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EFFECT OF PLANT DENSITY AND FERTILIZER LEVELS ON YIELD AND ECONOMICS OF QUALITY PROTEIN MAIZE (*ZEA MAYS* L.) UNDER IRRIGATED CONDITION

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ABSTRACT

A field experiment was conducted at Agricultural Research Sation, Siruguppa, Karnataka during the *kharif* 2015, to study the effect of plant density and fertilizer levels on yield and economics of quality protein maize under irrigated condition. The soil of the experimental site was clay loam in texture, low in organic carbon, available N, medium in available phosphorus and high in potassium. Treatments consisted of sixteen treatment combinations of four plant densities viz., S_1:1,11,111, S_2:83,333, S_3:74,074 and S_3:66,666 plants ha^{-1} in main plots and four fertilizer levels F_1:150:75:37.5 kg NPK ha^{-1}, F_2:187.5:93.75:46.88, F_3:225:112.5:56.25 kg NPK ha^{-1} and F_4:Nutrient Expert based target yield 10 t ha^{-1}(NE) in sub plots. Plant density 1,11,111 plants ha^{-1} recorded higher grain (7839 kg ha^{-1}) and stover yield (13114 kg ha^{-1}) compared to other plant densities. On the contrary yield parameters *viz*., number of grains per row, number of rows per cob, cob girth, cob length and test weight were higher in plant density of 66,666 plants ha^{-1} compared to other plant densities. Among the fertilizer levels application of 225:112.5:56.25 kg NPK ha^{-1} recorded higher grain yield (8023 kg ha^{-1}), stover yield (13434 kg ha^{-1}) and yield parameters viz., number of grains per row, number of rows per cob, cob girth, cob length and test weight as compared to other fertilizer levels. Higher net returns was registered with plant density of 1,11,111 plants ha^{-1} (Rs.77592 ha$^{-1)}$ and application of 225:112.5:56.25 kg NPK ha^{-1} (Rs.80348 ha^{-1}), respectively.

KEY WORDS: Fertilizer levels, plant density, quality protein maize, Nutrient Expert and economics.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. In India, maize is the third most important food crops after rice and wheat. It is cultivated over an area of 9.43 m ha with a production of 24.35 m t and productivity of 2583 kg ha^{-1} (Anon, 2015). The predominant maize growing states that contributes more than 80 per cent of the total maize production in Karnataka (16.5%) (Anon, 2015). In spite of several important uses, maize has an inbuilt drawback of being deficient in two essential amino acids, *viz*., lysine and tryptophan. This leads to poor protein utilization and low biological value of traditional maize genotypes. To overcome this problem, maize breeders have developed quality protein maize (QPM) by incorporating Opaque-2 gene, which is particularly responsible for enhancing lysine and tryptophan content of maize endosperm protein. QPM looks and taste like normal maize with same or higher yield potential, but it contains nearly twice the quantity of essential amino acids, lysine and tryptophan which makes it richer in quality proteins (Anon, 2009). Maize being an exhaustive crop, its fertilizers requirement especially nitrogen is prominent. Nitrogen is essential constituent of chlorophyll, protoplasm and enzymes. Further, it governs utilization of phosphorus and potassium. It is an important factor for better vegetative growth and boosting up the yield of cereals (Shrivastava and Sinha, 1992). Quality protein maize cultivation being a relatively new practice in Karnataka it needs an investigation for development of suitable production technologies in realizing higher yield and monetary returns before it could be popularized among maize growers. Since spacing and fertilizer levels are most important factors in agriculture and the information on these interaction effects with other inputs is rather limited. Keeping this background in mind, the present study was carried out.

MATERIALS & METHODS

A field experiment was conducted during the *kharif* 2015 at Agriculture Research Station, Siruguppa, Karnataka, situated on the latitude 15^{0}38' N, longitude 76^{0}54'E, 380 m elevation from MSL belongs to Northern Dry Zone (Zone 3) of Karnataka. The experiment was laid out in spilt plot design. The soil of the experimental site was clay loam in texture, neutral pH (7.94) and low in electrical conductivity (0.37 dSm^{-1}). The soil organic carbon content was 0.41 per cent and soil was low in available N (220 kg ha^{-1}), medium in available phosphorus (21 kg ha^{-1}) and high potassium (375 kg ha^{-1}). The hybrid HQPM-1 was used in the investigation resistant to stem borer, downy mildew and leaf blight diseases. Treatments consisted of sixteen treatment combination of four plant densities viz., S_1:1,11,111, S_2:83,333, S_3:74,074 and S_3:66,666 plants ha^{-1} in main plots and fertilizer levels F_1:150:75:37.5 NPK kg ha^{-1}, F_2:187.5: 93.75:46.88, F_3:225:112.5: 56.25 NPK kg ha^{-1} and F_4:Nutrient Expert based target yield 10 t ha^{-1} in sub plots. For Nutrient Expert based fertilizer recommendation ready recknor software developed by International Plant Nutrition Institute (IPNI), 2014 was used for the study. At basal, half of nitrogen, entire dose of phosphorus and potassium in the form of Urea, Di ammonium phosphate (DAP) and Muriate of potash (MOP) were applied as per the treatments. Remaining half of recommended nitrogen was top dressed at 30 and 45 days after sowing (DAS). Immediately after sowing Atrazine 50% WP @ 1.0 kg *a.i* ha^{-1} was applied to control weeds as pre emergent. Further, bicycle weeder was used at 20 DAS and hand weeding has been done at 35 and 50 days after sowing to manage weeds. All yield and yield parameters collected including number of grains cob^{-1}, hundred seed weight and grain yield $plant^{-1}$ were recorded at harvest of the crop. Grain and stover yield from net plot area was converted into per hectare basis. Economic returns were worked out based on the prevailing market prices of inputs, cost of fertilizers and outputs. The experimental data were analyzed statistically.

RESULTS & DISCUSSION

Among the plant density significantly higher cob length (20.15 cm), cob girth (14.18 cm), number grains per row (39.95), number grain rows per cob (15.02), and hundred seeds weight (27.10 g) were observed at low plant density 66,666 plants ha^{-1} and decreased with increase in plant density 1, 11,111 plants ha^{-1}. However, it was on par with plant density of 74,074 and 83,333 plants ha^{-1}, which indicating a stress free environment. This clearly indicates that plants at lower plant density exploited maximum natural resources efficiently, besides responding to externally applied inputs and expressed its maximum potential compared to plants at higher plant density where competition would be high. These results are in conformity with findings of Zarapkar (2006) and Shoo and Mahapatra (2007). Among the fertilizer levels The higher cob length (19.84 cm), cob girth (14.78 cm), number of grains per row (39.33), number grain rows per cob (15.50), hundred seeds weight (27.2g) were observed with application of 225:112.5:56.25 NPK kg ha^{-1} and lower values with the 150:75:37.5 NPK kg ha^{-1} (Table 1).

TABLE 1. Number of cobs $plant^{-1}$, cob length, cob girth, number of grain rows cob^{-1}, number of grains row^{-1} and hundred seed weight of quality protein maize as influenced by plant density and fertilizer levels under irrigated condition

Treatment	Cob length (cm)	Cob girth (cm)	No. of grain rows cob^{-1}	No. of grains row^{-1}	Hundred seed weight (g)
Plant density					
S_1: 1,11,111 (45 cm x 20 cm)	17.90	12.94	13.63	34.90	23.76
S_2: 74,074 (45 cm x 30 cm)	19.47	13.88	14.67	37.95	25.06
S_3: 83,333 (60 cm x 20 cm)	18.57	13.81	14.37	37.63	24.64
S_4 : 66,666 (75 cm x 20 cm)	20.15	14.18	15.02	39.95	27.10
S.Em.±	0.37	0.24	0.26	0.65	0.50
C.D. (P=0.05)	1.27	0.83	0.88	2.25	1.72
Fertilizer levels					
F_1: 150:75:37.5 NPK kg ha^{-1}	17.97	12.73	13.57	35.85	23.23
F_2: 187.5:93.75:46.88 NPK kg ha^{-1}	19.28	13.80	14.53	38.33	25.91
F_3: 225:112.5:56.25 NPK kg ha^{-1}	19.84	14.78	15.50	39.33	27.23
F_4: Nutrient Expert based target yield 10 t ha^{-1} (NE_{10})	18.99	13.50	14.08	36.92	24.20
S.Em.±	0.30	0.20	0.23	0.67	0.54
C.D. (P=0.05)	0.89	0.59	0.68	1.95	1.59
Interaction					
S.Em.±	0.61	0.41	0.46	1.33	1.09
C.D. (P=0.05)	NS	NS	NS	NS	NS

This is because that inorganic fertilizer contains the nutrients in available forms which would have been easily taken up by the plant for growth and development. Similar findings are also reported by Kunjir (2004) and Keerthi *et al.* (2013). Significantly higher grain (7839 $kgha^{-1}$) and stover yield (13114 kg ha^{-1}) was recorded with panting density of 1,11,111 plants ha^{-1}. Significantly lower grain yield (6907 kg ha^{-1}) and stover yield (11397 kg ha^{-1}) was registered under plant density of 66,666 plants ha^{-1}. But it was on par with 83,333 plants ha^{-1} (7648 kg ha^{-1} and 12701 kg ha^{-1}, grain and stover yield, respectively). These results are in agreement with the results obtained by Muhammad *et al*. (2010) and Gaurav *et al.* (2013). The higher yield under higher plant density was due to more number of cobs per unit area. In another study conducted elsewhere, reported that linear increase in fodder yield with increasing in plant density was also noticed by Ashok Kumar (2009) and Kar *et al.* (2006). Among the fertilizer levels significantly higher grain and stover yield (8023 kg ha^{-1} and 13434 kg ha^{-1}, respectively) were recorded with application of 225:112.5:56.25 NPK kg ha^{-1} and lower grain and stover yield was recorded with application of 150:75:37.5 NPK kg ha^{-1} (6606 kg ha^{-1} and 11391 kg ha^{-1}, respectively). These results are in accordance with findings of Muhammad *et al.* (2010) and Nandita *et al.* (2015). The increased grain yield in quality protein maize was with application of 225:112.5:56.25 NPK kg ha^{-1} might be due to readily available from which would have been easily taken up by the plant for growth and development. Harvest index did not differ significantly by varying plant density and fertilizer levels (Table 2).

TABLE 2. Grain yield, stover yield and harvest index of quality protein maize as influenced by plant density and fertilizer levels under irrigated condition

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
Plant density			
S_1: 1,11,111 (45 cm x 20 cm)	7839	13114	0.37
S_2: 74,074 (45 cm x 30 cm)	7181	12067	0.37
S_3: 83,333 (60 cm x 20 cm)	7648	12701	0.38
S_4: 66,666 (75 cm x 20 cm)	6907	11397	0.38
S.Em.±	135	210	0.05
C.D. (P=0.05)	469	727	NS
Fertilizer levels			
F_1: 150:75:37.5 NPK kg ha^{-1}	6606	11391	0.37
F_2: 187.5:93.75:46.88 NPK kg ha^{-1}	7598	12432	0.38
F_3: 225:112.5:56.25 NPK kg ha^{-1}	8023	13434	0.37
F_4: Nutrient Expert based target yield 10 t ha^{-1} (NE_{10})	7348	12022	0.38
S.Em.±	108	200	0.05
C.D. (P=0.05)	316	583	NS
Interaction			
S.Em.±	216	339	0.01
C.D. (P=0.05)	NS	NS	NS

NS: Non significant

Among the plant density the higher cost of cultivation was recorded with 1,11,111 plants ha^{-1} (Rs. 30,229 ha^{-1}) than rest of the planting densities and lower cost of cultivation was observed in 66,666 plants ha^{-1} (Rs. 27,349 ha^{-1}). The higher cost of cultivation (Rs. 30,021 ha^{-1}) was recorded by application of 225:112.5:56.25 kg NPK ha^{-1} compared to other fertilizer levels and lower cost of cultivation (Rs. 26682 ha^{-1}) incurred under nutrient expert based target yield 10 t ha $^{-1}$ (NE_{10}) NPK kg ha^{-1}. Among the planting densities higher gross returns and net returns (Rs. 1,07,820 ha^{-1} and Rs. 77,592 ha^{-1}, respectively) was registered with the plant density of 1,11,111 plants ha^{-1} compared to other plant density and it was on par with plant density of 83,333 plants ha^{-1} (Rs.1,05,128 ha^{-1} and `77,406 ha^{-1}, respectively). Minimum gross returns and net returns were noticed with plant density of 66,666 plants ha^{-1} (Rs. 94,888 ha^{-1} and Rs. 67,539 ha^{-1}, respectively). These higher gross and net returns were mainly attributed to higher grain and straw yield. These results are in conformity with findings of Ashwani *et al.* (2015) and Dutta *et al.* (2015). Maximum gross returns and net returns (Rs.1,10,369 ha^{-1} and Rs. 80,348 ha^{-1}, respectively) was recorded with the application of 225:112.5:56.25 NPK kg ha^{-1} compared to other fertilizer levels and minimum gross returns and net returns (Rs. 91,113 ha^{-1} and Rs. 63,249 ha^{-1}, respectively) was registered under the application of 150:75:37.5 NPK kg ha^{-1} These results are in conformity with findings of Ashwani *et al.* (2015) were due to lowest yield (Table 3). Interaction effect between plant density and fertilizer levels were shown non significant.

TABLE 3. Cost of cultivation, gross returns, net returns and BC ratio of quality protein maize production as influenced by plant density and fertilizer levels under irrigated condition

Treatment	Cost of cultivation (` ha^{-1})	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	BC ratio
Plant density				
S_1: 1,11,111 (45 cm x 20 cm)	30,229	10,7820	77,592	3.56
S_2: 74,074 (45 cm x 30 cm)	27,496	98,814	71,318	3.59
S_3: 83,333 (60 cm x 20 cm)	27,722	1,05,128	77,406	3.80
S_4: 66,666 (75 cm x 20 cm)	27,349	94,888	67,539	3.47
S.Em.±	-	-	1,796	0.06
C.D. (P=0.05)	-	-	6,213	0.22
Fertilizer levels				
F_1: 150:75:37.5 NPK kg ha^{-1}	27,864	91,113	63,249	3.27
F_2: 187.5:93.75:46.88 NPK kg ha^{-1}	28,228	1,04,299	76,071	3.70
F_3: 225:112.5:56.25 NPK kg ha^{-1}	30,021	1,10,369	80,348	3.68
F_4: Nutrient Expert based target yield 10 t ha^{-1} (NE_{10})	26,682	1,00,869	74,188	3.78
S.Em.±	-	-	1,405	0.05
C.D. (P=0.05)	-	-	4,102	0.14
Interaction				
S.Em.±	-	-	2,811	0.10
C.D. (P=0.05)	-	-	NS	NS

NS: Non significant

The benefit cost ratio (3.80) was highest in plant density of 83,333 plants ha^{-1} compared to rest of the planting densities and it was on par with plant density of 74,074 plants ha^{-1}(3.59). Significantly lower benefit cost ratio was recorded under plant density of 66,666 plants ha^{-1} (3.47). The highest benefit cost ratio (3.78) was recorded under

Nutrient Expert based target yield 10 t ha^1 (NE_{10}) than lower fertilizer level and it was closely followed by the application of 225:112.5:56.25 kg NPK ha^{-1} (3.68) and 187.5: 93.75: 46.88 NPK kg ha^{-1} (3.70) and least benefit cost ratio (3.27) was noticed under the application of 150:75:37.5 kg NPK ha^{-1} (Table 3). These results are in accordance with findings of Dutta *et al.* (2015). However, interaction effects between plant density and fertilizer levels were not differed significantly.

CONCLUSION

Significantly higher grain yield and stover yield in quality protein maize was recorded with plant density of 1,11, 111 plants ha^{-1} (45cm x 20cm) compared to other plant density. Application of 225:112.5:56.25 NPK kg ha^{-1} was recorded significantly higher grain and stover yield compared to other fertilizer levels. Plant density of 1,11, 111 plants ha^{-1} and application of 225:112.5:56.25 NPK kg ha^{-1} registered maximum gross and net returns than rest of the plant density and fertilizer levels. Maximum BC ratio was recorded with plant density of 83,333 plants ha^{-1} compared to rest of the plant density and it was closely followed by plant density of 74074 plants ha^{-1}. Application of nutrient expert targeted yield 10 t ha^{-1} (NE_{10}) was registered significantly higher benefit cost ratio compared to application of 150:75:37.5 NPK kg ha^{-1}.

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