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Influence of Iron Nutrition and Arbuscular Mycorrhiza on Yield and Economics of Hybrid Maize in Calcareous Soil

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Field experiment was conducted at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *kharif* 2010 to study the influence of iron nutrition and arbuscular mycorrhiza (AM) inoculation on yield attributes, yield and economics of hybrid maize in calcareous soil. The experiment was laid out in factorial randomized block design with three replications. The treatments included were arbuscular mycorrhiza (M_+) and control (M_-) under factor 'A' and soil application of 25 kg and 50 kg $FeSO_4$ ha^{-1}, Foliar spray of $FeSO_4$,0.5% and combination of soil application and foliar spray and Control, under factor 'B'. The results revealed that among the iron treatments, 50 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray recorded better yield attributes and higher grain yield. It was comparable with 25 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray which was economically profitable. Regarding the mycorrhizal treatments, AM inoculated plants recorded better yield attributes and grain yield. Among the treatment combinations, 25 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray along with AM recorded better yield attributes and higher grain yield, net return and B: C ratio (2.16)

Key words: Hybrid maize, mycorrhiza, iron, yield attributes, yield, economics.

Maize has high yield potential and responds greatly to nutrient application. Apart from major nutrients, despite being needed in small quantities, micronutrients are also essential for the overall performance and health of the maize crop. They include iron, manganese, zinc, copper, molybdenum and boron. Among the micronutrients, Fe and Zn are more important to maize. Iron deficiencies are found mainly on calcareous soils which reduces iron uptake by plants causing iron chlorosis.

Mycorrhiza is the symbiosis between the roots of most land plants and many soil fungi that colonize the cortical tissue of roots during periods of active plant growth, from which both partners benefit. Arbuscular mycorrhiza (AM) are the most common mycorrhiza. Arbuscular mycorrhizal fungi are widespread and agronomically important plant symbiont and often stimulate plant uptake of nutrients such as P, Zn, Cu, and Fe in deficient soils (Liu *et al.,* 2000). The micronutrient improvement in mycorrhizal plants is always associated with rhizosphere acidification (Dodd *et al*., 1987), more external mycelium in the soil (Jakobsen *et al*., 1992) and soil biochemical changes (Subramanian and Charest, 2007).

Subramanian *et al*. (2009) reported that AM inoculation at varying levels of Zn concentrations exhibited prominent increase in yield components such as cob length, cob girth, row cob^{-1}, grains row^{-1} and test weight of maize. AM fungus *Glomus intraradices* enhanced the yield of sorghum plants under drought conditions (Ibrahim *et al*., 1990). *G.mosseae* inoculation increased maize grain yield over uninoculated control in nonfumigated soil (Khadge *et al.,* 1992). Ziaeian and Malakouti (2001) concluded that Fe fertilization caused significant increase in grain and straw yield, 1000-grain weight and the number of seeds per spikelet. With the application of Fe, their concentration and total uptake in grain and flag leaves and the grain protein content also increased significantly.

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The AM isolates improve Fe acquisition in maize grown under Fe deficiency conditions. Improved host plant, root development, morphology and acquisition of P may have been involved in enhanced Fe acquisition by AM plants (Clark and Zeto, 1996). AM inoculated plants may mobilize or take up iron from calcareous soil low in Fe and translocate it to maize plants. With these ideas in view, the present investigation was carried out to study the influence of iron and AM inoculation on yield attributes, yield and economics of hybrid maize in calcareous soil.

Materials and Methods

A field experiment was conducted during the *Kharif* season of 2010 at Tamil Nadu Agricultural University, Coimbatore. The experimental soil was sandy clay loam in texture having a pH of 7.58. The fertility status was low in available N (220 Kg ha^{-1}), medium in available P (13.1 Kg ha^{-1}) and high in available K (457 Kg ha^{-1}). The available Fe (DTPA-extractable) content was 2.24 mg kg^{-1}.

The experiment was laid out in factorial randomized block design with three replications. The treatments included were arbuscular mycorrhiza (M_+) and control (M_-) under factor 'A' and T_1 - 25 kg $FeSO_4$ ha^{-1}, T_2 - 50 kg $FeSO_4$ ha^{-1},T_3 - 0.5% $FeSO_4$ foliar spray, T_4 - 25 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ foliar spray, T_5 - 50 kg $FeSO_4$ ha^{-1} + 0.5 % $FeSO_4$ foliar spray and T_6 – Control, under factor 'B'.

Hybrid maize (CO H(M)5) was used as test crop and it was grown by adopting a spacing of 60 x 25 cm. Seeds of maize hybrids under AM inoculation treatments were sown with vermiculite based mycorrhizal inoculum at 100 kg ha_{-1} at a depth of 3 cm below the seeds. Uniform fertilizer schedule was followed at the rate of 150: 75: 75 NPK kg ha_{-1}. Nitrogen was applied in three splits *viz*., 25, 50 and 25 per cent as basal, 25 and 45 days after sowing, respectively. The entire dose of phosphorus was applied basally. The potassium was applied in two equal split doses *viz*., basal and at 45 days after sowing. Iron was applied basally and foliar spray of 0.5% $FeSO_4$. Foliar spray was given twice at 35 and 45 days after sowing. During the course of investigation, yield attributes and yield were recorded and economics computed.

Results and Discussion

Yield attributes

The yield attributes of hybrid maize *viz.,* cob weight and test weight were the highest with application of 50 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray followed by 25 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray and were comparable with each other (Table 1). This might be due to increased availability and better uptake of iron and all the other nutrients which might have resulted in the improvement in all the yield attributes. Ramu and Reddy (2007) reported that yield attributes of maize were higher with foliar application of Fe and Zn. Inoculation of mycorrhiza positively influenced the yield attributes. The meristems originating ears are formed at early maize developmental stage, an improved nutrition at those stages increase the number of kernels formed and filled (Barry and Miller, 1989). AM inoculation significantly increased the yield attributes. This might be due to the formation of external mycelium around the roots by AMF fungi which made the availability of all the nutrients better for crop uptake. Similar result was obtained by Ananthi, (2010) in hybrid maize.

Grain yield

Application of 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS recorded the highest grain yield of 5752 kg ha_{-1} followed by 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS and 50 kg $FeSO_4$ and both were comparable with each other (Table 1). This increase in yield was due to effective utilization of applied nutrients. The positive and significant improvement in LAI and DMP noticed at different stages, increased yield attributes and nutrient uptake due to both soil and foliar application of $FeSO_4$ would have resulted in enhanced grain yield. The results are in conformity with the findings of Amanullah *et al.,* (2007) in sorghum and Ramu and Reddy (2007). Inoculation of mycorrhiza significantly influenced grain yield (5820 kg ha_{-1}). This yield gain in mycorrhizal plants caused by the intense flow of minerals and metabolites from the leaf to the developing kernel. A higher yield of maize due to mycorrhizal inoculation has been reported previously by Solaiman and Harita (1998).

Table 1. Effect of iron application and AM inoculation on yield attributes of hybrid maize

Treatment	Cob weight (g)			Test weight (g)			Grain yield (kg ha_{-1})			Stover yield (kg ha_{-1})		
	M-	M+	Mean	M-	M+	Mean	M-	M+	Mean	M-	M+	Mean
T_1 - 25 kg $FeSO_4$	164.2	225.8	195.0	27.90	32.31	30.11	4501	5407	4954	7581	8705	8143
T_2 - 50 kg $FeSO_4$	182.1	227.3	204.7	31.02	33.11	32.07	5208	5764	5486	8346	9206	8776
T_3 - 0.5% $FeSO_4$ FS	170.2	229.8	200.0	28.71	33.46	31.09	4919	5868	5394	7917	9248	8583
T_4 - 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS	175.7	233.6	204.7	30.24	34.67	32.46	5023	6470	5747	8313	9561	8937
T_5 - 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS	186.2	231.2	208.7	31.77	34.02	32.90	5451	6053	5752	8547	9088	8817
T_6 – Control	162.1	224.1	193.1	27.14	31.18	29.16	4468	5357	4912	7646	8651	8148
Mean	173.4	228.6		29.47	33.13		4928	5820		8058	9076	
	SEd	CD		SEd	CD		SEd	CD		SEd	CD	
T	5.4	11.1		0.58	1.21		164	337		161	323	
M	3.3	6.8		0.34	0.70		94	196		110	221	
T X M	7.32	14.7		0.83	NS		221	467		232	465	

NS: Not Significant

Stover yield

The stover yield recorded treatment wise showed that Fe application either through soil or foliar had influenced significantly registering the highest value (Table 1). The treatment 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS (8937 kg ha_{-1}) recorded the highest yield followed by 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS and 50 kg $FeSO_4$ and both were comparable with each other. The application of $FeSO_4$ either soil or foliar would help to recover the crop from chlorosis and yield well especially in calcareous soil. AM inoculation significantly influenced the stover yield. AM inoculated plants recorded significantly higher (9076 kg ha_{-1}) stover yield. It is due to increase in growth parameters 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) and Ananthi (2010) in maize.

Economics

The highest gross return was recorded with application of 25 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray followed by 50 kg $FeSO_4$ + 0.5% $FeSO_4$ foliar spray (Table 2). It is obvious that a realization of higher gross return was the result of higher yield. Remunerative economic returns (net return and B: C ratio) play a key role to convince the farmers for adoption of any refined version of agro techniques. In the present study, higher yields as well as high gross returns were obtained under the treatment combination 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS along with AM inoculation (Rs 56539) with a B: C ratio of 2.16.

Table 2. Effect of iron application and AM inoculation on yield and economics of hybrid maize

Treatment	Gross Return		Net return		B: C ratio	
	M-	M+	M-	M+	M-	M+
T_1 - 25 kg $FeSO_4$	41798	47611	18697	21510	1.84	1.82
T_2 - 50 kg $FeSO_4$	45842	50716	22511	24385	1.96	1.93
T_3 - 0.5% $FeSO_4$ FS	43312	51569	20395	25652	1.89	1.99
T_4 - 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS	44340	56539	21193	30392	1.92	2.16
T_5 - 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS	47881	52971	24504	26594	2.05	2.01
T_6 – Control	39566	47184	16695	21313	1.73	1.82

Data not analysed statistically

The study revealed that 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS, AM inoculation recorded better yield attributes and yield. It was comparable with 50 kg $FeSO_4$ + 0.5% $FeSO_4$ FS along with AM inoculation. Iron applied at 25 kg $FeSO_4$ + 0.5% $FeSO_4$ FS along with AM inoculation enhanced the grain yield of maize and net profit in calcareous soil.

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