Sudan University of Science and Technology

College of Graduate Studies

Effect of Mycorrhiza on Growth and Yield of some Sorghum Cultivars

Sorghum bicolor L Moench

اثر استخدام المايكورايزا في نمو وانتاجية بعض اصناف الذرة الرفيعة

A Thesis submitted for Partial Fulfillment of the Requirement for the Degree of Master in Agronomy

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March 2015

DEDICATION

I dedicate this research report affectionately to:

My parents,

My brother,

My sisters,

My Supervisor,

And my friends,

ACKNOWLEDGEMENTS

This research has been undertaken in partial fulfillment of the Degree of Master of Education.

I wish to acknowledge certain institutions and individuals for their contributions towards the production of this research.

I would like to thank my family with sincere gratitude for their unconditional support. My sincere thanks also go to my sponsors.

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Abstract

The experiment was conducted during summer season (2014), in Demonstration Farm of the College of Agricultural Studies at Shambat , Sudan University of Science and Technology, to study the role of Mycorrhiza and their possible utility in five genotypes of grain sorghum (*Sorghum bicolour* L Moench). The experiment was arranged in split trial with the mycorrhiza in the main plot(with and without) and five sorghum cultivars (Butana, Tabat , ArfaGadamak , Wad Ahmed , Tetron) as the sub-plot with four replications.

Characters studied were plant height, stem diameter, number of leaves per plant, leaf area, days to 50% flowering, panicle length, fresh and dry weight, weight of seed /panicle ,yield/plant, thousand seed weight, yield (Ton/ha). The results showed that there were significant differences among most of the characters studied. Plant height, number of leaves, length of panicle, weight of seeds.

مستخلص

أجريت هذه الدراسة بالمزرعة التجريبية التابعة لكلية الدراسات الزراعية جامعة السودان للعلوم والتكنولوجيا (شمبات). خلال الصيف ٢٠١٤ ، لدراسة تأثير المايكورايزا علي ٥اصناف من الذرة الرفيعة(بطانه ،طابت ،ارفع قدمك، ود احمد ،تترون) تم استخدام تصميم القطاعات العشوائية المنشقة تم وضع المايكورايزا كأحواض رئيسيه (مايكورايزا وبدون مايكورايزا) والخمسة اصناف من الذرة كأحواض فرعيه.

القياسات التي أخذت للصفات كانت طول النبات، سمك الساق، عدد الاوراق، مساحة الورقة، الوزن الجاف للنبات، عدد الأيام ل% ٥٠ إزهار ،الوزن الرطب والوزن الجاف ، طول السنبلة، وزن البذور للنبات، وزن الألف بذرة والإنتاجية بالطن للهكتار.

أظهرت النتائج فروقات معنوية بين المعاملات . معظم الصفات تحت الدراسة أظهرت فروقات معنوية عالية، طول النبات وعدد الاوراق وسمك الساق وطول السنبلة ووزن البذور في النبات.

CHAPTER ONE

INTRODUCTION

Sorghum *Sorghum bicolor* (L) Moench is member of the family Poaceae. It is a grass species cultivated for its grain, which is used for food and feed. Sorghum is not used only for human food, but also for fodder and feed for animals, building material, fencing, or for brooms (Doggett, 1988; House, 1985; Rooney and Waniska, 2000). Sorghum grain has traditionally been used for livestock feed and stems and foliage for green chop, hay, silage, and pasture. Sorghum is favored by the gluten intolerant and is often cooked as a porridge to be eaten along side other foods. The grain is fairly neutral in flavor, and sometimes slightly sweet. This makes it well adapted to a variety of dishes, because, like tofu, sorghum absorbs flavors well. It can also be eaten plain. The grain is commonly eaten with the hull, which retains the majority of nutrients. The plant is very high in fiber and iron, with a fairly high protein level as well. This makes it well suited to its use as a staple starch in much of the developing world.

Landraces from Sudan has been extensively used in sorghum breeding programs worldwide (Bantilan *et al.,* 2004). However, average yield per unit area in Sudan is very low (540 kg/ha) compared to the world average (1300 kg/ha) (Elagib *et al.,* 2004). In Sudan traditionally sorghum growing areas were Blue Nile State, North and south Gdaref, Gezira, Sennar, White Nile State.

Mycorrhiza is a mutualistic symbiosis between fungi and the roots of terrestrial plants. The ancient fungi colonize approximately 90% of the Earths land plant species (Gadkar *et, al* 2001). Also improved phosphorus nutrition by Mycorrhiza during the periods of water deficit which has been postulated as a primary mechanism for enhancing host plant drought tolerance (Bethlen *et al* 1998).

In addition to phosphorus nutrition, mycorrhiza symbiosis assists host plants to use nitrogen forms that are not available to non-mycorrhizal plants, thereby contributing to plant growth and nutrition under drought conditions (Subramanian *et al* 2006) .It has been found to improve water relations of many plants. For example mycorrhizal colonization of roots has shown to increase drought tolerance of maize, wheat (Subramanian and Charest 1995).

Mycorrhiza symbiosis also improved leaf water potential. The potential mechanisms include extensive absorption of water by external hyphae, stomatal regulation through hormonal signals, an indirect effect of improved phosphorus nutrition upon water relations, and greater osmotic adjustment in mycorrhizal plant (Auge 1986 and Auge 1994).

The aim of this study was to investigate the role of Mycorrhiza and their possible utility in growth and yield characters in five sorghum varieties.

CHAPTER TWO

LITERATURE REVIEW

2-1General background about sorghum:

Sorghum (2n = 2x = 20) is a C4 plant that displays excellent tolerance to high moisture stress (Doggett, 1998). It has the highest water use efficiency among major crop plants and is unusually tolerant to low soil fertility. It is also has traits essential for survival and productivity in arid and semi-arid areas with limited irrigation capability (Zhanguo *et al.,*.2008). Global cultivation of sorghum covers an area of 43.73 mha with annual production of 64 mt (Sasaki and Antonio, 2009). It is the fifth most important cereal crop grown globally after wheat, maize, rice and barley production (Sato *et al.,* 2004 and Khalil, 2008), providing food and fodder for the inhabitants of drought-prone regions. Recently, sorghum has been demonstrated as a viable bio-energy feedstock (Wang and Shi 2008). Its remarkable ability to reliably produce grains under adverse conditions makes sorghum important "fail-safe" sources of food, feed and fuel (Addissu, 2011).

2-2 Adaptation:

Since sorghum is quite tolerant to drought, the species is grown mostly in areas where rain fall is insufficient for corn production. Sorghum responds well to irrigation and the crop is well adapted to region of limited rainfall with an average of 17-25 inches per annum. The most favorable mean temperature for growth is about 27^o, the minimum temperature is 17^o.Sorghum is short-day plant but most of the forage varieties are relatively insensitive to photo-period. Sorghum is produced successfully on all types of soil, growth being dependent upon relative fertility and soil moisture supply. It is more tolerant to alkali or salts than most cultivated crops (Quinpy and Karper 1981).

2-3 Origin and distribution:

The origin of sorghum is Ethiopia and has spread to other countries in Africa, Asia, Australia, and United states (Skerman and Riveros,1990). The crop is cultivated to varying extent in almost all tropical and sub-tropical areas of the world (Tarr, 1962). Sorghum has spread over much of the old sorghum growing world, being found in India and China (Mann et al., 1983).

2-4 Sorghum in Sudan:

Sorghum is traditionally processed to remove fibrous and often colored pericarp and testa layers and to reduce the grain into flour used to prepare a variety of traditional foods and beverages. Methods of processing vary from one locality to another depending on local customs, traditions and culture as well as food habits. At household level in the rural areas, sorghum is washed and spread out to dry. Foreign matter is removed. The dried grains may or may not be dehulled.

Traditionally, food grains are ground dry or moistened between grinding stones or pounded in a mortar with a pestle. The flour is made into paste, fermented and baked to produce kisra. It is believed that processing improves the quality and acceptability of the food product prepared(FAO/WFP 2011). Insome areas especially in towns powered grinding mills for sorghum, work on a commercial basis. These are becoming common and are gradually replacing grinding stones as mortars (Abdellatif 1999).

With the assistance of UNDP and FAO, pilot plans for sorghum decortications and baking of composite wheat/sorghum flour bread were set up at the Food Research Center in Khartoum North. Sales of decorticated sorghum flour for (kisra and acida) and those of composite flour bread were made and the demand response for both products was outstanding. It was concluded that 15-20 percent of wheat flour can be substituted by sorghum flour for bread making and hence substantial savings on wheat imports can be made.

Four sorghum plants with a total annual capacity of 750 tones were established on the basis of recommendations of the Food Research Center. These were meant to sell decorticated sorghum flour. At the Food Research Center it has been shown that white decorticated sorghum flour can be used partially in the biscuit industry. This industry is utilizing 55000 tons of wheat flour annually. Also the resultant flour can be partially used in the macroni and the starch and glucose industry(Administration of Agricultural Statistics 2000-2001).

2-5 Benefits of organic fertilizer:

Organic fertilizer have been used to improve the biodiversity and long-term productivity of soil (Enwall, *et al.,* 2005), and may prove a large depository for excess carbon dioxide (Lal, 2004, Rees and Eifion, 2009).

Organic nutrients increase the abundance of soil organisms by providing organic matter and micronutrients for organisms such as fungi and mycorrhiza (David, *et al.,* 2005), which aid plants in absorbing nutrients, and can drastically reduce external inputs of pesticides, energy and fertilizer, and the cost of decreased yield (Mader, *et al.,* 2002).

2-6 **Mychorriza:**

Vascular arbuscular mychorriza was found to improve the availability of phosphorus and other immobile elements like zinc and iron (Baylis, 1959). This was thought to increase the root volume through the association with fungi mycelia .Mahdi, 2006 reported that mychorrizal symbiosis improves nodulation and N_2 fixation in legume crops. He attributed this improvement to phosphorus availability which is very important in the rhizobium attachment on the root hairs, and the synthesis activity of the nitrogenase enzyme which needs energy as ATP. The significance of phosphorous for nodulation was also reported by (Elshiekh 1999) as well, as increased availability of iron and nitrogen fixation. Silver and Hardy (1878) showed that the nitrogenase enzyme is composed of Fe-protein and Fe-Mo-protein. The poor availability of both phosphorous and iron under the condition of alkaline clay soil was reported to hinder nodulation and N_2-fixation in guar, (Hamid 2005).

Soil and rhizosphere fungi can confer plant abiotic and biotic stress tolerance, increasing biomass and decreasing water consumption،or can alter resource allocation (Smith and Read, 2008؛ Bever *et al.,* 2010). Entophytic fungi are microorganisms that inhabit healthy plant tissues at least one stage of their life cycle، without causing any apparent symptom of disease or negative effects on their hosts (Petrini *et al.,* 1992). Arbuscular mycorrhizal (AM) fungi are the most widespread root-endophyte associate fungi. This symbiosis can benefit plant growth, particularly through enhanced phosphorus, water and mineral uptake (Smith and Read،2008). Ascomycetous root endophytic fungi can be considered as two groups, the dark septate endophyte (DSE) and fungi with hyaline and pale hyphae (Addy *et al.,* 2005). These two groups are considered at least as ubiquitous as mycorrhizal associations among temperate-zone plants (Arnold *et al.,* 2001). The ascomycetous DSE probably constitute the most abundant and most wide spread group of root colonizer and parallel AM fungi in occurrence and colonization of plant species (Mandyam and Jumpponen, 2005). Fungi with hyaline and pale hyphae are also commonly found in plants root but are less studied because they are less conspicuous and easier to overlook than the DSE (Addy *et al.,* 2005).

The interactions of ascomycetous root entophytic fungi with host plants can vary from pathogenic to beneficial mutualize (Smith and Read, 2008). Endophytic fungal colonization is importantto improve the ecological adaptability of host enhancing tolerance to biotic and abiotic stresses (Schulz and Boyle, 2005). Moreover, root colonization by endophytic fungi may confer benefitsto the host plant by means of growth promotion, protection against disease or assistance in phosphorous uptake (Sieber, 200٢). It is known that AM symbiosis is influenced by the activities of microorganisms in the soil (Lecomte *et al.,* 2011) .DSE coexist often with different AM fungi. The role of endophytic fungi in ecological situation with AM fungi is important for plant development and plant communities (Mandyam and Jumppone ٢٠٠٥).It is known that some DSE, such as Drechslera sp., are able to colonize root of grasses such as sorghum and the exudates producedby the host stimulated the pre-symbiotic stage development of AM fungi (Navarro, 2008; Scervino *et al.,* 2009). However, studieson the effect of root endophytic fungi on AM fungi are scarce.

2-7 The symbiosis between sorghum and mychorriza:

The symbiosis between sorghum roots and arbuscular mycorrhizal (AM) fungi influences the sorghum striga interaction. Colonization by AM fungi reduced attachment and emergence on sorghum (Lendzemo,2001).The underlying mechanisms for the lower performance of *Striga* on cereal crops upon AM fungal colonization are unknown. Preliminary investigations suggested that colonization by AM fungi also reduced seed germination of sorghum (Lendzemo, 2001).

In order to germinate, *Striga* seeds require signal molecules that are exuded by the roots of their hosts, called germination stimulants. These signal molecules belong to the class of the strigolactones (Bouwmeester et al 2003). Strigolactones have recently also been identified as signal molecules in the earliest stage of the interaction between plant roots and AM fungi (Akiyama and Hayashi, 2006). This double role for strigolactones suggests that the non-mycorrhizal Orobanchaceae have hijacked the molecular communication between host plants and AM fungi. Vierheilig 2004 reviewed the regulatory mechanisms during the interaction between host plants and AM fungi. He noted that AM plants show autoregulation, i.e., plants that are colonized by an AM fungus suppress subsequent colonization by AM fungi through altered root exudation. Vierheilig 2004, proposed the hypothesis of “one mechanism-two symptoms”, i.e., the possibility that changed root exudates not only autoregulate further mycorrhizal colonization but also repress soil pathogens that are attracted to the root by the same compounds in the exudate.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Field experiments Location:

The experiments was carried out in summer season of 2014 at the Demonstration Farm, Sudan University of Science and Technology, , College of Agricultural Studies. Shambat is located on longitude 32-35E and 15-40N, and altitude 386m above sea level(Adam, 2003). The soil of the site is clay with pH 7.5-8 as described by Adbelgader (2010).

3.2 Cultural operation and Design:

The land was ploughed, harrowed and ridged, then divided into plots each composed of 4 ridges, using a randomized complete block design (RCBD) with four replications, within split plot arrangement. The land was divided into 3x 3.5m^2 plots, 3meters long. Seeds were sown on the ^{21th} of July 2014 in low than the top of the ridge, 20 cm spacing between holes. And 5 seeds in holes .Hand weeding were done when needed. Irrigation was practiced every 10-12 days.

Sorghum was infested by stem borer and it was controlled by FALEMAT 800.

3.3 Materials:

3.3.1 Plant material:

Five genotypes of *Sorghum bicolor (L.)* Moench (Butana, Tabat ,ArfaGadamak , Wad Ahmed , Tetron) were obtained from JICA laboratory collected from many part of Sudan.

3.3.2 Fertilizer:

Mycorrhiza (*Inoqglomus intraradices B*) was obtained from JICA Laboratory and it is of German origin.

3.4 Data collection:

When the plants reached physiological maturity, five plants from the two inner ridges in each plot were randomly selected and tagged and from them data for the following growth and yield characters was obtained

3.4.1 Growth character:

3.4.1.1 Plant height (cm):

The plant height was measured from the base of the main stem to the tip of panicle using meter tape.

3.4.1.2 Number of leaves/plant:

Leaves were counted for the five tagged plants and the average was determined.

3.4.1.3 Stem diameter (cm):

The diameter was determined at maturity on the stalk at 10 cm above the ground level.

3.4.1.4 Leaf area (cm^2):

It was calculated according to the following formula as described by (Sticker et al 1961).

Leaf area (LA) =Maximum Length ×Maximum Width × 0.75

3.4.1.5 Fresh weight per Plant (gm):

The five tagged plant were weighted and the average weight was then determined.

3.4.1.6 Dry weight per Plant (gm):

The five tagged plant were dried naturally and the average weight was then determined.

3.4.2 Yield Characters:

3.4.2.1 Panicle length (cm):

The length of five plants was measured from the base of the panicle to its tip using the meter tape, and then the average was obtained.

3.4.2.2 Grain yield/plant (gm):

After harvest the panicles of the five selected tagged plants stored at room temperature for four weeks to minimize change in weight due to moisture content, then they were threshed manually and the grain yield/plant was determined using sensitive balance.

3.4.2.3 1000 grain weight (gm):

The weight of 1000 grains was determined by weighting 1000 grain obtained randomly from the five selected panicles using sensitive balance.

3.4.2.4 Grain yield (Ton /ha):

After harvest all the covered heads from the middle ridges of each plot were cut and then stored for four weeks to minimize change in weight due to moisture content, manually threshed ,cleaned weighted by using the sensitive balance and the grain yield t/ /ha was determined by the following formula :

$$\text{Grain yield Ton/ha.} = \frac{(\text{grain weight/plot}) \times 10000}{\text{Plot area} \times 1000 \times 1000}$$

3.5 Data Statistical Analysis:

The data collected was subjected to statistical analyses to obtain the ANOVA and then the means were separated by LSD using STATISTIX8 computer package.

CHAPTER FOUR

RESULTS

4.1 Growth characters:

4.1.1 Plant height (cm):

Statistical analysis revealed no significant differences between mycorrhiza treatment but there is significant differences (0.05) among the five varieties of sorghum (Table4-1). However, the interaction between mycorrhiza and the five varieties of sorghum were not significant. The taller plants were attained in plant which treated with mycorrhiza (127.66cm) while the shortest were obtained at without mycorrhiza (121.30 cm) (Table4-2).As shown in (Table4-3) Titron gave significantly taller plants (162.30cm) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Titron with mycorrhiza had significant taller plants (168.40 cm) than the other combinations while Arfagadamk without mycorrhiza had the significantly lower plant height (٨٨.٨٥cm) as shown in Table (4-4).

4.1.2 Number of leaves/plant:

No significant differences were shown between mycorrhiza treatments but there are significant differences (0.05) among the five varieties of sorghum (Table4-1). However the interaction between mycorrhiza and the five varieties of sorghum was not significant. The highest number of leaves were attained in plant which treated with mycorrhiza (11.03) while the lowest were obtained at without mycorrhiza (10.70) (Table4-2).As shown in (Table4-3) Butana gave significantly highly number of leave in plants (11.70) than the other four varieties .The interaction between mycorrhiza and the five varieties of sorghum revealed that Butana with mycorrhiza had a significant highest number of leave in plants (12.30) than the other combinations while Arfagadamk with mycorrhiza had the significantly lower number (٩.٦٠) as shown in Table (4-4).

4-1-3 Stem diameter (cm):

Statistical analysis revealed no significant differences between mycorrhiza treatment and among the five varieties of sorghum (Table4-1). However the interaction between mycorrhiza and the five varieties of sorghum was significant. The highest stem diameter was attained in plant which treated with mycorrhiza (11.01cm) while the lowest was obtained at without mycorrhiza (9.90 cm) (Table4-2).As shown in (Table4-3) Butana gave significantly highest stem diameter (11.10cm) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Butana without mycorrhiza had a significant highest stem diameter (11.80cm) than the other combinations while Arfagadamk without mycorrhiza had the significantly lower stem diameter (٨.٦0cm) as shown in Table (4-4).

4.1.4 Leaf Area (cm^2):

No significant differences were shown between mycorrhiza treatment and no significant differences among the five varieties of sorghum (Table4-1). Also the interaction between mycorrhiza and the five varieties of sorghum was not significant. The highest leaf area was attained in plant which treated with mycorrhiza (151.82cm^2) while the lowest was obtained at without mycorrhiza (142.55cm^2) (Table4-2).As shown in (Table4-3) Arfagadamk gave significantly highest leaf area (160.79cm^2) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Butana with mycorrhiza had a significant highest leaf area(164.06cm^2) than the other combinations while Wadahmed without mycorrhiza had the significantly lower leaf area (١١٤.٤٤cm^2) as shown in Table (4-4).

4-1-5 Plant fresh weight (gm):

Statistical analysis revealed no significant differences between mycorrhiza treatment, among the five genotypes of sorghum and the interaction between mycorrhiza and the five varieties of sorghum (Table 4-1). The highest weight was attained in plant which treated with mycorrhiza (0.59g) while the lowest was obtained at without mycorrhiza (0.57g) (Table4-2).As shown in (Table4-3)Butana gave significantly highest weight (0.68g) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Butana with mycorrhiza had a significant highest weight (0.75g) than the other combinations while Titron without mycorrhiza had the significantly lower weight (٠.٥٨g) as shown in Table (4-5).

4-1-6 Plant dry weight (gm):

No significant differences were shown between mycorrhiza treatment, among the five varieties of sorghum and the interaction between mycorrhiza and the five varieties of sorghum (Table4-1). The highest dry weight was attained in plant which treated with mycorrhiza (0.36g) while the lowest was obtained at without mycorrhiza (0.32g) (Table4-2).As shown in (Table4-3) Butana gave significantly highest dry weight (0.38g) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Butana with mycorrhiza had a significant highest weight (0.42g) than the other combinations while Titron and Wadahmed without mycorrhiza had the significantly lower weight (٠.٢٨g) as shown in Table (4-5).

4.2 Grain yield characters:

4-2-1 Length of panicle (cm):

Statistical analysis revealed no significant differences between mycorrhiza treatments but there were high significant differences (0.01) among the five varieties of sorghum (Table4-1). However the interaction between mycorrhiza and the five varieties of sorghum was not significant. The teller panicle was attained in plant treated with mycorrhiza (18.00 cm) while the shortest was obtained at without mycorrhiza (16.90cm) (Table4-2). As shown in (Table4-3) Arfagadamk gave significantly taller panicle (20.12cm) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Titron with mycorrhiza had a significant taller panicle (22.00 cm) than the other combinations while Tabat with mycorrhiza had the significantly lower panicle (١٤.٠٠cm) as shown in (Table 4-5).

4-2-2 Weight of seeds /panicles (gm):

Significant differences (0.05) were shown between mycorrhiza treatments but there are no significant differences among the five varieties of sorghum or the interaction between mycorrhiza and the five varieties of sorghum (Table4-1). The highest weight was attained in plant which treated with mycorrhiza (14.88g) while the lowest was obtained at without mycorrhiza (14.13g) (Table4-2).As shown in (Table4-3) Butana gave significantly highest weight (17.90g) than the other four varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Tabat with mycorrhiza had a significant highest weight (20.10 g) than the other combinations while Titron with maycorrhiza had the significantly lower weight (١٠.٧٠g) as shown in (Table 4-5).

4-2-3 Weight of 1000 seeds (g):

Statistical analysis revealed no significant differences between mycorrhiza treatment, among the five genotypes of sorghum and the interaction between mycorrhiza and the five genotypes of sorghum(Table4-1). The highest weight was attained in plant which treated with mycorrhiza (12.90 g) while the lowest was obtained at without mycorrhiza (23.05g) (Table4-2).As shown in (Table4-3) Tabat gave significantly highest weight (27.75g) than the other five varieties. The interaction between mycorrhiza and the five varieties of sorghum revealed that Tabat with mycorrhiza had a significant highest weight (28.25g) than the other combinations while Butana with mycorrhiza had the significantly lower weight (٦.٠٠g) as shown in (Table 4-5).

4.2 .4 Grain yield (Ton/ha):

The grain yield was not statistically different for mycorrhiza, cultivars or the interaction between mycorrhiza and cultivars (Table 4-1) The yield with mycorrhiza was highest than without mycorrhiza (Table 4-2). Cultivar Tabat had the highest yield (0.81t/ha) while cultivar Butana gave the lowest grain yield (0.55t/ha) (Table 4-3). However the interaction between mycorrhiza and cultivar revealed that Tabat without mycrrhiza (0.92 t/ha) had the higher grain yield (Table 4-5) compared to Butana with mycorrhiza (0.47 t/ha).

Table (4-1): F Values of different characters of Sorghum

SOURCE	DF	F. value									
		Plant height (cm)	Stem diameter (cm)	Number of leaves	Leaf Area (cm^2)	plant fresh weight (g)	Plant dry weight (g)	Length of panicle	Grain yield/ plant(gm)	Weight of 1000 seeds	Yield Ton/ha
REP	3	-	-	-	-	-	-	-	-	-	-
Mycorrhiza	1	0.32^{NS}	4.38NS	0.23NS	0.69^{NS}	0.20^{NS}	2.18^{NS}	0.42^{NS}	0.04*	0.22^{NS}	0.06^{NS}
ERROR a	3	-	-	-	-	-	-	-	-	-	-
Cultivars	4	2.34^{*}	0.87 NS	2.85 *	0.69^{NS}	0.51^{NS}	0.29^{NS}	4.27^{**}	1.12^{NS}	1.36^{NS}	1.28^{NS}
TREAT*VAR	4	0.63^{NS}	2.31 *	0.98 NS	0.85^{NS}	0.70^{NS}	0.27^{NS}	2.05^{NS}	1.48^{NS}	2.05^{NS}	0.43^{NS}
ERROR b	24	-	-	-	-	-	-	-	-	-	-
TOTAL	39	-	-	-	-	-	-	-	-	-	-
EMS		1935.52	1.6070	3.06721	1689.20	0.06463	0.02438	10.9373	39.845	27.0583	0.0832
CV		35.34	12.6	16.11	27.29	-	-	18.93	-	22.16	-

*Significant(0.05)

**Highly Significant(0.01)

Ns: non-Significant

Table (4-2): Effect of Mycorrhiza on different parameters of Sorghum :

w p	plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf Area (cm^2)	Plant fresh weight (g)	Plant dry weight (g)	Length of panicle	Weight of seeds /panicle	Weight of 100 seeds	**Yield Ton/ha**
With Mycorrhiza	127.66 ^{a}	11.037 ^{a}	11.019^{a}	151.82^{a}	0.5890 ^{a}	0.3550 ^{a}	18.000^{a}	14.880 ^{a}	23.900^{a}	0.6868^{a}
WithoutMycorrhiza	121.30 ^{a}	10.707 ^{a}	9.997^{a}	142.55^{a}	0.5690 ^{a}	0.3150 ^{a}	16.950^{a}	14.135 ^{a}	23.050^{a}	0.6433^{a}
Means	124.48	10.872	10.508	147.185	0.579	0.335	17.475	14.135	23.475	0.6651

Mean followed by the same letter for each Column for each cultivar is not significantly different at 5% LSD.

Table (4-3): Effect of Cultivars on different parameter of Sorghum:

P	plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf Area (cm^2)	Plant fresh weight (g)	Plant dry weight (g)	Length of panicle	Weight of seeds /panicle	Weight of 1000 seeds	**Yield Ton/ha**
Wad ahmed	118.63^{ab}	11.541^{a}	10.318	137.34^{a}	0.5313 ^{a}	0.3125^{a}	14.625^{c}	13.762^{b}	24.625 ^{a}	0.6033^{ab}
Butana	127.73^{ab}	11.775 ^{a}	11.103^{a}	149.84^{a}	0.6838 ^{a}	0.3750 ^{a}	16.500^{ab}	17.900 ^{a}	22.250 ^{a}	0.5469^{b}
Titron	162.30^{a}	11.091 ^{a}	10.449^{a}	132.36^{a}	0.5238 ^{a}	0.3000 ^{b}	19.875^{a}	11.900^{ab}	24.375 ^{a}	0.5994^{ab}
Arfagadamk	97.60^{b}	9.125 ^{b}	9.986^{a}	160.79^{a}	0.5725 ^{a}	0.3500 ^{a}	20.125^{bc}	13.188^{ab}	20.375 ^{a}	0.7622^{ab}
Tabat	116.15^{b}	10.825^{ab}	10.685^{a}	155.60^{a}	0.5837 ^{a}	0.3375 ^{a}	16.250^{ab}	15.787^{ab}	25.750 ^{a}	0.8133 ^{a}
Means	124.48	10.871	10.5082	147.168	0.579	0.335	17.475	14.501	23.475	0.6650

Mean followed by the same letter for each Column for each cultivar is not significantly different at 5% LSD.

Table4-4 Interaction between Mycorrhiza and Sorghum Cultivars for growth parameter**:**

Cultivars	Mycorrhiza	Characters measured			
		Plant height(cm)	Leaf number	Stem diameter(cm)	Leaf area(cm^2)
Wad Ahmed	M+	128.35^{ab}	11.332^{ab}	10.887^{ab}	160.24^{a}
	M-	108.90^{c}	11.750^{a}	9.747^{b}	114.44^{b}
	Mean	118.63	11.543	10.318	137.34
Butana	M+	123.75^{ab}	12.300^{a}	10.625^{ab}	164.06^{a}
	M-	117.70^{ab}	11.250^{ab}	11.580^{a}	135.61^{ab}
	Mean	127.73	11.775	11.103	149.84
Titron	M+	168.40^{a}	11.800^{a}	9.873^{b}	129.59^{ab}
	M-	156.20^{a}	11.383^{ab}	11.025^{a}	135.13^{ab}
	Mean	162.30	11.091	10.449	132.36
Arfagadamak	M+	106.35^{b}	9.600^{b}	8.697^{b}	151.45^{ab}
	M-	88.85^{c}	8.650^{b}	11.275^{a}	170.13^{a}
	Mean	97.60	9.125	9.986	160.79
Tabat	M+	97.45^{c}	9.600^{b}	9.902^{b}	151.45^{ab}
	M-	134.85^{ab}	8.650^{b}	11.467^{a}	170.13^{a}
	Mean	116.15	9.125	10.685	160.79

Mean followed by the same letter for each Colum for each cultivar is not significantly different at 5% LSD.

Table4-5: Interaction between Mycorrhiza and Sorghum Cultivars for yield parameters:

Cultivars	Mycorrhiza	Characters measured					
		plant fresh weight (g):	**plant dry weight (g):**	**Length of pencil** (cm)	**Weight of seeds /pencil**(g)	**Weight of 1000 seeds(g):**	**Yield Ton/ha**
Wad Ahmed	M+	0.6125^{ab}	0.3500^{a}	14.500^{c}	15.875^{ab}	14.250^{b}	0.6156^{a}
	M-	0.4500^{ab}	0.2750^{ab}	14.750^{c}	11.650^{b}	25.000^{a}	0.5911^{ab}
	mean	0.5313	0.3125	14.625	13.762	24.625	0.6033
Butana	M+	0.7450^{a}	0.4250^{a}	15.000^{b}	16.125^{ab}	6.000^{c}	0.4667^{b}
	M-	0.6225^{ab}	0.3250^{ab}	18.000^{ab}	19.675^{a}	18.500^{ab}	0.6272^{a}
	mean	0.6838	0.3750	16.500	17.900	22.250	0.5469
Titron	M+	0.4650^{b}	0.2750^{ab}	22.000^{a}	10.750^{c}	23.250^{ab}	0.6522^{a}
	M-	0.5825^{ab}	0.3250^{ab}	17.750^{ab}	13.050^{ab}	25.500^{a}	0.5467^{ab}
	mean	0.5238	0.3000	19.875	11.900	24.357	0.5994
Arfagadamak	M+	0.5200^{ab}	0.2750^{b}	19.250^{a}	11.550^{b}	17.750^{ab}	0.7733^{a}
	M-	0.6250^{b}	0.3250^{ab}	21.000^{a}	14.825^{ab}	23.000^{ab}	0.7511^{b}
	mean	0.5725	0.3000	20.125	13.188	20.375	0.7622
Tabat	M+	0.5025^{ab}	0.3500^{c}	14.000^{c}	20.100^{a}	28.250^{a}	0.7089^{b}
	M-	0.6650^{a}	0.3250^{ab}	18.500^{ab}	11.475^{b}	23.250^{ab}	0.9178^{a}
	mean	0.5837	0.3375	16.250	15.787	25.750	0.8133

Mean followed by the same letter for each Colum for each cultivar is not significantly different at 5% LSD.

CHAPTER FIVE

DISCUSSION

Five varieties of sorghum were used in the experiment to study the effect of Maycorrhiza on growth and yield characters.

Most of the growth characters were affected by Mycorrhiza specially plant height, stem diameter and number of leaves. Moreover, Mycorrhiza significantly increased plant height in all verities except Tabat. The range of plant height was (168.40-97.40 cm), Titron cultivars has highest value. This increase could be due to the beneficial effect of Mycorrhiza on plant growth. This was in line with Vierheiling (2004) who is working on mycorrhizal fungus interaction.

Numbers of leaves were also affected by Mycorrhiza and there is a significant difference in values that ranges between (12.30-8.60) and the highest value was obtained for Butana. On the other hand, stem diameter and leaf area were not significant and the value ranged between (10.80-8.60) and (170.13-114.40) respectively.

Mycorrhiza had significant effect on some yield component specially in length of panicle with highly significant effect in all the varieties of sorghum used in this study, There were no significant effects in fresh weight and dry weight and 1000 seed weight. The significant effect of length of panicle in all cultivars might be due to the positive effect of mycorrhiza on phosphorus which in turn affected plant growth and hence length of panicle. These findings were on line with Kothari *et al* (1993) results.

Length of panicle showed high value in Titron (22.00cm) whereas, Tabat reveled small value (14.00 cm) among all variety the value ranged between (22.00-14.00 cm).The differences between varieties on panicle length might be due to the genetic difference between verities. Weight of seeds/panicle showed high value in Tabat (20.00 g) whereas, Arfagadmak reveled small value (11.50 g). On the other hand fresh weight and dry weight and 1000 weight seeds were not significant and the value ranged between (0.75-0.45g), (0.43-0.28g),(25.00-6.00 g) respectively. Tetron is the best variety in most characters and it is more affected by mycorrhiza.

The results agreed with the findings of (Kothari *et al* 1993) who reported that mycorrhizal colonization with *Glomus fasciculatum* improved the drought tolerance of field-grown maize plants as a result of enhanced P status under varying intensities of drought stress. The response to mycorrhizal colonization increased with increasing intensities of drought stress under field conditions. The results showed that the mycorrhiza enhance the uptake of the root to many mineral from the soil like phosphorus and nitrogen (Hodge *et al* 2001, Liu *et al* 2004, Harrier 2001 and Rillig and Mummey 2006).

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CHAPTER SIX
SUMMARY AND CONCLUSIONS

The results obtained in this study, can be summaries as follows:

1. All genotypes under the study were significantly different in growth characters and yield component.

2.Butana showed high values in leaf number, leaf area, fresh and dry weight

3.Tabat showed high values in weight of seed /panicle and weight of1000 seed.

4. Titron was the best variety in most characters.

5. The experiment should be repeated for another season and preferably in another location to confirm results.

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