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Dynamics of soil fertility as influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels in maize-sunflower cropping system

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Abstract

Field experiments were conducted for two consecutive years (2010-11 and 2011-12) at Eastern Block Farm, Tamil Nadu Agricultural University, Coimbatore on sandy clay loam soils consisting sunflower was raised as residual crop during summer in a sequence of maize sown in winter. The experiments were laid out in split-split plot design with three factors. In respect of succeeding crop sunflower, all the treatment plots were further divided into two equal parts by adopting the following treatment schedule. Three intercropping systems *viz*., sole maize - sunflower (I1), maize+cowpea - sunflower (I2) and maize+ greengram - sunflower (I3) were the treatments under main plot. Four mycorrhizal treatments *viz*., M1 - uninoculated (Both crops), M2 - uninoculated (Sunflower), M3 - inoculated (Sunflower), M4 - inoculated (Both crops) were included under sub plot. Three fertilizer levels *viz*., 75% RDF (F1), 100% RDF (F2), and 125% RDF (F3) under sub-sub plot. Regarding the dynamics of various soil fertility parameters *viz*., N, P and K uptake of sunflower were found higher to a considerable extent under preceding maize + cowpea intercropping followed by maize + greengram intercropping at both the stages. With respect to mycorrhizal inoculation, nutrient uptake was higher under mycorrhiza inoculated treatments for both the crops over uninoculated treatments. Among the fertilizer levels, 125% RDF to preceding maize recorded higher N, P and K uptake followed by 100% RDF at both the stages of observation. With regard to soil available nutrients, among the intercropping systems, preceding sole maize registered higher soil available N, P and K followed by maize + cowpea intercropping. Among the mycorrhizal treatments, mycorrhiza uninoculated to both the crops and among the fertilizer levels, 125% RDF recorded higher soil available nutrients. As regards the balance sheet of soil available N, P and K,lower actual N loss was (-32.7 kg ha^{-1}), P loss was (-1.2 kg ha^{-1}) and K loss was (-22.1 kg ha^{-1}) under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops and 125% RDF (I2F3M+) during 2011. Regarding 2012, the maximum actual N gain was (5.0 kg ha^{-1}), P gain was (0.1 kg ha-1) and K gain was (12.3 kg ha^{-1}) under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops with 125% RDF (I2F1M+). The maximum actual loss was recorded under the treatment combination of sole maize without mycorrhizal inoculation to both the crops with 75% RDF.

Keywords: Maize, sunflower, nutrient uptake, soil available nutrients, nutrient balance

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops of the world, occupying third rank in production after wheat and rice. In India, maize ranks third in terms of area sown and production next to rice and wheat. In India, maize is cultivated in an area of 9.4 m ha with production of 22.27 m t. However, its productivity is 2.5 t ha^{-1} which is much lower than the global average (Manjanagouda *et al*. 2018) [16]. Maize has wide distribution and varied uses as food, feed and fodder. Maize is an exhaustive crop and requires very high doses of nitrogen and other nutrients. Ensuring balanced quantity of nutrients in a given soil for good plant growth is the greatest challenge of the day as yield potentials vary among soils. For maintaining sustained crop production, balanced manuring is essential to build up soil health. Wide use of short statured high yielding varieties and hybrids is common in maize.

The availability of land for agriculture is shrinking every day as it is increasingly utilized for non-agricultural purposes. Under this situation, one of the important strategies to increase agricultural output is the development of new high intensity cropping systems including intercropping systems. The main purpose of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop efficiently. Cereal-legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping (Evans *et al*., 2001) [7].

Maize expresses its full genetic potential when it is grown in an ideal environment with optimum soil fertility. 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.

At present, some studies on nutrient utilization in intercropping system of different crops are available but effect of inoculation with AMF on the performance of sequential cropping system is not very well- known. This study is aimed to clarify the impact of AMF inoculation on plant nutrition, and nutrient contents of soil in the maize- sunflower cropping system. Keeping these points in view the present study on dynamics of soil fertility as influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels in maize-sunflower cropping system was undertaken.

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 dynamics of soil fertility as influenced by intercropping systems, mycorrhizal inoculation and fertilizer levels in maize-sunflower cropping system. The experiment was laid out in a split-split design with three replications. In respect of succeeding crop sunflower, all the treatment plots were further divided into two equal parts *viz*., 4.5x 3.0 m adopting the following treatment schedule. Three intercropping systems *viz*., sole maize - sunflower (I1), maize+cowpea - sunflower (I2) and maize+ greengram - sunflower (I3) were the treatments under main plot. Four mycorrhizal treatments *viz*., M1 - uninoculated (Both crops), M2 - uninoculated (Sunflower), M3 - inoculated (Sunflower), M4 - inoculated (Both crops) 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 of10 kg ha^{-1}. The recommended fertilizer dose followed for maize was 150:75:75 kg NPK ha^{-1}.

In one part sunflower seeds were sown in the flat bed at 60 cm apart by dibbling one seed hill^{-1} with plant to plant spacing of 30 cm within the row as per treatments. In another part, the seeds were sown along with vermiculite based mycorrhizal inoculum at a depth of 5 cm below the seeds. The seeds were pre-treated with carbendazim @ 2 g kg^{-1} of seed against seed borne diseases.

Nutrient uptake by crop

Digestion of plant samples

One gram plant samples were pre-digested with 5 ml nitric acid and digested with di-acid mixture of nitric acid and perchloric acid (9:4). The clean digested material was made up to 50 ml volume with 6 N HCl and was used for the analysis of all mineral elements. Nitrogen content was estimated by modified micro-kjeldhal's method as outlined by Jackson (1967) [11] and expressed in percentage. Phosphorus content in the digested plant sample was estimated by vanadomolybdo phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 460 nm wave length as outlined by Jackson (1973) [10].

Potassium in the plant and tuber samples digest were estimated by atomizing the diluted acid extract in a flame photometer as described by Jackson (1973) [10].

The nutrient uptake by crop was computed from their respective elemental (NPK) concentration and dry matter production and presented in kg ha^{-1}.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{\% of nutrient} \times \text{Total dry matter production (kg ha}^{-1})}{100}$$

Chemical analysis of soil

Representative soil samples from the experimental plots were drawn from the top 45 cm depth before sowing of the crop. Similarly, the surface soil samples from 0 to 45 cm depth were also collected from each experimental plot after harvest of crop. Soil samples collected were air dried in shade, powdered with wooden mallet and passed through 2 mm sieve and chemically analyzed for available nitrogen, phosphorus and potassium content of the soil. Available nitrogen was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956) [28].

Available phosphorus was determined by Olsen's method as outlined by Jackson (1967) [11]. Available potassium was determined by Neutral normal ammonium acetate solution using flame photometer as outlined by Jackson (1967) [11].

Nutrient balance

The net gain in available nitrogen, phosphorus and potassium during the period of two seasons put together was calculated using the corresponding available nutrient status at the beginning and at the end of the specified period. The residual and cumulative effects were not accounted in the calculation (Sadanandan and Mahapatra, 1973) [25].

Results and Discussion

Nutrient uptake of sunflower

In the first crop during 2011, in respect of intercropping systems, higher N uptake of sunflower was recorded under plots previously grown with maize + cowpea intercropping (35.9 and 93.3 kg ha^{-1} at 45 and 90 DAS, respectively) followed by maize + greengram intercropping at both the stages (Table 1). By introducing legume crops in cropping systems, soil fertility and productivity might have increased because legumes are able to fix nitrogen in their root and supplied the residual nitrogen to following sunflower crop and increased the nutrient uptake. These similar result observed by Kumbhar *et al*. (2007) [15] is in concomitant to the present results. This is in agreement with the findings of Jayakumar and Surendran (2015) [13] who reported that, better nitrogen use efficiency was associated with cotton + blackgram intercropping and 75% inorganic N + 25% N through poultry manure.

The favourable effect of decomposed crop residues on soil structure, organic carbon content increased water holding capacity, facilitated quick and greater availability of plant nutrients and provided better environment for growth and proliferation and more absorptive surface for uptake of nutrients in cowpea grown plots. The least N uptake was recorded under sole maize grown plots at 45 and 60 DAS.

Among the intercropping systems, plots grown with maize intercropped with cowpea registered higher P uptake (16.6 and 27.1 kg ha^{-1} at 45 and 90 DAS, respectively) (Table1). This might be due to the increased availability of nutrients due to addition of legumes in cropping systems. The increased activity of microbes in the soil enhanced the root activity which would have taken more nutrients from the soil. The overall enhancement in the growth and DMP due to maize intercropped with cowpea and the increased nutrient content might have increased the P uptake of sunflower. The least P uptake was recorded under sole maize grown plots at 45 and 60 DAS.

In plots where maize was grown intercropped with cowpea in the previous season registered higher K uptake followed by maize intercropped with greengram at 90 DAS and both were comparable with each other. The increased uptake was due to increased plant biomass, which included both growth and yield components. The least K uptake was recorded under sole maize grown plots at 45 and 60 DAS.

With respect to mycorrhizal inoculation, N uptake was higher under mycorrhiza inoculated treatments for both the crops over uninoculated treatments at 45 and 90 DAS. AMF might have facilitated the transfer of N from the soil to the maize plant. The mechanism of how this occurred can be by direct active transport through the mycelia from the soil to the plants. Nitrate uptake enhancement by AMF colonization was supported in a study conducted by Faure *et al.* (1998) [8] who reported larger N labelled urea to study the impact of two species of AMF on N uptake at four P fertilization levels. They observed that inoculation with AMF improved the growth and N content of cotton plants. The least uptake of nitrogen was recorded with non-mycorrhizal treatments.

Considering the mycorrhizal treatments, inoculation of mycorrhiza to both the crops recorded higher P uptake at both the stages. AM fungi seem to be related to the width and evenness of spread of the extraradical mycelium (Jakobsen *et al*. 1992) [12] which had the transfer capability from fungus to plant (Smith *et al.* 1994) [27]. The promotion of P uptake and growth in inoculated soil compared to non-inoculated soil when *Glomus intraradices* was present presumably related to similar properties of spread of mycelium and transfer of P by this fungus combined with a good ability of the extraradical mycelium to persist in undisturbed soil. The effect seen was a stimulation of P uptake and growth in the undisturbed soil rather than a depression of these properties in the disturbed soil, as noted previously (McGonigle and Miller 1996) [18]. Similar results of increase in phosphorus uptake due to mycorrhizal inoculation were also reported earlier by Miller (2000) [20] in maize. Numerous studies have shown conclusively that plants colonized by AM fungi are much more efficient in taking up soil P than uninoculated plants (Hetrick *et al*. 1996 [9]; Smith and Read 1997 [26]; Subramanian *et al*., 2006 [29]; Ananthi *et al.*, 2010 [4].

With respect to mycorrhizal inoculation, K uptake was higher under mycorrhiza inoculated to both the crops followed by mycorrhiza treated to sunflower only and this was comparable with mycorrhiza untreated plots to sunflower. This might be due to root colonization of sunflower plants, which increased the absorption of potassium in the present study. These results are also supported by the findings of Mesbahi *et al.* (2012) [19].

The least uptake of P and K were recorded with non-mycorrhizal treatments Among the fertilizer levels, 125% RDF recorded higher N uptake followed by 100% RDF at both the stages of observation. In all the cases, the least N uptake was associated with 75% RDF (Table 1). The N uptake was higher under higher dose of fertilizer. Increased uptake of nitrogen at higher doses might have resulted in initial build-up of plants due to vigorous growth and high photosynthetic rate which led to better uptake throughout the crop growth period. When a considerable amount of N is applied at or near anthesis, there is greater possibility of its accumulation in sink rather than other vegetative parts (Nair and Singh, 1974) [22]. This is in confirmity with the findings of Vivek *et al*. (1994) [34]. The improved nutritional status of sunflower is mainly attributed to higher dry matter production and to a lesser extent caused by the increased nitrogen or phosphorus nutrient concentrations.

With regard to fertilizer levels, higher P uptake was registered under 125% RDF followed by 100% at both the stages of observation and both were comparable with each other. Enhanced dry matter production as a result of nitrogen addition and the synergistic effect between nitrogen and phosphorus might have contributed for more concentration of phosphorus in sunflower. At higher nitrogen and phosphorus levels, better utilization of the applied phosphorus in the presence of higher nitrogen might have resulted in higher phosphorus uptake (Thavaprakash *et al*., 2002) [32].

Regarding the fertilizer levels, 125% RDF recorded higher K uptake followed by 100% RDF. This might be due to synergistic effect of N and K and also due to better foraging capacity of roots due to increased NP application which resulted in increased dry matter production. Similar results were reported earlier by Manojkumar and Singh (2003) [17] and Ananthi *et al.* (2010) [4].

In all the stages, the least P and K uptake were associated with 75% RDF applied to the previous crop. Similar trend of results was evident in the second crop of 2012, regarding intercropping systems, mycorrhizal inoculation and fertilizer levels. In both the crops, the interaction effect was absent.

Post-harvest available soil nutrients of sunflower

Among the intercropping systems, preceding maize + cowpea intercropping registered higher soil available N (196.1 and 191.7 kg ha^{-1} during 2011 and 2012, respectively) followed by maize + greengram intercropping. Higher soil available P and K were recorded under maize + cowpea intercropping raised in previous plots followed by maize + greengram intercropping during both the years (Table 2). This might be due to application of RDF to maize and sunflower leads to higher availability of nutrients in soil. The results are in conformity with the findings of Ananthi *et al*. (2017) [3] and Ashish *et al*. (2015) [5]. Another reason was the leguminous nature and complementary effect of cowpea. Especially after the harvest of cowpea, the N fixed by cowpea might have been taken up by maize followed by sunflower resulting in optimum uptake of soil nutrients especially N, without depleting the soil nutrients. Further, the organic acids produced by the residue of legumes during decomposition might have accelerated the liberation of nutrients especially available P to the sunflower crop. Similar results were also reported by Tiwari *et al.* (2004) [33] in maize-wheat cropping system. This might be due to application of RDF to maize and proportionate RDF for intercrops leads to higher availability of nutrients in soil.

Among the mycorrhizal treatments, mycorrhiza inoculated to both the crops recorded higher soil available N (195.4 and 189.7 kg ha^{-1} during 2011 and 2012, respectively), higher soil available P (12.9 and 11.8 kg ha^{-1} during 2011 and 2012, respectively) and higher soil available K (590.7 and 579.7 kg ha^{-1} during 2011 and 2012, respectively) than mycorrhiza uninoculated treatments to both the crops (Table 2). With regard to mycorrhiza, the soil from mycorrhizal inoculated sunflower plants had more available phosphorous (P) than from non-inoculated plots. Mycorrhiza-inoculated plants were reported to release organic acids that reduce rhizospheric pH and facilitate nutrients availability (Koide and Kabir, 2000) [14].

Regarding the fertilizer levels, 125% RDF to preceding crop registered higher soil available N, P and K followed by 100% RDF. The post-harvest available potassium status of the soil was significantly influenced by different fertilizer levels. However, the soil available nitrogen, phosphorus and potassium status at harvest were reduced from the initial soil available nutrient status. This might be due to increased uptake in the treatments. The results conform to the findings of Ramyadevi (2011) [24]. The fertilizer level 75% RDF to preceding crop recorded the least soil available nutrients during both the years of the study.

Nutrient balance in maize-sunflower cropping system

During 2011, the actual gain or loss in soil available N was negative in all treatment combinations. Lower actual N loss was (-32.7 kg ha^{-1}), P loss was (-1.2 kg ha^{-1}) and K loss was (-22.1 kg ha^{-1}) under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops and 125% RDF (I2F3M+) followed by the combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops with 100% RDF I2F2M+ (-34.0 kg of N ha^{-1}, -1.6 kg of P ha^{-1} and -26.9 kg of K ha^{-1} respectively). The maximum actual loss of N, P and K were recorded under the treatment combination of sole maize without mycorrhizal inoculation to both the crops and 75% RDF (- 49.8 kg of N ha^{-1}, -2.8 kg of P ha^{-1} and -65.9 kg of K ha^{-1} respectively).

Regarding 2012, the maximum actual N gain was (5.0 kg ha^{-1}), P gain was (0.1 kg ha^{-1}) and K gain was (12.3 kg ha^{-1}) under under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops with 125% RDF (I2F1M+) followed by the preceding crop treatment combination maize intercropped with cowpea along with mycorrhizal inoculation to both the crops with 100% RDF (I2F2M+). The maximum actual loss was recorded under the treatment combination of sole maize without mycorrhizal inoculation to both the crops with 75% RDF.

Nutrient balance in the cropping system in terms of available NPK is monitored in the experimental plot after the harvest of sunflower during both the years and just before the commencement of each of the cropping cycles.

The negative balance evidenced in the present investigation indicated that that the nutrient uptake by the crops exceeded the quantity of nutrients applied. Sole maize, mycorrhizal inoculation and fertilizer levels exerted influence on the soil fertility nutrient balance and showed a considerable depletion of soil available nutrients due to sole maize and reduction in the fertilizer level to 75 per cent (Fig 1 and Table 3,4,5).

The higher negative nutrient balance recorded in sole maize followed by sunflower as a succeeding crop might be due to depletion of soil nutrient by exhausting maize and sunflower crop. Similar result of nutrient depletion by maize reported by Olasantan *et al.* (1995) [23] and Amanullah *et al.* (2007) [1] in cassava-maize intercropping system.

Maize/cowpea intercropping did not deplete the soil that of sole maize followed by sunflower and this might be due to the atmospheric N fixed by cowpea in the earlier stages which could have met at least part of the N requirement of maize and legumes in maize/legume intercropping and sunflower which might have helped to reduce the depletion of soil N as reported by (Thamburaj and Muthukrishnan 1991) and Amanullah *et al.* (2007) [1] is concomitant to the present result.

In general, inoculation of mycorrhiza resulted in low depletion of the soil N. Among the mycorrhizal treatments, the depletion was higher in the uninoculated treatments. Mycorrhizal inoculation registered minimum loss of nutrients in maize intercropped with cowpea followed by sunflower. Slow decomposition of crop residues led to steady N release to meet the requirement of maize crop at critical stages. Even after the completion of maize growing period, minerlisation of nutrients could be continued and added to the soil pool (Bouldin, 1998) [6]. This might have helped in maintaining the soil available nutrients, inspite of depletion by the sunflower crop.

The minimum actual loss of N, P and K in the treatment combination in maize+cowpea intercropping followed by sunflower as a succeeding crop applied with mycorrhizal inoculation to both the crops with 125% RDF might be due to the cumulative effect of atmospheric N fixed by cowpea and the slow release and minerlisation of N from crop residues. Mycorrhiza maintained higher levels of P in soil solution for a longer period due to more mobilization of native P and uptake by the crop (Subramanian *et al*., 2009) [30]. The treatment combination sole maize followed by sunflower without mycorrhizal inoculation applied with 75% RDF recorded maximum actual loss and this might be due to the absence of intercrop residues and the low organic matter content led to the low soil fertility.

Nutrient balance studied earlier by Modgal *et al.* (1995) [21] revealed that there was increasingly positive balance of NPK with the application of organic manures coupled with high levels of recommended NPK in different rice based cropping systems and this lend support to the present result.

Conclusion

Based on the finding of this experiment, it may be concluded that, regarding the dynamics of various soil fertility parameters *viz.*, N, P and K uptake of sunflower were found higher to a considerable extent under preceding maize + cowpea intercropping at both the stages. With respect to mycorrhizal inoculation, nutrient uptake was higher under mycorrhiza inoculated treatments for both the crops over uninoculated treatments. Among the fertilizer levels, 125% RDF to preceding maize recorded higher N, P and K uptake followed by 100% RDF at both the stages of observation. With regard to soil available nutrients, among the intercropping systems, preceding sole maize registered higher soil available N, P and K followed by maize + cowpea intercropping. Among the mycorrhizal treatments, mycorrhiza uninoculated to both the crops and among the fertilizer levels, 125% RDF recorded higher soil available nutrients. As regards the balance sheet of soil available N, P and K, lower actual N loss, P loss and K loss were recorded under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops and 125% RDF (I2F3M+) during the year 2011. Regarding 2012, the maximum actual N, P and K gain were recorded under the treatment combination maize + cowpea intercropping along with mycorrhizal inoculation to both the crops with 125% RDF (I2F1M+). The maximum actual loss was recorded under the treatment combination of sole maize without mycorrhizal inoculation to both the crops with 75% RDF.

Table 1: Effect of intercropping, mycorrhiza and fertilizer levels on nutrient uptake (kg ha^{-1}) of sunflower hybrid

Treatment	Winter, 2011						Winter, 2012					
	N		P		K		N		P		K	
	45 DAS	90 DAS	45 DAS	90 DAS	45 DAS	90 DAS	45 DAS	90 DAS	45 DAS	90 DAS	45 DAS	90 DAS
Intercropping systems (I)												
I_1 - Sole maize	25.7	81.0	14.1	23.8	60.5	149.6	20.3	75.0	11.2	21.5	56.7	145.8
I_2 - Maize + Cowpea	35.9	93.3	16.6	27.1	68.0	158.4	30.8	87.7	14.0	25.0	64.5	154.0
I_3 - Maize + Green gram	33.0	87.3	14.7	25.6	63.4	154.5	29.2	83.0	12.7	24.0	60.5	149.9
SEd	0.9	1.5	0.5	0.7	1.9	0.9	0.8	1.4	0.4	0.6	1.8	0.7
CD (P=0.05)	1.9	2.9	0.9	1.4	3.7	1.8	1.6	2.7	0.8	1.2	3.5	1.4
Mycorrhizal inoculation (M)												
M_1- Uninocula ted (Both crops)	27.5	83.0	8.4	17.5	57.1	155.4	23.0	78.0	8.3	17.8	56.0	148.7
M_2- Uninocula ted(Sunflower)	31.3	88.6	16.4	27.2	64.9	152.5	26.4	81.6	13.2	24.5	60.6	148.9
M_3- Inoculated (Sunflower)	33.0	87.0	17.6	28.4	66.0	153.3	28.2	83.3	14.3	25.5	61.9	150.1
M_4- Inoculated (Both crops)	34.3	90.0	18.1	28.9	67.8	155.4	29.4	84.5	14.9	26.3	63.7	151.9
SEd	1.1	1.7	0.5	0.8	2.2	1.1	0.9	1.6	0.4	0.7	2.0	0.8
CD (P=0.05)	2.2	3.4	1.0	1.6	4.3	2.1	1.8	3.2	0.9	1.4	4.1	1.6
Fertilizer levels (F)												
F_1 - 75% RDF	29.5	85.1	14.4	24.6	62.4	151.9	24.8	79.9	11.8	22.5	58.9	147.7
F_2 - 100% RDF	31.6	87.6	15.1	25.7	64.0	154.2	26.8	81.9	12.8	23.9	60.8	149.9
F_3 - 125% RDF	33.4	88.8	16.0	26.2	65.5	156.3	28.6	83.8	13.4	24.1	62.0	152.1
SEd	0.9	1.5	0.5	0.7	1.9	0.9	0.8	1.4	0.4	0.6	1.8	0.7
CD (P=0.05)	1.9	2.9	0.9	1.4	3.7	1.8	1.6	2.7	0.8	1.2	3.5	1.4
Interaction	Sig	NS	Sig	Sig	NS	NS	Sig	NS	Sig	Sig	NS	NS

Table 2: Effect of intercropping, mycorrhiza and fertilizer levels on post-harvest available soil nutrients of sunflower hybrid

Treatment	Winter, 2011			Winter, 2012		
	N	P	K	N	P	K
Intercropping systems (I)						
I_1 - Sole maize	189.3	12.2	560.5	185.2	10.4	549.3
I_2 - Maize + Cowpea	196.1	12.9	582.3	191.7	12.0	574.4
I_3 - Maize + Green gram	190.1	12.2	572.3	184.2	10.5	563.7
SEd	1.4	0.2	8.6	2.7	0.2	7.7
CD (P=0.05)	2.8	0.4	17.1	5.4	0.4	15.4
Mycorrhizal inoculation (M)						
M_1- Uninoculated (Both crops)	186.5	12.1	561.0	181.3	10.5	552.8
M_2- Uninoculated (Sunflower)	192.0	12.2	570.7	187.6	10.8	561.6
M_3- Inoculated (Sunflower)	193.3	12.3	564.3	189.5	10.8	555.7
M_4- Inoculated (Both crops)	195.4	12.9	590.7	189.7	11.8	579.7
SEd	1.6	0.3	9.9	3.1	0.2	8.9
CD (P=0.05)	3.2	0.5	19.7	6.3	0.5	17.8
Fertilizer levels (F)						
F_1 - 75% RDF	188.9	12.1	566.9	183.8	10.8	556.6
F_2 - 100% RDF	191.1	12.3	571.6	186.1	10.9	561.1
F_3 - 125% RDF	195.4	12.7	576.6	191.1	11.2	569.7
SEd	1.4	0.2	8.6	2.7	0.2	7.7
CD (P=0.05)	2.8	0.4	17.1	5.4	0.4	15.4
Interaction	NS	NS	NS	NS	NS	NS

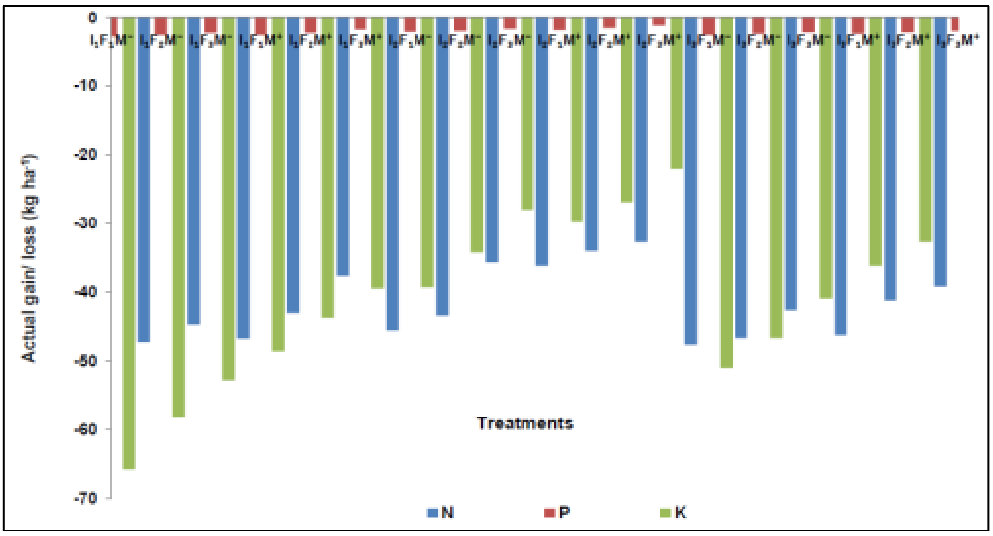

Fig 1: Balance sheet for soil available nutrients (Kg ha-1) in maize -sunflower cropping system during winter 2011

Table 3: Balance sheet for soil available N (kg ha^{-1}) in maize-sunflower cropping systems during winter, 2012

Treatment	Initial N (A)	Added N (B)		Crop N uptake by		Total N uptake (C)	Expected Balance (D) (A+B)-C	Soil available N (E)	Apparent gain (E-D / loss (D-E)	Actual Gain (E-A) / loss (A-E)
		Maize	Sun Flower	Maize+ Inter crop	Sun Flower					
$I_1F_1M^-$	191.8	112.5	60.0	225.0	72.2	297.3	67.0	178.1	111.0	-13.7
$I_1F_2M^-$	191.8	150.0	60.0	225.8	75.0	300.7	101.1	181.0	79.9	-10.8
$I_1F_3M^-$	191.8	187.5	60.0	228.3	73.2	301.5	137.8	183.1	45.3	-8.7
$I_1F_1M^+$	191.8	112.5	60.0	237.7	74.5	312.2	52.1	184.5	132.4	-7.3
$I_1F_2M^+$	191.8	150.0	60.0	241.4	78.7	320.1	81.7	184.4	102.7	-7.4
$I_1F_3M^+$	191.8	187.5	60.0	240.3	76.4	316.7	122.6	190.6	67.9	-1.2
$I_2F_1M^-$	191.8	112.5	60.0	250.3	83.9	334.3	30.0	185.5	155.5	-6.3
$I_2F_2M^-$	191.8	150.0	60.0	256.6	87.4	343.9	57.9	187.0	129.1	-4.8
$I_2F_3M^-$	191.8	187.5	60.0	258.9	87.3	346.2	93.1	193.0	99.9	1.2
$I_2F_1M^+$	191.8	112.5	60.0	264.6	86.9	351.5	12.8	192.7	179.9	0.9
$I_2F_2M^+$	191.8	150.0	60.0	270.1	91.3	361.4	40.4	195.2	154.8	3.4
$I_2F_3M^+$	191.8	187.5	60.0	278.5	89.4	367.8	71.5	196.8	125.4	5.0
$I_3F_1M^-$	191.8	112.5	60.0	232.8	80.2	313.0	51.3	178.9	127.6	-12.9
$I_3F_2M^-$	191.8	150.0	60.0	238.6	82.6	321.3	80.5	179.5	99.0	-12.3
$I_3F_3M^-$	191.8	187.5	60.0	252.3	84.3	336.5	102.8	186.5	83.7	-5.3
$I_3F_1M^+$	191.8	112.5	60.0	251.9	81.8	333.7	30.6	183.3	152.7	-8.5
$I_3F_2M^+$	191.8	150.0	60.0	259.5	85.2	344.7	57.1	183.9	126.8	-7.9
$I_3F_3M^+$	191.8	187.5	60.0	257.6	83.6	341.2	98.1	195.0	96.8	3.2

Data not analysed statistically

Table 4: Balance sheet for soil available P (kg ha^{-1}) in maize-sunflower cropping systems during winter, 2012

Treatment	Initial P (A)	Added P (B)		Crop P uptake by		Total P uptake (C)	Expected Balance (D) (A+B)-C	Soil Available P (E)	Apparent gain (E-D / loss (D-E)	Actual Gain (E-A) / loss (A-E)
		Maize+Inter crop	Sunflower	Maize	Sunflower					
$I_1F_1M^-$	12.4	56.3	90.0	48.4	19.5	68.0	90.7	9.7	-80.9	-2.7
$I_1F_2M^-$	12.4	75.0	90.0	48.9	20.7	69.6	107.8	9.8	-79.2	-2.6
$I_1F_3M^-$	12.4	93.8	90.0	50.9	20.0	71.0	125.2	10.3	-77.4	-2.1
$I_1F_1M^+$	12.4	56.3	90.0	52.5	22.3	74.7	83.9	10.4	-73.5	-2.0
$I_1F_2M^+$	12.4	75.0	90.0	55.7	23.6	79.3	98.1	10.6	-68.8	-1.8
$I_1F_3M^+$	12.4	93.8	90.0	53.0	22.8	75.8	120.3	10.7	-72.1	-1.7
$I_2F_1M^-$	12.4	56.3	90.0	53.5	21.7	75.2	83.5	11.5	-90.8	-0.9
$I_2F_2M^-$	12.4	75.0	90.0	54.7	23.7	78.4	99.0	11.7	-87.3	-0.7
$I_2F_3M^-$	12.4	93.8	90.0	56.2	22.4	78.6	117.5	12.2	-86.4	-0.2
$I_2F_1M^+$	12.4	56.3	90.0	57.4	25.8	83.2	75.5	12.0	-82.3	-0.4
$I_2F_2M^+$	12.4	75.0	90.0	62.6	28.9	91.5	85.9	12.1	-73.9	-0.3
$I_2F_3M^+$	12.4	93.8	90.0	66.3	27.8	94.1	102.1	12.5	-70.8	0.1
$I_3F_1M^-$	12.4	56.3	90.0	49.9	21.5	71.5	87.2	9.9	-114.7	-2.5
$I_3F_2M^-$	12.4	75.0	90.0	49.8	23.1	72.9	104.5	10.2	-113.0	-2.2
$I_3F_3M^-$	12.4	93.8	90.0	51.6	22.2	73.8	122.4	10.3	-112.1	-2.1
$I_3F_1M^+$	12.4	56.3	90.0	54.7	24.5	79.2	79.4	10.7	-106.3	-1.7
$I_3F_2M^+$	12.4	75.0	90.0	58.8	26.6	85.4	92.0	10.9	-99.8	-1.5
$I_3F_3M^+$	12.4	93.8	90.0	57.0	26.3	83.3	112.9	11.4	-101.5	-1.0

Data not analysed statistically

Table 5: Balance sheet for soil available K (kg ha^{-1}) in maize-sunflower cropping systems during winter, 2012

Treat ment	Initial K (A)	Added K (B)		Crop K uptake by		Total K uptake (C)	Expec ted balance (D) (A+B)-C	Soil available K (E)	Apparent gain (E-D / loss (D-E)	Actual Gain (E-A) / loss (A-E)
		Maize+ Inter crop	Sun flower	Maize	Sun flower					
$I_1F_1M^-$	571.0	56.3	60.0	165.7	144.1	309.8	377.4	535.3	157.9	-35.7
$I_1F_2M^-$	571.0	75.0	60.0	169.3	146.5	315.8	390.2	542.6	171.2	-28.4
$I_1F_3M^-$	571.0	93.8	60.0	171.2	146.9	318.2	406.6	547.8	178.7	-23.2
$I_1F_1M^+$	571.0	56.3	60.0	167.8	144.0	311.8	375.4	552.5	177.1	-18.5
$I_1F_2M^+$	571.0	75.0	60.0	174.1	147.3	321.4	384.6	556.9	191.1	-14.1
$I_1F_3M^+$	571.0	93.8	60.0	170.3	145.8	316.1	408.6	560.7	189.6	-10.3
$I_2F_1M^-$	571.0	56.3	60.0	208.8	150.1	359.0	328.3	565.1	218.1	-5.9
$I_2F_2M^-$	571.0	75.0	60.0	212.6	154.4	367.0	339.0	571.7	232.7	0.7
$I_2F_3M^-$	571.0	93.8	60.0	215.0	153.8	368.8	356.0	579.8	242.6	8.8
$I_2F_1M^+$	571.0	56.3	60.0	217.7	152.1	369.7	317.5	572.7	236.5	1.7
$I_2F_2M^+$	571.0	75.0	60.0	218.4	157.8	376.1	329.9	578.7	248.8	7.7
$I_2F_3M^+$	571.0	93.8	60.0	225.0	155.7	380.7	344.1	583.3	258.0	12.3
$I_3F_1M^-$	571.0	56.3	60.0	189.4	147.3	336.6	350.6	549.4	161.3	-21.6
$I_3F_2M^-$	571.0	75.0	60.0	193.9	150.9	344.8	361.2	560.8	180.9	-10.2
$I_3F_3M^-$	571.0	93.8	60.0	203.6	150.3	353.9	370.9	569.1	198.3	-1.9
$I_3F_1M^+$	571.0	56.3	60.0	195.1	148.7	343.8	343.4	564.4	183.5	-6.6
$I_3F_2M^+$	571.0	75.0	60.0	205.7	152.6	358.3	347.7	567.7	201.2	-3.3
$I_3F_3M^+$	571.0	93.8	60.0	199.8	149.7	349.5	375.2	577.6	202.4	6.6

Data not analysed statistically

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