Influence of Weeds on Arbuscular Mycorrhizal (AM) Diversity and Biomass Production in Jowar and Safflower During Rabi Season

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Abstract: **Arbuscular mycorrhizal fungi (AMF) are important soil microorganisms that form beneficial symbioses with the roots of most agricultural plants. The present study was initiated to examine the effect of the weeds on AM fungal association and the subsequent effect on productivity in jowar and safflower at 90 DAS. In Sorghum bicolor, 77% AM root colonization anda spore density of 538 spores/100g soil was recorded. While in Carthamus tinctorius,70%AM root colonization and a spore density of 539 spores/100g soil were recorded.In all, 13 weedy plant species were recorded from sorghum and safflower field during the rabi season. Among these, highest % root colonization was found in Dichanthiumcaricosum(84.0±3.51)followed by Dinebera retiflexa (75.44±1.55)while minimum in Abelomoschus manihot (41.56±2.55).The spore density was found maximum in A.indicum (1168spores/100g soil) followed byC.benghalensis(1003 spores/100g soil) while minimum inParthenium hysterophorus and Commelina albescens(136 spores/100g soil) respectively. A total of four AM fungal species viz.,Acaulospora tuberculata, Rhizophagus multicaule, Rhizophagus aggregatum, and Gigaspora margarita were found and Rhizophagus aggregatum found dominant in both the crop.**

Key Words: **AMF colonization, spore density, biomass productivity, Mycorrhizal status,**

INTRODUCTION

*Sorghum bicolor*L.(Sorghum) is an important C_4 crop grown for food, feed, and fibre. Good grain-producing varieties for foodprovide calories and essential nutrients for humans and are particularly important as survival crops in the parts of Africa and Asia (Shakoor*et al.*, 2014).Thus, grain yield and increased nutrient concentrations, particularly Zn and Fe, are essential for people who depend on sorghum as a staple food (Cakmak and Kutman, 2017). Safflower *Carthamus tinctorius* L. (Safflower) is an excellent oil-yielding plantadapted to moderate drought climates and low water rates. Safflower was primarily cultivated for its pharmaceutical usage but is nowgrown to produce edible oil from the seeds (McPherson *etal.*, 2004). The main advantages of this plant are the high percentage of seed oil (25-40%) and its high quality (due to the presence of oleic acid and linoleic acid), resistance to abiotic stresses such as salinity, drought, and chilling (Nabipour *et al.*, 2007).

Study sites lack natural resources and are prone to drought, rocky, and dry with low and uncertain rainfall. It leads to loss of soil fertility due to excessive use of fertilizers that have adversely impacted agricultural productivity and soil quality and have caused soil degradation. Now there is a growing realization that adopting ecological and sustainable farming practices can only reverse the refuse trend in the global productivity and environment protection (Jim, 1988; Wani and Lee, 1992; Wani*et al.*,1995). It was reported that the distribution of certain AM fungal species had been related to physicochemical parameters (Abbott and Robson, 1991), vegetation, or hydrologic condition of the soil(Ingham and Wilson,1999;Miller and Bever,1999).

Mycorrhizaeare found in soils with very different water establishments, including various habitats. Mycorrhizal fungi haveestablished symbiotic relationships with plants and play a vital role in plant growth, disease management, and soil quality. The ‘P’ deficiency is widespread in tropical soils in existing soils and under such conditions (Smith et al., 2003). Weeds are an important variable in organic crop production, both economically and ecologically and weeds may serve to maintain diversity and agronomically beneficial taxa of AM fungi (Nicolson,1967). It was observed that the number of AM fungal spores increased significantly

with increasing weed species numbers(Vatovec et al.,2005).Therefore the present investigation was aimed atthe status and influence of weeds on biomass productivity and the mycorrhizal status of jowar and Safflower crops in the rabi season.

Salinity stress can produce osmotic stress and limit plants' ability to take up water. Mycorrhizae canadjust the osmotic potential of their host plants by increasing the concentration of organic products such asproline, glycine betaine, carbohydrates, sucrose and mannitol, and thus improve the water use efficiency of plants (Porcel*et al.*,2012).

Mycorrhiza is considered one of the most essential biological tools for enhancing plant growth and shoots biomass and maintaining a sustainable environment in agricultural production and also noted that utilization of AM is an eco-friendly approach and a valuable component to achieve sustainable production in agriculture crops

MATERIALS AND METHODS

Physico-chemical parameters

Soils fromjowar and safflower growing fields were collected for analysis. The soil was air-dried, ground, and sieved using a 2 mm sieve and used for analysis.Various parameters *viz.*,colour, pH, Electrical Conductivity (EC), Organic carbon, and macro- and micro- nutrients were analysed. Nitrogen (N) was estimated by the alkaline permanganate method by using Kjeldahl tube (Subbiah and Asija, 1956). Available Phosphorus (P) in soil was determined by the Olsen's method using a spectrophotometer (Olsen *et al.,* 1954;Bray and Kurtz., 1945).Water-soluble and exchangeable Potassium (K) was estimated by the Ammonium acetate method of Hanway and Heidel using a Flame photometer (Hanway and Heidel,1952).Calcium (Ca) and Magnesium (Mn) cationswere analysedby the EDTA titration method (GOI, 2011). Analyses of Iron (Fe) and Manganese (Mn) were carried out by acid digestion (Jackson, 1967).

Collection of rhizosphere soil and root samples

Rhizosphere soil and roots samples were collected from jowar and safflower plants. Rhizospheresoil collected in polyethylene bags was dried and stored at 4^0C until analysed.

Root colonization

The roots of weeds growing in jowar and safflower grown fields were collected in *rabi* season during 2015-2016, and assessed of AM fungal root colonization using Phillips and Hayman method (1970). The stained root segments were observed under the binocular compound microscope (LOBAMED Vision 2000) and photographed with a Sony digital camera (DSC-W310/BC E37). Root showing hyphae, and vesicles orarbuscules were present was considered mycorrhizal. The percentage of root colonization was calculated using the following formula of Giovannetti and Mosse(1980)

$$\text{Root colonization (\%)} = \frac{\text{Number of colonized segments}}{\text{Total number of segments examined}} \times 100$$

Isolation and quantification of AM fungal spores

The rhizosphere soil of both the plant species was collected polyethylene zip-lock bags from the field. The soil was employed for isolation of AM fungal spores using the Wet sieving and decanting method (Gerdemann and Nicolson, (1963).Identification of AM fungal spores was carried out based on morphotaxonomic criteria using INVAM International Collection of Vesicular Arbuscular Mycorrhizal (http://invam.wvu.edu/the-fungi) and available manuals (Schenck and Perez, 1990; Rodrigues and Muthukumar,2009). Spore density and spore diversity was calculated.

Biomass estimation

Three plants each from jowar and safflower were harvested eight weeks after planting. The soils from the roots were washed off carefully. Fresh weight of root and shoot samples was recorded. The samples oven-dried at 60°C for 48 hoursand the dry weight was recorded (Muthukumar and Udaiyan, 2000). Leaf area was measured at harvest by disc method.Fifty leaf discs of known size from randomly selected leaves were used for calculating the leaf area as per the formula given by Vivekanandan *et al* (1972).

Statistical analysis

The data collected was statistically analysed as per Mungikar (1997).

RESULTS AND DISCUSSION

Physico-Chemical Parametersof soil

The physico-chemical parameters of thesoil are depicted in Table 1**.** The colour of the soil was black to brownish-black. The soil was alkaline in nature

with optimum Electrical conductivity (EC). Organic carbon was higher in jowar and optimum in safflower grown soils. Nitrogen was higher in jowar and less in safflower growing soils, P was higher in safflower than in jowar grown soils. Calcium and Mg were found in less amounts, Zn, Fe and Mn werehigher in jowar than in safflower.

Diversity of weeds

In all, 13 weedy plant species were recorded from sorghum and safflower field during the *rabi* season. Among these, highest % root colonization was found in *Dichanthium caricosum* (84.0±3.51) followed by *Dinebera retiflexa* (75.44±1.55) while minimum in *Abelomoschus manihot* (4156±2.55).The spore density was found maximum in *A.indicum* (1168) followed by *C. benghalensis* (1003) while minimum in *Parthenium hysterophorus* and *Commelina albescens* (136) respectively. The results of the study indicate that by virtue of extensive colonization. These weedy species assist in higher colonization of sorghum and safflower and resulting biomass and yield production in both crop plants (Table 2).

Biomass Productivity

In *S.bicolor*, a total of 12 parameters, i.e. Plant height (cm),stem girth (cm), root length (cm),leaf number, total leaf area (cm^2), fresh and dry weight of shoot (g) and root (g),length of inflorescence (cm),matured weight of ear heads and yield in quintal/ha including biomass and productivity were studied at maturity(90 DAS) (Table 3). It was recorded a yield of 12 q/ha.

In *C. tinctorius***,**a total of 11 parameters, i.e.plant height (cm), stem girth of (cm),root length (cm),number of branches, leaf number, total leaf area (cm^2), number of flowers, fresh and dry weight of shoot (g) and root (g) and yield in quintal/ha including biomass and productivity of *C. tinctorius* werestudied at maturity (90 DAS) and yield of 6 q/ha was recorded. (Table 4).

Colonization and AM diversity

In *S. bicolor*,the AM root colonization was higher in *S. bicolor* (77%) than in *C. tinctorius* (70%) and reported the presence of arbuscules,vesicles, intra-radical hyphae, and spores(Table 4 fig. 1).AM spore density was almost similar in both the plant species. Four

AM fungal species *viz.,Acaulospora tuberculata, Rh izophagus multicaule, Rhizophagus aggregatum* and *Gigaspora margarita* were frequently observed and *Rhizophagus aggregatum* found dominant in both the crop (Table5; Fig.1).

Paula et al., (1991) reported AM colonization in sweet sorghum, while Deepadevi *et al.,* (2010) reported increased plant growth, N and P uptake suggesting their potential role in sweet sorghum production. Aliasgharzad et al. (2006.) reported the mycorrhizal association with soybean plants had significantly higher root and shoot dry weights than non-mycorrhizal plants at all moisture levels. The studies of Bryla and Duniway (1997) and Ruiz-Lozano and Azcon (1995) have suggested that, under drought conditions, any increase in water uptake by fungal hyphae would play a vital role in increasing plant drought resistance through improving leaf water potential, maintaining turgor pressure and increasing the net photosynthetic rate and stomatal conductance. The existence of Glomus as the dominant genus in the root zone of safflower indicates either the influence of soil or plant type. It may be due to the qualitative and quantitative nature of the exudates from the root. The predominant occurrence of *Glomus* spp. in the rhizosphere soils of other plants was also reported earlier by several different authors (Vyas et al., 2006; Hindumathi and Reddy, 2011). This study indicated that AM fungi were influenced by the soil properties such as moisture content, soil available phosphorus and potassium, and root colonization influenced by spore density. It was reported that among agricultural weeds that are AMF hosts, AMF infection has been shown to improve growth and productivity (Heppell et al., 1998).

It was reported that when *Glomus intraradices* were applied to *Oryza sativa* Increased shoot height (40.90%) and photosynthetic efficiency (39.9%) over control in drought stress conditions (Ruíz-Sáncheza et al., 2011). Arthurson et al. (2011) reported that when *Triticum aestivum* was treated with *Glomus mosseae,* it increased shoot length (11.42%) and shoot dry weight (44.73%) over control. It was reported that when AMF spores @250 spores/kg of soil to *Sorghum bicolor* in field condition, each treatment was replicated three times. *Glomus* and *Acaulospora* application gave the highest increase in biomass for the mixture; hence this study provides a good scope for commercially utilizing the efficient strains of AMF to improve the establishment of slow-growing seedlings and improved growth (Sebuliba et al.,2010).

It is also possible that AMF may have negative effects on agro-ecological functioning of weed communities anda variety of weeds appear to be host species, such as *Ambrosia artemisiifolia L., Avena fatua L., Abutilon theophrasti,* or *Setaria lutescens* (Crowell &Boerner, 1988; Koide et al., 1994).It was reported theagricultural weeds that are members of families that commonly host AMF (e.g. Poaceae, Compositae) have been shown in some cases to be non-mycorrhizal (Feldmann& Boyle, 1999).It seems that the promotion of water absorbing and nutrients from soil caused to positive effects on growth and performance of safflower andshowed that the inoculated with the *Glomus* increased the efficiency of nitrogen and phosphorus and plant growth (Sharma,2003).The challenge is to determine the balance of beneficial and negative effects of AMF on agro-ecological functions of weed communities.

Table 1: Physico-chemical parameters of jowar and safflower soils.

Sr. No.	Parameter	Jowar	Safflower
1	Colour	Blackish	Brownish black
2	pH	7.45±1.01	7.45±2.21
3	EC	0.51±0.01	0.47±0.02
4	Organic carbon %	3.26±1.10	0.45±0.02
5	Nitrogen kg /ha	282.24±3.01	125.44±7.55
6	Phosphorus kg/ha	18.76±2.11	31±4.41
7	Potassium kg/ha	1190.78±5.22	1104±12.21
8	Calcium (m. Eq.)	4.00±1.10	1.87±0.01
9	Magnesium (m. Eq.)	10.55±3.02	4.92±1.31
10	Sodium (m. Eq.)	0.79±1.21	0.67±0.21
11	Zinc (ppm)	4.28±0.11	1.99±0.21
12	Ferrous (ppm)	4.59±2.02	2.14±0.01
13	Manganese (ppm)	6.42±2.22	2.99±1.21
14	Copper (ppm)	2.43±0.03	1.13±0.22
15	Boron (mg/g)	46±2.11	96±3.01
16	Sulfur (mg/kg)	7.85±2.11	7.79±2.01
17	Molybdenum(mg/kg)	7.15±1.31	6.78±1.01

Values are means of three replicates; ±-Standard Deviation

Table 2: Diversity of weedy plant species growing in jowar & safflower field in rabi season.

Sr. No.	Name of Weeds	Family	RC (%)	Spore Density/100g
1	*Partheniumhysterophorus*L.	Asteraceae	71.87±2.00	136
2	*Celosia argentea*L.	Amaranthaceae	65.62±5.27	282
3	*Euphorbia hirta*L.	Euphorbiaceae	66.66±2.51	666
4	*Cyprus rotundus*L.	Cyperaceae	62.05±4.11	146
5	*Cynodon dactylon* (L) Pers.	Poaceae	71.87±6.11	398
6	*Dichanthium caricosum*(L) A.Camus	Poaceae	84.0±3.51	831
7	*Dinebera retroflexa*(Vahl)Panz.	Poaceae	75.44±1.55	912
8	*Commelinabenghalensis* L.	Commeliniaceae	50.00±3.22	1003
9	*Abutilon indicum* L.	Malvaceae	62.5±4.22	1168
10	*Corchoruscapsularis* L.	Tiliaceae	70.83±3.11	859
11	*Corchorusolitorius* L.	Tiliaceae	47.61±3.31	569
12	*Commelinaalbescens* L.	Commeliniaceae	53.33±3.11	136
13	*Abelomoschus manihot* (L.) Medik	Malvaceae	41.56±2.55	282

Values are means of three replicates; ±-Standard Deviation

Table 3: Biomass and yield production in S.*bicolor*.

Sr.No.	Parameters	90 DAS (Maturity)	Mean ± SD
1	Plant height (cm)	193.1	125.77 ± 84.32
2	Stem girth (cm)	7.91	6.05 ± 2.26
3	Root length (cm)	29.00	18.4 ± 9.90
4	Number of leaves	10.00	09.00 ± 1.74
5	Fresh wt. of shoot (g)	458.15	308.00 ± 248.86
6	Fresh wt. of root (g)	63.38	46.39± 37.85
7	Dry wt. of shoot (g)	105.87	69.14± 50.18
8	Dry wt. of root(g)	27.23	16.63± 13.59
9	Length inflorescence (cm)	12.81	13.39 ± 0.69
10	Matured wt. of ear heads	252.11	187.14 ± 86.57
11	Total leaf area (cm^2)	2441	1957 ±728.61
12	Yield in quintal/ha	12	-

Values are means of three replicates; ±-Standard Deviation

Table 4: Biomass and yield in *C. tinctorius*.

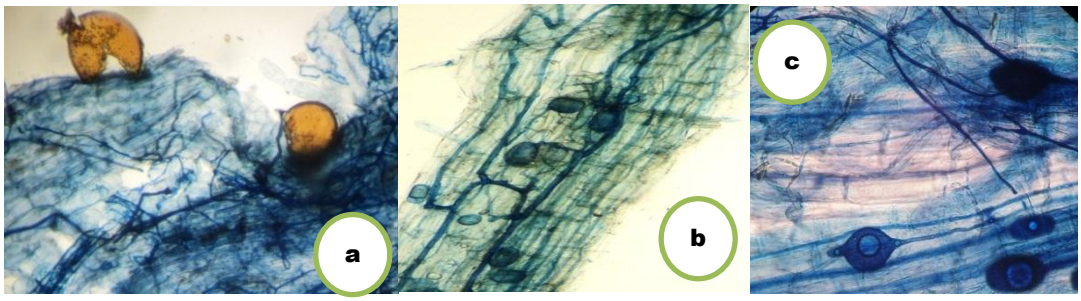
Sr.No.	Parameter	90 DAS (Maturity)	Mean ± SD
1	Plant height (cm)	52.4	36.14 ± 24.14
2	Stem girth of (cm)	5.21	4.20 ± 0.96
3	Root Length (cm)	25.6	18.34± 9.81
4	Number of branches	8.00	437.00± 3.51
5	Number of leaves	128	83.34± 65.62
6	Number of flowers	17.00	7.66 ± 8.62
7	Fresh wt. of shoot (g)	83.17	44.00 ± 37.96
7	Fresh wt. of root (g)	4.65	2.99 ± 1.73
8	Dry wt. of shoot (g)	40.85	19.43 ± 19.75
9	Dry wt. of root (g)	2.08	1.00 ± 0.85
10	Total leaf area (cm^2)	1114.11	865.53± 536.97
11	Yield in quintal/ha	06	-

Values are means of three replicates;±-Standard Deviation

Table 5: Arbuscular Mycorrhizal fungal status in jowar and safflowerafter 45DAS (*n=30).

Sr.No.	Parameter	Jowar	Safflower
1.	Root colonization (%)	76.77± 4.23	69.55± 8.00
2.	Type of colonization	Hyphal, arbuscles, vesicles,Arum types of arbuscles, and Intra-radical hyphae	Hyphal, arbuscular, vesicular,Polymorphic vesicles, and Arum types of arbuscles extra-radical spores
3	Spore density/ 100 g soil	537.66 ±70.18	538.66± 123.56
4.	Dominant Genera	*Acaulospora tuberculata, Rhizophagus multicaule, Rhizophagus aggregatum, Gigaspora margarita*	

***n** =number of root segments; values are means of three replicates, ±-Standard Deviation



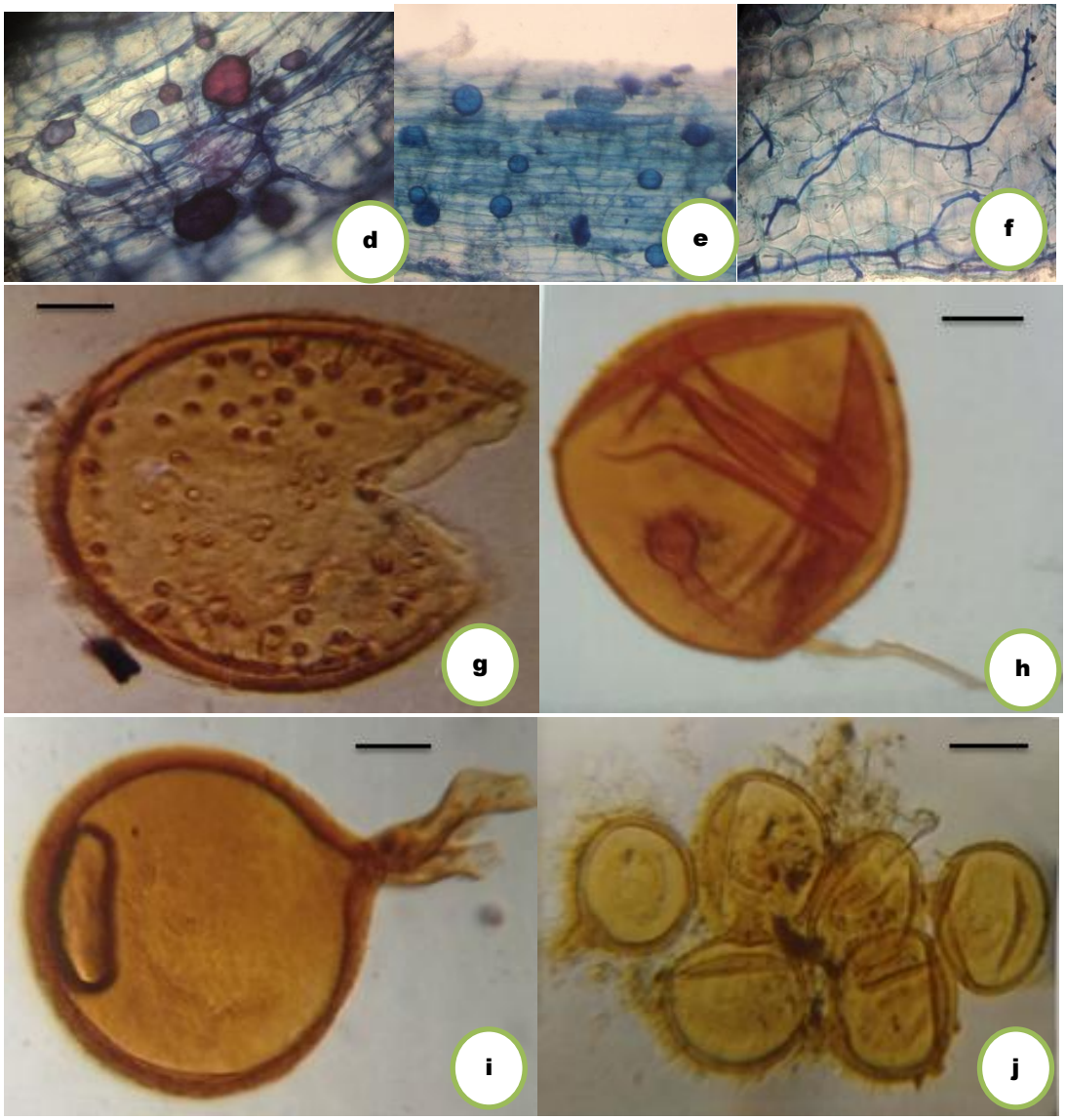


Figure 1: Showing Arbuscular Mycorrhizal Fungal Root colonization and some dominant morphospecies of jowar and safflower plants a-hyphae and intra-radical spores, b-intra-radical hyphae and vesicles, c-intra-radical vesicles with hyphae,d-hyphal and polymorphic Vesicles,e-hyphal and Vesicles,f-branched hyphae,g-*Acaulospora tuberculata*,h-*Gigaspora margarita*,i-*Rhizophagus multicaule*, j-*Rhizophagus aggregatum*(Scale Bar= 10 µm).

CONCLUSION

The study concluded that the weed species differed in response to AM root colonization in both crops. Weeds were found to provide some important ecosystem services for agriculture, hence needs experimental approaches in future as benefits due to weed competition and quantify the contribution of diverse weed communities in reducing crop competition and in providing ecosystem services.Present evidence permits the hypotheses that certain weed species can play beneficial roles by helping to achieve these objectives and AMF: weed interactions may be critically important to realizing these beneficial roles of weeds. We recommend an expanded research effort to test these hypotheses.

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Conflict of Interest

The authors declare there is no conflict of interest.

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