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Evaluation of maize (*Zea mays*) cultivars under organic production system in north-western Indo-Gangetic Plains of India

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ABSTRACT

Increased awareness of environmental degradation and growing concern of human health has attracted worldwide attention towards organic farming. A field experiment was carried out during *kharif* of 2013–2014 to identify suitable maize (*Zea mays* L.) cultivars having high yield potential under organic production system. Twelve released cultivars of maize varied in duration and nitrogen requirement were evaluated. Results revealed that late maturing cultivars PMH-1 and PMH-3 being at par to each other recorded the significantly higher values of growth parameters like plant height, dry matter accumulation and leaf area index; and yield attributes in terms of cobs plant, cob length, cob girth, grain rows/cob, grains/row and test weight, whereas the extra early cultivars like Vivek QPM-9 being at par with Vivek Hybrid-9 registered the lowest values of growth and yield attributes. The late maturing cultivars like PMH-1, PMH-3, Seed tech-2324 and Bio-9681 produced significantly higher grain yield (>5.0 t/ha) and biological yield (>12.5 t/ha). Cultivars PMH-4 among medium maturity group produced comparable yield with late cultivars. Grain yield across the varied duration cultivars had a significant positive correlation with cob length, grains/row and N uptake. As per their maturity class, the extra early and early cultivars commence silking (<50 days) and physiological maturity (<82 days) significantly earlier than medium and late cultivars. Moreover, extra early cultivars (Vivek Hybrid-9 and Vivek QPM-9) recorded significantly higher protein content in grain amongst the cultivars tested. The late cultivars PMH-1 and PMH-3 being at par with each other recorded the highest N, P and K uptake in plants while lowest nutrient uptake was observed in the extra early Vivek QPM-9 and Vivek Hybrid-9. Late cultivar PMH-3 followed by PMH-1 recorded the highest net returns (₹ 66,759) and B:C ratio (1.79) of organic maize cultivation. Soil fertility status in terms of organic carbon, available P and K could not be influenced significantly, however the available N content was significantly higher under extra early cultivars Vivek QPM-9 (172.1 kg/ha) and Vivek Hybrid-9 (170.3 kg/ha). Thus, it can be concluded that PMH-1 and PMH-3 cultivars of maize are most suitable for growing in north-western plains region of Uttar Pradesh under organic production system.

Key words: Cultivars, Indo-gangetic plains, Maize, Organic Production, Productivity.

Maize (*Zea mays* L.) is the third most important food grain in India after wheat and rice. Besides its use for human food and animal feed it is also widely used for corn starch industry, corn oil production, baby corns etc. In India, about 28% of maize produced is used for food purpose, about 11% as livestock feed, 48% as poultry feed, 12% in wet milling industry and 1% as seed (Layek *et al.* 2016). Increased awareness of environmental degradation and growing concern of human health due to indiscriminate use of fertilizers and pesticides in post Green Revolution era has attracted worldwide attention towards organic farming. As organic manure increases soil productivity by enhancing soil physical, chemical and biological properties (Patel *et al.* 2014). The application of organic sources of nutrients not only supplies all essential nutrients but also facilitates the growth and development of beneficial microbes, assists better uptake of nutrients by crop plants and counteracts the harmful effect of agrochemicals (Bana *et al*. 2012). Hence, organic farming is considered as one of the best option for protecting and sustaining soil health and produce healthy food (Das *et al.* 2010). Due to its diverse agro-climatic conditions India is bestowed with potential to produce all kind of organic products. However, organic agriculture is often criticized as low-yielding as several yield trial have shown significantly lower yields for organic systems (Ryan *et al*. 2004). Hence, the major challenge of organic farming systems is to maintain high yields and excellent quality (Tilman *et al*. 2002). It is estimated that more than 95% of

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organic agriculture is based on crop varieties that were bred for the conventional high-input sector; lacking important traits required for organic and low-input production conditions (Bueren *et al*. 2011). For getting desired result from organic farming, organic input responsive varieties are to be identified. Hence, this study was conducted to identify maize varieties that perform better under organic production system in North-western plain regions of Uttar Pradesh.

MATERIALS AND METHODS

A field experiment were conducted for two consecutive years (2013-2014) at the Research Farm of the ICAR-IIFSR, Modipuram (UP), India (29.4' N latitude, 77.5' E longitude and 230 m amsl). Modipuram falls under the north-western plain agro-climatic zone. The climate of Modipuram is broadly classified as semi-arid sub-tropical characterized by very hot summers and cold winters. The rainfall during cropping season from June to October was 808.2 mm and 209.6 mm during 2013 and 2014, respectively. The soil at site was Typic Ustochrept deep sandy loam in texture, alkaline in reaction (pH 8.2), low in organic carbon (0.355%) and available N (141.2 kg/ha); medium in available P (11.2 kg/ha) and available K (166.3 kg/ha).

In the experiment 12 cultivars of maize; selected based on crop duration and nutrient requirement were evaluated under organic conditions (Table 1) to identify potential varieties suitable for growing in organic conditions under prevailing agro-climatic conditions. The experiment was laid out in randomized complete block design with three replications. The crop was grown using all the organic inputs at a spacing of 60 × 20 cm during first week of July, each year maintaining gross plot area of 5.0 × 4.0 m. For nutrient management, organic sources like FYM, vermicompost and green manure were applied on the basis of nitrogen (N) equivalent to meet the requirement of recommended dose of fertilizers N, i.e. 120 kg N/ha. Prophylatic plant protection was attempted through bioagents (Table 2). On the basis of rainfall, need based irrigations at critical stages (knee high stage, flowering and grain filling) were applied and weeding was done manually.

For observations, five plants, randomly sampled from each plot, were tagged and plant height, dry matter accumulation, yield parameters (cobs/plant, cob length, cob girth, grain rows/cob, grains/row and 1000-seed weight) were recorded at harvest. Crop phonological parameters like days to 50% silking and days to maturity were measured based on visual observations. Leaf area of selected plants was measured at days to 50% silking stage with the help of leaf area meter and then converted into leaf area index

Table 1 Details of maize cultivars evaluated under organic conditions

Cultivar	Maturity group	Maturity duration	Nutrient requirement
PMH -1	Late	110	Performed better at low N
PMH -3	Late	110	Responsive to higher doses of fertilizers
Seed tech- 2324	Late	100-110	Performed better at low N
Bio- 9681	Late	110	Performed better at low N
HQPM-1	Late	110	Responsive to higher doses of fertilizers
PMH -4	Medium	95	Responsive to higher doses of fertilizers
Bio- 9637	Medium	95	Performed better at low N
HQPM-5	Early	80	Responsive to higher doses of fertilizers
Prakash*	Early	80	Performed better at low N
PMH-5	Early	80	Performed better at low N
Vivek Hybrid-9	Extra early	75	Performed better at low N
Vivek QPM- 9	Extra early	75	Performed better at low N

Table 2 Details of organic inputs used in maize cultivation

Input	Rate of application	Time of application	Nutrient Content (%) (mean of two years)		
			N	P_2O_5	K_2O
Nutrient management					
FYM	6.0 t/ha (equivalent to 30 kg N/ha)	10 days before sowing	0.51	0.30	0.65
Sesbania green manuring	2.62 t/ha dry matter (equivalent to 60 kg N/ha)	20 days before sowing	2.25	0.41	3.01
Vermi compost	2.5 t/ha (equivalent to 30 kg N/ha)	30 days after sowing	1.28	0.47	1.39
Neem cake	0.25 t/ha	10 days before sowing	4.15	0.78	1.54
Azotobactor culture	30 g/kg seed	Seeds treatment			
PSB culture	5 kg/ha	Soil treatment			
Plant protection					
Pseudomonas fluorescence	10 g/kg of seed	Seed treatment			
Trichoderma harzianum	4 g/kg of seed	Seed treatment			
Trichogramma chilonis	1 lakh eggs/ha	5-6 times at 7-10 days intervals starting from 15 DAS			

Result and Discussion

following Watson (1947). At harvest, grain and stover yield was estimated from each plot from a net area of 2.0 × 2.0 m and the yield was then converted to q/ha. Harvest index was obtained through the ratio of grain yield/biological and expressed as percentage. Separate replicated plant samples of each cultivar were collected and analyzed for N, P and K content in grain and stover and NPK uptake by cultivars. Protein content in grain was estimated by multiplying N content with standard factor of 6.25. Soil samples up to the depth of 15 cm were collected at the end of cropping cycle and analyzed for organic carbon and available N, P and K content by following standard laboratory procedures. Economics of growing different cultivars under organic conditions was calculated based on prevailing market price of inputs and output.

The data pertaining to each parameter were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by F test (Gomez and Gomez 1984). Where significant differences were detected, the means were separated by the least significant difference (LSD) at 5% probability level. Interrelationships among traits were estimated using the Pearson's correlation coefficient.

RESULTS AND DISCUSSION

Growth and development parameters: The mean values of the growth attributes and developmental parameters evaluated in this study showed significant differences for these traits ($P<0.05$) suggest the existence of wide variation in the cultivars. A perusal of data on growth parameters (Table 3) shows that mean values of plant height among the cultivars was 215±21.0 cm, which ranged from 243–187 cm. Cultivar PMH-3 had the significantly highest plant height (243 cm) followed by PMH-1 (240 cm), while Vivek QPM-9 was observed as shortest cultivar. As plant height is a genetically controlled factor so the height of different cultivars varied significantly. These results are in accordance with Ali (1994). Dry matter accumulation and leaf area index were also follows the same trend with mean values of 117±13.9 g/plant and 3.4±0.4, respectively. Early maturing varieties required fewer heat units to reach flowering, while late maturing cultivars exhibited extended vegetative period. Therefore, early flowering maize plants are smaller (plant height) and have fewer leaves (low leaf area index) with low grain yield compared with late cultivars (Khan *et al*. 2011).

In terms of development parameters, the cultivars differed significantly in terms of days to 50% silking and days to maturity with mean values of 55.3±6.8 and 93.9±14.6 days, respectively. Late cultivars such as PMH-1, PMH-3, Seed tech-2324 and Bio-9681 took more than 60 days for silking while early and extra early cultivars such as HQPM-5, Prakash, PMH-5, Vivek Hybrid-9 and Vivek QPM-9 commenced silking before 50 days after sowing. Crop duration for maturity of different cultivars followed similar trend to that of silking (Table 3). These results were expected as the cultivars were of different maturity classes (early, late and intermediate), different genetic backgrounds and bred for different traits. These results followed the trends of Layek *et al*. (2016).

Yield attributes and yield: Yield attributes and yield of maize were significantly influenced by cultivars under organic production system (Table 3). In general, the late and medium duration cultivars recorded higher values of yield attributes as compared to early and extra early varieties. The highest number of cobs/plant (1.4) was recorded in late cultivars PMH-1 while lowest in extra early cultivar Vivek QPM-9 (1.2); where mean across the cultivars was 1.3±0.1. In general maize taller plants produced higher numbers of cobs than the shorter ones (Dilshad *et al.* 2001). The length of the cobs also varied significantly among the cultivars and it ranged from 18.7 cm in PMH-3 to 13.7 cm in Vivek QPM-9 with a mean length of 16.2±1.4 cm. Significant variation was obtained in number of grain rows/cob and number of grains/row among the cultivars with mean values of 13.4±1.0 and 14.6±1.1, respectively. Number of grain rows/cob and number of grains/row were ranged from 11.1 and 12.7 in Vivek QPM-9 to the highest value of 14.7 and 17.2 in PMH-3, respectively (Table 3). Test weight of cultivars also differs significantly with mean value of 261±15.3. As the final grain weight depends largely on grain filling duration hence it followed the same trend as in yield attributes. A higher N uptake from soil or remobilization of N from vegetative tissues to grains after silking delays leaf senescence prolongs grain filling period producing heavier grains. Hence, late cultivars which had a less rapid silking produced heavier seeds amongst all the varieties and corroborate the findings of Cantarero *et al*. (1999).

The maize cultivars also differed significantly in terms of grain and biological yield with mean values of 48.3±6.0 and 119.0±13.5, respectively (Table 3). Late/medium duration cultivars out-yielded early maturing ones. It is generally recognized that long duration cultivars produced greater yield by enabling metabolic transformation into grain and stover yields for a long duration (Wang *et al*. 2011). The highest grain and biological yield was recorded by late cultivars PMH-3 (5.83 and 14.07 t/ha, respectively) followed by PMH-1; while, the lowest grain and biological yield was recorded in extra early cultivars Vivek QPM-9 (4.02 and 9.91 t/ha, respectively). Among others, one medium duration cultivars PMH-4 also recorded comparable grain yield (5.05 t/ha) to late cultivars. Two sequential events one as a sink of pollinated kernels capable of further development must be created and these must be supplied with photosynthates over the period of their development; are reportedly involved in the production of grain yield in maize (Duncan 1975). Hence, higher values of growth and yield attributes in late cultivars resulted in higher seed yield. Harvest index being a genetic character could not influence significantly among the cultivars tested (Table 3). The highest harvest index was found in HQPM-5 (41.5%); whereas, the minimum was recorded in Vivek Hybrid-9 (39.9%).

Table 3. Growth parameters, yield attributes, yield and quality of maize cultivars under organic cultivation (mean data of two year)

Cultivar	Plant height (cm)	DMA (g/plant)	LAI	Days to 50% silking	Days to maturity	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Grain rows/ cob	Grains/ row	Test weight (g)	Grain yield (t/ ha)	Biological yield (t/ ha)	Harvest Index (%)	Protein content (%)
PMH-1	240	131	3.89	63.8	110	1.4	17.7	14.3	14.3	15.3	287	5.67	13.68	41.1	10.1
PMH-3	243	137	4.04	64.0	112	1.3	18.7	15.0	14.7	17.2	282	5.83	14.07	41.0	10.0
Seed tech-2324	239	128	3.78	62.4	108	1.3	17.2	14.0	14.3	14.7	280	5.27	12.87	41.0	10.1
Bio-9681	235	126	3.69	61.9	109	1.3	17.0	13.7	13.9	15.2	255	5.14	12.67	40.6	9.8
HQPM-1	193	105	3.11	59.4	103	1.2	15.1	13.6	12.6	14.1	245	4.26	10.65	40.5	10.7
PMH-4	224	121	3.62	54.9	94	1.3	16.8	14.1	13.9	14.6	254	5.05	12.47	39.5	9.8
Bio-9637	206	116	3.19	56.2	98	1.3	15.6	13.9	13.5	14.3	250	4.60	11.21	40.6	10.3
HQPM-5	194	113	3.17	48.6	81	1.2	15.4	14.0	12.7	14.2	241	4.30	10.69	41.5	9.9
Prakash	217	118	3.55	48.6	82	1.3	16.7	13.9	13.6	14.7	257	4.92	12.45	40.2	9.7
PMH -5	213	117	3.21	48.8	79	1.3	15.8	13.6	13.5	14.7	270	4.77	11.85	40.3	10.1
Vivek Hybrid-9	190	98	3.05	47.4	76	1.3	15.2	12.6	12.3	13.7	253	4.10	10.30	39.9	10.4
Vivek QPM-9	187	89	2.97	47.7	75	1.2	13.7	12.2	11.1	12.7	253	4.02	9.91	40.6	10.8
Mean	215±21.0	117±13.9	3.4±0.4	55.3±6.8	93.9±14.6	1.3±0.1	16.2±1.4	13.7±0.7	13.4±1.0	14.6±1.1	261±15.3	4.83±0.6	11.9±1.3	0.41	10.1±0.3
SEm±	4.85	2.90	0.10	1.91	1.6	0.10	0.418	0.481	0.37	0.35	5.20	0.20	0.45	0.01	0.20
LSD (P=0.05)	14.2	8.5	0.28	5.61	5	0.3	1.2	1.4	1.1	1.0	15.2	0.6	1.33	NS	0.6

Correlation among traits in maize cultivars: Among yield attributes the highest significant correlation of grain yield was observed with cob length (coefficient of determination R^2=0.93) followed by that between grain yield and grains/row (R^2=0.78). Cob length was found to be highly positively correlated with dry matter accumulation (R^2=0.91) and leaf area index (R^2=0.93); whereas leaf area index was found significantly positively correlated with N uptake (R^2=0.860). Earlier studies also reported that grain yield in maize was related to the number of cobs, grain rows, grains/row and test weight (Dhillon 2001). In this study, the late maturing variety PMH-3, which produced heavy cobs (cob length and girth) also produced highest grain yield. Ultimately by contributing to growth and yield parameters, N uptake contributed significantly to grain yield (R^2=0.94).

Quality: Protein content in grain with mean value of 10.1±0.3 differed significantly amongst the cultivars evaluated (Table 3). Extra early cultivars such as Vivek Hybrid-9 and Vivek QPM-9 being at par; recorded higher protein content in grain (10.8 and 10.4%, respectively); while the lowest being in Prakash (9.7%). This may be due to specific trait of QPM and sufficient supply of N to plants for protein synthesis.

Nutrient uptake: Among the cultivars, the late maturing cultivars registered higher nutrient uptake than early and extra early maturing cultivars and registered significant differences in terms of N, P and K uptake (Table 4). The significantly highest N and K uptake was recorded in PMH-3 while highest P uptake was recorded in PMH-1. The lowest amount of nutrient (N, P and K) uptake was recorded in Vivek QPM-9. Cultivar PMH-3 recorded 33.5, 33.0 and 40.6% higher N, P and K uptake over Vivek QPM-9. Sufficient amount of plant biomass accumulation due to higher plant height, dry matter and cob parameters in terms of length and girth for comparatively longer duration resulted in higher nutrient uptake in late duration cultivars.

Economics: Amongst the cultivars, the highest net returns (₹ 66759) and B:C ratio (1.79) was obtained in PMH-3 closely followed by PMH-1. However, the lowest net returns and B:C ratio were recorded in Vivek QPM-9 (Table 4). It was due to yield differences among the cultivars as the production cost being the same except for meager differences in seed cost of each variety.

Soil properties: Organic manures were reported to improve the soil organic carbon, available N, P and K in soil, thereby sustaining the soil health (Das *et al.* 2010). The highest soil organic carbon was recorded under cultivar PMH-1 (0.401%) and PMH-3 (0.399%) followed by Seed Tech-2324 and Bio-9681. But the difference was not statically significant (Table 5). The differences in available P and K content in the soil were non-significant due to different varieties. However, significantly highest soil available N was observed under cultivar Vivek QPM-9 (172.1 kg/ha) followed by Vivek Hybrid-9 (170.3 kg/ha). It may be due to lower uptake of N from soil due to lower yield potential of these cultivars (Layek *et al*. 2016). Application of FYM, vermincompost along with green manure helps in proper nutrition and maintenance of soil fertility in maize fields replenishing the required nutrients which in turn help in getting the optimum grain yield and harvest index of maize varieties.

Table 4 Nutrient uptake and economics of maize cultivars under organic cultivation (mean data of two year)

Cultivar	Nutrient uptake (kg/ha)			Economics*		
	N uptake	P uptake	K uptake	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
PMH-1	114.2	24.3	85.4	101167	63971	1.72
PMH-3	117.2	23.4	86.9	103955	66759	1.79
Seed tech-2324	107.6	22.2	80.2	94214	57017	1.53
Bio-9681	101.4	22.1	80.9	92171	54975	1.48
HQPM-1	92.8	18.8	67.3	76500	39303	1.06
PMH-4	98.0	20.7	77.6	90485	53288	1.43
Bio-9637	95.9	19.5	69.9	82222	45026	1.21
HQPM-5	87.6	19.6	67.9	77171	39974	1.07
Prakash	98.3	21.6	79.0	88649	51453	1.38
PMH -5	98.4	21.1	75.3	85619	48423	1.30
Vivek Hybrid-9	87.8	18.5	66.4	73776	36580	0.98
Vivek QPM-9	87.8	17.6	61.8	72008	34812	0.94
SEm±	3.73	0.96	3.34			
LSD (P=0.05)	10.9	2.8	9.8			

Cost of maize cultivation under organic farming = ₹ 37196/ha; sale price of organic maize = ₹ 15.72/kg (MSP+ 20% premium price)

Table 5 Soil properties (0-15 cm) under organic cultivation of different maize cultivars (mean data of two year)

Cultivar	Organic Carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
PMH-1	0.401	156.0	10.5	166.1
PMH-3	0.399	154.7	10.0	162.1
Seed Tech-2324	0.393	153.5	10.5	168.0
Bio-9681	0.393	152.4	10.4	168.1
HQPM-1	0.391	146.2	11.8	173.1
PMH-4	0.395	156.6	11.0	168.8
Bio-9637	0.390	144.6	11.6	170.8
HQPM-5	0.391	144.8	11.3	172.2
Prakash	0.389	142.3	10.7	170.0
PMH-5	0.385	142.7	10.6	170.7
Vivek Hybrid-9	0.387	170.3	11.8	173.2
Vivek QPM-9	0.389	172.1	11.7	174.9
SEm±	0.011	3.13	0.60	3.34
LSD (P=0.05)	NS	9.0	NS	NS

Hence, the present study demonstrates that the late maturing cultivars like PMH-1, PMH-3, Seed tech-2324 and Bio-9681 produced significantly higher grain yield (>5.0 t/ha) and biological yield (>12.5 t/ha) by registering higher values of growth parameters, yield attributes and nutrient uptake as compared to early and extra early cultivars. Late maturing cultivar also recorded the higher net returns and B:C ratio of organic maize cultivation. Amongst the late maturity group PMH-3 being at par with PMH-1 recorded the highest grain yield (5.67 t/ha) and net returns (₹ 66759/ha) but considering their maturity duration (110 days) they fit well in maize-wheat system of the region. Medium maturity cultivar PMH-4 having average maturity of 94 days and comparable yield (5.05 t/ha) and net returns (₹ 53288/ha) can be a option for maize-potato cropping system in the region as it save around 15 days with mere sacrifice in returns around ₹ 10000/ha. Thus, it can be concluded that according to prevailing cropping system late cultivars PMH-1and PMH-3 and medium duration PMH-4 cultivars of maize can be promoted for organic cultivation in north-western plain region of Uttar Pradesh.

REFERENCES

Ali Z. 1994. 'Comparative economic returns of different maize genotypes'. M Sc thesis, Department of Agronomy, University of Agriculture, Faisalabad. *Pakistan Journal of Life and Social Sciences* **6**(2): 118–20.

Bana R S, Gautam R C and Rana K S. 2012. Effect of different organic sources on productivity and quality of pearl millet and their residual effect on wheat. *Annals of Agricultural Research* **33**(3): 126–30.

Buerena Lammerts van E T, Jones S S, Tamm L, Murphy K M, Myers J R, Leifert C and Messmer M M. 2011. The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A review. *NJAS - Wageningen Journal of Life Sciences* **58**(3–4): 193–205.

Cantarero M G, Cirilo A G and Rade F H. 1999. Night temperature at silking affects kernels set in maize. *Crop Science* **39**(3): 703–10.

Das A, Patel D P, Munda G C and Ghosh P K. 2010. Effect of organic and inorganic sources of nutrients on yield, nutrient uptake and soil fertility of maize (*Zea mays*) – mustard (*Brassica campestris*) cropping system. *Indian Journal of Agricultural Sciences* **80**: 85–8.

Dhillon B S. 2001. Maize. *Breeding Field Crops: Theory and Practice*. Chopra V L (Ed). Oxford and IBH Publishing Company Pvt. Ltd., New Delhi, India. pp 147–85.

Dilshad M D, Lone M I, Ghullam J, Malik M A, Yousaf M, Khalid R and Shamin F. 2001. Integrated plant nutrient management on maize under rain-fed conditions. *Pakistan Journal of Nutrition* **9**(9): 896–901.

Duncan W G. 1975. Maize. In: *Crop Physiology: Some Case Histories*. Evans L T (Ed.). Cambridge University Press, London, UK. pp 23–50.

Gomez K A and Gomez A A. 1984. *Statistical Procedure for Agricultural Research*. International Rice Research Institute. 2nd edn. John Wiley and Sons, New York and Singapore.

Khan K, Sher H, Iqbal M. and Al-Qurainy F. 2011. Development and release of indigenous maize hybrids to enhance maize yield in Khyber-Pakhtoonkhua province of Pakistan. *African Journal of Agricultural Research* **6**(16): 3789–92.

Layek J, Ramkrushna G I, Suting D, Ngangom B, Krishnappa R, Utpal De and Das A. 2016. Evaluation of maize cultivars for their suitability under organic production system in North eastern hill region of India. *Indian Journal of Hill Farming* **29**(2): 19–24.

Patel D P, Das A, Kumar M, Munda G C, Ngachan S V, Ramkrushna G I, Layek J, Naropongla B J and Somireddy U. 2014. Continuous application of organic amendments enhances soil health, produce quality and system productivity of vegetable based cropping systems at subtropical eastern Himalayas. *Experimental Agriculture* doi: 10.1017/S0014479714000167.

Ryan M H, Derrick J W and Dann P R. 2004. Grain mineral concentrations and yield of wheat grown under organic and conventional management. *Journal of the Science of Food and Agriculture* **84**: 207–16.

Tilman D, Cassman K G, Matson P A, Naylor R and Polasky S. 2002. Agricultural sustainability and intensive production practices. *Nature* **418**: 671–7.

Wang X, Chang J, Qin G, Zhang S, Cheng X and Li C. 2011. Analysis on yield components of elite maize variety Xundan 20 with super high yield potential. *African Journal of Agriculture Research* **6**(24): 5490–5.

Watson D. 1947. Comparative physiological studies in the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. *Annals of Botany* **11**: 41–76.