Journal of Agriculture and Ecology Research International

12(3): 1-7, 2017; Article no.JAERI.35303
ISSN: 2394-1073

Effect of Mycorrhizal Inoculation (VAM) and Phosphorus Levels on Yield, Quality, Nutrient Uptake and Post Harvest Nutrient Status of Sunflower

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Authors' contributions

This work was carried out in collaboration between all authors. Author CK designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Authors SJ and RR managed the analyses of the study. Author MVS managed the literature searches and wrote the final draft. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2017/35303
Editor(s):
(1) Gabriela Civeira, Instituto Nacional de Tecnología Agropecuaria, Argentina.
Reviewers:
(1) Mehmet Demir Kaya, Eskişehir Osmangazi University, Turkey.
(2) Hamza Abdulmajeed, University of Ibadan, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/20491

Original Research Article

Received 5th July 2017
Accepted 8th August 2017
Published 14th August 2017

ABSTRACT

The field experiment was conducted to study the effect of mycorrhizal inoculation (VAM) and different levels of phosphorus (0, 25, 50, 75 and 100 kg/ha) on yield, quality, nutrient uptake and post-harvest nutrient status of hybrid sunflower cv. sunbred. The experiment was conducted in factorial randomized block design with two replications. The treatments consisted of 5 levels of P_2O_5 applied in the presence or absence of VAM inoculates. The results of experiment revealed that mycorrhizal inoculated plants produced maximum seed and stalk yield, oil content, oil yield, protein content, nutrient uptake than non mycorrhizal inoculation while nutrient availability were

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maximum in non mycorrhizal inoculation. Among the various phosphorus levels tried, P_2O_5 at 100 kg ha^{-1} recorded the maximum values for yield, quality, nutrient uptake while P_2O_5 at 0 kgha^{-1} registered maximum NPK availability over other levels. With regard to interaction effect, mycorrhizal inoculation with 100 kg ha^{-1} of P_2O_5 recorded maximum values for yield, quality and nutrient uptake of sunflower but it was on par with mycorrhizal inoculation with P_2O_5 at 75 kg ha^{-1}. Non-mycorrhizal inoculation without P_2O_5 application recorded maximum values for post-harvest nutrient status of sunflower. Lowest values of yield, quality and nutrient uptake were recorded by non-mycorrhizal inoculation without P_2O_5. Mycorrhizal inoculation with P_2O_5 at 100 kg ha^{-1} recorded minimum values for post-harvest nutrient status of Sunflower.

Keywords: Sunflower; VAM; yield; quality; NPK uptake; availability.

1. INTRODUCTION

In India, oil seed crops constitute the second largest agricultural produce, next only to food grains and they contribute 5% to GNP. Sunflower oil has excellent nutritional properties, and has a relatively high concentration of linoleic acid [1]. It is also a wealthy source of vitamins A and D. Mycorrhiza has symbiotic association between the soil fungi and roots of higher plants. These fungi enhance the plant growth through making availability of mineral nutrients such as P, Zn and Cu [2]. These glomeromycolan fungi bank on their plant host for carbon in return for which fungus improves nutrition especially phosphate nutrition [3]. Phosphorus is an essential plant macronutrient which is required to build important molecules such as nucleic acids and phospholipids, and plays vital role during energy transfer in processes like NADPH, ATP and regulation of enzymatic and metabolic reactions. P is an essential plant nutrient required for higher and sustained productivity of oil from sunflower. Its influence on seed yield, oil yield and oil quality has been well established [4]. Phosphorus moves by diffusion in soil and is taken up by plants through root interception. The true phosphate levels available to plant around the soil are used to be very low.

As phosphorus typically constitutes around 30-80% of total P in the soil as organic P but still the availability of 80-99% for uptake in plant is scarce because of different factors like adsorption, precipitation or conversion into organic forms. The conceivable role of AM fungi in terms of their ability in phosphate nutrition has been gaining much importance in recent years. Hence, the present study was taken up to find out the effect of mycorrhizal inoculation and phosphorus on yield, quality, nutrient uptake and post harvest nutrient status of hybrid sunflower.

2. MATERIALS AND METHODS

Field experiment was conducted during July – October 2015 at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University. The experimental soil was clay loam with pH 8.1, OC 5.0 g kg^{-1}, $KMnO_4$- N (235 kg ha^{-1}), Olsen- P (22.1 kg ha^{-1}) and NH_4OAc- K (356 kg ha^{-1}). The experiment consisted of ten treatments and was laid out in factorial randomized block design with two replications. M_1-Non inoculated and M_2-inoculated *Glomus intraradices* were tried along with different phosphorus levels (P_0-0, P_1-25, P_2-50, P_3-75 and P_4-100 kg P_2O_5 ha^{-1}) through SSP. Recommended dose of 60:60 kg of NK ha $^{-1}$ was applied in the form of Urea, and MOP respectively. Half the dose of N and entire dose of K were applied basally. P was applied as per the treatments. The remaining quantity of N was applied at 30 DAS. The mycorrhizal inoculum was applied near the root zone of sunflower @ 2 gm per plant by placement method. At harvest seed and stalk yield was recorded. Oil content was analysed by using commercial Nuclear Magnetic Resonance Spectrometer (NMRS) method and oil yield was calculated by multiplying seed yield with oil content. N content of seed was analysed and multiplied with 6.25 to get crude protein. Seed was analysed for N, P and K content and corresponding nutrient uptake was computed. Post harvest soil was analyzed for available N, P and K following the standard procedures.

3. RESULTS AND DISCUSSION

3.1 Yield

Mycorrhizal inoculated plants showed significant influence on yield (Table 1) over non mycorrhizae. Mycorrhizal inoculation recorded the maximum seed yield (1845 kg ha^{-1}) and stalk yield (4069 kg ha^{-1}) compared to non-mycorrhizal inoculation. The seed yield increase in this treatment was 28% than non mycorrhizal inoculation. The yield increase might be due to increased growth, which resulted in increased rate of photosynthesis and stomatal conductance which can be due to more absorption of nutrients and ultimately resulted in increased seed and stalk yield. The finding was in harmony with the work of [5,6].

Phosphorus levels significantly influenced the yield (Table 1). Among the different levels, P_2O_5 at 100 kg ha^{-1} produced maximum seed yield (2048 kg ha^{-1}) and stalk yield (4379 kg ha^{-1}). Phosphorus improves plants photosynthesis, resulting in higher assimilates production and consequently higher grain yield. The lowest value for yield was recorded in the treatment P_2O_5 at 0 kg ha^{-1}. This result is in conformity with the findings of [7].

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant (Table 2). The treatment combination of mycorrhizal inoculation along with P_2O_5 at 100 kg ha^{-1} recorded higher values for yield but it was on par with mycorrhizal inoculation along with P_2O_5 at 75 kg ha^{-1}. This might be due to availability of phosphorus and other nutrients at both vegetative and productive stages. Similar findings were earlier reported by [8]. The lowest values for seed and stalk yield were recorded under the treatment combination of non mycorrhizal inoculation with 0 kg P_2O_5 ha^{-1}. This might be due to the absence of mycorrhiza resulted in reduced growth and yield attributing characters and seed and stalk yield. The result in the present study was confirmed by significant positive linear relationship between yield with P uptake (Y= 108.6x -527.3; R^2 = 0997**) and available P (Y= -391.6x + 8619; R^2= 0.993** (Figs. 1a, 1b). Our findings were in harmony with [9].

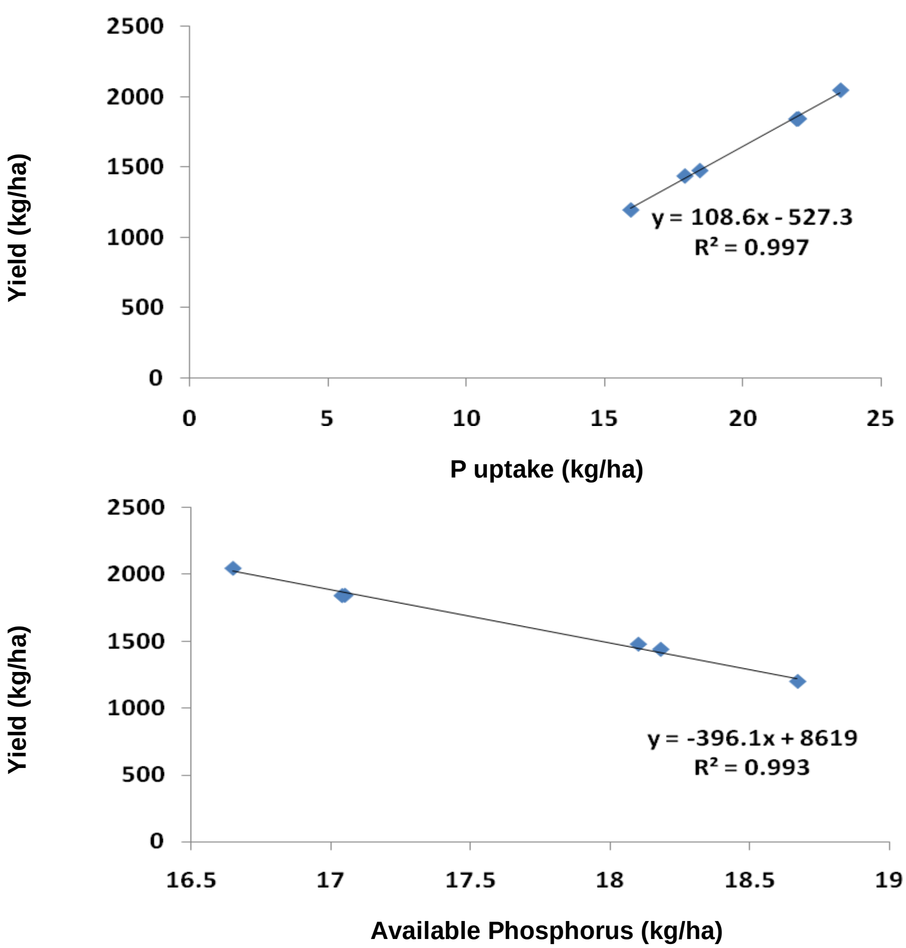

Fig. 1. Linear relationship between seed yield with a) P uptake b) Available P

Table 1. Effect of mycorrhizal inoculation (VAM) and phosphorus levels on yield, quality characters, nutrient uptake and post harvest nutrient status of sunflower

Treatments	Yield		Quality characters			Nutrient uptake ($Kg\ ha^{-1}$)			Post harvest nutrient status ($Kg\ ha^{-1}$)		
	Seed yield ($kg\ ha^{-1}$)	Stalk yield ($kg\ ha^{-1}$)	Oil content (%)	Oil yield ($Kg\ ha^{-1}$)	Crude protein content (%)	N	P	K	N	P	K
VAM											
M_1	1438	3570	40.29	586	15.43	75.5	17.9	66.5	214.5	18.18	321.8
M_2	1845	4069	42.54	790	17.64	79.5	22.0	70.5	202.8	17.05	310.6
SEd	28.46	20.75	0.16	12.35	0.06	0.37	0.15	0.27	0.57	0.06	0.61
CD(P=0.05)	61.05	44.51	0.34	26.49	0.13	0.78	0.33	0.57	1.23	0.13	1.31
Phosphorus levels ($kg\ ha^{-1}$)											
P_0	973	2692	39.01	380	14.12	66.1	14.17	60.8	223.1	18.93	332.6
P_1	1197	3179	39.12	470	14.27	73.4	15.95	64.2	219.6	18.67	326.9
P_2	1477	3589	40.58	603	15.96	76.1	18.44	67.1	213.6	18.10	320.7
P_3	1843	4129	42.47	786	17.61	79.4	21.93	70.4	203.5	17.04	310.4
P_4	2048	4379	43.49	891	18.30	81.4	23.52	72.5	197.9	16.65	307.1
SEd	40.25	29.35	0.22	17.46	0.09	0.52	0.22	0.38	0.81	0.08	0.86
CD(P=0.05)	86.34	62.95	0.48	37.46	0.19	1.11	0.47	0.81	1.74	0.18	1.85

Table 2. Interaction effect between VAM and phosphorus levels on yield, quality nutrient uptake and post harvest nutrient status of sunflower

Treatments	Seed yield ($Kg\ ha^{-1}$)	Stalk yield ($Kg\ ha^{-1}$)	Oil content (%)	Oil yield ($kg\ ha^{-1}$)	Crude protein (%)	Nutrient Uptake ($kg\ ha^{-1}$)			Nutrient availability ($kg\ ha^{-1}$)		
						N	P	K	N	P	K
M_1P_0	880	2712	38.01	335	13.02	65.2	12.1	58.1	229.3	19.4	339.2
M_1P_1	1019	2946	38.15	388.6	13.15	71.7	13.9	62.2	223.9	18.9	331.5
M_1P_2	1219	3271	39.18	477.7	14.28	73.4	15.7	64.3	221.10	18.7	327.4
M_1P_3	1571	3795	41.05	645.0	16.52	76.8	19.5	68.07	211.6	17.8	316.9
M_1P_4	1942	4268	42.78	831.0	17.78	80.3	22.5	71.5	201.5	17.2	311.3
M_2P_0	996	2968	38.69	385	14.96	72.1	17.1	62.3	210.9	18.4	322.4
M_2P_1	1376	3412	40.09	552.0	15.40	75.1	18.0	66.2	215.3	18.3	322.3
M_2P_2	1735	3908	41.99	729.0	17.65	78.5	21.2	69.9	206.1	17.6	314.0
M_2P_3	2114	4464	43.89	927.8	18.70	81.9	24.4	72.7	195.5	16.2	303.8
M_2P_4	2153	4491	44.19	952.0	18.82	82.5	24.6	73.4	194.4	16.09	302.8
SEd	56.9	41.5	0.31	24.70	0.13	0.73	0.31	0.53	1.15	0.12	1.22
CD (P = 0.05)	122.1	89.03	0.68	52.97	0.27	1.57	0.66	1.15	2.46	0.26	2.61

3.2 Quality Characters

Mycorrhizal inoculated plants significantly influenced the quality characters *viz.* oil content, oil yield and crude protein content (Table 1). Mycorrhizal inoculation recorded the highest oil content (42.54%), oil yield (790 kg ha^{-1}) and crude protein content (17.64%) than non-mycorrhizal inoculation. Increased oil content and oil yield in this might be due to increased P availability in the plants because of the P absorption and availability. Similar findings were earlier reported by [10,11]. The reason for increase in crude protein content with the inoculation of mycorrhizae might be ascribed to the fact that the protein content had a higher degree of positive relationship with the mycorrhizal plants which have assimilated greater amounts of P and translocated to grains which assisted in enrichment of protein. Similar finding was earlier reported by [12]. Minimum oil content, oil yield and protein content were noticed in the treatment M_1 (non-mycorrhizal inoculation). This might be due to lesser availability and uptake of nutrients for oil synthesis in the sunflower seeds. Similar findings were earlier reported by [13].

Among the different levels of phosphorus, application of P_2O_5 at 100 kg ha^{-1} significantly recorded highest oil content (43.49%), oil yield (891 Kg ha^{-1}) and crude protein content (18.30%). Phosphorus is known to play an important role in carbohydrate metabolism and helps in conversion of carbohydrate into oil. The lowest values for quality characters were recorded in the treatment P_2O_5 at 0 kg ha^{-1}. Similar finding was earlier reported by [14] and [15].

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant. The treatment combination of mycorrhizal inoculation along with P_2O_5 at 100 kg ha^{-1} recorded maximum values for quality characters but it was on par with mycorrhizal inoculation along with P_2O_5 at 75 kg ha^{-1}. This might be due to mycorrhizal inoculation and phosphorus application and its effect by enhancing photosynthesis activity which, in turn, resulted in seed formation, an increase in oil content, oil yield of hybrid sunflower. Similar result was earlier reported by [7]. The lowest values for quality characters were recorded in the treatment combination of non mycorrhizal inoculation with 0 kg P_2O_5 ha^{-1} which could be due to inadequate availability of nutrients.

3.3 Nutrient Uptake

Mycorrhizal inoculated plants significantly influenced the uptake of N, P and K (Table 1). Mycorrhizal inoculation recorded the highest N uptake (79.5 kg ha^{-1}), P uptake (22.0 kg ha^{-1}) and K uptake (70.5 kg ha^{-1}), than non-mycorrhizal inoculation. The association of AMF with sunflower plants exerted a stimulating effect on P and K uptake by the plants.

Phosphorus levels significantly influenced the uptake of N, P and K (Table 1). Among the different levels, P_2O_5 at 100 kg ha^{-1} recorded maximum N uptake (81.4 kg ha^{-1}), P uptake (23.52 kg ha^{-1}) and K uptake (72.5 kg ha^{-1}). Increased uptake of nutrients at higher doses of phosphorus 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. The lowest nutrient uptake of N, P and K was recorded in the treatment P_2O_5 at 0 kg ha^{-1}. This result is in conformity with the findings of Rajendran and Veeraputhiran and Madhavi et al. [16].

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant (Table 2). The treatment combination of mycorrhizal inoculation along with P_2O_5 at 100 kg ha^{-1} recorded higher uptake of N, P and K but it was on par with mycorrhizal inoculation along with P_2O_5 at 75 kg ha^{-1}. Similar finding was earlier reported by Kumaresan et al. [17]. The lowest nutrient uptake of N, P and K were recorded under the treatment combination of non-mycorrhizal inoculation with 0 kg P_2O_5 ha^{-1}. Similar finding was earlier reported by Kumaresan et al. [17].

3.4 Post Harvest Soil Available Nutrients

Non-mycorrhizal inoculation recorded the highest available N (214.5 kg ha^{-1}), P (18.18 kg ha^{-1}) and K (321.8 kg ha^{-1}). This might be due to poor uptake of N, P and K under this treatment. The least soil available N, P and K status was observed under mycorrhizal inoculation.

Among the phosphorus levels, 0 kg P_2O_5 ha^{-1} recorded the highest post-harvest N (223.1 kg ha^{-1}), P (18.93 kg ha^{-1}) and K (332.6 kg ha^{-1}). The lowest values for N, P and K availability were recorded under P_2O_5 at 100 kg ha^{-1}.

The interaction effect between mycorrhizal inoculation and phosphorus was significant in both the crops (Table 2). The maximum amount of N, P and K was available in non-mycorrhizal inoculation without P_2O_5. The least value was recorded under mycorrhizal inoculation with 100 kg P_2O_5 ha^{-1} due to maximum uptake of N, P and K Similar findings were earlier reported by Choudhary et al. [18].

4. CONCLUSIONS

Mycorrhizal inoculation with P_2O_5 at 100 kg ha^{-1} recorded maximum values for yield, quality and nutrient uptake of sunflower but it was on par with mycorrhizal inoculation with P_2O_5 at 75 kg ha^{-1}.

There is no competing interest exist while this work was undertaken Kalaiyarasan, C designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. S. Jawahar and R. Ramesh managed the analyses of the study. M.V. Sriramachandrasekharan managed the literature searches and wrote the final draft. All authors read and approved the final manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20491