## OCCURRENCE AND DISTRIBUTION OF ARBUSCULAR MYCORRHIZAL FUNGI IN WHEAT AND MAIZE CROPS OF MALAKAND DIVISION OF NORTH WEST FRONTIER PROVINCE

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#### Abstract

Arbuscular Mycorrhizal (AM) fungi are of considerable interest because of their ability to form symbiotic associations with various crop species. Rhizosphere soil samples were collected both from marginal and fertile soil alongwith wheat and maize roots during the year 2005. In wheat, maximum numbers of white spores were found in Kanju, Beha, Besham, Bunir, Mingora, Alpuri., brown spores in Pirsabak, Mingora and Beha and black spores in Badwan, Shangla, Bunir, Marghuzar and Besham soil series with fungal infection rates rang in from 32 to 68% in roots of wheat crop. In maize, highest concentrations of white spores were found in Pirsabak, Besham, Kanju, Shangla, Bunir and Marghuzar, brown spores in Marghuzar Shangla Badwan, Beha, Khwazakhela and Alpuri and black spores in Pirsabak Khwazakhela and Besham soil series with 24 to 60% infection rates in roots of maize crop. Results suggest that spores density in soil and roots infection intensity varied from one site to another under different agro-ecological conditions and higher AM infections rates were observed in soil with low organic matter contents.

### Introduction

The ability to exploit the natural resources constitute a major step towards economic prosperity for developing country like Pakistan as chemical fertilizers are expensive, short and may cause the problems of environmental pollution (Freney & Simpson, 1983). Arbuscular Mycorrhizal (AM) fungi are distributed worldwide (Gerdeman, 1968). Infection of crop roots with AM fungi can improve the uptake of nutrients, particularly of phosphorus and increase crop production (Menge & Johnson, 1987; Young *et al.*, 1988; Jalaluddin *et al.*, 2008). Response of tropical and subtropical cultures to endomycorrhizal fungi are obligate symbiotic fungi, the hyphae of which develop mycelia, arbuscules and in most fungal genera vesicles in roots. These hyphae can explore an area around the root which far exceeds that available to root hairs. It is the ability of these hyphae to absorb relatively immobile or fixed elements (P, Zn, Cu) in acid or alkaline soils, especially in the plants with coarse root systems (Allen *et al.*, 1995; Mosse, 1973).

Association of AM fungi with plant roots can help plants to overcome water stress by stomata regulation in plants (Robert, 2001). There is a great lack of information on the ranges of specific soil variables under which specific AM fungal species occur and thus on conditions which may be tolerable or optimum for them. Very limited information is available about the incidence of AM in Pakistan (Saif & Parveen, 1977; Burni *et al.*, 1995; Burni & Jabeen, 1997). No detailed and systematic studies have been conducted on the precise status of mycorrhizal association of plant in different ecological zones of Pakistan and particularly in NWFP. This research project was planned to conduct the comprehensive field survey in both nutrient deficient and fertile soils to evaluate AM fungi in wheat-maize cropping system of Peshawar, NWFP as wheat and maize crops rotation is very common in the area with cultivation on 0.742 and 0.506 million ha area having production of 1.03 and 0.87 million tones of wheat and maize, respectively in NWFP (Anon., 2004).

## **Materials and Methods**

Field survey was conducted during the year 2005 to determine the status of AM fungal spores concentrations in soil and their colonization in roots of wheat and maize crops in different soil series of Malakand division.

**Soil and roots sampling:** Rhizosphere soil samples attached with plant roots were collected from fertilized soil with better crop growth conditions as well as from unfertilized soil with poor plant growth conditions along with plant roots randomly from 10-15 plants to make a composite sample from wheat and maize crops of different soil series of Malakand area. Half of the soil sample was stored at 4°C for the determination of mycorrhizal spores while remaining half of sample was air dried, ground and passed through 2 mm sieves for the analysis of soil physical and chemical characteristics. Crop root samples were also stored at temperature of 4°C for the estimation of mycorrhizal infection rates.

**Soil analysis:** Total N concentration of soil samples was determined by the Kjeldhal method of Bremner (1996). Soil texture was determined by hydrometer method as described by Koehler *et al.*, (1984). AB-DTPA extractable P, K, Cu, Fe, Zn and Mn were analyzed by the method as described by Soltanpour & Schawab (1977). Soil pH and electrical conductivity were determined in soil and water suspension of 1:5 by McClean (1982). Soil organic matter content was determined by using  $K_2Cr_2O_7$  as an oxidizing agent as described by Nelson & Sommer (1982).

**Isolation of AM fungal spores from soil:** Spores of AM fungi were isolated from soil by wet-sieving and decanting techniques as described by Brundrett (1996). Soil was suspended in water and then passed through sieves of different sizes. Spores concentrations of different size, shape and color were observed in different numbers under binocular microscope, which were grouped as high (>3333 spores kg<sup>-1</sup> soil), medium (1400 – 3333 spores kg<sup>-1</sup> soil) and low (<1333 spores kg<sup>-1</sup> soil) according to the criteria as developed by Brundrett (1996). These spores were identified according to their morphological characteristics including shape, size, colour, distinct wall layer, attached hyphae and surface orientation of spores as described by Schenck & Parez (1990).

**Estimation of AM fungal infections:** Infection rates by AM fungi in the roots of wheat and maize crops were determined by staining the mycorrhizal chitin with lactic-trypan blue according to the procedure as described by Koske & Gemma (1989). The presence of vesicles, arbuscules or hyphae (minimum or maximum) were measured by the techniques as described by Giovannetti and Mosse (1980). Soil organic matter contents and spores density were correlated with roots infections rates by AM fungi in wheat and maize crops of this area.

## **Results and Discussion**

Soils of Malakand division ranged from moderate to very good land and is either canal irrigated or moderate dry farm land with mean annual rainfall from 800 to 1500 mm (Anon., 1976).

**Physical and chemical characteristics of soils of the study area:** Data given in Table 1 showed that pH values of the well managed fertile rhizosphere soil of this area ranged from 6.88 to 8.10, electrical conductivity from 0.067 to 0.433 dSm<sup>-1</sup>, soil organic matter content ranged from 1.82 to 2.53% and lime from 2.9 to 14.1%. In marginal rhizosphere soils, pH values ranged from 6.17 to 8.02, electrical conductivity from 0.044 to 0.287 dSm<sup>-1</sup>, lime contents from 2.8 to 14.5% and soil organic matter contents ranged from 1.10 to 2.13%. Relatively higher soil organic matter contents in fertile and marginal soils were recorded as soils attached with roots contain more organic materials with higher microbial activities (Alexander, 1978).

**Soil nutrient concentrations:** Data in Table 2 describe the concentrations of soil total N and AB-DTPA extractable P, K, Zn, Fe, Cu and Mn in soils of Malakand division. Total N ranged from 0.223 to 0.350%, AB-DTPA extractable P from 6.3 to 12.1 mg kg<sup>-1</sup>, K from 115.2 to 294.3 mg kg<sup>-1</sup>, Zn from 0.46 to 1.45 mg kg<sup>-1</sup>, Fe from 9.64 to 41.28 mg kg<sup>-1</sup>, Cu from 4.8 to 9.6 mg kg<sup>-1</sup> and Mn ranged from 42.5 to 135.1 mg kg<sup>-1</sup> in well managed fertile rhizosphere soil of Malakand division. In marginal rhizosphere soil of this area, AB-DTPA extractable P from 3.6 to 10.3 mg kg<sup>-1</sup>, K from 107.6 to 236.6 mg kg<sup>-1</sup>, Zn from 0.17 to 1.04 mg kg<sup>-1</sup>, Fe from 8.72 to 35.16 mg kg<sup>-1</sup>, Cu from 3.4 to 8.5 mg kg<sup>-1</sup> and Mn ranged from 27.1 to 106.1 mg kg<sup>-1</sup> and total N ranged from 0.211 to 0.298%. Relatively higher total soil N contents in fertile and marginal soils were recorded as soils attached with roots contain more organic materials with higher microbial activities (Alexander, 1978).

**Density of AM fungal spores and their roots colonization in wheat crop:** Density of AM fungal spores varied greatly due to different soil types in different locations (Table 3). In fertile soil, high numbers (>3333 spores kg<sup>-1</sup> soil) of white spores were found in Kanju, Beha and Besham soil series, brown spores in Pirsabak and Mingora soil series and black spores were recorded in Shangla soil series of Malakand division. Medium (1400–3333 spores kg<sup>-1</sup> soil) or lower (<1333 spores kg<sup>-1</sup> soil) numbers of white, brown and black spores were recorded in all other soil series of this area. In marginal soil, maximum numbers of white spores (>3333 spores kg<sup>-1</sup> soil) were found in Kanju, Bunir, Mingora and Alpuri soil series, brown spores in Beha, Mingora and Pirsabak soil series whereas maximum black spores were recorded in Badwan, Bunir, Marghuzar, Shangla and Besham soil series. Medium (1400–3333 spores kg<sup>-1</sup> soil) or lower (<1333 spores kg<sup>-1</sup> soil) were found in Kanju, Bunir, Mingora and Alpuri soil series, brown spores in Beha, Mingora and Pirsabak soil series whereas maximum black spores were recorded in Badwan, Bunir, Marghuzar, Shangla and Besham soil series. Medium (1400–3333 spores kg<sup>-1</sup> soil) or lower (<1333 spores kg<sup>-1</sup> soil) or lower (<1333 spores kg<sup>-1</sup> soil) numbers of white, brown and black spores were recorded in all other soil series of Malakand division.

Root infection rates by AM fungi varied in wheat crop from one site to another. In fertile soil of Malakand division, 32 to 56% AM fungal infection rates were noted in roots of the wheat crop where as 44 to 68% infection rates by mycorrhizal fungi were observed in marginal soil of this area (Table 3). In the area of Malakand division, relatively more roots infections rates in wheat crop by AM fungi were observed in unfertilized soil (S-II) as compared with fertilized (S-I) soil (Fig. 1) and more number of AM fungal spores caused to increase the roots infections rates of wheat crop in this area (Fig. 2). The relationship between pH values and root colonization indicated that infections rates by AM fungi in wheat crop decreased with increases in soil pH values (Fig. 3) and higher wheat root infections rates by AM fungi were noted in soil with lower organic matter contents (Fig. 4).

**Density of AM fungal spores and their roots colonization in maize crop:** Data regarding density of AM fungal spores and maize roots infection are given in Table 4.

ies         Location         Soil type         pH         E.C.         SOM         Line           Badwan         S-1         7.85         0.210         2.27         7.1           Badwan         S-1         7.85         0.210         2.27         7.1           Badwan         S-1         7.85         0.210         2.27         7.1           Eardaki         8.01         0.169         2.10         13.6           Kabal         7.93         0.173         2.42         6.9           Beha         7.93         0.173         2.42         6.9           Beha         7.51         0.433         1.82         13.3           Zar         Manglore         7.51         0.433         1.82         13.3           Zar         Manglore         7.75         0.082         2.13         7.4           Alpuri         7.40         0.308         2.12         2.9         12.4           Alpuri         7.40         0.308         2.12         2.9         14.5           Rabal         7.40         0.308         2.13         7.4           Besham         7.40         0.308         2.13         7.4	esLocationSoil typeBadwanBadwanS-1BadwanS-1LandakiShahi Nagar*KabalBeha*Shanglore**Charbagh**AlpuriShangla*BeshamShangla*Shahi Nagar**Shahi Nagar*Shahi Shahi Nagar*Shahi Shahi Shahi Shahi*Shahi Shahi Shahi Shahi*Shahi Shahi	oar.	:	нu	C II	NO S	T times	
Badwan       S-I       7.85       0.210       2.27       7.1         Landaki       "       8.01       0.169       2.10       13.6         Kabal       "       8.06       0.229       2.14       14.1         Kabal       "       7.93       0.173       2.42       6.9         Kabal       "       7.93       0.173       2.42       6.9         Beha       "       7.51       0.433       1.82       13.6         Charbagh       "       7.51       0.433       1.82       13.3         Alpuri       "       7.75       0.082       2.00       5.8         Shangla       "       7.40       0.308       2.12       2.4         Alpuri       "       7.40       0.308       2.13       7.4         Badwan       "       7.40       0.308       2.13       7.4         Badwan       "       7.40       0.308       2.13       7.4         Badwan       "       7.40       0.308       2.13       7.4         Shahi Nagar       "       7.40       0.308       2.13       7.4         Shahan       "       7.40       0.308	Badwan Landaki Shahi Nagar Kabal Beha ar Charbagh chela Khwazakhela Shangla Alpuri Besham Besham Besham Besham Shanda Shanda Charbagh Char	idwan ndaki ahi Nagar	oil type	(1:5)	(dSm <sup>-1</sup> )	(%)	(%)	Soil textural class
Landaki       "       8.01       0.169       2.10       13.6         Shahi Nagar       "       8.06       0.229       2.14       14.1         Kabal       "       7.93       0.173       2.42       6.9         Beha       "       7.93       0.173       2.42       6.9         Rabal       "       7.51       0.433       1.82       13.3         Anglore       "       7.51       0.443       1.82       13.3         Shangla       "       7.75       0.082       2.00       5.8         Alpuri       "       7.11       0.67       2.43       3.8         Besham       "       7.40       0.308       2.12       2.9         Besham       "       7.40       0.308       2.12       2.9         Besham       "       7.40       0.308       2.12       2.9         Badwan       "       7.40       0.308       2.12       2.9         Basham       "       7.40       0.338       2.12       2.9         Basham       "       7.40       0.338       2.12       2.9         Basham       "       7.40       0.38       <	Landaki Shahi Nagar Kabal Beha ar Kabal Beha Charbagh chela Khwazakhela Shangla Alpuri Besham Besham Shahi Nagar Kabal ar Manglore Charbagh chela Khwazakhela	ndaki ahi Nagar	S-I	7.85	0.210	2.27	7.1	Sandy loam
Shahi Nagar       "       8.06       0.229       2.14       14.1         Kabal       "       7.93       0.173       2.42       6.9         Beha       "       7.93       0.173       2.42       6.9         Beha       "       7.51       0.433       1.82       13.3         Abuit       "       7.51       0.433       1.82       13.3         Abuit       "       7.75       0.082       2.00       5.8         Alpuri       "       7.40       0.308       2.14       7.4         Alpuri       "       7.40       0.308       2.12       2.9         Backam       "       7.40       0.308       2.12       2.9         Badwan       "       7.11       0.067       2.43       3.8         Badwan       "       7.40       0.308       2.12       2.9         Shahi Nagar       "       7.4       0.067       2.43       3.8         Kabal       "       7.4       1.067       2.43       3.6         Shadyan       S-II       7.9       0.079       2.13       7.4         Shadyan       S       0.189       0.176	Shahi Nagar Kabal Beha Beha Alanglore Charbagh Khwazakhela Shangla Alpuri Besham Besham Shahi Nagar Kabal ar Manglore Charbagh chela Khwazakhela	ahi Nagar		8.01	0.169	2.10	13.6	Sandy loam
Kabal       7.93       0.173       2.42       6.9         arr       Manglore       7.51       0.433       1.82       13.3         Beha       R.       7.51       0.433       1.82       13.3         Charbagh       7       7.51       0.433       1.82       13.3         Charbagh       7       7.03       0.145       2.53       2.9         Shangla       7       7.03       0.145       2.53       2.9         Alpuri       7       7.03       0.163       1.82       13.3         Alpuri       7       7.10       0.067       2.43       3.8         Badwan       7       7.40       0.308       2.12       2.9         Badwan       7.11       0.067       2.43       3.8       12.4         Shahi Nagar       7       7.40       0.308       2.13       7.4         Shahi Nagar       7       7.40       0.308       2.13       7.4         Shahi Nagar       7       7.40       0.33       2.13       7.4         Shahi Nagar       7       7.40       0.176       1.86       12.7         Shahi Nagar       7       7.58       0.	Kabal Beha ar Manglore Charbagh chela Khwazakhela Shangla Alpuri Besham Badwan Landaki Shahi Nagar Kabal Beha ar Manglore Charbagh chela Khwazakhela			8.06	0.229	2.14	14.1	Clay loam
ar       Beha       "       8.10       0.220       2.14       7.8         ar       Manglore       "       7.51       0.433       1.82       13.3         charbagh       "       7.51       0.433       1.82       13.3         charbagh       "       7.75       0.082       2.53       2.9         shangla       Khwazakhela       "       7.75       0.082       2.00       5.8         Alpuri       "       7.40       0.308       2.12       2.9       29         Alpuri       "       7.40       0.308       2.12       2.9       29         Badwan       "       7.11       0.067       2.43       3.8       12.4         Badwan       "       7.11       0.067       2.43       3.8       12.4         Shahi Nagar       "       7.96       0.189       2.13       7.4       2.5         Shabal       "       7.96       0.189       2.13       7.4       2.5         Shabal       "       7.96       0.189       2.13       7.4         Shabal       "       7.96       0.176       1.86       12.7         Shabal       "	ar Beha ar Manglore " Charbagh chela Khwazakhela " Shangla " Alpuri Besham " Besham " Besham " Landaki " Shahi Nagar " Kabal " Shanda " Charbagh " Charbagh " Shanda "	ıbal		7.93	0.173	2.42	6.9	Silt loam
ar       Manglore       7.51       0.433       1.82       13.3         chela       Khwazakhela       7.75       0.082       2.53       2.9         chela       Khwazakhela       7.75       0.082       2.00       5.8         Shangla       7.75       0.082       2.00       5.8       2.4         Alpuri       7.74       0.082       2.00       5.8       2.4         Badwan       7.11       0.067       2.43       3.8       2.4         Badwan       8.11       7.96       0.189       2.13       7.4         Badwan       8.02       0.176       1.86       12.7         Shahi Nagar       7       7.96       0.173       1.92       3.6         Kabal       7       7.96       0.173       1.92       3.6         Beha       7       7.8       0.173       1.92       3.6         ar       Manglore       7       7.23       0.148       1.10       7.1         Shangla       7       7.23       0.165       1.30       3.3         Alpuri       7       7.32       0.165       1.47       10.5         Alpuri       6.17       0.	ar Manglore " Charbagh " Charbagh Khwazakhela Khwazakhela Khwazakhela " Shangla " Alpuri " Besham " Badwan S-II Landaki " Kabal " Kabal " Shahi Nagar " Kabal " Charbagh " Charbagh " Shanda "	sha		8.10	0.220	2.14	7.8	Loam
chela       Khwazakhela       "       7.03       0.145       2.53       2.9         shangla       "       7.75       0.082       2.00       5.8       2.5         Shangla       "       6.88       0.163       1.89       12.4         Alpuri       "       7.40       0.308       2.12       2.9         Badwan       "       7.11       0.067       2.43       3.8         Badwan       S-II       7.96       0.189       2.13       7.4         Badwan       S-II       7.96       0.176       1.86       12.7         Badwan       "       7.11       0.067       2.43       3.8         Rabal       "       7.96       0.176       1.86       12.7         Shahi Nagar       "       7.96       0.173       1.92       3.6         Rabal       "       7.28       0.173       1.92       3.6         Beha       "       7.23       0.148       1.10       7.1         Charbagh       "       7.32       0.165       1.47       10.5         Shangla       "       7.32       0.165       1.47       10.5         Alpuri <td< td=""><td>chela Charbagh chela Khwazakhela Khwazakhela Khwazakhela Shangla """"""""""""""""""""""""""""""""""""</td><td>anglore</td><td></td><td>7.51</td><td>0.433</td><td>1.82</td><td>13.3</td><td>Sandy loam</td></td<>	chela Charbagh chela Khwazakhela Khwazakhela Khwazakhela Shangla """"""""""""""""""""""""""""""""""""	anglore		7.51	0.433	1.82	13.3	Sandy loam
chela       Khwazakhela       7.75       0.082       2.00       5.8         Shangla       "       6.88       0.163       1.89       12.4         Shangla       "       7.40       0.308       2.12       2.9         Besham       "       7.40       0.308       2.12       2.9         Badwan       "       7.11       0.067       2.43       3.8         Shahi Nagar       "       7.96       0.189       2.13       7.4         Kabal       "       7.96       0.176       1.86       12.7         Shanglore       "       7.28       0.173       1.92       3.6         Resham       "       7.28       0.173       1.92       3.6         Resham       "       7.23       0.148       1.10       7.1         Resham       "       7.23       0.165       1.47       10.5         Anburi       "       7.53       0.1	chela Khwazakhela Khwazakhela Khwazakhela Shangla """"""""""""""""""""""""""""""""""""	ıarbagh		7.03	0.145	2.53	2.9	Silt loam
Shangla       "       6.88       0.163       1.89       12.4         Alpuri       "       7.40       0.308       2.12       2.9         Besham       "       7.11       0.067       2.43       3.8         Badwan       "       7.11       0.067       2.43       3.8         Badwan       "       7.11       0.067       2.43       3.8         Badwan       S-II       7.96       0.189       2.13       7.4         Shahi Nagar       "       7.96       0.176       1.86       12.7         Shahi Nagar       "       7.96       0.173       1.92       3.6         Beha       "       7.28       0.173       1.92       3.6         Beha       "       7.23       0.148       1.10       7.1         ar       Manglore       "       7.32       0.165       1.45       5.3         chela       Khwazakhela       "       7.32       0.165       1.47       10.5         Shangla       "       7.53       0.165       1.47       10.5       9.4         Alpuri       "       7.53       0.169       1.47       10.5       9.4	Shangla Shangla Alpuri Alpuri Besham Badwan S-II Landaki S-II Kabal Kabal ar Kabal ar Manglore " " " " " " " " " " " " " " " " " " "	ıwazakhela		7.75	0.082	2.00	5.8	Silty clay loam
n       Alpuri       7.40       0.308       2.12       2.9         n       Besham       "       7.11       0.067       2.43       3.8         n       Badwan       "       7.11       0.067       2.43       3.8         n       Badwan       "       7.11       0.067       2.43       3.8         n       Badwan       S-II       7.96       0.176       1.86       12.7         k       Kabal       "       7.96       0.287       1.59       14.5         k       Kabal       "       7.28       0.173       192       3.6         ik       Beha       "       7.28       0.173       192       3.6         ix       7.28       0.173       192       3.6       7.1         ix       7.23       0.148       1.10       7.1         ix       7.32       0.165       1.30       3.3         akhela       Khwazakhela       "       7.53       0.165       1.47       10.5         a       Shangla       "       7.53       0.165       1.47       10.5       9.4         a       Alpuri       "       7.53       0.165	n Alpuri n Besham n Besham n Badwan " Landaki " Shahi Nagar " k Kabal k Kabal " Izar Manglore " akhela Khwazakhela "	angla		6.88	0.163	1.89	12.4	Silt loam
n Besham " 7.11 0.067 2.43 3.8 n Badwan S-II 7.96 0.189 2.13 7.4 3 Landaki " 8.02 0.176 1.86 12.7 3 shahi Nagar " 7.96 0.287 1.59 14.5 6 Kabal " 7.96 0.287 1.59 14.5 6 12.7 3 1.92 3.6 7 uzar Manglore " 7.23 0.148 1.10 7.1 3 ra Charbagh " 7.23 0.148 1.10 7.1 3 ra Shangla " 7.53 0.189 1.63 6.4 5 a Alpuri " 6.17 0.059 1.47 10.5 9 Besham " 7.07 0.044 1.88 2.9 5 1.0.5 9 1.47 10.5 5 1.0.5 9 1.47 10.	n Besham n Badwan S-II Landaki S-II ak Kabal " ak Kabal " uzar Manglore " ra Charbagh " akhela Khwazakhela "	puri		7.40	0.308	2.12	2.9	Silt loam
n       Badwan       S-II $7.96$ $0.189$ $2.13$ $7.4$ Landaki       "       8.02 $0.176$ $1.86$ $12.7$ ak       Kabal       " $7.96$ $0.287$ $1.59$ $14.5$ $9$ ak       Kabal       " $7.96$ $0.287$ $1.59$ $14.5$ $9$ ak       Kabal       " $7.28$ $0.173$ $1.92$ $3.6$ $14.5$ $9$ ak       Beha       " $7.28$ $0.173$ $1.92$ $3.6$ $7.4$ $5.3$ uzar       Manglore       " $7.28$ $0.173$ $1.92$ $3.6$ $7.1$ uzar       Manglore       " $7.23$ $0.148$ $1.10$ $7.1$ $92$ akhela       Khwazakhela       " $7.32$ $0.165$ $1.63$ $6.4$ $92$ akhela       Khwazakhela       " $7.53$ $0.165$ $1.47$ $10.5$ $9.4$ akhela       Manglore       " $7.53$ $0.166$ $1.63$ $6.4$ $9.6$	n Badwan S-II Landaki " Shahi Nagar " ak Kabal " Beha " uzar Manglore " ra Charbagh " skhela Khwazakhela "	sham		7.11	0.067	2.43	3.8	Silt loam
Landaki       "       8.02       0.176       1.86       12.7         shahi Nagar       "       7.96       0.287       1.59       14.5       0         sk       Kabal       "       7.28       0.173       1.92       3.6       9         uzar       Beha       "       7.28       0.173       1.92       3.6       9         uzar       Beha       "       7.28       0.148       1.10       7.1       9         uzar       Manglore       "       7.23       0.148       1.10       7.1       9         ra       Charbagh       "       7.32       0.148       1.10       7.1       9         ra       Charbagh       "       7.53       0.165       1.30       3.3       9         akhela       Khwazakhela       "       7.53       0.189       1.63       6.4       9         a       Shangla       "       6.17       0.059       1.47       10.5       9         a       Alpuri       "       6.83       0.158       1.47       10.5       9         a       Alburi       "       6.83       0.158       1.47       10.5       9 </td <td>Landaki Shahi Nagar " Shahi Nagar " Kabal " Beha uzar Manglore " ra Charbagh " sakhela Khwazakhela "</td> <td>ldwan</td> <td>S-II</td> <td>7.96</td> <td>0.189</td> <td>2.13</td> <td>7.4</td> <td>Sandy loam</td>	Landaki Shahi Nagar " Shahi Nagar " Kabal " Beha uzar Manglore " ra Charbagh " sakhela Khwazakhela "	ldwan	S-II	7.96	0.189	2.13	7.4	Sandy loam
ak       Shahi Nagar       "       7.96       0.287       1.59       14.5         ak       Kabal       "       7.28       0.173       1.92       3.6       3.6         Beha       "       7.28       0.173       1.92       3.6       3.6         nuzar       Beha       "       7.28       0.188       1.54       5.3       3.6         nuzar       Manglore       "       7.23       0.148       1.10       7.1       30         vra       Charbagh       "       7.23       0.165       1.30       3.3       3         zakhela       Khwazakhela       "       7.53       0.189       1.63       6.4       3         la       Shangla       "       7.53       0.189       1.63       6.4       3         m       Alpuri       "       6.17       0.059       1.47       10.5       9         Mangla       "       6.83       0.158       1.88       2.9       1.05       9         Mangla       "       6.83       0.158       1.47       10.5       9       1.47       10.5       10	ak Kabal ak Kabal ak Kabal ak Kabal "" Beha " nuzar Manglore " ra Charbagh " zakhela Khwazakhela " banda Shanda	ndaki		8.02	0.176	1.86	12.7	Sandy loam
ak     Kabal     "     7.28     0.173     1.92     3.6       Beha     "     7.28     0.188     1.54     5.3       nuzar     Bandore     "     7.88     0.188     1.54     5.3       nuzar     Manglore     "     7.23     0.148     1.10     7.1       ora     Charbagh     "     7.23     0.148     1.10     7.1       ora     Charbagh     "     7.32     0.165     1.30     3.3       zakhela     Khwazakhela     "     7.53     0.189     1.63     6.4       da     Shangla     "     7.53     0.189     1.63     6.4       da     Shangla     "     6.17     0.059     1.47     10.5       i     Alpuri     "     6.83     0.158     1.88     2.9	ak Kabal " Beha " Duzar Beha " Duzar Manglore " Dra Charbagh " Zakhela Khwazakhela " Chanda	ahi Nagar		7.96	0.287	1.59	14.5	Clay loam
Beha       "       7.88       0.188       1.54       5.3       1         nuzar       Manglore       "       7.23       0.148       1.10       7.1       7         ra       Charbagh       "       7.23       0.148       1.10       7.1       7         ra       Charbagh       "       7.23       0.165       1.30       3.3       7         zakhela       Khwazakhela       "       7.53       0.189       1.63       6.4       7         Ja       Shangla       "       7.53       0.189       1.63       6.4       7         i       Alpuri       "       6.17       0.059       1.47       10.5       1         i       Alpuri       "       6.83       0.158       1.88       2.9       2.9         m       Bacham       "       6.83       0.158       1.08       2.9       2.9	Beha " nuzar Beha " nuzar Manglore " rate Charbagh " zakhela Khwazakhela " ta Shanola "	ıbal		7.28	0.173	1.92	3.6	Silt loam
Manglore       "       7.23       0.148       1.10       7.1         Charbagh       "       7.23       0.148       1.10       7.1         Charbagh       "       7.32       0.165       1.30       3.3       3         Khwazakhela       "       7.53       0.189       1.63       6.4       3         Shangla       "       7.53       0.189       1.63       6.4       3         Alpuri       "       6.17       0.059       1.47       10.5       3         Beeban       "       6.83       0.158       1.88       2.9       3	Manglore " Charbagh " Khwazakhela " Shanola "	tha		7.88	0.188	1.54	5.3	Loam
Charbagh       "       7.32       0.165       1.30       3.3         Khwazakhela       "       7.53       0.189       1.63       6.4       3.3         Shangla       "       7.53       0.189       1.63       6.4       3.3         Alpuri       "       6.17       0.059       1.47       10.5       3.3         Bescham       "       6.83       0.158       1.88       2.9       3.8	Charbagh Khwazakhela Shanola	anglore		7.23	0.148	1.10	7.1	Sandy loam
Khwazakhela       "       7.53       0.189       1.63       6.4       3         Shangla       "       6.17       0.059       1.47       10.5       3         Alpuri       "       6.83       0.158       1.88       2.9       3         Besham       "       7.07       0.044       1.08       2.9       3	Khwazakhela " Shanola "	ıarbagh		7.32	0.165	1.30	3.3	Silt loam
Shangla     "     6.17     0.059     1.47     10.5     9       Alpuri     "     6.83     0.158     1.88     2.9     9       Basham     "     7.07     0.044     1.08     2.8     2.9	Shanela "	ıwazakhela		7.53	0.189	1.63	6.4	Silty clay loam
Alpuri " 6.83 0.158 1.88 2.9 5 Besham " 7.07 0.044 1.08 2.8 5	Duangia	angla		6.17	0.059	1.47	10.5	Silt loam
Bacham " 707 0.044 1.08 3.8	Alpuri "	puri		6.83	0.158	1.88	2.9	Silt loam
DCSIIdIII 1.70 1.07 2.0 2.0		sham		7.07	0.044	1.98	2.8	Silt loam

1304

		Table 2. Soil n		oncentration	utrients concentrations of Malakand Division	nd Division.			
Coil contoc	Lootion	Coil trucc	N	Ь	К	Zn	Fe	Cu	Mn
Soll Series	LOCATION	sour types	(%)			(mg F	Kg <sup>-1</sup> )		
Badwan	Badwan	S-I	0.333	10.3	270.5	0.83	15.84	4.8	127.7
Kanju	Landaki		0.223	11.8	294.3	0.71	9.64	5.6	135.1
Bunir	Shahi Nagar		0.228	9.1	210.3	0.46	18.62	5.3	42.5
Pirsabak	Kabal		0.249	9.2	201.7	0.81	18.34	7.4	45.8
Beha	Beha		0.350	10.7	235.1	1.05	17.90	9.3	83.5
Marghuzar	Manglore		0.306	12.1	192.0	1.44	17.3	6.2	45.5
Mingora	Charbagh		0.341	6.8	122.4	1.41	27.1	8.8	55.3
Khwazakhela	Khwazakhela		0.298	6.3	148.5	0.64	25.9	9.6	38.7
Shangla	Shangla		0.263	10.9	139.3	0.56	41.28	6.3	104.5
Alpuri	Alpuri		0.303	10.2	166.7	1.45	25.92	9.1	62.7
Besham	Besham		0.298	10.5	115.2	1.14	30.14	5.9	65.5
Badwan	Badwan	II-S	0.298	4.5	117.2	0.71	14.50	3.4	106.1
Kanju	Landaki		0.220	10.3	236.6	0.29	8.72	4.9	103.9
Bunir	Shahi Nagar		0.215	3.6	139.1	0.17	16.06	4.5	28.6
Pirsabak	Kabal		0.211	8.7	202.2	0.73	12.12	5.6	41.2
Beha	Beha		0.298	6.1	227.9	0.78	17.38	8.3	52.4
Marghuzar	Manglore		0.228	7.1	160.4	0.86	10.36	4.5	27.1
Mingora	Charbagh		0.241	5.7	115.3	1.04	21.40	7.9	48.7
Khwazakhela	Khwazakhela		0.290	5.5	108.2	0.59	19.26	8.5	36.2
Shangla	Shangla		0.260	7.3	119.3	0.31	35.16	6.2	46.8
Alpuri	Alpuri		0.248	8.1	116.1	1.03	16.44	8.2	48.8
Besham	Besham		0.271	7.4	107.6	0.99	21.04	3.9	42.2
S-I= Fertilized so S-II= Unfertilized	S-I= Fertilized soil with better crop growth conditions S-II= Unfertilized soil with poor plant growth conditions	owth conditions growth condition	JS						

			Spo	Spores concentrations	ions	Root infection
Soll Series	госанов	sour types	White	Brown	Black	(%)
Badwan	Badwan	S-I	Medium	Low	Low	32
Kanju	Landaki		High	Low	Low	36
Bunir	Shahi Nagar		Low	Medium	Medium	44
Pirsabak	Kabal		Medium	High	Low	48
Beha	Beha		High	Low	Low	36
Marghuzar	Manglore		Medium	Low	Low	44
Mingora	Charbagh		Medium	High	Low	56
Khwazakhela	Khwazakhela		Medium	Low	Medium	44
Shangla	Shangla		Medium	Medium	High	49
Alpuri	Alpuri		Medium	Medium	Medium	42
Besham	Besham		High	Medium	Medium	40
Badwan	Badwan	S-II	Medium	Low	High	47
Kanju	Landaki		High	Medium	Medium	44
Bunir	Shahi Nagar		High	Medium	High	52
Pirsabak	Kabal		Low	High	Medium	64
Beha	Beha		Medium	High	Low	52
Marghuzar	Manglore		Medium	Low	High	64
Mingora	Charbagh		High	High	Medium	68
Khwazakhela	Khwazakhela		Medium	Medium	Medium	56
Shangla	Shangla		Medium	Low	High	59
Alpuri	Alpuri		High	Medium	Low	52
Besham	Besham	"	Medium	Low	High	52

1306

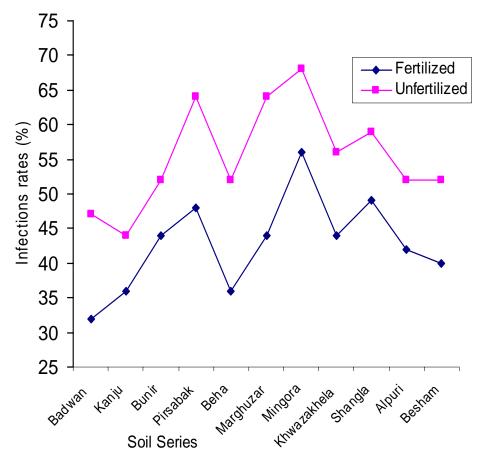


Fig. 1. Comparison of wheat infection rats by AM fungi in fertilized and unfertilized soils.

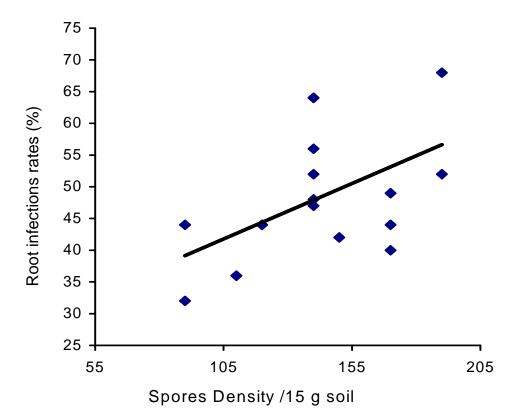


Fig. 2. Relationship between spores density and AM infection rates in wheat roots.

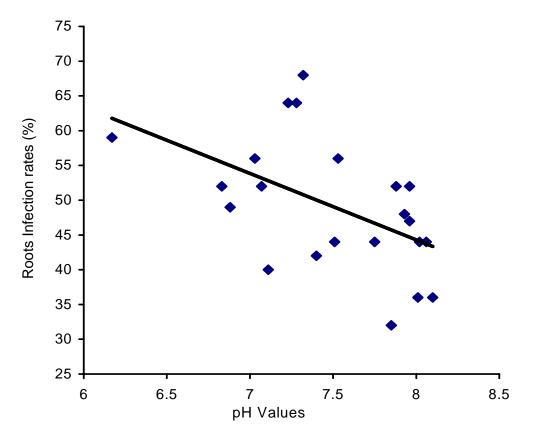


Fig. 3. Relationship between pH values and AM infection in wheat root of Malakand soils.

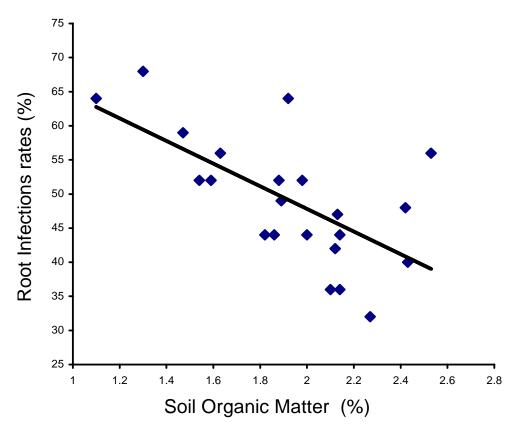


Fig. 4. Relationship between soil organic matter and AM infection rates in wheat roots.

	Spores concentrations		S	<b>Spores concentrations</b>	ns	Root infection
Soll series	госацов	source sources	White	Brown	Black	(%)
Badwan	Badwan	S-I	Low	Medium	Low	29
Kanju	Landaki		Low	Medium	Medium	28
Bunir	Shahi Nagar		Low	Medium	Low	24
Pirsabak	Kabal		High	Medium	High	48
Beha	Beha		Low	Medium	Medium	30
Marghuzar	Manglore		Medium	High	Low	34
Mingora	Charbagh		Low	Medium	Low	32
Khwazakhela	Khwazakhela		Low	Medium	High	37
Shangla	Shangla		Medium	High	Medium	34
Alpuri	Alpuri		Medium	Low	Medium	48
Besham	Besham		High	Medium	Medium	42
Badwan	Badwan	S-II	Medium	High	Low	40
Kanju	Landaki		High	Medium	Medium	32
Bunir	Shahi Nagar		High	Medium	Low	42
Pirsabak	Kabal		Low	Medium	High	60
Beha	Beha		Medium	High	Low	42
Marghuzar	Manglore		High	Medium	Medium	54
Mingora	Charbagh		Low	Medium	Low	40
Khwazakhela	Khwazakhela		Medium	High	Medium	50
Shangla	Shangla		High	Medium	Low	45
Alpuri	Alpuri		Low	High	Medium	56
Besham	Besham		Low	Medium	High	50

It can be inferred from the data regarding the AM fungal spores density of different color and their root colonization in maize crop of fertilized and unfertilized soils of Malakand division that high numbers (>3333 spores kg<sup>-1</sup> soil) of white spores were found in Pirsabak and Besham soil series, brown spores in Badwan, Beha, Khwazakhela and Alpuri soil series and black spores were found in Pirsabak and Besham soil series in fertilized soil of Malakand division. All other soil series of this area gave either medium  $(1400 - 3333 \text{ spores } \text{kg}^{-1} \text{ soil})$  or lower (<1333 spores  $\text{kg}^{-1} \text{ soil})$  numbers of white, brown and black spores. In unfertilized soil, maximum numbers of white spores (>3333 spores kg<sup>-1</sup> soil) were found in Kanju, Bunir, Marghuzar and Shangla soil series, brown spores in Badwan, Beha, Khwazakhela and Alpuri soil series where as maximum black spores were noted in Pirsabak and Besham soil series. Medium  $(1400 - 3333 \text{ spores kg}^{-1} \text{ soil})$  or lower (<1333 spores kg<sup>-1</sup> soil) numbers of white, brown and black spores were recorded in all other soil series of Malakand division. Data on root infections rates by AM fungi in maize crop ranged from 24 to 48% in fertile soil and that of 32 to 60% in marginal soil of Malakand division (Table 4). Like wheat crop, relatively more roots infections rates in maize crop by AM fungi were observed in marginal soil and more number of AM fungal spores caused increased root infections rates.

Density and their roots infections rates by AM fungi varied in different soil types and locations. The highest number of AM fungal spores and their infections of wheat and maize roots in some soil series of NWFP may be attributed to the root exudates of these crops, which stimulated the germination of mycorrhizal spores and their infection rates under the prevailing conditions of the area. The most plant species in Gramineae family are normally mycorrhizal (Hayman, 1982). Morley & Mosse (1976) reported that wheat and maize crops vary in mycorrhizal infections according to cultivars and environmental conditions. Soils, plants, environment and their management mainly affect the mycorrhizal fungi, their development and crop root infections in an ecosystem. The diversity of AM fungal species and their roots infection intensity decline from natural ecosystem to high input agricultural systems. Relatively high numbers of AM fungal spores and their roots colonization in wheat and maize crops were found in marginal soil. Fertilizers applications may counteract super optimum AM fungal populations (Sieverding, 1989) as the reactions of fertilizers in soils are faster enough and the plants are not or only slightly depend on AM fungi and thus the reproduction of fungi will be low under this conditions, which will result low AM populations and root colonization in such soils generally.

**Identification of AM fungal spores:** Spores of *Glomus fasciculatum* were found in abundance in all soil samples where as spores of G. *intraradices* G. *mosseae*, G. *Aggregatum*, *Acaulospora melleae*, *Sclerocystis* and *Sclerocystis pakistanica* (Iqbal & Parveen, 1980) were also identified in the soil samples but in lower densities. These identified spores still require further confirmation by crop inoculation, re-isolation and re-identification.

### Conclusion

It is concluded from the results of this study that relatively higher AM fungal spores and their root colonization in wheat and maize crops were observed in unfertilized soil with varied spores density and infections intensity from one site to another under different agro-ecological conditions. Higher spores density caused increased roots infections intensity in wheat and maize crops and roots infection rates were higher in soil with low organic matter contents. There were almost similar trends of AM fungal density and their roots intensity in wheat and maize crops in area under investigations. Possible interactions of AM fungi with other soil microorganisms, there mass production and management through agronomic practices to further improve their efficiency for economically feasible and sustainable crop production are needed to be focused in future research.

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