Interactive Effects of Plant Population and Fertility Levels on the Productivity of Maize under Rice-Maize System

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ABSTRACT. The response of hybrid maize to plant density and fertilizer requirement varies widely under irrigated condition. As the area under rice- fallow maize under zero- tillage is increasing and being the exhaustive nature of the system the higher nutrient doses are warrant to realize higher grain yields. Increasing productivity per unit area through agronomic management is one of the important strategies to increase the production of maize grain. Hence, a field experiments were conducted during *rabi* 2010-11 and 2011-12 at Maize Research centre, Hyderabad, Andhra Pradesh to evaluate the interactive effect of plant population (plant spacing and density), and fertility levels on productivity of maize under zero-tilled conditions in rice-maize system. Three plant densities with different plant spacing of 50x20 cm (100,000 plants/ha), 60x20 cm (83,333 plants/ha) and 75x20 cm (66,666 plants/ha) in main-plots and four fertility levels (150-60-60, 200-75-75,250-90-90 and 300-105-105 kg N-P_2O_5-K_2O/ha) in sub-plots were tested in split-plot design. Rice crop was raised with normal recommended package of practices during *kharif* 2010 and 2011 followed by maize during *rabi* after harvest of rice under zero-tilled conditions and imposed the treatments. A high yielding rice variety MTU 1010 and a single cross hybrid maize DHM 117 were used in the study. The two year pooled results indicated that the highest maize cob (9283 kg/ha) and grain (8106 kg/ha) yields and also system productivity (12962 kg/ha) were registered with 60x20 cm spacing (83333,plant /ha) with superior growth and yield attributing characters compared to higher (100,000plants/ha) and normal plant densities (66,666 plants/ha) under 50x20 cm and 75 x20 cm spacings respectively. The fertility level of 250-90-90 kg N-P_2O_5-K_2O/ha was recorded higher cob (9786 kg/ha) and grain (7952 kg/ha) yields and system productivity (12808 kg/ha).The interaction effect between plant density and fertility level was found significant in terms of dry matter and cob yields. Higher maize cob yield (10648 kg/ha) were realized under 60x20 cm plant spacing (83,333, plants/ha) fertilized with 250-90-90 kg N-P_2O_5-K_2O/ha however, it was on par with 300-105-105 kg N-P_2O_5-K_2O/ha N-P_2O_5-K_2O/ha (10712 kg/ha). In terms of economic returns, adoption of high plant density up to 83,333 plants/ha under plant spacing of 60x20 cm realized higher gross (Rs.89113 /ha), net (Rs.65207 /ha) returns and B:C ratio (3.71 in maize crop when grown in sequence to *kharif* rice under zero-tillage conditions.

Key words: rice-maize system, plant density, geometry, fertility level, productivity

Introduction

In Coastal Peninsular India, the dominant rice-rice rotation has become difficult to be adopted by farmers due to shortage of irrigation water, particularly during winter. In such situations, maize is rapidly emerging as a favorable option due to its higher productivity and profitability with less water requirement and fewer pest and disease problems as component crop of rice based system. Moreover, the total system productivity of rice-maize was also higher compared to that of rice-rice cropping system. Presently, rice-maize system covered nearly 0.4 million ha in Coastal region of Andhra Pradesh.

As the area under rice-fallow maize under zero-tillage is increasing and being the exhaustive nature of the system the higher nutrient doses are warrant to realize higher grain yields. However, the high yielding rice-maize system extract large amounts of mineral nutrients from the soil. Continuous rice-maize cropping system without adequate and balanced nutrients has resulted in a wide spread problem of multiple deficiencies (Timsina and Connor 2001). On the other hand, long term experiments and other studies indicated that crop productivity can be sustained with balanced fertilization. Moreover, the response of hybrid maize to plant density and fertilizer requirement varies widely under irrigated condition. Optimum plant spacing is one of the important factors for higher production, by efficient utilization of underground resources and also harvesting as much as solar radiation and in turn better photosynthethate formation (Thavaprakaash *et al.* 2005). In view of this, an evaluation was under taken to study the interactive effect of plant density and spacing and fertility levels on productivity of maize under zero-tilled conditions in rice-maize system.

Materials and Methods

A field experiments were conducted at Maize Research Centre, Rajendranagar, Hyderabad, A.P during 2010-11 and 2011-12 *rabi* season to evaluate the agronomic management of plant densities with different plant spacing and fertility levels on growth and yield component of maize and system productivity of rice-maize sequence cropping . The farm is geographically situated at 78^o 23‘ E Longitude, 17^{o}19‘ N Latitude and at an altitude of 542.6 m above mean sea level. It is covered under Southern Telangana agro-climatic zone of Andhra Pradesh, which falls under semi-arid climate with dry, hot summers and cold winters. The average rainfall of the season was 1094 mm. The soil of the experimental field is sandy clay loam in texture, slightly alkaline in reaction with low in available nitrogen (225 kg/ha), medium in available phosphorus (29.6 kg/ha) and high in available potassium (434 kg/ha) and low in zinc content (0.4 ppm).

To achieve the desired plant densities of 100,000, 83,333 and 66,666 plants/ha, three different geometry were evaluated by keeping 50, 60 and 75 cm as inter-row spacing and 20 cm uniformly as intra- row spacing in main-plots. Four fertility levels (150-60-60 (State recommendation) 200-75-75,250-90-90 and 300-105-105 kg N-P_2O_5-K_2O/ha) in sub-plots were tested in a split-plot design with a net plot size of 4.5x4.0 m. A common dose of 25 kg $ZnSO_4$/ha was basally applied in each treatment. Rice crop was raised as bulk without any treatments with normal recommended package of practices during *kharif* 2010 and 2011 followed by zero-tilled maize during *rabi* after harvest of rice and imposed the treatments. A high yielding rice variety MTU 1010 and a single cross hybrid maize DHM 117 were used in the study. For rice, a common fertilizer dose of 120-60-40 kg N-P_2O_5-K_2O/ha was applied and for maize the above four fertility treatments were imposed after harvest of rice. The P and Zn nutrients were applied at sowing separately where N was applied in three splits (33% basally, 33% at tillering and 33% at P.I. stages for rice and 33% basally, 33% at knee high, and 33% at tasseling and silking stages for maize) while K was applied in two splits (50% basal and 50% at P.I stage for rice and 50% basal and 50% at tasseling and silking stage for maize).

Uniform cultural operations and plant protection measures were adopted in all treatments. In rice only the grain yield was recorded and converted to hectare basis for calculating total rice-maize system yields and for maize the observations on growth and yield parameters were recorded and the average of two years are reported and discussed. The yield of rice grain was expressed in terms of maize equivalent yield by multiplying the rice yield with price of rice and divided by price of maize grain and arrived system productivity of rice –maize cropping sequence. The economic returns were compared by calculating cost of cultivation for different plant density and fertility level treatments for zero tillage maize.

Results and Discussion

Growth Parameters

All the growth parameters *viz.*,final plant population, plant height, LAI, dry matter and days to 50% silking which were influenced by different plant densities and fertility levels in zero-tillage maize were presented in Table 1.

Significantly higher plant population per hectare were observed in high density planting of 100,000plants/ha under 50 20cm plant spacing followed by 83,333 plants/ha and 66,666 plants/ha.There was marginal increase in final plant population with 250-90-90 kg N-P_2O_5-K_2O/ha compared to 150-60-60 kg N-P_2O_5-K_2O/ha fertility level.

Zero-tilled maize grown at wider row spacing of 75x20 cm (66,666 plant/ha) produce taller plants (181 cm) as compared to closer spacing of 60x20 cm (83,333 plants/ha) (159.8 cm) and 50x20 cm (100,000 plants/ha) (157.8 cm) respectively. Wider row spacing might have increased the root spread which eventually utilized the resources such

Table 1. Effect of plant density, spacing, and fertility levels on growth parameters of zero-tilled maize, Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

Treatments	Final plant population (000'/ha)	Plant height (cm)	Days to 50% silking	Drymatter (kg/ha)	LAI
Plant spacing and density					
50x20cm (100,000 plants/ha)	69.7	157.8	63.8	10796	2.32
60x20cm (83,333 plants/ha)	63.5	159.8	62.7	13628	2.48
75x20cm (66,666 plants/ha)	59.2	181.0	60.6	12725	2.12
CD (P=0.05)	2.03	13.7	1.7	1294	0.26
Fertility levels (kg N-P_2O_5-K_2O/ha)					
150-60-60-25	61.6	158.0	58.6	10030	2.00
200-75-75-25	63.7	163.0	61.7	11080	2.25
250-90-90-25	65.2	173.7	62.7	13828	2.35
300-105-105-25	65.9	170.0	62.3	14596	2.42
CD (P=0.05)	1.71	NS	0.97	1920	0.08

as water, nutrients, space and light. This trend also explains that as the number of plants increased in a given area, the competition among the plants for nutrients uptake and sunlight interruption also increased (Sangakkara *et al*. 2004).The fertility level of 250-90-90 kg N-P_2O_5-K_2O/ha produced comparatively taller plants, however, it was not statistically superior with other fertility levels.

Significantly enhanced LAI (2.47) was recorded with a plant density of 83,3333 plants/ha as compared to higher 100,000 (2.32) and normal plant densities of 66,6666 plants/ha (2.12). The increased LAI might be due to increased functional leaves and more area occupied by green canopy per unit area. These results are in agreement with the findings of Saberali (2007).The consistent increase in LAI was observed up to 250-90-90 kg N-P_2O_5-K_2O/ha but it was on par with 300-105-105 kg N-P_2O_5-K_2O/ha.

Dry matter production at maturity was significantly influenced by plant densities. Maximum dry matter yield was produced at a plant density of 83,333 plants/ha (13,628 kg/ha) followed by 66,666 plants/ha(12,725 kg/ha). The lower dry matter was produced by higher plant density of 100,000 plants/ha(10,796 kg/ha). Several studies have shown that dry matter decreases progressively as the number of plants increases in a given area because the production of individual plant is reduced (Hamidia *et al*. 2010). Increase in fertility level increased the dry matter content in zero-tillage maize. An increase in dry matter of 3,798 kg/ha and 2,748 kg/ha was obtained with 250-90-90 kg N-P_2O_5-K_2O/ha compared to 150-60-60 kg/ha and 200-75-75 kg N-P_2O_5-K_2O/ha fertility levels respectively. The dry matter produced with 250-90-90 kg N-P_2O_5-K_2O/ha was on par with 300-105-105 kg N-P_2O_5-K_2O/ha.

The interaction effect between plant densities and fertilizer levels on dry matter production was found significant. Irrespective of the plant density, with increase in level of fertilizers increase in biomass yield was obtained. However, significantly higher dry matter(15,918 kg/ha) was found at a plant density of 83,333 plants/ha under 60x20 cm plant spacing with 250-90-90 kg N-P_2O_5-K_2O/ha fertility level and it was shown on par with a fertility level of 300-105-105- kg N-P_2O_5-K_2O/ha (16703 kg/ha) at same plant density (Table 4).

Days to 50% silking increased with the increase in plant densities. Silking was delayed by three days as plant population increased from 66,666 to100,000 plants/ha and 2 days from 66,666 to 83,333 plants/ha. The high plant population might have increased the ASI (Anthesis and Silking Interval) compared to normal plant density (66,666 plants/ha).Higher fertility levels of 300-105-105 and 250-90-90 kg N-P_2O_5-K_2O/ha delayed the mid silking by four days as compared to lower fertility level of 150-60-60 kg N-P_2O_5-K_2O/ha. The results are in agreement with the findings of Alpha *et al*.(2006).

The yield attributes *viz.*, number of cobs per hectare, number of grain rows per cob, number of grains per row, number of grains per cob, 1000 gain weight , cob yield, grain yield, and Harvest Index were presented in Table 2.

The number of cobs per hectare was significantly influenced by plant densities and fertility levels. Maximum number of cobs were produced at plant density of 100,000 plants/ha compared to 83,333 and 66,666 plants/ha which might be due to higher final plant population in respective plant densities. Similarly, maximum number of cobs were produced with higher fertility levels of 300-105-105 and 250-90-90 kg N-P_2O_5-K_2O/ha compared to lower fertility doses of 200-75-75 kg and 150-60-60 kg N-P_2O_5-K_2O/ha. Similar results were also reported by Abuzar *et al.*(2011).

Table 2. Effect of plant density, geometry and fertility levels on yield attributes and yield of zero-tilled maize, Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

Treatments	Cob number ('000/ha)	Number of grain rows/ cob	Number of grains/ row	Grains/ cob	1000 grain weight (g)	Grain yield (kg/ha)	HI (%)	Cob yield (kg/ha)
Plant spacing and density								
50x20cm (100,000 plants/ha)	67.8	14.2	30.0	332	201	6794	34.8	8277
60x20cm (83,333 plants/ha)	61.7	14.3	32.7	407	212	8106	38.9	9283
75x20cm (66,666 plants/ha)	49.5	13.8	31.3	392	216	7364	36.3	8751
CD (P=0.05)	3.75	NS	1.79	59	6.35	627	2.16	895
Fertility levels (kg N-P_2O_5-K_2O/ha)								
150-60-60-25	55.8	12.2	29.4	333	170	6310	30.5	374
200-75-75-25	59.7	13.7	30.4	366	202	7140	36.8	8025
250-90-90-25	61.2	15.1	32.3	403	225	7952	39.1	9786
300-105-105-25	62.1	15.8	33.1	407	225	8280	40.6	9898
CD (P=0.05)	2.25	1.32	2.09	25	9.8	433	1.59	494

Table 3. Interaction effect of plant density, geometry and fertility levels on cob yield (kg/ha). Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

Treatments	Plant spacing and density			
Fertility levels (kg N-P_2O_5-K_2O/ha)	50x20 cm (100,000 plants/ha)	60x20 cm (83,333 plants/ha)	75x20 cm (66,666 plants/ha)	Mean
150-60-60-25	7406	7551	7164	7374
200-75-75-25	7531	8610	7935	8025
250-90-90-25	9061	10648	9650	9786
300-105-105-25	9112	10712	9871	9898
Mean	8277	9283	8751	
SEm$\pm$	203			
CD(P=0.005)	605			

Table 4. Interaction effect of plant density, geometry and fertility levels on dry matter (kg/ha). Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

Treatments	Plant spacing and density			
Fertility levels (kg N-P_2O_5-K_2O/ha)	50x20 cm (100,000 plants/ha)	60x20 cm (83,333 plants/ha)	75x20 cm (66,666 plants/ha)	Mean
150-60-60-25	9790	10307	9993	10030
200-75-75-25	10907	11583	10750	11080
250-90-90-25	14720	15918	10847	13828
300-105-105-25	15487	16703	11597	**14596**
Mean	12725	13628	10796	
SEm$\pm$	791			
CD(P=0.005)	2352			

Number of grain rows per ear were not significantly influenced by different plant densities. The maximum grain rows per ear were observed only with a fertility level of 300-105-105 kg N-P_2O_5-K_2O/ha and there was no significant difference in grain rows per ear between any of the other fertility levels.

Significant influence in number of grains per row was noticed with different plant densities. Maximum number of grains per row (32.7) were recorded with 83,333 plants/ha followed by 66,666 plants/ha (31.3) and lowest number of grains per row recorded with higher plant density of 100,000plants/ha (30.0). Both 250-90-90 and 300-105-105 kg N-P_2O_5-K_2O/ha fertility levels were recorded on par number of grains per row which were superior over 150-75-75 and 200-75-75 kg N-P_2O_5-K_2O /ha levels.

Significant increase in grain number per cob was noticed at a plant density of 83,333 plants/ha (407) compared to higher plant density of 100,000 plants/ha (332). However, there was no significant difference in grain number per cob between 66,666 and 83,333 plants/ha. Similar results were reported by Abuzar *et al*. 2011. The reason might be attributed due to the availability of better resources in low plant density. In high plant density, the number of individual plants per area is increased beyond the optimum plant density, there is severe consequences that are detrimental to ear ontogeny that result in barrenness (Sangoi. 2001).

In terms of 1000 grain weight on par results were observed both with normal plant density of 66,666 plants/ha (216 g) and 83,333 plants/ha(212 g). Low grain weight in high plant density of 100,000 plants/ha (201) was probably due to the availability of less photosynthetates for grain development on account of high inter specific competition which resulted in low rate of photosynthesis and high rate of respiration as result of enhanced mutual shading (Zamir *et al*. 2011).

Cob yield was significantly influenced by plant densities and fertility levels in zero-tillage maize. Higher cob yield was noticed at a plant density of 83,333 plants/ha(9283 kg/ha) under 60x20 cm geometry which was on par

Table 5. Effect of plant density, geometry and fertility levels on economic returns of zero-tilled maize, Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

Treatments	Maize yield (kg/ha)	Gross returns (Rs/ha)	Net returns (Rs /ha)	B:C ratio
Plant spacing and density				
50x20cm(100,000plants/ha)	6794	74744	50837	3.11
60x20cm(83,333 plants/ha)	8106	89113	65207	3.71
75x20cm(66,666 plants/ha)	7364	81007	57101	3.37
CD (P=0.05)	627	6886	6885	0.29
Fertility levels (kg N-P_2O_5-K_2O/ha)				
150-60-60-25	6310	69397	47951	3.23
200-75-75-25	7140	78544	55317	3.37
250-90-90-25	7952	87472	62737	3.53
300-105-105-25	8280	91075	64857	3.47
CD (P=0.05)	433	4761	4762	0.23

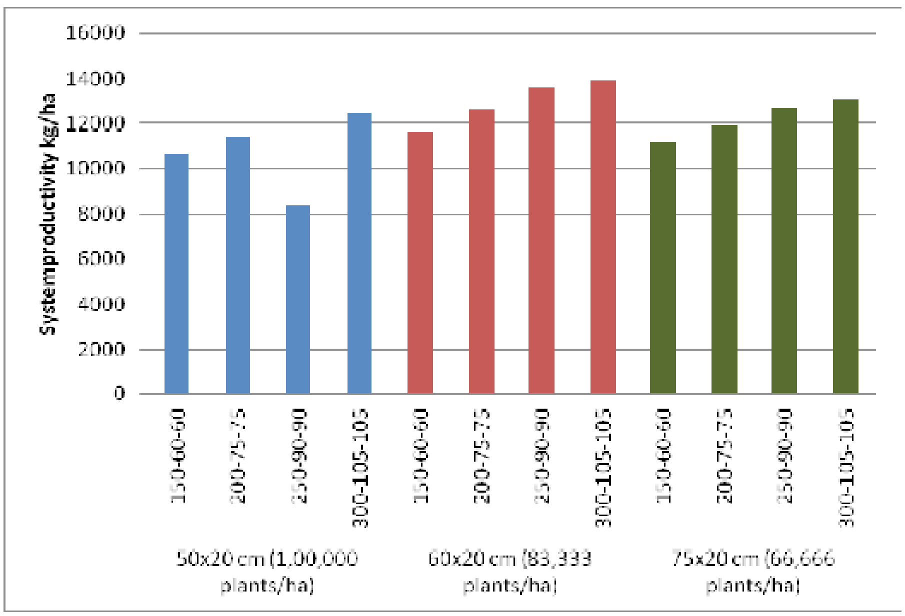

Figure 1. Effect of plant density, geometry and fertility levels on System productivity of rice-maize system, Rajendranagar, Hyderabad, 2010-11 and 2011-12 *rabi* season.

with 66,666 plants/ha (8751 kg). However, there was no significant difference in cob yield between 100,000and 66,666 plant/ha under 50x20 and 75x20 cm spacing which might be due to more final plant population realized in 100,000 plants/ha plant density. There was consistent increase in cob yield with increase in fertility levels. However, the significant influence was obtained up to 250-90-90 kg N-P_2O_5-K_2O/ha level.

The interaction effect between plant densities and fertilizer levels on cob yield was found significant (Table 3). Irrespective of the plant density, increase rate of fertilizer application increased the cob yield. However, significantly higher cob yield (10.648 kg/ha) was obtained at a plant density of 83,333 plants/ha under 60x20 cm spacing with 250-90-90 kg N-P_2O_5-K_2O/ha fertility level. It was shown on par with a fertility level of 300-105-105- kg N-P_2O_5-K_2O/ha (10,712 kg/ha).

Grain yield and System Productivity

The Grain yield, presented as an average over two years, responded positively to increasing plant density and fertility level. The difference in grain yields among plant density and fertility treatments were more associated with total plant dry matter and HI. A grain yield increase of 1,312 kg/ha (16 %) and 742 kg/ha (9%) was obtained at plant density of 83,333 plants/ha under 60x20 cm spacing compared to high plant density of 100,000plants/ha under 50x20cm and normal plant density of 66,666 plants/ha under 75x20 cm spacings, respectively. Higher number of grains cob$^-$ and 1000 grain weight might contributed to higher grain yield at 83,333 plants/ha under 60x20 cm spacing. These results are supported by Emam (2001).Different fertility levels improved the grain yield significantly. With increase in fertility level, a progressive increase in grain yield was obtained up to 250-90-90 kg N-P_2O_5-K_2O/ha level (7,952 kg/ha) which realized an increase of 1,642 kg and 812 kg grain yield /ha over 150-60-60 and 200-75-75 kg N-P_2O_5-K_2O/ha fertility levels, respectively.

The system productivity of rice-maize cropping system as affected by plant densities and fertility levels were depicted in Fig.1.Significantly higher system productivity of rice- maize system was obtained when maize was grown in sequence to *kharif* rice under zero-tillage conditions at a plant density of 83,333 plants/ha under 60x20 cm spacing (12,962 kg/ha) which was superior over a plant densities of 100,000 (11,653 kg/ha) and 66,666 (12,220 kg/ha) plants/ha under 50x20cm and 75x20 cm plant spacing respectively. The system productivity was significantly affected by different fertility levels. Maximum system productivity (12,808 kg/ha) was obtained with a fertility level of 250-90-90 kg N-P_2O_5-K_2O/ha which was on par with 300-105-105Kg N-P_2O_5-K_2O/ha (13,136 kg/ha).

Economic Return

The influence of plant density and fertility levels in zero-tillage maize in terms of economic returns were presented in Table 5. Significantly higher gross (Rs.89113/ha) and net returns (Rs.65207/ha) and B:C ratio (3.71) were realized at a plant density of 83,333 plants/ha under 60x20 cm spacing. This mainly due to higher cob and grain yields obtained at the same plant density compared to higher and normal plant densities of 100,000 and 66,666 plants/ha under 50x20 and 75x20 cm spacing. Different fertility levels influence the maize gross and net returns significantly. Increase in fertilizer rates, increased the economic returns progressively. Higher gross returns (Rs.87472 /ha), net returns (Rs.62737 /ha) and B:C ratio (3.53) was realized with a fertility level of 250-90-90 kg N-P_2O_5-K_2O/ha.

Conclusion

Adoption of high plant density up to 83,333 plants/ha under a plant spacing of 60x20 cm and application of 250-90-90-25 kg N-P_2O_5-K_2O-$ZNSO_4$ /ha to maize crop when grown in sequence to *kharif* rice under zero-tillage conditions proved to be economical in realizing higher grain yields and system productivity. However, there is a need to study the impact of residual effects of the applied nutrients to rice on succeeding maize and vice versa.

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