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Research Paper

Effect of organic, integrated and chemical sources of nutrient on growth and productivity of maize (*Zea mays*)

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ABSTRACT

A field experiment was conducted at Ludhiana, Punjab, during 2015–16 and 2016–17, to study the effect of organic, integrated and chemical sources of nutrition on growth and productivity of maize (*Zea mays* L.). Application of 50% recommended NPK + 50% N as FYM resulted in the maximum plant height, dry-matter accumulation, cob length, cob girth, grains/cobs, 100-seed weight, grain and stover yields than sole organic farming and chemical farming treatments. However, treatment with organic management package (T_2), comprising bio-fertilizer containing N and P carriers was at par with integrated application of nutrients through organic sources and fertilizers and significantly better than 100% recommended NPK application. Integrated management of nutrient application resulted in 12.52% more grain yield than 100% NPK. Treatment with organic management package (T_2) comprising bio-fertilizer containing N and P carriers exhibited 7.09% more grain yield than 100% NPK. The lowest value of growth and yield attributes was recorded with 50% N as FYM + bio-fertilizer (*Azotobacter*) for N + rockphosphate + phosphorus-solubilizing bacteria.

Key words: Bio-fertilizer, Fertilizer, FYM, Growth, INM, Maize, Yield

Maize (*Zea mays*) is one of the most versatile and widely cultivated cereal crops of the world. Maize is referred as the 'Miracle crop' or the 'Queen of cereals' because of its higher yield potential than any other cereal crop and adaptability to wide range of environments. It is highly productive crop and exhausts higher amount of nutrient from the soil. Production of maize has increased more than 17 times from a mere 1.73 million tonnes 1950–51 to 28.72 million tonnes in 2018–19 (FAOSTAT, 2019) and presently it occupies 9.22 million ha area with yield of 31.15 tonnes/ha. So, for maintaining the future sustainability of the maize, production will greatly depend on the improvement in soil resource base through the balance fertilizsation. Nutrient management by appropriate application of organic sources and micronutrients is essential to ensure optimal crop output. Furthermore, one of the most critical elements influencing maize crop development and yield productivity is fertilizer management (Ghosh *et al.*, 2020). Chemical fertilisers can alter soil *p*H, disrupt beneficial microbial ecosystems, increase pests, and possibly contribute to greenhouse gas emissions. Moreover, non-judicious application of chemical fertilizers in intensive cropping systems is the main reason for stagnation in productivity, insecurity in food and environmental hazards. The current NPK fertilizer consumption ratio is 10 : 2.9 : 1 as against optimal ratio of 4 : 2 : 1 (Walia and Kler, 2010). This non-judicious nutrient application by farmers causes multi-nutrient deficiencies. In this context, smart use of integrated nutrient management is one of the greatest options for ensuring long-term crop productivity, while maintaining soil fertility in maize and other cereal-based cropping systems. This ultimately improves crop yield (Garima and Pant, 2018).

MATERIALS AND METHODS

A long-term field experiment was conducted at Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, representing the Indo-Gangetic alluvial plains, situated at (30° 56' N, 75° 52' E and at an altitude of 247 m above mean sea-level). The climate of experimental site is characterized by sub-tropical semi-arid type with hot summers from April to June and very cold winters from November to January. The average annual rainfall is 705 mm, approximately 80% of which is received during July–September. The soil was loamy sand, having 172.4, 14.3 and 186.4 kg/ha of available N, P_2O_5 and K_2O, respectively, with a soil *p*H of 8.1, electrical conductivity (0.23

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ds/m) and organic carbon content of 0.31%. The experiment was laid out in randomized complete block design with 4 replications and 7 treatments in plot of 100 cm^2 size. The treatment comprised T_1, 50% recommended NPK + 50% N as FYM; T_2, different organic sources each equivalent to 1/3 of recommended N [FYM + vermi-compost + castor-cake (*Ricinus communis* L.)]; T_3, T_2 + intercropping Soybean, *Glycine max* (L.) Merr.); T_4, T_2 + agronomic practices from weed control [sowing of cowpea, *Vigna unguiculata* (L.) Walp.] between the row of maize and harvested at 40 days after sowing; T_5, 50% N as FYM + bio-fertilizer for N (*Azotobacter*) + rockphosphate + phosphorus solubilising bacteria (PSB); T_6, T_2 + bio-fertilizer containing N and P carriers; and T_7, 100% recommended dose of fertilizer (RDF, 125 : 60 : 30 kg/ha N: P_2O_5 : K_2O). The N, P and K were applied through urea, single superphosphate and muriate of potash, respectively. The recommended fertilizer dose (100% RDF) of N, P_2O_5 and K_2O was 125, 60 and 30 kg/ha, respectively in which one-third of N and full dose of P and K were applied basal. The remaining dose of N was divided into 2 equal parts and applied at knee high stage (30 days after sowing) and pre-tasselling stage (47 days after sowing) as per treatments. Organic manure, viz. FYM, vermi-compost and non-edible oil-cake (castor cake) were applied on the basis of N content as per the treatment 15 to 20 days before sowing in the riny season (*kharif*) of every year. The present study was undertaken on the above long-term nutrient-management experiment with maize cv. 'PMH 1' during the *kharif* 2015 and 2016. Plant height was recorded at 30 days after sowing (DAS) and after fortnightly interval from 5 random plants in central rows of each experimental unit. Plant height was measured from ground level to the base of whorl during early stages and base of the tassel at tasselling stage. Dry-matter accumulation was recorded with 2 representative plants selected at random from each plot and were sun dried and then dried in the oven at $60C^{\%}$ to a constant weight for recording dry weight of biomass. Total number of cobs from each net plot was divided by total number of plants at harvesting to calculate number of cobs per plant. At harvesting, 5 cobs from the sample of 5 randomly selected tagged plants from each plot were taken out and the length was measured with the help of centimetre scale and a mean was recorded as average length cm per cob. Length of unfilled area of five representative cobs from each plot was measured with the scale in centimeter and then mean values were worked out. Cob diameter of the above 5 representative selected cobs was measured with the help of a Vernier calliper from the base, centre and the top and then the 3 values were averaged out to give average girth (cm) of a single cob. Number of grains was counted in each 5 representative cobs from each plot and then means values were worked out for number of grains/cob. One hundred grains were counted from produce of each plot and then weighed in gram.

RESULTS AND DISCUSSION

Plant height

The maximum plant height (Table 1) was recorded at all intervals with the application of 50% N through FYM + 50% N through inorganic fertilizers (T_1) which was significantly better than 100% NPK and 50% N as FYM + bio-fertilizer + rock phosphate + PSB. The plant height increased at increasing rate from 30 to 60 DAS and after that slower increase was observed in plant height. Maximum increase in plant height was observed between 45 and 60 DAS. Data clearly showed that the application of 50% N through FYM + 50% N through inorganic fertilizers (T_1) resulted in tallest plants of maize at all the growth stages. This might be attributed to rapid meristematic cell-division and cell elongation, satisfactory moisture in FYM-treated plots. The application of 50% N through FYM + 50% N through inorganic fertilizers (T_1) was found statistically at par with 1/3 N FYM + 1/3 N vermicompost + 1/3 N castor-cake (T_2) and T_2 + bio-fertilizer containing N and P carriers (T_6) at 30, 45 and 60 DAS. But, at 75 and 90 DAS these

Table 1. Effect of organic, integrated and chemical sources of nutrient on plant height of maize

Treatment	Plant height (cm)	
	30 DAS	90 DAS
T_1, 50% recommended NPK + 50% N as FYM	39.4	213.0
T_2, One-third N (FYM) + one-third N (vermicompost) + one-third N (castor-cake)	37.5	206.9
T_3, + intercropping (soybean)	32.8	203.4
T_2, + agronomic practices from weed control	34.4	204.6
T_5, 50% N as FYM + bio-fertilizer + rockphosphate + PSB	26.0	188.8
T_2, + Bio-fertilizer containing N and P carriers	39.2	209.3
T_7, 100% NPK + secondary and micro-nutrients based on soil test report	29.7	194.6
SEm±	1.3	3.2
CD (P=0.05)	4.1	9.7

FYM, Farmyard manure; PSB, phosphorus-solubilizing bacteria; DAS, days after sowing results were also at par with T_2 + intercropping (soybean) (T_3) and T_2 + agronomic practices from weed control (T_4). Treatment with organic management packages (T_2) + bio-fertilizer containing N and P carriers (T_6) was found significantly better result than 100% NPK and 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB but at par with 1/3 N FYM + 1/3 N vermi-compost + 1/3 N castor-cake at all intervals. Treatment with organic management packages + bio-fertilizer containing N and P carriers (T_6) was also at par with treatment with organic management packages+ intercropping (soybean) (T_3) and treatment with organic management packages + agronomic practices from weed control (T_4) at 60, 75 and 90 DAS. Habib *et al*. (2012) and Joshi *et al*. (2013) also reported higher growth with combined application of chemical fertilizers and organic nutrient source as compared to sole inorganic fertilizers. The combination of organic fertilizers along with inorganic fertilizers provided better soil condition for plant growth and also corrected the deficiency of both macro and micronutrients to attain more crop growth.

Dry-matter accumulation

At 30 DAS, the dry matter accumulation (DMA) was non-significantly and after that the highest DMA was recorded under 50% N through FYM + 50% NPK as compared to 100% NPK through inorganic fertilizer (Table 2), but at par with organic treatment T_6 at 45, 60, 75 and 90 DAS and with T_2 at 60, 75 and 90 DAS. Dry-matter production of maize gradually increased with age of crop. The dry-matter accumulation was found significantly low in 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB as compared to treatment with organic management packages (T_2) + bio-fertilizer containing N and P carriers. Treatment with organic management packages + bio-fertilizer containing N and P carriers (T_6) recorded significantly highest DMA as compared to 100% NPK, but at par with treatment (T_2) at all intervals. At 75 and 90 DAS, treatment with organic management packages + intercropping (soybean) (T_3) and treatment with organic management packages + agronomic practices from weed control (T_4) was also at par with T_6 treatment. Application of 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB resulted in the minimum dry-matter accumulation due to un-adequate supply of plant nutrients. The highest DMA under 50% N through FYM + 50% NPK was owing to the higher nutrient availability in case of combined use of organic and inorganic sources of nitrogen (Sahoo *et al*., 2021). Haque *et al*. (2012) was also observed the highest DMA with integrated treatment.

Yield attributes of maize

The yield attributes of maize such as cob length, cob girth, grains/cob and 100- seed weight were significantly influenced by various treatments (Tables 3 and 4).

Number of cobs per plant: The cob-bearing capacity is one of the most important crop yield components. More or less cobs, it is the genetic character of any cultivar but some improvement can be expected owing to agronomic manipulations. The number of cobs per plant was not affected significantly by different sources of nutrients. Highest number of cobs per plant was observed with application of integrated sources of nutrient.

Cob length: Cob length was significantly higher under 50% N through FYM + 50% N through inorganic fertilizers (Table 3). Cob length was 3.6% more in 50% N through FYM + 50% N through inorganic fertilizers than chemical fertilizer. In organics, significantly highest cob length was observed with organic management packages + bio-fertilizer containing N and P carriers (T_6) as compared to treatment receiving 50% N as FYM+ bio-fertilizer (*Azotobacter*) for N + rockphosphate, but at par with T_2, T_3 and T_4 treatments. The chemical fertilizer treatment was also at par with organic and integrated treatment. The highest cob length was recorded owing to continuous application of

Table 2. Effect of organic, integrated and chemical sources of nutrient on dry-matter accumulation of maize

Treatment	Dry-matter Accumulation (g/plant)	
	30 DAS	90 DAS
T_1, 50% recommended NPK + 50% N as FYM	32.5	234.1
T_2, One-third N (FYM) + one-third N (vermicompost) + one-third N (castor-cake)	27.9	224.2
T_3, + intercropping (soybean)	27.1	219.1
T_4, + agronomic practices from weed control	27.5	220.0
T_5, 50% N as FYM + bio-fertilizer + rockphosphate + PSB	24.6	190.0
T_6, + Bio-fertilizer containing N and P carriers	31.0	228.9
T_7, 100% NPK + secondary and micro-nutrients based on soil test report	27.6	217.2
SEm±	0.53	3.18
CD (P=0.05)	NS	12.1

FYM, Farmyard manure; PSB, phosphorus-solubilizing bacteria; DAS, days after sowing

Table 3. Effect of organic, integrated and chemical sources of nutrient on yield attributes of maize

Treatment	Cobs/ plant	Cobs length (cm)	Unfilled portion of cob (cm)	Cob girth (cm)	Grains/ cob
T_1, 50% recommended NPK + 50% N as FYM	1.1	18.8	1.3	14.0	322.1
T_2, One-third N (FYM) + one-third N (vermicompost) + one-third N (castor-cake)	1.0	18.3	1.4	13.6	310.5
T_2, + intercropping (soybean)	1.0	18.1	1.4	13.3	302.0
T_2, + agronomic practices from weed control	1.0	18.2	1.4	13.5	306.4
T_5, 50% N as FYM + bio-fertilizer + rockphosphate + PSB	1.0	16.4	1.5	11.9	277.0
T_2, + Bio-fertilizer containing N and P carriers	1.1	18.5	1.4	13.7	316.1
T_7, 100% NPK + secondary and micro-nutrients based on soil test report	1.0	18.0	1.5	13.3	297.1
SEm±	0.012	0.3	0.017	0.3	3.6
CD (P=0.05)	NS	1.1	NS	1.1	10.8

FYM, Farmyard manure; PSB, phosphorus-solubilizing bacteria; DAS, days after sowing

Table 4. Effect of organic, integrated and chemical sources of nutrient on 100-grain wt., grain and stover yield of maize

Treatment	100-grain wt (g)	Grain yield (t/ha)	Stover yield (q/ha)
T_1, 50% recommended NPK + 50% N as FYM	29.5	53.9	94.9
T_2, One-third N (FYM) + one-third N (vermicompost) + one-third N (castor-cake)	26.9	51.3	90.6
T_2, + intercropping (soybean)	25.0	48.9+3.3	89.0+11.5
T_2, + agronomic practices from weed control	26.4	49.5	89.6+78.4
T_5, 50% N as FYM + bio-fertilizer + rockphosphate + PSB	23.7	42.8	75.9
T_2, + Bio-fertilizer containing N and P carriers	29.4	52.7	94.0
T_7, 100% NPK + secondary and micro-nutrients based on soil test report	26.4	47.9	86.3
SEm±	0.5	0.8	1.2
CD (P=0.05)	1.7	2.5	3.7

FYM, Farmyard manure; PSB, phosphorus-solubilizing bacteria; DAS, days after sowing

50% N through FYM + 50% N through inorganic fertilizer. This might be because of adequate and harmonized availability of nutrients during the period of crop growth which resulted in enhancement of the yield attributes. Pathak *et al*. (2005) also observed the similar findings.

Unfilled portion of the cob: Different nutrient sources did not affect the unfilled portion of the cobs significantly. Maximum unfilled area was observed in 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB as compared to the other treatments. The minimum unfilled portion was shown in integrated treatment. Unfilled portion of the cob in integrated and organic treatment (except T_5) was lower than chemical treatment due to longer availability of essential nutrient to crop in their later reproductive stage.

Cob girth: Application of 50% N through FYM + 50% N through inorganic fertilizers resulted in significantly higher cob girth than 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB (T_5), but at par with rest of the treatments. The increase in cob girth with the application 50% N through FYM + 50% N through inorganic fertilizers was to tune of 5.26% as compared to 100% NPK. Among organics, the highest cob girth was recorded with treatment receiving organic management packages + bio-fertilizer containing N and P carriers (T_6) (13.7 cm) as compared to treatment receiving 50% N as FYM + bio-fertilizer for N + rock phosphate + PSB (T_5) (11.9 cm) which was more than T_5. Treatment T_6 was found at par with T_2, T_3, T_4 and T_7 treatments. Kumar *et al*. (2007) recorded better yield attributes with application of 75% of recommended rate of N through fertilizer + 25% N through farmyard manure or sheep manure or poultry manure.

Number of grains per cob: The different sources of nutrients had shown significant effect no grains/cob. Number of grains/cob was significantly higher by 8.45% under 50% N through FYM + 50% NPK and 6.39% under treatment T_6 than 100% NPK. Higher number of grains/cob was owing to more cob length in 50% N through FYM + 50% N through inorganic fertilizers as compared to 100% NPK. These results are also in accordance with the results obtained by Balai *et al*. (2011). In organics, application of T_2 + Bio-fertilizer containing N and P carriers recorded (14.11%) more number of grains/cob as compared to 50% N as FYM + bio-fertilizer (*Azotobacter*) + rockphosphate + PSB.

100-grain weight: The significant difference in 100-grain weight was observed among different treatments (Table 4). Application of 50% N through FYM + 50% N through inorganic fertilizers resulted in the highest weight of grains which was significantly higher than chemical treatment but was statistically similar with treatment receiving organic management packages (T_2) + bio-fertilizer containing N and P carriers. Application of 100% NPK recorded 11.7% less grain weight than the integrated use of nutrient. Among organic treatments, the highest 100-grain weight was observed under treatment receiving organic management packages (T_2) + bio-fertilizer containing N and P carriers which was significantly better than rest of organic treatment and (24%) more grain weight as compared to treatment receiving 50% N as FYM+ bio-fertilizer for N+ rock phosphate+ PSB (T_5). Treatment receiving organic management packages+ bio-fertilizer containing N and P carriers (T_6) recorded 11.5% more grain weight than chemical treatment. Cheema *et al*. (2010) also find the highest grain weight with application of integrated treatment.

Grain yield

The highest grain yield (53.9 q/ha) was recorded under 50% N through FYM + 50% N through inorganic fertilizers and it was significantly higher than yield obtained under chemical (47.9 q/ha) but statistically at par with T_2 + bio-fertilizer containing N and P carriers (52.7 q/ha). The increase in grain yield under 50% N through FYM + 50% N through inorganic fertilizers was to the tune of 12.52% than 100% NPK. The highest maize grain yield among organic treatments was recorded in T_2 + bio-fertilizer containing N and P carriers (52.7 q/ha), which was significantly better than T_3, T_4, T_5 and chemical but at par with T_2. Treatment T_6 was recorded (25.9%) more grain yield than treatment T_5 and (12.5%) more than 100% NPK. Maize-equivalent yield in T_2 + intercropping (soybean) was observed 52.2 q/ha, being at par with integrated treatment. Sonawane *et al*. (2009) also reported better grain and dry fodder yield with combined application of nutrient due to improvement in yield parameter of maize crop. Application of organic manures because of combination with inorganic fertilizers not only enhanced the nutrient supply for higher grain yield, but also alters the soil physical and chemical properties which favour better crop growth and yield (Prasad *et al*., 2011).

Stover yield

Maximum stover yield (95.1 q/ha) was recorded under 50% N through FYM + 50% N through inorganic fertilizers and it was significantly higher than yield obtained under chemical (86.3 q/ha) but statistically at par with T_2 + bio-fertilizer containing N and P carriers (93.9 q/ha). The increase in stover yield under 50% N through FYM + 50% N through inorganic fertilizers was to the tune of 9.96% than 100% NPK. Application of T_2 + bio-fertilizer containing N and P carriers showed the highest maize stover yield as compared to T_3, T_4, T_5 and chemical treatments. It was on a par with T_2 treatment. Treatment T_6 recorded 23.8% more stover yield than T_5 and 4.91% more than chemical treatment. Maximum stover yield was found due to statistically better plant height (Table 1) and dry-matter accumulation (Table 2) under integrated treatment as compared to rest of the treatments. Manjhi *et al*. (2014) reported the maximum grain and stover yield under integrated treatment. Karki *et al*. (2005) also recorded similar result in the respect of grain and stover yield of maize.

It can be concluded that, long-term (16 years) application of 50% N through FYM + 50% N through inorganic fertilizers in maize was found to be the best in respect of growth, yield attributes and yield of maize. Among the organic farming treatments, T_2 + bio-fertilizer containing N and P carriers exhibited better results in all observations and also at par result with integrated treatment.

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