PRODUCTIVITY OF MAIZE INTERCROPPING SYSTEMS UNDER ARBUSCULAR MYCORRHIZAL INOCULATION AND VARYING FERTILIZER LEVELS

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Abstract

Field experiments were conducted during winter season 2011-12 and 2012-13 at Eastern Block farm, Tamil Nadu Agricultural University, Coimbatore. The experiments were laid out in split-split plot design with three factors. In main plots viz., intercropping systems [(sole maize (I_1), maize+cowpea(I_2), maize+greengram (I_3)]. Two mycorrhizal treatments viz., no mycorrhizal inoculation (control) (M^-) and inoculation of mycorrhiza (M^+) were included under sub plot. Three fertilizer levels viz., 75% RDF (F_1), 100% RDF (F_2), and 125 % RDF (F_3) under sub-sub plot. The results revealed that among the intercropping systems, sole maize recorded taller plants, higher leaf area index and higher dry matter production at all the stages viz., 30, 60 and 90 DAS, respectively followed by maize + cowpea intercropping system during both the years of study. Higher grain yield was found with sole maize in both the years. Among the mycorrhiza, mycorrhizal inoculated treatments markedly influenced the plant height, leaf area index, dry matter production and grain yield. The fertilizer levels also significantly affected growth parameters and yield of maize in both the years of experimentation. The interaction effect of mycorrhizal inoculation along with 100% RDF recorded higher plant height, leaf area index and dry matter production at 60 and 90 DAS. Regarding the treatment combinations, sole maize along with mycorrhizal inoculation and 125% RDF recorded significantly higher yield (8531 kg ha^{-1} and 7976 kg ha^{-1} during 2011 and 2012, respectively). However, the yield was comparable with maize cowpea intercropping along with mycorrhizal inoculation and application of 100% RDF.

Key words: Maize, mycorrhiza, fertilizer, intercrop, growth, yield

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. It has got immense potential and is therefore called as "**miracle crop**" and also "**queen of cereals**". Maize, being a C_4 plant is an efficient converter of carbon and absorbed nutrients into food.

Maize is one of the world's leading crops cultivated over an area of about 179.9 million hectares with a production of about 1013.6 million tonnes and productivity of 5.63 tonnes of grain ha^{-1} (USDA, 2016). In India, maize is cultivated in an area of 9.3 million hectares with a production of 24.2 million tonnes and productivity of 2564 kg ha^{-1}. In Tamil Nadu, maize is cultivated in an area of 3.4 million hectares with a production of 18.30 million tonnes and the productivity is 5359 kg ha^{-1} (Season and crop report, 2014 - 15).

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.

AMF are beneficial soil microbes that form symbiotic associations with majority of wild and cultivated plant species. AMF play a vital role in plant nutrition and soil fertility and could thus be of great benefit which include increased nutritional uptake, productivity, and improved yield and quality to many crops grown by smallholders across the world. In mycorrhizal symbiosis, the role of the plant's root hair is complemented by the fungus, which acts as an extension of the root system. Mycorrhizal colonization increases the absorption surface area, exposes greater soil areas, and increases the life-span of absorbing roots. In this way, soluble nutrients are better utilized and retained because of reduced reaction with soil colloids or leaching losses. Nodulation and atmospheric nitrogen fixation potential in legumes are also increased by AMF (Turk *et al.,* 2008). This is because AMF improve phosphorous uptake by the plant, which in turn would avail more energy for nitrogen fixation by rhizobia. Thus, dual inoculation of plants with rhizobia and AMF would show synergistic effects on nodulation and nitrogen fixation (Tajini *et al.,* 2012).

Soil fertility is one of the major challenges that smallholder farmers encounter. Most of the soils in such farming systems are low in nutrients such as P and N since farmers are not able to replenish soils using costly chemical fertilizers. Chemical fertilization is an agricultural practice that poses threat to AMF symbiosis. The presence of high levels of chemical fertilizers in soil not only leads to environmental drift and possible pollution of underground water reservoirs but also alters the association between microbial communities and plants. The vital role of AMF in plant nutrition makes them very sensitive to changes in availability of soil nutrients. AMF form a mycelia network that increases the magnitude of soil volume which can be explored by a plant. In this way, a mycorrhizal root would be more efficient in phosphate uptake compared to a non mycorrhizal root (Asghari and Cavagnaro, 2014).

In tropical regions, corn has been considered as the best component in most of intercropping system (Ijoyah, 2012). Intercropping is an effectual and the economical production system not only increases the production per unit area and time, but also increases the resource use efficiency and economic stock of the growers (Baghdadi *et al*., 2016). Presently, intercropping is gaining acceptance among small holder farmers as it provides a yield advantage compared to sole cropping through yield stability and achieving diversified domestic needs (Bhatti *et al.,* 2013). Research on intercropping has indicated how niche differences in crop species can lead to resource capture and conversion leading to increased biological efficiency and yield advantage. Keeping in view the above review, the present study was undertaken to determine the productivity of maize intercropping systems under arbuscular mycorrhizal inoculation and fertilizer levels.

Materials And Methods

Field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during winter 2011-12 to study the productivity of maize intercropping systems under arbuscular mycorrhizal inoculation and fertilizer levels 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% RDF (F_1), 100% RDF (F_2), and 125 % 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 single cross hybrid released by syngenta private ltd, India was chosen for the study.

Seeds of maize hybrids were sown on the flat beds 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 x 10 cm and a seed rate of 10 kg ha^{-1}. 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 dose of fertilizer 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% 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.

Growth parameters, namely, plant height (cm), leaf area index, dry matter production (kg ha^{-1}) were recorded at 30, 60 and 90 DAS, respectively and days to 50% flowering was recorded from penultimate rows of each plot.

From five randomly selected plants in each treatment plot, maximum length and breadth of the fully opened third leaf from the top of the plant was measured. The total number of leaves in all the five plants was counted. The mean values were worked out for the maximum length, breadth and number of leaves $plant^{-1.}$ The leaf area of each leaf was calculated by multiplying the length, maximum width and number of leaves. The value thus obtained was multiplied by a constant 0.796 to get actual leaf area and then leaf area index (LAI) was calculated by dividing the leaf area per plant by ground surface provided to each plant (1500 cm^2). Five randomly selected plants in each plot were tagged for various periodic observations. The same procedure was followed for both the years. For recording of data on the grain yield of each net plot was thoroughly cleaned and sun-dried. The yield from each plot was recorded separately as kg $plot^{-1}$ and then converted in kg ha^{-1} and statistical analysis was performed using standard tools.

Results And Discussion

Plant height

Plant height which represents the time trend of growth was recorded at different phenophases of maize. Significant difference in plant height was observed with intercropping systems, mycorrhizal inoculation and fertilizer levels at all the stages of observation in both 2011 and 2012.

In 2011, among the intercropping systems, taller plants (77.89, 210.5 and 239.6 cm at 30, 60 and 90 DAS, respectively) were recorded under sole maize followed by maize + cowpea intercropping. During 2012, sole maize recorded taller plants at 30 and 60 DAS (72.97 and 201.1 cm) followed by maize intercropped with cowpea. At 90 DAS, taller plants (229.0 cm) were recorded under sole maize followed by maize + cowpea intercropping and both were comparable with each other (Table 1). Increase in plant height under sole maize treatment was due to the fact that the wider space available in sole maize reduced the competition of light and nutrients, which probably provided favourable physical environment and helped the plants to grow taller. Increase in plant height under sole maize was also observed by Hugar and Palled (2008). Similar results were also reported by Mandal *et al.* (2014) that maize in pure stand gave comparatively greater plant height than intercropping height situation with legume.

Inoculation of mycorrhiza significantly increased the plant height at 30, 60 and 90 DAS than the non mycorrhizal inoculation during both the years (Table 1). It is clearlevident from the present study the positive effect of AMF inoculation on mycorrhization and growth response of maize plants. The maize plants inoculated with AMF fungus have shown improved growth and development as compared to plants under control. The present results are in accordance with that of Tarafdar and Marschner (1994) who concluded that mycorrhizal plants performed better in terms of plant height. They mentioned that due to the inoculation of VAM, the mitotic activity of stem cells enhanced, resulting in taller plants. Another reason is the formation of external mycelium around the roots 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 increased growth of treated plants due to mycorrhization of *G. intraradices* is in conformity with the findings of Earanna *et al.* (2001) and Karthikeyan *et al.* (2009). Xiaoying Chen *et al*. (2014) reported that across the five AMF treatments, plant height and total dry weight were significantly higher under ambient than under low temperature, whereas the reverse was the case for the root-to-shoot ratio.

In 2011, with regard to fertilizer levels, 125 % RDF recorded taller plants (77.88, 209.5 and 239.4 cm at 30, 60 and 90 DAS, respectively) followed by 100% RDF at all the stages of observation and both were comparable with each other (Table 1). 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*. (2009a). Shamim Gul *et al*. (2015) reported significant increase in the plant height of *kharif* maize with 100% recommended fertilizer dose (RFD) compared to 75% RFD.

The interaction between mycorrhizal inoculation and fertilizer levels was significant at 60 and 90 DAS (Fig 1&2). During these stages, the treatment combination mycorrhiza along with 100% RDF (M^+F_2) recorded taller plants at 60 and 90 DAS, respectively than the other treatment combinations during both the years of study (Fig 1 & 2).

Leaf Area Index (LAI)

Leaf area index (LAI) was significantly influenced by intercropping systems, fertilizer levels and mycorrhizal inoculation at all the phenophases of maize in 2011 and 2012. In 2011, with regard to intercropping systems, sole maize registered higher LAI than maize intercropped with cowpea or greengram (Table 1). Choudhary *et al.* (2012) recorded higher LAI under sole maize followed by 1: 2 maize + cowpea intercropping and 1: 1 maize + cowpea intercropping and all were statistically comparable. According to them, the smothering effect of cowpea was greater in the form of yellowing of older leaves of maize in cowpea intercropped plots and that might have reduced the leaf duration and the number of functional leaves thereby causing a reduction in LAI. The highest and lowest leaf area and plant biomass were measured in sole crop and intercropped treatments of maize and groundnut, respectively at 3 months after planting (Sutharsan and Srikrishnah, 2015). Similar results were also reported by other researchers (Mandal *et al.,* 2014; Alom *et al.,* 2010) that had an opinion that sole maize produced higher value than any other intercropping situation.

All the mycorrhizal inoculated treatments recorded higher LAI (1.86, 5.70 and 4.94 at 30, 60, and 90 DAS, respectively in 2011) than non mycorrhizal treatments (Table 2). 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).

During 2011, among the fertilizer levels, 125 % RDF recorded higher LAI at 30, 60 and 90 DAS with values of 1.79, 5.61 and 4.68

respectively, indicating the role of NPK in LAI improvement (Table 2). This trend might be due to higher uptake of NPK which might have led to production of more number of leaves per plant and good vegetative growth as reported by Srikanth *et al*. (2009a) and Shamim Gul *et al*. (2015) in maize.

The interaction between mycorrhizal inoculation and fertilizer levels was significant at 60 and 90 DAS. During these stages, the treatment combination mycorrhiza along with 100% RDF ($M^{+}F_2$) recorded higher LAI (5.83 and 5.08 at 60 and 90 DAS, respectively in 2011 than the other treatment combinations (Fig 3& 4). The leaf area index recorded in the second crop (2012) also indicated similar trend as that of the previous crop when intercropping systems, mycorrhizal inoculation and fertilizer levels.

Table 1. Effect of arbuscular mycorrhiza and fertilizer levels on plant height (cm) and leaf area index of maize under intercropping systems

Treatment	Plant height (cm)						Leaf Area Index (LAI)					
	Winter, 2011			Winter, 2012			Winter, 2011			Winter, 2012		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Intercropping systems (I)												
I_1	77.89^{a}	210.5^{a}	239.6^{a}	72.97^{a}	201.1^{a}	229.0^{a}	1.85^{a}	5.68^{a}	4.82^{a}	1.78^{a}	5.51^{a}	4.54^{a}
I_2	76.05^{b}	207.2^{b}	237.0^{b}	71.93^{b}	199.2^{b}	225.7^{b}	1.77^{b}	5.47^{b}	4.58^{b}	1.74^{b}	5.34^{b}	4.46^{b}
I_3	74.37^{c}	205.0^{bc}	235.7^{bc}	69.06^{c}	196.8^{c}	221.2^{c}	1.69^{c}	5.41^{bc}	4.38^{c}	1.66^{c}	5.15^{bc}	4.26^{c}
SEd	0.41	1.1	0.9	0.14	0.5	1.3	0.02	0.06	0.05	0.01	0.09	0.02
CD (P=0.05)	**1.15**	**3.2**	**2.4**	**0.39**	**1.4**	**3.6**	**0.07**	**0.16**	**0.15**	**0.03**	**0.24**	**0.07**
Mycorrhizal inoculation (M)												
M^{-}	73.10^{b}	202.1^{b}	233.9^{b}	67.83^{b}	192.4^{b}	217.9^{b}	1.68^{b}	5.34^{b}	4.25^{b}	1.61^{b}	5.09^{b}	4.07^{b}
M^{+}	79.10^{a}	213.0^{a}	241.0^{a}	74.82^{a}	205.7^{a}	232.7^{a}	1.86^{a}	5.70^{a}	4.94^{a}	1.84^{a}	5.58^{a}	4.76^{a}
SEd	1.22	1.3	1.1	0.63	0.5	1.8	0.02	0.08	0.07	0.01	0.06	0.02
CD (P=0.05)	**2.98**	**3.1**	**2.6**	**1.53**	**1.2**	**4.4**	**0.06**	**0.19**	**0.18**	**0.03**	**0.14**	**0.05**
Fertilizer levels (F)												
F_1	74.30^{b}	204.6^{b}	234.3^{b}	69.21^{b}	195.7^{b}	221.6^{b}	1.72^{b}	5.37^{b}	4.45^{b}	1.67^{b}	5.20^{b}	4.25^{b}
F_2	76.13^{ab}	208.6^{ab}	238.7^{ab}	71.86^{ab}	199.6^{ab}	226.2^{ab}	1.79^{ab}	5.58^{ab}	4.66^{ab}	1.75^{ab}	5.37^{ab}	4.49^{ab}
F_3	77.88^{a}	209.5^{a}	239.4^{a}	72.89^{a}	201.8^{a}	228.1^{a}	1.80^{a}	5.61^{a}	4.68^{a}	1.76^{a}	5.44^{a}	4.51^{a}
SEd	0.92	1.0	1.1	0.83	1.2	1.1	0.02	0.06	0.06	0.02	0.06	0.05
CD (P=0.05)	**1.89**	**2.1**	**2.2**	**1.72**	**2.5**	**2.3**	**0.05**	**0.11**	**0.12**	**0.03**	**0.11**	**0.11**
Interaction	**NS**	**Sig**	**Sig**	**NS**	**Sig**	**Sig**	**NS**	**Sig**	**Sig**	**NS**	**Sig**	**Sig**

Within columns, means followed by same letter do not significantly differ from each other $p < 0.05$ LSD).
I_1 -Sole maize; I_2 - Maize + Cowpea; I_3-Maize + Green gram; M^{-} -Uninoculated (control); M^{+} - Inoculated with AMF; F_1-75% RDF; F_2 - 100% RDF; F_3 :125%RDF

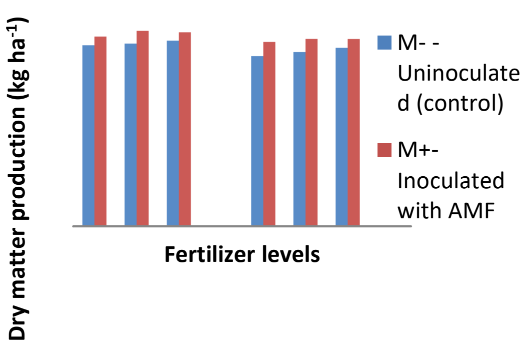

Fig 1. Interaction effect of mycorrhizal inoculation and fertilizer levels on plant height (cm) of maize hybrid at 90 DAS

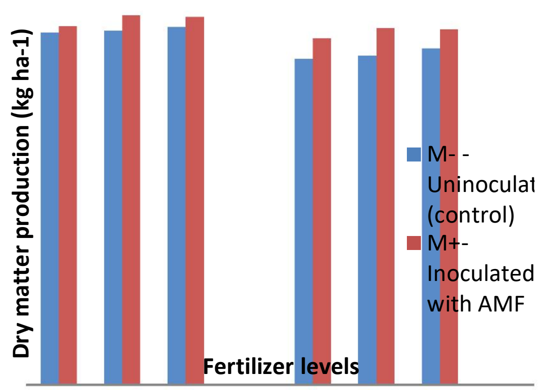

Fig 2. Interaction effect of mycorrhizal inoculation and fertilizer levels on plant height (cm) of maize hybrid at 90 DAS

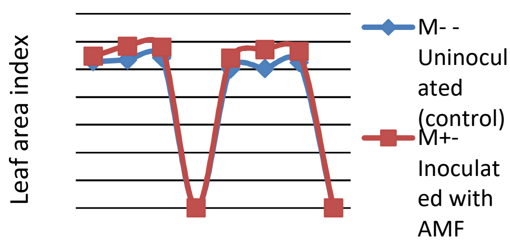

Fig 3. Interaction effect of mycorrhizal inoculation and fertilizer levels on leaf area index of maize hybrid at 60 DAS

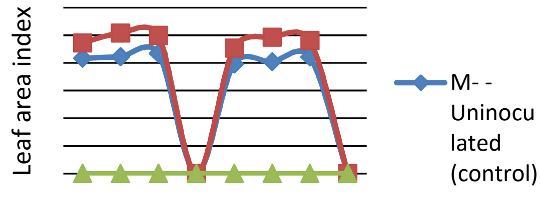

Fig 4. Interaction effect of mycorrhizal inoculation and fertilizer levels on leaf area index of maize hybrid at 90 DAS

Dry matter production (DMP)

In 2011, the dry matter production was higher in sole maize at 30 DAS (520 kg ha^{-1}), 60 DAS (7229 kg ha^{-1}) and 90 DAS (13635 kg ha^{-1}). During 2012, higher DMP was recorded under sole maize at 30 DAS (476 kg ha^{-1}), 60 DAS (6442 kg ha^{-1}) and 90 DAS (13603 kg ha^{-1}) followed by maize + cowpea intercropping at all the stages of observation and both were comparable with each other (Table 2). This might be due to rapid increase in plant height and leaf area at these stages. Similar finding was also reported by Eskandari and Ghanbari (2010) in wheat-bean intercropping. Gabatshele *et al.* (2012) reported that higher maize dry matter weight observed in the sole maize crop could be attributed to high plant density and lack of competition for resources such as light, nutrients and water. The reduction in DMP under intercropping might be due to the competition of intercrops during the earlier stages for nutrients, sunlight, moisture etc. which was evidenced in reduction in plant height and LAI in this study and the reduction being higher with greengram. Similar findings were also reported earlier by Sutharsan and Srikrishnah (2015) in maize.

With regard to mycorrhiza, the dry matter production was higher with mycorrhizal inoculation at all the stages viz., 30 DAS (542 kg ha^{-1}), 60 DAS (7517 kg ha^{-1}) and 90 DAS (14410 kg ha^{-1}) than control. The higher uptake of nutrients due to the formation of external mycelium around the roots by AM fungi might be the reason for the higher DMP. The results are in agreement with the findings of earlier work by Gupta and Janardhan (1991). Kumar and Murugesh (2002) reported that mycorrhizal inoculation was more advantageous in obtaining healthy vigorous seedlings and resulted in higher biomass of maize plants.

Among the fertilizer levels, 125 % RDF recorded the highest DMP but was comparable with 100% RDF at all the stages. The increase in DMP might be attributed 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. Similar increase in the DMP at higher N level upto 200 kg in maize hybrids was reported by Srikanth *et al.* (2009a).

The dry matter production recorded in second crop (winter, 2012) also indicated similar trend as that of the previous crop with regard to mycorrhizal inoculation and fertilizer levels.

The interaction between mycorrhizal inoculation and fertilizer levels was significant at 60 and 90 DAS. The highest DMP was recorded under the treatment combination mycorrhizal inoculation along with 100% RDF (M^+F_2) but was comparable with mycorrhizal inoculation and 125% RDF (M^+F_3) during both the years (Table 3 & 4).

Number of days taken for 50% flowering

Significant advancement in the phenological stages of maize was observed due to the influence of mycorrhizal inoculation and fertilizer levels. Tasseling is a prerequisite of cob formation and finally the maturity of the crop.

Among the mycorrhizal inoculation, mycorrhiza uninoculated plants delayed the phenological events like tasseling and silking of maize by 2 to 3 days when compared to inoculated plants (Table 2). The similar trend was observed in 2012 also. The process of flowering and fruiting was early in the mycorrhizal plants. The results are in good agreement with that of Khan (1994), who also reported that mycorrhizal plants reduce cropping time due to earlier flowering and fruiting. Similar result was also reported by Yaseen *et al.* (2012) in chickpea varietie

Table 2. Effect of arbuscular mycorrhiza and fertilizer levels on dry matter production (kg ha^{-1}) and number of days taken to 50% flowering of maize under intercropping systems

Treatment	Dry matter production						Number of days taken to 50% flowering			
	Winter, 2011			Winter, 2012			Winter, 2011		Winter, 2012	
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	Days taken for 50% tasseling	Days taken for 50% silking	Days taken for 50% tasseling	Days taken for 50% silking
Intercropping systems (I)										
I_1	520^{a}	7229^{a}	13635^{a}	476^{a}	6442^{a}	13603^{a}	59.2	67.3	58.1	66.5
I_2	504^{ab}	6896^{b}	13110^{b}	466^{b}	6307^{ab}	13273^{b}	59.6	67.9	59.0	66.8
I_3	484^{c}	6616^{c}	12641^{bc}	459^{c}	6005^{c}	12515^{c}	60.1	68.2	60.1	67.4
SEd	4	101	176	2	65	270	0.3	0.5	0.7	1.2

CD (P=0.05)	**12**	**279**	**488**	**6**	**182**	**751**	**NS**	**NS**	**NS**	**NS**
Mycorrhizal inoculation (M)										
M^-	464^{b}	6311^{b}	11848^{b}	423^{b}	5667^{b}	11719^{b}	60.7	69.0	59.9	67.6
M^+	542^{a}	7517^{a}	14410^{a}	511^{a}	6835^{a}	14542^{a}	58.6	66.5	58.3	66.1
SEd	5	75	125	5	65	168	0.3	0.5	0.5	0.5
CD (P=0.05)	**12**	**184**	**305**	**12**	**158**	**411**	**0.7**	**1.3**	**1.3**	**1.2**
Fertilizer levels (F)										
F_1	485^{b}	6576^{b}	12365^{b}	449^{b}	5860^{b}	12145^{b}	58.7	66.6	57.5	65.0
F_2	507^{b}	7036^{ab}	13371^{ab}	470^{ab}	6368^{ab}	13416^{ab}	59.9	68.1	59.1	66.9
F_3	517^{a}	7130^{a}	13650^{a}	482^{a}	6525^{a}	13830^{a}	60.3	68.7	60.8	68.8
SEd	4	70	162	6	79	212	0.3	0.4	0.6	0.7
CD (P=0.05)	**9**	**144**	**334**	**12**	**163**	**437**	**0.5**	**0.8**	**1.3**	**1.4**
Interaction	**NS**	**Sig**	**Sig**	**NS**	**Sig**	**Sig**	**NS**	**NS**	**NS**	**NS**

Within columns, means followed by same letter do not significantly differ from each other $p < 0.05$ LSD).
I_1 -Sole maize; I_2 - Maize + Cowpea; I_3-Maize + Green gram; M^- -Uninoculated (control); M^+ - Inoculated with AMF; F_1-75% RDF; F_2 - 100% RDF;F_3:125%RD

During 2011 and 2012, with regard to fertilizer levels, earlier flowering (tasseling and silking) was observed under 75 % RDF followed by 100% RDF. Applying higher dose of fertilizers delayed the process of flowering. This shows negative relationship between earliness with yield. Under the fertilizer level of 75 % RDF, because of the insufficiency of source and transformation of reproductive phase, these treatments could not supply sufficient photosynthates for the developing sinks. These observations are in accordance with Gent (1992) and Lohar and Peat (1998), who observed that when plants were subjected to stress like drought, high temperature, competition between plants for resources etc., they readily entered into reproductive phase before putting forth sufficient vegetative growt

Table 3. Interaction effect of mycorrhizal inoculation and fertilizer levels on dry matter production (kg ha^{-1}) of maize hybrid at 60 DAS

Mycorrhizal inoculation	**Winter, 2011**				**Winter, 2012**			
	Fertilizer levels				**Fertilizer levels**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
M^- -Uninoculated (control)	6075^{e}	6295^{d}	6564^{c}	**6311**	5156^{e}	5743^{d}	6103^{c}	**5667**
M^+- Inoculated with AMF	7077^{b}	7777^{a}	7696^{ab}	**7517**	6564^{b}	6993^{a}	6947^{ab}	**6835**
Mean	**6576**	**7036**	**7130**		**5860**	**6368**	**6525**	
		SEd	**CD (P=0.05)**			**SEd**	**CD (P=0.05)**	
	M at F	110	241		**M at F**	112	243	
	F at M	128	263		**F at M**	118	242	

Within columns, means followed by same letter do not significantly differ from each other $p < 0.05$ LSD).

Table 4. Interaction effect of mycorrhizal inoculation and fertilizer levels on dry matter production (kg ha^{-1}) of maize hybrid at 90 DAS

Mycorrhizal inoculation	**Winter, 2011**				**Winter, 2012**			
	Fertilizer levels				**Fertilizer levels**			
	F_1	**F_2**	**F_3**	**Mean**	**F_1**	**F_2**	**F_3**	**Mean**
M^- -Uninoculated (control)	10864^{e}	12047^{d}	12632^{c}	**11848**	10597^{e}	11781^{d}	12778^{c}	**11719**
M^+- Inoculated with AMF	13866^{b}	14696^{a}	14667^{ab}	**14410**	13693^{b}	15051^{a}	14883^{ab}	**14542**
Mean	**12365**	**13371**	**13650**		**12145**	**13416**	**13830**	
		SEd	**CD (P=0.05)**			**SEd**	**CD (P=0.05)**	
	M at F	225	489		**M at F**	297	647	
	F at M	234	478		**F at M**	312	638	

Within columns, means followed by same letter do not significantly differ from each other $p < 0.05$ LSD).

Effect on Grain yield

The maize grain yield was significantly influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels during both the years of study.

Effect of intercropping systems

Among the intercropping systems, sole maize recorded the highest grain yield (8531 kg ha^{-1} and 7976 kg ha^{-1} during 2011 and 2012, respectively) but was comparable with maize intercropped with cowpea (Fig 5). The yield reduction due to intercropping cowpea was negligible 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). Ashish Dwivedi *et al*. (2015) reported that the effect of rainfed maize (*Zea mays* L.) based intercropping systems on maize yield and observed that intercropping systems reduced the values of grain yield of maize than sole cropping of maize, but significant reduction in grain yield was recorded only with sesame, turmeric, and forage intercropping systems.

Effect of mycorrhizal inoculation

During 2011, mycorrhizal inoculation recorded higher grain yield (8892 kg ha^{-1}) than no inoculation (7981 kg ha^{-1}) and reduction in yield being 10.25%. Mycorrhiza had positive influence on grain yield of maize crop (Fig 5). 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). Dania *et al.* (2014) reported that the inclusion of mycorrhiza and organomineral fertilizer application in maize-pigeon pea intercropping system has significantly improved the yield of intercrop maize compared to other treatments without fertilizer application.

Effect of fertilizer levels

During 2011, comparing the yield of maize grain obtained under different fertilizer levels, 125 % RDF recorded the highest grain yield and was comparable with 100% RDF (Fig 5). Fertilizer level of 75% RDF recorded lower grain yield and was 4.7 %and 4.5 % lesser than 125% and 100% 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*. (2009b) lend support to the present findings. Venkata Rao *et al.* (2014) reported that the field experiments conducted at Dharwad during *kharif* and *rabi* seasons revealed that application of 200 per cent RDN (300 kg N ha^{-1}) recorded significantly higher grain yield of hybrid maize (DMH-2) and was on par with that of 150 per cent RDN (225 kg N ha^{-1}) due to 'law of diminishing returns'.

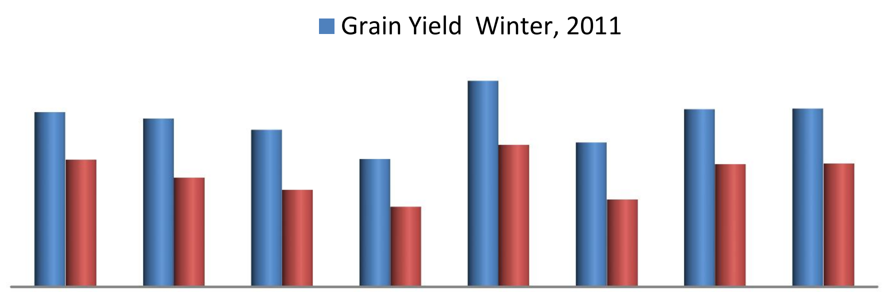

Fig 5. Effect of intercropping, mycorrhiza and fertilizer levels on grain yield (kg ha^{-1}) of maize hybrid

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% RDF (M^+F_2) followed by 125% RDF and was comparable with each other.

The interaction between intercropping systems, mycorrhizal inoculation and fertilizer levels on maize grain yield was significant (Table 5). The treatment combination sole maize with 125% RDF along with mycorrhizal inoculation ($I_1F_3M^+$) recorded significantly higher yield (9600 kg ha^{-1} during 2011 and 8644 kg ha^{-1} during 2012) followed by maize + cowpea intercropping with 100% RDF along with mycorrhizal inoculation ($I_2F_2M^+$) and both were comparable among themselves. 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.

Even though maize intercropped with cowpea and 100% 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 Uddin *et al.* (2003) and Pandey *et al.* (2003). Under maize + cowpea intercropping systems, 100% 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.*

Table 5. Interaction effect of intercropping, mycorrhiza and fertilizer levels on grain yield (kg ha^{-1}) of maize hybrid

Mycorrhizal Inoculation	Winter, 2011				Winter, 2012			
	Fertilizer levels				Fertilizer levels			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
I_1M^-	7793^{lm}	7992^{mn}	8146^{jk}	**9085**	7150^{qr}	7763^{hi}	7833^{gh}	**8369**
I_1M^+	8625^{fg}	9029^{cd}	9600^{a}	**7977**	8071de	8393^{bc}	8644^{a}	**7582**
I_2M^-	7854^{qr}	7966no	8335^{ij}	**8859**	7091^{rp}	7174^{op}	7731^{ij}	**8207**

I_2M^+	8534^{gh}	9405^{ab}	8636^{ef}	**8052**	7976^{fg}	8582^{ab}	8062^{ef}	**7332**
I_3M^-	7764^{pq}	7934^{op}	8044^{kl}	**8732**	7138^{pq}	7377^{mn}	7608^{lm}	**7871**
I_3M^+	8485^{hi}	9038^{bc}	8674^{de}	**7914**	7657^{kl}	8239^{cd}	7718^{jk}	**7374**
Mean	**8176**	**8561**	**8572**		**7514**	**7921**	**7932**	
		SEd	**CD (P=0.05)**		**SEd**	**CD (P=0.05)**		
	F at IM	245.0	488.0	**F at IM**	434.0	865.0		
	M at IF	220.0	478.0	**M at IF**	309.0	673.0		
	I at MF	208.0	431.0	**I at MF**	263.0	545.0		

Within columns, means followed by same letter do not significantly differ from each other $p < 0.05$ LSD).
I_1 - Sole maize; I_2 - Maize + Cowpea; I_3 - Maize + Green gram; M^- - Uninoculated (control); M^+ - Inoculated with AMF; F_1 - 75% RDF; F_2 - 100% RDF; F_3 - 125% RDF

Conclusion

Based on the finding of this experiment, it may be concluded that among the intercropping systems, sole maize recorded better growth and higher 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 growth, yield attributes and grain yield of maize. Interaction effect of fertilizer levels and mycorrhiza had significant influence on growth and yield. Higher values of growth and higher grain yield were obtained under fertilizer level of 100% RDF with mycorrhizal inoculation. 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% RDF along with mycorrhizal inoculation which was followed by maize + cowpea intercropping and 100% RDF along with mycorrhizal inoculation and both were comparable with each other.

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