta *et al*., 7 and Chaudhary *et al*., 2). However, minimum number of shoots and leaves was observed in T_{10} (1.2) and T_{21} (8.0), respectively. The highest number of leaves (8.9) was recorded in plants treated with combination of FYM 10 t ha^{-1} and 300, 120 and 120 kg N, P and K ha^{-1} (T_1). This marked increase in leaf number with higher doses of nutrients may be due to the increased availability of nutrients, alleviating activation of apical meristems and enhanced the biosynthesis of carbohydrates and proteins, which leads to the proliferation of leaf primordium (Kumar and Misra, 11; Gajhbhiye *et al*., 5). Important quality assessment characters like spike and rachis length were found maximum with the application of higher doses of NPK and FYM *i.e.* in $F_{10}N_3P_3K_3$ (T_1) (115.1 and 72.0 cm) followed by $F_{10}N_3P_2K_3$ (T_5) and $F_{10}N_3P_2K_2$ (T_8) whereas minimum spike (101.4 cm) and rachis length (59.6 cm) was observed in control (Table 1). This might be due to greater uptake of nutrients into the plant system, which assured a rapid growth of stems by mobilization of nutrients toward the developing spikes. Similar beneficial effects of higher doses of primary nutrients on spike and rachis length were reported earlier (Kumar *et al*., 12; Chouhan *et al*., 3).

Average of two years data revealed that full dose ($F_{10}N_3P_3K_3$) of NPK and FYM showed significant influence on the number of florets per plant and diameter of the third fully open floret. T_1 ($F_{10}N_3P_3K_3$) leads with 17.4 florets and 12.2 cm diameter, while minimum (15.2 and 11.1 cm) was recorded in control. Abundant availability of nutrients at elevated levels might have shown a positive influence on mobilization of nutrient reserves to put forth vegetative growth which lead to more assimilation of food reserves. The accumulated reserves could have been diverted for flower bud differentiation and resulted in more number of florets per spike. These findings are supported with differential applications of N, P, K and FYM on number of florets by Khan and Ahmad (9) and Chouhan *et al*. (3). An increase in floret size might be due to maximum turgidity and loosening of cell wall material which is a prerequisite of cell expansion caused by potassium levels (Zubair, 19). Maximum

Table 1. Effect of FYM and NPK on vegetative and floral attributes of gladiolus cv. Trader Horn.

Treatment	Plant height (cm)	No. of shoots	No. of leaves	Spike length (cm)	Rachis length (cm)	No. of florets/ spike	Florets open at a time	Duration of flowering (days)	Dia. of floret (cm)	No. of spikes m^{-2}
$F_{10}N_3P_3K_3$	141.9^{a}	1.4^{a}	8.9^{a}	115.1^{a}	72.03^{a}	17.4^{a}	5.9^{a}	14.8^{cdef}	12.2^{a}	19.1^{a}
$F_{10}N_2P_1K_2$	134.5^{bcdef}	1.3^{bcde}	8.5^{bcdef}	107.9^{bcdefg}	66.7^{defghij}	16.0^{efghi}	5.1^{fg}	14.0^{gh}	11.9^{abc}	17.6^{bcde}
$F_{10}N_2P_3K_2$	134.7^{bcdef}	1.3^{bcd}	8.5^{bcdef}	108.1^{bcdefg}	67.4^{bcdefgh}	16.2^{cdefgh}	5.2^{defg}	13.8^{hi}	12.1^{ab}	17.7^{bcd}
$F_{10}N_0P_2K_2$	132.3^{cdefg}	1.3^{defg}	8.3^{defg}	106.3^{cdefgh}	64.8^{ghijkl}	15.7^{ghij}	4.8^{hij}	14.6^{efgh}	11.8^{abcd}	16.9^{def}
$F_{10}N_3P_2K_3$	139.8^{ab}	1.4^{a}	8.8^{ab}	112.3^{ab}	70.7^{ab}	17.1^{ab}	5.5^{bc}	14.6^{efgh}	12.2^{a}	18.80^{a}
$F_{10}N_0P_0K_0$	134.2^{bcdef}	1.3^{efgh}	8.2^{efg}	105.2^{fgh}	63.3^{kl}	15.6^{ghij}	4.7^{ij}	14.4^{fgh}	11.7^{abcd}	16.7^{efg}
$F_{10}N_3P_1K_1$	136.4^{abcde}	1.4^{abc}	8.7^{abcd}	109.2^{bcdef}	67.7^{bcdefg}	16.4^{bcdefg}	5.3^{cdef}	14.1^{gh}	12.1^{a}	18.3^{abc}
$F_{10}N_3P_2K_2$	136.9^{abcd}	1.4^{abc}	8.78^{abc}	111.2^{abcd}	69.2^{abcde}	16.8^{abcd}	5.6^{b}	14.2^{fgh}	12.1^{ab}	18.3^{abc}
$F_5N_3P_3K_1$	136.4^{abcde}	1.4^{a}	8.73^{abcd}	110.6^{abcde}	68.5^{bcdef}	16.9^{abc}	5.4^{bcd}	15.6^{ab}	12.1^{ab}	18.8^{a}
$F_5N_0P_0K_0$	127.4^{g}	1.2^{h}	8.18^{fg}	104.5^{fgh}	62.4^{lm}	15.5^{hij}	4.8^{hij}	14.6^{efg}	11.3^{de}	16.0^{g}
$F_5N_2P_2K_1$	133.6^{bcdefg}	1.4^{abc}	8.57^{abcdef}	108.2^{bcdefg}	66.1^{efghijk}	16.2^{cdefgh}	5.2^{defg}	15.4^{abcd}	11.9^{abcd}	18.3^{abc}
$F_5N_1P_2K_1$	130.4^{defg}	1.3^{def}	8.37^{cdefg}	105.8^{efgh}	64.7^{ghijkl}	15.6^{hij}	5.0^{gh}	14.7^{cdefg}	11.6^{bcde}	17.0^{def}
$F_5N_3P_3K_2$	135.4^{abcdef}	1.4^{a}	8.74^{abcd}	111.4^{abc}	70.3^{abc}	16.7^{abcdef}	5.4^{bcde}	16.0^{a}	12.2^{a}	19.1^{a}
$F_5N_2P_2K_0$	132.3^{cdefg}	1.2^{fgh}	8.56^{abcdef}	107.2^{bcdefg}	66.3^{efghijk}	15.9^{fghij}	5.0^{gh}	14.6^{efg}	11.8^{abcd}	16.5^{fg}
$F_5N_2P_3K_3$	133.1^{cdefg}	1.4^{ab}	8.63^{abcde}	108.9^{bcdef}	67.3^{cdefghi}	16.6^{bcdef}	5.2^{defg}	15.2^{bcde}	11.8^{abcd}	18.4^{ab}
$F_5N_1P_2K_2$	131.6^{cdefg}	1.3^{cde}	8.48^{bcdef}	106.4^{cdefg}	63.7^{jkl}	15.7^{ghij}	5.1^{fg}	14.6^{efgh}	11.5^{bcde}	17.4^{cde}
$F_0N_2P_0K_2$	129.6^{fg}	1.2^{fgh}	8.59^{abcdef}	106.0^{defgh}	64.4^{hijkl}	16.1^{defghi}	4.6^{jk}	15.2^{bcde}	11.8^{abcd}	16.40^{fg}
$F_0N_3P_2K_1$	138.0^{abc}	1.4^{a}	8.85^{ab}	111.9^{ab}	69.6^{abcd}	17.1^{ab}	5.5^{bc}	15.5^{abc}	12.2^{a}	18.86^{a}
$F_0N_2P_1K_1$	132.2^{cdefg}	1.4^{abc}	8.63^{abcde}	105.9^{defgh}	64.3^{hijkl}	16.2^{cdefgh}	5.1^{fg}	14.2^{fgh}	11.9^{abcd}	18.26^{abc}
$F_0N_2P_2K_3$	134.7^{bcdef}	1.4^{a}	8.67^{abcd}	108.0^{bcdefg}	68.8^{abcde}	16.7^{abcde}	5.4^{bcd}	14.9^{bcdef}	12.2^{a}	18.66^{a}
$F_0N_0P_0K_0$	127.0^{g}	1.2^{gh}	8.00^{g}	101.4^{h}	59.6^{m}	15.2^{ij}	4.4^{k}	13.2^{i}	11.1^{e}	16.13^{fg}
$F_0N_1P_1K_1$	129.3^{fg}	1.3^{defg}	8.33^{defg}	103.5^{gh}	62.2^{lm}	15.3^{ij}	4.9^{ghi}	14.2^{fgh}	11.5^{cde}	16.93^{def}
$F_0N_2P_2K_2$	133.5^{bcdefg}	1.4^{abc}	8.73^{abcd}	106.1^{cdefgh}	65.5^{fghijkl}	16.1^{defghi}	5.1^{efg}	14.8^{cdef}	12.0^{abc}	18.26^{abc}
$F_0N_1P_1K_2$	129.9^{efg}	1.3^{cde}	8.34^{defg}	104.9^{fgh}	64.1^{ijkl}	15.6^{ghij}	5.0^{gh}	14.7^{defg}	11.7^{abcde}	17.46^{cde}
LSD (5%)	6.63	0.06	0.42	5.32	3.26	0.73	0.25	0.73	0.58	0.87

F = FYM (0, 5 and 10 t ha^{-1}); Number 0, 1, 2 and 3 represents NPK at four levels. (N: 0,100, 200 and 300 kg ha^{-1}), (P and K each of 0, 40, 80 and 120 kg ha^{-1}), respectively.

flower diameter was obtained with full dose of NPK (Dubey *et al*., 4); NPK and FYM (Shankar and Dubey, 18), and this could be due to steady decomposition of FYM coupled with inorganic sources which release the nutrients throughout the crop growth period thus helps in improved assimilation.

The ability of florets opening at one time was recorded maximum in T_1, *i.e*. $F_{10}N_3P_3K_3$ (5.9) while minimum was noticed in control (4.4). Higher uptake of NPK from soil available and external applied nutrients might have helped in carbohydrate and sugar metabolism which leads to synchronous opening of florets at a time. These results are in conformity with Chaudhary *et al*. (2) and Dubey *et al*. (4). The application of various doses of nutrients significantly affected the duration of flowering. T_{13} ($F_5N_3P_3K_2$) was found to be the best with respect to the longest flowering duration (16 days) which was at par with T_9 ($F_5N_3P_3K_1$) and T_{15} ($F_5N_2P_3K_3$) with 15.6 and 15.2 days, respectively. High dose of NPK and FYM might have encouraged vigorous vegetative growth with more photosynthetic area for greater production and mobilization of photosynthates and prevention of chlorophyll degradation. Thus, sufficient amount of nutrient (N, P, and K) availability ultimately delayed the reproductive phase thereby improving duration of flowering. These findings are in line with application of NPK in gladiolus as reported by Atta-Alla *et al*. (1).

Number of spikes m^{-2} is directly correlated with number of shoots per plant. The highest spike yield m^{-2} (19.1) was obtained from the treatment receiving

10 t ha^{-1} FYM + 300, 120 and 120 kg NPK ha^{-1}, whereas the lowest spike yield was recorded in T_{10} and T_{21} (control). This increase in yield is probably due to effective utilization of applied nutrients, increased sink capacity and nutrient uptake by the crop.

Post harvest soil available N, P and K were favourably influenced by FYM and NPK levels. Mean alkaline $KMnO_4$-N, Olsen's-P and NH_4OAc-K content indicated a considerable increase in post harvest soil N, P and K in parallel to the increment in fertilizer dose (Table 2). This implied that, not all the N, P and K, supplied through FYM and NPK fertilizer application were utilized by gladiolus. The highest values of soil available nutrients in respective plots can be ascribed to accumulation of these nutrients as gladiolus could not utilize them for completion of life cycle. Gladiolus has the ability to utilize stored carbohydrate reserves in the corm to support its growth and development apart from externally applied nutrients which resulted in residual effects of N, P and K. Similar findings were reported by Kumar and Misra (11).

The treatments containing high soil available nutrients have shown a physiological advantage in nutrient uptake in contrast to low fertile plots due to their easy availability and high absorption capacity. The total plant N uptake significantly varied from 112 to 214.8 kg ha^{-1}, P uptake ranged from 11.6 to 27.7 kg ha^{-1} and K uptake was recorded in between 92.5 to 188 kg ha^{-1} (Table 2) considering two years in response to variation in nutrient dose. These

Table 2. Effect of FYM and NPK on soil available NPK and plant uptake of gladiolus cv. Trader Horn.

Treatments	Soil N	Soil P	Soil K	N uptake	P uptake	K uptake
$F_{10}N_3P_3K_3$	255.0^{a}	46.1^{a}	336.0^{a}	214.8^{a}	27.7^{a}	188.0^{a}
$F_{10}N_2P_1K_2$	248.4^{abc}	29.3^{ghi}	320.6^{b}	163.4^{g}	22.2^{d}	137.8^{fg}
$F_{10}N_2P_3K_2$	250.6^{ab}	40.8^{b}	321.2^{b}	187.7^{cd}	22.2^{de}	164.9^{d}
$F_{10}N_0P_2K_2$	242.9^{bcde}	35.6^{d}	312.0^{bcd}	152.8^{i}	22.5^{defg}	125.9^{hij}
$F_{10}N_3P_2K_3$	241.8^{bcde}	28.3^{hijk}	288.1^{fgh}	188.0^{cd}	23.1^{c}	162.1^{cd}
$F_{10}N_0P_0K_0$	239.0^{bcdef}	28.7^{hij}	303.5^{de}	121.2^{jk}	18.2^{l}	105.9^{k}
$F_{10}N_3P_1K_1$	246.5^{abcd}	28.3^{ijk}	305.7^{cd}	185.7cd	25.0^{bc}	160.0^{cd}
$F_{10}N_3P_2K_2$	239.6^{bcdef}	35.2^{d}	311.0^{bcd}	166.9^{g}	21.3^{defg}	137.8^{fg}
$F_5N_3P_3K_1$	246.1^{abcd}	36.3^{d}	283.9^{gh}	195.6^{b}	16.7^{jk}	159.7^{c}
$F_5N_0P_0K_0$	237.7^{cdef}	26.9^{kl}	319.9^{bc}	112.0^{k}	15.6^{n}	99.8^{k}
$F_5N_2P_2K_1$	240.2^{bcdef}	28.6^{hij}	323.8^{ab}	173.6^{f}	20.5^{fgh}	144.1^{ef}
$F_5N_1P_2K_1$	215.4^{g}	30.7^{fg}	299.4^{def}	163.0^{g}	22.5^{def}	128.2^{hi}
$F_5N_3P_3K_2$	229.5^{f}	32.9^{e}	318.4^{bc}	193.6^{cd}	25.1^{b}	171.5^{b}
$F_5N_2P_2K_0$	238.8^{bcdef}	25.6^{lm}	290.5^{efg}	158.1^{g}	18.4^{jkl}	112.6^{ij}
$F_5N_2P_3K_3$	234.8^{def}	44.7^{a}	310.5^{bcd}	178.2^{ef}	20.9^{efgh}	155.3^{cd}
$F_5N_1P_2K_2$	236.1^{def}	27.2^{jk}	261.3^{ij}	151.7^{hi}	19.7^{ij}	132.3^{hij}
$F_0N_2P_0K_2$	242.3^{bcde}	22.6^{n}	274.3^{hi}	148.2^{i}	18.4^{kl}	127.0^{j}
$F_0N_3P_2K_1$	236.5^{def}	36.3^{d}	261.2^{ij}	201.2^{a}	24.2^{b}	159.4^{cd}
$F_0N_2P_1K_1$	232.5^{ef}	24.3^{m}	261.1^{ij}	175.9^{ef}	20.2^{hi}	138.5^{g}
$F_0N_2P_2K_3$	231.5^{ef}	31.8^{ef}	265.4^{i}	194.2^{bc}	21.4^{fgh}	161.8^{cd}
$F_0N_0P_0K_0$	232.4^{ef}	24.5^{m}	267.1^{i}	113.5^{j}	11.6^{op}	92.5^{k}
$F_0N_1P_1K_1$	229.2^{f}	29.9^{gh}	261.2^{ij}	162.6^{gh}	17.7^{m}	136.5^{h}
$F_0N_2P_2K_2$	239.0^{bcdef}	39.0^{c}	260.1^{ij}	181.4^{de}	19.9^{gh}	150.3^{e}
$F_0N_1P_1K_2$	228.8^{f}	27.7^{ijk}	247.7^{j}	155.9^{ghi}	17.9^{kl}	131.4^{hi}
LSD (5%)	11.82	1.60	14.23	9.16	1.075	8.47
S/NS	S	S	S	S	S	S

F = FYM (0, 5 and 10 t ha^{-1}); Number 0, 1, 2 and 3 represents NPK at four levels. (N: 0, 100, 200 and 300 kg ha^{-1}), (P and K each of 0, 40, 80 and 120 kg ha^{-1}), respectively.

results are in conformity with Naik (14) in marigold, where he reported that increased dose of N, P and K improved the nutrient uptake. Moreover, positive interaction between organic (FYM) and inorganic (NPK) nutrients resulted in initial buildup of vigorous growth and higher photosynthetic rate which led to better uptake of nutrients during the crop growth period (Patil and Dhaduk, 15).

It can be concluded that, integrated use of fertilizer NPK with organic FYM significantly increased the growth, flower attributes, soil available NPK and nutrient uptake over their corresponding sole applications in gladiolus. Application of FYM 10 t ha^{-1} and 300, 120 and 120 kg NPK ha^{-1} (T_1) was found to be a balanced optimal dose for sustained productivity and better quality of gladiolus spikes in Inceptisols of Delhi.

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Effect of gibberellic acid and oxalic acid on colour retention and storage quality of cold stored fruits of *ber* cv. Gola

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ABSTRACT

***Ber* (*Zizyphus mauritiana* Lamk.) fruits are perishable in nature and have poor shelf-life. To extend the shelf-life of *ber* fruits, different post-harvest treatments, like pre-cooling, hot water treatment (HWT) at 55°C for 10 min., HWT (55°C, 10 min.) + 10% oxalic acid for 15 min., GA_3 (30, 60 and 90 ppm) were given to fruits and their effects were studied on the storage life and quality of cv. Gola fruits under cold storage conditions (5 ± 1°C and 85 ± 5% RH). Fruits of uniform size and colour were harvested, from healthy plants and subjected to post harvest dip of different chemicals, before placing in cold storage. The effect of different treatments accessed after 7, 14, 21 and 28 days of storage for physiological loss in weight (PLW), total soluble solids (TSS), marketability and palatability rating. The PLW and TSS increased and marketability decreased during storage under each treatment. The sensory rating increased up to 7 days under all treatments but subsequently decreased during storage. It can be concluded that *ber* cv. Gola fruits can be stored up to 21 days by post-harvest treatment using GA_3 at 90 ppm with acceptable quality.**

Key words: *Zizyphus mauritiana*, browning, cold storage.

INTRODUCTION

Ber (*Zizyphus mauritiana* Lamk.) fruit is very popular among consumers due to its high nutritive value and comparatively low market price. For producing early crop of *ber* under rainfed conditions, cv. Gola is recommended by SDAU (Gujarat) for cultivation in arid and semi-arid regions of Gujarat. However, the poor storage-life and high post-harvest losses are the major constraints in developing *ber*-based industry (Salunkhe and Kadam, 15). After harvest fresh *ber* fruits are usually stored at ambient/room temperature (25-35°C), causing high deterioration and thus, cannot be kept for more than 10 days. The fast fruit ripening and senescence, triggered by the major ripening hormone ethylene, results in a short storage life and poor eating quality, *e.g.* pulp softening, browning and decay. Pareek and Gupta (11) reported that fruits of cv. Gola showed high degree of pathological infection and loss in colour and could be stored for only 7 days. *Ber* fruit quality is highly affected during storage due to high respiration rate, increased metabolic activity and higher activity of cell wall degrading enzymes resulting in deterioration of fleshy organs, which subsequently leads to fruit decay (Looney, 8). However, the post-harvest ripening process can be delayed with the application of fruit ripening hindering hormones. Jawandha *et al*. (7) reported that application of growth regulators like gibberellic acid (GA_3) affects the physico-chemical properties and are known to promote the shelf-life of *ber* fruits. Mehta *et al*. (10) reported that GA_3 at 100 ppm significantly suppresses the succinate activities of malate-dehydrogenase enzyme during post-harvest ripening of papaya thereby retarding the ripening process. Pareek *et al*. (12) reported that postharvest dipping of *ber* fruits cultivars Gola and Umran in 200 ppm of maleic hydrazide increased the marketability percentage and improved the storage life and keeping quality of ripe *ber* fruits for up to 12 days under ambient storage conditions. Physiological loss in weight (PLW) is mainly due to high evaporation of water, high respiration and degradative processes during postharvest handling of fruits (Pareek *et al*., 12). Postharvest dipping of 'Gola' fruits in 500 ppm fungicides (Thiabendazole, Captan and Dithane M-45) improved the shelf-life by reducing rate of respiration and cold water dipping reduced respiration as well as ethylene production and degradating enzymatic activities, whereas, hot water treatment (40°C) hindered the development of pathogens, reduced evaporation water loss and PLW, thereby prolonging the shelf-life and quality of fruits (Gupta and Mehta, 5). For maintaining postharvest fruit quality, fungicide solution dipping (Thiabendazole, Captan and Dithane M-45) and sulphur fumigation (Underhill *et al*., 17) are in common practices. Oxalic acid (OA) is a natural antioxidant and might play an

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important role in the natural and artificial preservation of oxidized materials. The post-harvest fruit treatment with controlled OA is a safe and promising method for maintaining eating quality during postharvest storage. Oxalic acid is the most effective anti-browning agent on litchi (Marboh *et al*., 9), whereas, GA_3 is well known to promote the shelf-life of *ber* fruits as reported by various previous workers (Jawandha *et al*., 7). Growers and consumers of *ber* fruit can be benefited if shelf-life is fruit. Therefore, the present investigation was conducted to examine the effect of post-harvest application of various chemicals on fruit quality of *ber* under during cold storage.

MATERIALS AND METHODS

The experiment was carried out at the ICAR-CAZRI, Regional Research Station, Kukma, Bhuj, Gujarat on *ber* fruits of cv. Gola. Fruits were harvested at optimum maturity in the month of April from the selected trees from an orchard of Arid Horticulture Block and healthy and uniform fruits were used for this study. The treatments consisted of without precooling (control), pre-cooling (T_1), hot water treatment (HWT) at 55°C for 10 min. (T_2), HWT (55°C, 10 min.) + 10% oxalic acid (OA) for 15 min. (T_3), GA_3 (30 ppm) (T_4), GA_3 (60 ppm) (T_5) and GA_3 (90 ppm) (T_6) before packaging. For applying HWT and OA, the air-dried pre-cooled fruits were dipped in hot water kept at 55°C for 10 min., air-dried and finally dipped in 10% OA for 15 min. For GA_3 treatment, fruits were dipped in different concentration of GA_3 solution for 10 min. and air-dried to remove surface moisture. Thereafter, the packed fruits were packed in nylon carriers and kept for observations under cold storage conditions (5 ± 1°C and 85 ± 5% RH). Fruits subjected to pre-cooling, without pre-cooling, HWT were included for comparisons. Each treatment was replicated three times and each replication consists of 50 fruits. Observations on physico-chemical properties, *viz*., PLW, browning index, decay loss, marketability, TSS, fruit colour and taste were carried out periodically at every one week interval.

The PLW was calculated based on initial weight and weight at subsequent intervals. Fruit TSS was determined by a hand refractometer of 0-32°Brix. Three fruits for each treatment were homogenized and the degree brix was measured. Titratable acidity was estimated as per the method suggested by Ranganna (13). Post-harvest decay was assessed on a 1-5 hedonic scale, based on the severity of post-harvest fungal decay : 1 = no decay; 2 = 25%; 3 = 50%; 4 = 75% of the fruit surface affected and 5 = 100% fruit decay and oozing (De Jagger and Korsten, 3). Browning index was assessed using the scale as described by Marboh *et al*. (9): 0 = no browning (excellent quality); 1 = slight browning; 2 = 25% browning; 3 = 25-50% browning; 4 = 50-75% browning and 5 > 75% (very poor quality) and was calculated using the following formula: Browning Index = Σ (browning scale × percentage of corresponding fruit within each class). Fruit marketability was assessed visually using hedonic based on the method suggested by Sivakumar *et al*. (16). Fruit colour and taste were evaluated at 7^{th}, 14^{th} and 28^{th} days of storage, using a semi-trained panel consisting of seven judges, based on the following scale 5 = Excellent; 4 = good; 3 = fair (acceptable); 2 = poor (unacceptable for export); 1 = very poor (totally unacceptable). The data were analyzed statistically through completely randomized design (CRD) method (Gomez and Gomez, 4)

RESULTS AND DISCUSSION

Data presented in Table 1 revealed a significant increase in physiological loss in weight (PLW) with the increase of storage period regardless of various treatments. After one week of storage, the mean 3.80% PLW was noted, which increased upto 8.15%, at the last day of storage. However, treatment that involved a combination of HWT (55°C, 10 min.) and 10% OA dipping for 15 min. record the highest weight loss (10.20%), followed by control (6.98%) treatment which was *at par* with precooling treatment after 4 week of storage, which might be due to a reduction in fruit firmness, indicating structural damage to the cross-linkages in the cell wall (Saengnil *et al.*, 14). The minimum PLW (3.55%) was recorded in GA_3 (90 ppm) treated fruits, followed by (4.96%) in GA_3 (60 ppm) treatment. Similar results were also reported by Jawandha *et al*. (7) in *ber* and Marboh *et al*. (9) in litchi fruit.

The *ber* fruits treated with HWT (T2) and GA_3 60 ppm (T5) gave the highest mean TSS (20.89% each) after 4 week of storage under 5 ± 1°C and 85 ± 5% RH. Whereas, minimum mean TSS (17.30%) was recorded in fruits with pre-cooling, which was statistically at par with fruits treated with GA_3 90 ppm. No significant decline of TSS noted in the fruit treated with GA_3 (60 & 90 ppm) during the experiment period. However, interpretation of the interaction effect between various treatments and storage days divulges that there was a gradual increase in TSS of fruits initially upto 21 days, which then gradually declined later on till the end of experiment except in GA_3 (60 & 90 ppm) treatments. This initial increase might be due to the breakdown of starch and polysaccharides into simple sugars and organic acids and water loss during the subsequent storage, but after 21 days the decline in TSS might be due

Table 1. Effect of various treatments on Total soluble solids (%) of *ber* fruits during cold storage.

Treatment	Total soluble solids (%)					Titratable acidity (%)					Physiological loss in weight %				
	Storage period (day)					Storage period (day)					Storage period (day)				
	0	7	14	21	28	Mean	0	7	14	21	28	Mean	7	14	21	28	Mean
T1	16.17	16.80	17.17	18.43	17.93	17.30	0.20	0.19	0.18	0.18	0.17	0.18	2.47	5.53	8.30	9.63	6.48
T2	19.30	19.97	19.97	22.67	22.57	20.89	0.22	0.21	0.19	0.19	0.18	0.20	2.50	6.13	6.53	9.50	6.17
T3	17.47	18.10	19.23	20.90	19.43	19.03	0.22	0.20	0.19	0.18	0.18	0.19	8.17	11.10	11.13	10.40	10.20
T4	18.70	19.37	19.80	21.20	20.87	19.99	0.20	0.19	0.19	0.18	0.18	0.19	4.17	5.57	6.47	7.20	5.85
T5	19.83	20.43	20.93	21.50	21.73	20.89	0.21	0.20	0.19	0.19	0.19	0.20	3.20	4.47	5.37	6.80	4.96
T6	17.10	17.47	17.77	18.60	19.23	18.03	0.21	0.20	0.20	0.19	0.19	0.20	2.33	4.07	3.45	4.37	3.55
Control	18.53	19.70	20.47	21.43	21.53	20.33	0.21	0.20	0.18	0.18	0.17	0.19	3.77	7.33	7.70	9.13	6.98
Mean	18.16	18.83	19.33	20.68	20.47		0.21	0.20	0.19	0.18	0.18		3.80	6.31	6.99	8.15	
CD at 5%																	
Treatment (A)					1.19						0.01						0.31
Storage period (B)					1.01						0.01						0.24
A × B					2.66						0.01						0.63

to their utilization in evapo-transpiration and other biochemical activities. However, it can be argued that the large declined in TSS due to Hot water treatment might be due to increased senescence of the tissues (Saengnil *et al*., 14), which can be attributed to a decrease in sucrose (Marboh *et al*., 9).

A gradual declining trend in the acidity content of fruit in all the treatment was observed with the advancement of storage period regardless of post-harvest treatments (Table 1). The higher titratable acidity (0.20%) was noted in fruits treated with higher concentration of GA_3 (60 and 90 ppm), fruits treated with GA_3 (60 and 90 ppm) were showing lowest decreasing trend in acidity. While, the highest decrease in acidity from initial day of storage to last day of storage noted in HWT (55°C, 10 min.) and 10% OA dipping for 15 min. and control. It possibly is due to the utilization of organic acids in respiratory process and other biodegradable reactions (Saengnil *et al*., 14). However, under acid treatment, Marboh *et al*. (9) opined that there was a slight penetration of acid into the fruit aril might be responsible for decreasing acidity.

Pericarp browning increased with storage time and use of OA significantly reduced pericarp browning. Minimum browning index was recorded in HWT (55°C, 10 min.) + 10% OA for 15 min. followed by higher concentration of GA_3 (90 ppm) (Fig. 1A). This is due to the effect of HWT prior to an OA dip, in facilitating the penetration of acid (Marboh *et al*., 9) thereby inhibiting polyphenol oxidase (PPO) and peroxidase (POD) activities and resulted in stabilization of anthocyanin's (Saegnil *et al*., 14). However, use of no precooling of fruits and fruit treated with hot water (55°C, 10 min.*),* has been found to accelerate the extent of browning in fruits, which is primarily attributed to enhanced enzymatic activity due to loss of compartmentation of enzymes and substrates as reported by Hu *et al*. (6).

The highest and significant decay index was noted in fruits without precooling followed by fruit treated with hot water (55°C, 12 min.) at the last day of storage. However, under the combined HWT (55°C,12 min.) + 10% OA for 15 min., and higher concentration of GA_3 (90 ppm) treatment, fruit spoilage was minimum (Fig. 1 B). Plant growth regulators (GA_3) applied after harvest delayed ripening and increased shelf-life of fruits as well as reduce the postharvest decay losses of fruits (Abbas, 1). Low spoilage loses under the combined HWT (55°C, 10 min.) + 10% OA for 15 min. might be due to the combined fungistatic effects of the applied treatments (HWT) by killing the organisms on and below the fruit surface (Marboh *et al*., 9) and OA by providing an acidic conditions on the peel surface, that provide an unfavourable conditions

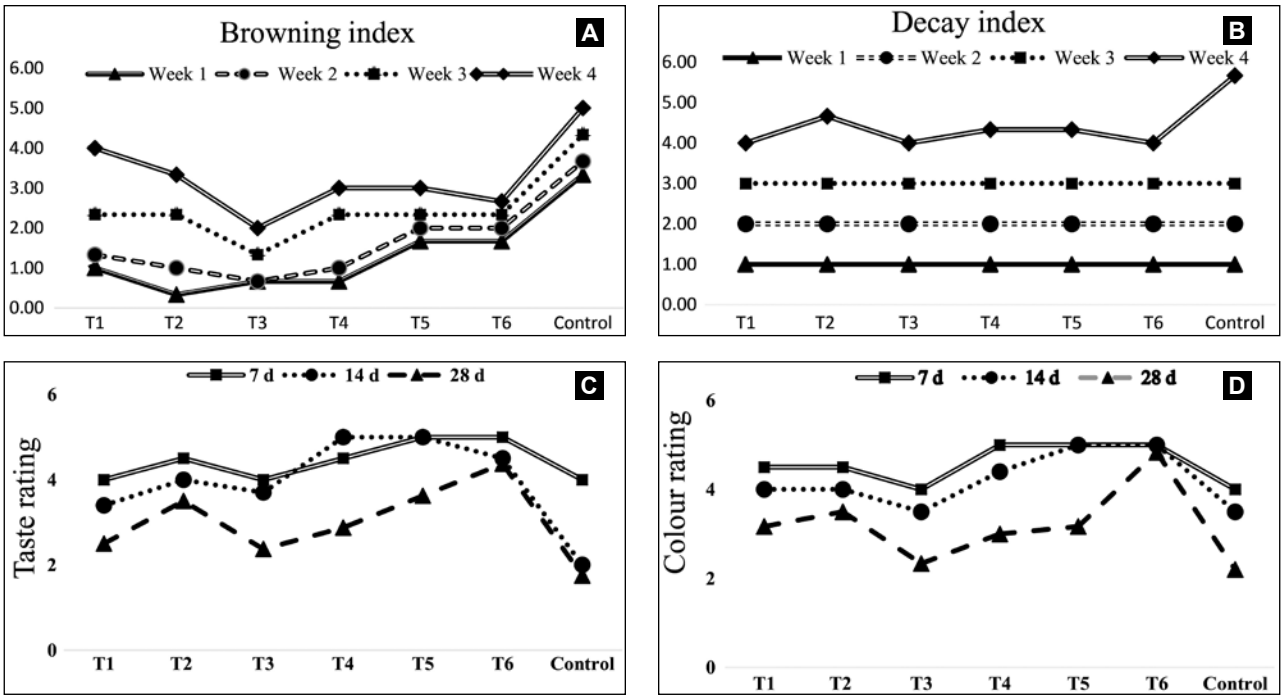

Fig. 1. Effect of different treatments on storage quality of *ber*. T_1 = pre-cooling; T_2 = HWT (55°C, 10 min.); T_3 = HWT (55°C, 10 min.) + 10% OA (15 min.); T_4= GA_3 (30 ppm); T_5= GA_3 (60 ppm); GA_3 (90 ppm); T_6 (control, without pre-cooling;) on (A) Browning index (B) decay index, (C) taste and (D) colour of fruits cv Gola.

for the development of most fungi, as confirmed by Saegnil *et al*. (14) in litchi.

Data presented in Table 2 show the effect of various treatments in influencing the marketable value of Gola *ber*. Highest and significant effect (80.85%) on marketability percentage of fruits was recorded in higher concentration of GA_3 (90 ppm), which was at par (80.27) with GA_3 (60 ppm) treated fruits. Interpretation of the data clearly indicate the role of the combined effects of HWT and OA in reducing browning but due to high shrinkage percentage the marketability of fruit reduced considerably. Significantly, poor marketable

Table 2. Effect of various treatments on fruit shrinkage (%) and marketability (%) of *ber* fruits during cold storage.

Treatment	Shrinkage (%)						Marketability (%)					
	Storage period (day)						Storage period (day)					
	0	7	14	21	28	Mean	0	7	14	21	28	Mean
T1	0.00	17.33	24.67	31.67	40.00	22.73	100	90.89	86.78	74.44	57.50	77.40
T2	0.00	19.67	28.00	31.67	40.00	23.87	100	91.78	86.00	76.11	63.75	79.41
T3	0.00	59.67	67.00	71.67	76.67	55.00	100	78.44	74.33	66.11	55.83	68.68
T4	0.00	21.67	29.00	35.00	36.67	24.47	100	91.11	87.00	73.33	62.33	78.44
T5	0.00	10.00	15.00	20.00	23.33	13.67	100	92.00	83.33	78.33	67.42	80.27
T6	0.00	11.00	16.67	26.67	36.67	18.20	100	91.67	82.78	75.11	73.83	80.85
Control	0.00	44.67	59.67	68.33	73.33	49.20	100	73.44	57.44	43.89	29.67	51.11
Mean	0.00	26.29	34.29	40.71	46.67		100	87.05	79.67	69.62	58.62	
CD at 5%												
Treatment (A)					4.03							
Storage period (B)					3.41							
A × B					9.01							

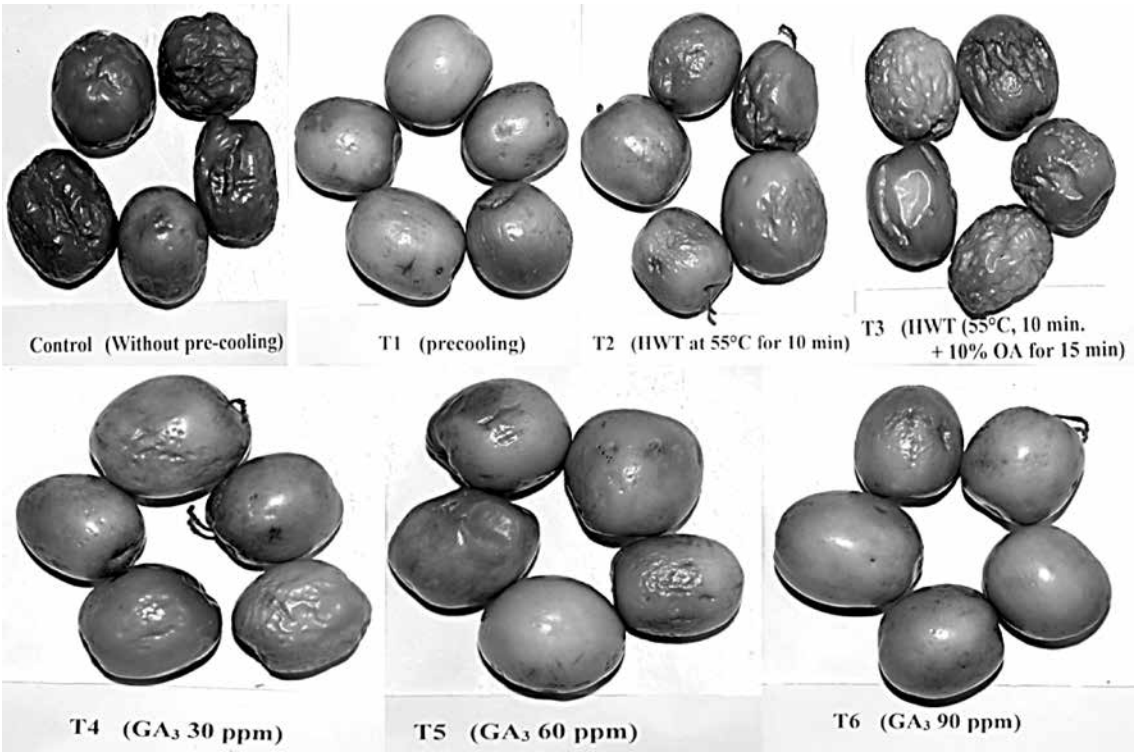

Fig. 2. Effect of different treatments on storage quality of *ber* cv Gola. T_1 = pre-cooling; T_2 = HWT (55°C, 10 min.); T_3 = HWT (55°C, 10 min.) + 10% OA (15 min.); T_4= GA_3 (30 ppm); T_5= GA_3 (60 ppm); GA_3 (90 ppm); T_6 (control, without pre-cooling;) on (A), Browning index (B) decay index, (C) taste and (D) colour of fruits.

fruits (51.11%) were recorded in control followed by HWT at 55°C for 10 min. + 10% OA (68.68%) due to combined effects of extensive shrinkage, browning, spoilage and palatability ratings. Plant growth regulator improves the shelf-life, keeping quality and marketability of fruits for a longer period (Pareek *et al*., 12).

Fruit palatability rating declined during the entire storage period. As illustrated in Fig. 1 (C and D), pronounced effects of the applied treatments on the organoleptic parameters of fruit was observed. Among the treatments, GA_3 (90 ppm) was superior in retaining fruit colour and improving taste of *ber* fruit to after 28 days storage period. The maximum colour (4.8) and taste (4.4) rating were recorded in GA_3 (90 ppm) treated fruits followed by HWT (55°C, 10 min.) + 10% OA (15 min.) in term of fruit colour retention (3.5) and GA_3 (60 ppm) treated fruits in case of fruit taste (3.6). The minimum ratings for colour (1.8) and taste (2.2) at the last day of storage were observed in control fruits. Similar results were also reported by Chahal and Bal (2) in *ber* fruits after 30 days of cold storage. This could be attributed to the low rates of respiration and transpiration in fruits as well as due to the role of the applied treatment maintenance of higher TSS and acidity content of fruits, as reported earlier by many workers (Saegnil *et al*., 14; Marboh *et al*., 9; Jawandha *et al*., 7).

From the study, it could be concluded that ber fruits treated with GA_3 (90 ppm) and stored at low temperature (5±1°C and 85 ± 5% RH) was the most effective treatment. This treatment also gives maximum retention of physico-chemical parameters of *ber* cv. Gola fruit. The fruit remained in acceptable condition up to 21 days of cold storage under this treatment (Fig. 2). After this period the due to higher enzyme activity degradation/senescence process started in fruits that ultimately deteriorated their quality.

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Effect of Chitosan on biochemical and microbial quality of minimally processed mango (*Mangifera indica* L.) cubes during storage

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ABSTRACT

Fresh-cut mango cubes of cv. Mallika coated with acidified chitosan solutions at concentrations of 1, 2 and 3% along with untreated cubes as control were placed into plastic trays, over-wrapped with cling film (10µ thickness) and stored in refrigerator at 8±2°C for 8 days. Analytical determinations were made after 2, 4, 6 and 8 days. Chitosin coating, especially 2 and 3% was effective in inhibiting loss of weight, total carotenoids and total phenols content. Chitosin 3% coating was highly effective in inhibiting growth of bacteria and yeast/mould on the cubes. At the end of the storage minimum weight loss (2.46%) was observed in 3% chitosan treated cubes and higher weight loss (4.51%) found in control. Higher total phenols (41.79 mg TAE/100 g) were estimated in 2% chitosan treated samples while maximum total carotenoids content (5.35 mg/100 g) were observed with 3% chitosan treatment. Maximum total soluble solids (25.65°Brix) were observed in control. Minimum bacterial load (2.04 log CFU/g) and yeast/mould load (1.78 log CFU /g) was observed with 3% chitosan treatment while maximum bacterial load (3.02 log CFU/ g) and yeast/mould count (3.92 log CFU/g) was found in control. Overall results suggests that chitosan (3%) coating on the mango cubes effectively reduced weight loss, prevented biochemical changes and inhibited microbial growth.

Key words: Edible coatings, mango cubes, microbial growth, biochemical changes.

INTRODUCTION

Minimally processed fruits are one of the major growing segments in food retail markets. However, the major hurdle to commercial marketing of these commodities is limited shelf-life due to excessive tissue softening and microbial growth. Edible coatings are known to improve the quality and prolong the shelf-life of fresh-cut fruits and vegetables. They act as barriers to water loss and gas exchange by developing a micro-modified atmosphere over the surface of the product (Baldwin *et al*., 1). Edible coatings were applied as a thin layer of protective material to the surface of the fruits. Fresh cut fruits are directly dipped into the coating formulations, drained and dried, whereby a thin membranous film is formed over the commodity surface (Tharanathan, 13). Chitosan is a natural polymer, nontoxic and biodegradable, derived by deacetylation of chitin [poly-b-(1 fi 4)-N-acetyl-d-glucosamine]. It has been documented to possess a film-forming property for use as edible films or coating. Chitosan has attracted attention as a potential food preservative of natural origin due to its antimicrobial activity against fungi, yeast and bacteria (Sagoo *et al*., 11) and can improve the storability of perishable foods by modifying the internal atmosphere as well as decreasing the transpiration losses (Zhang and Quantick, 16).

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Numerous studies have been conducted to assess the effect of chitosan coatings on sensory quality and shelf life of fruits such as strawberry (Hermandz-Munoz *et al*., 5), litchi (Zhang and Quantick, 16), pomegranate (Zahran *et al*., 15) and mango (Wang *et al*., 14) but they were applied chitosan coating to whole fruit. Very few studies, were conducted on chitosan coating on minimally processed 'ready to eat' fresh cut fruits (Chien *et al*. 2; Zhelyazkov *et al*. 18). Hence, the present investigation was undertaken to study the effect of chitosan coating on changes in biochemical and microbial quality parameters in minimally processed fresh cut mango cubes under low temperature storage.

MATERIALS AND METHODS

Healthy mature fruits of cv. Mallika were obtained in month of July 2016 from the experimental orchard of the ICAR-Central Institute for Subtropical Horticulture, Lucknow in July 2016. Fruits were washed in tap water and sanitized for 5 min in chlorinated water (200 ppm sodium hypochlorite) and air dried. Fruits were treated with ethylene for ripening. The semi ripe fruits were selected and peeled manually with a stainless steel knife. Fruit cheeks were cut from both sides of the seed and cut into cubes of (4 × 2 × 1 cm^2) size. Chitosan flakes

purchased from Central Drug House (P) Ltd, New Delhi, India (deacetylated chitin; 95%; molecular weight 760 kDa) was ground to a fine powder by extensive grinding in a mortar, washed 3 times in distilled water (20 ml of water per g of chitosan), pelleted by low-speed centrifugation and air-dried at room temperature. The purified chitosan was used for preparation of 1, 2 and 3% solution by dissolving in 0.5% (v/v) glacial acetic acid under continuous stirring, and the pH was adjusted to 5.6 using 1 N NaOH. Fresh-cut mango cubes of cultivar "Mallika" were divided in 4 lots and dipped in acidified chitosan solutions for 2 minutes, air dried and were placed into plastic trays, over-wrapped with cling film (10 microns thickness) and stored in refrigerator at 8±2°C for 8 days.

Weight loss (%) was determined by measuring the difference between initial and final weight of each replicate and results were expressed as a percentage loss of initial weight. Firmness was measured using a 'McCormick fruit tester FT 327' penetrometer and expressed in Newton. Total Soluble Solids (TSS) were measured by using hand refractometer (Erma, Japan), while titratable acidity by titrimetric methods using 0.1N NaOH. Total carotenoids was extracted (by repeated extraction) with petroleum ether and acetone (3:2 v/v, 60-80°C) according to the method of Ranganna (8). The total phenols content was expressed in mg of tannic acid equivalents (TAE)/ 100 g of extract by following Folin-Ciocalteau method. Microbiological analysis was carried out as per method of Speck (12). Mango cubes were dipped in equal weight of sterile distilled water and shook well for 2 min. The surface microbial wash was diluted appropriately and pours plated on Nutrient Agar and Rose Bengal Chloramphenicol Agar for getting counts of bacteria and yeast & moulds, respectively. The plates were incubated at 35±2°C for 72 hr. The data obtained were subjected to statistical analysis by using 'Statistical Software Package for Agricultural Research Workers' software at 5% significance level.

RESULTS AND DISCUSSION

The results indicated that the chitosan coating could retard the weight loss of fresh-cut mango (Fig. 1A). During storage period, the weight loss percentage of uncoated and chitosan 1% treated mango cubes was significantly greater than that of 2 and 3% chitosan coated mango cubes ($p \leq 0.05$). However, there was no significant difference in weight loss between the cubes treated with 2 and 3% chitosan ($p > 0.05$). At the end of storage period, the uncoated sample had 4.51±0.063% loss in weight, whereas the weight loss of samples coated with 1, 2 and 3% chitosan was 3.82±0.047%, 2.57±0.043% and 2.46±0.115%, respectively. The results obtained were in accordance with previous studies in which chitosan was observed to be more effective for reducing weight loss in fresh cut minimally processed apple (Zhelyazkov *et al*., 18) and papaya (Chien *et al*. 2). The firmness is the important quality attribute related to metabolic changes and water content. It influences appearance and consumer acceptability of fresh cut fruits. The firmness of fresh cut cubes decreased with increasing storage time irrespective of treatment (Fig. 1B). Samples coated with the chitosin coating displayed a slower rate of decline in firmness than the uncoated samples. However, during first four days of storage no significant difference ($p > 0.05$) was found between the treatments. After end of the storage period of 8 days 3% chitosin coated cubes displayed ~57% higher firmness than control followed by chitosin 2% (~45%) and chitosin 1% (~29%). Chitosan coating seemed to delay firmness loss during storage because it act as a barrier to water transfer, delaying dehydration, retarding the metabolic and enzyme activities and, therefore, extending the firmness of the coated samples. These findings are in agreement with results of Zhelyazkov *et al*. (18) in apple and Hermandz-Munoz *et al*. (5) in strawberry.

Results depicted in Fig. 2A showed that total carotenoids content dropped as storage period progressed. However, it also shows that chitosan

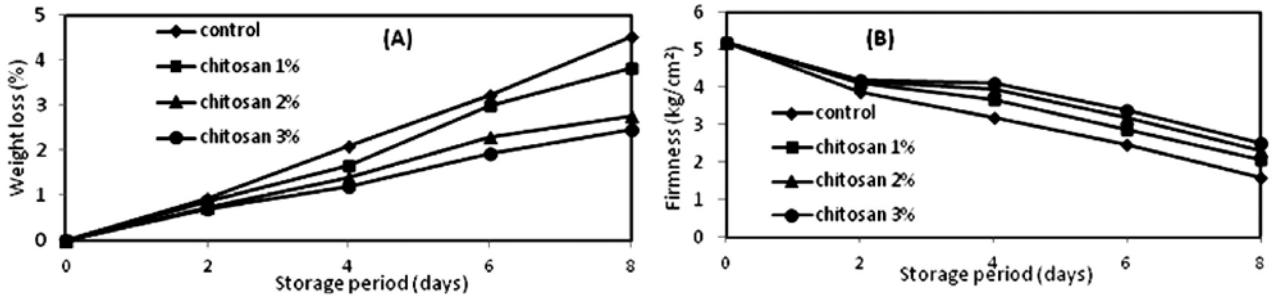

Fig. 1. Effect of chitosan coating on (A) weight loss (%) and firmness (kg/cm^2) in minimally processed fresh cut mango cubes during storage at 8±2°C for 8 days.

played a positive role in controlling degradation and maintaining of total carotenoids in fresh cut mango cubes. During first 2 days of storage, statistically significant difference was not observed among all investigated treatments and carotenoids content ranged from 5.8±0.20 to 6.14±0.11 mg/g. However, after 4 days of storage statistically significant difference was detected between coated and uncoated samples. The chitosan coating was effective in retaining total carotenoids during 8 days storage, as compared to control which exhibited ~44% higher decline (from 5.8±0.20 to 3.24±0.12 mg/100 g). At the end of the storage, the lowest degradation (~13%) of total carotenoids was observed in 3% chitosan coated cubes, from 6.14±0.11 to 5.35±0.09 mg/100 g. Robles-Sanchez *et al*. (9) reported reduction of carotenoids from 4.5 to 3 mg/100 g in fresh-cut 'Ataulfo' mango stored at 5°C for 10 days. Fresh-cut mango cubes stored at 5°C for 9 days showed 25% reduction in total carotenoids (Gil *et al*., 3). The observations illustrated in (Fig. 2B) revealed a declining trend in total phenol content during storage in both coated and control cubes, the decline being more pronounced (57.20%) in case of control (water dipped) cubes. At the end of the storage period of 8 days, chitosin coating 2 and 3% were able to retain significantly higher total phenol content (63.72% and 58.38%, respectively) as compare to control (42.79%). At the end of storage period total phenol content in cubes coated with 0, 1, 2 and 3% chitosan was 21.46±2.37, 24.35±1.61, 29.28±2.19 and 31.96±3.70 mg TAE/100 g, respectively. These results are compatible with the findings of Rodrigues *et al*., (10) in mango and Hermandz-Munoz *et al*. (5) in strawberry, who have also reported higher amount of total phenols in chitosan coated samples. Higher amount of phenols in coated samples may be attributed to the inhibition of polyphenol oxidase activity, an enzyme that is involved in the process of phenolic compound degradation (Jiang and Li, 6).

Changes in the total soluble solids of fresh-cut mango over the storage period are shown in Table 1. The total soluble solids of fruit increased with increasing storage time. After 8 days of storage, the total soluble solids content of uncoated and chitosan-coated samples were significantly different ($p>0.05$). However, the amount of total soluble solids was not significantly different between the fruits treated with 2 and 3% chitosan. Uncoated fresh-cut mango cubes contained higher total soluble solids than chitosan-coated cubes. A plausible explanation for the observed increment in total soluble solids is the considerable loss of water from uncoated cubes during storage. Similar results were obtained with

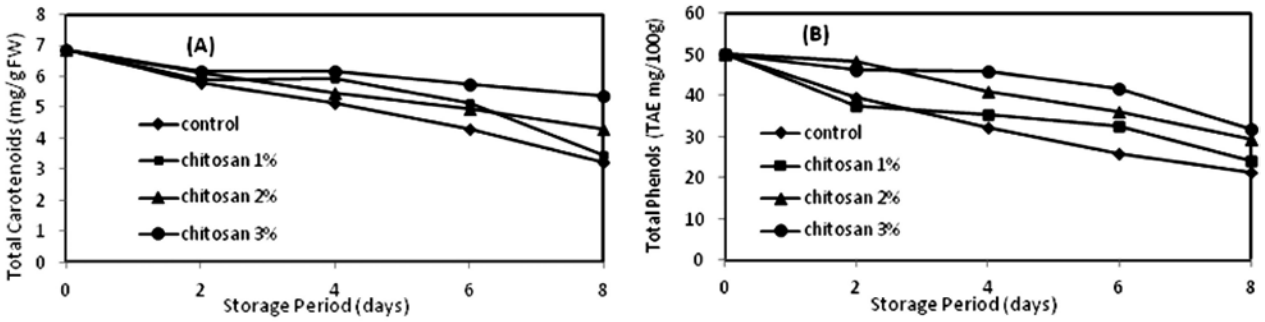

Fig. 2. Effect of chitosan coating on (A) Total carotenoids (mg/g FW) and (B) Total phenols (mg/100 g FW) in minimally processed fresh cut mango cubes during storage at 8±2°C for 8 days.

Table 1. Effect of application of chitosan coating on total soluble solids (TSS) in minimally processed fresh cut mango cubes during storage at 8±2°C for 8 days.

Treatment	Change in TSS during storage				
	Storage period (days)				
	0	2	4	6	8
Control	17.21	21.00 ± 0.24[a]	21.83 ± 0.24[a]	23.94 ± 0.22[a]	25.65 ± 0.15
Chitosan 1%	17.30	20.32 ± 0.17[b]	21.56 ± 0.27[a]	23.70 ± 0.31[a]	24.50 ± 0.12
Chitosan 2%	17.25	19.35 ± 0.11[c]	20.73 ± 0.32[b]	22.75 ± 0.32[b]	23.70 ± 0.20
Chitosan 3%	17.28	18.55 ± 0.14[d]	20.80 ± 0.17[b]	22.52 ± 0.10[b]	23.50 ± 0.21
CD at 5%	NS	0.55	0.17	0.81	0.55

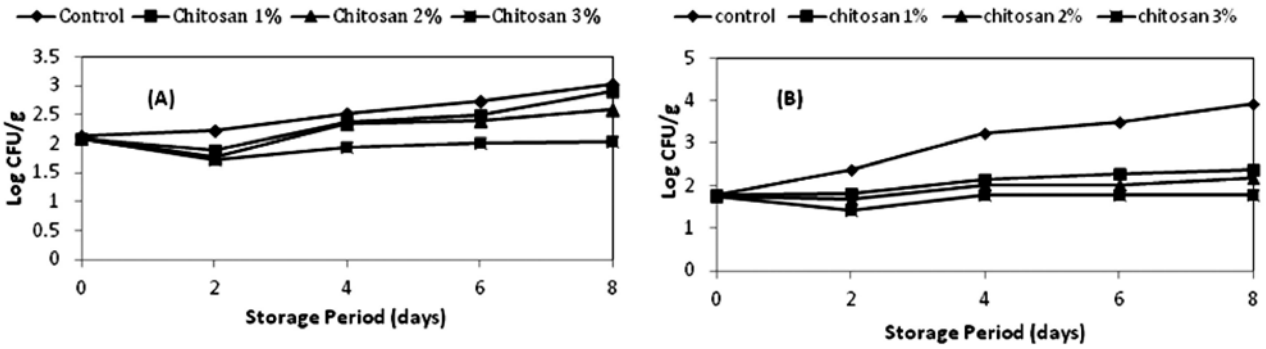

Fig. 3. Effect of chitosan coating on (A) bacterial load (Log CFu//) and (B) yeast/mould load (Log CFU/g) in minimally processed fresh cut mango cubes during storage at 8±2°C for 8 days.

1.5% chitosan coating in strawberry (Hermandz-Munoz *et al*., 5) and 0.8% chitosan coating in whole mango fruits (Wang *et al*., 14). It was found that the total acidity of uncoated and chitosan-coated samples was not significantly different ($p>0.05$). After 8 days of storage, the total acidity of uncoated mango cubes was 0.40±0.02% and 1, 2 and 3% chitosan coated samples were 0.46±0.02, 0.44±0.01 and 0.45±0.02%, respectively. The results obtained in this study indicated that coating with chitosan did not affect the total acidity of samples during storage.

It was observed that Chitosan coating inhibited the growth of microorganism. Initially, during 2 days the microbial load reduced in all chitosin coated samples (Fig. 3A). After 2 days, gradually it starts increasing. Minimum bacterial load (2.04 log CFU/g) and yeast/mould load (1.78 log CFU/g) was observed with 3% chitosan treated cubes while maximum bacterial load (3.02 log CFU/g) and yeast/mould count (3.92 log CFU/g) was found in control at the end of storage (Fig. 3B). The antimicrobial activity of chitosan has been attributed to the interaction between positively-charged chitosan molecules and negatively-charged microbial surfaces results in the disruption of cell membranes, leakage of intracellular constituents, and ultimately, microbial cell death (Kong *et al*., 7). Additionally, according to a second hypothesis, chitosan oligomers can penetrate into prokaryotic cells and interfere with the transcription of RNA and protein synthesis (Hafdani and Sadeghinia, 4). Another mechanism which makes chitosan effective is lower pH due to acetic acid. Our results indicated that anti microbial property of chitosan flim depended upon the concentration of chitosan. Higher anti microbial activity was observed in treatment 3% chitosan film consistent with previously published study (Zhang *et al*., 17) in apple. It can be concluded from the present study that dip treatment with chitosin (2 and 3%) was effective in reducing PLW, prolong firmness, slow degradation of total carotenoids and total phenols and inhibit growth of microbes which help in improving shelf-life of minimally processed mango cubes during storage at 8±2 °C for 8 days.

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Short communication

Characterization of *Vasconcellea cauliflora* for morpho-horticultural traits under climatic conditions of Pune, India

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ABSTRACT

***Vasconcellea cauliflora* is one of the few species in the family Caricaceae that have shown resistance against *Papaya ringspot virus* strain papaya (PRSV-P) which is a global limiting factor in papaya (*Carica papaya* L.) cultivation. *V. cauliflora* has a potential role in introgression of gene(s) of PRSV-P resistance in *C. papaya*. It was introduced in India for academic and research purposes. Therefore, very little information is available about its morpho-horticultural traits under Indian climate and its reaction against local isolates of PRSV-P. *V. cauliflora* plantation maintained at ICAR-Indian Agricultural Research Institute, Regional Station, Pune since 2011 provided valuable information on morpho-horticultural traits under climatic conditions of Pune and its reaction against local isolate of PRSV-P. Plants gained a height of 0.89 m and collar diameter of 6.94 cm in one season which increased in subsequent years. Yellowish white and waxy female flowers were 3.9 cm long. Pollen viability was 86%. Average fruit yield was 4.3 kg/plant in the first year, which increased to 8.4 kg/plant in the third year. Berry type fruits were long, round or intermediate in shape with smooth skin texture. The average fruit length and width was 6.8 cm and 3.7 cm, respectively. Ridges and grooves were prominent in long fruit shape as compared to intermediate and round ones. Seedlings showed resistance against PRSV-P under field conditions and when infected by challenge inoculation in glasshouse. The plants remained disease-free even when exposed to severe disease pressure under field conditions for more than three years. There is a renewed interest in *V. cauliflora* as a source of gene(s) for resistance against PRSV-P infection, especially after overcoming the crossing barrier with *C. papaya* in India.**

Key words: *Carica papaya*, traits, PRSV resistance, wild species, crossing barrier.

Papaya (*Carica papaya* L.) is a popular fruit crop cultivated mainly in Asia, Latin America and Africa. India produced two-thirds of world's papaya from one-fourth of the global area. *Papaya ringspot virus* strain Papaya (PRSV-P) infection is a global limitation for papaya cultivation. PRSV-P infection causes major yield losses and severely affects fruit quality. There are no prophylactic or therapeutic control measures to combat the disease. Since there is no source of PRSV-P resistance in the genus *Carica,* resistant varieties could not be developed by conventional breeding approach (Sharma and Tripathi, 11). However, some related plants, e.g., highland/mountain papaya (*Vasconcellea species*), exhibit varying degrees of PRSV-P resistance. The genus *Vasconcellea* is a group of 'wild type' papaya comprising 20 species and one hybrid. Earlier, all species of the genus *Vasconcellea* were classified in the genus *Carica.* Later on, based on molecular taxonomical revelation, all these species were rehabilitated in a separate genus, *Vasconcellea* (Aradhya *et al*., 1; Badillo 2; Badillo, 3). *V. cauliflora* is an important species as it is one of the few *Vasconcellea* species that shows resistance against PRSV-P. Although *V. cauliflora* is found in wild in Central America, it is maintained by various research organizations in different parts of the world for their academic and research interests.

One such plantation is maintained at ICAR-Indian Agricultural Research Institute (IARI), Regional Station (RS), Pune, India for academic and research purposes. Some morphological characters of the species were expected to be affected by the climate of Pune which is situated 560 metres above sea level on the Deccan plateau, while mountain/highland papaya thrives well at higher altitudes. Although *V. cauliflora* plants were earlier raised in India, few reports described their morphological characters and reaction to local isolate of PRSV-P (Jayavalli *et al*., 9). Such information is of crucial importance because of cross- incompatibility issue between *V. cauliflora* and *C. papaya*, and conflicting reports of *V. cauliflora* resistance against different strains of PRSV-P (Conover, 6; Sharma *et al*., 10). Considering their importance in the breeding programme, a study was undertaken to record morpho-horticultural traits contributing towards growth and yield of *V. cauliflora* under local climate and its reaction to the Pune isolate of PRSV-P.

V. cauliflora seeds were procured from ICAR-Indian Institute of Horticultural Research, Bengaluru,

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India in 2010. Since then, its subsequent generations were raised by sib mating among selected plants. A subset of morphological traits based on list of papaya descriptor of International Board for Plant Genetic Resources was recorded on one year old plants. Morphological traits associated with the plant growth, flowering and fruit yield were recorded. Height of the plant was measured from ground level to the top apical bud. Stem girth was measured from 15 cm above the ground level. First fruiting height and length of the fruiting column were measured from the ground level. Morphological characters of flowers were recorded. The fruit yield (kg per tree) was calculated by weighing all ripen fruits produced from a plant. Morphological characters of fruits and seed were recorded from ripen fruits. The traits were recorded up to three years, the average life of *V. cauliflora* under Pune climate. Each set of data is an average value of 25 plants.

Reaction of *V. cauliflora* to Pune isolate of PRSV-P was recorded at seedling stage. A set of ten plants with three replications, with susceptible *C. papaya* as the control, were challenge inoculated by sap inoculation (mechanical) method in a glasshouse. One gram of infected leaves was ground in a pre-chilled mortar and pestle using 10 ml of 0.1 M chilled sodium phosphate buffer (pH 7.2) containing β-mercaptoethanol and 0.01 M EDTA. The sap was rub-inoculated using the pestle on the young leaves of seedlings at three-leaf stage. Excess sap was washed off by distilled water after five minutes. The disease incidence was recorded from six to eight weeks after inoculation. Another set of *V. cauliflora* plants were exposed to severe disease pressure when planted in field surrounded with severely infected *C. papaya*. The presence/absence of PRSV-P in inoculated seedlings and plants exposed to field conditions was confirmed by Enzyme Linked Immunosorbent Assay (ELISA, Clark and Adams, 4) using PRSV specific antibody (Agdia Inc., USA).

Plants showed a shrub or tree like growing habit. Plant height of one year old *V. cauliflora* was 0.89 m which went up to 2.31 m in the third year. Collar diameter rose from 6.9 cm in the first year to 22.2 cm in the third year. 'Fruiting height' and 'fruiting column length' increased with the age of the plant. Fruiting height was 39 cm from the ground, while average length of the fruiting column was 36 cm in the first year. Fruit yield was 4.3, 6.2 and 8.4 kg/plant in the first, second and third year, respectively (Table 1). Many plants failed to survive after three years due to fungal root rot. Jayavalli *et al*. (9) reported similar growth data (plant height, collar diameter and first fruiting height) and negative PRSV-P reaction for one year old *V. cauliflora* plants from Tamil Nadu Agricultural University (TNAU), Coimbatore, India

Both female and male flowers were yellowish white having waxy texture. Lanceolate female flowers were pentamerous. Average length of female flowers was 3.9 cm (range: 3.5-4.4). Berry type fruits were round/long/intermediate in shape with smooth skin texture. Only one type of fruit shape was observed on a plant. Stalk-end of fruits was generally flattened or inflated, but sometimes it was pointed. The blossom end scar was small. Average fruit length and width were 6.8 cm (range: 5.25-11.50 cm) and 3.7 cm (range: 2.25-4.00 cm), respectively. The ratio between length and width was 1.8. Various fruit shapes are depicted in Fig. 2. Average fruit weight was 34.2 g (range: 43-73 g). Ridges on fruits were deep in long fruits and intermediate in round ones. Average number of seed per fruit was 30 (range: 22-35), weighing 1.02 g (range: 0.83-1.17 g). Test weight of seed was 3.3 g. Brown colour seeds were spherical with opaque surface. Seed surface was glossy due to high mucilage (Fig. 1, Table 2).

Average number of pollens per view was seven with average size of 3.1 µ. Out of which 86% pollens were viable. Pollen germination was 27% after four hours. The pollen tube growth was 20, 60 and 91 µ after four, eight and twelve hours (Table 3). Although data is not readily available for Pune climate to compare the result, they conform to the findings of Cohen and Spiegel-Roy (5) for papaya pollens.

No PRSV-P symptoms were observed on *V. cauliflora* six weeks after sap inoculation of the virus whereas severe symptoms were recorded on all inoculated susceptible control (*C. papaya*). Further confirmation of PRSV-P infection was done by ELISA using specific antibody for PRSV. The

Table 1. Growth, fruiting characters and fruit yield up to first three years of plant age.

Year	Plant height (m)	Collar diameter (cm)	Fruiting height (cm)	Fruiting column Length (cm)	Fruit yield (kg/plant)
2011-12	0.89 (±0.11)	6.94 (±1.20)	39.00 (±9.62)	36.00 (±2.24)	4.3 (± 0.60)
2012-13	1.28 (±0.23)	12.92 (±6.09)	40.00 (±16.96)	64.00 (±18.17)	6.2 (± 0.99)
2013-14	2.31 (±0.02)	22.15 (±1.97)	64.00 (±11.94)	144.00 (±9.62)	8.4 (± 1.01)

Figure in parentheses are standard deviation

Table 2. Morpho-horticultural traits of one year old *V. Cauliflora*.

Parameter	Description / average value (range)
Qualitative	
Fruit shape	Berry
Fruit shape	Round to elongated
Leaf shape	Palmate
Flower shape	Mostly lanceolate
Flower colour	Yellowish white
Flower texture	Waxy
Stalk end fruit shape	Flattened or inflated, sometime pointed
Size of blossom end scar	Small
Fruit skin texture when ripe	Smooth
Ridging on fruit surface	Deep to shallow
Seed surface lustre	Glossy
Seed shape	Spherical
Seed surface type	Opaque
Seed mucilage	Intermediate
Colour of seed coat	Brown
Quantitative	
Flower length (cm)	3.9 (3.5-4.4)
Fruit length (cm)	6.8 (5.25-11.50)
Fruit width (cm)	3.7 (2.25-4.00)
Fruit weight (g)	34.2 (43-73)
No. of seeds/fruit	30 (22-35)
Dry weight of seed per fruit (g)	1.0 (0.83-1.17)
Test seed weight (g)	3.3

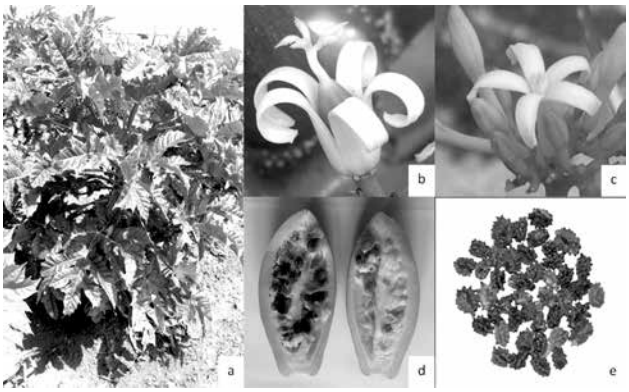

Fig. 1. A typical *Vasconcellea cauliflora* plant (a), female (b) and male (c) flowers, cut fruit (d) and seed (e).

Fig. 2. Variation in fruit shape of *V. Cauliflora* under Pune climate.

OD value at 405nm absorbance of ELISA reaction for inoculated *V. cauliflora* was 0.123 whereas the OD value for inoculated *C. papaya* plant was 1.7. ELISA value for healthy papaya plants was in the range of 0.102 to 0.111 (Table 4). This confirmed resistant status of *V. cauliflora* against Pune isolate of PRSV-P. Jayavalli *et al*. (Jayavalli *et al.*, 9) reported negative reaction of *V. cauliflora* to Coimbatore isolate of PRSV-P while analysing papaya intergeneric hybrids for morphological traits. In another report from the same place, *V. cauliflora* did not show PRSV-P symptoms 27 days after infecting them, using artificial inoculation method (Sudha *et al.*, 12) under glasshouse conditions.

V. cauliflora showed negative reaction against PRSV-P (Pune isolate) in challenge inoculation under glasshouse condition, and it remained virus-free for the entire life of three years when cultivated along with severely infected papaya plants under open field condition. This indicates that *V. cauliflora* will remain an important source of resistance genes for breeding programme. There is a renewed interest in

Table 3. Pollen characteristics of *V. cauliflora*.

Values	Pollen size (µ)	Pollen observed (No.)	Viable pollen (No.)	Pollen germinated after 4 h (No.)	Growth of pollen tube in length (µ) after			
					2 h	4 h	8 h	12 h
Mean	3.10	6.87	5.93 (86.32%)	1.60 (26.98%)	20.00	20.40	60.73	91.07
S.D.	0.54	2.53	2.60	1.06	10.11	16.23	31.95	31.21

Average of 15 field views, S.D.; standard deviation

Table 4. Confirmation of PRSV in artificially inoculated *V. cauliflora* plants by ELISA.

	Tested plants					
	V. cauliflora			*C. papaya*		
	PRSV inoculated	Buffer inoculated	Reaction	PRSV inoculated	Buffer inoculated	Reaction
ELISA value (OD 405 nm)	0.123	0.102	Negative	1.7	0.111	Positive

V. cauliflora especially after overcoming the crossing barrier with *C. papaya* by the use of 5% sucrose solution at IIHR, Bangalore (Dinesh *et al*., 7) and TNAU, Coimbatore (Jayavalli *et al.*, 8).

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Short communication

Studies on extent of polyembryony in salt tolerant mango rootstocks

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ABSTRACT

The present study was undertaken to know the extent of polyembryony in three mango rootstocks, namely Olour, Kurukkan and 13-1. Freshly harvested seeds after 10 days were sown in earthen pots (sand: soil: FYM; 1:1:1). The number of seedlings from stones of Olour, Kurukkan and 13-1 were recorded and extent of polyembryony was calculated. The extent of polyembryony was maximum in Kurukkan (74.43%) followed by 13-1 (51.85%) and Olour (33.15%). The number of seedlings per stone ranged from 1 to 5 in Olour & Kurukkan; and 1 to 4 in 13-1 rootstock. The average number of seedlings per stone was maximum in Kurukkan (2.35) followed by 13-1 (1.88) and Olour (1.51).

Key words: *Mangifera indica*, polyembryony, rootstock.

Mango (*Mangifera indica* L.) is the most popular fruit in the tropical and subtropical regions of the world and in India too. India is the largest producer of mango in the world with an annual production of 18.43 mt from an area of 2.52 mha, contributing 20.70% share in total fruit production with the productivity of 7.30 t/ha (Anonymous, 1). Mango cultivation is mainly hampered by non-availability of uniform standard rootstocks. Mango can be propagated by seeds or by grafting. For commercial purpose, grafting is the most appropriate method because it maintains the genetic purity of the propagated variety. To obtain grafted mango, it is important to use polyembryonic rootstocks since they produce a zygotic and several nucellar plantlets. The additional embryos do not always mature and their growth may be arrested at very early stage or may degenerate during seed development.

Therefore, percentage of polyembryony would be far less than its actual frequency if mature seeds are taken into account. In Horticulture, nucellar adventives polyembryony is of great importance. The nucellar embryos provide uniform seedlings of the parental type as obtained through vegetative propagation. Nucellar seedlings of mango, citrus provide better clones of orchard rootstock than cuttings. The experiment was conducted at the main orchard of the Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi during 2012-2013. Mature open-pollinated fruits were harvested from single Olour, Kurukkan and 13-1 polyembryonic mother plants maintained mango germplasm block. Stones of 13-1 and mother plant leaves were collected from Horticulture Farm of M/s Reliance Industries, Jamnagar, Gujarat. Stone of all the three polyembryonic mango genotypes were germinated in pots (sand: soil: FYM, 1:1:1). Observations on stone germination and emergence of seedlings were recorded. Stone having multiple seedlings emergence were selected and the data was analysed statistically. All the seedling arising from a single stone were tagged.

Analysis of data pooled over years clearly revealed that in Olour 75.10% stones germinated. Out of which 33.15% stones produced more than two seedlings per stone. However, 16.30% stones produced only two seedlings, 15.76% stones produced three seedlings and only 0.54% stones produced four to five seedlings. It was interesting to note that 66.84% stones produced only one seedling. The extent of polyembryony was in Olour 33.15% (Tables 1 & 2). Analysis of data pooled over years clearly revealed that in Kurukkan 81.09% stones germinated. Out of which 74.43% were polyembryonic having more than two seedlings per stone. However, 28.57% stones produced two seedlings and 33.08% produced three seedlings. Remaining, 10.52% stones produced four seedlings and 2.25% stones produced five seedlings per stone. It was interesting to note that 25.56% stones produced only one seedling. The extent of polyembryony in Kurukkan was 74.43% (Tables 1 & 2).

In 13-1 rootstock, 27% stones germinated. Out of which 51.85% stones produced more than two seedlings per stone. However, 18.51% stones produced two seedlings, while 29.62% stones produced three seedlings per stone. Remaining, 3.70% stones produced four seedlings per stone. It was interesting to note that 48.14% stones produced only one seedling. The extent of polyembryony was 51.85% in rootstock 13-1 (Tables 1 & 2). In our investigation, maximum germination was observed in Kurukkan (81.09%) followed by Olour (75.10%) and minimum in 13-1 (27%). Similar results were observed by Srivastava *et al.* (7).

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Table 1. Germination and poly-embryony percentage in mango rootstocks (pooled data).

Rootstock	No. of stones sown	No. of stones germinated	Germination (%)	Polyembryony (%)	Monoembryony (%)
Olour	245	184	75.10 (55.37)	33.15 (25.55)	66.85 (47.22)
Kurukkan	164	133	81.09 (62.81)	74.43 (51.48)	25.56 (39.17)
13-1	100	27	27.00 (42.09)	51.85 (50.17)	48.14 (38.40)
$CD_{0.05}$	-	-	(5.32)	(7.01)	(5.16)

*Value in parentheses are angular transformed values.

Table 2. Extent of mono- and poly-embryony in mango rootstocks (pooled data).

Rootstock	No. of stones having 1 seedling	No. of stones having 2 seedlings	No. of stones having 3 seedlings	No. of stones having 4 seedlings	No. of stones having 5 seedlings
Olour	123	30	29	1	1
Kurukkan	34	38	44	14	3
13-1	13	5	8	1	-

They evaluated 10 polyembryonic mango varieties and observed maximum germination Olour (75.93%) followed by Mylepalian (67.82%) and minimum in Nekkare (40.57%). Sane *et al*. (5) observed highest germination percentage in Bappakai (75.8%) followed by Vellaikulumban (73.8%) and Kurukkan (73.7%) and lowest in the Peach (35.0%). Maximum germination and polyembryony percentage were highest in Kurukkan 81.09 and 74.43%, respectively. However, minimum germination observed in 13-1 (27%) and minimum polyembryony in Olour (33.15%). In contradiction to this, Sane *et al*. (5) recorded the highest polyembryony in Olour (84.4%) followed by Moreh (75.5%). Rao and Reddy (4) reported the maximum polyembryony in Peach (338%) followed by EC 959862 (296%) and minimum in Kurukkan (138%). The average number of seedlings per stone was maximum in Kurukkan (2.35) followed by 13-1 (1.88) and minimum in Olour (1.51). Singh and Reddy (6) observed maximum number of seedling per stone in Peach and Kurukkan. Khobragade *et al.* (2) observed maximum number of seedlings per stone in Kitchner (3.66) and lowest in Nekkare (1.14). Srivastava *et al.* (7) recorded maximum number of seedlings per stone in Vellaikolamban and Moovandan (1-7) and minimum in Mylepelian (1-3). However, Ochoa *et al.* (3) observed 97 and 95%, polyembryony in Manila and Ataulfo cultivars with an average 3.4 and 3.2 embryos per seed, respectively and more than 80% seeds were recorded with 2-4 embryos per seed. If genotype has polyembryony higher than 80%, the possibility of obtaining nucellar seedlings increases, making it possible to have a uniform rootstock.

Among the three polyembryonic mango rootstocks studied, Kurukkan was found best in terms of polyembryony, germination percentage and seedlings/ stone. However, Olour was a weak polyembryonic rootstock.

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Short communication

Growth, yield and fruit quality of Kinnow mandarin as affected through foliar application of zinc and boron

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ABSTRACT

The investigation was undertaken with a view to determine the growth, yield and fruit quality of Kinnow mandarin as affected through foliar application of zinc and boron. The results revealed that combined application of 0.2 per cent boric acid + 0.5 per cent zinc sulphate at fruit set and peach size stage of fruit through foliar spray exerted significant influence on plant height, tree spread and shoot length. The maximum fruit retention (71.77 %), number of fruits plant^{-1}(486.24), fruit weight (163.23 g), fruit volume (194.79 cc), fruit diameter (7.16 cm), yield plant^{-1} (79.32 kg) and yield ha^{-1} (31.73 t) were recorded in treatment T_9 (0.2 per cent boric acid + 0.5 per cent zinc). The same treatment had markedly influenced the quality of Kinnow fruit and the maximum TSS (12.18 °Brix), TSS/acid ratio (16.66), reducing sugars (3.87%), total sugar (7.22%), ascorbic acid (25.16mg/100 g) and juice content (41.43%) were recoreded in this traetement (T_9). The lowest acidity (0.73 %) and rind thickness (2.79 mm) were also recorded in treatment T_9 (0.2 per cent boric acid + 0.5 per cent zinc). This treatment also increased the zinc (100.08 ppm) and boron (80.81 ppm) level of kinnow mandarin leaves.

Key words: Boric acid, zinc sulphate, foliar spray.

Kinnow a mandarin hybrid (*C. nobilis* Lour. × *C. deliciosa* Tenora) is one of the most important and finest varieties of mandarin grown especially in North India. It has assumed great importance among North Indian growers and a large acreage is being brought under its cultivation particularly in Punjab, Haryana, Rajasthan and Himachal Pradesh. Its pulp is used to make delicious desserts, jams and sauces and skin can be used to make cosmetics and essence. It is a well established fact that deficiency of micronutrient adversely affects the vegetative growth, fruit quality and yield of fruit. The deficiency of micronutrients causes heavy flower and fruit drop, which result in production of poor quality fruit coupled with yield losses. Deficiency of zinc and boron is widespread in citrus orchards of country. Zinc is one of the important micro-element essential for plants due to its involvement in the synthesis of tryptophan which is a precursor of indole acetic acid synthesis (Pedler *et al*., 8). It has important role in starch metabolism, and acts as co-factor for many enzymes, affects photosynthesis reaction, nucleic acid metabolism and protein biosynthesis (Alloway, 3). Similarly, boron (B) as a micronutrient is a part and parcel of the growth behavior and productivity of citrus trees. It increases pollen grain germination, pollen tube elongation, consequently fruit set percentage and finally the yield (Abd-Allah, 2). Foliar spray of micronutrients has been reported to be more effective than soil application in curing deficiencies in citrus. Keeping in view, the unfavourable physico-chemical conditions of our soils, it is very important to supply micronutrients in proper amount through foliar spray to increase citrus production. At present, little is known about the effects of combined application of B and Zn on citrus in general and mandarin in particular under Rajasthan conditions. Therefore, keeping the above factors in view the present study on growth, yield and fruit quality of Kinnow mandarin as affected through foliar application of zinc and boron was carried out at KVK, Chittorgarh, Maharana Pratap University of Agriculture and Technology, Udaipur during the year 2013-14.

Five-year old twenty seven uniform and healthy Kinnow mandarin trees grafted on rough lemon (*Citrus jambhiri* L.) root stock planted in square system at 5 m distance and grown under uniform soil conditions were selected and nine treatments comprising T_1 (control), T_2 (0.1% boric acid), T_3 (0.2% boric acid), T_4 (0.4% zinc sulphate), T_5 (0.5% zinc sulphate), T_6 (0.1% boric acid + 0.4% zinc sulphate), T_7 (0.1% boric acid + 0.5% zinc sulphate), T_8 (0.2% boric acid + 0.4% zinc sulphate), T_9 (0.2% boric acid + 0.5% zinc sulphate) applied at fruit set and peach size stage of fruit through foliar spray. These treatments were evaluated under one way analysis of variance replicated thrice with uniform cultural schedules during the experimentation. The

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vegetative parameters regarding the tree height (m), tree spread [N-S & E-W (m)] were measured at the beginning and at end of the experiment and average increase in the tree height (m), tree spread (m) were recorded. Five newly emerged flushes were tagged from each side (North, South, East and West) of experimental trees to record the shoot length. The yield attributes per cent fruit retention was calculated on the basis of initial number of fruit set and total numbers of fruits at the time of fruit maturity. Average fruit weight was calculated by weighing fruit on digital electronic balance and fruit volume was measured by water displacement method. Fruit diameter and rind thickness were measured by digital vernier caliper. The total fruit yield tree-$^{-1}$ was calculated by multiplying total number of fruits tree-$^{-1}$ with the average fruit weight and estimated yield ha^{-1} was calculated by multiplying total fruit yield per tree with number of plant ha^{-1}. All quality parameters of fruits were analyzed as per standards methods given in (A.O.A.C., 1). Juice was extracted from weighed fruits and percentage was calculated. Data were collected for leaf nutrient analysis (Zn and B) before and after treatment application. Uniform, healthy and physiologically mature leaves (50 to 70 leaves per tree) of similar age from the experimental trees were collected at random for Zn and B determination. The micronutrient (Zn) was determined by using Atomic Absorption Spectrophotometer with specific lamp. Whereas, the amount of B in the leaves were determined by the method reported by Saxena *et al.* (11). Data were analyzed as per standard statistical methodology.

Foliar application of zinc and boron significantly affected the vegetative growth parameters of kinnow mandarin (Table 1). Trees sprayed with 0.2 per cent boric acid + 0.5 per cent zinc sulphate at fruit set and peach size stage of fruit (T_9) revealed the maximum increase in tree height (3.55 m), tree spread (3.98 and 3.98 m) N-S and E-W, respectively and shoot length (102.92 cm) of Kinnow mandarin as compared to minimum in control. However, T_6, T_7, T_8 and T_9 treatment were found to be at par with respect to all the growth parameters. This might be due to the favourable influence of applied micronutrients (zinc + boron) on vegetative characteristics because of their catalytic or stimulatory effect on most of the physiological and metabolic process of plants. Zinc and boron are essential component of enzymes responsible for nitrogen and carbohydrates metabolism respectively, thereby resulting into increased uptake of nitrogen by the plant. Further, involvement of Zn in the synthesis of tryptophan which is a precursor of indole acetic acid synthesis, consequently increased tissue growth and development. Boron increases the phenolic compounds which regulate polar auxin transport. The increased auxin activity results in increased vegetative growth characters. Khan *et al*. (6) also reported a synergistic effect of B and Zn on the vegetative growth in Feutrell's Early mandarin when applied at fruit set stage.

Table 1. Effect of zinc and boron on growth and yield attributes of Kinnow mandarin.

Treatment	Tree height (m)	Tree spread (m)		Shoot length (cm)	Fruit retention (%)	No. of fruits plant^{-1}	Fruit weight (g)	Fruit vol. (cc)	Fruit dia. (cm)		Yield plant^{-1} (kg)	Yield ha^{-1} (t)
		N-S	E-W						Equatorial	Polar		
A. Absolute control v/s rest treatments:												
Control	3.46	3.90	3.86	96.35	65.83	446.00	145.53	174.64	6.25	5.33	64.92	25.97
Treatment	3.51	3.95	3.92	99.64	68.73	465.31	154.90	185.42	6.69	5.80	72.14	28.85
CD at 5%	0.04	0.05	NS	NS	NS	NS	NS	5.97	0.34	0.29	NS	3.47
B. Among treatments:												
T_2	3.49	3.92	3.87	96.75	67.61	457.71	147.50	177.00	6.34	5.55	67.48	26.99
T_3	3.53	3.94	3.91	97.05	68.18	460.96	148.83	178.59	6.44	5.57	68.64	27.45
T_4	3.49	3.92	3.90	97.43	67.00	453.59	151.37	181.64	6.56	5.65	68.68	27.47
T_5	3.51	3.95	3.91	99.26	67.13	454.47	154.13	183.93	6.62	5.90	70.12	28.05
T_6	3.51	3.96	3.92	100.45	68.92	466.58	156.33	187.58	6.71	5.78	72.99	29.20
T_7	3.53	3.97	3.93	101.11	69.27	468.95	157.73	188.75	6.78	5.83	74.00	29.60
T_8	3.52	3.98	3.96	102.20	70.02	474.03	160.14	191.08	6.91	6.08	75.94	30.37
T_9	3.55	3.98	3.98	102.92	71.77	486.24	163.23	194.79	7.16	6.10	79.32	31.73
CD at 5%	0.037	0.04	0.06	4.01	3.30	22.29	10.01	4.87	0.28	0.24	7.01	2.80

Maximum fruit retention (71.77%) and maximum number of fruits plant^{-1} (486.24) were recorded with foliar application of 0.2 per cent boric acid + 0.5 per cent zinc sulphate at fruit set and peach size stage of fruit (T_9) as compared to minimum in control (Table 1). Increase in fruit retention and fruit number might be due to reduction in the fruit drop (Data not presented). Earlier, Nijjar (7) reported that Zn is required for preventing the abscission layer formation and consequently, the reduction in pre-harvest fruit drop. Zinc and boron application reduced fruit drop and increased fruit retention which might be due to the fact that zinc play important role in biosynthesis of IAA. These finding are in conformity with those of Sajid *et al.* (10) in sweet orange.

The fruit weight and fruit volume of Kinnow differed significantly with the sprays of zinc and boron alone or in combination. The maximum fruit weight (163.23 g) and volume (194.79) were recorded when 0.2 per cent boric acid + 0.5 per cent zinc sulphate (T_9) was sprayed. It was followed by 0.2 per cent boric acid + 0.4 per cent zinc sulphate (T_8) while, the minimum were measured under control (Table 1). The increase in fruit weight and volume might be due to increased rate of cell division and cell enlargement leading to more accumulation of metabolites in the fruit (Babu and Singh, 5).

The foliar spray of zinc and boron showed better response in improving the fruit diameter, yield plant^{-1} and estimated yield ha^{-1}. The maximum increase in fruit diameter (7.16 and 6.10 cm) equatorial and polar, respectively, yield plant^{-1} (79.32 kg) and estimated yield ha^{-1} (31.73 t) were observed with T_9 (0.2 % B + 0.5% Zn) which was at par with T_8 (0.5% 0.2% B + 0.4% Zn) treatments and minimum in control (Table 1). The higher fruit diameter due to combined application of zinc and boron may be attributed to their stimulatory effect of plant metabolism. The increase in yield is obviously due to the consolidated effect of increased size and weight of fruits caused by foliar spray of zinc and boron. Moreover, increased fruit set and reduced fruit drop as a result of zinc and boron spray could give higher number of fruits and consequently the yield. The present results are in conformity with the findings of Rajkumar *et al.* (9) in guava. It is evident from the data presented in the Table 2 that different treatments had significant effect on physico-chemical characteristics of fruits. Maximum TSS (12.18 °B), minimum acidity (0.73%), highest TSS/Acid ratio (16.66), maximum reducing sugar (3.87%) and total sugar (7.22 %) were recorded with foliar application of 0.2 per cent boric acid + 0.5 per cent zinc sulphate at fruit set and peach size stage of fruit (T_9) as compared to other treatments. However, application of zinc and boron micronutrients could not bring significant variation in respect to reducing sugar content of fruit. Among treatments T_8 and T_9 were better over control and at par with each other.

The plant which received 0.2 per cent boric acid + 0.5 per cent zinc sulphate (T_9) resulted in maximum juice content (41.43%). Among the treatments maximum ascorbic acid content (25.23 mg/100 g)

Table 2. Effect of zinc and boron on physico-chemical characteristics and leaf nutrients content of kinnow.

Treatment	TSS (°Brix)	Acidity (%)	TSS/ Acid ratio	Reducing sugars (%)	Total of fruit sugars (%)	Ascorbic acid (mg/ 100 g)	Rind thickness (mm)	Juice content (%)	Leaf Zn (ppm)	Leaf B (ppm)
A. Absolute control v/s rest treatments:										
Control	10.30	0.77	13.42	3.74	6.56	20.22	3.14	32.86	16.19	27.04
Treatment	11.62	0.75	15.49	3.82	7.08	24.55	2.96	37.51	67.21	65.56
CD at 5%	0.69	NS	1.73	NS	0.25	1.34	0.15	1.38	2.22	2.63
B. Among treatments:										
T_2	11.31	0.75	15.09	3.78	6.92	23.52	3.20	33.13	22.71	67.41
T_3	11.80	0.74	16.03	3.83	7.11	24.50	2.95	34.70	27.21	78.52
T_4	11.38	0.80	14.30	3.77	6.80	23.53	3.25	35.80	64.37	35.16
T_5	11.20	0.78	14.30	3.81	7.09	24.66	2.99	37.10	77.91	39.92
T_6	11.40	0.74	15.36	3.83	7.14	24.78	2.92	38.30	70.35	69.77
T_7	11.70	0.74	15.75	3.84	7.18	25.06	2.86	38.94	81.62	73.54
T_8	12.00	0.73	16.45	3.82	7.21	25.23	2.79	40.69	93.44	79.01
T_9	12.18	0.73	16.66	3.87	7.22	25.16	2.79	41.43	100.08	80.81
CD at 5%	0.56	0.05	1.41	NS	0.21	1.09	0.12	1.13	1.81	2.15

was recorded in treatment T_8 (0.2% B + 0.4% Zn) closely followed by treatment T_9 (25.16 mg/100 g) and minimum in control (Table 2), while minimum rind thickness (2.79 mm) recorded in treatment T_8 and T_9 (2.79 mm) as compared to other treatments.

The improvement in quality of fruit might be due to the fact that micronutrients directly play an important role in plant metabolism as zinc is needed in enzymatic reaction like hexokinase, formation of carbohydrate and protein synthesis. Further, boron facilitated sugar transport through boron-sugar complex and it also increase hydrolysis of saccharides into simple sugar. The reduction in acidity might be due to accumulation of reducing and non-reducing sugars. The increase in juice percentage due to zinc and boron might have regulated the water relations in plants and augmentation of ascorbic acid percentage of kinnow fruit might have been due to higher synthesis of nucleic acid, on account of maximum availability of plant metabolism. The findings of present study are in accordance with those of Babu and Yadav (4) in khasi mandarin and Sajid *et al.,* (10) in sweet orange.

The results of the present experiment revealed that leaf nutrient status with respect to zinc and boron contents increased due to various treatments over control (Table 2). Among the different nutritional treatments, the application of 0.2 per cent boric acid + 0.5 per cent zinc sulphate (T_9) showed maximum zinc content (100.08 ppm) and boron content (80.81 ppm) of leaves whereas, minimum zinc and boron content was recorded with control. The increase of zinc and boron content with foliar spray might be due to the absorption of good amount of these elements by the leaves. Similarly, Khan *et al.* (6) reported increase in boron content in Feutrell' Early leaves with 0.5 per cent zinc spray.

Based on the above findings, it could be recommended that Kinnow plant should be foliar sprayed with 0.2 per cent boric acid + 0.5 per cent zinc sulphate at fruit set and peach size stage of fruit for better growth, sustaining higher fruit yield and quality in Kinnow mandarin under Southern Rajasthan conditions

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Short communication

Relationship between orchard soil management practices, fruit drop and economic aspects in Kinnow mandarin

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ABSTRACT

The study comprised of eight orchard floor management practices *viz*., rotavation, disc harrowing and chemical method of weed control singly and their combinations on Kinnow mandarin. Determinations were made to compare effectiveness of the management practices in terms of fruit set, fruit drop, fruit harvest, fruit weight, yield, expenditure incurred and economic aspects. The data indicated that all the growth parameters responded significantly to management practices.The results indicated superiority of mowing over conventional orchard floor management practices giving higher yield and economic returns per unit area. The maximum yield (112.39 kg/ plant) was found in T_8 (mowing of weeds) with 6.64 per cent fruit set and 612 fruits per plant. The cost of intercultural operations in this treatment came out to be Rs 1,200/- and net income Rs. 1,59,884/-.

Key words: Orchard floor management, fruit quality, yield, economic return.

Citrus is a major fruit crop in Punjab among all fruit crops, Kinnow mandarin comprises 62.4% area of total fruit crop area in the state. Generally, citrus trees particularly 'Kinnow' bear large number of flowers and fruits, all of which are unable to carry to full maturity. Besides other factors, fruit drop has been considered a major cause of low fruit yield in citrus. Fruit drop is a common phenomenon that occurs in many crop plants in response to developmental and environmental causes, leading to significant crop losses (Marcelis *et al*., 3). There are usually three periods of fruit abscission (Racsko *et al*., 5). The most of the fruit set (80-91%) was dropped during the first month after final fruit set (Saleem *et al*., 6). Only 5-7 percent of flowers develop into mature fruits. Various management options include clean cultivation, mulching, herbicide application and mowing etc. Management practices are essential to keep weeds suppressed below a critical threshold level (Skroch and Shribs, 8. Therefore, to avoid the economic loss as well as to maintain the health of the orchards it is imperative to manage excessive fruit drop by adopting integrated approach (Hogue and Neilsen, 1). The present investigation was carried out to examine the extent of different types of fruit drop in relation to soil disturbance or inter-cultivation and their economic impact on fruit yield and quality.

The present investigations were carried out at Punjab Agricultural University, Regional Research Station, Bathinda,. In the experiment, seven-year-old, uniform and disease-free trees of Kinnow mandarin raised on rough lemon rootstock were selected to study the relationship between orchard soil management practices, fruit drop and economic aspects. There were eight treatments replicated thrice, *viz.* T_1 (clean cultivation with disc harrow), T_2 (clean cultivation with rotavator), T_3 (alternative clean cultivation with disc harrow and rotavator), T_4 (alternative chemical and mechanical floor management with rotavator), T_5 (chemical floor management), T_6 (alternative chemical floor management and mowing of weeds), T_7 (alternative mechanical floor management and mowing of weeds) and T_8 (mowing of weeds).

Under clean cultivation, the orchard floor was kept free of weeds throughout the year mechanically using disc harrow and rotavator. Chemical weed management was carried out by spraying Glycel 41 SL (glyphosate) @ 1.6 l per acre as post emergence herbicide during second fortnight of March and July. Under mowing, the weeds were mowed down throughout the year whenever these attained the height of about 9 inches. Similarly, combinations of these practices were also carried out for comparison. The other cultural practices and inputs were used as per package and practices for cultivation of citrus in Punjab by PAU, Ludhiana. The number of flowers, fruit set, fruit drop (early, June and pre-harvest), final fruit harvest was calculated by tagging the braches on the all sides of experimental trees. Fruit weight of randomly selected 10 fruits from each replication was recorded and average was worked out. The yield in terms of kg/ plant was calculated by multiplying the average fruit weight and number of fruits per plant.

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The costs on the different floor management aspects were calculated on the basis of prevailing market rates, *viz*. disc harrowing @ Rs. 500/ acre/ time, cultivation with rotavator @ Rs. 600/- per acre/ time, spray of weedicide along with chemical @ Rs. 775 per acre/spray and mowing of weeds @ Rs. 300/-per acre/mowing. The cost on cleaning of tree basins depends upon the orchard floor management practices and the cost incurred on this purpose was calculated (Table 1).

Similarly, the quantum of dead wood or pruned wood also vary with the orchard floor management practices and the cost incurred on pruning and removal of dead wood was calculated as per the man day required to prune the trees under different floor management practices as listed below (Table 2).

The costs on intercultural practices, cleaning of tree basins and pruning of trees was accounted in total costs on orchard floor management practices and the expenditure incurred on the other general management practices or inputs for citrus orchards under all treatments remained constant. The MD was calculated as per the prevailing rate, *i.e.* Rs. 275/- per day for laborer employed for pruning and basin cleaning works. The fruit yield and gross income was calculated on the basis of prevailing market rate, *i.e.* Rs. 14.0 per kg of fruit.

The data in Table 3 clearly indicates that maximum number of flowers (262.33) was observed in treatment T_6 (alternative chemical floor management and mowing of weeds) and maximum fruit set per cent (6.64%) was noted in T_8 (mowing of weeds) and minimum fruit set per cent (5.87%) was noted in T_3 (alternative clean cultivation with disc harrow and rotavator). Higher fruit set may be attributed to least disturbance to orchard floor and mulching effect of mowed weeds. Maximum early fruit drop per cent (8.62%) was counted in T_5 (chemical floor management) and minimum (7.29%) in T_1 (clean cultivation with disc harrow). Lesser floral density

Table 1. Effect of different orchard-soil-management practices (man day and cost) in Kinnow cultivation.

Floor management practice	No. of basins cleaned per man day (MD)	No. of plants per acre	Man Day (MD) per acre	Cost/acre@ Rs. 275/- per Man Day (MD)
Rotavation	20	110	4.5	1237.5
Disc harrowing	16	110	4.6	1265.0
Mowing	15	110	5.1	1402.5
Chemical management	32	110	3.5	962.50

Table 2. Man day requirement for management of Kinnow mandarin orchards.

Orchard floor management practice	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
No. of plants pruned/ MD	5.25	5.60	6.70	7.50	7.50	7.70	7.50	7.80
MD required for pruning one acre	20.95	19.64	16.42	14.67	14.67	14.29	14.67	14.10

Table 3. Economic aspects of different orchard soil management practices and pruning of 'Kinnow' orchard.

Treatment	Costs on intercultural operations (Rs.)	Pruning of plants/acre		Basin cleaning /acre (4 times)		Total expenditure on OSM and pruning (Rs.)	Income/ plant (Rs.) @ Rs 14/ kg fruit	Gross income/ acre (Rs.)	Net income/ acre (Rs.)
		Man days (MD) required	Expenditure @ Rs. 275 / MD	Man days (MD) required	Expenditure @ Rs. 275/ MD				
T_1	2,000	20.95	5,762	6.875	7,563	15,325	1,290	1,41,900	1,26,575
T_2	2,100	19.64	5,402	6.524	7,176	14,678	1,328	1,46,080	1,31,402
T_3	2,200	16.42	4,515	6.189	6,808	13,523	1,275	1,40,250	1,26,727
T_4	2,750	14.67	4,033	4.469	4,916	11,699	1,453	1,59,852	1,48,153
T_5	2,975	14.67	4,033	3.953	4,348	11,356	1,480	1,62,800	1,51,444
T_6	2,150	14.29	3,929	5.385	5,924	12,003	1,488	1,63,680	1,51,677
T_7	1,500	14.67	4,033	6.876	7,564	13,097	1,540	1,69,400	1,56,303
T_8	1,200	14.10	3878	7.335	8,068	13,146	1,573	1,73,030	1,59,884

results lesser early fruit drop (EFD) under treatments involving rotavation and disc harrowing. However, maximum 'June' drop and 'pre-harvest drop of 1.07 and 3.55% was counted in T_1 (clean cultivation with disc harrow), respectively. This may be attributed to more soil disturbance leading to injury to feeder roots and higher soil surface temperature under treatments involving cultivation practices. The 'June' and 'pre-harvest fruit drop' was lowest, *i.e.* 0.50 and 2.73% in T_6 (alternative chemical floor management and mowing of weeds), respectively, due to conserved moisture and optimized soil temperature under mowed or dried weeds flora. Similarly, maximum total fruit drop percent (12.69%) was noted in T_5 and minimum (11.30%) in T_6. To elucidate the precise impact of orchard floor management practices on physical and chemical characteristics of single fruit, weight per fruit was measured.

Maximum fruit weight (190.66 g) was noted in T_1 and minimum (183.66 g) in T_7 (alternative mechanical floor management and mowing of weeds). The higher fruit weight under treatments of mowing may be due to improved soil moisture and temperature conditions compared to treatments involving soil cultivation. However, all the treatments were non-significant in terms of fruit weight. Highest fruit yield (112.39 kg/ plant) was found in T_8 followed by 110.01 in T_7, while, the yield was lowest (91.10 kg/ plant) in T_3 (alternative clean cultivation with disc harrow and rotavator. Higher yields in mowed treatment may be attributed to improved fruit size, more shoot growth and canopy spread. In this context results are consistent with Sanchez *et al*. (7). Tree growth showed a positive response to mowing than clean cultivation probably because of improved soil physical conditions and increased nutrient availability. These results are in agreement with the findings of Yao *et al.* (9) who reported that tree health and yield increased with the ground management.

Orchard growers generally prefer the use of herbicides, however; cultivation in the tree row is currently the most common management practice in fruit orchards. It provides weed control but is costly and impairs soil quality and N availability (Sanchez *et al*., 7). The obtained results for both fruit set and total fruit drop percentages confirmed those of Lin (2) on Satsuma variety. There has been increased interest in using other methods of orchard floor management to reduce the use of chemicals in fruit production (Merwin *et al*., 4).

The expenditure incurred on the floor management practices and associated cultural practices, *i.e.* intercultural operation, basin cleanliness and pruning of dead wood was taken into consideration. The Table 3 clearly depicts that the orchard soil management treatment with respect to inter-cultural operation in T_5 (chemical floor management) was most costly (Rs. 2,975/-) and minimum cost (Rs. 1,200/-) was incurred in T_8 treatment. Likewise, maximum (7.8) plants pruned per man day (MD) as there was less dead or dried branches under this treatment hence; only Rs. 3,838/- were incurred by employed 14.1 MD per acre. However, in T_1 maximum (20.95 MD) man days per pruning were required to prune trees @ 5.25 trees per MD and total of Rs.5,762/- was incurred on pruning in this treatment. Similarly, expenditure of Rs. 5,402/- was incurred on pruning of trees under T_2 treatment. For cleaning of tree basins maximum labour and cost (Rs. 7,563/-) in T_1 treatment followed by Rs.7,176/- in T_2 treatment. Minimum cost of Rs.4348/- on this aspect was incurred in T_5 followed by Rs. 4,916/- in T_4 treatment. Likewise, highest cost (Rs. 15,325/-) on orchard soil management practices was also incurred in T_1 treatment followed by Rs. 14,678/- in T_2 treatment, while, in T_6 treatment it was least (Rs. 11,356/-) followed by 11,699/- in T_4 treatment.

The results indicated superiority of mowing practice over conventional cultivation towards plant growth, yield and improvement in soil physical properties. Similarly, fruit yield were increased with higher farm returns.

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Short communication

Influence of micronutrients on growth dynamics, fruit yield and quality of Arka Neelamani grape

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ABSTRACT

An investigation was carried out at Bankura, West Bengal on 4-year-old vines of Arka Neelamani planted at 3 m × 2 m on Y-trellis with the objective to study the effect of micronutrients on growth dynamics, yield and fruit quality. There were 11 treatments *viz.*, $ZnSO_4$ at 0.1 & 0.2%; borax at 0.2 & 0.3%; $FeSO_4$ at 0.1 & 0.15%; $CuSO_4$ at 0.1 & 0.15%; $MnSO_4$ at 0.1 & 0.15% and control (water spray). The experiment was conducted following randomized block design having three replications with three vines in each replication. Results of three consecutive years of investigation revealed that micronutrients had significant role in respect of growth dynamics, fruit yield, quality improvement and maintaining the vine vigour. Among the micronutrients, borax and zinc at 0.2% concentration of each played dominant role on various aspect of growth morphogenesis, yield and fruit quality. The treatments not only gave higher fruit production in respect of yield (7.2-8.5 kg), bunch weight (233-289 g) and 10-berry weight (29.1-29.2 g) but also improved the fruit quality in respect of higher TSS/acid ratio (35.4-38.7). The treatments helped for better growth morphogenesis, which resulted in more fruiting spurs (84.1-91.4%) for the current year crop and renewal spurs (85.7-86.2%) for the next year crop. Besides, the treatments maintained the better plant vigour by producing less number of dead shoots.

Key words: Fruit quality, fruit yield, grape, growth dynamics, micronutrients.

Grape (*Vitis vinifera* L), one of the important export oriented fruit crops, commercially grown in Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and Other northern states in India. Considering its good market demand and high monetary return, attempts have been made to explore its cultivation in non-traditional areas like red and laterite zone of West Bengal where agro-climatic condition is sub-tropical. As a result of concentrated efforts for more than a decade, it was possible to produce quality grapes in some commercial cultivars (Ghosh *et al*., 6) and found Arka Neelamani cultivar performed the best (Ghosh *et al*., 5) in respect of yield and fruit quality. It is well established that successful viticulture requires specific technology which vary from region to region. Among the various agronomical manipulations for sustainable production of quality grapes, micronutrient application is considering one of the vital cultural practices in India. However, specific micronutrients and its dose is vary from place to place (Sindhu *et al.,* 10) even variety to variety in a same place (Prabu and Singaram, 9; Kumar *et al.,* 8). The growth dynamic in grape is an important physiological event which determines the fruit yield not only for the current year but also next year cropping. Considering the important role of micronutrients on vine growth, production and fruit quality, an investigation was, therefore, taken up to know its effect on grape Arka Neelamani.

The investigation was taken up on 4-year-old grape vine cv. Arka Neelamani planted at spacing of 2 m (plant to plant) × 3 m (row to row) at the Horticulture Research and Development Farm, Government of West Bengal, Taldangra, Bankura, West Bengal during the period 2010-13. Geographically, the farm is situated at 23°N latitude and 87°E longitude at an elevation of 88 m amsl. The top soil of the orchard was collected before starting of the experiment and analysed. The pH of the soil was 5.5, available N, P and K were 284.3, 40.3 and 107.7 kg/ha. The plants have been trained on Y trellis system. There were eleven treatments, *viz.*, zinc in the form of $ZnSO_4$ at 0.1%, 0.2%; boron in the form at borax, 0.2 & 0.3%; iron in the form of $FeSO_4$ at 0.1 & 0.15%; copper in the form of $CuSO_4$ at 0.1 & 0.15%; manganese in the form of $MnSO_4$ at 0.1 & 0.15% and control (water spray). The treatments were applied in the form of foliar spray three times, *i.e.* at 4 leaf stage, at fruit set stage and at 10 mm berry size stage. The pH of the spray solution was adjusted by adding required amount of lime and sticker was added in the spray solution. The experiment was conducted following the randomized block design having three replications with three plants in each replication. The plants

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were maintained under uniform cultural practices. The plants were fertilized with 40 kg of FYM, 360 g N, 360 g P_2O_5 and 240 g K_2O/ plant/ year at 3 split doses during first week of February (after pruning), first week of March (after fruit set) and first week of June (after fruit harvest). Timely plant protection measure was taken against pest and diseases as and when it was required. The vines were pruned on 30th January every year at 4 node (spur pruned). Observations were made on different parameters. Five bunches were weighed from each plant and average bunch weight was calculated and expressed in grams. The TSS was measured by hand refractometer while acidity, total sugar and ascorbic acid content of fruit were determined following standard procedures (AOAC, 1).

The results (Table 1) clearly indicated that micronutrients have significant effect on pruned shoots, kept for fruiting (fruiting spur) as well as renewality (renewal spur). Fruitfulness and renewality of spurs (growth dynamic) is directly related to fruit production in the current and subsequent year. It was revealed from the Table 1 that all micronutrient treated vines had higher fruitfulness as compared to control vines. Highest fruitfulness was noted from the vine sprayed with borax at 0.2% (91.4%) followed by borax at 0.3% (84.5%). Zinc sulphate treated plants also showed higher fruitfulness in the spur (84.1 to 82.6%). Lowest fruitfulness of spurs was observed from the control vines (35.1%). Renewability of vegetative spurs after pruning is an important physiological event in the vine that determines the productive for the next year crop. Renewality of vegetative spurs in the vine significantly varied due to micronutrients application. All the micronutrients were effective in increasing renewality of vegetative spurs at either lower or higher dose as compared to control vine. Maximum (88.7%) renewal shoots was noted from the vine spayed with $MnSO_4$ at 0.1% closely followed by the vine with $FeSO_4$ at 0.1% (88.2%). The control plant showed 75.1% renewality (Table 1).

Mortality of fruiting spurs or arms after pruning is a common phenomenon in all the grape growing areas in the country and several factors are responsible for such mortality and anthracnose disease is considered to be important ones (Chadha and Shikhamany, 2). It was observed that the vines sprayed with borax at 0.2% had the lowest spur mortality (3.2%) followed by $ZnSO_4$ at 0.2% (3.5%). Highest spur mortality was noted from the control plants (17.20%). Total shoot mortality was also highest in control vines (10.8%) and lowest in $ZnSO_4$ at 0.2% treated vines (4.8%) followed by borax at 0.2% (5.2%) (Table 1). This observation clearly indicated that micronutrients are helpful in maintaining the plant health by giving less number of dead shoots. Less mortality in micro-nutrient applied vines may be due to the fact that micronutrients impart resistance / tolerance against diseases and pests by improving their own defense system (Edward Raja, 4; Kausadikar and Ismail, 7). Diameter of fruiting shoot did not vary significantly due to different micronutrient treatments (Table 1).

Table 1. Effect of micronutrients on growth dynamics and fruit yield of grape cv. Arka Neelamani.

Treatment	*Fruit-fullness of spur (%)	*Renewality of spur (%)	*Mortality of fruiting spur (%)	*Total shoot mortality (%)	*Diameter of fruiting shoot (cm)	Fruit yield (kg/ vine (1st yr)	Fruit yield (kg/vine (2nd yr)	Fruit yield (kg/vine) (3rd yr)	Fruit yield (kg/ vine) (pooled)
$ZnSO_4$ - 0.1%	82.6	85.9	8.6	8.6	4.5	4.2	6.9	6.7	5.9
$ZnSO_4$ - 0.2%	84.1	86.2	3.5	4.8	4.1	4.9	7.0	7.2	6.4
Borax - 0.2%	91.4	85.7	3.2	5.2	4.3	5.6	8.7	8.5	7.6
Borax - 0.3%	84.5	84.5	5.0	5.5	4.3	5.1	7.9	7.5	6.8
$FeSO_4$ - 0.1%	69.4	88.2	8.8	8.2	4.3	3.6	5.9	6.0	5.2
$FeSO_4$ - 0.15%	67.4	85.0	8.0	8.0	4.2	4.5	6.0	6.2	5.6
$CuSO_4$ - 0.1%	78.6	85.7	9.2	5.7	4.2	4.3	6.5	6.7	5.8
$CuSO_4$- 0.15%	80.3	86.9	9.5	6.5	4.4	4.4	6.2	6.4	5.7
$MnSO_4$ - 0.1%	41.7	88.7	11.6	6.2	4.3	1.8	2.9	5.0	3.2
$MnSO_4$ - 0.15%	60.3	84.6	12.8	6.6	4.5	2.4	3.8	5.5	3.9
Control (Water spray)	35.1	75.1	17.2	10.8	4.1	1.2	2.3	3.5	2.3
CD (P = 0.5)	2.2	5.0	1.3	2.80	N.S.	0.94	1.03	1.04	1.01

*Av. of last two years

Table 2. Effect of micronutrients on bunch weight, 10-berry weight and fruit quality of grape cv. Arka Neelamani.

Treatment	Bunch wt. (g)	10-berry wt. (g)	Juice (%)	TSS (°Brix)	Acidity (%)	TSS: acid ratio	Total sugars (%)	Ascorbic acid (mg/100 ml)
$ZnSO_4$ - 0.1%	224	28.9	72.2	17.5	0.52	33.7	13.0	2.9
$ZnSO_4$ - 0.2%	233	29.1	73.4	18.2	0.47	38.7	13.2	3.6
Borax - 0.2%	289	29.2	73.5	17.7	0.50	35.4	13.1	3.2
Borax - 0.3%	266	28.0	73.0	17.2	0.52	33.1	13.8	3.3
$FeSO_4$ - 0.1%	262	32.6	75.8	18.0	0.54	33.3	12.9	3.2
$FeSO_4$ - 0.15%	245	32.5	75.5	18.3	0.52	35.2	13.0	3.1
$CuSO_4$ - 0.1%	265	28.8	73.9	16.7	0.53	31.5	12.1	3.7
$CuSO_4$ - 0.15%	230	28.5	74.5	16.0	0.53	30.2	12.3	3.4
$MnSO_4$ - 0.1%	210	30.1	75.5	15.5	0.55	28.2	12.0	3.4
$MnSO_4$ - 0.15%	211	28.5	75.0	16.0	0.56	28.6	13.0	3.8
Control (Water spray)	179	26.0	72.4	15.5	0.50	31.0	12.4	3.0
CD (P = 0.5)	25.5	1.7	NS	0.9	NS	2.3	NS	NS

*Av. of last two years

Results from three consecutive years of investigation revealed that micronutrients had significant role in yield increment over control (Table 1). Average highest yield was recorded from the plant sprayed with 0.2% borax (7.6 kg/vine) followed by 0.3% borax (6.8 kg/vine) and 0.2% $ZnSO_4$ (6.4 kg/vine). The result was close conformity with the findings of Prabhu and Singaram (9) who also recorded highest yield in Mucat grape with foliar application of $ZnSO_4$ + borax. Highest yield from the boron or zinc treated vines was due to more number of fruiting spurs as compared to other treatments. The control vines gave fruit yield of 2.3 kg/vine only. Yield increment due to boron (as borax) or zinc (as $ZnSO_4$) may be attributed to the fact that zinc in grape is required for normal development of leaf, shoot elongation, pollen formation, fruit set and berry development (Christensen, 3). Edward Raja (4) opined that zinc is highly immobile in soil and its deficiency is common in many fruit crops like grape, pomegranate, etc. So, it is assumed that additional zinc application may result in higher berry yield as observed during the period of investigation. Boron is essential for regular carbohydrate metabolism. It is also important for pollen germination, growth of pollen tube and normal fruit set (Chadha and Shikhamany, 2). Besides, boron is essential for formation of inflorescence primordia (Christensen, 3). It was noted that all the micro-nutrient treated vines gave higher yield as compared to control in all the years.

It was observed from the data in Table 2 that micronutrient specially boron (as borax) at 0.2% was found to be the superior as it produced highest weighable bunch (289 g) as compared to other treatments. 10-berry weight was recorded higher in all the micronutrients sprayed vines as compared to control (Table 2). Higher 10-berry weight (32.6 to 32.5 g) was measured from the vines sprayed with $FeSO_4$ (0.1 to 0.15%). Fruit quality in grapes is expressed mainly as T.S.S./acid ratio and juice content. TSS/acid ratio indicates the organoleptic taste of the fruit which appeal the consumers' acceptance. Higher TSS/acid ratio (38.7) was calculated from the vines sprayed with 0.2% $ZnSO_4$ at followed by 0.2% borax (35.4). Prabhu and Singaram (9) also observed with higher TSS/acid ratio in Muscat grape with foliar application of 0.5% $ZnSO_4$ and 0.2% borax. Higher TSS content in berry in micro-nutrients sprayed vines may be due to more intensive transformation of starch into sugar and its translocation into berry (Kumar *et al*., 8).

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Short communication

Effect of exogenous application of plant growth regulators on vine growth, yield and quality attributes in kiwifruit cv. Hayward

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ABSTRACT

Present investigation was carried out on 11-year-old vines of kiwifruit cv. Hayward trained on a T bar trellis system for two years. Four different plant growth regulators *viz*., GA_3 (25 & 50 mg l^{-1}), BA (10 & 20 mg l^{-1}), 2,4-D (10 & 25 mg l^{-1}), TRIA (10 & 20 mg l^{-1}) and a natural extract (4 g ml^{-1}) were sprayed four weeks after full bloom. All the growth regulators proved effective in improving vine growth, yield and physico-chemical characteristics of fruits as compared to control. Maximum shoot growth (157.27 & 153.49 cm) was observed with the application of 50 mg l^{-1} GA_3. Maximum leaf area (190.25 & 188.34 cm^2) was obtained with 25 mg l^{-1} of GA_3. The highest fruit retention (86.19 & 81.06%) and yield per vine (57.98 & 54.82 kg) was recorded with 10 mg l^{-1} 2,4-D. Advancement in harvest maturity was noted with 10 mg l^{-1} TRIA. Among all the treatments, application of 25 mg l^{-1} GA_3 followed by 10 mg l^{-1} 2,4-D proved to be more effective in improving fruit physical characteristics *viz*., fruit weight, fruit length & fruit diameter; and chemical characteristics *viz*., total soluble solids and total sugars.

Key words: Plant growth substances, kiwifruit, physical parameters, chemical parameters.

Kiwifruit (*Actinidia deliciosa* Chev.) has emerged as a success story in temperate fruit growing areas in India. Kiwifruit is very much acclaimed for its nutritive and medicinal values. Of few cultivars, the most common kiwifruit cv. Hayward accounts for 75 per cent of the global kiwifruit production due to its attractive green colour pulp, superior flavour and storage-life. Use of synthetic growth regulators and natural plant extract are known to influence various plant activities. Triacontanol (TRIA), a primary alcohol, is reported to cause increased uptake of water and nutrients and results in increased growth of the plants and improved CO_2 exchange (Mishra and Srivastava, 6). Gibberellic acid plays a major role in stimulating cell division and cell elongation, benzyl adenine, a cytokinin in cell division, whereas 2,4-D an auxin is known to promote size and control fruit drop. Therefore, the present study was undertaken to standardize the best growth regulators for improving vine growth, yield and quality of kiwifruit.

The investigations were carried out on 11-year-old Hayward kiwifruit vines planted at a spacing of 6 m × 5 m. Canopies of the vines were trained on T-bar system. The vines were irrigated using drip irrigation system and managed giving uniform agronomic practices. There were 10 treatments, *viz*. gibberellic acid @ 50 (T_1) and 25 mg/l (T_2); benzylaminopurine (6-BA) @ 20 (T_3) and 10 mg/ l (T_4); 2,4-D @ 25 (T_5) and 10 mg/l (T_6); triacontanol (TRIA) @ 20 (T_7) and 10 mg/l (T_8); Natural extract (auxin + cytokinin + GA_3) (T_9) and control (water spray) (T_{10}). The treatments were applied as spray 4-weeks after full bloom on a plot size of 2 plants/ treatment in three replications. Data on annual shoot extension growth were recorded during the last week of November. Leaf area was measured in July (LiCor-Model 3100). The total number of fruits retained on the tagged branches was counted at the time of harvest (Westwood, 9). Fruits were taken as mature stage when TSS was around 6.2^{0}Brix. Other parameters recorded were days from full bloom to maturity, total fruit weight, average yield per vine, fruit weight, fruit length & diameter. Fruit firmness was recorded using digital fruit pressure tester (Toshiba-India). Amongst the quality parameters TSS, titratable acidity and total sugars content were also determined as per the standard methods. The data generated were analysed randomized block design.

Annual shoot extension growth, leaf area, fruit retention and days taken to maturity of kiwifruit cv. Hayward were significantly influenced by exogenous application of plant growth regulators (Table 1). Maximum shoot length was recorded with the application of 50 mg l^{-1} GA_3 (T_1) (157.27 cm during first year and 153.49 cm during 2nd year), which was significantly superior over rest of the treatments. Lowest shoot growth was recorded in control (T_{10}). Maximum leaf area (190.25 and 188.34 cm^2) was recorded in vines, which received 25 mg $l^{-1}$$GA_3$ (T_2) in comparison to other treatments. However, lowest leaf area was observed in control (T_{10}) (170.57 and 173.62

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Table 1. Effect of exogenous application of plant growth regulators on annual shoot growth, leaf area, fruit retention and days taken to maturity in kiwifruit cv. Hayward.

Treatment	Annual shoot extension growth (cm)		Leaf area (cm^2)		Fruit retention (%)		Days taken to maturity	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	157.27	153.49	185.77	183.82	81.32	72.12	183.34	185.21
T_2	150.76	151.21	190.25	188.34	85.43	78.75	181.21	182.97
T_3	142.32	137.04	177.17	176.42	76.23	73.10	180.65	181.56
T_4	139.77	140.14	179.18	177.23	78.64	70.04	178.86	180.29
T_5	145.17	143.19	180.14	179.19	83.12	76.34	180.13	184.01
T_6	148.36	148.97	184.07	182.46	86.19	81.06	176.10	180.16
T_7	141.14	141.01	173.03	173.98	79.32	64.19	177.11	175.21
T_8	139.23	134.15	175.13	174.84	84.19	78.72	174.27	174.43
T_9	146.23	143.65	181.27	179.37	73.39	70.26	177.67	179.36
T_{10}	125.91	129.31	170.57	173.62	63.71	60.92	177.11	178.13
$CD_{0.05}$	2.41	2.23	1.41	1.39	2.01	2.21	0.57	1.21

cm^2). The promotion of growth in terms of increase in shoot length and leaf area has been attributed to increasing plasticity of the cell wall followed by hydrolysis of starch to sugars, which lowers the water potential of cell, resulting in the entry of water into the cell causing elongation.

Fruit retention was highest with 10 mg l^{-1}2,4-D (T_6) (86.19 and 81.06%) in comparison to other treatments. However, lowest per cent fruit retention was recorded in control (T_{10}) (63.71 and 60.92%). Reduction in fruit drop as a response of gibberellic acid may also be due to an increase in initial growth of ovaries which ultimately reduce the magnitude of peak of abscission (Agusti, 1). The results are also in conformation to the findings of Rani and Brahmachari (7). Fruits of the vines treated with a foliar spray of 10 mg l^{-1} of TRIA (T_8) took minimum time (174.27 and 174.43 during 2012) to reach maturity. It advanced the date of maturity by 3-4 days over control (T_{10}). However, treatment with 50 mg l^{-1} GA_3 (T_1) delayed harvesting by about 6-7 days as compared to control (T_{10}). This advancement in harvest maturity might have occurred due to stimulated ethylene production as a result of TRIA treatment. The rate of photosynthesis gradually increased with the advancement of growth (Mishra and Srivastava, 6).

Maximum yield per vine was noticed with 10 mg l^{-1} 2,4-D (T_6) (57.98 and 54.82 kg $vine^{-1}$) followed by 25 mg l^{-1} 2-4-D (T_5) (56.18 and 52.63 kg $vine^{-1}$) (Table 2). The significantly lower fruit yield was recorded in control (T_{10}), *i.e.* 40.95 and 39.79 kg $vine^{-1}$. Increased number of fruits per tree and increased fruit size and weight might have contributed towards increase in yields due to growth regulators application. 2,4-D treatments have also known to increase total yields in other fruits like Nagpur mandarin (Ansari *et al*., 2).

Fruit weight was significantly more in vines treated with 25 mg l^{-1} GA_3 (T_2) (87. and 89.94 g) in comparison to other treatments (Table 2). However minimum fruit weight was recorded in control (T_{10}) (66.96 and 68.43 g). Maximum increase in fruit length was observed with the application of 25 mg l^{-1} GA_3 (T_2) (7.54 7.20 cm) and maximum fruit diameter was recorded with 10 mg l^{-1} 2,4-D (T_6) (5.29 and 5.36 cm). Exogenous application of GA_3 is known to increase cell size thus increased fruit length (Zhang *et al.*, 10).

Fruit firmness was higher with the application of 25mg l^{-1} GA_3 (T_2) (7.76 N and 7.55) (Table 3). The lowest firmness was recorded in untreated fruit (T_{10}) (7.01 and 7.04 N). Choi *et al.* (3) also reported that GA_3 increased fruit firmness at harvest and decreased the rate of fruit softening. Total soluble solids was found to be highest with foliar application of 25 mg l^{-1} GA_3 (T_2) (12.91° and 13.32°B). Increase in total soluble solids might be due to conversion of carbohydrates into simple sugars with GA_3 application (Rub *et al.*, 8). Earlier, Clayton *et al.* (4) also reported that GA_3 spray increased fruit soluble solids in sweet cherry.

Minimum acidity was recorded with 25 mg l^{-1} GA_3 (T_2) (0.85 and 0.77%) followed by 50 mg $l^{-1}$$GA_3$ (T_1) and 10 mg l^{-1} 2,4-D (T_6), respectively. These treatments were at par with one another. Maximum acidity was recorded with 25 mg l^{-1} 2,4-D (T_5) (1.41 and 1.35). Maximum total sugars were recorded with the application of 25 mg l^{-1} GA_3 (T_2) (12.76 and

Table 2. Effect of exogenous application of plant growth regulators on fruit yield, fruit weight, fruit length and fruit diameter in kiwifruit cv. Hayward.

Treatment	Yield per vine (kg)		Fruit wt. (g)		Fruit length (cm)		Fruit dia. (cm)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	51.45	48.13	79.84	81.82	7.11	7.09	5.19	5.20
T_2	53.29	49.08	87.39	89.94	7.54	7.20	5.03	5.22
T_3	47.89	44.73	79.21	81.11	6.54	6.74	5.13	5.15
T_4	48.15	46.99	78.34	78.74	6.38	6.64	5.11	5.16
T_5	56.18	52.63	84.75	84.97	7.01	7.02	5.15	5.27
T_6	57.98	54.82	86.24	87.11	7.39	7.13	5.29	5.36
T_7	44.79	41.13	80.79	81.24	6.57	6.59	5.16	5.14
T_8	46.14	43.29	78.30	79.99	6.23	6.41	4.88	4.95
T_9	46.28	43.12	79.11	74.86	6.85	6.80	5.06	5.11
T_{10}	40.95	39.79	66.96	68.43	5.85	5.73	5.01	4.50
$CD_{0.05}$	1.33	1.09	0.11	0.04	0.17	0.14	0.11	0.19

Table 3. Effect of exogenous application of plant growth regulators on fruit firmness, TSS, titrable acidity and total sugars in kiwifruit cv. Hayward.

Treatment	Fruit firmness (N)		TSS (^{0}B)		Titrable acidity (%)		Total sugars (%)	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
T_1	7.69	7.50	12.80	13.11	0.93	0.78	12.65	11.67
T_2	7.76	7.55	12.91	13.32	0.85	0.77	12.76	12.01
T_3	7.34	7.13	12.29	12.45	1.17	1.13	11.32	11.31
T_4	7.46	7.25	12.42	12.84	1.16	1.01	12.05	11.58
T_5	7.64	7.46	12.65	12.98	1.41	1.35	8.65	9.21
T_6	7.53	7.32	12.78	13.23	0.95	0.89	8.91	9.36
T_7	7.32	7.37	12.11	12.65	1.40	1.31	11.21	11.28
T_8	7.05	7.07	11.93	12.87	1.21	1.04	10.32	11.34
T_9	7.23	7.29	11.10	12.11	1.09	1.11	11.20	11.18
T_{10}	7.01	7.04	11.25	11.32	1.35	1.27	9.05	9.17
$CD_{0.05}$	0.08	0.04	0.51	0.07	0.06	0.11	0.01	0.32

12.01%), while was in 25 mg l^{-1} 2,4-D (T_5) (8.65 and 9.21%). The increase in the content of total sugars in fruits may be due to degradation of polysaccharides into simple sugars by metabolic activities, conversion of organic acids into sugars, and loss of moisture with growth regulators application (Kumar *et al.*, 5).

From the above discussion it may be concluded that growth regulators, *viz*., 25 mg/l GA_3 and 10 mg/l 2,4-D may be used for enhancing the plant growth and yield of better quality fruits in cv Hayward.

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Short communication

Performance of cactus pear at two geographical locations in Indian arid zone

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ABSTRACT

Twenty cactus pear (*Opuntia ficus-indica* Mill.) genotypes were introduced in India to assess its suitability and performance at two geographical locations *i.e.*, Jodhpur, Rajasthan (26°18'N:73°04'E, 216 m MSL) and Kutch-Bhuj, Gujarat (23°21'N:69°77'E, 15 m MSL) for survival and growth. The cladodes were planted in the potting mixture of soil and compost (6:1) with initial moisture regulated at 7-9% to prevent rotting. The rooted plants were transplanted in the field at 2 × 3 m spacing. Mortality due to bacterial rot ranged from 50 to 100 per cent at Jodhpur. The highest plant survival in the field after one year of planting was recorded in genotypes RojaxRoja-4-Pianta-25 and ARL spineless (50%) followed by 33.33% each in genotypes Bianco Macomer, Roja Castel Sardo, Gymnocarpe and clone No. 1270. Absolute mortality occurred in varieties Roja San Cono, Clone No.1287, Giall × Giall, Trunzara Red San Cono, A. Giant, Lyria and Militelo White. In contrast, better survival per cent (20-90%) was observed at Bhuj in different accessions. However, the performance and survival in pots under shade net house was almost 100% at both the locations but the growth was better at Bhuj as compared to Jodhpur. The establishment and growth of cactus pear was affected at Jodhpur due to high temperature coupled with low relative humidity (27.81-58.39%, 10 years mean). The coastal areas of Kutch-Bhuj have comparatively higher relative humidity (44-76%) favoured better growth of cactus. Based on this study, it can be inferred that Kutch-Bhuj region is comparatively better location for growing cactus pear.

Key words: *Opuntia ficus-indica*, pear, plant survival, high temperature, field establishment.

The Indian hot arid zone covers an area of 31.70 m.ha spread across seven states with major chunk in Rajasthan and Gujarat. These areas have extremes of temperature (often >45°C in peak summer and sub zero in winter), high wind velocity, light sandy soil, low uncertain and erratic annual rainfall (100-400 mm), with very high frequency of drought. The edible cactus pear could be considered a new hope for wasteland development (Singh and Peter, 7). This can be potential alternate crop especially to meet the fodder requirement of large animal population, an integral component in arid farming system. The cultivation and commercial exploitation of cactus pear for various purposes has been done in many countries (Pimienta *et al*., 6; Barbera *et al*., 1). In view of above, it has been introduced in India under various collaborative programmes from time to time. The most recent one was made during 2010-11 when 43 accessions were brought to CAZRI from Tunisia and Italy in collaboration with ICARDA. We present here the details of their performance at two locations in India.

Nineteen introduced cactus pear germplasm were first multiplied in the pots under shade net. The potting mixture was prepared by mixing the sandy soil and compost manures in 5:1 ratio. Partially moist (7-9% moisture) potting mixture was filled in pots. About one year old cladodes were planted in the pots after 15th of February, 2011. No irrigation was given till 15 days of planting to avoid rotting of cladodes from the base. These cladodes were grown in the pots till October, 2011, which produced 2-3 new cladodes each. These plants were carefully transplanted in the field on 15th November, 2001 with entire soil of the pot undisturbed at the spacing of 2 m × 3 m with flat surface facing east-west side in Randomized Block Design with three replications having three plants per replication at two geographical locations, *i.e.* Jodhpur ((26°18'N:73°04'E, 216 amsl) and Kutch-Bhuj (23°21'N:69°77'E, 15 amsl) for evaluation in terms of growth and survival. Light irrigation was given after one week of planting by avoiding direct contact of water with the stems. The mean monthly weather data with respect to temperature, relative humidity, and rainfall and Sun shine hours were recorded at both the locations with the help of automatic weather station (Fig. 1 & 2). Periodical data were recorded on transplant success, incidence of rotting, number of new leaves produced etc. The uninfected aerial part of the rotten plants were separated and planted in the pots for rooting and multiplication for gap filling. Visible impact of high temperature, low atmospheric humidity and damage to plants by vertebrate pest were also recorded.

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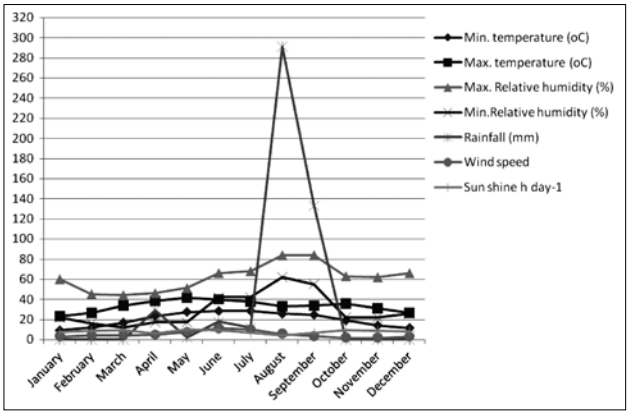

Fig. 1. Mean monthly weather conditions at Jodhpur.

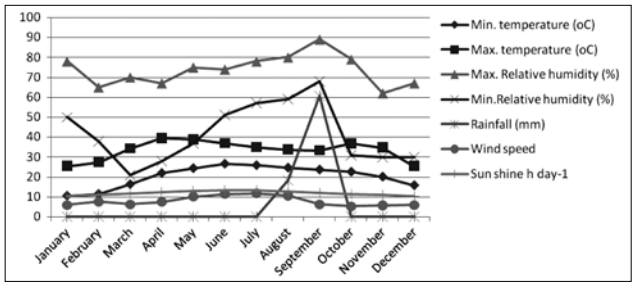

Fig. 2. Mean monthly weather conditions at Bhuj.

The field establishment of cacti were affected due to rotting at the basal part which ranged from 0 to 100 per cent in different accessions. The rotten plants were replaced with fresh plants raised in pots during March 2012. The mean survival of all the germplasm accession taken together was 74.88% and only 24.12% were lost due rotting during three months. The mean survival in June was highest (100%) in variety Roja × Roja-4 Pianta- 25, clone No. 1308 and accession from Botanical Garden, CAZRI, while clone No. 1270, Clone No. 1271, varieties Roja San Cono, ARL Spineless, Bianco Macomer and A. Giant showed 80-88 % survival. The remaining varieties had survival ranging between 40-80 per cent with lowest value in case of Trunzara Red San Cono (Table 1). The observations on post rainy season (22.8.12) survival indicated further loss of plants due to rotting with mean survival of 46.13 per cent. The genotype Lyria was lost completely during this period. The highest survival in the field after one year of planting

Table 1. Per cent survival (mean) of cacti genotypes at different time intervals post planting at Jodhpur.

Genotype	No. planted	Survival (%) in mid March	No. after gap filling in March	Survival (%) mid June	Survival (%) mid August	Survival (%) mid December	Mean No. of new cladodes/ yr
Clone No.1270	9	11.11	9	88.88	55.55	33.33	4.5
Clone No.1308	9	33.33	9	100.00	55.55	11.11	4.0
Clone No.1271	9	33.33	9	88.88	44.44	11.11	3.6
Clone No.1287	9	22.22	9	44.44	33.33	0.00	4.2
Roja San Cono	9	66.66	8	87.5	62.50	0.00	3.5
ARL Spineless	5	40.00	6	83.33	50.00	50.00	5.5
Cristallina	9	55.55	8	62.5	12.50	25.00	4.2
Red San Cono	3	55.55	9	77.77	66.66	22.22	2.5
Seedless Santa Margherita Balice	8	12.50	9	77.77	55.55	22.22	3.6
Bianco Macomer	6	83.33	6	83.33	66.66	33.33	4.5
Roja Castel Sardo	6	50.00	6	66.66	50.00	33.33	3.6
Gymnocarpe	4	50.00	6	66.66	16.66	33.33	5.5
Roja × Roja-4, Pianta 25	4	100.00	6	100.00	66.66	50.00	6.6
Giall × Giall	6	0.00	4	75.00	75.00	0.00	2.5
Trunzara Red San Cono	2	100.00	5	40.00	40.00	0.00	2.5
A. Giant	8	0.00	5	80.00	20.00	0.00	3.2
Militello White	1	0.00	2	50.00	50.00	0.00	3.2
Lyria	4	25.00	2	50.00	0.00	0.00	2.5
BG	9	44.44	9	100.00	55.55	11.11	9.6
Total/ Mean	120	41.21	118	74.88	46.13	17.68	4.17

was recorded in Roja × Roja-4-Pianta-25 and ARL spineless (50%) followed by 33.33% each in genotype Bianco Macomer, Roja Castel Sardo, Gymnocarpe and clone No. 1270. Absolute mortality occurred in varieties Roja San Cono, Clone No.1287, Giall × Giall, Trunzara Red San Cono, A. Giant, Lyria and Militelo White. The number of cladodes developed after 12 month of planting was maximum (9.60) in the old accession from botanical garden, CAZRI, Jodhpur while others it ranged between 2.5 to 6.6 (Table 1.) Pathological examination of the rotten part revealed that rotting was due to bacteria. The isolated samples were cultured on nutrient agar medium and pure cultures were obtained by streaking on to the petri-plates containing NA medium. It was then multiplied on NA Broth medium for DNA isolation using Bacterial Genomic mini kit.16s rRNA gene and subjected to DNA sequencing. The sequences resulted in molecular identification of pathogen as *Enterobacter cloacae.* Accordingly, to save cladodes from this bacterial infection these were treated with fixed copper formulation/streptomycin before planting. Even this treatment was also not effective to prevent rotting. During peak summer months when the atmospheric humidity was lowest and high temperature was at peak, the cladodes were found to shrivel (Fig. 3). Peacocks, parrots, squirrels and rats eat upon young cladodes too as they are rich in carbohydrates.

Twenty genotypes including two local genotypes from Bhuj was planted in pots under shed net house and in field. Significantly higher survival per cent was recorded both in pots and field as compared to its performance at Jodhpur. The survival per cent of all the accessions in pots was more than 95 percent after 180 days of planting except the variety Militelo White (0%), Clone No. 1308 (36.0%), Clone No. 1270 (45.5%) and Clone No. 1271 (66.7%). Similarly in open field also the survival of more than 60 per cent was recorded in most of accessions. However, in Clone No. 1271 it was only 20 per cent (Table 2).

The climatic factors that controls the growth and distribution of *Opuntia-ficus-indica* are rainfall, atmospheric humidity, temperature, nature of soils and drainage thereof (Monjauze and Houerou, 4). The mean monthly weather conditions at Jodhpur and Kutch-Bhuj in India where the performance trial was conducted indicate that at both the locations temperature remains much higher (av. 33.4°C at Jodhpur with a range 9.3-41.6°C) than optimum required (<30°C) during most part of the year, *i.e.* from March to October. Comparatively better climatic conditions with respect to maximum temperature (mean 25.38, range 25.52-39.36°C and minimum RH (30-68%) prevailed in coastal areas of Bhuj led

Fig. 3. Shrivelling in cactus pear due to high temperature.

Table 2. Plant survival of different cactus pear genotypes at Kutch-Bhuj, Gujarat.

Genotype	Survival (%) after 180 days	
	Pot	Field
Clone No. 1270	45.5 (22)*	50 (10)
Clone No. 1271	66.7 (27)	20 (10)
Clone No. 1308	36.0 (25)	60 (10)
CAZRI Kukma 1	95 (20)	90 (10)
CAZRI, Botanical Garden	95 (20)	75 (15)
Clone No. 1287	100 (6)	-
Roso San Cono	100 (1)	-
Giall × Giall	100 (1)	-
Trunzara Red San Cono	100 (1)	-
Piantra-25	100 (2)	-
ARL Spinless	100 (1)	-
Red San Cono	100 (2)	-
Militelo White	0.0 (1)	-
Cristallina	100 (1)	-
Rosa Castle Sardo	100 (1)	-
Bianco Macomer	100 (6)	-
Seedless Santa Margherita Belice	100 (1)	-
Gymnocarpe	100 (2)	-
CAZRI Kukma 2	100 (1)	-
CAZRI Kukma 3	100 (4)	-

*No. planted

to better performance in terms of survival and growth. The climatic requirement of the species indicate that it tolerates dryness and is very resistant to high temperatures, however, its photosynthetic productivity can diminish enormously if 30°C or more is exceeded even when the water supply is sufficient; temperatures higher than 30°C cause reductions of up to 70% of photosynthetic activity; while temperatures lower than 0°C, even for 4 h, produced irreversible damage to the cladode tissue and the fruit (Inglese, 2). Similarly, atmospheric humidity plays significant roles in deciding the ecological region for satisfactory growth of cactus pear. Empirical observations seems to demonstrate that *Opuntia ficus-indica* is eliminated from areas where the average R.H. remains below 40% for more than one month consecutively (Monjauze and Houerou, 4; Peyre de Fabrsgues, 5). For that reason cacti can not grow in the Sahel where the average annual R.H. is ca 38% ca 24 HPa and mean saturation deficit (SD) nor do they grow in Sudanian zone with R.H. of 52% and SD of 17 Hpa; but they normally develop in eastern and southern Africa with annual R.H. of 60-65% and SD of ca 11 HPa (Le Houerou *et al*., 3). Satisfactory growth of cacti in Indian arid zone has been observed during February to March. The growth is much suppressed during May to July due to high temperature. The temperature remains favourable during August-September but that being the peak monsoon season in the region of study lead to water stagnation in the root zone result in rotting especially during the year of planting or till the collar region become woody. Satisfactory period of growth can be considered during October-November when both temperature and humidity conditions are most favourable. The growth is again checked during December-January due to low temperature. The mean survival diminished from 74.88% in pre monsoon to about 17% in post monsoon period. There was heavy rainfall in 2012 on the standing plants of cacti during August-September, 2012 leading to water stagnation for some time, which led to rotting and mortality.

Compared to Jodhpur, the performance of cacti was better in Bhuj both in terms of better field establishment and growth due to lower summer temperature and higher relative humidity. Thus, in view of these findings, Bhuj can be considered better location for large scale performance trial on different varieties of cacti.

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Short communication

Evaluation and variability study in garlic

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ABSTRACT

Thirty diverse genotypes of garlic (*Allium sativum* L.) were evaluated for important quantitative and qualitative traits. The genotype JAS 28 showed highest value for quantitative traits such as, leaf length (36.33 cm), leaf width (1.74 cm), pseudostem diameter (0.84 cm), equatorial diameter of bulb (4.16 cm), average weight of bulb (27.0 g), marketable yield (117.0 q/ha) and total yield (118.0 t/ha). Further, maximum plant height (62.20 cm), number of cloves/ bulb (23.66) and average weight of bulb(27.0 g) were observed in the genotype JAS 16. The genotype JAS 5 had maximum polar diameter of bulb (3.82 cm) and matured in minimum days (137.33 days), which could be easy selection for earliness along with high yield. Looking to the diversity among the genotypes, the traits evaluated for variability analysis showed high PCV and GCV for number of cloves/ bulb, pseudostem diameter and width. The heritability coupled with genetic advance as per cent of mean among the genotypes was, however, high in case of marketable yield, total yield, average weight of bulb, leaf length, average weight of 10 cloves and pseudostem length. Thus, the present investigation showed maximum diversity among the genotypes and the genotypes JAS 28 and JAS 16 were found to be good parental material to be used in breeding programme.

Key words: *Allium sativum*, coefficient of variation, heritability, variability.

Garlic (*Allium sativum* L.) is one of the most important remunerative bulbous spice and medicinal crop. It is second most widely used spice after onion belonging to Alliaceae family. Garlic is rich in protein, phosphorus, potassium, calcium, magnesium and carbohydrates. The fresh peeled garlic cloves contain 62.8% moisture, 29% carbohydrate, 6.3% protein, 1% mineral matter, 0.8% fiber, 0.1% fat, 1% total ash, 0.03% calcium, 0.31% phosphorus, 0.0001% iron, 0.4 mg/100 g nicotinic acid and 13 mg/100 g vitamin 'C'. The uninjured bulb contains a colourless, odourless water soluble amino acid 'allin'. On crushing the garlic bulb the enzyme allinase breaks down allin to produce allicin of which the principle ingredient is the odouriferous diallyldisulphide. Garlic contains about 0.1% volatile oil. The exploration of genetic variability in the available germplasm is a prerequisite in a breeding programme for effective selection of superior genotype. The partitioning of total variability into heritable and non-heritable components by using suitable design will enable the breeder to know whether the superiority of selection is inherited by the progenies.

An experiment was conducted at the Vegetable Research Farm, Horticulture Complex, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur during *Rabi* 2013-14 to evaluate thirty garlic genotypes. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and each replication consisted of thirty plants. These genotypes of garlic were collected from Mandsaur, Ratlam, Chhindwara, Betul, Neemach and Seoni districts of Madhya Pradesh for investigation. Randomly marked ten plants from each plot were taken for observation on fourteen characters *viz.,* plant height (cm), No. of leaves/ plant, leaf length (cm), leaf width (cm), pseudostem length (cm), pseudostem diameter (cm), polar diameter of bulb (cm), equatorial diameter of bulb (cm), No. of cloves/ bulb, average bulb weight (g), average weight of 10 cloves (g),marketable yield (q/ha), total yield (q/ha) and days to maturity. The variance components and coefficient of variation were determined according to Burton (2). The heritability in broad sense (h^2bs) was calculated using formula proposed by Hanson *et al.* (3) and expected genetic advance was worked out as suggested by Johnson *et al.*(5).

Mean performance of thirty genotypes on fourteen characters of garlic is presented in Table 1. The analysis of variance showed that the genotypes under study differed significantly among themselves for all the characters studied. Wide range of variation was recorded in leaf length (26.73-36.33 cm), days to maturity (137.33-147.33), average weight of bulb (10.67-15.50 g), No. of cloves/ bulb (23.66-21.25), plant height (40.73-62.20 cm), total bulb yield (79.20-118.80 q/ha) and marketable bulb yield (70.87-117 q/ha). These observations also corroborated with those of Jabeen *et al.* (4), Tsega *et al.* (12) and Mishra *et al.* (9).

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Table 1. Mean performance of thirty genotypes on different characters of garlic

Genotypes	Plant height (cm)	No. of leaves/ plant	Leaf length (cm)	Leaf width (cm)	Pseudo stem length (cm)	Psedostem diameter (cm)	Polar diameter of bulb (cm)	Equatorial diameter of bulb (cm)	No. of cloves/ bulb	Average weight of 10 cloves (g)	Days to maturity	Average weight of bulb (g)	Marketable yield (q/ha)	Total yield (q/ha)
JAS 1	46.60	6.93	28.13	0.95	7.87	0.42	2.18	3.07	18.67	10.67	140.00	19.33	79.00	83.60
JAS 2	52.23	7.40	30.53	0.97	6.80	0.48	2.18	3.15	11.00	14.16	138.66	15.67	90.79	96.80
JAS 3	46.53	6.40	29.60	0.84	7.66	0.42	2.02	3.02	12.66	14.33	139.00	18.00	73.24	83.53
JAS 4	54.93	7.53	29.66	1.03	7.86	0.49	2.42	3.40	15.33	13.66	138.66	20.33	85.21	90.20
JAS 5	47.86	6.86	31.93	1.12	6.80	0.74	3.82	3.58	21.00	11.36	137.33	23.00	72.62	103.40
JAS 6	43.40	6.73	28.46	1.00	7.00	0.65	2.37	3.59	17.66	13.33	139.33	23.33	80.23	83.53
JAS 7	48.93	6.86	30.66	1.14	6.60	0.75	2.36	3.58	14.66	14.16	139.66	20.67	88.97	103.27
JAS 8	47.93	7.06	29.53	1.18	6.93	0.74	2.45	3.39	14.33	15.50	144.66	22.00	92.29	96.80
JAS 9	50.26	7.26	29.93	1.08	7.86	0.62	2.46	3.40	15.33	12.30	140.66	20.67	90.61	101.20
JAS 10	53.20	7.40	30.40	1.02	8.93	0.68	2.48	3.70	20.00	12.33	140.33	23.67	73.26	81.40
JAS 11	52.33	7.60	29.33	1.02	7.86	0.70	2.37	3.32	17.33	14.00	144.33	24.33	74.78	100.13
JAS 12	49.60	7.46	30.06	1.12	7.73	0.64	2.33	3.42	16.00	12.33	140.00	19.00	78.48	99.00
JAS 13	51.80	7.66	30.40	1.06	6.20	0.73	2.46	3.59	17.00	13.83	140.00	22.67	99.73	116.60
JAS 14	48.20	7.00	31.86	1.22	7.66	0.79	2.47	3.81	15.33	12.66	141.00	20.67	93.58	103.33
JAS 15	49.73	6.66	32.20	1.10	8.26	0.73	2.35	3.56	23.66	10.76	141.00	25.00	91.41	96.73
JAS 16	62.20	7.20	32.33	1.18	7.53	0.83	2.49	3.86	23.00	14.30	147.33	27.00	115.00	116.60
JAS 17	58.53	7.40	35.60	1.21	7.53	0.79	2.55	4.01	19.66	11.83	141.33	24.00	100.12	103.40
JAS 18	56.33	7.60	31.93	1.15	8.26	0.79	2.50	3.68	19.33	13.16	144.00	26.00	103.43	107.80
JAS 19	55.86	8.06	33.66	1.12	8.60	0.71	2.49	3.65	19.66	11.33	140.66	23.00	89.31	103.40
JAS 20	54.00	7.60	31.73	1.27	6.73	0.82	2.48	3.80	17.66	13.50	146.00	21.67	98.81	112.20
JAS 21	41.00	6.93	26.73	1.08	6.46	0.53	2.27	3.33	16.33	12.33	141.00	19.00	80.30	85.80
JAS 22	40.73	6.73	27.00	0.88	7.80	0.62	2.24	3.09	16.00	13.00	140.00	21.00	80.86	94.47
JAS 23	50.40	7.40	29.40	1.00	7.00	0.64	2.33	3.33	20.66	12.50	140.00	24.67	88.99	96.73
JAS 24	42.80	6.80	27.53	0.93	7.06	0.59	2.16	3.09	20.33	11.33	145.00	22.67	70.87	79.20
JAS 25	44.66	6.80	29.40	0.94	6.86	0.63	2.17	3.21	22.00	11.83	140.66	23.67	81.55	96.73
JAS 26	46.20	6.53	31.66	1.07	7.00	0.70	2.36	3.68	19.33	12.50	141.66	23.67	108.09	116.60
JAS 27	47.06	7.33	31.33	1.36	6.20	0.78	2.50	3.65	18.33	12.46	140.00	23.00	88.96	96.73
JAS 28	61.73	6.53	36.33	1.74	6.26	0.84	2.77	4.16	22.33	14.90	146.66	27.00	117.00	118.80
JAS 29	52.20	7.20	30.33	1.04	7.53	0.64	2.43	3.64	21.66	11.33	140.66	24.00	83.65	90.07
JAS 30	51.53	7.60	31.06	0.94	7.80	0.62	2.40	3.46	23.00	11.66	145.33	24.00	92.63	99.00
SEm±	3.11	0.16	0.24	0.07	0.19	0.04	0.07	0.13	1.55	0.26	1.34	0.24	0.52	0.49
C.D. 5% level	8.89	0.47	0.70	0.20	0.55	0.12	0.20	0.39	4.45	0.76	3.84	0.69	1.49	1.42

The genotypic and phenotypic coefficients of variations are of greater use in determining the extent of variability present within the material. The genetic parameters for some characters of garlic are presented in Table 2. The phenotypic coefficient of variation (PCV) varied from 2.29% for days to maturity to 21.25% for No. of cloves/ bulb. PCV expressed in terms of percentage was comparatively high for No. of cloves/ bulb (21.25%), pseudostem diameter (18.45%) and leaf width (17.90%). The results were in agreement with the findings of Khar *et al.* (7) and Panse *et al.* (10). However, moderate PCV was

Table 2. Genetic parameters for fourteen characters of Garlic

Characters	Grand Mean	Range		Coefficient of variations		Heritability % (bs)	Genetic Advance	GA as % of mean
		Min.	Max.	PCV	GCV			
Plant height (cm)	50.29	40.73	62.20	13.89	8.84	40.48	5.83	11.58
No. of Leaves/ plant	7.15	6.40	8.06	6.61	5.27	63.51	0.62	8.65
Leaf length (cm)	30.62	26.73	36.33	9.71	6.57	95.72	4.04	13.21
Leaf width (cm)	1.09	0.84	1.74	17.90	13.85	59.86	0.24	22.16
Pseudostem length (cm)	7.35	6.20	8.93	10.35	9.29	80.67	1.26	17.21
Pseudostem diameter (cm)	0.67	0.42	0.84	18.45	14.66	63.17	0.16	23.48
Polar diameter of bulb (cm)	2.43	2.02	3.82	7.16	4.99	48.54	0.17	7.02
Equatorial diameter of bulb (cm)	3.51	3.02	4.16	9.79	6.99	50.99	0.36	10.28
No. of cloves/ bulb	18.31	11.00	23.66	21.25	15.32	51.95	4.16	22.74
Average weight of 10 cloves (g)	12.78	10.67	15.50	9.88	9.20	86.69	2.27	17.79
Days to maturity	141.5	137.33	147.33	2.29	1.59	48.12	3.21	2.27
Average weight of bulb (g)	22.42	15.67	27.00	11.81	11.66	97.49	5.31	23.68
Marketable yield (q/ha)	88.84	70.87	117.00	13.78	13.75	99.45	25.09	28.24
Total yield (q/ha)	98.56	79.20	118.80	11.12	11.08	99.38	22.43	22.76

recorded for plant height (13.89%), marketable yield (13.78%), average weight of bulb (11.81 %), total yield (11.12%) and pseudostem length (10.35%), whereas low PCV for average weight of 10 cloves (9.88 %), equatorial diameter of bulb (9.79 %), leaf length (9.71%), polar diameter of bulb (7.16%), No. of leaves/ plant (6.61%) and days to maturity (2.29%) was recorded which indicated that there is limited scope for improvement (Table 2). Agarwal and Tiwari (1) reported lowest values for number of leaves per plant. As estimated phenotypic variation can not differentiate between the effects of genetic and environmental effects was carried out to partition the real genetic differences.

The genotypic coefficient of variations (GCV) were comparatively high for No. of cloves/ bulb (15.32%) and moderate for plant height (13.89%), pseudostem diameter (14.66%), leaf width (13.85), marketable yield (13.75%), average weight of bulb (11.66%) and total yield (11.08%). Similar results were also reported by Singh and Chand (11) and Mishra *et al.* (9). Low GCV was recorded for pseudostem length (9.29%), average weight of 10 cloves (9.20%), plant height (8.84%), equatorial diameter of bulb (6.99%), leaf length (6.57%), No. of leaves/ plant (5.27%), polar diameter of bulb (4.9%) and days to maturity (1.59%).

The relative amount of heritable portion of total variation was found out with the help of heritability estimates and genetic advance. In the present study, high heritability estimates were obtained for most of the traits *viz.,* marketable yield, total yield, average weight of bulb, leaf length, average weight of 10 cloves and pseudostem length. These results were in close proximity to those of Singh and Chand (11) and Khar *et al.* (7). High heritability coupled with genetic advance as per cent of mean was observed for marketable yield, total yield, average weight of bulb, pseudostem diameter, number of cloves per bulb and leaf width suggesting preponderance of additive genes. It also indicated high response for selection of high yielding genotypes as these traits are governed by additive gene actions. High values of heritability supplemented with moderate genetic advance as per cent of mean were manifested by pseudostem length and average weight of 10 cloves which might be attributed to additive gene action conditioning their expression and phenotypic selection for their amenability can be brought out. These findings are in agreement to those of Singh and Chand (11), Kumar *et al.* (8), Kalra *et al.* (6) and Mishra *et al.* (9).

It can, therefore, be concluded that there was good range of variability among the genotypes studied and the genotypes JAS 28 and JAS 16 could be included as parental material in improvement programme.

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First Circular

8th Indian Horticulture Congress-2018

on

Shaping Future of Indian Horticulture

Venue **:** Indira Gandhi Krishi Vishwavidyalaya at Raipur, Chhattisgarh

(29th October to November 1st, 2018)

Estd. 1942

The R&D efforts made in the four decades have impacted Horticulture in the country in many ways. The importance of horticulture is being realized by one and all be it a small farmer, the corporate sector and policy makers at all levels. There is now a large R&D network in the country with establishment of several institutions and launching a number of developmental programmes. Horticulture has come out of village confines to the urban areas. The society has been organizing congresses biennially since 2004. The seven earlier congresses on different topical issues were successfully organized at New Delhi (2004, 2010 & 2016), Shillong (2007), Bhubaneswar (2008), Ludhiana (2012) and Coimbatore (2014).

It is now proposed to hold the **8th Indian Horticulture Congress-2018** at Indira Gandhi Krishi Vishwavidyalaya at Raipur, Chhattisgarh from October 29th to November 1st, 2018. The following themes/ sub-themes have been identified for the Congress.

CROPS COVERED

All horticulture crops namely, Fruits, Vegetables & Tuber Crops, Floriculture, M&A Plants, Spices, Plantation Crops, Bamboo and Mushroom.

THEMES/SUB-THEMES

- **Innovative Production Systems:** Urban and Peri-urban horticulture, Protected Cultivation, Hydroponics, Aeroponics and Vertical Farming
- **Breeding Approaches:** Genetic Resources for trait specific breeding, Pre-breeding for abiotic and biotic stresses, next generation breeding approaches for trait specific improvement (nutrition, quality, processing and export), breeding of rootstocks, Harnessing underutilized crops, QTL mapping, genome editing, use of molecular markers, application of omics, transgenes, csgenics, genotyping chips, NGs and bio-informatics.
- **Input Management for Improving Productivity and Quality:** Canopy architecture, HDP, juvenility, new generation inorganic/organic fertilizers, bio-fertilizers, fertigation, organic horticulture, conservation horticulture, emerging nutrient and water efficient technologies, Deficit irrigation.
- **Managing Pest & Diseases:** Emerging Pest problems, modern approaches for diagonistics disease protection, disease & pest dynamics under climate change, new molecules and botanicals, bio-control for enhancing productivity and quality; safe food, pesticide residues and environmental issues.
- **Horticultural Engineering:** Mechanisation and automation, sensors, robotics, drones, customized tools and implements, use of non-conventional energy.
- **Post-harvest Management:** Post harvest handling protocols, emerging post harvest technologies, ozonation, UV treatments, irradiation, nano encapsulation
- **Value Addition:** Minimal procession, Thermal and non-thermal processing, functional foods, field and industrial waste.
- **Quality Planting Material:** Innovation in production of elite quality planting material/seed, diagnostics, plug plant production and vegetable grafting.
- **Innovation in Social Sciences and Horti-business**: New Startups in Horticulture sector, employment generation, extension innovations, capacity building and skill development, Public Private Partnership (PPP) in extension, ICT in agriculture, Advisory services and Policy needs in horticulture, GAP, Certification, Farmer-Producer Organisations (FPO).
- **Opportunities in Horticulture R&D in Chhattisgarh**: Horticulture research and development in Chhattisgarh; Tribal area Horticulture led development models, Developmental schemes and their impact, crops insurance and marketing innovations, promotion of ethnic crops and ITKs in Horticulture, Successful entrepreneurs and PPP models.

PRESENTATIONS

The Congress will cover lead, oral and poster papers. While lead papers are being invited, suggestions for oral papers related to different themes indicating the title of the paper and the speaker (from within or outside country) are invited by the Programme Committee latest by 15.05.2018. All members/ non-members of the HSI, students, farmers, foreign delegates and representative of corporate sector are invited to participate.

IMPORTANT DATES

Last date for receiving abstract(s)	: June 30, 2018
Last date for sending acceptance letter	: July 30, 2018
Last date for sending full length paper	: August 31, 2018
Last date for sending registration fee	: September 30, 2018

REGISTRATION FEE

Details of Registration Fee for various categories of participants are as under:

Category	On time	With late fee
Corporate sector	₹ 12,000/-	₹ 13,000/-
Non members of HSI	₹ 10,000/-	₹ 11,000/-
HSI members	₹ 7,500/-	₹ 8,500/-
Students and Research Fellows	₹ 3,000/-	₹ 3,500/-
Farmers	₹ 2,500/-	₹ 2,500/-
SAARC countries (US$ 150) others US$ 200 or € 150		

FURTHER CORRESPONDENCE

Further correspondence can be made with the following members of Organizing Committee:

Chairman **National Organizing Committee** **Dr K.L. Chadha** President, The Horticultural Society of India F-1, Societies Block, NASC Complex, DPS Marg, Pusa, New Delhi - 110 012 Phone : 011-25842127; Mob.: 9312005646	*Chairman* **Local Organizing Committee** **Dr. S.K. Patil** Vice-Chancellor, Indira Gandhi Krishi Vishwa Vidyalalya Krishak Nagar, Raipur - 492 012, Chhattisgarh Phone: 0771-2443419; Mob.: 9425515922
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Congress E-mail : ihc2018hsi@gmail.com ***Website : www.hsi1942.in***	

Announcement

The Horticultural Society of India Awards 2018

The Horticultural Society of India (HSI) has instituted various awards for individuals who have made significant contributions and displayed leadership in the field of Horticulture or its sub-disciplines, *e.g.,* Fruit Science (including plantation crops), Vegetable Science (including tuber crops and spices), Floriculture (including medicinal and aromatic crops) and Post-Harvest Technology (Horticultural crops). Nominations are invited from eligible candidates for various HSI awards for the year 2018. The details of these awards are given below:

1. **HSI-Shivsakthi Life Time Achievement Award in Horticulture :** This award was instituted in 2006 with corpus money donated by M/s Shivsakthi Biotech Plantec. Ltd., Hyderabad. It is an Apex Award given every year by the Horticultural Society of India. The award is open to all individuals engaged in research/ development related to Horticulture or any related disciplines in India. The awardees should have made outstanding contributions as a lifetime achievement in the field of horticultural research/ development resulting in significant impact on quality of life of people in India. The award consists of cash prize of Rs. 51,000/-, a medal and a citation.
2. **HSI-Dr B.R. Barwale Young Researcher Award in Horticultural Biotechnology (Doctoral Thesis Research) :** This award has been instituted in 2016 in the name of Dr. B.R. Barwale, Founder & Chairman, Maharashtra Hybrid Seed Company Ltd. from the donation made by Maharashtra Hybrid Seeds Company (Mahyco) Ltd. The award will be given annually to a student/applicant from any Indian University/ Deemed to be university/Institute for best doctoral thesis related to Biotechnological techniques in Horticultural Crops submitted during 2016. The award consists of a cash prize of Rs. 25,000/-, a medal and a citation.
3. **HSI-Sh. D. P. Ghosh Memorial Young Scientist Award :** This award has been instituted in 2016 from the donation made by Dr S. P. Ghosh, former Deputy Director General (Horticulture), Indian Council of Agricultural Research, New Delhi in the memory of his Late father Sh. D.P. Ghosh. This award will be given annually to a young scientist (**not more than 45 years of age on 01.01.2017**), who has made significant contributions in any frontier area of horticultural sciences as evidenced from publications, technology development, patents, etc. The award consists of a cash prize of Rs. 25,000/-, a medal and a citation.
4. **Shri Girdhari Lal Chadha Memorial Medal in Fruit Science :** This award was instituted in 1992 with the money donated by Dr K.L. Chadha, former DDG (Hort.), ICAR and President, the Horticultural Society of India. The award is given in the memory of his father late Shri Girdhari Lal Chadha to promote Fruit Science research and development. The award is given to a scientist, who has made significant contributions and displayed leadership in the field of Fruit Science (including plantation crops) as evidenced by publications, varieties, technology development, patents, etc. The award consists of a medal and a citation.
5. **Dr Kirti Singh Medal in Vegetable Science :** This award was instituted in 2004 and renamed as Dr Kirti Singh

Medal in 2007 with corpus money donated by Dr Kirti Singh, former Chairman ASRB, New Delhi and Senior Vice President, the Horticultural Society of India. This award is given to a scientist, who has made significant contributions and displayed leadership in the field of Vegetable Science (including tuber crops and spices) as evidenced by publications, varieties, technology development, patents, etc. The award consists of a medal and a citation.

6. **Dr. Manmohan Attavar Medal in Floriculture :** This award was instituted in 2004, renamed as Dr. Manmohan Attavar Medal in 2016 with corpus money donated by Dr. Manmohan Attavar, Chairman, Indo American Hybrid Seed Company, Bengaluru. This award is given to a scientist, who has made significant contributions and displayed leadership in the field of Floriculture (including medicinal and aromatic plants) as evidenced by publications, varieties, technology development, patents, etc. The award consists of a medal and a citation.
7. **Dr J.C. Anand Memorial Medal in Post-Harvest Technology :** This award was instituted in 1992 from the donation made by Dr J.C. Anand, former Project Coordinator (Post-Harvest Technology of Horticultural Crops) at the Indian Agricultural Research Institute, New Delhi. This award is given to a scientist, who has made significant contributions and displayed leadership in the field of post-harvest management of horticultural crops as evidenced by publications, technology development, patents, etc. The award consists of a medal and a citation.

GENERAL GUIDELINES

- The application proforma is available on www.hsi1942.in.
- The application for award(s) is required to be submitted in the proforma ***(visit www.hsi1942.in)* covering 8 pages strictly**. Separate applications are required to be submitted for different awards.
- One copy of the application should be sent by e-mail (**hortsociety42@gmail.com**), while 6 additional copies of application should be sent through post with one set of relevant supportive documents, if any.
- Application for the award(s) should be submitted through proper channel (i.e. competent authority of the Institute / University or other organizations) to the Secretary, the Horticultural Society of India, National Societies Block, F-1, NASC Complex, Dev Prakash Shastry Marg, New Delhi-110 012.
- In case of **HSI-Dr B.R. Barwale Award** a brief biodata alongwith summary of thesis may be submitted by e-mail while 6 hard copies of summary and a copy of thesis be submitted by post through Supervisor.
- Announcement for selected awardees is generally made in the month of October and the awards are presented during the Foundation Day Celebrations of the Society or during any other appropriate function organized by the Society.
- The last date for receipt of applications for the above Awards is 30th June, 2018 and applications not as per the above guidelines or incomplete shall not to be considered.

Announcement

The Horticultural Society of India Fellowships 2018

The Horticultural Society of India (HSI) has instituted various categories of Fellowships for national and foreign scientists or as corporate, who have made significant contributions and displayed leadership in the field of Horticulture or its sub-disciplines, e.g., Fruit Science (including plantation crops), Vegetable Science (including tuber crops and spices), Floriculture (including medicinal and aromatic crops) and Post Harvest Technology (Horticultural crops).

The Horticultural Society of India now invites nominations for the award of Fellowship of the Horticultural Society of India (FHSI) from the eligible distinguished Scientists, who have made significant contributions and displayed leadership in any sub-disciplines of Horticulture (Fruit and plantation crops, vegetable crops, spices, potato and tuber crops, mushrooms, floriculture, medicinal and aromatic crops, post-harvest technology) as evidenced by publications, varieties, technology development, patents and other recognitions.

GENERAL GUIDELINES

- **The application proforma and list of Fellow is available on www.hsi1942.in**
- Nominations for Fellows of the Society may be made from among Life Members of the Horticultural Society of India with at least 5 continuous years membership as on December 31, 2016. Life members of the Society up to the age of 65 years are only eligible for induction as Fellows.
- The application for Fellowships is required to be submitted in the proforma ***(Annexure-I)*** **covering only 8 pages.**
- One copy of the application should be sent by e-mail to **hortsociety42@gmail.com**, while 6 additional copies of application should be sent through post with one set of relevant supportive documents, if any.
- Applications for the fellowships duly nominated by a Fellow of the Society (list available on website) should be forwarded to the Secretary, The Horticultural Society of India, National Societies Block, F-1, NASC Complex, Dev Prakash Shastry Marg, New Delhi-110 012.
- Nominations once received by due date remain valid for a period of 3 years. An annual updated application (six copies) is needed to be submitted by the nominated candidates for reconsideration. In the event of non-submission of updated bio-data, the candidature of applicant shall not be considered.
- In the event of final selection of a life member to the Fellowship (FHSI) of the Society, the elected Fellow will have to pay a Fee of Rs. 2,500/- for induction as Fellow of the society.
- Announcement for selected Fellows is generally made in the month of October and the fellowships are normally conferred during the Annual General body Meeting of the society or during any other appropriate function organized by the Society.
- **The last date for receipt of applications for the above Awards is 30th June, 2018 and applications not as per the above guidelines or incomplete shall not to be considered.**

STATEMENT OF OWNERSHIP AND OTHER PARTICULARS ABOUT INDIAN JOURNAL OF HORTICULTURE

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I, Dr K.L. Chadha, hereby declare that the particulars given are true to the best of my knowledge and belief.

30th March, 2018

Sd/-
(K.L. Chadha)
Signature of the Publisher

GUIDELINES TO THE CONTRIBUTORS

Indian Journal of Horticulture is the official publication of **the Horticultural Society of India**. It features the original research in all branches of Horticulture and other cognate sciences of sufficient relevance and primary interest to the horticulturists. The publication is generally open to the members the Horticultural Society of India but it also accepts papers from non-members on subjects related to Horticulture. The journal publishes three types of articles, *i.e.*, **Review/ Strategy paper** (exclusively by invitation from the personalities of eminence), **Research paper** and **Short communication**. The manuscripts should be submitted in duplicate in all respect to **the Editor-in-Chief, the Horticultural Society of India, F1, National Society's Block, National Agricultural Science Centre Complex, Todapur, Pusa Campus, New Delhi - 110 012, India.** Each manuscript must be typed doubled spaced on one side of a A4 size page. Clearness, brevity and conciseness are essential in form, style, punctuation, spelling and use of English language. Manuscripts should conform to the S.I. system for numerical data and data should be subjected to appropriate statistical analysis. On receipt of an article at the Editorial Office, an acknowledgement giving the manuscript number is sent to the corresponding author. This number should be quoted while making any future enquiry about its status.

***Review/ Strategy paper*:** This article is received through invitation. It should be comprehensive, up-to-date and critical on a recent topic of importance. The maximum page limit is of **16 double-spaced typed pages** including tables and figures. It should cite latest literatures and identify some gaps for future. It should have a specific **Title** followed by the **Name(s) of the author(s)**, **Affiliation**, **Abstract, Key words,** main text with subheadings, **Acknowledgements** (wherever applicable) and **References**.

***Research paper*:** The paper should describe a new and confirmed findings. Should not generally exceed **12 typed pages** including tables/ figures etc. A research paper has the following features.

Title followed by **Author**(s) and **Affiliation:** Address of the institution(s) where the research was undertaken.

Abstract: A concise summary (200 to 300 words) of the entire work done along with the highlights of the findings.

Key words: Maximum of five key words to be indicated.

Introduction: A short introduction of the crop along with the research problem followed by a brief review of literature.

Materials and methods: Describe the materials used in the experiments, year of experimentation, site etc. Describe the methods employed for collection of data in short.

Results and discussion: This segment should focus on the fulfillment of stated objectives as given in the introduction. Should contain the findings presented in the form of tables, figures and photographs. As far as possible, the data should be statistically analyzed following a suitable experimental design. Same data should not be presented in the table and figure form. Avoid use of numerical values in findings, rather mention the trends and discuss with the available literatures. At the end give short conclusion. Insertion of coloured figures as photograph(s) will be charged from the author(s) as applicable and suggested by the printer.

Acknowledgements (wherever applicable).

References: Reference to literature should be arranged alphabetically and numbered according to author's names, should be placed at the end of the article. Each reference should contain the names of the author with initials, the year of the publication, title of the article, the abbreviated title of the publication according to the World List of Scientific Periodicals, volume and page(s). In the text, the reference should be indicated by the author's name, followed by the serial number in brackets. **Maximum of 15 key references to be cited**.

1. Scaffer, B. and Guaye, G.O. 1989. Effects of pruning on light interception, specific leaf density and chlorophyll content of mango. *Scientia Hort.* **41**: 55-61.
2. Laxmi, D.V. 1997. Studies on somatic embryogenesis in mango (*Mangifera indica* L.). Ph.D. thesis, P.G. School, Indian Agricultural Research Institute, New Delhi.
3. Sunderland, N. 1977. Nuclear cytology. **In**: *Plant Cell and Tissue Culture*, Vol. II. H.E. Street (Ed.), University of California Press, Berkeley, California, USA, pp.171-206.
4. Chase, S.S. 1974. Utilization of haploids in plant breeding: breeding diploid species. **In**: *Haploids in Higher Plants*: *Advances and Potential. Proc. Intl. Symp.* 10-14 June, 1974, University of Guelph. K.J. Kasha (Ed.), University of Guelph, Canada, pp. 211-30.
5. Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers*, Indian Council of Agricultural Research, New Delhi, 381 p.

***Short communication*:** The text including table(s) and figure(s) **should not exceed five typed pages**. It should have a short **title**; followed by name of **author(s)** and **affiliation**, **Abstract** (100 words), **Key words** (3-5), **Short research paper** and **References (7 max.)**. There should be no sub-headings, *i.e.* Introduction, Materials and Methods, Results & Discussion etc. The manuscript should be in paragraphs mentioning the brief introduction of the of the topic and relevance of the work, followed by a short description of the materials and the methods employed, results and discussion based on the data presented in 1 or 2 table(s)/ figure(s) and a short conclusion at the end.

General instructions

- All the manuscript should be typed double-spaced on one side of A4 size paper with proper margin.
- Generic and specific names should be italicized throughout the manuscript. Similarly, the vernacular names are to italicized.
- Each table should have a heading stating its content clearly and concisely. Place at which a table is to be inserted should be indicated in the text by pencil. Tables should be typed on separate sheets, each with a heading. Tables should be typed with the first letter (T) only capital, table No. in Arabic numerals. All measurements should be in metric units.
- Data to be presented in graphical form should be sent on quality glossy contrast paper without folding. Each illustration must be referred to in the text and Roman numerals should be used in numbering. Photograph(s) of good contract must be mounted on hard paper to avoid folding and a separate sheet must be given for the title for each photograph sent as figure.
- At the bottom of the first page present address of the corresponding author, **E-mail ID** etc. must be specified.
- Revised manuscript is acceptable in duplicate along with a **CD/E-mail**. It is essential to cite related research papers published in Indian Journal of Horticulture and other horticultural journals and update the references while revising a manuscript.
- No reprint of the published article will be supplied to the authors.
- Article forwarded to the Editor-in-Chief for publication is understood to be offered to INDIAN JOURNAL OF HORTICULTURE exclusively. It is also understood that the authors have obtained a prior approval of their Department, Faculty or Institute in case where such approval is a necessary.
- **Acceptance of a manuscript for publication in Indian Journal of Horticulture shall automatically mean transfer of Copyright to the Horticultural Society of India. At the time of acceptance of a manuscript, all the authors should be the annual member of the Society.**
- The Editorial Board takes no responsibility for the fact or the opinion expressed in the Journal.
- Electronic submission of manuscript : www.indianjournals.com; hsi42@rediffmail.com
- **All submissions should strictly follow journal format. Deviation from format and exceeding the page limit are liable for non-starter of the review process and further processing. Up-to-date literature must be cited. Avoid self citation.**

CONTENTS

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