



## EFFECT OF EDAPHIC FACTORS ON THE DIVERSITY OF VAM FUNGI

**Rajan K. Gupta**

Pt. L.M.S. Government Post Graduate College, Rishikesh (Dehradun)  
Uttarakhand

Corresponding author Email : [rajankgupta1@rediffmail.com](mailto:rajankgupta1@rediffmail.com)

### **Abstract:**

The present study deals with the diversity and distribution of VAMF at different sites with different selected plants. Maximum number of VAMF species were found at site IV (57 species) out of which *Glomus* species was most dominant (58%), followed by *Acaulospora* (19%), *Scutellospora* (8%), *Sclerocystis* (4.8%) and *Gigaspora* (1.6%) respectively. In site II 56 species of VAMF were observed with *Glomus* (55%), followed by *Acaulospora* (22.5%), *Scutellospora* (8%), *Gigaspora* (1.6%) and *Sclerocystis* (3.2%) respectively. In site III 55 species of VAMF occurred with *Glomus* (51.6%) followed by *Acaulospora* (22.5%), *Scutellospora* (9.7%), *Sclerocystis* (4.8%) and *Gigaspora* (0%) respectively. In site I 54 species of VAMF were found; out of these *Glomus* was highest 53% followed by *Acaulospora* (22.5%), *Scutellospora* (5%), *Sclerocystis* (1.6%) and *Gigaspora* (1.6%) respectively. These results suggest that selected study sites are rich in VAMF frequency and diversity. The Shannon-Wiener index confirms that diversity of VAMF fungal species varies with the test plant and maximum diversity was observed with *Ocimum sanctum* (3.948), and *Withania somnifera* (3.909) respectively. Maximum ANOVA value recorded in case of and *Withania somnifera* (0.20) and *Ocimum sanctum* (0.19) respectively. Maximum richness value was observed in case of *Ocimum sanctum* (0.3948) and *Withania somnifera* (0.0391).

### **Keywords:**

VAMF, *Glomus*, Diversity, Mycorrhizae, richness

### **Introduction:**

Mycorrhizae is the mutualistic symbiosis (non-pathogenic association) between soil borne with the roots of higher plants (Quilambe., 2003), revealed that they are found in wide range of habitats usually in the roots of angiosperms, gymnosperms and pteridophytes. They also occurs in the gametophytes of some mosses, lycopods and psilotes, which are rootless (Mosse et al., 1981; Vyas et al., 2007, 2008). AMF have shown to be potentially able to take up both organic (Hodge, Campbell & Fitter, 2001) and inorganic nitrogen from the soil (Govindarajulu et al., 2005). VAM fungi are essential components of ecosystem





for both re-vegetation of the degraded lands and maintenance of soil structure (Caravaca et al., 2005), thereby reducing the risks of erosion and desertification. Soil characteristics, plant species, and climate may all regulate the arbuscular mycorrhizal (AM) fungi community. The distribution of certain VAM fungal species has been related to soil pH, phosphorus level, salinity, soil disturbance (Abbott and Robson 1991), vegetation (Johnson et al., 1992), or hydrologic condition of the soil (Ingham and Wilson, 1999; Miller and Bever, 1999). In general terms, increases in soil pH, nutrient status and salinity in soil are related to a decrease in VAM root colonisation or spore density (Abbott and Robson, 1991). Despite the importance of VAM fungi in the physiology and nutrition of plants, as well as in shaping plant communities (Grime et al., 1987; Van der Heijden et al., 1998; Smith et al., 1999), factors affecting the presence, diversity, spore density, and root colonisation by AM fungi in soil are poorly understood. One reason is the difficulty of establishing causation from correlation of soil and plant factors with VAM fungal populations. Another reason is that AM fungi can associate with a wide range of hosts present in community, but the sporulation rates of AM fungi have been found to be host dependent (Bever et al., 1996; Lugo and Cabello, 2002). Host-dependence of VAM fungal population growth rates in soil may play an important role in the maintenance of VAM fungal species diversity in grasslands (Bever et al., 1996), and suppression of mycorrhizal symbioses may result in a decreasing of the dominant plant and an increase in species diversity (Hartnett and Wilson, 1999). In addition, plant diversity may increase or decrease if the dominant plant competitors are more weakly or more strongly mycotrophic than their neighbours (Hartnett and Wilson, 1999). An additional factor influencing populations of VAM fungi in soil, which may in turn affect the performance of plant species relative to each other, is the hydrologic condition of the soil, which may vary seasonally. The hydrologic condition of the soil plays an important role in determining plant community structure, and this effect is even more important when soils are commonly subjected to periods of dryness





and flooding (Chaneton et al., 1998). VAM fungi have been found in the roots of many plants in wetlands (Ingham and Wilson, 1999; Miller and Bever (1999), or salt marshes (Brown and Bledsoe 1996). This is relevant because the fungi are believed to require well-aerated soils, and are thought to have problems adapting to flooded conditions (Mosse et al., 1981). Nevertheless, little is known of VAM fungi patterns in wetlands or of the influence of the hydrologic condition of the soil on populations of AM fungus species. The most important and historical account of medicine in the form of 'Ayurveda'(2500 to 900 B.C.), which is considered as 'Upaveda' ,Charak Samhita and Susruta Samhita' also dealt with plants related to medicine and their use in health management. These days many people cultivating medicinal plants to fulfil the increasing demands of pharmaceutical industries. The major biochemical constituents of Ashwagandha (is a small, woody shrub in the Solanaceae family) that root are steroidal alkaloids and steroidal lactones in a class of constituents called withanolides. At present, 12 alkaloids, 35 withanolides, and several saponins from this plant have been isolated and studied. A saponin is a withanolide containing a glucose molecule at carbon 27. Much of ashwagandha's pharmacological activity has been attributed to two main withanolides, withaferin A and withanolide D. Tulsi, Queen of Herbs, the legendary

### **Material and Method:**

For the present investigation two test sites were selected, (I) Kariaya Village (II) Jaitpur Village. The experiments were conducted for quantitative and qualitative estimation of AM fungi were done from rhizosphere and non-rhizosphere soil and roots of test plants. The rhizosphere soil and root samples of selected test medicinal plants were collected from study sites up to 0-10, 10-20, 20-30, 30-40 cm depth. The VAM spores were isolated from the collected soil samples by wet sieving and decanting method (Gerdemann and Nicolson, 1963). Mycorrhizal spores are identified according to their spore morphology by





conventional taxonomic key of Schenck and Perez (1990&http://www.invam.cat.wu.edu). For the estimation of AM spores, a technique provided by Gour and Adholeya (1994) was followed. The soil pH was determined in 1:5 suspension of soil; deionized water ratio, electrometrically by glass electrode pH meter 335 (Jackson, 1982). Statistical analysis of data for comparison of means, analysis of variance (ANOVA), etc. was followed after Gupta and Kapoor (1997).

### **Result and Discussion:**

The result obtained from the present study depicted in the table 1, which show the relative abundance of VAMF spores associated with test plants *Withania somnifera* and *Ocimum sanctum*, growing in the Karaiya village and Jaitpur village. Variance in relative abundance (RA) of VAMF spores along with the depths of the soil was observed. Maximum value recorded of VAMF spores was observed from the soil surface up to 10 cm length and it reduces and minimum was recorded at 30-40 cm depth. Shannon-Weaver diversity index and evenness of VAM fungi is shown in table (2). The Shannon-Weaver index value suggests that *W. somnifera* harbours more diverse morphotypes of *O. sanctum*. Comparatively soil of Jaitpur village has fairly greater number of morphotypes in *W. somnifera* than in the soil of Karaiya, H 2.351 and H 2.250 respectively. However, Shannon –Weaver index (H') values confirm that (VAMF) reduces whereas in contrast H' value obtained from the different depth of rhizosphere of *O. sanctum* growing in Jaitpur village soil showed to maximum value at the depth of 10-20 cm (2.143), and further deeper region showed linear decrease an H` value. However, *O. sanctum* growing Karaiya village showed maximum H` value up to 10 cm depth and below this H` value gradually decreased The value obtained for evenness (J') of VAMF with *W. somnifera* growing in Karaiya or Jaitpur village soil are also described in table (2). Interestingly there is little hike in J` value at 20-30 cm and 30-40 cm deep in respectively with *W. somnifera* plants growing in Jaitpur village soil. However, same species growing





at Karaiya village dose not show any significant difference in  $J'$  value. Evenness of VAMF  $J'$  value of *O.sanctum* in both the sites Karaiya village soil and Jaitpur village soil showed poorly different trend. At Kariaya village soil  $J'$  value almost remains same upto 30 cm depth, but suddenly significant reduction in  $J'$  value was observed. In contrast to this Jaitpur village soil though  $J'$  value remains same upto the depth of 30 cm but a significant increase in  $J'$  value at 40 cm depth was recorded. During the present study, a total of 27 morphologically distinct VAM species were isolated from the rhizosphere of *Withania somnifera* and *Ocimum sanctum* growing at two different sites; Karaiya village and Jaitpur village (Fig.1). Out of 27 VAM fungal species, 13 different species were found associated only with *W. somnifera*, six species were found only with *O. sanctum* and eight species were found common in both the plants. Thus, a total of 21 species associated with *W. somnifera* and 14 species were found associated with *O. sanctum*. Among the 21 VAM species found associated with *W. somnifera*, five VAMF species viz. *Acaulospora mellea*, *A. scrobiculata*, *Glomus claroideum*, *G. etunicatum* and *G. macrocarpum* were not found in Jaitpur soil, whereas *A. bireticulata*, *A. denticulata*, *G. dimorphicum* were not found in Jaitpur village soil (Fig. 2). *Acaulospora* sp., *A. nicolsonii*, *G. clarum* and *G. hoi* were the prominent species of the VAM fungi which were isolated from surface to 40 cm. depths in the Karaiya village soil. *G. intraradices* and *G. mosseae* were isolated from the depth of 30 cm. *A. denticulata* and *Glomus* sp. were obtained from the depths of 10-20 and 20-30 cm. *G. ambisporum*, and *G. fasciculatum* were isolated from 0-10 and 10-20 cm depths. *A. bireticulata*, *G. australe*, *G. desrticola*, *G. dimorphicum*, and *G. pustolatum* were isolated from 0-10 cm depth in the Karaiya village soil (Table 1). In the Jaitpur village soil, *A. nicolsonii*, *G. clarum*, *G. hoi* and *G. intraradices* were isolated from the topsoil to of 40 cm depth. *G. etunicatum*, *G. mosseae* and *G. versiforme* were collected from of 30 cm depth. *A. mellea* and *G. desrticola* were isolated from 0-10, 10-20, and 30-40 cm soil depth. *A. scrobiculata*, *G. australe*, *G. fasciculatum*, *G. macrocarpum*, and *G.*





pusotlatum were isolated from 0-10 and 10-20 cm depth. Acaulospora sp. and Glomus sp. were isolated from 0-10 and 20-30 cm depth. G. ambisporum was isolated only 10- 20 cm (Table 1). Out of 27 VAMF species, 14 species were found associated with *O. sanctum* in both the sites (Fig. 1). Among the 14 VAMF species, three species viz. *A. foveata*, *Entrophospora infrequens* and *G. etunicatum* were not found in Karaiya village soil (Fig. 2). *A. nicolsonii* and *G. clarum* were the two VAMF species found very prominent in Karaiya village soil and isolated in all measured soil depth. *A. spinosa*, *G. fasciculatum*, *G. heterosporum* and *G. hoi* were isolated from the depth of 30 cm. Whereas, *A. scrobiculata*, *G. ambisporum* and *G. intraradices* were isolated from the depth of 20 cm. *G. botryoides* was isolated in topsoil (0-10 cm) and *Scutellospora pellucida* was isolated from 20-30 and 30-40 cm soil depth (Table 1). In Jaitpur village soil *G. clarum*, *G. fasciculatum* and *G. intraradices* were isolated from 40 cm depth. *A. nicolsonii*, *G. heterosporum* and *G. hoi* were collected from 30 cm depth while, *A. foveata*, *G. ambisporum* and *G. etunicatum* 20 cm depth. *A. spinosa* was isolated from 10-20, 20-30 and 30-40 cm soil depths, respectively. Here, also *G. botryoides* was isolated from the topsoil. *E. infrequens* was isolated from 20-30 and 30-40 cm depth and *S. pellucida* was isolated from 30-40 cm depth (Table 1). The result shown in fig.3 clearly indicate that 14 VAMF species associated with *W. somnifera*, commonly occurring in both the sites Karaiya village soil as well as Jaitpur village soil. Among 14 VAMF species, 11 species associated with *O. sanctum*. It was also observed that 6 VAMF species viz. *A. nicolsonii*, *G. ambisporum*, *G. clarum*, *G. fasciculatum*, *G. hoi* and *G. intraradices* were found associated with both the test plants at in both the sites. However, three species *A. bireticulata*, *A. denticulata* and *G. desrticola* which are associated with *W. somnifera* were found only in Karaiya village soil. A linear regression analysis with coefficient of determination (= squared correlation coefficient or  $r^2$ ) of VAMF spore population with soil depth, soil pH, and soil moisture per cent in *W. somnifera* and *O. sanctum* at both the sites were presented in fig. 4 (A-F) and fig. 5 (A-F).





It is clearly evident from the result that the VAMF spore population showed a strong negative correlation with soil depth, pH and moisture of the soil. It is assumed that an increase in single variable (depth pH, or moisture) resulted in decrease in VAMF spore population in both the test plants at both the sites. In Karaiya village soil, depth and moisture of rhizosphere soil of both the test plants show highly significant correlation, while, variation found in correlation between soil pH and spore population of both the plants. Here, VAMF spore population had weak correlation ( $r^2 = 0.563$ ) with the pH of rhizosphere soil with *W. somnifera* in comparison to *O. sanctum* ( $r^2 = 0.943$ ). Whereas, in Jaitpur village soil, VAMF spore population showed similar trend as observed at Karaiya village soil with the depth and percent moisture of rhizosphere of both the plants. These two attributes significantly, correlated with the VAMF spore population (Fig. 5 A-F). The data presented in table (3) show the comparative analysis of average values of soil pH, soil moisture, VAMF spore population and Shannon-Weaver diversity index at four soil depths from both the sites. The mycorrhizal population dropped significantly from the upper to lower soil depth level. Both the soils showed similar relationships for depths and mean total spore population (Fig. 6). In the present study average soil moisture present initially increased two fold with the increasing depth (Fig. 7). Average soil pH found increased. Interestingly, soil pH values showed a general tendency to increase with increasing soil depth in both the site (Fig.8).

### **Discussion:**

In the present study, the rhizosphere of two medicinal plants viz. *Withania somnifera* and *Ocimum sanctum* in different soil depth at two locations showed common as well as variant VAMF flora. Such variations in the VA mycorrhizal fungal community at differ

### **Conclusion:**

This study shows that the frequency of genera and species of VA mycorrhizal fungi isolated from both the site varied with the above ground vegetation and with changes in soil moisture and soil pH. Currently, we have limited means





for accurately determining the complex of genera and species that forming symbiosis with host plants in natural soil and that are responsible for variations in fungal density obtained from soil samples. Recent advancements in characterizing mycorrhizae with molecular markers will greatly improve our understanding of the ecology of these fungi.

### **Acknowledgement:**

Authors are thankful to Head, Department of Botany, Dr. H.S. Gour University, Sagar, RKG thankfully acknowledge UGC & UCOST for financially assistance.

### **Reference**

- Abbott, L. & A. Robson. 1991. Factors influencing the occurrence of vesicular-arbuscular mycorrhizas. *Agric Ecosyst Environ* 35: 121–150
- An, Z.Q., J.H. Grove, J.W. Hendrix, D.E. Hershman & G.T. Henson .1990. Vertical distribution of endogonaceous mycorrhizal fungi associated with soybean, as affected by soil fumigation. *Soil Biology and Biochemistry* 22: 715-719.
- Bagyaraj D.J. 1991. Ecology of vesicular-arbuscular mycorrhizae. In: Arora DK, Rai B, Mukerji KG, Knudsen GR. eds. *Handbook of applied mycology: Soil and plants vol. I*. Marcel Dekker, Inc., New York, New York. Pp. 3-34.
- Bever, J., J. Morton, J. Antonovics & P. Schultz .1996. Host-dependent sporulation and diversity of arbuscular mycorrhizal fungi in a mown grassland. *J Ecol* 84:71–82
- Bever, J.D., P.A. Schultz, A. Pringle & J.B. Morton. 2001. Arbuscular mycorrhizal fungi: more diverse than meets the eye, and the ecological tale of why. *Bioscience* 51: 923-931.
- Brown, A. & C. Bledsoe. 1996. Spatial and temporal dynamics of mycorrhizas in *Jaumea carnosa*, a tidal saltmarsh halophyte. *J Ecol* 84:703–715







- Caravaca, F., M.M. Alguacil, J.M. Barea & A.Roldan. 2005. Survival of inocula and native AM fungi species associated with shrubs in degraded Mediterranean ecosystem. *Soil Biol. Biochem.* 37:227-233
- Daniels, B.A. & J.M. Trappe. 1980. Factors affecting spore germination of the vesicular-arbuscular mycorrhizal fungus, *Glomus epigaeus*. *Mycologia* 72: 457-471.
- Douds, D.D., L. Galvez, R.R. Janke & P.Wagoner. 1995. Effects of tillage and farming systems upon populations and distribution of vesicular arbuscular mycorrhizal fungi. *Agriculture, Ecosystems and Environment* 52: 111-118.
- Dubey, A. 2006. Studies on diversity of AM fungi with special reference to rice crop. Ph.D. Thesis, Dr. H. S. Gour University, Sagar (M.P.) India.
- Dwivedi, O.P., R.K. Yadav, D. Vyas & K.M. Vyas. 2004. Role of potassium on the occurrence of vesicular arbuscular mycorrhizal spores in the rhizosphere of *Lantana* sp. In; *Microbiology and Biotechnology for sustainable developments* (Ed.) P.C. Jain, CBS Publishers and distributors, New Delhi 248-253. ecosystem variability and productivity. *Nature* 396:69-72
- Friese, C.F. & R.E. Koske .1991. The spatial dispersion of spores of vesicular-arbuscular mycorrhizal fungi in a sand dune: micro-scale patterns associated with the root architecture of American beach grass. *Mycological Research* 95: 952-957.
- Gerdemann J.W.& T.H. Nicolson. 1963. Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting. *Transactions of the British Mycological Society* 46:235-244.
- Gour A. & A. Adholeya. 1994. Estimation of VAMF spores in soil: A modified method. *Mycorrhiza News* 6: 10-11.
- Govindarajulu, M., P.Pfeffer, H.R. Jin, J. Abubaker, D.D. Douds, J.W. Allen, H. Bucking, P.J. Lammers and Y.Shachar-Hill .(2005). Nitrogen transfer in the arbuscular mycorrhizal symbiosis. *Nature* 435: 819-823.





- Green, N.E., S.O. Graham and N.C.Schenck. 1976. The influence of pH on the germination of vesicular-arbuscular mycorrhizal spores. *Mycologia* 68: 929- 934
- Grime, J.P., J.M. Mackey, S.M. Hillier and D.J. Read. 1987. Floristic diversity in a model system using experimental microcosms. *Nature* 328:420–422
- Guadarrama, P. and F. Alvarez-Sanchez .1999. Abundance of arbuscular mycorrhizal fungi spores in different environments in a tropical rain forest, Veracruz, Mexico. *Mycorrhiza* 8: 267-270.
- Gupta S.C. and V.K. Kapoor. 1997. Fundamentals of applied statistics (III ed) S Chand and Sons. New Delhi.
- Hartnett, D. and G. Wilson. 1999. Mycorrhizae influence plant community structure and diversity in tallgrass prairie. *Ecology* 80:1187–1195
- Hodge, A., C.D. Campbell, and A.H. Fitter. (2001). An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. *Nature* 413: 297-299
- Ingham, E. and M. Wilson .1999. The mycorrhizal colonization of six wetland species at sites differing in land use history. *Mycorrhiza* 9:233–235
- Jackson M.L. 1967. Soil Chemical Analysis. Prentice Hall of India (Ltd.) New Delhi, pp. 428.
- Jakobsen, I. and N.E. Nielsen. 1983. Vesicular arbuscular mycorrhiza in field-grown crops I. Mycorrhizal infection in cereals and peas at various times and soil depths. *New Phytologist* 93: 401-413.
- Jansa, J.A., A. Mozafar, T. Anken, R. Ruh, I.R. Sanders and E. Frossard .2003. Soil tillage affects the community structures of mycorrhizal fungi in maize roots. *Ecological Applications* 13: 1164-1176.
- Johnson, N.C., D. Tilman and D. Wedin .(1992). Plant and soil controls on mycorrhizal fungal communities. *Ecology* 73:2034–2042
- Kabir, Z., I.P. O'Halloran, P. Widden and C. Hamel .1998. Vertical distribution of arbuscular mycorrhizal fungi under corn (*Zea mays* L.) in no-till and conventional tillage systems. *Mycorrhiza* 8: 53-55.





- Lugo M.A. and M.N. Cabello. 2002. Native arbuscular mycorrhizal (AMF) from mountain grassland (Córdoba, Argentina) I. Seasonal variation of fungal spore diversity. *Mycologia* 94:579–586
- Mader, P., A. Fliessabach, D. Dubois, L. Gunst, P. Fried and U. Niggli. 2002. Soil fertility and biodiversity in organic farming. *Science* 296: 1694-1697.
- Miller, S. and J. Bever .1999. Distribution of arbuscular mycorrhizal fungi in stands of the wetland grass *Panicum hemitomon* along a wide hydrologic gradient. *Oecologia* 119:586–592
- Mosse, B., D. Stribley and F. Le Tacon. 1981. Ecology of mycorrhizas and mycorrhizal fungi. In: Alexander M (ed) *Advances in microbial ecology*. Plenum Press, New York, pp 137–210
- Mosse, B., D.P. Stribley and F. Tacon . (1981). Ecology of mycorrhizae and mycorrhizal fungi Oehl, F., E. Sieverding, K. Ineichen, E.A. Ris, T. Boller & A. Wiemken. 2005. Community structure of arbuscular mycorrhizal fungi at different soil depths in extensively managed agroecosystems. *NewPhytologist* 165: 273-283.
- Oehl, F., E. Sieverding, K. Ineichen, P. Mader, D Dubos, T Boller and A. Wiemken .2004. Impact of long-term conventional and organic farming on the diversity of arbuscular mycorrhizal fungi. *Oecologia* 138: 574-583
- Oehl, F., E. Sieverding, K. Ineichen, P. Mader, T. Boller & A. Wiemken. 2003. Impact of land use intensity on the species diversity of arbuscular mycorrhizal fungi in agroecosystems of central Europe. *Applied and Environmental Microbiology* 69: 2816-2824.
- Peat, H.J.& A.H. Fitter.1993. The distribution of arbuscular mycorrhizas in the British flora. *New Phytologist* 125: 845- 854.
- Powell, C.L. & D.J. Bagyaraj 1984. *VA-Mycorrhiza*. CRC Press, Boca Raton, Florida. pp. 234. Quilambo, O.A. (2003). The vesicular- arbuscular mycorrhizal symbiosis. *African J.Biotechnol.* 2:539-546
- Read D.J. 1989. Mycorrhizas and nutrient cycling in sand dune ecosystems. *Proceedings of the Royal Society of Edinburgh*, 96: 89-110.





- Redhead J.F. 1977. Endotrophic mycorrhizas in Nigeria: Species of the Endogonaceae and their distribution. Transactions of the British Mycological Society 69: 275-280.
- Rillig, M.C. and C.B. Field. 2003. Arbuscular mycorrhizae respond to plants exposed to elevated atmospheric CO<sub>2</sub> as a function of soil depths. Plant and soil 254: 383-391.
- Schenck N.C. and Y. Perez. 1987. Manual for identification of VAM fungi. Synergistic Pub. Gainesville. Fl., U.S.A.
- Schenck, N.C., and R.A. Kinloch 1980. Incidence of mycorrhizal fungi on six field crops in monoculture on a newly cleared woodland site. Mycologia 72: 445-455.
- Schwab, S. and F.B. Reeves .1981. The role of endomycorrhizae in revegetation practices in the semi-arid West. III. Vertical distribution of vesicular-arbuscular (VA) mycorrhiza inoculum potential. American Journal of Botany 68: 1293-1297.
- Sharma, S.K., G.D. Sharma and R.R.Mishra. 1986. Status of mycorrhizae in sub-tropical forest ecosystem of Meghalaya. Acta Botanica Indica 14: 87-92.
- Smith T.F. 1978. A note on the effect of soil tillage on the frequency and vertical distribution of spores of vesicular-arbuscular endophytes. Australian Journal of Soil Research 16: 359- 361.
- Smith, M., D.Hartnett and G.Wilson. 1999. Interacting influence of mycorrhizal symbiosis and competition on plant diversity in tallgrass prairie. Oecologia 121:574-582
- Sparling, G.P. and P.B.Tinker 1975. Mycorrhizae in Pennine grassland. In: Sanders FE, Mosse B, Tinker PB. eds. Endomycorrhizae., Proceedings of a Symposium held at the University of Leeds, 22-25 July 1974, Academic Press, New York, New York, Pp. 545-560.
- Sutton, J.C. and G.L. Barron .1972. Population dynamics of Endogone spores in soil. Canadian Journal of Botany 50: 1909-1914.





- Tamuli, P. and P.Boruah. 2002. VAM association of agar wood tree in Jorhat district of the Brahmaputra valley. *Indian Forester* 128 (9): 991-994.
- Thompson J.P. 1991. Improving the mycorrhizal infection of the soil through cultural practices and effects on growth and phosphorous uptake by plants. In: Johansen C, Lee KK, Sahrawat KL, eds. Phosphorous nutrition of grain legumes in the semi-arid tropics. Pantancheru, India: International Crops Research Institutes for the Semi-arid Tropics, 117-138.
- Trinick M.J. 1977. Vesicular arbuscular infection and soil phosphorus utilization in *Lupinus* spp. *New Phytologist* 78: 297-304.
- Van der Heijden, M.G.A., J.N. Kilonomos, M.Ursic, P.Moutoglis, R.Streitwolf-Engel, T.Boller, A.Wiemken and I.R. Sanders. 1998. Mycorrhizal fungal diversity determines plant biodiversity, Vyas, D., & A.Soni 2004. Diversity and distribution of VAMF in the seminatural grassland. *Indian Journal of Ecology* 31: 170-171
- Vyas, D., A. Dubey, A. Soni, M.Mishra and P. Singh. (2007). Arbuscular mycorrhizal fungi in early land plants. *Mycorrhiza News*.19(2)
- Vyas, D., P. Singh, M. Mishra, and A. Dubey. (2008). VA Mycorrhizal Association in Weeds of Seminatural Grassland of Sagar. *Indian J. Agroforestry* 10(2): 91-97
- Vyas. D., A. Dubey, P.K.Singh, M.K. Mishra, A. Soni and P.Soni .2006a. VA mycorrhizal fungi in tropical monsoonic grassland. *Journal of Basic and Applied Mycology* 5 (I&II): 78-81.
- Wang, G., D.P. Stribley, P.B. Tinker and C.Walker. 1993. Effects of pH on arbuscular mycorrhiza I. Field observations on the long-term liming experiments at Rothamstead and Woburn. *New Phytologist* 124: 465-472.
- Warcup J.H. 1951. Soil-streaming: a selective method for the isolation of fungi of Ascomycetes from soil. *Transactions of the British Mycological Society* 34: 515-518.

