



Effect of Vam and Phosphorus Levels on Growth, Yield, Quality, Nutrient Uptake, Root Parameters and Post Harvest Nutrient Status of Sunflower

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Abstract: The Field experiment was conducted at Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu during July – October 2015 to study the effect of mycorrhizal inoculation (VAM) and different levels of phosphorus on growth, yield, quality, nutrient uptake, root parameters and post harvest nutrient status of hybrid sunflower cv. sunbred. The experiment was conducted by factorial randomized block design with two replications. The treatments consisted of 4 levels of P_2O_5 (0,25,50,75 and 100kg/ha) 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, nutrient availability were maximum in non mycorrhizal inoculation. Among the various phosphorus levels tried, P_2O_5 at 100 kg ha⁻¹ recorded maximum values for growth, yield, quality, nutrient uptake and root parameters while P_2O_5 at 25 kg ha⁻¹ registered maximum NPK availability over other levels. With regard to interaction effect, mycorrhizal inoculation with P_2O_5 @ 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 @ 75 kg ha⁻¹. Non-mycorrhizal inoculation with P_2O_5 @ 25 kg ha⁻¹ recorded maximum values for post harvest nutrient status of Sunflower. Lowest values of yield, quality and nutrient uptake were recorded by non- mycorrhizal inoculation with P_2O_5 @ 25 kg ha⁻¹. Mycorrhizal inoculation with P_2O_5 @ 100 kg ha⁻¹ recorded minimum values for post harvest nutrient status of Sunflower.

Keywords: Sunflower, VAM, yield, quality, NPK uptake & availability.

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 (Seiler, 2007). It is also a wealthy source of vitamins A and D. Mycorrhiza has symbiotic association between the soil fungi and roots of higher plants (Smith *et al.*, 2010). These fungi enhance the plant growth through making availability of mineral nutrients such as P, Zn and Cu (Phiri *et al.*, 2003). These glomeromycotan fungi bank on their plant host for carbon in return for which fungus improves nutrition especially phosphate nutrition (Smith and Read, 1997). 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 (Bahl and Toor, 1999). 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 (Karandoshov, 2005). In general, external supply of nutrient in terms of costly fertilizers to crops by farmers as of low economy may lead to low yield and supply to common society. 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.

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 5.0g kg⁻¹, available N (235 kg ha⁻¹), P (22.1 kg ha⁻¹) and K (356 kg ha⁻¹). The experiment consisted of eight treatments and was laid out in factorial randomized block design with two replications. M₁-Non inoculated and M₂-inoculated *Glomus intraradices* were tried along with different phosphorus levels (P₁-25, P₂-50, P₃-75 and P₄-100 kg P₂O₅ 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 of VAM was applied 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.

RESULTS AND DISCUSSION

Growth attributes

Mycorrhizal inoculated plants significantly influenced the growth attributes *viz.*, plant height, LAI, DMP and CCI (Table 1). Mycorrhizal inoculation recorded

the highest plant height at harvest (147.0 cm), leaf area index at flowering (4.26), dry matter production at harvest (4994 Kg ha⁻¹) and chlorophyll content index (23.43) at flowering stage than non-mycorrhizal inoculation. This might be due to the formation of external mycelium around the roots by AM fungi which possibly helped to increase the availability of nutrients to the surface of the roots and thereby increased the nutrient uptake and growth of the plant. Similar finding was earlier reported by Kavitha and Nelson (2014).

Among the different levels of phosphorus, application of P₂O₅ at 100 kg ha⁻¹ significantly recorded highest plant height at harvest (153.8 cm), leaf area index at flowering (4.05), dry matter production at harvest (5316 Kg ha⁻¹) and chlorophyll content index (24.73) at flowering stage. The lowest values for growth attributes were recorded in the treatment P₂O₅ at 25 kg ha⁻¹. This might be attributed to the P stimulating effect on root growth and expansion by increasing crop growth rate. Similar findings were earlier reported by Adebayo *et al.* (2010) and Abubaker Ali *et al.* (2014).

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant (Table 2). The treatment combination of mycorrhizal inoculation along with P₂O₅ at 100 kg ha⁻¹ recorded maximum values for growth attributes but it was on par with mycorrhizal inoculation along with P₂O₅ at 75 kg ha⁻¹. The highest values under these treatments might be due to mycorrhizal inoculation, because this biofertilizer can enhance absorption of phosphorus by plant. The lowest growth attributes was recorded in the treatment combination of non mycorrhizal inoculation with 25 kg P₂O₅ ha⁻¹. This could be due to inadequate availability of nutrients. This result is in conformity with the findings of Khirood Doley and Paramjit Kaur Jite (2012).

Yield

Mycorrhizal inoculated plants showed significant influence on yield (Table 1). Mycorrhizal inoculation

recorded the maximum seed yield (1845 kg ha⁻¹) and stalk yield (4069 kg ha⁻¹) than 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. These finding is conformed to the report of Tahereh Vaseghmanesh *et al.* (2013) and Naser Hajiketabi *et al.* (2014).

Phosphorus levels significantly influenced the yield (Table 1). Among the different levels, P₂O₅ 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 P₂O₅ at 25 kg ha⁻¹. This result is in conformity with the findings of Babaei *et al.* (2012).

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant (Table 2). The treatment combination of mycorrhizal inoculation along with P₂O₅ at 100 kg ha⁻¹ recorded higher values for yield but it was on par with mycorrhizal inoculation along with P₂O₅ 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 Vaseghmanesh *et al.* (2013). The lowest values for seed and stalk yield were recorded under the treatment combination of non mycorrhizal inoculation with 25 kg P₂O₅ ha⁻¹. This might be due to the absence of mycorrhiza resulted in reduced growth and yield attributing characters and seed and stalk yield. Similar findings were earlier reported by Ultra Jr *et al.* (2007) and Mostafa Heidari and Vahid Karami (2014).

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 Martin *et al.* (2012) and Abdallah *et al.* (2013). The reason for increase in crude protein content with the inoculation of mycorrhiza 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 Karami (2011). Minimum oil content, oil yield and protein content was noticed in the treatment M₁ (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 Mostafa Heidari and Vahid Karami (2014).

Among the different levels of phosphorus, application of P₂O₅ 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 P₂O₅ at 25 kg ha⁻¹. Similar finding was earlier reported by Hemalatha *et al.* (2013) and Rajendran and Veeraputhiran (2001).

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant. The treatment combination of mycorrhizal inoculation along with P₂O₅ at 100 kg ha⁻¹ recorded maximum values for quality characters but it was on par with mycorrhizal inoculation along with P₂O₅ 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 Babaei *et al.* (2012). The lowest values for quality characters were recorded in the treatment combination of non mycorrhizal inoculation with 25 kg P₂O₅ ha⁻¹ which could be due to inadequate availability of nutrients.

Nutrient uptake

Mycorrhizal inoculated plants significantly influenced the nutrient 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 (Apolino Jose Nogueira da Silva *et al.*, 2015).

Phosphorus levels significantly influenced the uptake of N, P and K (Table 1). Among the different levels, P₂O₅ 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 P₂O₅ at 25 kg ha⁻¹. This result is in conformity with the findings of Rajendran and Veeraputhiran (2001) and Madhavi *et al.* (2015).

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant (Table 2). The treatment combination of mycorrhizal inoculation along with P₂O₅ at 100 kg ha⁻¹ recorded higher uptake of N, P and K but it was on par with mycorrhizal inoculation along with P₂O₅ at 75 kg ha⁻¹. Similar finding was earlier reported by

Kumaresan *et al.* (2003). The lowest nutrient uptake of N, P and K were recorded under the treatment combination of non mycorrhizal inoculation with 25 kg P₂O₅ ha⁻¹. Similar finding was earlier reported by Kumaresan *et al.* (2003).

Root parameters (Table 4)

Mycorrhizal inoculated plants observed significant influence on root length at 60 DAS and root colonization in sunflower. Mycorrhizal inoculation registered the maximum root length of 21.49 cm. The extensive root growth of AM plants might be attributed to the improved 'P' nutrition of host plants. This might be due to better development of root system resulting in tapping larger volume of bound soil water and nutrients especially phosphorus which plays a significant role in several physiological and biochemical plant activities like photosynthesis, transformation of sugar to starch and transporting of the genetic traits. This results is in conformity with the finding of Hemavani and Thippeswamy (2014). The minimum values for root length and root colonization was noticed in the treatment M₁ (non-mycorrhizal inoculation).

Application of phosphorus significantly influenced the root length in both the crops. Application of P₂O₅ at 100 kg ha⁻¹ significantly recorded highest root length of 22.62 cm. This was followed by P₂O₅ at 75 kg ha⁻¹. The application of P₂O₅ at 25 kg ha⁻¹ recorded the least root length. With regard to mycorrhizal root colonization, application of P₂O₅ at 25 kg ha⁻¹ recorded the highest mycorrhizal root colonization of 22.2. The least root colonization percentage was recorded in 100 kg P₂O₅ ha⁻¹. This might be due to low levels of P favour the occurrence and distribution of AM fungi. Linderman and Davis (2004) found that in treatments with a high dose of fertilizer decreased AM spore number as well as root colonization was detected.

The interaction effect between the mycorrhizal inoculation and phosphorus was not significant on

root length of sunflower. The treatment combination of VAM with P₂O₅ at 100 kg ha⁻¹ recorded maximum root length but it was on par with VAM with P₂O₅ at 75 kg ha⁻¹. The lowest root length was recorded in the treatment combination of non-mycorrhizal colonization with 25 kg P₂O₅ ha⁻¹.

In case of mycorrhizal root colonization VAM with P₂O₅ at 25 kg ha⁻¹ recorded highest root colonization percentage while VAM with P₂O₅ at 100 kg ha⁻¹ recorded lowest root colonization percentage. This might be due to high rate of chemical phosphorous fertilizer application lead to antagonistic interaction with mycorrhiza. In low amount of chemical phosphorus fertilizer, mycorrhiza was able to increase the root colonization significantly. Similar findings was earlier reported by Soleimanzadeh (2010).

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, 25 kg P₂O₅ ha⁻¹ recorded the highest post harvest N (219.6 kg ha⁻¹), P (18.67 kg ha⁻¹) and K (326.9 kg ha⁻¹). The lowest values for N, P and K availability were recorded under P₂O₅ 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 with P₂O₅ @ 25 kg ha⁻¹. The least value was recorded under mycorrhizal inoculation with 100 kg P₂O₅ ha⁻¹ due to maximum uptake of N, P and K. Similar findings were earlier reported by Choudhary *et al.* (2011).

Table 1
Intracross effect between VAM and phosphorus on growth and yield
attributes of sunflower

<i>Treatments</i>	<i>Plant height (cm) At harvest</i>	<i>LAI at flowering</i>	<i>DMP (kg ha⁻¹) at harvest</i>	<i>Head diameter (cm)</i>	<i>No. of filled seeds head⁻¹</i>	<i>Test weight (g)</i>	<i>Seed yield (Kg ha⁻¹)</i>	<i>Stalk yield (Kg ha⁻¹)</i>
M₁P₁	35.4	3.58	3883	13.6	366.1	4.78	1019	2946
M₁P₂	39.3	3.78	4175	14.4	435.1	5.07	1219	3271
M₁P₃	46.7	4.04	4697	16.5	563.1	5.47	1571	3795
M₁P₄	54.8	4.36	5184	18.4	692.4	5.94	1942	4268
M₂P₁	42.9	3.90	4319	15.2	490.6	5.26	1376	3412
M₂P₂	50.9	4.15	4807	17.2	621.8	5.71	1735	3908
M₂P₃	57.9	4.48	5403	19.1	758.4	6.16	2114	4464
M₂P₄	59.6	4.50	5448	19.3	768.2	6.18	2153	4491
SEd	2.18	0.035	50.22	0.19	16.03	0.032	56.9	41.5
CD (P = 0.05)	4.65	0.075	107.73	0.40	34.39	0.068	122.1	89.03

Table 2
Effect of mycorrhizal inoculation (VAM) and phosphorus levels on yield, quality characters,
nutrient uptake and post harvest nutrient status of sunflower

<i>Treatments</i>	<i>Yield</i>		<i>Quality characters</i>			<i>Nutrient uptake (Kg ha⁻¹)</i>			<i>Post harvest nutrient status (Kg ha⁻¹)</i>		
	<i>Seed yield (kg ha⁻¹)</i>	<i>Stalk yield (kg ha⁻¹)</i>	<i>Oil content (%)</i>	<i>Oil yield (Kg ha⁻¹)</i>	<i>Crude protein content (%)</i>	<i>N</i>	<i>P</i>	<i>K</i>	<i>N</i>	<i>P</i>	<i>K</i>
VAM											
M1	1438	3570	40.29	586	15.43	75.5	17.9	66.5	214.5	18.18	321.8
M2	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)											
P1	1197	3179	39.12	470	14.27	73.4	15.95	64.2	219.6	18.67	326.9
P2	1477	3589	40.58	603	15.96	76.1	18.44	67.1	213.6	18.10	320.7
P3	1843	4129	42.47	786	17.61	79.4	21.93	70.4	203.5	17.04	310.4
P4	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 3
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 ₁ P ₁	1019	2946	38.15	388.6	13.15	71.7	13.9	62.2	223.9	18.9	331.5
M ₁ P ₂	1219	3271	39.18	477.7	14.28	73.4	15.7	64.3	221.10	18.7	327.4
M ₁ P ₃	1571	3795	41.05	645.0	16.52	76.8	19.5	68.07	211.6	17.8	316.9
M ₁ P ₄	1942	4268	42.78	831.0	17.78	80.3	22.5	71.5	201.5	17.2	311.3
M ₂ P ₁	1376	3412	40.09	552.0	15.40	75.1	18.0	66.2	215.3	18.3	322.3
M ₂ P ₂	1735	3908	41.99	729.0	17.65	78.5	21.2	69.9	206.1	17.6	314.0
M ₂ P ₃	2114	4464	43.89	927.8	18.70	81.9	24.4	72.7	195.5	16.2	303.8
M ₂ P 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	122.1	89.03	0.68	52.97	0.27	1.57	0.66	1.15	2.46	0.26	2.61

(P = 0.05)

Table 4
Effect of VAM and phosphorus on root length (cm), mycorrhizal root colonization (%) of sunflower

Treatment	Root length (cm)	Mycorrhizal root colonization (%)
VAM		
M1	19.13	3.7
M2	21.49	24.2
SEd	0.053	0.07
CD (P=0.05)	0.113	0.16
Phosphorus levels		
P1	17.76	22.2
P2	19.37	15.3
P3	21.51	10.6
P4	22.62	7.6
SEd	0.07	0.10
CD (P=0.05)	0.23	0.22

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