Madras Agric. J., 98 (1-3): 62-66, March 2011
https://doi.org/10.29321/MAJ.10.100243

Influence of Mycorrhiza, Nitrogen and Phosphorus on Growth, Yield and Economics of Hybrid Maize

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Field experiment was conducted at Agricultural Research Station, Bhavanisagar during kharif 2009 to study the influence of mycorrhizal inoculation and fertilizer levels on the yield and grain quality of hybrid maize under irrigated condition. The experiment was laid out in a factorial randomized block design with four replications. Four fertilizer levels *viz*., 200:100:100, 150:100:100, 200:75:100 and 150:75:100 NPK kg ha^{-1} were the treatments under factor 'A'. Two mycorrhizal treatments *viz*., no inoculation of mycorrhiza (control) (M$^-$) and inoculation of mycorrhiza (M$^+$) were included under factor 'B'. The results revealed that among the fertilizer levels, 200:100:100 NPK kg ha^{-1} and among the mycorrhizal treatments, mycorrhizal inoculation recorded taller plants, higher number of leaves, LAI, DMP, grain yield and BC ratio. However the yield was comparable with 200:75:100 NPK kg ha^{-1}. Regarding the treatment combinations, eventhough higher CGR and RGR were recorded under fertilizer level of 200:100:100 NPK kg ha^{-1} and inoculation of mycorrhiza, application of 150:75:100 NPK kg ha^{-1} along with mycorrhizal inoculation recorded significantly better growth, yield and BC ratio of maize hybrid.

Key words: Hybrid maize, fertilizer levels, mycorrhiza, growth attributes, yield, economics

Maize (*Zea mays* L.) is one of the most versatile crops and can be grown in diverse environmental conditions and has diversified uses as human food and animal feed. Besides its use as food and fodder, maize is now gaining importance on account of its potential uses in manufacturing of starch, resins, syrups, ethanol, etc. It has got immense potential and is therefore called as "miracle crop" and also "queen of cereals". Maize, being a C4 plant is an efficient converter of absorbed nutrients into food.

The productivity of any crop is the ultimate result of its growth and development. Plant population, inorganic and organic fertilization are the important prime factors that determine the yield of maize crop. Among the essential nutrients, macro-nutrients such as, nitrogen, phosphorus and potassium play a crucial role in deciding the growth and yield. Many workers have indicated that nitrogen is the foremost limiting factor for maize production. On the other hand, intensive cultivation only results in considerable removal of nutrients from the soil and their replenishment through organic manure is very limited and thus newly evolved hybrids with good yield potential show positive response to high levels of NPK fertilizers. 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.

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Arbuscular mycorrhiza fungi are considered as obligate symbionts to crop plants for better utilization of P and other essential elements. The readily available form of N to any crop plant is NO_3- which is highly labile in soil solution and thus the role of mycorrhiza is insignificant. Conversely, drought stress impedes the mobility of NO_3- ions in soils due to its low concentration and diffusion rate (Azcon *et al.,* 1996). Under such environmental condition, AM fungi may play a crucial role in transporting N from the soil to the root surface, thereby contributing to plant growth and nutrition.

Phosphorus is generally available in small quantities in soil solution because most of inorganic phosphate ions are bound to soil colloids or fixed as iron aluminium PO_4 (Larsen, 1967). Nearly 98 percent of the Indian soils are deficient in P and about 10-15 percent of P from soil is utilized by plants. Moreover, less than 15-25 percent of P from PO_4 fertilizer applied to soil is normally available to plants and a large quantity of P remains unavailable due to its fixation (Bradey, 1990; Singh and Singh, 1992). Under such circumstances AM fungi can be effectively utilized to enhance the P mobilization.

Increased use of NPK fertilizers generally devoid of micronutrients and soil fertility has brought about several problems related to nutrient deficiency by depleting finite beneficial organisms reserve of the soil. Hence, it becomes, important to maintain proper balance of major nutrients with organic fertilizers for

sustaining the crop production. Keeping this in view, a field investigation was carried out to find out the effect of mycorrhizal inoculation and different nitrogen and phosphorus levels on growth, yield and economics of hybrid maize.

Materials and Methods

Field experiment was conducted at Agricultural Research Station, Bhavanisagar during kharif 2009 to study the influence of mycorrhizal inoculation and fertilizer levels on growth, yield and economics of hybrid maize under irrigated condition. The experiment was laid out in a factorial randomized block design with four replications. Four fertilizer levels *viz*., 200:100:100, 150:100:100, 200:75:100 and 150:75:100 NPK kg ha^{-1} were the treatments under factor 'A'. Two mycorrhizal treatments viz., no inoculation of mycorrhiza (control) (M^-) and inoculation of mycorrhiza (M^+) were included under factor 'B'. The soil of the experimental field was red sandy loam in texture belonging to Typic Paleustalfs. The nutrient status of soil was low in available nitrogen (229.6 kg ha^{-1}), medium in available phosphorus (20.2 kg ha^{-1}) and medium in available potassium (268.2 kg ha^{-1}). Maize hybrid, COH (M) 5, a high yielding single cross hybrid released by Tamil Nadu Agricultural University, Coimbatore was chosen for the study.

Seeds of maize hybrids were sown on the side of the ridges by adopting a spacing of 75 x 20 cm along with vermiculite based mycorrhizal inoculum at a depth of 5 cm below the seeds. The inoculum with the spore density of 200 spores g^{-1} was applied as a thin layer beneath the seeds prior to sowing @ 100 kg ha^{-1}. Seeds were dibbled at the rate of one seed $hill^{-1}$.

Well decomposed farm yard manure at the rate of 12.5 t ha^{-1} was applied uniformly over the field before last ploughing. $ZnSO_4$ @ 37.5 kg ha^{-1} was applied uniformly as basal to all the plots. As per the treatment schedule, nitrogen was applied in three splits viz., 25: 50:25 per cent as basal and on 25 and 45 DAS, respectively. The entire dose of phosphorus was applied basally. The potassium was applied in two equal split doses *viz*., 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.

Results and Discussion

Growth parameters

Among the fertilizer levels, fertilizer dose of 200:100:100 NPK kg ha^{-1} and among the mycorrhizal treatments, mycorrhizal inoculation recorded taller plants, higher number of leaves, LAI and DMP (Table 1). Regarding the treatment combination, application of 150:75:100 NPK kg ha^{-1} along with mycorrhizal inoculation recorded significantly better growth parameters. This indicated that hybrid maize responded to NPK linearly. The increasing trend of plant height with N or NP together was probably due to the role of N in cell division and cell enlargement, which ultimately affect the vegetative growth particularly height of the plant. Similar results were reported by Srikanth *et al*. (2009). These results are also supported by the findings of Shahzad *et al.* (1996) who also have reported similar results.

The maize plants inoculated with AMF fungus have shown improved growth and development as compared to plants under control. This might due to the formation of external mycelium around the roots

Table 1. Growth parameters of maize hybrid as influenced by mycorrhiza, nitrogen and phosphorus levels

Treatment	Plant height (cm)			Leaf area index			Dry matter production(Kg ha^{-1})		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F_1- 200:100:100	110.9	227.3	229.6	3.35	6.45	4.47	1265	7528	17337
F_2- 150:100:100	105.4	210.5	217.7	2.94	5.83	4.00	1113	6937	16134
F_3- 200:75:100	110.6	225.3	231.6	3.26	6.41	4.38	1239	7246	17052
F_4- 150:75:100	105.8	216.4	222.9	3.16	6.14	4.30	1213	7244	16567
SEd	4.59	5.75	5.01	0.12	0.20	0.14	53.05	136.5	246.2
CD (P = 0.05)	NS	11.95	10.41	0.25	0.41	0.29	110.3	283.9	512.1
Mycorrhizal inoculation									
(M^-)	102.8	210.1	215.8	2.83	5.78	3.86	973	6864	14629
(M^+)	113.7	229.6	235.1	3.52	6.64	4.71	1442	7613	18916
SEd	3.25	4.06	3.54	0.08	0.14	0.10	37.51	96.49	174.1
CD (P = 0.05)	6.76	8.45	7.36	0.18	0.29	0.20	78.02	200.7	362.1
F x M									
SEd	6.5	8.1	7.0	0.17	0.28	0.19	75.0	193	348
CD (P = 0.05)	13.4	16.9	14.7	0.35	0.58	0.41	156.0	401	724

M^- - Uninoculated (control) M^+ - Inoculated with AMF (*Glomus intraradices)*

by AMF fungi which possibly helped to increase the availability of nutrients to the surface of the roots and thereby the nutrient uptake and height of plants. The above results of increased growth of treated plants due to mycorrhization of G. intraradices are in conformity with the findings of Karthikeyan *et al.* (2009).

The NP levels significantly enhanced the LAI. This might be due to the production of more number of leaves per plant by increased NP levels as reported by Srikanth *et al.* (2009a). Inoculation of mycorrhiza significantly increased the LAI both at 60 and 90 DAS. This might be due to the increase in the number of leaves and the leaf enlargement due to better nutrient uptake. Similar results were reported in the case of corn (Kothari *et al.,* 1991) and maize (Subramanian *et al.*, 1995).

The DMP increased steadily with time and reached the highest at 90 DAS. At 30 DAS, the DMP was less and at 60 and 90 DAS a steep increase was noticed. This might be due to rapid increase in plant height and leaf area at these stages.

The increase in DMP might be attributed due to the improved foraging ability; higher nutrient availability and uptake of nutrients with better assimilation which could 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 higher LAI, indicating the higher 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.This is in accordance with the earlier findings of Jat and Balyan (2004).

Kumar and Murugesh (2002) reported that mycorrhizal inoculation was more advantageous in obtaining healthy vigorous seedlings and resulted in higher biomass of maize plants. Similar results were also reported earlier by Wang *et al. (*2006) in Zea mays, Kelly *et al*. (2001) in sugar cane, maize and soybean, Omar (1995) and Subramanian and Charest (1997) in maize.

Physiological attributes

Among the fertilizer levels, 200:100:100 NPK kg ha^{-1} recorded higher CGR but was comparable with 200:75:100 NPK kg ha^{-1}(Table 2). Higher nutrient uptake associated with higher nitrogen application might have resulted in increased photosynthates accumulation. This would have lead to higher crop growth and hence the crop growth rate and relative growth rate. Similar results were reported by Banga *et al.* (1994).

Inoculation of mycorrhiza significantly recorded higher CGR and RGR than the control. This might be due to the better growth of plants due to better uptake of nutrients as evident by higher LAI and DMP recorded under this treatment, in this present study.

Table 2. Crop growth rate and relative growth rate of maize hybrid as influenced by mycorrhiza, nitrogen and phosphorus levels

Fertilizer levels NPK Kg ha^{-1}	Crop growth rate (CGR) (g m^{-2} day^{-1})						Relative growth rate (RGR) (mg g^{-1} day^{-1})					
	Stage I (30-60 DAS)			Stage II (60-90 DAS)			Stage I (30-60 DAS)			Stage II (60-90 DAS)		
	(M^-)	(M^+)	Mean	(M^-)	(M^+)	Mean	(M^-)	(M^+)	Mean	(M^-)	(M^+)	Mean
F_1- 200:100:100	6388	6600	6494	9875	9913	9894	0.025	0.031	0.028	0.064	0.056	0.060
F_2- 150:100:100	5775	6313	6044	9025	9700	9363	0.025	0.031	0.028	0.065	0.057	0.061
F_3- 200:75:100	6151	6755	6453	9450	10025	9738	0.026	0.030	0.028	0.065	0.055	0.060
F_4- 150:75:100	5163	7275	6219	8838	10525	9681	0.025	0.040	0.027	0.068	0.054	0.061
Mean	5869	6736		9297	10041		0.025	0.030		0.065	0.056	
	SEd	CD										
(P=0.05)		SEd	CD									
(P=0.05)		SEd	CD									
(P=0.05)		SEd	CD									
(P=0.05)												
F	147.2	306.2		170.3	354.2		0.001	NS		0.002	NS	
M	104.1	216.5		120.4	250.5		0.001	0.001		0.001	0.002	
F x M	208.2	433.0		240.8	501		0.001	NS		0.002	NS	

Grain yield and stover yield

Among the fertilizer levels, 200:100:100 NPK kg ha^{-1} recorded the highest grain yield of 6494 kg ha^{-1} but was comparable with 200:75:100 NPK kg ha^{-1} and 200:75:100 NPK kg ha^{-1}. The increase in grain yield with 200:100:100 and 200:75:100 NPK kg ha^{-1} was 20.5 and 19.9 per cent, respectively, over the fertilizer level of 150:75:75 NPK kg ha^{-1} (Table 3).

Mycorrhizal inoculation recorded higher grain yield (6736 kg ha^{-1}) than no inoculation (5869 kg ha^{-1}).

The interaction between fertilizer levels and mycorrhizal inoculation on maize grain yield was significant. The highest grain yield (7275 kg ha^{-1}) was recorded under the treatment combination 150:75:100 NPK kg ha^{-1} with mycorrhizal inoculation followed by 200:75:100 NPK kg ha^{-1}.

Table 3. Grain and stover yield of maize hybrid as influenced by mycorrhiza, nitrogen and phosphorus levels

Fertilizer levels NPK Kg ha^{-1}	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	Mycorrhizal Inoculation			Mycorrhizal Inoculation		
	(M^-)	(M^+)	Mean	(M^-)	(M^+)	Mean
F_1- 200:100:100	6388	6600	6494	9875	9913	9894
F_2- 150:100:100	5775	6313	6044	9025	9700	9363
F_3- 200:75:100	6151	6755	6453	9450	10025	9738
F4- 150:75:100	5163	7275	6219	8838	10525	9681
Mean	5869	6736		9297	10041	
	SEd	CD (P=0.05)		SEd	CD (P=0.05)	
F	147.2	306.2		170.3	354.2	
M	104.1	216.5		120.4	250.5	
F x M	208.2	433.0		240.8	501	

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 noticed at different stages would have resulted in enhanced grain yield. The present findings are in line with the findings of Maddonni *et al.* (2006). The positive responses of hybrid maize upto 250 kg N ha^{-1} as reported by Srikanth *et al*. (2009b) lend support to the present findings.

Since N is the major structural constitute of cells, as N level increased, the rate of vegetative and reproductive growth also increased in plants due to increase in assimilating surface of plants as well as total photosynthesis. In physiological terms, the grain yield of maize is largely governed by source (photosynthesis) and sinks (grain) relationship which is directly related to N. These resulted in more grain yield when N was higher.

Mycorrhiza had positive influence on grain yield of maize crop. The improved nutritional status of AM fungus-inoculated plants resulted in higher grain yields by 20% in comparison to uninoculated treatments. This yield gain in mycorrhizal plants was mainly caused by the intense flow of minerals and metabolites from the leaf to the developing kernel. The increased yields of AM fungus inoculated plants thus suggest that significant amounts of P and N were translocated from the source to the sink to support kernel development and grain yield (Subramanian and Charest, 1997). A higher yield of maize due to mycorrhizal inoculation has been reported previously by Subramanian *et al.* (2008).

Increasing the fertilizer levels increased the stover yield significantly. Fertilizer level of 200:100:100 NPK kg ha^{-1} recorded higher stover yield (9894 kg ha^{-1}) followed by 200:75:100 NPK kg ha^{-1}. The positive and significant improvement in LAI and DMP noticed at different stages due to higher dose of fertilizer would have resulted in enhanced stover yield. These results are in confirmity with the findings of Srikanth *et al*. (2009b). Inoculation of mycorrhiza significantly influenced the stover yield of maize. Mycorrhizal inoculated plants recorded significantly higher (10041 kg ha^{-1}) stover yield. Mycorrhiza inoculation might have increased the stover yield of treated plants, due to increase in plant height, leaf area index and total biomass as evidenced in the present investigation. Similar results of increase in stover yield due to mycorrhizal inoculation were also reported earlier by Lauzon and Miller, (1997) in maize.

Economics

Economic viability of crop management is the foremost criteria in transforming new investigations to farmer's field. The results revealed that the highest gross return of Rs. 70,738 and net return of Rs. 46,587 were recorded under the fertilizer dose of 150:75:100 NPK kg ha^{-1} along with mycorrhizal inoculation followed by fertilizer dose of 200:75:100 NPK kg ha^{-1} along with mycorrhizal inoculation (Table 4).

Table 4. Economics of maize hybrid as influenced by mycorrhiza, nitrogen and phosphorus levels

Treatment	Cost of cultivation (Rs.ha^{-1})	Gross return (Rs.ha^{-1})	Net return (Rs. ha^{-1})	Benefit cost ratio
F_4M^-	22513	62425	39912	2.77
F_1M^-	22083	56488	34405	2.56
F_2M^-	22181	60086	37905	2.71
F_3M^-	21651	50881	29230	2.35
F_4M^+	25013	64356	39343	2.57
F_1M^+	24583	61663	37080	2.51
F_2M^+	24681	65808	41127	2.67
F_3M^+	24151	70738	46587	2.93

Data not analyzed statistically

Remunerative economic returns realized under this treatment combination might be due to the reduced cost of fertilizers and increased yields obtained even though additional cost was involved in terms of mycorrhizal inoculation.

Ramu and Reddy (2007) reported that regarding the N levels, 240 kg N ha^{-1} recorded the highest net return and BC ratio which were, however, comparable with 180 kg N ha^{-1}, indicating the fact that application of nitrogen beyond 180 kg ha^{-1} was not economical. In general this might be due to the increase in input prices decreased productivity as well as profit. Remunerative economic returns realized with 180 kg N ha^{-1} were obviously due to reduced cost of nitrogen with 180 kg N ha^{-1} compared to 240 kg N ha^{-1}.

In any investment economics, it is the B: C ratio which is more important to compare the profitability of the treatments to identify input technologies to improve the yield. From the study conducted, it is found that application of fertilizer at 150:75:100 NPK kg ha^{-1} along with mycorrhizal inoculation recorded the highest B:C ratio followed by 200:75:100 NPK kg ha^{-1} along with inoculation of mycorrhiza. This

might be due to the very extensive hyphal network development in soil, exploiting nutrients more efficiently and improving plant uptake. Even though the initial cost of mycorrhizal inoculum was high, mycorrhizal inoculation has recorded higher yield and hence increased the B:C ratio.

Based on the above discussion, it can be concluded that application of 150:75:100 NPK kg ha^{-1} in combination with mycorrhizal inoculation can be recommended under irrigated condition for maximum productivity and benefit cost ratio in hybrid maize.

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Received: October 5, 2010; Accepted: February 23, 2011