Effect of Plant Density and Nutrient Management on Yield and Economics of Maize (*Zea mays* L.) Hybrids

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ABSTRACT

The field experiments wereconducted during *kharif* season (June to October)of both 2016 and 2017 to determine the effect of plant density and nutrient management on yield and economics of maize hybrids at Kalyani AB Block seed farm situated atLatitude 22°57/ N,Longitude 88°20/ E, West Bengal, India.The experiments were arranged at split-split plot design with three replication, two maize hybrids (Pioneer 3077 and Kaveri 50) were in main plot, two plant density (60×20 cm² and 50×20 cm²) were in sub plot and three nutrient levels (Recommended Dose of Fertilizer i.e. 120:60:60 $N:P_2O_5:K_2O$ kg ha^{-1}, Soil test crop response i.e. 170:60:68 $N:P_2O_5:K_2O$ kg ha^{-1} and Site Specific nutrient management i.e. 130:44:66$N:P_2O_5:K_2O$ kg ha^{-1}) were in sub-sub plot. Result indicated that maize hybrid pioneer 3077 recorded higher grain yield, stover yield and net return and B:C ratio of maize than other hybrid. Higher plant density 50×20 cm² produced significantly higher yield and economics of maize than lower plant density. Among the nutrient management, Soil Test Crop Response (STCR) was found significantly superior than others and recorded highest grain yield, stover yield and economics of maize. Soil Test Crop Response based nutrient management increased in grain yield was 24.26% over Recommended Dose of Fertilizer (RDF) and 12.29% over Site Specific nutrient management (SSNM).

KEYWORDS: Grain yield, nutrient management, maize hybrids, plant density

1. INTRODUCTION

Maize (*Zea mays* L.) is the World's leading crop and is cultivated as cereal grain in India that contributed to nearly 9% of the national food security. Maize (*Zea mays* L.) is the third most important crop after rice and wheat in India. The demand for maize grain is increasing due to rapid growth in poultry and animal husbandry feed sector (Shyam et al., 2021 and Singh et al., 2018) and production is increasing owing to multifarious usage. (Yadav et al., 2016). The productivity of maize in India is still very low (2689 kg ha^{-1}), as compared to the world (5500 kg ha^{-1}), showing a large gap between potential productivity and actual productivity. (Singh et al., 2020). Among various factors responsible for low crop yield, plant population in the field and selection of unsuitable cultivars are of prime importance (Biswas et al., 2020, Yao et al., 2016 and Battaglia et al., 2019). Xu et al., 2017 stated that as planting density increased from 67,500 to 90,000 plants ha^{-1} grain yield was significantly increased by 7%. Thus, maintenance of optimum plant density play a vital role in nutrient absorption and partition in different plant parts (Hang et al., 2018 and Zhai et al., 2018). Planting density has proven to be a very effective agronomic strategy to improve maize grain yield (Shi et al., 2016). Newer hybrids were more tolerant to high plant population than the older hybrids. Therefore, the recently released hybrids were more adapted to biotic stress. High yielding maize hybrids, with very high biomass production, extracts higher amounts of mineralnutrients from the soil than other major cereals like rice orwheat. Nutrient requirement of maize varies from field tofield due to high variability in soil fertility across farmer's fields and also varies with the yield potential of hybrids (Hargilas et al., 2017). There is a good genotype interaction of maize in varied ecology and management practices (Kumar et al., 2016). Nitrogen, P and K are very important nutrients for maize crop in order to harvest high yield in *kharif* season (Singh et al., 2017). Maize being an exhaustive crop requires a large quantity of nutrients during different growth periods. The yield improvements were realized by adopting more efficient technologies and improved N fertilizer management (Zhang et al., 2018). The blanket fertilizer recommendations do not account the change in ecology and the genetic potential of the genotype (Parihar et al., 2017). Several approaches used for fertilizer recommendation in maize, like precision nutrient management through spatial variability assessment and variable rate technologies, site specific nutrient management (SSNM), soil test crop response (STCR), nutrient expert (NE) and recommended dose of fertilizer etc. Among several soil test-based fertilizer application techniques, site specific nutrient management (SSNM) and soil test crop response (STCR) are plant need based approaches with specific yield target. (Singh et al., 2017 and Neha et al., 2018). To address this complex problem of nutrient mining and deterioration of soil health, Site Specific Nutrient Management (SSNM) is one of the way of increasing the crops productivity and sustains the soil health through ensuring adequate supply of the nutrients specific to the crop and soil (Singh et al., 2016). The SSNM and STCR approaches not only aim to reduce or increase fertilizer use and also cost effective tools for supplying crop nutrient as and when needed to achieve higher yield, besides this they also aims to increase system nutrient use efficiency (Shreenivas et al., 2017 and Joshi and Chandrasekhar, 2017). Therefore, it is imperative to optimize fertilizer management during the maize growth period, which can not only reduce N input but also improve grain yield and environmental sustainability (Young et al., 2018). Increasing productivity and production are essential to meet the food requirement of the burgeoning population. This is achieved through its unique balance of nutrients and clay minerals, which also increases microbial activity and builds long term soil fertility (Ranva et al., 2019). Therefore, a reasonable increase of planting density and supplying adequate N application are important agronomic practices to increase maize grain yield (Du et al., 2021 and Chen et al., 2018). For increasing productivity, better nutrient management systems are needed to complement genetic improvement efforts (Ray et al., 2018). Since there are differential response to applied nutrients and crop geometry, it is imperative to evaluate performance of hybrids for their efficiency and response to nutrients and intra-row spacing. It was, therefore, considered worthwhile to undertake this present investigation in order to evaluate the effect of plant density and nutrient levels on yield and economics of maize hybrids during *kharif* season.

2. MATERIALS AND METHODS

2.1. Experimental site description

The experiments were conducted at Kalyani, AB Block seed farm (Latitude 22°57/N, Longitude 88°20/E and at of 9.75 m above sea level), West Bengal, India during the *kharif* season (June to October) of 2016 and 2017, respectively. The soil of the experimental site was sandy clay loam having pH neutral in reaction with medium in organic carbon (0.52%) and available nitrogen (269 kg ha^{-1}), high in available phosphorus (34 kg ha^{-1}) and medium in available potassium (209 kg ha^{-1}). The study area falls under sub-humid tropical climate. Kalyani usually receives an average annual rainfall of 1600 mm out of which 1300 mm occurs during monsoon. The maximum and minimum temperature was 24.1 and 34.2°C during 2016 and 23.8 and 35.1°C during 2017, respectively.

2.2. Agronomic practices

Before sowing of the crop, the field was well prepared by ploughing twice with tractor followed by one planking**.** Well decomposed farm yard manure at the rate of 12 t ha^{-1} was applied before last ploughing. Maize seeds were sown in the 2nd week of June and harvested in the middle of October in both the years respectively. As per the treatment, nitrogen was applied in the form of urea (46%) in three splits, viz., 25, 50, 25% as basal, 25 and 45 days after sowing. The entire dose of phosphorus in the form of single super phosphate (16%) and potassium in the form of muriate of potash (60%) were applied as basal. Weed, pests and diseases control were done in a timely manner.

2.3. Experimental design and treatments

The experiment was arranged at split-split plot design with three replication, two maize hybrids (pioneer 3077 and Kaveri 50) were in main plot, two plant density (60×20 cm^{2}and 50×20 cm^2 were in sub-plot and three nutrient levels (RDF i.e. 120:60:60 N:P$_2$O$_5$:K$_2$O kg ha^{-1}, STCR i.e. 170:60:68 N:P$_2$O$_5$:K$_2$O kg ha^{-1} and SSNM i.e. 130:44:66 N:P$_2$O$_5$:K$_2$O kg ha^{-1}) were in sub-sub plot.In STCR (Soil Test Crop Response) based nutrient recommendations, the basic data viz., nutrient requirement (NR) (kg t^{-1}), and percent contribution from the soil available nutrients [CS (%)] and the percent contribution from the applied fertilizer nutrients [CF (%)] were transferred into workable adjustment equation. Fertilizer dose = [Nutrient requirement (kg t^{-1}) of grain]/ [CF (%)] 100xT (t ha^{-1})-[CS (%)]/[CF (%)]×[soil test value (kg ha^{-1})]. Where T is targeted yield (t ha^{-1}).

For site specific nutrient management (SSNM), the nutrient status of the soil, previous crops etc. were used for computing the nutrient requirement by using IPNI (International Plant Nutrition Institute) Nutrient Expert for hybrid maize software. Nutrient Expert® is an interactive, computerbased decision-support tool that enables smallholder farmers to rapidly implement SSNM in their individual fields with or without soil test data. The software estimates the attainable yield for a farmer's field based on the growing conditions determines the nutrient balance in the cropping system based on yield and fertilizer/manure applied in the previous crop and combines such information with expected N, phosphorus (P) and potassium (K) response in target fields to generate location-specific nutrient recommendations. The software also does a simple profit analysis comparing costs and benefits between farmers' current practice and recommended alternative practices. The algorithm for calculating fertilizer requirements was developed from on-farm research data and validated over 5 years of testing.

2.4. Observation and statistical analysis

Biometric observations likes plant height, dry matter accumulation, cob length, cob girth, rows cob^{-1}, seeds cob^{-1}, 100 seed weight, grain yield and stover yield were recorded at harvest. The harvest index, economics, benefit: cost ratio of crop were calculated on the basis of the local market prices of the inputs and outputs. The collected pooled data of the two seasons were statistically analysed according to the analysis of variance (ANOVA) by using MSTAT-C computer.

3. RESULTS AND DISCUSSION

Details of the observation had been mentioned in Table 1 and 2. The results had been described under different sections as below.

3.1. Growth parameters

3.1.1. Effect of maize hybrids

The plant height of maize was significantly influenced by maize hybrids. Among the hybrids, the tallest plant height (205.9 cm) was recorded under Pioneer 30R77at harvesting stage. Lowest plant height (191.80 cm) was reported by hybrids Kaveri 50. The differential growth with respect to plant height observed between the varieties might be attributed to differences in genetic characteristics of the individual varieties, including the height of the varieties. Maize hybrids Pioneer 30R77 produced highest dry matter accumulation (1135.00 g m^{-2}) at harvest than other maize hybrids Kaveri 50. Genotypic character of different genotypes might have attributed difference in plant height and dry matter accumulation in this investigation. Similar findings were observed by Wijewardana et al. (2019), Coelho et al., 2020 and Ke and Ma, 2021. Growth parameters are also strongly influenced by environmental conditions during stem elongation and other growth stages, although there is considerable varietal variation in this characteristic. (Khedwal et al., 2018).

3.1.2. Effect of planting density

The plant density had significant effect on plant height and dry matter accumulation of crop. Plant height was the highest (204.8 cm) with higher plant density owing to inter-plant competition for light. The significant increase in plant height with decreased intra row spacing seems to be the resultant of competition for light. The result is in close accordance with findings Al-Naggar et al., 2021 and Bernhard and Below 2020. Dry matter accumulation was also higher (1105.33 g m^2) at higher planting density than lower planting density. Under high plant density, more number of plants per unit area was responsible for higher dry matter accumulation. Naik et al., 2019 reported that dry matter accumulation was significantly influenced by different planting density and higher plant density increased the dry matter accumulation at different growth stages.

Table 1: Effect of planting densities and nutrient management on growth and yield attributing characters of maize

Treatments	Plant height at harvest (cm)	Dry matter accumulation g m^{-2} at harvest	Cob length (cm)	Cob diameter (cm)	No. of rows cob^{-1}	No. grains cob^{-1}	100 seed weight (g)
Hybrids							
Pioneer-30R77	205.9	1135.00	18.7	15.6	13.6	34.1	32.4
Kaveri 50	191.80	1099.00	16.6	14.5	13.2	31.1	28.4
SEm±	4.19	20.42		0.40	0.27	0.89	1.17
CD (*p*=0.05)	12.7	61.25	NS	NS	NS	NS	3.5
Planting density							
60×20 cm²	190.9	1035.67	16.6	14.2	12.8	31.5	29.3
50×20 cm²	204.8	1105.33	18.7	15.9	14.0	33.7	31.6
SEm±	4.09	19.72		0.42	0.32	0.74	0.90
CD (*p*=0.05)	12.01	59.25	NS	1.3	1.0	2.2	NS
Nutrient management (NPK kg ha^{-1})							
Recommend dose of fertilizer	188.4	1022.20	16.7	14.2	12.8	30.3	27.5
Soil test crop response	195.4	1202.50	18.6	15.9	14.1	34.7	33.2
Site specific nutrient management	212.7	1158.45	17.7	15.0	13.3	32.8	30.7
SEm±	4.21	19.62		0.31	0.26	1.06	0.77
CD (*p*=0.05)	12.7	58.90	NS	0.90	0.80	3.20	2.30

Table 2: Effect of planting densities and nutrient management on yield and economics of maize

Treatments	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Harvest index (%)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
Hybrids						
Pioneer-30R77	10201.00	10448	39.77	142308.50	92769.20	3.025
Kaveri 50	8869.00	10338.90	41.40	127210.50	76679.40	2.65
SEm±	184.14	38.6	0.012	5616.50	4625.50	0.082
CD (*p*=0.05)	552.50	115.20	NS	16850.25	13877.00	0.248
Planting density						
60×20 cm²	8070.00	9764.50	40.21	116119.00	65580.40	2.482
50×20 cm²	10828.50	12280.45	40.60	154390.40	103852.50	3.247
SEm±	192.40	182.70	0.07	5081.50	4049.80	0.080
CD (*p*=0.05)	577.30	548.25	NS	15245.00	12149.50	0.245
Nutrient management (NPK kg ha^{-1})						
Recommend dose of fertilizer	8234.25	9702.50	40.60	117900.40	67409	2.474
Soil test crop response	10872.50	12292.40	40.72	152200.50	100971	3.058
Site specific nutrient management	9536.80	11075.80	40.07	136670.40	85780.58	3.00
SEm±	142.82	154.20	0.14	5852.50	3794.20	0.03
CD (*p*=0.05)	428.45	462.80	0.41	17560.50	11382.80	0.12

1US\$=₹ 67.8286 INR in 2016 and 1US\$=₹ 65.0966 INR in 2017

3.1.3. Effect of nutrient management

Different nutrient management significantly influenced the plant height and dry matter accumulation of crop. Maximum plant height (195.4 cm) and dry matter accumulation (1202.50 g m^{-2}) was recorded under STCR based nutrient management treatment compared than others. Lowest plant height (188.4 cm) and dry matter accumulation (1022.20 g m^{-2}) was recorded under RDF based nutrient management treatment. Singh et al., 2021 reported that maize growth parameters like plant height and dry matter accumulation were higher by STCR based nutrient management. Shreenivas et al., 2017 reported significantly higher plant height and number of branches, respectively was observed in residual effect of nutrients through SSNM approach targeted yield of 8.0 t ha^{-1} (36.55 cm and 29.57) and by STCR approach targeted yield of 8.0 t ha^{-1} (36.20 cm and 28.87) as compared to other treatments. Shyam et al., 2021 stated that plant height and other growth parameters influenced by precision nutrient management in maize.

3.2. Yield attributing characters

3.2.1. Effect of maize hybrids

Pooled data of the experiment showed that yield attributing character like 100 seed weight was significantly influenced by maize hybrids. Effect of maize hybrids on cob length, cob girth, number of rows per cob and number of grains per rows were non-significant. Maize hybrid Pioneer-30R77 recorded maximum 100 seed weight (32.4 g) than Kaveri 50 hybrid. The variation in yield characters between both the varieties might be due to genetical variation in the varieties. (Singh., 2016, Khedwal et al., 2018 and Coelho et al., 2020).

3.2.2. Effect of planting density

Pooled data showed that planting density significantly influenced the cob girth, number of rows per cob and 100 seed weight but cob length and number of grains per row were non-significant. Higher planting density recorded higher cob girth (15.9 cm), number of rows per cob (14.0) and 100 seed weight (32.4 g) and it was comparable with 60×20 cm^2 planting density. Increased planting density produced a significant 23% increase of average ear number; kernel number and other yield components. (Xu et al., 2017 and Al-Naggar et al., 2021)

3.2.3. Effect of nutrient management

Different nutrient management significantly influenced different yield parameters except cob length. STCR based nutrient management produced significantly higher cob girth (15.9 cm), number of rows per cob (14.1), number of grains per row (34.7) and 100 seed weight (33.2 g) which were statically at par with SSNM based nutrient management (Singh et al., 2021). Lowest cob diameter

(14.2 cm), number of rows per cob (12.8), number of grains row^{-1} (30.3) and 100 seed weight (27.5 g) were recorded in plot receiving recommended dose of fertilizer. Shreenivas et al., 2017 reported that higher yield attributes were obtained with the nutrient application through targeted yield approach. (STCR based). Enhanced yield attributes under precision nutrient management resulted in enhanced seed yield. There was higher nutrient uptake, and partitioning of the NPK and other nutrients and which accelerated the growth and yield attributes. (Shyam et al., 2020)

3.3. Yield

3.3.1. Effect of maize hybrids

Pooled data of experiment showed that maize hybrids were significantly influenced grain yield and stover yield of crop. Among the maize hybrids, Pioneer- 30R77 produced higher grain yield (10,201 kg ha^{-1}) and stover yield (10,448.45 kg ha^{-1}). This might be due to better vegetative and reproductive growth of hybrids Pioneer 30R77 contributed to better dry matter accumulation and yield attributing parameters at the same time grain and stover yield of maize. The increase in grain yield could be attributed to the higher yield attributing parameters in Pioneer-30R77. The variation in yields between both the varieties might be due to genetical variation in the varieties. Singh., 2016, Khedwal et al., 2018 and Coelho et al., 2020 reported the similar findings.

3.3.2. Effect of planting density

Among the planting density, higher density of planting (50×20 cm^2) recorded significantly higher grain yield (10, 828.50 kg ha^{-1}) and stover yield (12, 280.45 kg ha^{-1}) of maize than the lower planting density (60×20 cm^2). Light interception was increased with increased plant density, under high plant density increased plant heights as well as light interception. At high density vegetative growth of maize was extended, more number of leaves per plant were produced that increased light interception at the high density, as a result more assimilates were produced by maize crop that increased plant heights as well as light interception which ultimately lead to higher grain yields at high density planting than at low plant density. At low plant density, there in adequate number of plants and therefore ears, that was concluded limits grain yield. Al-Naggar et al., 2021 reported that increasing planting density from 47,600 to 71,400, 95,200 and 119,000 caused a significant increase in grain yield/ha. As planting density increased from 67,500 to 90,000 plants ha^{-1}, grain yield was significantly increased by 7% (from 9,556.5 to 10,184.5 kg ha^{-1}) across years. (Xu et al., 2017). Yu et al., 2019 stated that the increase of planting density from 75,000 plants ha^{-1} to 90,000 plants ha^{-1}, yields of high-yielding spring maize varieties improved. Bernhard and Below 2020 reported that narrower row spacings helped

mitigate crowding stress at greater plant populations by promoting phenotypic changes that consequently led to greater yield. Higher productivity was observed in the high density treatments. (Du et al., 2021)

3.3.3. Effect of nutrient management

The significantly higher grain and stover yield of maize was observed in STCR based nutrient management, followed by SSNM approach. This may be due to increased uptake of nitrogen, phosphorus and potassium being part of essential nutrients, required for the production of meristematic tissues and physiological activities of leaves, roots, shoots etc. leading to an efficient translocation of water and nutrients. These physiological activities increased the nutrient uptake which resulted in higher total dry matter production and ultimate the yield of crops. These findings are accordance with experimental results of Yadav and Kumar (2018). Shabnam et al., 2017 stated that STCR based nutrients application in treatment for target yield of 40 q ha⁻¹ with and without FYM resulted in the significantly better productivity of maize (3.76 t ha⁻¹ and 3.67 t ha⁻¹), as compared to conventional treatments. Also the highest B: C ratio (2.30) was recorded under STCR (non-IPNS) approach based target yield treatment for 40 q ha⁻¹. Shreenivas et al., 2017 reported that the grain yield of maize was recorded higher (8.62 t ha⁻¹) with treatment receiving SSNM approach targeted yield of 8.0 t ha⁻¹ as compared to absolute control (2.91 t ha⁻¹), farmers practice (4.74 t ha⁻¹), state recommendation (5.82 t ha⁻¹) and soil test laboratory (STL) method (6.25 t ha⁻¹) and it was found at par with STCR approach targeted yield of 8.0 t ha⁻¹ (8.37 t ha⁻¹).The STCR-based nutrient application increased grain yield by 5.7%,respectively over balanced fertilization (recommended doses of NPKZn) (Jhosi et al., 2016). Singh et al., 2021 stated that the STCR-targeted yield approach improved the yield of maize. The increased yield under the STCR approach, with and without FYM, might have been due to the balanced application of fertilizers, as per the soil test, and the crop demand for growth and development. Enhanced yield attributes under precision nutrient management resulted in enhanced seed yield of maize. (Shyam et al., 2020)

3.4. Harvest index (%)

3.4.1. Effect of maize hybrids

No significant differences were found in harvest index of maize influenced by hybrids.

3.4.2. Effect of planting density

Harvest index was not significantly varied by different plant densities.

3.4.3. Effect of nutrient management

The harvest index of maize was significantly varied by different nutrient management. The highest harvest index (40.72%) was obtained in treatment receiving STCR based nutrient management. The lowest harvest index was notice in treatment receiving recommended dose of fertilizer. Singh et al., 2021 reported that the highest harvest index was recordedin STCR based treatment (44.30%), which differed significantly from other. Higher dry matter partitioning to grain might be the reason for the higher harvest index under STCR based treatment.

3.5. Economies

3.5.1. Effect of maize hybrids

Maize hybrids recorded significant influence on gross return, net return and B: C ratio of maize. Among the hybrids, Pioneer-30R77 showed maximum gross return (₹ 1, 42,308.50 ha⁻¹), net return (₹ 92,769.20 ha⁻¹) and maximum B:C ratio (3.025) of maize. While minimum gross return (₹ 1, 27,210.50 ha⁻¹), net return (₹ 76, 679.40) ha⁻¹ and B: C ratios (2.65) were recorded under Kaveri 50 hybrids. This might be due to the fact that hybrids Pioneer-30R77 having greater potential to produce more grain and stover yield resulting in greater return. The variations in net income between hybrids might due to variation in grain and stover yield. (Khedwal et al., 2018). The B:C ratio was also noted in similar manner under both the hybrids. (Singh et al., 2018)

3.5.2. Effect of planting density

Two years of the experiment data showed that planting density 50×20 cm² recorded highest gross return (₹ 1,54,390.40 ha⁻¹), net return (₹ 1,03,852.50ha⁻¹) and B:C ratio (3.247) of maize. The difference in gross return, net return and B:C ratio might be due to yield variation between the plant densities. Similar findings were also reported by Singh et al., 2016.

3.5.3. Effect of nutrient management

The results of the experiment indicated that the higher gross return (₹ 1, 52,200.50 ha⁻¹), net return (₹ 1,00,971 ha⁻¹) were recorded in STCR based nutrient management. The highest B:C ratio was noticed in STCR based nutrient management which was statistically at with SSNM based nutrient management. (Singh et al., 2021). The lower gross return, net return and B: C ratio was found in the treatments receiving RDF (Recommended Dose of Fertilizer). Consistently higher gross returnswere realized during 2012 and 2013, respectively, in balanced application of NPKZn based on STCR approach to maize, which was significantly superior to recommended doses of nutrient. (Joshi et al., 2016, Shyam et al., 2020 and Shreenivas et al., 2017).

4. CONCLUSION

The maize hybrid Pioneer-30R77 under 50×20 cm² planting density with soil test crop response (STCR)

based nutrient management is recommended for achieving higher yield and economic benefit of maize during *kharif* season in West Bengal, India.

4. ACKNOWLEDGMENT

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