International Journal of Agricultural Sciences
Volume 12 | Issue 2 | June, 2016 | 288-293 ■ e ISSN-0976-5670
DOI:10.15740/HAS/IJAS/12.2/288-293
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RESEARCH PAPER

Effect of intercropping system, mycorrhizal inoculation and fertilizer levels on the yield of hybrid maize (*Zea mays* L.)

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Abstract : Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore to study the effect of hybrid maize (*Zea mays*) under different intercropping systems, mycorrhizal inoculation and fertilizer levels on the yield component and yield of maize. The experiment was laid out in split – split plot design during winter 2011-12. The results indicated that among the cropping systems, sole maize recorded significantly better yield attributes and higher yield that was comparable with maize + cowpea intercropping system. With respect to mycorrhiza, mycorrhizal inoculated treatments recorded higher grain and stover yield. Among the fertilizer levels, 125 per cent RDF recorded higher grain yield. Regarding the treatment combinations, sole maize along with mycorrhizal inoculation and 125 per cent RDF recorded significantly higher yield parameters and yield. However, the yield was comparable with maize intercropped with cowpea along with mycorrhizal inoculation and application of 100 per cent RDF.

Key Words : Hybrid maize, Intercropping systems, Mycorrhiza, Fertilizer levels, Yield attributes, Yield

View Point Article : Ananthi, T., Amanullah, M. Mohamed and Mariappan, G. (2016). Effect of intercropping system, mycorrhizal inoculation and fertilizer levels on the yield of hybrid maize (*Zea mays* L.). *Internat. J. agric. Sci.*, **12** (2) : 288-293, **DOI:10.15740/HAS/IJAS/12.2/288-293.**

Article History : Received : 06.02.2016**; Revised :** 12.03.2016**; Accepted :** 07.05.2016

INTRODUCTION

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. 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 plant nutrients, primary nutrients such as, nitrogen, phosphorus and potassium play a crucial role in deciding the growth and yield. The nitrogen use efficiency can be improved with the use of hybrids, soil application of arbuscular mycorrhiza and application of fertilizers coinciding with peak need by the crop.

Phosphorus is known to stimulate early and extensive development of root systems, which enables rapid maize growth and to mature early (Sankaran *et al.*, 2005). Enhancement of P uptake by mycorrhizal hyphae can also be indirectly attributed to the faster

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uptake rate of P by the hyphae and the disturbance of the solution solid P equilibrium, which will increase the sorption of absorbed phosphate into soil solution (Nye and Tinker, 1977).

The initial slow growth of the maize crop roots introduction of legume as intercrop in the inter row space and such a system will also enhance the productivity. Most of research work and approaches to develop production technologies for maize in the past, but now there is need to work with cropping systems that farmers can practice to exploit location specific agro-climatic conditions for enhanced production. Considering the limited net sown area, it will be necessary to raise the cropping intensity so as to grow more crops on the same piece of land. Hence, an attempt was made to study the yield of hybrid maize as influenced by different intercropping systems, mycorrhizal inoculation and fertilizer levels during winter season.

MATERIAL AND METHODS

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during winter 2011-12 to study the influence of maize under different intercropping systems, mycorrhizal inoculation and fertilizer levels on the yield attributes and yield of hybrid maize under irrigated condition. The experiment was laid out in a split-split design with three replications. Three intercropping systems *viz.*, sole maize, maize+cowpea and maize+greengram were the treatments under main plot. Two mycorrhizal treatments *viz.*, no mycorrhizal inoculation (control) (M^-) and inoculation of mycorrhiza (M^+) were included under sub plot. Three fertilizer levels *viz.*, 75 per cent RDF (F_1), 100 per cent RDF (F_2) and 125 per cent RDF (F_3) under sub-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 (234 kg ha^{-1}), medium in available phosphorus (14.6 kg ha^{-1}) and high in available potassium (612.0 kg ha^{-1}). Maize hybrid, NK 6240, a high yielding widely adopted hybrid released by Syngenta Private Ltd., India was chosen for the study.

Seeds of maize hybrids were sown on the side of the ridges by adopting a spacing 60 x 25 cm along with vermiculite based mycorrhizal inoculum at a depth of 5 cm below the seeds. The mycorrhizal inoculum (*Glomus intraradices* TNAU-03-08) used in this study was purchased from the Department of Agricultural Microbiology, Tamil Nadu Agricultural University. This strain was cultured in maize plants and propagules comprised of infected root bits and spores were blended in sterile vermiculite. The inoculum with the spore density of 10 spores g^{-1} was applied as a thin layer beneath the seeds one week after sowing @ 100 kg ha^{-1}. Seeds were dibbled at the rate of one seed $hill^{-1}$.

As an intercrop, cowpea CO (CP) 7 and greengram (CO 6), were raised as per the treatments with a spacing of 30 × 10 cm and seed rate of 10 kg ha^{-1}. One row of intercrops were sown in between the rows of main crop as additive series.

Adjacent to the treatment plots, sole cowpea and greengram were also raised in dummy plots with same management practices to calculate the yield advantages.

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. The recommended fertilizer dose followed for maize was 150:75:75 kg NPK ha^{-1}.

As per the treatment schedule, nitrogen as urea 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 as single super phosphate was applied basally. The potassium as muriate of potash was applied in two equal split doses *viz*., basal and at 45 DAS.

The crops were harvested at their physiological maturity. The grain yield was recorded for individual treatment at 14 per cent seed moisture and expressed in kg ha^{-1}.

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Yield components :

The yield attributes such as cob length, cob girth, number of grain rows cob^{-1}, number of grains row^{-1}, cob weight and test weight were favourably influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels.

Effect of intercropping systems :

Significantly higher values of cob length (19.1 cm), cob girth (15.6 cm), number of grain rows cob^{-1} (13.6), number of grains row^{-1}(32.5), cob weight (244.5 g) and test weight (32.9 g) were recorded by sole maize followed by maize cowpea intercropping (Table 1).

However, more number of grain rows cob^{-1} was recorded in sole maize followed by maize intercropped with cowpea and both were comparable with other. This higher yield attributes due to no intercrop competition for light, nutrients, moisture, and space. This corroborates with the findings of Karim *et al.* (1990) and Uddin *et al.* (2003).

Effect of mycorrhizal inoculation :

Inoculation of mycorrhiza significantly increased the cob length, cob girth, number of grain rows cob^{-1}, number of grains row^{-1}, cob weight and test weight. It has been suggested that, since the meristems originating ears are formed at early maize developmental stages, an improved nutrition especially 'P' due to mycorrhiza at those stages might increase the number of kernels formed and filled (Barry and Miller, 1989). Another possible explanation is that given that the time to reach reproductive stage seems to be shortened by increased early P nutrition there could be more warm days for grain filling which could thereby increase grain yield. Khan (1975) also reported an increased yield and number of kernels in relation to early mycorrhizal development and P nutrition of maize in the field. The effect of mycorrhizal colonization in decreasing the time taken to initiate the reproductive stage and increasing fruit production has already been documented from field experiments (Mayra *et al.*, 1998).

Effect of fertilizer levels :

Successive increase in fertilizer levels from 100 per cent RDF to 125 per cent RDF had marked influence on the yield attributes of hybrid maize. Application of 125 per cent RDF recorded higher cob length (19.3 cm), cob girth (15.6 cm), more number of grain rows cob^{-1} (13.5), number of grains row^{-1} (32.8), cob weight (244.7 g) and test weight (33.1 g). The increase in yield attributes due to increase in N levels might be due to the better uptake of all the nutrients and increased translocation of photosynthates from source to sink in hybrid maize upto 225 kg was also reported by Singh *et al.* (1997) and upto by 250 kg by Mukhtar *et al.* (2011).

Increased doses of P had marked influence on yield attributes. Saleem *et al.* (2003) observed response in hybrid maize upto 150 kg P_2O_5 ha^{-1}. Elevated doses of phosphorus might have increased the forage activity, accumulation of food reserves, increased functional leaves and LAI, higher nutrient uptake which lead to higher yield attributes and yield. The results are in accordance with those of Maqsood *et al.* (2001) who reported that nitrogen and phosphorus fertilizer

Table 1 : Effect of intercropping, mycorrhiza and fertilizer levels on yield attributes and yield of maize hybrid

Treatment	Cob weight (g)	Cob length (g)	Cob girth (g)	Number of grain rows cob^{-1}	Number of grains row^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Intercropping systems (I)								
I_1 - Sole maize	244.5	19.1	15.6	13.6	32.5	32.9	8531	12560
I_2 - Maize + Cowpea	240.1	18.8	15.3	13.3	32.3	32.1	8455	12223
I_3 - Maize + Green gram	230.7	18.8	15.2	12.9	31.3	30.9	8323	12205
S.E. ±	1.8	0.1	0.1	0.1	0.2	0.3	54	83
C.D. (P=0.05)	5.1	0.2	0.3	0.4	0.5	0.8	151	231
Mycorrhizal inoculation (M)								
M^- - Uninoculated (control)	221.2	18.2	14.9	12.6	31.1	29.1	7981	11810
M^+ - Inoculated with AMF	255.7	19.6	15.9	14.0	33.0	34.8	8892	12849
S.E. ±	2.4	0.1	0.3	0.2	0.2	0.6	73	67
C.D. (P=0.05)	5.9	0.3	0.7	0.4	0.4	1.4	179	164
Fertilizer levels (F)								
F_1 - 75% RDF	228.2	18.3	15.1	12.9	31.2	30.3	8176	12051
F_2 - 100% RDF	242.4	19.0	15.5	13.4	32.2	32.4	8561	12444
F_3 - 125% RDF	244.7	19.3	15.6	13.5	32.8	33.1	8572	12494
S.E. ±	3.2	0.2	0.2	0.1	0.3	0.5	90	113
C.D. (P=0.05)	6.7	0.3	0.4	0.3	0.6	1.1	185	232
Interaction	Sig	NS	NS	NS	NS	NS	Sig	Sig

NS=Non-significant

applications significantly affected the cob length, number of grain rows cob-1 and grains number cob^{-1}.

Interaction effect :

The interaction between the fertilizer levels and mycorrhizal inoculation was significant. It could be observed from the data presented in Table 2 that higher cob weight was recorded in the treatment combination mycorrhiza along with 100 per cent RDF (M^+F_2) than the other treatment combinations followed by the cob weight recorded under mycorrhiza along with 125 per cent RDF and both were comparable. It is indicated that AM fungi application to maize plants with 100 per cent recommended NPK fertilizers seems to be beneficial in terms of increasing yield and saving fertilizer inputs. So mycorrhiza could be considered as a suitable substitute for chemical phosphorus and nitrogen fertilizers in organic agricultural systems. This result is in conformity with the findings of Vaseghmanesh *et al.* (2013).

Grain and stover yield :

The maize grain yield was significantly influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels (Table 1).

Effect of intercropping systems :

Among the intercropping systems, sole maize recorded the highest grain yield of 8531 kg ha^{-1} but was comparable with maize intercropped with cowpea. The yield reduction due to intercropping cowpea was negligible (0.89 %) comparing the yield under sole maize. Higher yield under sole maize was only due to nil competition for sunlight, space, water and nutrients as it was in intercrops having shading effect curtail efficient utilization of natural resources and restrict growth of maize from initial stages to harvest resulted in yield competition in intercrop (Yilmaz *et al.,* 2008). Similar findings were also obtained by Haque *et al.* (2008) and Choudhary *et al.* (2013).

Effect of mycorrhizal inoculation :

Mycorrhizal inoculation recorded higher grain yield (8892 kg ha^{-1}) than no inoculation (7981 kg ha^{-1}) and reduction in yield being 10.25 per cent. Mycorrhiza had positive influence on grain yield of maize crop. The improved nutritional status of AM fungus-inoculated plants resulted in higher grain yield in comparison to uninoculated treatments. This yield gain in mycorrhizal treatments 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 treatments 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) and Ananthi *et al.* (2011).

Effect of fertilizer levels :

Comparing the yield of maize grain obtained under different fertilizer levels, 125 per cent RDF recorded the highest grain yield of 8572 kg ha^{-1} and was comparable with 100 per cent RDF. Fertilizer level of 75 per cent RDF recorded lower grain yield and was 4.7 per cent and 4.5 per cent lesser than 125 per cent and 100 per cent RDF.

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 yield attributes and nutrient uptake 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.* (2009) 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

Table 2 : Interaction effect of mycorrhizal inoculation and fertilizer levels on cob weight (g) and stover yield (kg ha^{-1}) of maize hybrid

Mycorrhizal inoculation	Cob weight				Stover yield			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
M^- – Uninoculated (control)	216.3	221.8	225.4	221.2	11657	11732	12041	11810
M^+ – Inoculated with AMF	240.1	262.9	264.0	255.7	12445	13155	12947	12849
Mean	228.2	242.4	244.7		12051	12444	12494	
		S.E. ±	C.D. (P=0.05)			S.E. ±	C.D. (P=0.05)	
	M × F	4.5	9.7		M × F	146	318	

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 sink (grain) relationship which is directly related to N. These resulted in more grain yield when N was higher.

Interaction effect :

The interaction between mycorrhizal inoculation and fertilizer levels on maize grain yield was significant. The highest grain yield (9157 kg ha^{-1}) was recorded under the treatment combination mycorrhizal inoculation with 100 per cent RDF (M^+F_2) followed by 125 per cent RDF and was comparable with each other.

The interaction between intercropping systems, mycorrhizal inoculation and fertilizer levels on maize grain yield was significant (Fig. 1). The treatment combination sole maize with 125 per cent RDF along with mycorrhizal inoculation ($I_1F_3M^+$) recorded significantly higher yield (9600 kg ha^{-1}). In sole maize, there was no competition for various resources except intra-species competition and the immediate supply of nutrients due to the addition of inorganic fertilizers and the significant amounts of P and N were translocated from the source to the sink in mycorrhizal inoculated maize plants, might be the reason for increase in growth and yield parameters which would have increased the yields in the treatments mentioned.

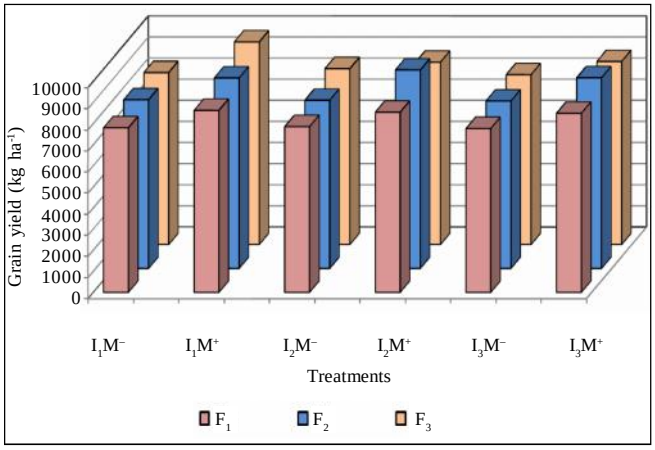

Fig. 1 : Interaction effect of intercropping, mycorrhiza and fertilizer levels on grain yield (kg ha^{-1}) of maize hybrid

Even though maize intercropped with cowpea and 100 per cent RDF along with mycorrhizal inoculation ($I_2F_2M^+$) recorded lesser yield than the $I_1F_3M^+$, the yield reduction was not significant. The reduction of maize yield was probably due to intercrop competition between maize and cowpea. However, additional yield from cowpea not only compensated the deficit, but also gave extra income. This finding is in conformity with that of Quayyum and Maniruzzaman (1995); Uddin *et al.* (2003) and Pandey *et al.* (2003). Under maize + cowpea intercropping systems, 100 per cent RDF with mycorrhizal inoculation produced higher yield. This might be due to mycorrhizal fungi increased the root efficiency to absorb nutrient and in nutrient depleted soil, mycorrhizal fungi develop strand in the soil and absorb phosphorus through the root hairs, thereby increase nodulation and nitrogen, this character of the fungi enhanced plant growth and yield (Muok *et al.*, 2009). Mycorrhizal inoculum significantly increased the growth and yield of maize and cowpea resulting from the interaction between mycorrhizal fungi and *rhizobia.*

Stover yield did exhibit similar trend as that of grain yield. Regarding intercropping systems, sole maize recorded the highest stover yield (12560 kg ha^{-1}) followed by maize intercropped with cowpea which was comparable with sole maize. This might be due to higher plant height, LAI and DMP in sole maize and also there is no inter plant competition. Mycorrhizal inoculated plants recorded significantly higher (12849 kg ha^{-1}) stover yield, which might be 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.

Increasing the fertilizer levels increased the stover yield significantly. Fertilizer level of 125 per cent RDF recorded higher stover yield (12494 kg ha^{-1}) followed by100 per cent RDF. The positive and significant improvement in LAI and DMP at different stages and higher nutrient uptake due to higher dose of fertilizer would have resulted in enhanced stover yield. These results are in conformity with the findings of Srikanth *et al.* (2009).

Conclusion :

Among the intercropping systems, sole hybrid maize recorded better higher yield attributes and yield followed by maize intercropped with cowpea and the grain yield obtained under both were comparable. Among the mycorrhizal treatments, mycorrhizal inoculation favourably increased the yield attributes and grain yield of maize. Among the fertilizer levels, 125 per cent RDF favourably increased the yield attributes and grain yield of hybrid maize.

With regard to interaction effect of intercropping systems, mycorrhizal inoculation and fertilizer levels, higher grain yield was obtained under the treatment combination sole maize with 125 per cent RDF along with mycorrhizal inoculation which was followed by maize

+ cowpea intercropping and 100 per cent RDF along with mycorrhizal inoculation and both were comparable with each other.

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