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Growth and yield response of maize cultivars to organic farming in central India

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Abstract
The field experiment was conducted at the Indian Institute of Soil Science, Bhopal to study the performance of twelve different maize cultivars under organic farming during *kharif* 2014 in a vertisol. The twelve varieties of maize viz. Kanchan, Arawali, Sona-222, JM-8, JM-12, JM-216, Pratap-5, Pratap-6, Proagro-4412, CPGB-4202, Popcorn-1 and Sweetcorn were grown in a randomized block design (RBD) with three replications under organic farming. The cultivars were raised with 100 kg N ha^{-1} through cattle dung manure, vermicompost and poultry manure in equal proportion (1:1:1) on nitrogen equivalent basis under under rainfed condition. The growth and yield attributes and yield of all the cultivars were recorded at periodic intervals (at 45 DAS, 75 DAS and Harvest). The results of the present study showed that the cultivar Proagro-4412 and Kanchan resulted in higher yield to the tune of 3.4 to 3.5 tons/ha. However Popcorn-1 and Sweetcorn were the least responsive cultivars under organic farming. Cultivars JM-12, JM-8 also resulted higher yield those were significantly lower than Kanchan and Proagro-4412. Most of the maize cultivars were able to perform under organic farming practices. Among the studied cultivars of maize, Proagro-4412 and Kanchan showed better performance as compared to rest varieties.

Keywords: Maize cultivars, organic farming, growth, yield, plant height

Introduction
The inadequacy of fertilizers (deficit of more than 10 million tonnes) and their cost are the major constraints for crop production. The difference between nutrient demand and supply is increasing in the country year after year and is need to be bridged for sustaining the crop productivity and soil health. The imbalanced use of chemical fertilizers threatens the sustainability of agricultural production as the long term field experiments have clearly visualized the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003) [22]. Organic farming is a holistic production management system that promotes and enhances health of agro-ecosystem related to bio-diversity, nutrient bio-cycle and soil biological and microbial activities. It is a form of agriculture that relies on technique such as crop rotation, green manure, compost and biological pest control (Subba Rao *et al.*, 2013) [18]. However, it has been assumed that the cultivation of high yielding varieties is not possible under organic farming as HYV demands more nutrients which cannot be fulfilled by organic sources due to slow release pattern but experimental findings revealed that nonetheless of slow in break down and supply rate of nutrients from the organic source, they still maintaining the good organic matter content which helps the plant to uptake nutrient for longer time (Sharma and Mittra, 1991; Vanlauwe *et al.*, 2004; Abou el-Magd *et al.*, 2005) [1, 15, 21]. The selection of variety for organic production plays important role in crop production. The identification of region specific cultivars of organic maize production has already been initiated in India (Layek *et al.*, 2016) [10]. Maize 'the queen of cereals' is one of the most potential cereals grown globally, and is the third after wheat and rice in total food grain production in the country. Maize is now widely cultivated around the world, and a greater weight of maize is produced each year than any other grain (Singh *et al.*, 2010) [17]. The state of Madhya Pradesh is one of the traditional and potential maize growing states, accounting for 13 per cent of the total maize area and contributing equally to the total maize production in the country. However, the productivity of maize in Madhya Pradesh is low if compared to that of other maize-growing states. Today the production level of maize is ranging been 4-8 t/ha depending upon soil type, climate, cultivars, management practices etc. Hence the response of maize cultivars to organic farming was studied with selected common varieties of maize.

Materials and Methods

The present study was conducted under Network Project on Organic Farming (NPOF) at Indian Institute of Soil Science, Bhopal during *kharif* 2014. The study site located at 23˚ 18' N, 77˚ 24' E and 485 m above mean sea level having sub-humid tropical climate with a mean annual air temperature of 25˚C and annual rainfall of 1208 mm. The soil of the experimental site is clayey in texture (*Typic Haplustert*), medium in organic C, slightly alkaline, and non-saline with low available N, medium P, and high K contents (Table 1).

Table 1: Initial properties of experimental soil (0-15 cm)

Soil characteristics	Value
Sand (%)	25.2
Silt (%)	18.0
Clay (%)	56.8
pH	7.85
EC (dS m^{-1})	0.50
Organic C (%)	0.67
Available N (kg ha^{-1})	154.2
Available P (kg ha^{-1})	12.77
Available K (kg ha^{-1})	530.2

The twelve varieties of maize viz. Kanchan, Arawali, Sona-222, JM-8, JM-12, JM-216, Pratap-5, Pratap-6, Proagro-4412, CPGB-4202, Popcorn-1 and Sweetcorn were selected for present study. The field experiment was laid in a randomized block design (RBD) with three replications under organic farming in *kharif* 2014. All the cultivars were sown in July with a spacing of 60 cm from row to row and 25 cm from plant to plant and harvested at physiological maturity in Mid-October. The cultivars were raised with similar dose of organic manures viz. cattle dung manure + vermicompost + poultry manure (1:1:1) meeting a total of 100 kg N ha^{-1} applied before sowing. The maize cultivars were grown under rainfed condition with standard package of practice of organic farming. Field observations were recorded at periodic intervals (at 45 DAS, 75 DAS and Harvest) on plant height, number of leaves per plant and biomass. The yield and yield attributes viz. number of cobs per plant, number of rows per cob, number of grains per cob, cob length and 100 seed weight were recorded at the harvest. The data obtained with respect to crop growth, yield attributes and yield were subjected for statistical analysis using WASP 2 software developed by ICAR Coastal Agricultural Research Institute, Goa. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P < 0.05$ confidence level using ANNOVA statistics as outlined by Gomez and Gomez (1984) [7].

Results and Discussion

Growth attributes of maize cultivars

Plant height

The plant height at 45 DAS varied between 71.2 and 108.0 cm among different maize cultivars (Table 2). The highest plant height was recorded for CPGB-4202 followed by var. JM-12 (107.9 cm) and JM-8 (104.9 cm). The lowest plant height was recorded for var. Sona-222 (71.2 cm). The plant height recorded for var. CPGB-4202, JM-12, JM-8, Pratap-5 and Pratap-6 was statistically significant over all other varieties. Similarly, the plant height recorded at 75 DAS was ranged from 125.1 cm for Popcorn-1 to 205.7 cm for Pratap-6. The var. Popcorn-1 and Sweetcorn showed lowest plant height as compared to other varieties. Further, at harvest stage, Pratap-6 showed significantly highest plant height (217.1 cm) followed by Sona-222 (191.4 cm) and JM-216 (190.2 cm). The varieties viz. Popcorn-1 and Sweetcorn showed poor performance with respect to plant height at all growth stages viz. 45 DAS, 75 DAS and at harvest stage (Table 2).

Table 2: Growth attributes of maize cultivars under organic farming

Maize Cultivar	Plant height (cm)			No. of Leaves $Plant^{-1}$ (at 75 DAS)	No. of Cobs $Plant^{-1}$	Cob length (cm)
	45 DAS	75 DAS	Harvest			
Kanchan	87.8	164.2	171.3	10.4	1.3	16.6
Arawali	81.1	170.0	173.8	9.7	1.2	13.5
Sona-222	71.2	189.1	191.4	11.1	1.3	14.2
JM-8	104.9	150.1	156.0	8.2	1.3	13.2
JM-12	107.9	166.6	170.1	9.3	1.2	12.7
JM-216	85.7	185.5	190.2	10.4	1.3	13.8
Pratap-5	95.6	159.9	166.0	9.3	1.1	13.9
Pratap-6	93.9	205.7	217.1	10.8	1.3	17.7
Proagro-4412	84.2	156.4	160.7	9.2	1.3	15.4
CPGB-4202	108.0	175.9	184.3	11.0	1.3	14.3
Popcorn-1	77.3	125.1	128.6	8.7	1.6	14.9
Sweetcorn	80.7	123.6	127.6	8.9	1.3	10.5
SEd (±)	8.7	10.2	10.8	0.5	0.2	1.2
CD (0.05)	18.0	21.1	22.3	1.0	NS	2.4

Number of leaves per plant, cobs per plant and cob length

The data revealed that, the number of leaves per plant ranged from 8.2 to 11.1 among different varieties under study. The var. Sona-222, CPGB-4202 and Pratap-6 showed significantly higher number of leaves per plant (11.1, 11.0 and 10.8, respectively) over other varieties whereas, var. JM-8 showed least number of leaves per plant (8.2). All maize varieties under present investigation were statistically at par with respect to the number of cobs per plant. However, the cob length was significantly varied among these varieties and it was ranged from 10.5 cm in var. Sweetcorn to 17.7 cm in var. Pratap-6. The maize varieties Kanchan, Proagro-4412, Popcorn-1, CPGB-4202 and Sona-222 were found statistically at par with respect to cob length (Table 2).

Yield attributes and yield of maize cultivars

Number of rows per cob, grains per row, grains per cob and seed index

The number of grains per row varied between 23.6 and 32.5 among different maize varieties. The var. Pratap-6, Popcorn-1, Kanchan, Proagro-4412 and Arawali were significantly superior over all other varieties whereas, it was statistically at

par with each other with respect to the number of grains per row. The data on 100 seed weight revealed that, it was statistically at par among all the varieties except for var. Sweetcorn and Popcorn-1 (Table 3).

Table 3: Yield attributes and yield of maize cultivars under organic farming

Maize cultivar	No. of rows cob^{-1}	No. of grain row^{-1}	No. of grain Cob^{-1}	Seed index (g)	Grain Yield (kg ha^{-1})	Total Biomass (kg ha^{-1})	Harvest Index
Kanchan	12.8	30.5	388.7	32.0	3426	7423	0.46
Arawali	13.1	28.2	365.9	27.3	2509	5605	0.45
Sona-222	12.7	25.1	306.7	30.7	2122	4873	0.44
JM-8	13.6	26.7	358.5	26.7	2971	6421	0.46
JM-12	12.0	25.3	300.8	28.0	2777	6064	0.46
JM-216	12.8	25.8	324.1	27.3	2309	5164	0.45
Pratap-5	12.7	26.7	330.2	28.7	2492	5407	0.46
Pratap-6	11.5	32.5	361.0	30.0	2494	5933	0.42
Proagro-4412	12.4	28.2	339.9	25.3	3499	8003	0.44
CPGB-4202	12.3	24.7	296.9	26.0	2223	4885	0.45
Popcorn-1	12.3	30.9	380.0	15.3	1665	3575	0.47
Sweetcorn	13.9	23.6	308.3	20.0	1538	3568	0.43
SEd (±)	0.6	2.1	37.1	3.6	139.6	147.2	0.02
CD (0.05)	NS	4.3	NS	7.5	290	305	NS

Grain yield, total biomass and harvest index

The cultivars Proagro-4412 procuced more stover biomass yield but statistically at par yield (3499 kg ha^{-1}) with Kanchan that recorded maximum grain yield of 3426 kg ha^{-1} (Table 3). With respect to JM-8 and JM-12 were statistically at par grain yield, however, JM-216 resulted in significantly lower yield. Cultivars Arawali, Pratap-5, Pratap-6 as well as CPGB-4202 produced significantly at par maize grain yield. Popcorn-1 and Sweetcorn produced the minimum grain yield of maize similar to stover yield. The total biomass production of maize cultivars ranged between 3568 kg ha^{-1} (Popcorn-1) and 8003 kg ha^{-1} (Proagro-4412). The second highest biomass production was recorded with Kanchan (7423 kg ha^{-1}) followed by JM-8. The behavior of Pratap-5 and Pratap-6 was also statistically different. The harvest index ranged between 0.42 (Pratap-6) and 0.47 (Popcorn-1) (Table 3).

Leaves, stalk and stover biomass

Leaves biomass

The data pertaining to dry leaf biomass of various maize varieties at 45 DAS, 75 DAS and at harvest stage has been presented in Table 4. The leaves biomass at 45 DAS ranged from 239 kg/ha in var. Sona-222 to 804 kg ha^{-1} in var. Proagro-4412. Cultivars Kanchan and Pratap-6 were next to Proagro-4412 but were statistically lower. Similarly JM-8, JM-12, Pratap-5 and CPGB-4202 further recorded statistically lower leaf biomass yield over the top 3 cultivars. Almost similar trend of leaf biomass yield was recorded at 75 DAS and at crop harvest stage where Popcorn-1 & or Sweetcorn recorded the lowest biomass yield and Proagro-4412 followed by Kanchan recorded the maximum leaf biomass yield (Table 4).

Table 4: Leaves, stalk and stover biomass of maize cultivars under organic farming

Maize cultivar	Leaves biomass			Stalks biomass			Stover biomass		
	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	Harvest	45 DAS	75 DAS	Harvest
Kanchan	559	1145	1269	657	2339	2728	1216	3484	3997
Arawali	325	815	912	565	1817	2184	890	2633	3096
Sona-222	239	521	829	388	1422	1922	627	1943	2751
JM-8	421	910	1052	552	1992	2398	973	2902	3450
JM-12	426	722	981	538	2006	2306	964	2728	3288
JM-216	320	661	827	468	1850	2028	789	2511	2855
Pratap-5	382	718	863	402	1575	2053	783	2293	2916
Pratap-6	568	980	1084	455	1565	2354	1023	2545	3438
Proagro-4412	804	1273	1404	756	2784	3101	1560	4057	4505
CPGB-4202	377	691	859	345	1504	1803	722	2195	2662
Popcorn-1	308	490	586	283	1047	1324	591	1536	1910
Sweetcorn	262	480	628	279	1119	1401	541	1599	2029
SEd (±)	44.5	41.2	47.2	23.6	79.1	48.5	57.7	88.5	71.1
CD (0.05)	92	85	98	49	164	101	120	183	147

*Values in kg ha^{-1}

Stalks Biomass

At 45 DAS the dry biomass yield varied between 283 and 756 kg ha^{-1} only. Cultivars Proagro-4412 and Kanchan were found to have high biomass yield while sweet corn and Popcorn-1 recorded the lowest biomass yield of 279 and 283 kg ha^{-1} respectively. Cultivars Arawali, JM-8 and JM-12 produced significantly at par biomass. Similarly JM-216 and Pratap-6 were at par for biomass production. Also, Pratap-5 and Sona-222 were statistically at par with each other in biomass production (Table 4).

At 75 DAS there was sharp increase in the dry biomass production that increased by 3 to 5 times over 45 DAS for different cultivars. At this stage Proagro-4412 again recorded the highest stalk biomass production of 2784 kg ha^{-1} which was significantly higher than Kanchan (2339 kg ha^{-1}) and JM-12. Many composite and hybrid varieties resulted in

statistically at par biomass stalk yield (Sona-222, JM-8, JM-12 and JM-216). Similarly Sona-222, Pratap-5, Pratap-6 and CPGB-4202 were statistically at par with each other in which stalk biomass varied between (1422 & 1575 kg ha^{-1}). At harvest, there was not much improvement in stalk biomass yield over 75 DAS and the increase over 75 DAS was around 20%. The dry stalk biomass yield varied between 1324 (Popcorn-1) and Proagro-4412 (3107 kg ha^{-1}). At harvesting Popcorn-1 and sweet corn were statistically at par with lowest biomass production followed by CPGB-4202 and Sona-222. Cultivars JM-12 and JM-216 were also at par with each other (Table 4).

Stover biomass

The data on stover biomass has been presented in Table 4. The stover biomass of maize cultivars at 45 DAS ranged between 541 and 1560 kg ha^{-1}. Sona-222, Popcorn-1 and Sweet corn cultivars recorded least stover biomass followed by CPGB-4202, Pratap-5 and JM-216. At this stage JM-8 and JM-12, Arawali were statistically at par with respect to stover biomass. The highest yield was recorded by Proagro-4412 (1560 kg ha^{-1}) followed by Kanchan and Pratap-6. At 75 DAS the crop picked up fast growth and the yield increased by 3-4 folds and ranged between 1536 and 4057 kg ha^{-1}. The behavior of cultivars was more or less the same. The highest stover yield was reorded by Proagro-4412 (4057 kg ha^{-1}) followed by Kanchan (3484 kg ha^{-1}). At harvest the total stover yield ranged between 1910 and 4505 kg ha^{-1} with a slight improvement of around 15% over 75 DAS. At this stage the lowest stover yield was observed under Popcorn-1 (1910 kg ha^{-1}) and Sweetcorn (2029 kg ha^{-1}) which was statistically lower than Sona-222 and JM-216. Further, JM-8 was statistically better over JM-12 and JM-216 with respect to stover yield at harvest and was at par with Pratap-6. Kanchan and Proagro-4412 were the highest producer of maize stover and were statistically different from selected each other (Table 4). Plants may not differentiate among the nutrients supplied through fertilizers or other organic sources; however, the adequacy of available nutrients during the crop growth may determine the productivity of a crop. The success of integrated nutrient management in maize crop has already been documented (Shilpashree *et al.*, 2012; Lone *et al.*, 2013; Kannan *et al.*, 2013; Ghaffari *et al.*, 2011; Ebrahimpour *et al.*, 2011; Meena *et al.*, 2018) [16, 11, 4, 13]. The data on the performance of different cultivars under organic farming has revealed that all the cultivars could be grown successfully with the 100 kg ha^{-1} N equivalent dose of organic manures through vermicompost, cow dung manure and poultry manure in 1:1:1 ratio. Significant variations in plant parameters were recorded among the cultivar with respect to plant height, number of leaves per plant, cob length, number of grains per row, number of grains per cob, 100 seed weight, leaves biomass, stalk biomass, grain yield, and total biomass of different maize cultivars which may be attributed to the genetic makeup of these cultivars and/or limited supply of nutrients from the manures. Jaime and Viola (2011) [8] also reported increased plant height, leaf area, pod number, as well as pod weight with application of cattle dung applied at the rate of 10 t ha^{-1} to cowpea in a mixed farming system. The growth of *kharif* crops is generally fast in the initial stages. Maize crop attained a height of 77-108 cm at 45 DAS. At this stage CPGB-4202, JM-12 and JM-8 were fast grown, however by 75 DAS the rate of growth was picked up by other varieties like Pratap-6, Sona-222 and JM-216. At crop maturity the same cultivars retained the maximum plant height. At 45 DAS there were some difference among the cultivars with respect to number of leaves per plant but at 75 DAS all were statistically at par with each other. Number of leaves per plant at maturity was recorded by Pratap-6 followed by Proagro-4412 and CPGB-4202. Some other parameters recorded at maturity have shown no difference among cultivars with regard to number of rows per cob and number of grains per cob. However, Pratap-6 recorded the highest number of grains per row followed by Popcorn-1 and Kanchan. The highest 100 seed weight was recorded by Kanchan however it was statistically at par with all the cultivars except Popcorn-1 and Sweetcorn (Table 3). The plant growth parameters such as plant height, number of leaves per plant, cob length, number of grains per row, number of grains per cob and 100 seed weight are genetically as well as environmentally controlled and different cultivars and hybrids have differences in these growth parameters. Besides environmental factors, the ability of plant to remove the soil nitrogen also influences the growth and different growth attributes of cultivars (Ehdaie and Waines, 2001) [5]. In our study, all maize cultivars differed significantly with respect to these parameters. Tahir *et al.* (2008) [19].also have reported that plant height ranged between 176 and 206 cm among different hybrids of maize in Pakistan. As far as the effects of environmental factors on plant growth parameters are concerned it could not be neglected but the selection of proper crop cultivar manages the influence of environment. These results are in accordance with the findings of Ali *et al.* (2012) who also reported significant differences in plant growth parameters of different maize hybrids. Leaves biomass ranged between 262 and 804 kg ha^{-1} at 45 DAS among different cultivars. It increased till harvest stage where it varied between 586 and 1404 kg ha^{-1}. The Proagro-4412 cultivar has been able to produce more leaf biomass than other cultivars followed by Kanchan and Pratap-6. The biomass yield of stalks was more than the leaves. In fact major share of biomass is held in stalks. The trend of biomass was similar to those of leaves of most of cultivars. Grain yield is the combined outcome of genetic potential and environment interaction and it is the ultimate objective of all the research. The variability in genetic potential among varieties is a major component of variable yield. The variability in the yield of maize in particular is also attributed to plant density, fertilizer use, water supply, weed control, insect pest management and the selection of cultivars under a given set of environments (Tahir *et al.*, 2008). The grain yield is related with many other agronomic parameters such as number of cob per plant, number of row per cob, number of grains per row and 1000-grain weight etc. So an increase or decrease in any of the above factors may influence the crop yield. The grain yield of maize cultivars ranged between 1538 kg ha^{-1} (Sweetcorn) and 3499 kg ha^{-1} (Proagro-4412). It is proportional to total biomass yield. The grain yield data indicated that maize cultivars varied significantly for grain yield (Table 3). Uribelarrea *et al.* (2004) [20]. Reported that, varieties that have been able to absorb and store nitrogen in their reproductive organs had more total biomass and grain yield due to the use of the absorbed material and more photosynthesis. McCutcheon *et al.* (2001) [21]; Olakajo and Iken (2001) [14] and Akbar *et al.* (2009) [9] have also reported significant differences in grain yield among different maize cultivars grown under similar conditions.

Conclusions

The cultivar Proagro-4412 and Kanchan resulted in higher yield to the tune of 3.4 to 3.5 tons/ha. However Popcorn-1 and Sweetcorn were the least responsive cultivars under organic farming. Cultivars JM-12, JM-8 also resulted higher yield those were significantly lower than Kanchan and Proagro-4412. Similar trend was observed with respect to stover yield. Most of the maize cultivars were able to perform under organic farming practices with the 100 kg N equivalent dose of organic manures (Cattle dung manure + Vermicompost + poultry manure). However, all the cultivars have been sown at one point of time, although some of them may be suited for early sown or late sown conditions. Thus their optimum potential under organic farming may be further assessed as per actual suitable time of sowing.

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