Original Research Article

Economics of different intercropping systems of maize under mycorrhizal inoculation and different fertilizer levels

ABSTRACT

A field experiment was conducted in order to evaluate the economics of different intercropping systems of maize under mycorrhizal inoculation and different fertilizer levels at Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore during the winter season in 2011 and 2012. 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. Data regarding net field benefit, benefit cost ratio, dominance analysis, and marginal rate of return were collected. The experimental results showed that maximum Net Field Benefits of Rs. 1,25,990 during 2011 and Rs. 1,14, 215 during 2012 were recorded in maize +cowpea intercropping system along with mycorrhizal inoculation and 100% RDF ($I_2F_2M^+$), respectively. While the maximum benefit cost ratio (BCR) of 3.45 and 2.74 was found in maize +cowpea intercropping system along with 100% RDF and with mycorrhizal inoculation ($I_2F_2M^+$) during the year 2011 and 2012, respectively. Dominance analysis of maize intercropped with green gram along with mycorrhizal inoculation and different fertilizer levels at 75% RDF, 100%RDF and 125% RDF, respectively were dominated dominated due to their lower net field benefits as compared to other treatments, while maximum marginal rate of return (8911 %) was obtained by sole maize without mycorrhizal inoculation and fertilizer level of 75% RDF ($I_1F_1M^+$) during 2011. In 2012, maize intercropped with greengram without mycorrhizal inoculation and fertilizer level at the rate of 100% RDF recorded maximum marginal rate of returns (6167%) than other treatments.

Keywords: Maize intercropping, Fertilizer levels, Mycorrhiza, Economic Analysis, Benefit Cost Ratio

INTRODUCTION

Self-sufficiency in maize (*Zea mays* L) production is a major strategy for achieving food security in India. The strategy is adopted to avoid undue reliance on unstable and unpredictable world food markets and to generate incomes to farmers and landless laborers (Mousavi and Eskandari, 2011). Apart from being grown for grain, maize can be produced ‘green’ to be consumed as a vegetable. Intercropping systems are more productive than sole crops grown on the same land, because they are associated with greater yield stability, greater land-use efficiency, increased competitive ability against weeds, improvement of soil fertility due to N fixation, and some favorable root exudates from leguminous species incorporated in the systems (Mousavi and Eskandari, 2011 and Lithourgidis *et al*., 2011).

Intercropping is a type of mixed cropping and defined as agricultural practice of cultivating two or more crops in the same space at the same time. The important reason to grow two or more crops together may be increase of productivity per unit of land. In intercropping system, all the environmental resources utilized to maximize crop production per unit area and per unit time. Thus, intercropping systems can provide many benefits through increased efficiency of land use, enhancing the capture and use of light, water and nutrients, controlling weeds, insects, diseases and increasing the length of production cycles. Other benefits of intercropping may be improve quality of the seed, and better control of water quality through minimizing the use of inorganic N fertilizers, replacing them by the use of legumes (Elmira Charani *et al.*, 2017 and Hamd Alla *et al* ., 2014).

Cereal-legume intercropping plays an important design in allowance food production in both developed and developing countries, especially in situations of restricted water resources (Tsubo *et al*., 2005). Dahmardeh (2013) reported that mixed cropping especially with legumes can betterment both forage quality and quantity because legumes are well source of protein. Intercropping of legumes and cereals is an old drill in tropical agriculture that dates back to old urbanity.

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agroclimatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. Maize is ranked third after wheat and rice among the most important cereal crops. In India, maize is essential for human and live-stocks consumption as a major source of carbohydrates, oil, as well as a minor source of protein. It is required for several industrial purposes such as starch and oil. At the same time, cowpea is an important legume crop. It is a primary source of plant protein for humans and animals. Cowpea can be used as a cover crop and to fix nitrogen in the soil (Asiwe *et al*., 2009). Greengram is one of the most important pulse crops in India because of its adaptation to short growth duration, low water requirement, low soil fertility and is favoured for consumption due to its easy digestibility and low production of flatulence (Shil and Bandopadhyay, 2007). Being a leguminous crop, it has the capacity to fix atmospheric nitrogen through symbiotic nitrogen fixation and also used as a green manure crop. As short duration crop, it fits well in various multiple and intercropping systems.

Intercropping is spread accepted as a sustainable practice due to its yield advantage, high used efficiency of light and water. Lupwayi and Kennedy (2007) were indicated that intercropped pulse crops benefit the associated cereal crop like maize by either transferring a part of fixed N_2 because of their less N requirement (–Lupwayi and Kennedy, 2007). Intercropping is known to have the potential to keep high and viable natural population of AM fungi in soils because of the higher diversity of plants involved. Benard Oula Muok *et al.* (2009) reported that intercropping system between maize and soybean stimulated proliferation of AM fungi as compared to a monoculture system.

Ahmaed *et al.*, (2013) reported that simultaneous sowing of maize + fodder cowpea at 1:1 row proportion recorded significantly higher grain yield (5349 kg ha^{-1}) and stover yield (7581 kg ha^{-1}) over all other intercropping treatments except, maize sown after 1 week at 1:1 row proportion. Intercropping of maize and pigeonpea at 4:2 row ratio with 100:50 population recorded significantly higher maize equivalent yield (8970 kg ha^{-1}), net returns (Rs.36008 ha^{-1}) and B:C ratio (3.25) over sole and other intercropping systems except 2:2 and 3:1 row ratios with 100:50 population of maize and pigeon pea. Though intercropping resulted in significant reduction in the yield of sole crops, it was better compensated by components crops in terms of total yield and income (Lingaraju *et al.*, 2008).

On the other hand, using monetary advantage index Mutusso *et al.* (2017) reported that intercropping with two rows of cowpea and one row of millet gave significantly higher economic benefit than mixture with one row of each of the crops. Using the same MAI, Mutusso *et al.* (2017) found that intercropping with two rows of sorghum and one row of cowpea gave higher economic return compared to the other planting arrangements and the sole crops.

Amanullah *et al.* (2011) revealed that the highest gross return of Rs. 70,738 and net return of Rs. 46,587 were recorded in maize 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.

Sankaran *et al*. (2005) opined that the enhancement in fertilizer application in maize to the tune of 25-50 percent above the recommended level increased the gross, net return and

BC ratio. Application of 150 % recommended dose of fertilizer is suggested for obtaining maximum productivity and BC ratio under irrigated condition.

From the foregoing review, information pertaining to intercropping, mycorrhiza and fertilizer requirement of hybrid maize varies widely. In maize, the effect of intercropping, mycorrhiza and fertilizer levels is well documented. So, keeping in view the importance of intercropping systems the present study was undertaken to examine economics of maize which were planted with mycorrhizal inoculation and different fertilizer levels in intercropping systems.

MATERIALS AND METHODS

Field experiments were conducted during winter season of 2011-12 and 2012-13 at Eastern Block of the Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore to study the production potential and monetary advantage of maize intercropping systems influenced by mycorrhizal inoculation and varying 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 (F1), 100% RDF (F2), and 125 % RDF (F3) 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. The inoculum with the spore density of 10 spores g^{-1} was applied as a thin layer beneath the seeds one week after sowing at the rate of 100 kg ha^{-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}. The recommended fertilizer dose followed for maize was 150:75:75 kg NPK ha^{-1}.

Observations on maize grain yield were assessed on the basis of the produced yield recorded from the net plot. During both the years of experimentation meteorological parameters were more or less same and the crops were normal. The two year experimental data were subjected to statistical analysis as described by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Net Field Benefits (NFB)

Farmers are more interested in variability in benefits than yields, therefore net field benefits were calculated against the variable costs. Table 1&3 reveals that maximum NFB of Rs. 1, 25, 990 during 2011 and Rs. 1, 14, 215 during 2012 were achieved in maize +cowpea intercropping system along with mycorrhizal inoculation and 100% RDF ($I_2F_2M^+$) against the minimum in (Rs. 93, 465 and Rs. 85, 536 during 2011 and 2012, respectively) in sole maize without mycorrhizal inoculation and 75% RDF) ($I_1F_1M^-$).

*Benefit Cost Ratio (BCR***)**

Benefit cost ratio also important to farmers because they are interested in the increase in net returns with given increase in the total cost of production. The maximum benefit cost ratio (BCR) of 3.45 and 2.74 was found in maize +cowpea intercropping system along with 100% RDF and with mycorrhizal inoculation ($I_2F_2M^+$) during the year 2011 and 2012, respectively and this was followed by maize +cowpea intercropping system along with 100% RDF ($I_2F_2M^-$) and without mycorrhizal inoculation and maize + cowpea intercropping system and 75% RDF along with mycorrhizal inoculation ($I_2F_1M^+$). This was mainly due to the better performance of component crops, which gave higher net returns in the treatment combinations and thus increased the B:C ratio. Even though the initial cost of mycorrhizal inoculum was high, mycorrhizal inoculation has recorded higher yield by better uptake of nutrients and hence increased the B:C ratio. These results are in agreement with Madar (2001) in maize + pigeonpea, and Surve *et al*. (2012) in sorghum + cowpea who reported similar results.

Even though the initial cost of mycorrhizal inoculum was high, mycorrhizal inoculation has recorded higher yield by better uptake of nutrients and hence increased the B:C ratio. These results are in agreement with the results of Amanullah *et al.* (2011) who reported similar finding in maize.

Table 1: Effect of intercropping, mycorrhiza and fertilizer levels on net returns, net field benefits and benefit cost ratio of maize hybrid during 2011

Treatments	Maize grain yield (kg ha^{-1}) A	Gross income (₹ ha^{-1}) B	Variable cost (₹ ha^{-1}) C	Total cost (₹ ha^{-1}) D	Net field benefits (₹ ha^{-1}) (B-C)	Net return (₹ ha^{-1}) (B-D)	Benefit cost ratio (B/D)
$I_1F_1M^-$	8625	99461	5996	32375	93465	67086	3.07
$I_1F_2M^-$	9029	101946	7466	33845	94480	68101	3.01
$I_1F_3M^-$	9600	103837	9930	36309	93907	67528	2.86
$I_1F_1M^+$	7793	109784	9996	36375	99788	73409	3.02
$I_1F_2M^+$	7992	114888	11466	37845	103422	77043	3.04
$I_1F_3M^+$	8146	121988	13930	40309	108058	81679	3.03
$I_2F_1M^-$	8534	117649	8746	35125	108903	82524	3.35
$I_2F_2M^-$	9405	119749	10216	36595	109533	83154	3.27
$I_2F_3M^-$	8636	125405	12680	39059	112725	86346	3.21
$I_2F_1M^+$	7854	127769	12746	39125	115023	88644	3.27
$I_2F_2M^+$	7966	140206	14216	40595	125990	99611	3.45
$I_2F_3M^+$	8335	129970	16680	43059	113290	86911	3.02
$I_3F_1M^-$	8485	106506	8596	34975	97910	71531	3.05
$I_3F_2M^-$	9038	109588	10066	36445	99522	73143	3.01
$I_3F_3M^-$	8674	113055	12530	38909	100525	74146	2.91
$I_3F_1M^+$	7764	118817	12596	38975	106221	79842	3.05
$I_3F_2M^+$	7934	128193	14066	40445	114127	87748	3.17
$I_3F_3M^+$	8044	122406	16530	42909	105876	79497	2.85

Maize grain rate = Rs.12/kg; Maize stover, cowpea and greengram haulm rate= Rs. 0.50/kg; Cowpea grain rate = Rs.30/kg; Greengram grain rate = Rs. 35/kg; Total fixed cost = Rs.26379

Dominance analysis

As net field benefit (NFB) does not indicate the rate of return in relation to investment, final recommendation for the production technology cannot be specified only on the basis of NFB. Dominance and marginal analysis compares the variable costs with the gross margin, showing the increase in costs required to gain a given increase in gross margin. Treatments were first listed in increasing order of variable costs. Any treatment that had a total gross margin less than (or equal to) those of a treatment with lower total variable costs is dominated. Therefore, dominated treatments have a lower extra gross margin per unit of extra costs than other treatments (Anjum *et al*., 2015).

Net Field Benefits of some treatments were less to those with lower cost comparative to an increase in variable cost among treatments (Table 2 & 4). As a result these treatments were dominated (D). The remaining un-dominated treatments were further considered for the marginal analysis. During the year 2011 and 2012, it was observed that the maize intercropped with green gram along with mycorrhizal inoculation and different fertilizer levels at 75% RDF, 100%RDF and 125% RDF, respectively, maize intercropped with green gram without mycorrhizal inoculation and fertilizer level at the rate of 125% RDF, maize intercropped with cowpea along with mycorrizal inoculation and fertilizer level at the rate of 125% RDF ($I_2F_3M^+$), and sole maize along with mycorrhizal inoculation and fertilizer level 125% RDF ($I_1F_3M^+$) were dominated due to their lower net field benefits as compared to the preceding treatment (Table 2 & 4).

Table 2: Effect of intercropping, mycorrhiza and fertilizer levels on dominance analysis of maize hybrid during 2011

Treatments	Cost that vary (PRs·ha^{-1})	Net field benefits (PRs·ha^{-1})
$I_1F_1M^-$	5996	93465
$I_1F_2M^-$	7466	94480
$I_3F_1M^-$	8596	97910
$I_2F_1M^-$	8746	108903
$I_1F_3M^-$	9930	93907
$I_1F_1M^+$	9996	99788
$I_3F_2M^-$	10066	99522
$I_2F_2M^-$	10216	109533
$I_1F_2M^+$	11466	103422
$I_3F_3M^-$	12530	100525**D**
$I_3F_1M^+$	12596	106221**D**
$I_2F_3M^-$	12680	112725
$I_2F_1M^+$	12746	115023
$I_1F_3M^+$	13930	108058**D**
$I_3F_2M^+$	14066	114127**D**
$I_2F_2M^+$	14216	125990
$I_3F_3M^+$	16530	105876**D**
$I_2F_3M^+$	16680	113290**D**

Table 3: Effect of intercropping, mycorrhiza and fertilizer levels on net returns, net field benefits and benefit cost ratio of maize hybrid during 2012

Treatments	Maize grain yield (kg ha^{-1}) A	Gross income (₹ ha^{-1}) B	Variable cost (₹ ha^{-1}) C	Total cost (₹ ha^{-1}) D	Net field benefits (₹ ha^{-1}) (B-C)	Net return (₹ ha^{-1}) (B-D)	Benefit cost ratio (B/D)
$I_1F_1M^-$	8071	91732	6196	37969	85536	53763	2.42
$I_1F_2M^-$	8393	99203	7467	39240	91736	59963	2.53
$I_1F_3M^-$	8644	100238	10230	42003	90008	58235	2.39
$I_1F_1M^+$	7150	103207	10696	42469	92511	60738	2.43
$I_1F_2M^+$	7763	107161	11967	43740	95194	63421	2.45
$I_1F_3M^+$	7833	110335	14730	46503	95605	63832	2.37
$I_2F_1M^-$	7976	108096	9946	41719	98150	66377	2.59
$I_2F_2M^-$	8582	109740	11217	42990	98523	66750	2.55
$I_2F_3M^-$	8062	117715	13980	45753	103735	71962	2.57
$I_2F_1M^+$	7091	121192	14446	46219	106746	74973	2.62
$I_2F_2M^+$	7174	129932	15717	47490	114215	82442	2.74
$I_2F_3M^+$	7731	123075	18480	50253	104595	72822	2.45
$I_3F_1M^-$	7657	98695	9796	41569	88899	57126	2.37
$I_3F_2M^-$	8239	102599	11067	42840	91532	59759	2.39
$I_3F_3M^-$	7718	107650	13830	45603	93820	62047	2.36
$I_3F_1M^+$	7138	108841	14296	46069	94545	62772	2.36
$I_3F_2M^+$	7377	118379	15567	47340	102812	71039	2.50
$I_3F_3M^+$	7608	110823	18330	50103	92493	60720	2.21

Maize grain rate = Rs.12/kg; Maize stover, cowpea and greengram haulm rate = Rs. 0.50/kg; Cowpea grain rate = Rs.30/kg; Greengram grain rate = Rs. 35/kg; Total fixed cost = Rs. 31773/-

Table 4: Effect of intercropping, mycorrhiza and fertilizer levels on dominance analysis of maize hybrid during 2012

Treatments	Cost that vary (PRs·ha^{-1})	Net field benefits (PRs·ha^{-1})
$I_1F_1M^-$	6196	85536
$I_1F_2M^-$	7467	91736
$I_3F_1M^-$	9796	88899
$I_2F_1M^-$	9946	98150
$I_1F_3M^-$	10230	90008
$I_1F_1M^+$	10696	92511
$I_3F_2M^-$	11067	91532
$I_2F_2M^-$	11217	98523
$I_1F_2M^+$	11967	95194
$I_3F_3M^-$	13830	93820**D**
$I_2F_3M^-$	13980	103735
$I_3F_1M^+$	14296	94545**D**
$I_2F_1M^+$	14446	106746
$I_1F_3M^+$	14730	95605**D**
$I_3F_2M^+$	15567	102812**D**
$I_2F_2M^+$	15717	114215
$I_3F_3M^+$	18330	92493**D**
$I_2F_3M^+$	18480	104595**D**

Marginal Analysis

Marginal analysis was calculated to check the economic impact of mycorrhizal inoculation and fertilizer levels on maize intercropping systems. This analysis assists the farmers to get the maximum benefit from the inputs by using the limited resources. Marginal analysis formed the basis of economic reasoning and it showed the effects of a small change in the control variable. As real differences were found in the yield among different treatments, therefore marginal analysis was done. Table 5 shows the marginal analysis of un-dominated treatments. Maximum marginal rate of return (8911%) was obtained by sole maize without mycorrhizal inoculation and fertilizer level of 75% RDF ($I_1F_1M^+$) during 2011 followed by maize intercropped with cowpea without mycorrhizal inoculation and fertilizer level at the rate of 75 % RDF ($I_2F_1M^-$).

During 2012, maize intercropped with greengram without mycorrhizal inoculation and fertilizer level at the rate of 100% RDF ($I_3F_2M^-$) recorded maximum marginal rate of returns (6167%) than other treatments (Table 6). Minimum marginal rate of return (-2867%) was obtained under the treatment of maize intercropped with greengram without mycorrhizal inoculation and fertilizer level at the rate of 75% RDF ($I_3F_1M^-$). It is evident from the results that farmers with poor resources can accomplish maximum benefits by solo planting / maize intercropped with cowpea/ maize intercropped with greengram without any mycorrhizal inoculation and minimum fertilizer application at the rate of 75 % RDF, respectively. Farmers with better resources can move towards planting sole maize/maize + greengram intercropping without mycorrhizal inoculation and fertilizer level at the rate of 125 % RDF /75 % RDF, respectively.

Table 5. Effect of intercropping, mycorrhiza and fertilizer levels on marginal analysis of maize hybrid during 2011

Treatments	Cost that vary (PRs·ha^{-1})	Marginal cost that vary (PRs·ha^{-1})	Net field benefits (PRs·ha^{-1})	Marginal net benefits (PRs·ha^{-1})	Marginal rate of return (%)
$I_1F_1M^-$	5996	-	93465	-	-
$I_1F_2M^-$	7466	1470	94480	1015	69
$I_3F_1M^-$	8596	1130	97910	3430	304
$I_2F_1M^-$	8746	150	108903	10993	7329
$I_1F_3M^-$	9930	1184	93907	-14996	-1267
$I_1F_1M^+$	9996	66	99788	5881	8911
$I_3F_2M^-$	10066	70	99522	-266	-380
$I_2F_2M^-$	10216	150	109533	10011	6674
$I_1F_2M^+$	11466	1250	103422	-6111	-489
$I_2F_3M^-$	12680	1214	112725	9303	766
$I_2F_1M^+$	12746	66	115023	2298	3482
$I_2F_2M^+$	14216	1470	125990	10967	746

Table 6. Effect of intercropping, mycorrhiza and fertilizer levels on marginal analysis of maize hybrid during 2012

Treatments	Cost that vary ($PRs \cdot ha^{-1}$)	Marginal cost that vary ($PRs \cdot ha^{-1}$)	Net field benefits ($PRs \cdot ha^{-1}$)	Marginal net benefits ($PRs \cdot ha^{-1}$)	Marginal rate of return (%)
$I_1F_1M^-$	6196	-	85536	-	-
$I_1F_2M^-$	7467	1271	91736	6200	488
$I_2F_1M^+$	9796	2329	88899	-2837	-122
$I_3F_2M^-$	9946	150	98150	9251	6167
$I_3F_1M^-$	10230	284	90008	-8142	-2867
$I_2F_1M^-$	10696	466	92511	2503	537
$I_1F_3M^+$	11067	371	91532	-979	-264
$I_2F_2M^-$	11217	150	98523	6991	4661
$I_1F_3M^-$	11967	750	95194	-3329	-444
$I_2F_2M^+$	13980	2013	103735	8541	424
$I_3F_3M^-$	14446	466	106746	3011	646
$I_3F_1M^+$	15717	1271	114215	7469	588
$I_2F_3M^+$	18330	2613	92493	-21722	-831

CONCLUSION

Maize +cowpea intercropping system along with 100% RDF and with mycorrhizal inoculation gave higher benefit cost ratio (3.45 and 2.74 during 2011 and 2012, respectively). During 2011, maximum marginal rate of return (8911 %) was obtained by sole maize without mycorrhizal inoculation and fertilizer level of 75% RDF ($I_1F_1M^+$). In 2012, maize intercropped with greengram without mycorrhizal inoculation and fertilizer level at the rate of 100% RDF recorded maximum marginal rate of returns (6167%) than other treatments.

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