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Influence of Fertilizer Levels and Growth Regulating Substances on Growth, Nutrient Use Efficiency and Yield of Hybrid Maize

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A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* 2008 to study the influence of fertilizer levels and foliar spray of plant growth substances on growth, nutrient use efficiency and yield of hybrid maize under irrigated condition. The experiment was laid out in a split plot design replicated thrice. Three fertilizer levels viz., 150:75:75, 200:100:100 and 250:125:125 NPK kg ha^{-1} constituted the main plot treatments. Foliar spray of growth substances viz., control (no spray), salicylic acid 100 ppm, boric acid 0.3%, PGR consortia 1.5%, TNAU Panchagavya 3% and Pink-pigmented facultative methylotrophic bacteria (PPFM) 10^{6} dilution were assigned to sub plot. The results of the experiment revealed that among the fertilizer levels, 250:125:125 NPK kg ha^{-1} recorded taller plants, higher LAI, DMP, nutrient uptake and yield. However, the yield was comparable with 200:100:100 NPK kg ha^{-1}. Regarding the growth substances, PGR consortia 1.5% recorded better growth parameters, higher nutrient uptake and yield than the other growth substances. The highest agronomic efficiency (AE) and apparent recovery (AR) for nitrogen, phosphorus and potassium were recorded under the treatment combination 200:100:100 NPK kg ha^{-1} along with the foliar spray of PGR consortia @ 1.5%.

Keywords: Fertilizer Levels, Growth Substances, Growth, Nutrient Uptake, Use Efficiency, Yield

Maize (*Zea mays* L.) is the third most important cereal next to rice and wheat, in the world as well as in India. It is called as “miracle crop” and also “queen of cereals”. Maize is cultivated both in tropical and temperate regions of the world. In India, maize occupies third place among the cereals after rice and wheat and it is cultivated over an area of 8.26 million hectares with a production of 19.30 million tonnes and the average productivity is 2337 kg ha^{-1} (Agricoop, 2007- 08). In Tamil Nadu, maize is cultivated in an area of 0.20 million hectares with a production of 0.24 million tonnes and productivity of 1189 kg ha^{-1} (Crop Report, 2006 - 07).

Among the plant nutrients, primary nutrients such as nitrogen, phosphorus and potassium play a crucial role in deciding the growth and yield. Nitrogen is the most deficient primary nutrient in Indian soils. The response of crops to nitrogen varies widely from place to place, depending upon the fertility level of soil and other environmental conditions. This necessitates the study on the response of crop to different levels of fertilizer. Maize has high yield potential and responds greatly to applied fertilizers. Therefore, proper management of nutrients is essential to realize maximum potential of the crop and to get higher economic benefit.

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Nutrients are important and crucial elements, which are required for the plant for its growth and development. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance effective partitioning of the accumulates from source and sink in the field crops (Solaimalai *et al*., 2001). Foliar application of growth regulators and chemicals at the flowering stage may improve the physiological efficiency and may play a significant role in raising the productivity of the crop (Dashora and Jain, 2004).

The nutrient-use efficiency (NUE) of a crop production system is the yield per unit input of fertiliser. This can be improved by foliar application of growth substances, which can effectively improve the translocation of photo-assimilates from source to sink for development of economic part. Hence, with this in view, an attempt was made to study the influence of graded levels of fertilizers and plant growth substances on growth, nutrient uptake, fertilizer use efficiency and yield of hybrid maize.

Materials and Methods

A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* 2008 to study the influence of fertilizer levels and foliar spray of plant growth substances on growth,

nutrient uptake, fertilizer use efficiency and yield of hybrid maize under irrigated condition. The experiment was laid out in a split plot design replicated thrice. Three fertilizer levels viz., 150:75:75, 200:100:100 and 250:125:125 NPK kg ha^{-1} constituted the main plot treatments. Foliar spray of growth substances viz., control (no spray), salicylic acid 100 ppm, boric acid 0.3%, PGR consortia 1.5%, TNAU Panchagavya 3% and Pink-pigmented facultative methylotrophic bacteria (PPFM) 10^6 dilution were assigned to sub plot. The soil of the experimental field was sandy clay loam in texture belonging to *Typic Ustropept*. The nutrient status of soil was low in available nitrogen (302.4 kg ha^{-1}), medium in available phosphrous (20.22 kg ha^{-1}) and high in available potassium (540.4 kg ha^{-1}). Maize hybrid, CO H(M) 5, a high yielding single cross hybrid released by the Department of Millets, Tamil Nadu Agricultural University, Coimbatore was chosen for the study.

Well decomposed farmyard manure at the rate of 12.5 t ha^{-1} was applied uniformly over the field before the last ploughing. $ZnSO_4$ @ 37.5 kg ha^{-1} was applied uniformly as basal to all the plots. Seeds of maize hybrids were sown on the side of the ridges by adopting a spacing of 75 x 20 cm. Seeds were dibbled at the rate of one seed $hill^{-1}$. The seeds were pre-treated with ridomil @ 2 g kg^{-1} of seeds and azospirillum, 600 g per hectare of seeds before sowing the seeds. As per the treatment schedule, nitrogen was applied in three splits *viz*., 25, 50 and 25 per cent as basal, 25 and 45 DAS, respectively. The entire dose of phosphorus was applied basally. The potassium was applied in two equal split doses as basal and at 45 DAS. The N, P and K fertilizers were applied in the form of urea (46 % N), single super phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O), respectively. The fertilizers were placed at 5 cm depth on sides of the ridges by forming small furrows. Foliar spray of growth substances was given twice on 45 and 55 days after sowing. PGR consortia is a product formulated by the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore. It is a granule formulation mainly consisting of plant growth regulators *viz.,* Indole Acetic Acid (IAA)), Indole Butyric Acid (IBA), Naphthalene Acetic Acid (NAA), Salicylic Acid and Boric Acid etc,

The LAI was calculated by using the following formula suggested by Balakrishnan *et al*. (1987). Grain yield was recorded for individual treatment at 14 per cent seed moisture and expressed in kg ha^{-1}. The nitrogen, phosphorus and potassium content were analysed by the standard procedure given by Jackson (1967), Olsen and Sommers (1982) and Piper (1966), respectively. The nutrient values obtained as percentage in the analysis were computed to kg ha^{-1} by multiplying with the corresponding DMP obtained for each treatment. The nutrient use efficiencies (NEU) *viz.,* agronomic efficiency (response ratio) and apparent recovery were calculated as follows;

The agronomic efficiency of nutrient was computed by the following formula as described by Yoshida (1981).

$$AE = \frac{[\text{Grain yield in fertilized plot (kg ha}^{-1})] - [\text{Grain yield in unfertilized plot (kg ha}^{-1})]}{\text{Quantity of fertilizer nutrient applied (kg ha}^{-1})}$$

Apparent recovery also known as recovery fraction was computed as per the formula suggested by Pillai and Vamadevan (1978).

$$\text{Apparent recovery (\%)} = \frac{Y_t - Y_o}{N_t} \times 100$$

Where

Y_t - Uptake in fertilized plot (kg ha^{-1})

Y_o - Uptake in unfertilized plot (kg ha^{-1})

Nt - Quantity of fertilizer nutrient applied (kg ha^{-1})

Results and Discussion

Growth parameters

The fertilizer levels significantly influenced the plant height, stem girth, LAI and DMP. Application of 250:125:125 NPK kg ha^{-1} recorded better growth parameters viz, plant height, LAI and DMP at both the stages (Table 1). The increase in plant height and DMP might be attributed to the improved foraging ability, higher nutrient uptake with better assimilation that may have helped the plants to grow taller with more LAI as already reported by Verma and Joshi (1999) as plant height and LAI were directly correlated to DMP. The better LAI indicating the better photosynthetic efficiency as a reflection of assimilation and dry matter production due to continuous release of nutrients by split application of nitrogen and potassium might be the plausible reason for such an increase in dry matter production.

Foliar spray of growth substances significantly influenced the plant height, LAI and DMP. Maize crop sprayed with foliar spray of PGR consortia @ 1.5% recorded the highest dry matter production (14278 kg ha^{-1}) but was comparable with foliar spray of boric acid @ 0.3%, panchagavya @ 3% and PPFM 10^6 dilution. NAA present in PGR consortia could have increased the dry matter production of the treated plants. Increase in DMP with PGR consortia @ 1.5 % is attributed to increase in plant height and LAI and thus in total biomass. NAA facilitates the chlorophyll synthesis in leaves and photosynthetic efficiency which ultimately led to accumulation of more photosynthates per unit leaf area thus enhancing the drymatter accumulation. The increase in DMP due to NAA application might also be due to its influence on respiration and photosynthesis which could have led to accumulation of more dry matter. Similar results were reported earlier by Muthukumar *et al.* (2005) in baby corn.

Nutrient uptake

Among the fertilizer levels, fertilizer dose of 250:125:125 NPK kg ha^{-1} recorded the highest nitrogen (245.9 kg ha^{-1}), phosphorus (29.27 kg ha^{-1}) and potassium (191.8 kg ha^{-1}) uptake followed by the application of 200:100:100 NPK kg ha^{-1}. The increased uptake of nutrients at higher doses resulted in initial build up of plants due to vigorous growth and higher photosynthetic rate which led to better uptake of nutrients throughout the crop growth period. Similar finding was also reported by Selvaraju and Iruthayaraj (1995), Shivay *et al*. (1999) and Parthipan (2000).

With regard to foliar spray treatments, application of PGR consortia @ 1.5% recorded the highest nitrogen (242.9 kg ha^{-1}), phosphorus (28.71 kg ha^{-1}) and potassium (186.8 kg ha^{-1}) uptake by maize crop but was comparable with foliar spray of boric acid @ 0.3% and panchagavya @ 3%. The least uptake of nitrogen was recorded with control (Table 2). This higher uptake of nitrogen, phosphorus and potassium due to application of PGR consortia @ 1.5 % might be due to better uptake and effective translocation of nutrients from source to sink. NAA was one of the growth regulators present in PGR consortia and thus its application might have resulted in higher production of sink tissues and effective translocation of photosynthates from source to sink as reported by Raffiq-uddin (1986).

Table 1. Effect of fertilizer levels and foliar sprays on growth parameters of hybrid maize at 60 and 90 DAS

Treatment	Plant height (cm)		LAI		DMP (kg ha^{-1})	
Fertilizer level (NPK kg ha^{-1})	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
150: 75: 75	190.1	205.3	5.05	3.78	6523	13242
200: 100: 100	198.6	213.2	5.37	4.12	7304	14174
250: 125: 125	210.7	221.7	5.61	5.10	7515	14264
SEd	3.5	5.0	0.11	0.08	93	242
CD (P = 0.05)	9.7	13.9	0.30	0.24	259	672
Foliar spray						
Control (no spray)	185.9	196.1	5.03	3.99	6770	13317
Salicylic acid (100 ppm)	198.6	210.4	5.13	4.15	6957	13604
Boric acid (0.3%)	204.2	219.7	5.50	4.50	7203	14183
PGR consortia (1.5%)	209.8	220.9	5.65	4.63	7464	14278
TNAU Panchagavya (3%)	200.7	213.2	5.42	4.43	7167	14016
(PPFM) 10^6 dilution	199.7	210.3	5.33	4.30	7122	13965
SEd	4.2	4.9	0.14	0.13	106	299
CD (P = 0.05)	8.6	10.4	0.29	0.27	217	612

Table 2. Effect of fertilizer levels and foliar sprays on nutrient uptake by hybrid maize

Treatment	Nutrient uptake (kg ha^{-1})		
Fertilizer level (NPK kg ha^{-1})	Nitrogen	Phosphorus	Potassium
150: 75: 75	192.5	22.05	149.2
200:100: 100	230.2	27.70	172.9
250:125: 125	245.9	29.27	191.8
SEd	3.8	0.52	2.7
CD (P =0.05)	10.6	1.45	7.4
Foliar spray			
Control (no spray)	153.1	18.10	120.8
Salicylic acid (100 ppm)	232.3	27.53	176.3
Boric acid (0.3%)	242.1	28.25	183.4
PGR consortia (1.5%)	242.9	28.71	186.8
TNAU Panchagavya (3%)	235.8	27.91	181.8
(PPFM) 10^6 dilution	231.2	27.55	178.8
SEd	3.5	0.46	2.4
CD (P= 0.05)	7.1	0.95	4.9

PPFM - Pink-pigmented facultative methylotrophic bacteria

Nutrient use efficiency (NUE)

The treatment combination of recommended level of fertilizer (i.e.) 150:75:75 NPK kg ha^{-1} without any foliar spray was taken as control to work out the NUE. The grain yield under this treatment combination was taken as zero for calculating nutrient use efficiency.

Agronomic efficiency (AE) of nutrients

Agronomic efficiency indicates the quantity of grain produced per unit of N applied and it is the product of efficiency of absorption as well as utilization. Increased levels of N tend to lower the productive efficiency. The highest agronomic efficiency of N (8.21 kg of grain produced per kg of applied N) was recorded with application of 200:100:100 NPK kg ha^{-1} along with foliar spray of PGR consortia @ 1.5 % (Table 3). This is in conformation with the result of Damodaran (2002) and Angayarkanni and Ravichandaran (2001). The highest agronomic efficiency of P and K was recorded with application of 200:100:100 NPK kg ha^{-1}. Similar trend of decreased phosphorus use efficiency and potassium use efficiency with increased fertilizer application was also reported by Jagadeeswaran *et al*. (2005).

Apparent recovery (AR) of nutrients

Apparent recovery, which indicates the efficiency of absorption of applied nutrients, decreased at

Table 3. Effect of fertilizer levels and foliar sprays on agronomic efficiency (AE) of nutrients

Treatment	Nitrogen	Phosphorus	Potassium
M_1S_1	-	-	-
M_1S_2	2.06	4.12	4.12
M_1S_3	2.01	4.03	4.03
M_1S_4	1.40	2.80	2.80
M_1S_5	0.70	1.40	1.40
M_1S_6	1.54	3.09	3.09
M_2S_1	3.02	6.03	6.03
M_2S_2	5.18	10.36	10.36
M_2S_3	6.69	13.37	13.37
M_2S_4	8.21	16.42	16.42
M_2S_5	5.85	11.70	11.70
M_2S_6	4.71	9.43	9.43
M_3S_1	3.41	6.82	6.82
M_3S_2	5.27	10.53	10.53
M_3S_3	5.51	11.01	11.01
M_3S_4	7.21	14.41	14.41
M_3S_5	5.38	10.76	10.76
M_3S_6	4.90	9.80	9.80

higher levels of fertilizer application. Each crop is having definite capacity to absorb a certain amount of nutrients, beyond which nutrients could not be taken up. When limited quantity of nutrients was applied, the crop efficiently absorbed the available nutrients in the soil solution and there by reduced the nutrient losses. The highest apparent recovery of N, P and K was recorded with treatment combination of 200:100:100 NPK kg ha^{-1} along with foliar spray of PGR consortia (Table 4). Alagesan (1997) in rice, Singh and Sharma (2000) in rice – wheat cropping system also reported similar findings.

Grain yield

Among the fertilizer levels, fertilizer application at 250:125:125 NPK kg ha^{-1} recorded the highest grain yield of 6546 kg ha^{-1} but was comparable with 200:100:100 NPK kg ha^{-1}. The grain yield increase with 250:125:125 and 200:100:100 NPK kg ha^{-1} was 17.2 and 14.6 per cent, respectively, over the fertilizer level of 150:75:75 NPK kg ha^{-1}.

Table 4. Effect of fertilizer levels and foliar sprays on apparent recovery (AR) of nutrients

Treatment	Nitrogen	Phosphorus	Potassium
M_1S_1	-	-	-
M_1S_2	49.51	8.66	78.48
M_1S_3	52.31	9.23	88.26
M_1S_4	47.84	8.95	83.66
M_1S_5	50.58	9.25	85.97
M_1S_6	44.16	7.92	83.50
M_2S_1	18.61	1.16	28.03
M_2S_2	51.23	12.61	82.25
M_2S_3	57.02	13.12	90.74
M_2S_4	61.07	14.33	92.51
M_2S_5	56.54	12.95	86.13
M_2S_6	51.82	12.67	77.69
M_3S_1	11.04	2.75	35.39
M_3S_2	50.34	11.03	78.19
M_3S_3	55.82	12.01	82.44
M_3S_4	56.22	12.35	92.03
M_3S_5	49.63	11.34	83.75
M_3S_6	51.80	11.48	84.65

The crop sprayed with PGR consortia @ 1.5% produced the highest grain yield (6444 kg ha^{-1}) followed by application of boric acid @ 0.3% (6231 kg ha^{-1}). The least grain yield was associated with control. The grain yield increase with PGR consortia @ 1.5% and boric acid @ 0.3% was 11.3% and 8.3%, respectively, over control (i.e.) crop without foliar spray (Table 5).

Table 5. Effect of fertilizer levels and foliar sprays on grain yield (kg ha^{-1}) of hybrid maize

Foliar spray	Fertilizer level (NPK kg ha^{-1})			Mean
	150: 75: 75	200:100: 100	250:125: 125	
Control (no spray)	5226	5829	6079	**5711**
Salicylic acid (100 ppm)	5536	6262	6543	**6114**
Boric acid (0.3%)	5528	6563	6603	**6231**
PGR consortia (1.5%)	5436	6869	7028	**6444**
TNAU Panchagavya (3%)	5331	6397	6572	**6100**
PPFM 10^6 dilution	5458	6169	6452	**6026**
Mean	5419	6348	6546	
	SEd	CD (P = 0.05)		
M	74	208		
S	51	210		
M at S	110	263		
S at M	89	182		

Among the treatment combinations, the highest grain yield (7028 kg ha^{-1}) was recorded at 250:125:125 NPK kg ha^{-1} with foliar spray of PGR consortia @ 1.5%. However, the yield obtained under this combination was comparable with the yield obtained under 200:100:100 NPK kg ha^{-1} along with foliar spray of PGR consortia @ 1.5% (6869 kg ha^{-1}). The least grain yield (5226 kg ha^{-1}) was obtained under 150:75:75 NPK kg ha^{-1} without any foliar spray.

This increase in yield was probably due to effective utilization of applied nutrients, increased sink capacity and nutrient uptake by crop. The yield potential of maize is mainly governed by the growth and yield components. The positive and significant improvement in LAI and DMP would have resulted in enhanced grain yield. The present findings are in line with the findings of Siva (2007) and Maddonni *et al*. (2006). The positive responses of hybrid maize upto 250 kg N ha^{-1} as reported by Srikanth *et al*. (2009) lend support to the present findings.

The increase in grain yield with PGR consortia spray might be due to effective translocation of photosynthates from source to sink. PGR consortia @ 1.5 % application might have facilitated effective translocation of assimilates from source to sink which has resulted finally in the cob yield. The

increase in grain yield might also be due to increased mobilization of reserve food materials to sink through increase in hydrolyzing and oxidising enzyme.

NAA promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in improving growth characteristics and also facilitated reproductive growth (Pareek *et al.* 2000). NAA present in PGR consortia could have increased the grain yield of the treated plants. Similar results of increase in yield due to NAA application were also reported earlier by Muthukumar *et al.* (2007) in baby corn.

Conclusion

The results of the experiment revealed that among fertilizer levels 250:125:125 NPK kg ha^{-1} recorded taller plants, higher LAI, DMP, nutrient uptake and yield. However, the yield was comparable with 200:100:100 NPK kg ha^{-1}. Regarding the growth substances, PGR consortia @ 1.5% recorded better growth parameters, higher nutrient uptake and yield than the other growth substances. The highest agronomic efficiency (AE) and apparent recovery (AR) for nitrogen, phosphorus and potassium were recorded under the treatment combination of 200:100:100 NPK kg ha^{-1} along with the foliar spray of PGR consortia @ 1.5%. Among the treatment combinations, the highest grain yield was recorded under 250:125:125 NPK kg ha^{-1} with foliar spray of PGR consortia @ 1.5% but, was comparable with 200:100:100 NPK kg ha^{-1} along with foliar spray of PGR consortia @ 1.5%.

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