African Journal of Biotechnology Vol. 10(43), pp. 8593-8598, 10 August, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.1494
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

Effect of arbuscular mycorrhizal inoculation on nutrient uptake, growth and productivity of cowpea (*Vigna unguiculata)* varieties

Tabassum Yaseen*, Tanvir Burni and Farrukh Hussain

Department of Botany, University of Peshawar, Pakistan.

Accepted 9 March, 2011

The objective of the present study is to find out the effect of *Arbuscular mycorrhiza* (AM) fungal inoculation on growth, productivity and nutrient uptake in two cowpea (*Vigna unguiculata*) varieties. The AM inoculated plants out performed than non-inoculated plants (control) in terms of growth, productivity parameters and nutrient uptake. AM fungal inoculation had a significant effect on productivity of cowpea attributed to growth, plant height, number of nodules, mycorrhizal dependency and number of flowers per plant.

Key words: Vesicular-arbuscular mycorrhizal (VAM), cowpea, nutrient uptake, mycorrhizal dependency (MD).

INTRODUCTION

Arbuscular mycorrhiza (AM) is widespread symbiotic associations that are commonly described as the result of co-evolution events between fungi and plants where both partners benefit from the reciprocal nutrient exchange (Sharma, 2003; Bonfante and Genre, 2008). AM is the most common type of mycorrhizal association, occurring in 2/3 of land plants (Hodge, 2000). Mycorrhizal fungi have been reported in roots of chickpea plants, improving the growth and yield of these plants, especially in phosphorus deficient soils (Zaidi et al., 2003).

Many workers have reported enhancement of phosphate uptake and growth of leguminous plants by vesicular arbuscular mycorhizal fungi (AMF) (Ezawa et al., 2000, Arihara and Karasawa, 2000, Meshram et al., 2000, Joner, 2000; Izagirre, 2000; Guriqbal et al., 2001; Mamatha et al., 2002; Atimanav and Adholeya, 2002).

AMF have been shown to differentially colonize plant roots, causing a variety of effects on plant growth, biomass allocation and photosynthesis (Fidelibus et al., 2000; Miransari et al., 2007). Mathew and Hameed (2002), Niranjan et al. (2002), Lukiwat and Simanungkalit (2002) Zaidi et al. (2003) Rohyadi et al. (2004), Singh et al. (2004), Jalaluddin (2005), Satyawati et al. (2005) Rajasekaran and Nagarajan (2005), Deshmukh et al. (2007) and Avis et al. (2008) studied the effect of vesicular-arbuscular mycorrhizal (VAM) (*Glomus mossae)* on the growth and productivity of legumes. They observed that VAM have significant effect when compared with non-mycorrhizal plants. Mycorrhizal plants performed better performance than non-mycorrhizal plants. Maximum flowers were produced with mycorrhizal treatments.

In the present investigation, *Vigna unguiculata* varieties with and without mycorrhiza were grown in the phosphorus deficient soil. The objective of this study is to determine the response of these legumes to VAM inoculation.

*Corresponding author. E-mail:sciences111@yahoo.com, tabassum_yasin@hotmail.com, tabassumyasin@yahool.com

Abbreviations: AMF, Arbuscular mycorhizal fungi; **VAM,** vesicular-arbuscular mycorrhizal; **MD,** mycorrhizal dependency.

MATERIALS AND METHODS

This study was conducted during winter at the Department of Botany, University of Peshawar. The site lies from 33°27″ to 34°27″N. In the experimental work, rhizospheric soil from wheat field having 145/100 gm of different Arbuscular mycorrhizal fungi (AMF) species *Glomus fasciculatum, Glomus mosseae* and *Glomus aggregatum* and roots of wheat and maize infected with arbuscular mycorrhiza were used as rhizobase inoculum. These root pieces

Table 1. Soil content analysis.

Parameter	Value
Organic matter (%)	0.69
Nitrogen (%)	0.034
Phosphorus (%)	2.95
pH of saturated paste	7.8

Plate 1. Effect of AM inoculation of plant height of cowpea variety (V1).

along with soil base inoculum (rhizospheric soil) were spread uniformly in layers at a depth of 3 and 6 cm before sowing. Inoculums for each pot consisted of 160 gm of mycorrhizal infected roots and adhering soil.

Analysis of soil was done following the methods of Jalaluddin and Anwar (1991), Nelson and Sommers (1982), Hussain (1989) and Olsen and Sommers (1982). Soil had organic matter 0.69%, nitrogen 0.034% and phosphorus 2.95%, pH of saturated paste (7.8) was determined by pH meter as recommended by Richards (1954) (Table 1). After sieving, soil was finely ground and mixed with sand in ratio of 2:1(soil/sand) resulting in the sandy loam textured soil (Plate1 to 2).

The experiment was laid out in a random block design (RCBD) with two treatments (control and uncontrolled), each treatment was replicated five times with five plants in each pot (Two treatments × 2 varieties of cowpea × 5 replicates). The following parameters were recorded: Agronomic and yield parameters including plant height, number of flowers/plant, no. of nodules/plant and nutrient uptake of micro-nutrient, macro-nutrients as known. Mycorrhizal dependency (MD) value of selected legumes was calculated by the formula given by Plenchette et al., (1983).

At each harvest, dry weights of roots and shoots were determined by drying samples at 70°C for 72 h. Shoot and roots were grinded homogenously and ashing was done at 400°C for 1 h, ash samples were analyzed for mineral including K, Ca, Mg, P, Al, Fe, S, and Si; chemical analysis were done by energy-dispersive x-ray analysis (EDXA) according the standard methods (Haq et al., 2003). Experimental data was statistically analyzed by applying the analysis of variance (ANOVA) test; the means were subjected to least significant difference (LSD) test.

Plate 2. Effect of AM inoculation of plant height of cowpea variety (V2).

RESULTS AND DISCUSSION

Effect of AM on plant growth and productivity in cowpea

Results of AM fungi inoculation on plant growth and productivity are given in Table 2. ANOVA and LSD are given in Table (3a, b and c) showing varieties, interaction between varieties and treatments and the effect of treatments that were significantly increased regarding growth and yield. Our results agree with the Mathew and Hameed (2002), Niranjan et al. (2002), Lukiwat and Simanungkalit (2002), Zaidi et al. (2003), Rohyadi et al. (2004), Singh et al. (2004), Jalaluddin (2005) Satyawati et al. (2005), Rajasekaran and Nagarajan (2005) and Deshmukh et al. (2007). Avis et al. (2008) studied the effect of *G. mossae* on the growth and productivity of legumes. They observed that arburcular mycorrhiza was significantly affected when compared with non-mycorrhizal plants. Mycorrhizal plants performed better than non-mycorrhizal plants. Maximum flowers were produced at mycorrhizal treatments. The process of flowering and fruiting was first appeared in the mycorrhizal plants. The results are in good agreement with that of Khan (1994) who also reported that, mycorrhizal plants reduce cropping time due to earlier flowering and fruiting. Pods per plant are an important yield-determining factor.

Mycorrhizal dependency (M.D)

Cowpea results showed that V2 (china variety) is more dependent than V1 (Watni variety), 38 and 29%, respectively (Figure 1). Our results correlate with the findings of Singh et al. (2004) who reported that, dry matter accumulation per plant increased with the advancement in age of the crop up to harvest in all treatments. The

Table 2. Effect of VAM inoculation on growth and yield of cowpea varieties.

Variety	Treatment	Parameter		
	Controlled and uncontrolled	Plant height (cm)	No. of nodules	No. of flowers/plant
Watni variety (V1)	M	10.3	3.00	1.00
		10.4	2.00	1.4
		9.4	3.4	0.4
		10.7	3.8	1.2
		10.7	1.6	0.2
	N	10.1	6.00	0.2
		9.1	2.6	0.6
		9.8	3.2	0.4
		9.3	3.2	0.00
		9.8	2.4	0.4
China variety (V2)	M	14.1	3.2	1.2
		14.00	4.2	1.4
		13.9	3.8	1.6
		14.1	2.9	1.2
		13.7	3.00	0.8
	N	11.2	3.4	1.4
		12.7	4.4	0.8
		11.6	2.00	1.00
		11.8	3.2	1.2
		12.9	3.6	0.6

Numerical values are the means of 5 replicates.

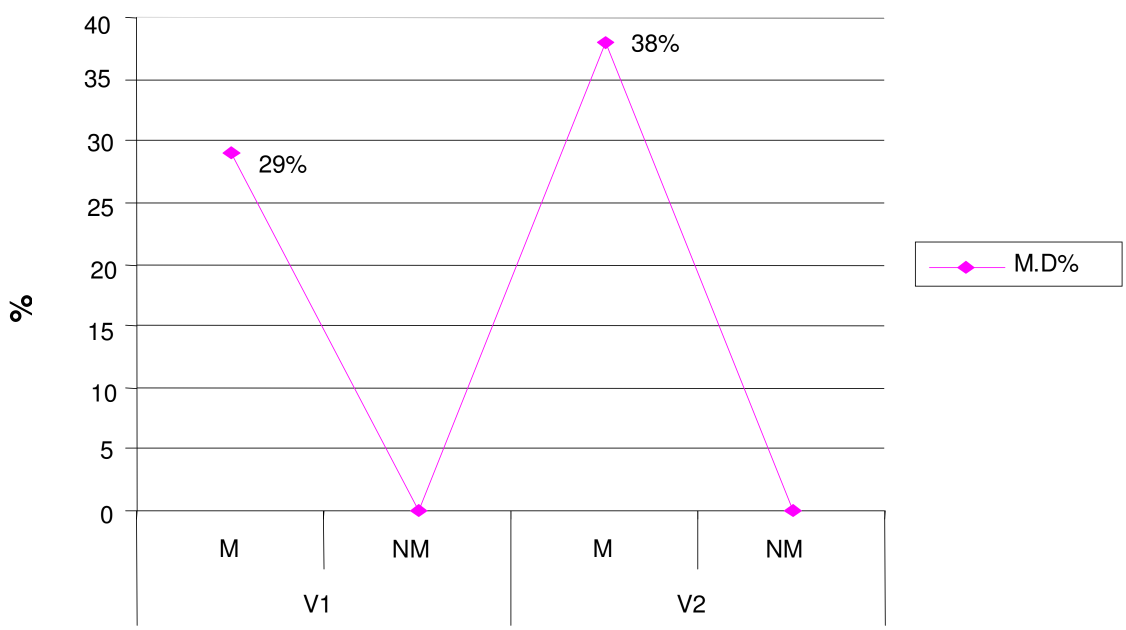

Figure 1. Mycorrhizal dependency index (MD) of cowpea varieties.

results of our investigation have shown that legumes were more dependent on mycorrhiza association for better growth in nutrient deficient soil. Studied legumes (cowpea) belong to Fabaceae family. Our results match

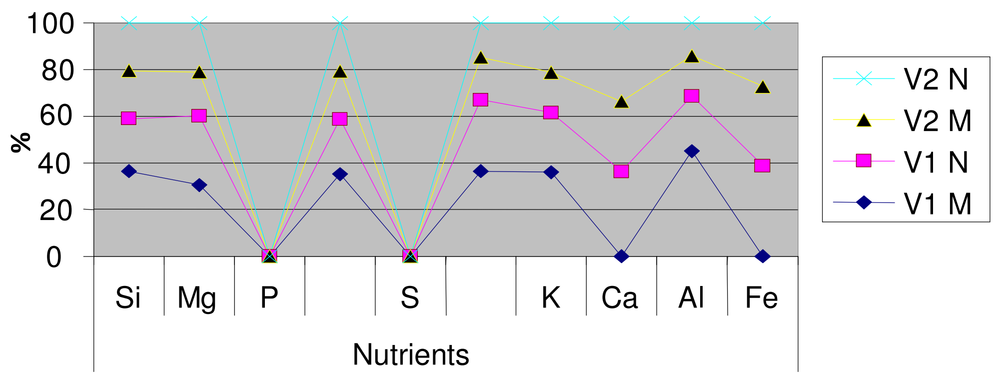

Figure 2. Effect of AM inoculation on nutrient uptake of cowpea varieties.

Table 3a. ANOVA for plant height.

K value	Source	Degree of freedom	Sum of square	Mean square	F value	Probability
1	Replicate	4	0.750	0.188	0.6994	
2	Var.	1	46.086	46.086	171.8320	0.0000
4	Treatment	1	8.295	8.295	30.9266	0.0001
6	Var.+Trt	1	1.848	1.848	6.8914	0.0222
-7	Error	12	3.218	0.268		
	Total	19	60.198			

Coefficient of variation: 4.51%; LSD value = 0.7976 at alpha = 0.05.

with the findings of Khalil et al. (1994) who studied the mycorrhizal dependency of soybean and corn. Soybean had a higher mycorrhizal dependency than maize. When mycorrhizal and non-mycorrhizal plants were compared, the N, P, K, Ca and Mg uptake were significantly increased in mycorrhizal plants. It is widely accepted that plants with highly branched root system (Gramineae) are less mycotrophic (less dependent on the fungi for normal growth) than those with coarser roots (e.g. cassava, onion). Root branching determines plant dependence on the symbiosis (Smith and Read, 1997; Barakh and Heggo, 1998). Zadeh and Rastin (1997) reported that; vesicular-arbuscular mycorrhizal fungi (VAMF) in soybean plants increased dry matter. The results are in accordance with our results that in V2 (China variety) and V1 (Watni variety), dry matter increased by AMF. The results showed that, all varieties were found to differ in their mycorrhizal dependency as also shown by Menge et al. (1978), Azcon and Ocampo (1981), Hall (1988), Bethlenfalvay et al. (1989) and Xavier and Germida (1998). Our results confirmed the findings of other workers who observed that plant species and even cultivars of same species differ in their mycorrhizal dependency. This difference is generally related with soil type, root geometry, plant growth rates, mycorrhizal species and soil phosphorus (Hall, 1975; Plenchette et al., 1983; Menge, 1983; Hatrick et al., 1992; Hatrick et al., 1993).

The mycorrhizal plants under observation showed root and shoot dry weight. As we know that due to VAM inoculum, the total biomass is a gain factor of plant height, leaves and root, which commonly resulted to more dry weight. These results are in line with the observations of Thompson and Wildermuth, (1987), Hatrick et al. (1992), Tarafdar and Marschner (1994) and Tarafdar and Marschner (1995), Shivana (1994) and Bai et al. (2008) who stated that, dry matter differences between mycorrhizal and non-mycorrhizal plants are due to benefits derived by plants from mycorrhizal association.

Nutrient uptake by mycorrhizal and non-mycorrhizal plants

Nutrients (Ca, K, Mg, P, Fe and Si S and Si) uptakes of cowpea (*V. unguiculata*) varieties are shown in Figure 2. It showed that varieties and the effect of treatments were significantly different. Maximum uptake of nutrient was attained in mycorrhizal plants. Our results are supported by the Singh et al. (2004), Sharma (2004) and Ghazala (2005) who reported that nutrient uptake of mycorrhizal plants was higher when compared with non-mycorrhizal one. One of the most dramatic effects of mycorrhizal infection on the host plant is the increase in phosphorus

Table 3b. ANOVA for no. of flower per plant.

K value	Source	Degree of freedom	Sum of square	Mean square	F value	Probability
1	Replicate	4	0.700	0.175	1.5766	0.2433
2	Var.	1	1.458	1.458	13.1315	0.0035
4	Treatment	1	0.722	0.722	6.5045	0.0254
6	Var.+Trt	1	0.098	0.098	0.8829	
-7	Error	12	1.332	0.111		
	Total	19	4.310			

Coefficient of variation: 39.2; LSD value = 0.5133 at alpha = 0.050.

Table 3c. ANOVA for nodules per plant.

K value	Source	Degree of freedom	Sum of square	Mean square	F value	Probability
1	Replicate	4	3.232	0.808	0.7491	
2	Var.	1	0.312	0.312	0.2897	
4	Treatment	1	0.481	0.481	0.4455	
6	Var.+Trt	1	0.840	0.840	0.7792	
-7	Error	12	12.944	1.079		
	Total	19	17.809			

Coefficient of variation: 32.01%.

(P) uptake (Veierhiling et al., 2000; Rohyadi et al., 2004; Bai et al., 2008) that are mainly due to the capacity of the mycorrhizal fungi to absorb phosphate from soil and transfer it to the host roots (Asimi et al., 1980). Our results was supported by the following state-ment, AMF have been shown to improve immobile nutrients uptake such as P, Zn and Cu (George 2000; Liu et al., 2002). Mycorrhizal fungi can also improve absorp-tion of phosphorus (Kalipada and Singh, 2003) potassium (Liu et al., 2002), magnesium (Liu et al., 2002), copper (George, 2000), zinc (Jamal et al., 2002; Habte and Osorio, 2002; Chen et al., 2003) and calcium (Liu et al., 2002).

REFERENCES

Arihara J, Karasawa T (2000). Effect of Previous crops on arbuscular mycorrhizal formation and growth of succeeding maize. Soil Sci. Plant Nutr. 46(1): 43-51.

Asimi S, Gianinazzi-Pearson V, Gianinazzi S (1980). Influence of increasing soil phosphorus levels on interactions between vesicular-arbuscular mycorrhizae and *Rhizobium* in soybeans. Can. J. Bot. 58: 2200-2205.

Atimanav G, Adholeya A (2002). AM noculations of five tropical fodder crops and inoculum production in marginal soil amended with organic matter. Biol. Fertil. Soil, 35: 214-218.

Avis TJ, Gravel V, Antoun H, Tweddell RJ (2008). Multifaceted beneficial effects of rhizosphere microorganisms on plant health and productivity. Soil Biol. Biochem. 40(7): 1733-1740.

Azcon R, Ocampo JA (1981). Factors effecting the VAM infection and mycorrhizal dependency of thirteen cultivars; New Phytol. 87: p. 677.

Bai JF, Lin XG, Yin R, Zhang HY, Wang JH, Chen XM, Luo YM (2008). The influence of arbuscular mycorrhizal fungi on As and P uptake by maize (*Zea mays* L.) from As-contaminated soils. Appl. Soil Ecol. 38(2): 137-145.

Barakh FN, Heggo AM (1998). Moisture Stress. *Bradyrhizobia*, vesicular arbuscular mycorrhiza and P-Fertilizers effect of soyabean growth, nutrient content and phosphate activity under calcareous soil. Ann. Agric. Sci. Carrio, 43(2): 261-475.

Bethlenfalvay GJ, Franson RL, Brown MS, Mehra KI (1989). The *Glycine, Glomus, Bradyrhizobium* symbiosis. IX. Nutritional, morphological and physiological responses of nodulated soybean to geographical isolates of mycorrhizal fungi *Glomus mosseae,* Physiol. Planarum, 76: 226-232.

Bonfante P, Genre A (2008). Plants and arbuscular mycorrhizal fungi: an evolutionary-developmental perspective. Trends Plant Sci. 13(9): 492-498.

Chen BD, Li XL, Tao HQ, Christie P, Wong MH (2003). The role of arbuscular mycorrhiza in zinc uptake by red clover growing in calcareous soil spiked with various quantities of zinc. Chemosphere, 50(6): 839-846

Deshmukh AM, Khobragade RM, Dixit Jaipur PP (2007). Handbook of Biofertilizers and Biopesticides/edited , Oxford Book Company, xviii, 308 p., tables, figs., ISBN 81-89473-15-0.

Ezawa T, Yamanoto K, Yoshida S (2000). Species composition and spore density of indigenous vesicular arbuscular mycorrhizal fungi under different condition of P-fertility as revealed by soybean trap culture. Soil Sci. Plant Nutr. 46(2): p. 297.

Fidelibus MW, Martin CA, Wright GC, Stutz JC (2000). Effect of arbuscular mycorrhizal (AM) fungal communities on growth of 'Volkamer' lemon in continually moist or periodically dry soil. Sci. Hortic. 84: 127-140.

Ghazala N (2005). Role of symbiotic soil fungi in controlling roadside erosion and in the establishment of plant communities.

George E (2000). Nutrientuptake, In: Arbuscular mycorrhizas: Physiology and function. Eds: Kappulnick Y and Douds Jr. DD. Kluwer Academic press, pp. 307-344.

Guriqbal S, Sekhon HS, Poonam S, Singh G, Sharma P (2001). Effect of *Rhizobium*, Vesicular arbuscular mycorrhiza and phosphorus on the growth and Yield of lentil (*Lens culinaris*) and field pea (*Pisum sativum*). Environ. Ecol. 19(1): 40-42.

Hall IR (1975). Endomycorrhizas of metrosideros umbellate and weinmannia racemose. New Zeal. J. Bot. 13: 463-472.

Hall IR (1988). Potential for exploiting vesicular arbuscular mycorrhizas in agriculture.In: Biotechnology in agriculture. Advances in biological process volume 9 Arshalom. M(Ed). Isreal Institute for biological research Ness Ziona, Isreal.
Habte M, Osorio NW (2002). Mycorrhizas: Producing and Appling Arbuscular Mycorrhizal Inoculation. Ecoliving Center. Overstory #102. http: //www. Ecoliving. Cat .Org .au.
Hatrick BAD, Wilson GWT,Cox TS (1993). Mycorrhizal dependency of modern wheat cultivars and ancestors: A synthesis. Can. J. Bot. 71(3): 512-518.
Hatrick BAD, Wilson GWT,Cox TS (1992). Mycorrhizal dependency of modern wheat varieties, landraces and ancestor. Can. J. Bot. 70(10): 2032-2040.
Hodge A (2000). Microbial ecology of the arbuscular mycorrhiza. FEMS Microbiol. Ecol. 32(2): 91-96.
Hussain F (1989). Field and Laboratory Manual of Plant Ecology.No.19 (130) NAHE. National Academy of higher Education University Grants commission, H-9, Islamabad.168-172: 233.
Haq I, Fraser I, Matiseuic E (2003). Preparation and characterization of finely dispersed pigment particals. Colloid Polym. Sci. 281: 542-549.
Izagirre Mayoral ML, Carballo O, Carreno L, de Mejia MG (2000). Effects of VA Mycorrhizal inoculation on growth, yield, N and P nutrition of nodulating bean varieties in two soil substrates of contrasting fertility. J. Plant Nutr. 23(8): 111 7-11 33.
Jalaluddin M (2005). Effect of inoculation with VAM fungi and *Bradyrhizobium* on growth and yield of soybean in sindh. Pak. J. Bot. 37(1): 169-173.
Jalaluddin M, Anwar QMK (1991). VAM fungi in wheat and rice field. Pak. J. Bot. 23(1): 115-122.
Jamal A, Ayub N, Usman M, Khan AG (2002). Arbuscular mycorrhizal fungi enhance zinc and nickel uptake from contaminated soil by soybean and lentil. Int. J. Phytoremed. 4(3): 203-221.
Joner EJ (2000). The effect of long-term fertilization with organic and inorganic fertilizers on mycorrhiza mediated P uptake in subterranean clover. Biol. Fert. Soil, 32: 435-440.
Kalipada P, Singh R-K (2003). Effect of levels and mode of phosphorus application with and without biofertilizers on yield and nutrient uptake by chickpea *(Cicer arietinum)*. Ann. Agric. Res. 24(4): 768-775.
Khalil S, Loynachan TE, Tabatabai MA (1994). Mycorrhizal dependency and nutrient uptake by improved and unimproved corn and soybean cultivars. Agron. J. 86(6): 949-958.
Khan AG (1994).The Pakistan develops biological alternative to chemical fertilizer. An interview to The News March 13.1994.
Liu A, Hamel C, Elmi A, Costa C, Ma B, Smith DL (2002). Concentrations of K, Ca and Mg in maize colonized by arbuscular mycorrhizal fungi under field conditions. Can. J. Soil Sci. 82(3): 271-278.
Lukiwat DR, Simanungkalit RDM (2002). Dry matter yield, N and P uptake of soybean with *Glomus manihotis* and *Bradyrhizobium japonicum*. In timetable of international Meeting on direct application of phosphorus rock and related technology-latest developments and practical experiences. International fertilizer development center muscle shoals (IFDC) USA Kuala Lumpur, Malaysia. July 16-20.
Mathew M-M, Hameed S-M-S (2002). Influence of microbial inoculants and phosphorus levels on the root characters, growth and yield of vegetable cowpea (*Vigna unguiculata* subsp. sesquipedalis [L.] Verdcourt). Thrissur, India: Kerala Agricultural University. J. Trop. Agric. 40(1/2): 71-73.
Mamatha G, Bagyaraj DJ, Jaganath S (2002). Inoculation of field established mulberry and papaya with VAM fungi and mycorrhiza helper bacterium. Mycorrhiza, 12: 313-316.
Menge J (1983). Utilization of VAM fungi in Ariculture. Can. J. Bot. 61930: 1015-1024.
Menge JA, Labanauskas CK, Johnson E, Platt KG (1978). Partial substitution of mycorrhizal fungi for phosphorus fertiliz ation in greenhouse culture of citrus. Soil Sci. Am. Proc. 42: 926-930.
Meshram AT, Jadhav AC, Konde BK, Wani PV (2000). Effect of VAM fungi and P-sources on nodulation, dry matter and yield of chickpea. J. Maharashtra Agric. Univ. 25(1): 99-101.
Miransari HA, Bahrami F, Rejali M, Malakouti J, Torabi H (2007). Using arbuscular mycorrhiza to reduce the stressful effects of soil compaction on corn (*Zea mays* L.) growth. Elsevier Ltd.
Nelson DW, Sommers LE (1882). Total Carbon, Organic carbon and Organic matter. In: Pag AL, Miller RH and Keeneys (eds.). Method of Soil Analysis Part 2. Agronomy 9, AM. Soc. Agric. Mad. WI, pp. 539-577.
Niranjan R, Shukla R, Pareek R, Rao V-M (2002). Dual inoculation effect of *Rhizobium* (cow pea miscellany) and VAM fungi on growth, nodulation and nitrogen fixation in *Prosopis cineraria*. Bharatpur, India Phytological Society. J. Phytol. Res. 15(2): 149-153.
Olsen SR, Sommers LE (1982). Potassium In: Page AL,Miier RH andKeeney DR (eds.). Method of Soil Analysis. Analysis. Part 2 Agronomy 9. America Society of Agronomy, Madison, W.L., pp. 403-427.
Plenchette CA, Fortin A, Forlan N (1983). Growth response of several plant species to mycorrhiza in a soil of moderate P-fertility. I. Mycorrhizae under field conditions. Plant Soil. 70:199-203.
Rajasekaran S, Nagarajan S-M (2005). Effect of dual inoculation (AM fungi and (*Rhizobium*) on chlorophyll content of *Vigna unguiculata* (L.) Walp. var. Pusa 151. New Delhi, India: Tata Energy Research Institute. Mycorrhiza- News; 17(1): 10-11.
Rohyadi A, Smith F-A, Murray R-S, Smith S-E (2004). Effects of pH on mycorrhizal colonisation and nutrient uptake in cowpea under conditions that minimise confounding effects of elevated available aluminium. Dordrecht, Netherlands: Kluwer Academic Publishers. Plant Soil, 260(1/2): 283-290.
Satyawati S, Suman K, Padma V (2005). Effect of bioinoculants on biomass productivity under agroforestry systems. New Delhi, India: National Institute of Science Communication and Information Resources. Indian J. Biotechnol. 4(1): 156-160.
Sharma OP (2003). Textbook of Fungi. TaTa McGraw-Hill Publishing Company Limited. India. p. 312.
Sharma AK (2004). Biofertilizers for sustainable agriculture. 1st ed. Published by Agrobios (India). pp. 201-209.
Singh A-P, Sumit C, Tripathi M-K, Singh S (2004). Growth and yield of green gram [*Vigna radiata* (L.) Wilczek] as influenced by biofertilizer and phosphorus application. Hisar, India Agric. Biol. Publishers. Ann. Biol. 20(2): 227-232.
Shivana MB, Merra MS, Hyakumachi M (1994). Sterile fungi from Zoysiagrass as plant growth promoters in spring wheat. Can. J. Microbial. Rev. 40(8): 637-644.
Smith SE, Read DJ (1997). Mycorrhizal symbiosis. Academic Press, Inc San Diego California. ISBN 0-12-652840-3.
Tarafdar JC, Marschner H (1994). Efficiency of VAM hyphae in utilization of organic phosphorus by wheat plants. Soil Sci. Plant Nutr. 40(4): 593-600.
Tarafdar JC, Rao AV (1995). Response of arid legumes to VAM fungal inoculation. Symbiosis. 22 (3): 265-274.
Thompson JP, Wildermuth GB (1987). Colonization of crop and pasture species with vesicular-arbuscular mycorrhizal fungi and a negetive correlation with root infection by *Bipolaris sorokiniana.* Can. J. Bot. 67: 687-693.
Vierheiling H, Garcia-Garrido JM, Wyss U, Piche Y (2000). Systemic supperession of mycorrhizal colonization of barley roots already colonized by AMFungi. Soil Biol. Biochem. 32: 589-595.
Xavier LJC, Germida JJ (1998). Response of spring wheat cultivars to *Glomus. clarum*. NT4 in P-deficient soil containing arbuscular mycorrhizal fungi. Jordan. J. Sci. 78(3): 481-484.
Zadeh AAN, Rastin SN (1997). The effects of inoculation with VAM fungi and *Brdyrhizobium japonicum* on growth and nutrient. Soil Water J. 10 (1): 1-12.
Zaidi A, Khan MS, Amil M (2003). Interactive effect of rhizotrophic micro organisms on yield and nutrient uptake of chickpea (*Cicer arietinum* L.) Eur. J. Agron.19(1): 15-21.