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Fertility Level and Plant Densities Affect the Productivity and Profitability of *Rabi* Maize (*Zea mays* L.) in Eastern-Gangetic Plains of India

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ABSTRACT

A field experiment was carried out in the farmer's fields of the Bhagalpur District of Bihar during the *rabi* seasons of 2016–17 and 2017–18 to ascertain the impact of high fertility levels and plant geometry on the productivity and profitability of *rabi* maize. There were total five treatments consisting of different plant geometry and fertilizer rate. The five treatments viz.,T_1- 60 × 20 cm spacing with 120:75:50 kg/ha (Farmers practice), T_2- 50 × 20 cm spacing with 150:93.75:62.5 kg/ha, T_3- 40 × 20 cm spacing with 150:93.75:62.5 kg/ha, T_4- 50 × 20 cm spacing with 180:112.5:75 kg/ha and T_5- 40 × 20 cm spacing with 180:112.5:75 kg/ha N, P_2O_5 and K_2O, respectively were arranged in a Randomized Block Design (RBD) with five replications. Polled data of two consecutive years revealed that all the higher fertility levels with reduced plant geometry produced higher yield attributes and yield of *rabi* maize and also sustained soil fertility as compare to the farmer's practice. Significantly, highest cob length (19.49 cm), cob girth (12.83 cm), 1000-grain wt (305.5 g), grain yield (115.94 q/ha) and net returns of INR 101434/ ha were recorded with 180 : 112.5 : 75 kg/ha N, P_2O_5 and K_2O with the plant spacing of 50×20 cm (T_4). Application of 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O at plant spacing 50 × 20 cm (T_2) being at par with 180:112.5:75 kg/ha N, P_2O_5 and K_2O with the plant spacing of 50 × 20 cm (T_4) and 180:112.5:75 kg/ha N, P_2O_5 and K_2O at plant spacing 40 × 20 cm (T_5).

Keywords Economics, Fertility levels, Maize, Planting geometry, Yield.

INTRODUCTION

Maize (*Zea mays* L.), commonly known as corn, is also called as Queen of Cereals due to high genetic yield potential and wide range of applicability. It is also used for various manufacturing like food, animal feed and raw material for ethanol, oil, disposable containers, fabrics, papers, plastics, proteins, starch,

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alcoholic beverages, cosmetics and biofuel. (Johnson *et al.* 2012, Fattah *et al.* 2019). It has high nutritional value, containing 70% carbohydrates, 10% protein and 4% oil (Godswill 2019). It is commercially very profitable due to higher market pricing and excellent production potential. Globally, 1147.7 mt of maize is being produced from an area of 193.7 million hectares with productivity of 5.75 t/ha (FAOSTAT 2020) and ranks third after rice and wheat in terms of acreage and production world wide. In India, *rabi* maize is grown in 1.2 million hectares with production of 5.08 million tonnes and productivity of 4.22 t/ha. The total area, production and productivity in Bihar under *rabi* maize is 0.323 million hectare, 2.325 million tonnes and 7.18 q/ha and under *kharif* 0.173 million hectare, 0.235 million tonnes and 13.52 q/ha, respectively (Directorate of Economics and Statistics, Bihar-2021-22). By the year 2018-19, its area has reached to 9.2 million ha and the production has increased 16 times in comparison to 1950-51. However, there is still remains tremendous untapped opportunity for further enhancing the maize production and productivity, especially in the states like Bihar having rich fertile soils, which finds prominent place in *rabi* maize production. It is now replacing upland rice in *kharif* and wheat in *rabi* season. Bhagalpur, Purnea, Begusarai, Samastipur, Khagaria and Katihar are the leading districts of Bihar in areas and production.

Rice-maize is the dominant cropping system that supports the livelihood of the rural people in Bihar. Although a number of factors influence the productivity of *rabi* maize. One of the most important factors among them is the management of nutrients and plant density. Crop response to fertilizers varies greatly from location to location, depending upon soil fertility level, environmental condition and genotype (Siddiqui *et al.* 2020). Farmers who cultivate *rabi* maize with hybrid varieties believe that maize planting densely and using more and more fertilizers gives more yield. Plant population has major role to influence crop growth and grain yield (Testa *et al.* 2016, Haarhoff and Swanepoel 2018). The yield of the crop will be higher, when the plant density optimum, hence optimizing the plant density is critical for enhancing maize productivity.

Keeping above facts in mind, the present study was undertaken to find out the optimum plant density of *rabi* maize with suitable fertility levels to achieve higher yield and profits.

MATERIALS AND METHODS

In order to determine the impact of high fertility levels and plant geometry on productivity and profitability of *rabi* maize, a field experiment was carried out by the Krishi Vigyan Kendra, Sabour, Bhagalpur, Bihar during the *rabi* seasons of 2016–17 and 2017–18 at a farmer's field in Bhagalpur, Bihar. The other purpose of this study was to validate, refine and popularize the technology for achieving higher productivity with balance use of fertilizer through optimum plant density. Participatory Rural Appraisal (PRA) was done to identify causes of low yield, profit and high cost of production involve in *rabi* maize. The mean value of physical and chemical characteristics of soils over the sites at the initiation of experiment indicated that, soil was clay loam with soil pH 7.16, EC 0.25 dS/m, organic carbon 0.39%, available N 150.30 kg/ha, P_2O_5 19.95 kg/ha and K_2O 147.40 kg/ha. Meteorological data of experimental site are presented in Fig.1. Rainfall during the first year was less but, distribution was good. However, during second year total rainfall was much higher during initial period of crop growth but, distribution of rainfall was very poor as compared to first year (Fig. 1). The five treatments viz., T_1- 60 × 20 cm spacing with 120:75:50 kg/ha (Farmers practice), T_2- 50 × 20 cm spacing with 150:93.75:62.5 kg/ha, T_3- 40 × 20 cm spacing with 150:93.75:62.5 kg/ha, T_4- 50 × 20 cm spacing with 180:112.5:75 kg/ha and T_5- 40 × 20 cm spacing with 180:112.5:75 kg/ha N, P_2O_5 and K_2O, respectively were arranged in a Randomized Block Design (RBD) with five replications. The unit plot size was 10 m × 10 m. As par treatment, the Isobilateral leaf type hybrids maize variety (Pioneer 3522) was planted in second week of November in flat bed during both the years. One third of the nitrogen and full quantity of P_2O_5 and K_2O was applied as basal in the form of urea, DAP and muriate of potash, while one third of N was applied after 25-30 days after planting at the time of earthing and remaining one third of nitrogen was top dressed at tasseling stage in the form of urea. Atrazine @ 1.0 kg a.i./ha as pre-emergence herbicide followed by one hand weeding and hoeing at 25-30

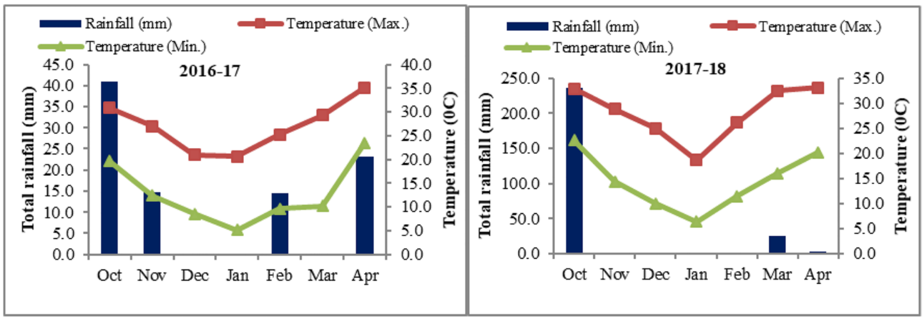

Fig. 1. Monthly average rainfall (mm), average maximum and minimum temperature (°C) in study location. Lines with filled triangles and squares represent the average minimum and maximum monthly temperatures, respectively, and bars represent the monthly average total rainfall.

DAS was done to control complex weed flora. All recommended cultural practices were followed for healthy *rabi* maize production. At the time of crop harvest, observations of growth and yield-attributing characteristics were made. The height of the plant was calculated from the soil's surface to the base of the tassel. When the cob sheath turned brown and the grains hardened, the crop was harvested. Both seed and stover yield were expressed as tone per hectare (t/ha). Shelling percentage was calculated by dividing the grain yield from cob weight and expressed in percentage. The monetary values of maize were calculated on the basis of minimum support price or prevailing market rate of products. Benefit: Cost ratio (B : C ratio) was expressed as ratio of net returns to cost of cultivation.

The production efficiency (PE, kg/ha/day) and monetary-efficiency (ME, INR/ha/day) was calculated using the following formulas :

$$\text{Production efficiency (PE)} = \frac{\text{Grain yield (kg/ha)}}{\text{Duration of crop in days}}$$

$$\text{Monetary efficiency (ME)} = \frac{\text{Net return (INR/ha)}}{\text{Duration of crop in days}}$$

RESULTS AND DISCUSSION

Growth and yield attributes

All the growth and yield attributes of maize (plant height, dry weight, cob length, cob girth and 1,000-seeds weight) were influenced significantly due to different fertility levels and plant geometry except grains per cob (Table 1). Significantly, highest dry weight (358.7 g), number of grains/cob (504.2), cob length (19.49 cm), cob girth (12.83 cm) and 1,000-grain weight (305.5 g) was recorded when the maize was planted at a spacing of 50 × 20 cm with fertility level of 180:112.5:75 kg/ha N, P_2O_5 and K_2O (T_4), which was statistically at par with the treatment T_2 (150:93.75:62.5 kg/ha N, P_2O_5 and K_2O at plant density of 50 × 20 cm) and 180:112.5:75 kg/ha N, P_2O_5 and K_2O at 40 × 20 cm spacing (T_5). This might be due to optimum plant population and fertility level resulted in higher yield attributing traits due to less competition for space, sunlight and nutrients. However, none of the treatment showed significant response towards number of grains/cob. However, highest plant height (221.60 cm), was noticed when maize was sown at density of 40 × 20 cm with fertility level of 180:112.5:75 kg/ha N, P_2O_5 and K_2O (T_5) which was statically at par with all treatments except

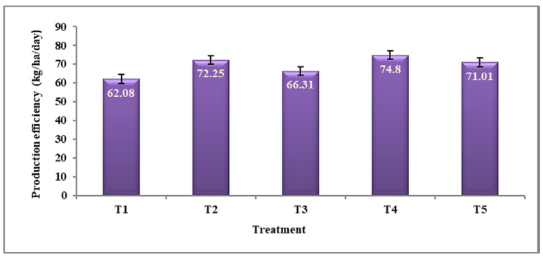

Fig. 2. Effect of fertilization levels and plant geometry on production efficiency of *rabi* maize.

Table 1. Effect of fertilization levels and plant geometry on plant growth and yield attributes of maize (Pooled data of two years).

Treatments	Plant height (cm) at harvest	Dry wt/plant (g) at harvest	Yield attributes Grains/cob	Cob length (cm)	Cob girth (cm)	1000-grain wt (g)
T_1-60×20 cm spacing with 120: 75:50 kg/ha N, P_2O_5 and K_2O (FP)	194.5	306.4	462.4	14.76	10.34	263.9
T_2-50×20 cm spacing with 150:93. 75:62.5 kg/ha N, P_2O_5 and K_2O	206.4	336.2	488.8	17.74	12.06	289.2
T_3-40×20 cm spacing with 150:93.75: 62.5 kg/ha N, P_2O_5 and K_2O	211.0	313.3	480.7	16.59	11.31	267.8
T_4-50×20 cm spacing with 180 : 112.5:75 kg/ha N, P_2O_5 and K_2O	215.0	358.7	504.2	19.49	12.83	305.5
T_5-40×20 cm spacing with 180 : 112.5:75 kg/ha N, P_2O_5 and K_2O	221.6	341.2	488.4	18.93	12.53	294.1
SEm±	8.4	12.6	18.23	0.728	0.534	11.4
CD (p=0.05)	25.2	37.8	NS	2.19	1.61	34.2

Table 2. Effect of fertilization levels and plant geometry on yield and economics of *rabi* maize (Pooled data of two years).

Treatments	Yield (q/ha) Grain	Stover	PE	Economics Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha	B:C	ME
T_1-60×20 cm spacing + 120:75:50 kg/ha N, P_2O_5 and K_2O (FP)	96.22	112.78	62.08	38567	120275	81708	2.12	527.15
T_2-50×20 cm spacing + 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O	111.99	129.99	72.25	41868	139988	98120	2.34	633.03
T_3-40×20 cm spacing + 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O	102.78	120.13	66.31	43056	128475	85419	1.99	551.09
T_4-50×20 cm spacing + 180:112.5:75 kg/ha N, P_2O_5 and K_2O	115.94	141.99	74.80	43491	144925	101434	2.33	654.41
T_5-40×20 cm spacing + 180:112.5:75 kg/ha N, P_2O_5 and K_2O	110.06	132.04	71.01	45275	137575	92300	2.04	595.48
SEm±	4.138	5.138						
CD (p=0.05)	12.4	15.40						

farmers practice (T_1). This might be due to low light interception in dense planting and high fertility levels. Our results are also in agreement with the findings of Liu *et al*. (2018), Hashim and Dhar, (2016) and Hashim *et al.* (2015) and Salifu and Doka (2019).

Table 3. Karl Pearson's correlation coefficient between important growth, yield parameters and yield related parameters.

Variables	Grain yield (q/ha)	grains/ cob	Cob length	Cob girth	1000-grain wt
Grain yield					
Grains/cob	0.968**				
Cob length	0.951*	0.952*			
Cob girth	0.966**	0.956*	0.998**		
1000-grain wt	0.957*	0.919*	0.953*	0.957*	

Productivity

The data pertaining to grain yield, stover yield and production efficiency are shown in Fig. 2 and Table 2. The maize crop received the fertility level of 180:112.5:75 kg/ha N, P_2O_5 and K_2O at plant density 50 × 20 cm (T_4) produced the highest grain yield (115.94 q/ha), stover yield (141.99 q/ha) and production efficiency (74.80 kg/ha/day) which was statistically at par with 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O at plant spacing 50 × 20 cm (T_2) and 180:112.5:75 kg/ha N, P_2O_5 and K_2O at plant spacing 40 × 20 cm (T_5) and significantly higher than T_1 and T_3. The highest yield in T_4 might be due to the highest

Table 4. Effect of fertilization levels and plant geometry of *rabi* maize on soil fertility status (Pooled of 2016-17 and 2017-18).

Treatments	pH	EC (dSm^{-1})	OC (%)	After harvest soil fertility status Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
T_1-60×20 cm spacing with 120:75:50 kg/ha N, P_2O_5 and K_2O (FP) 139.1	7.26	0.23	0.40	141.9	18.3	139.1
T_2-50×20 cm spacing with 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O	7.32	0.25	0.40	152.4	24.1	146.9
T_3-40×20 cm spacing with 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O	7.29	0.27	0.42	148.4	21.7	141.0
T_4-50×20 cm spacing with 180:112.5:75 kg/ha N, P_2O_5 and K_2O	7.25	0.25	0.42	161.6	25.1	154.8
T_5-40×20 cm spacing with 180 :112.5:75 kg/ha N, P_2O_5 and K_2O	7.24	0.26	0.42	156.1	24.2	149.0
SEm±	0.224	0.045	0.041	4.23	4.55	3.94
CD (p=0.05)	NS	NS	NS	12.7	2.5	11.8
			Initial fertility status			
	7.16	0.25	0.39	150.30	19.95	147.40

values of yield attributing characters. Similar observations have also been made by Hashim and Dhar (2016) and Hashim *et al.* (2015). Grain yield was found to be positively correlated with yield attributing traits (Table 3) namely plant height (R^2= 0.4962), dry weight (R^2= 0.917), grains/cob (R^2= 0.646), cob length (R^2= 0.6257), cob girth (R^2= 0.8961) and 1,000-seeds (R^2= 0.9051).

Soil fertility status

The pooled data of two years clearly shows that the pH, EC and organic carbon of soil did not influence significantly by various fertility levels and plant geometry after harvest of *rabi* maize (Table 4). However, available N, P_2O_5 and K_2O improved slightly from farmers practice, The highest available N, P_2O_5 and K_2O of soil were analyzed with the application of 180:112.5:75 kg/ha N, P_2O_5 and K_2O at 50 × 20 cm plant spacing, which was statistically at par with the application of same dose of fertilizer at 40 × 20 cm spacing (T_5) and 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O at 50×20 cm spacing (T_2). With increase in the levels of fertility also assured the availability of these nutrients to the crop plants in adequate amount and remained in soil in substantial quantity after fulfilling the crop requirement that ultimately improved the soil fertility status. Similar results have also been reported by Saha and Mondal (2006), Hashim *et al.* (2017) and Singh *et al.* (2010).

Profitability

Net returns and B: C ratio was also influenced significantly by various treatments of fertility levels with plant geometry (Table 2). The highest gross return (144925 INR/ha) and net return (101434 INR/ha) were calculated with the application of 180:112.5:75 kg/ha N, P_2O_5 and K_2O at 50 × 20 cm plant geometry (T_4). The highest monetary-efficiency (654.41 INR/ha/day) was also recorded in the same treatment. This was attributed only due to higher yield attributes and grain yield of *rabi* maize under this treatment. However, the highest B: C ratio (2.34) was found in 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O with 50 × 20 cm planting geometry (T_2). The higher B : C ratio in T_2 was only due to lower cost of cultivation and comparable grain yield than others. It is in close conformity with the findings of Sharma *et al*. (2020) in baby corn. Hashim and Shiva (2016) and Hashim *et al.* (2015) also reported the same results.

CONCLUSION

Iit is inferred from two years experimentation that the sowing of *rabi* maize at higher plant density of

50 × 20 cm with application of 150:93.75:62.5 kg/ha N, P_2O_5 and K_2O is more remunerative along with sustaining the soil fertility.

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