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Growth and Yield of *Rabi* Maize (*Zea mays* L.) at Different Planting Densities and N-Levels

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A B S T R A C T

A field experiment was conducted during *rabi* season 2014-15 at Agricultural College Farm, Bapatla to study the "Growth and yield of *rabi* maize at different planting densities and nitrogen levels". The experiment was laid out in a split plot design and replicated thrice. The results revealed that planting density of M_1 (1,00,000 plants ha^{-1}) and foliar application of $ZnSO_4$ with nitrogen at tasseling *i.e.*, S_8 (300 kg N ha^{-1}+ 0.5% $ZnSO_4$ as foliar spray at tasseling) recorded highest growth, yield attributes and yield which was on par with M_1 (1,00,000 plants ha^{-1}) and S_4 (300 kg N ha^{-1}). The interaction between planting densities and nitrogen levels was found to be non-significant.

Introduction

Maize is one of the major staple food in India. It has evolved from a purely subsistence to a successful commercial crop. Its production has increased over the years as people change their consumption trends. Maize recorded the highest annual growth rate of 2.5 per cent in the area as well as 5.5 per cent in production during the period 2004-05 to 2013-14. Maize production is dominated by Andhra Pradesh and Karnataka, producing approximately 38 per cent of India's maize in 2010-11. Andhra Pradesh has the highest yield followed by Tamil Nadu due to majority of the area being covered under Hybrids. Yield has also seen a high growth rate of 2.8 per cent as compared to other cereals. Maize production has improved with the adoption of improved technologies by farmers. These technologies include improved seeds like hybrid, open pollinated varieties, timely planting, proper spacing, timely weeding and harvesting. Maize crop bears high yield potential and responds to various agro-management practices. Low yield of maize is due to many constraints but among them, imbalanced use of fertilizers and lack of optimal crop stand are the factors of prime importance. This variable response is mainly due to differences in plant morphology (Benga *et al.,* 2001) intraspecific competition in maize plants (Maddonni and Otegui, 2004). Increasing level of nitrogen has increased yield components of maize during different research studies (Bangarwa *et el*., 1989) resulting in remarkable increase in grain yield. Maize grain yield is more affected by variations in plant population density than other members of the grass family due to its low tillering ability, its monoecious floral organization and the presence of a brief flowering period (Vega *et al.*, 2001).

Materials and Methods

The experiment was conducted during *rabi* season 2014-15 at Agricultural College Farm, Bapatla, Andhra Pradesh. The experimental site is situated at 80^0 25' E longitude, 15^0 54' N latitude and at an altitude of 5.49 m and 7 km away from the Bay of Bengal. The experimental soil was sandy loam in texture, slightly alkaline in reaction (pH 6.6), medium in organic carbon (0.52%), low in available nitrogen (206 kg ha^{-1}), medium in available phosphorus (24.1 kg ha^{-1}), high in potassium (301.5 kg ha^{-1}) and low in zinc (0.3 ppm). Nitrogen was estimated by Modified Micro Kjeldahl's method (Piper, 1966), phosphorus by Vanado Molybdate Phosphoric Acid method (Jackson, 1973), potassium by Flame Photometer method (Jackson, 1973) and zinc by DTPA extraction method (Lindsay and Norvell, 1978). The mean maximum and mean minimum temperatures were 30.0 ^{0}C and 18.3 ^{0}C.

The experiment was laid out in a split plot design with three main treatments and eight sub treatments replicated thrice. The treatments consisted of three planting densities *viz.*, M_1:50 cm x 20 cm (1,00,000 plants ha^{-1}), M_2 :60 cm x 20 cm (83,333 plants ha^{-1}) and M_3:75 cm x 20 cm (66,666 plants ha^{-1}) allotted as main plots and eight nitrogen levels *viz.*, S_1 (120 kg N ha^{-1}), S_2 (180kg N ha^{-1}) S_3 (240 kg N ha^{-1}) S_4 (300kg N ha^{-1}), S_5 (120 kg N ha^{-1} +0.5% $ZnSO_4$ as foliar spray at tasseling), S_6 (180 kg N ha^{-1} +0.5% $ZnSO_4$ as foliar spray at tasseling), S_7 (240 kg N ha^{-1} +0.5% $ZnSO_4$ as foliar spray at tasseling), S_8 (300 kg N ha^{-1} +0.5% $ZnSo_4$ as foliar spray at tasseling) alloted as subplots.

The maize hybrid, Laxmi-2277 was sown in 2^{nd} week of November 2014. Thinning and gap filling was done at 15 DAS by keeping one seedling per $hill^{-1}$. Entire dose of phosphorus were applied as basal dose through single super phosphate and nitrogen was applied as per treatments in three equal splits through urea as basal, at 30 DAS and at 60 DAS. Potassium was applied twice as basal and at 60 DAS, through muriate of potash. Whereas 0.5% $ZnSO_4$ was applied as foliar spray at tasseling as per treatments.

Results and Discussion

Growth parameters

In the present study, plant height was not significantly influenced by planting densities and nitrogen levels (Table 1). Drymatter accumulation was influenced by planting densities. Significantly highest drymatter was produced with closer spacing of M_1 (1,00,000 plants ha^{-1}) which was significantly superior to M_2 (83,333 plants ha^{-1}) and M_3 (66,666 plants ha^{-1}). Maximum drymatter at higher planting densities is due to more biomass accumulation with more number of plants per unit area. Similar observations were reported by Suryavanshi *et al.*, (2009).

Days to 50% tasseling and silking was not influenced by planting densities and nitrogen levels. Planting density of 66,666 plants ha^{-1} recorded less per cent barrenness than 83,333 plants ha^{-1} and 1,00,000 plants ha^{-1}. More barrenness at high densities was due to the absence of the usual sink for the assimilate supply which inhibited the plants to produce viable ears. These results are in agreement with Dawadi and Sah (2012).

Table.1 Growth parameters of maize at different planting densities and nitrogen levels

Treatments	Plant height (cm)	Drymatter production (kg ha^{-1})	Days to 50% tasseling	Days to 50% silking	% barrenness
Main plots (Planting densities)					
M_1:50 cm x 20 cm (1,00,000 plants ha^{-1})	189.5	11065	58.0	62.4	2.16
M_2 :60 cm x 20 cm (83,333 plants ha^{-1})	193.4	9992	57.4	61.4	1.85
M_3 :75 cm x 20 cm (66,666 plants ha^{-1})	198.4	8934	56.3	59.6	1.42
S.Em ±	4.78	266.5	1.00	0.87	0.042
CD (P=0.05)	NS	1046	NS	NS	0.16
CV (%)	12.1	13	8.6	7.01	11.35
Sub-plots (Nitrogen and zinc treatments)					
S_1:120 kg N ha^{-1}	178.3	7357	59.0	63.8	2.39
S_2:180 kg N ha^{-1}	187.0	9130	58.3	62.4	1.98
S_3:240 kg N ha^{-1}	192.1	10559	57.3	61.0	1.82
S_4:300 kg N ha^{-1}	206.6	12221	54.9	58.6	1.50
S_5: 120 kg N ha^{-1}+0.5% $ZnSO_4$ foliar spray at tasseling	186.7	7494	59.3	63.0	2.13
S_6: 180 kg N ha^{-1}+0.5% $ZnSO_4$ foliar spray at tasseling	191.5	9056	58.2	61.9	1.90
S_7: 240 kg N ha^{-1}+0.5% $ZnSO_4$ foliar spray at tasseling	196.3	11275	56.7	60.3	1.61
S_8:300 kg N ha^{-1}+0.5% $ZnSO_4$ foliar spray at tasseling	213.9	12885	54.9	58.6	1.28
S.Em ±	10.31	472.5	1.50	1.30	0.061
CD (P=0.05)	NS	1348	NS	NS	0.17
CV (%)	15.9	14	7.8	6.4	10.05
Interaction					
Planting densities at same nitrogen levels					
S.Em ±	17.38	810.5	2.64	2.31	0.112
CD (P=0.05)	NS	NS	NS	NS	NS
Nitrogen levels at same or different planting densities					
S.Em ±	17.86	818.3	2.60	2.28	0.101
CD (P=0.05)	NS	NS	NS	NS	NS

Table.2 Yield attributes of maize at different planting densities and nitrogen levels

Treatments	No. of cobs plant^{-1}	Cob length (cm)	No. of kernel rows cob^{-1}	Kernel weight cob^{-1} (g)	No. of kernels cob^{-1}	100-grain weight (g)
Main plots (Planting densities)						
M_1:50 cm x 20 cm (1,00,000 plants ha^{-1})	0.99	14.0	12.25	125.4	308.7	23.3
M_2 :60 cm x 20 cm (83,333 plants ha^{-1})	1.02	14.4	13.20	128.0	374.8	24.0
M_3 :75 cm x 20 cm (66,666 plants ha^{-1})	1.03	15.6	13.91	134.1	422.4	25.0
S.Em ±	0.005	0.30	0.35	2.57	9.03	0.43
CD (P=0.05)	0.01	1.1	NS	NS	35.4	NS
CV (%)	2.21	10.1	12.9	9.7	12.0	8.3
Sub-plots (Nitrogen and zinc treatments)						
S_1:120 kg N ha^{-1}	0.93	12.9	11.9	120.2	309.1	22.1
S_2:180 kg N ha^{-1}	1.00	14.0	12.4	124.0	339.8	22.7
S_3:240 kg N ha^{-1}	1.00	14.6	13.0	127.6	377.1	23.9
S_4:300 kg N ha^{-1}	1.07	16.0	14.4	138.9	433.1	24.9
S_5: 120 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	0.98	13.3	12.2	121.8	318.3	23.6
S_6: 180 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	1.00	14.5	13.1	127.7	342.2	24.1
S_7: 240 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	1.02	15.7	13.3	131.9	379.3	25.3
S_8:300 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	1.09	16.6	14.7	141.6	450.0	26.5
S.Em ±	0.028	0.60	0.47	4.32	12.93	0.86
CD (P=0.05)	0.07	1.7	1.3	12.3	36.9	2.4
CV (%)	8.24	12.3	10.8	10.0	10.5	10.8
Interaction						
Planting densities at same level of nitrogen						
S.Em ±	0.045	1.03	0.84	7.45	22.82	1.47
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nitrogen levels at same or different planting densities						
S.Em ±	0.048	1.05	0.82	7.47	22.40	1.51
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table.3 Kernel yield, stover yield and harvest index of maize at different planting densities and nitrogen levels

Treatments	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
Main plots (Planting densities)			
M_1:50 cm x 20 cm (1,00,000 plants ha^{-1})	4586	6120	42.2
M_2 :60 cm x 20 cm (83,333 plants ha^{-1})	4767	5095	48.1
M_3 :75 cm x 20 cm (66,666 plants ha^{-1})	4081	4698	46.0
S.Em ±	131.7	137.3	1.33
CD (P=0.05)	517.1	539	NS
CV (%)	14.4	12.6	14.3
Sub-plots (Nitrogen and zinc treatments)			
S_1:120 kg N ha^{-1}	3240	4033	43.5
S_2:180 kg N ha^{-1}	3923	4841	44.5
S_3:240 kg N ha^{-1}	4635	5646	45.0
S_4:300 kg N ha^{-1}	5578	6291	46.4
S_5: 120 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	3427	4301	44.5
S_6: 180 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	4203	5144	45.1
S_7: 240 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	5002	5697	47.1
S_8:300 kg N ha^{-1}+ 0.5% $ZnSO_4$ foliar spray at tasseling	5816	6478	47.6
S.Em ±	146.4	209.9	1.84
CD (P=0.05)	417	599.3	NS
CV (%)	16.0	11.8	12.2
Interaction			
Planting densities at same level of nitrogen			
S.Em ±	409.0	366.8	3.27
CD (P=0.05)	NS	NS	NS
Nitrogen levels at same or different planting densities			
S.Em ±	414.0	363.7	3.19
CD (P=0.05)	NS	NS	NS

Significantly highest drymatter was produced with S_8 (300 kg N ha^{-1} as foliar spray at tasseling) which was on par with S_4 (300 kg N ha^{-1}) and S_7 (240 kg N ha^{-1}) and significantly superior to the other doses. Adequate supply of N with Zn might have helped to increase their growth which in turn put forth more photosynthetic surface, thus resulting in higher drymatter accumulation. These results are in agreement with the findings of Aruna *et al.,* (2006). Per cent barrenness was found to be significantly less (1.28 %) with S_8 (300 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray at tasseling) which was significantly superior to other levels. Adequate supply of nitrogen together with zinc reduced barren plants at higher doses of N. These results are in accordance with Aruna *et al.,* (2006) and Dawadi and Sah (2012).

Yield attributes

Among yield components of maize, no. of cobs plant^{-1}, cob length (cm), number of kernels cob^{-1} were significantly influenced by planting densities and nitrogen levels while kernel weight cob^{-1}(g), number of kernel rows cob^{-1} and 100-grain weight was not significantly influenced by planting densities but influenced by nitrogen levels.

Test weight was not statistically influenced by planting densities. Interaction between them was found to be non-significant (Table 2). Lower planting density of 66,666 plants ha^{-1} recorded maximum number of cobs $plant^{-1}$, cob length and number of kernels cob^{-1} than 83,333 plants ha^{-1} and 1,00,000 plants ha^{-1}. Greater competition between plants for resources like nutrients, solar energy and soil water might have suppressed the performance of individual plants with higher plant density as reported by Wasnik *et al.,* (2012).

Number of cobs $plant^{-1}$, kernels rows cob^{-1} and kernels cob^{-1} recorded significantly highest with S_8 (300 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray at tasseling) which was on par with S_4 (300 kg N ha^{-1}) but significantly superior to other levels of nitrogen with or without zinc.

Significantly highest cob length (cm), kernel weight cob^{-1} (g) and 100- grain weight (g) was recorded with S_8 (300 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray at tasseling) which was on par with S_4 (300 kg N ha^{-1}) and S_7 (240 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray at tasseling). This might be due to better absorption of N and Zn through foliage and their synergistic effect improved the yield parameters of maize. These results are in accordance with Tank *et al.,* (2006).

Higher test weight was obtained with 300 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray which was on par with 240 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray, 300 kg N ha^{-1} and found significantly superior to other levels tested. Increase in test weight might be due to better absorption of zinc through foliage and availability of nitrogen and their synergistic effect might have helped better grain filling and hence higher 100-grain weight. These lines are in conformity with Aruna *et al.,* (2006).

Kernel and stover yield kg ha^{-1}

Planting densities and nitrogen levels significantly influence the kernel and stover yields of maize and their interaction was found to be non-significant (Table 3). Maximum grain of 4767 kg ha^{-1} was recorded with M_2 (83,333 plants ha^{-1}) and stover yield of 6120 kg ha^{-1} was recorded with M_1 (1,00,000 plants ha^{-1}). Significantly highest kernel and stover yields of maize was recorded with S_8 (300 kg N ha^{-1}+ 0.5% $ZnSO_4$ as foliar spray at tasseling) which was on a par with only nitrogen S_4 (300 kg N ha^{-1}) and significantly superior to other levels. This indicates that decline in yield components was more compensated with increase in plant density per unit area and adequate availability of nutrients and moisture. Similar results were reported by Gollar and Patil (2000).The increase in kernel yield at higher N levels together with Zn as foliar spray is due to better uptake of nutrients and zinc applied at tasseling. The results obtained are in consonance with the findings of Sekhar *et al.,* (2012). Maximum stover yield of maize at higher plant densities might be due to variation in the crop stand per unit area. These results are in agreement with Zamir *et al.,* (2011). As zinc plays a role in metabolism of plant as an activator of enzymes which in turn directly or indirectly affect the synthesis of carbohydrates, soil application of NPK coupled with $ZnSO_4$ as foliar spraying at tasseling influenced the stover yield of maize. These findings are in agreement with Tyagi *et al.,* (1998). Harvest index was not influenced by planting densities and nitrogen levels. Application of 300 kg N ha^{-1} + 0.5% $ZnSO_4$ as foliar spray at tasseling recorded numerically more harvest index followed by other nitrogen levels.

From the present study, it was clearly indicated that growth parameters and yield attributes of *rabi* maize were significantly highest with M_3 (66,666 plants ha^{-1}) while kernel yield was highest with M_2 (83,333 plants ha^{-1}) which was on par with M_1 (1,00,000 plants ha^{-1}). Stover yield was significantly superior with M_1 (1,00,000 plants ha^{-1}) compared to M_2 (83,333 plants ha^{-1}) and M_3 (66,666 plants ha^{-1}). Nitrogen levels had significant effect on growth and yield of *rabi* maize, maximum growth and yield was obtained @ 300 kg N ha^{-1}+ 0.5% $ZnSO_4$ as foliar spray at tasseling which was on par with 300 kg N ha^{-1} alone.

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