بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Efficiency of Phosphorus use of Five Grain Sorghum *Sorghum bicolor* ***L.*** Cultivars.

كفاءة أستخدام الفسفور بواسطة خمسة أصناف من الذرة الرفيعة.

A Thesis Submitted In Partial Fulfimment of the Requirements for the Degree of M.Sc(AGRONMY)

By

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الآية

قال تعالى:

(أَوَلَمْ يَرَ الَّذِينَ كَفَرُوا أَنَّ السَّمَاوَاتِ وَالْأَرْضَ كَانَتَا رَتْقًا فَفَتَقْنَاهُمَا وَجَعَلْنَا مِنَ الْمَاءِ كُلَّ شَيْءٍ حَيٍّ أَفَلَا يُؤْمِنُونَ)

صدق الله العظيم

سورة الأنبياء لآية (٣٠)

Dedication

As far as I go, I see them telling me: ''you can make it'', and when I ask them how much time do I have? They say: ''as long as it takes''.

For them: my wonderful brother Omer ElfarougHabib and my loving Uncle ElhassanElnasir. To the soul of both my grandfather and father Omer ElfarougElhassan and Habib Ali.

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Acknowledgment

My great thanks firstly to almightily allah

Who support me to finish this work successfully

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Abstract

The experiment was conducted during summer season (2014), in the Demonstration Farm of the College of Agricultural Studies at Shambat, Sudan University of Science and Technology, in order to study the effect of phosphorus fertilizer on growth and productivity of five cultivars of sorghum(*Sorghum bicolour* L Moench)., and also to evaluate phosphorus use efficiency.The experiment was arranged in asplit trial with phosphorus as the main plot(with and without) and five sorghum cultivars is (Butana, Tabat , ArfaGadamak , Wad Ahmed , Tetron) as the sub-plot with for replications. , Plant height(cm) , number of leave, leaf area(cm^2),stem diameter, plant fresh weight(g),plant dryweight(g),length of panicle(cm),weight of seed/panicle(g),cweight of 100seed(g),number of panicle, yield (t/ha)and phosphorus use efficiencywere measured. The results revealed that phosphorus affectedyieldandgrowth characters. Arfagadamakreveleded the bestphosphoruse efficiency , therefore the highest productivity (12.75 tan/h), and Wadahmedshowedthe lowest use of phosphorus and gave the lowest use efficiencyproductivity (9.45 t/ha).

Arabic Abstract

الخلاصة

أجريت هذه الدراسة بالمزرعة التجريبية التابعة لكلية الدراسات الزراعية جامعة السودان للعلوم والتكنولوجيا (شمبات). خلال صيف ٢٠١٤، لدراسة تأثيرالفسفور علي خمسةأصناف من الذرة الرفيعة(بطانه، وطابت،وارفع قدمك،وود احمد،وتترون). تم استخدام نظام القطاعات العشوائية المنشقة تم وضع الفسفور في أحواض رئيسيه (الفسفوروبدون فسفور) والخمسة أصناف من الذرة في أحواض فرعيه مع أربعة مكررات وتم قياس طول النبات (سم)،عدد الأوراق، سمك الساق(سم)، مساحة الورقة(سم),الوزن الرطب لنبات(جم)،الوزن الجاف لنباتجم)،طول القندول(سم)،وزن الفتدول(جم)،وزن ال١٠٠حبة(جم) وعددالسنابل في النبات و كفاءة استخدام الفسفور

كما تم قياس صفات النمو والإنتاج .أظهرت النتائج مدى تأثير سماد الفسفور علي صفات النمو وكذلك الإنتاجية حيث أوضحت النتائج أن أعلى كفاءة استخدام للفسفور كان لصنف أرفع قدمك وأقلها لصنف ودأحمد وتبعاً لذلك حصل الصنف أرفع قدمك علي أعلى إنتاجية (١٢.٧٥طن للهكتار) والصنف ودأحمد أقل إنتاجية (٩.٤٥طن لهكتار).

CHAPTER ONE

INTRODUCTION

Grain sorghum (*Sorghum bicolor*-L- Moench) is an important cereal crop it is a member of the family Poaceae and specifically to Sorghum bicolor .This Species contains ten pairs of chromosomes number. It ranks fifth among the world's cereals. It is grown mainly in semi arid areas of the tropics and subtropics. Grain sorghum is a basic human food crop in many developing Africa and Asian countries. It is also used as an animal feed. The sorghum stalks are used as construction material and fire fuel (Taha.1998).The total area under sorghum production in the world is more than 52 million hectares with an average grain yield of about 1.09 metric tons per hectare. In Africa sorghum is important in the region from Ethiopia and south wards through east and central to south Africa. Africa produces less than 1/4 of the world total production with average yield less than 1/3 of the world average. Sorghum is a basic food crop in many developing African countries. It is also used as animal feed and*Sorghum bicolor* (L) Moench for industrial purposes (Abdalla, 1987).The leading producing countries are the United states, Nigeria, India, Mexico, and Sudan. It is commonly called sorghum and also known as durra in Sudan. Sorghum grain is the staple food of poor and the most food-insecure people .Sorghum is the most important cereal crop in terms of acreage, total production and as a main dietary stable of Sudanese people (Ejeta, 1988). Traditionally sorghum was a peagant grain crop grown for local consumption by hand methods. In the last few years, more lands have been brought into mechanized crop production schemes, most of which lie in the central rain land areas (Gadarif, Dalli, Mazmoom, Habila and Damazin) (ELhassan, 1986). The sorghum is mostly consumed in form of

"Kisra" (unleavened bread from fermented dough). It is also used to make "Asida" (Thick porridge) and "Abreih" (a popular beverage) (Ejeta, 1988).Sorghum production in Sudan takes place in all three production systems. The irrigated sub-sector, the mechanized rainfed sector and the traditional rainfed sector (Taha, 1998).In the Sudan, It is the main staple food and ranks first among cereals in importance andproduction. It is grown mainly as a rainfed crop because it tolerates heat, drought and low soil fertility. Under these harsh environmental conditionas, its average grain yield in Sudan is low (539 kg/ha) compared to that of the world (1288kg/ha) (Abdalla, 1999). The rainfed sector produces 90% and only 10% of sorghum is produced in irrigated sector for food security to guard against risk of drought and environmental hazards. Sorghum is grown annually in an area ranging between 4.3 to 7.1 million hectares (ELamin and ELzein, 2006).

According to Arab Agricultural statistics year book for 2012-2013, the total cultivated area of sorghum in Sudan in the period between 2005-2009was (9099.55/1000mt), and the yield was (513kg/h). theproduction of(4669.20/1000ha)was recorded in2010 with the total of cultivated area as(13062.001000mt). In 2012-2013the total cultivated area was(10733.10/1000mt), with a production of(2260.00/1000ha).

Sorghum bicolor is generally known to be heavy grains and exhaustive to availablemineral nutrients in the soil,therefore fertilization is considered to be one of importantcultural practices. Currently most of the farms are using urea and triple-super-phosphateas fertilizer sources of nitrogen and phosphorus, so as to increase the yield ofgrain sorghum.

Therefore the main objective of this work is to study the response of five sorghum cultivars to phosphorus and to calculate phosphorus use efficiency.

CHATER TWO

LITERATURE REVIEW

2 .1 General background

Sorghum (2n = 2x = 20) is a C_4 crop 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 also has traits essential for survival and productivity in arid and semi-arid areas with limited irrigation capability (Zhanguo*et. al*.2008). The Root system is denser compared to mize which helps to tolerate dryness in addition to other factors like reduction in speed of transpiration. Thestem has tillers that come out from existing bud located near soil surface and its number depends on the environmental conditions and the cultivar and it may reach in majority of the cultivars (10-15) .Leaves are alternated on the stem and covered with layer of wax,. the number might reach in some cultivars to 25 leaves, and it decreased in early-mature cultivars. Panicle varies in size, color and shape according to different cultivars. It's self-pollinated crop (Dagash, 2012).Sorghum (*sorghum bicolor*) grain was harvested in about 170 million acres (43million/hectars) in 2000-2003, with an average production of 2.3billion bushels (57 million/mt) or 21bushels per acre (1.30kg/ha). Global cultivation of sorghum covers an area of 43.73millon hectares with annual production of 64mittrbton (Sasaki and Antonio, 2009). It is the fifth most important cereal crop grown globally after wheat, maize, rice and barley (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, *et.al.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:

It is an annual plant and is a native of Africa in the zone south of the desert where several closely related wide species are found and cultivated.

Sorghum is grown in warm or hot regions that have summer rainfall, as in warm/ irrigated areas. The most favourable mean temperature for the growth of the plant is about (27C). The minimum temperature for growth is (16C) the sorghum plant seems to withstand external heat better than other crops but extremely high temperatures during the fruiting period reduce the seed yield. Sorghum is a short-day plant. It is well adapted to summer rain fall regions where the average annual precipitation is only 17 to 25 Inches (430-to635mm)(Martin, 1941).

2.3. Distribution:

Sorghum grain is the staPle food of poor and the most food in-secure people, living mainly in the semiarid tropical (Ali et al, 2011).It is originated in Eastern Africa, (Sudan along with Ethiopia- Eretria areas) and now is cultivated widely in tropical and sub tropical regions. It is the most important staple cereal crop for more than 500 million people in more than 30 Countries worldwide (ICRISAT, 2011).The grain sorghum head is a panicle, with spikelet's in pairs. Sorghums are normally self-fertilized, but can have some cross pollination. Hybrid sorghum seed is produced utilizing cytoplasm genetic male sterility.Sorghum flowers begin to open and pollinate soon after the panicle has completely emerged from the boot. Pollen shedding begins at the top of the panicle and progresses downward for 6-9 days. Pollination normally occurs between 2:00 and 8:00 a.m., and fertilization takes place 6-12 hours later.(FAO, 2009). Sorghum can branch from upper stalk nodes. If drought and heat damage occur the main panicle, branches can bear panicles and produce grain. The grain is free-threshing, as the lemma and pale are removed during combining. The seed color is variable with yellow, white, brown, and mixed classes in the grain standards. Brown-seeded types are high in tannins, which lower palatability. Percentages of the seed components, endosperm (82%), embryo (12%), and seed coat (5-6%) are similar to corn

Sorghum is aC4 plant that makes better use of f CO_2. Its non structural carbohydrate contents are affected by temperature, time of day (Almodares et al, 2000) maturity (ALmodares et al., 1994b), cultivar (Almodares, and Sepahi, 1996), spacing and fertilization (Alomdares et al., 2008). Significant shading reduces leaf dry weights of sorghum (Kinijiry et al., 1992). Also carbohrate content was affected by water quality and growth stage (Almodares*et al*., 2007).

2.3Grain sorghum

Grain sorghum (*Sorghum bicolor* (L) Moench) is a major corp.In many parts of Africa that is noted for its versatility and diversity. Grain was the basic food crop for the first farmers more than 10000 years ago. Today, grain is still the most basic food crop. Grain is important for two reasons. First, it is the major source of food for the world's population. Second, it is used to feed livestock, which provide meat, dairy products, wool, and eggs. Grain is easy to store and will not spoil if properly stored. It is easy to convert into food. Grains are excellent sources of needed nutrients, particularly the carbohydrates which provide energy. They are also easy to grow in many different parts of the world (Douglas, et al, 1983).Sorghum grains are classified as sorghum bicolor (with many cultivars). There are many avarietiesof *Sorghum bicolor*ranging in color from white through red to brown and mixed classes in the grain standards (Baidab, 2012).

2.4 Sorghum in Sudan:

Sudan located within the geographical range where sorghum is believed to be domesticated for the first time and where the largest genetic variation for both cultivated and wild sorghum is found. A large collection of Sudanese Landraces from different parts of Sudan was collected at the Agricultural

Research Corporation Gene Bank. Today this collection amounts to more than 400 accessions (Mohamed, 2011).It is grown in an area ranging between 4.3 and 7.1 million ha with an average of 5.2 Million ha. In 2009, the total annual sorghum production in Sudan was 4.192 million metric tons from approximately 6.653 million ha, with an average yield of 0.63tons.ha^{-1}. (FAO STAT, 2010). The rain-fed production in the mechanized rain-fed sector accounts for most of the yield and only 10% of sorghum is produced in the irrigated sector for food security to guard against risk of drought and rainfall.

Sorghum contributes to about 65% of Sudan consumption of grain, 70% of the calories in the diet, and to considerable amount of protein. Sorghum is also mixed with wheat in composition of flour. There is an increasing demand on feed for livestock and contributes to foreign exchange generation. Sorghum is grown throughout the country in all agricultural sub-sectors (irrigated, mechanized and traditional) during the rainy season, from June to October. Sorghum production increased by 39% between 1960 s and the 1970s from 1.297 million metric tons 1.801 million, by 2metric tons 9% between the 1970s and the 1980s from 1.801 million MT to 2.33 million,metric tons and by 38% between the 1980s and the 1990 from 2.33 to 3.213 millionmetric tons.Sorghum research programs focus on varietal improvement withthe objective of developing high yielding varieties with good quality traits for consumer and market demand. Research also focuses on resistance to biotic and abiotic factor such as striga, insect, disease, drought etc. (Noureldin and Elamin, 2006).High yield potential cultivars, such as Tabat and Wad.Ahmedin addition to hybrid development with emphasis on strigaresistant The most significant outcome of Sudan's cooperative program with ICRI SAT (1977) was the release of commercial hybrid Hageen Dura in 1982 by ICRISAT and the Sudan Agricultural Corporation (ARC) (Doggett, 1988).

2.5 Uses of sorghum

Sorghum is avery important crop traditionally processed to remove fibrous and often colour pericarp and testalayers, to reduce the grain into flour used to prepare a variety of traditional foods. Methods of processing vary from one locality to another according to local customs, culture and traditions 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 grain may or may not bedehulled. Traditionally, food grains are ground, moistened or crushed 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. 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 and mortars. With the assistance of FAO and UNDP, pilot plant 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 "Aceda" 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 saving 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. They were meant tosell 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 macroin and the starch and glucose industry. In the Sudan, sorghum leads other crops, in both acreage and produce. The area about 75% of the total cereals produced in the country.

However, as more than 90% of the sorghum area is rain-fed, and most of it receives inadequate and erratic rainfall, yields are low and the area and production fluctuatewidely from year to year (EI-*Ahmadi et al*.,2003).

2.6. Fertilizer application

Sudan is the largest among all Africa and Arab countries (more than 250 million.ha) andsoils have different properties. Most of irrigated schemes are located in the central clay plain. The soil ismontmorolinitic in nature, characterized by high caly content (54-65%) and alkaline pH (8-8.4) low organic matter and low chemical fertility status. Nitrogen and phosphorus are predominantly deficient, whereas indications of potassium deficiency are detected in some parts of the Rhad scheme (Eltom, 1972; Elsharif, 1992; 1982).Experiments started since 1925 while commercial use began in 1950 using ammouimsulplate as source of N and changed to urea in the 1960s. In the 1980s use of triple super phosphate was introduced as asoure of P.This was followed late (mid 90) by the use of compound fertilizer, in soild or in liquid form, (Shama, et al., 2007).Sorghum responds to application or barnyard manure of 20 to 40 pounds per acres (22 to 45 kg/ha of nitrogen) in the semiarid great plains and 40 to 60 pounds per acres (45 to 60/ha) in the sub humid areas. To increase grain yield and to improve the quality to meet the high demand of the human poultry food, proper cultural practices and land preparation, seed rate, time of sowing, irrigation and fertilization should be optimized. Phosphorus (P) is one of the most important nutrients (next only to nitrogen) limiting crop production in many regions of the world. To improve the phosphorus nutrition of plants, the traditional approach is to apply large amounts of P fertilizers to soils. However, the use efficiency of applied phosphorus is generally very low, ranging from 10% to 30% in the year (McLaughlin et al., 1991).

Continuous application of phosphorus fertilizers also increases the risk of phosphorus loss from soil to water, causing toxic algal blooms in water bodies (Sharpley et al., 2000). Improving plant uptake of phosphorus from soil is an important part of the management system for low phosphorus soils and the enhancement of use efficiency of phosphorus fertilizers Genetic variations in phosphorus uptake efficiencies have been widely reported in many crops, such as clover (Trolove et al., 1996).

2.7. Effect of phosphorus:

Phosphorous plays a vital role in nutrition of sorghum plant (Govil and Prasad, 1971).It stimulates early root formation (Govil and Prasad, 1971; Patel et al., 2007).And hastens crop maturity (Govil and Prasad, 1971; Tisdale e al., 1985) and ultimately biomass production (Patel et al., 2007).

Adequate supply of nutrients at all stages of the plantis necessary for maximum yield (Vanderlip, 1972). Phosphorus is the next most yields – limiting nutrient after nitrogen. It is found in plant in many forms as phytin in seed. There are many phosphorus compounds involved in metadolic transfer process as the Adenosine Tri phosphate (ATP)(Jules, 1974).

Phosphorus is applied to the soil in the form of phosphorus fertilizer. Super phosphate is excellent phosphorus fertilizer for plant that can be used as direct application material (Liekam et al., 1990).

Phosphate fertilizer can help crops to increase the uptake of harmful nutrient such as excessive sodium uptake. Is the second most deficient element after nitrogen where more than 90% of phosphorus soil in Sudan requires moderate to high phosphorus for optimum crop growth. It exists in soil in organic and inorganic forms (Black, 1968). The efficiency of soil ranges between 2-15%

due to factors such as soil texture, aeration, temperature, soil pH and $CaCO_3$ content.

2.8. Sorghum cultivars

Grain sorghum is grass similar to corn in vegetative appearance, but has more tillers and more finely branched roots than corn. Growth and development of sorghum is similar to corn, and other cereals. Sorghum seedlings are smaller than corn due to smaller seed size. Before the 1940s, most grain sorghums were 5-7 feet tall, which created harvesting problems. Today, sorghums have either two or three dwarfing genes in them, and are 2-4 feet tall. While there are several grain sorghum groups, most current grain sorghum hybrids have been developed by crossing Milo with Kafir. Other groups include Hegari, Feterita, Durra, Shallu, and Kaoliang.In the period of 2008-2013 the ARC, represented in Dura Research program, released the Dura cultivars (Bashayer, Botana, Arfagadamk,-Pac-501) These cultivars are dry-resisting and can be harvested at early-maturity (80day to harvest), in addition to its high productivity.

Botanafatarita : has white grain and flour much like Tabat. It also has unchangeable seed color.Arfaagadamak: has a big seed and its flour is brown much like Wad ahmed and it contains high amount of protein. It's observed that this succeed in enhancing the character of tolerance to striga most cultivars use by farmers (ARC, 2013)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Genetic materials used in the study

The cultivar used in this study was consisted of five cultivars (Arfagadamk, Tetron, Botan, Tabt, and wadahmedof Sorghum (*Sorghum bicolour*L.Moench)which reseed by Agricultural Research Corporation (ARC), WadMadni.

3.2. Field experiments

Afield experiment was carried out at the Demonstration farm, College of Agricultural Studies, Sudan University of Science and Technology at, shambat, locatedat longitude 32.35” E and latitude 15.31” N, within the semi-desert region (Adam, 2003).The soil of the site is loamy clay with pH, 8.2 as described by Abdelgadir (2010)

The experiment was laid out in asplit arrangement in a randomized complete block design (RCBD) with four replications.The main plot was with or without addition of phosphorus while the sub-plot was the five sorghum cultivars .The field was disc ploughed, disc harrowed leveled and ridged up north-south, 70cm apart. The land was divided into2 x 3.5m^2plots, each composed of 4ridges two meters long. Seeds were sown in shedder of the ridge with, 25cmspacing between holes Phosphorus fertilizer was applied to the experiment sowing with arate of64kg /fedan.The experiment comprised of 40 plots.Seed were sown by hand on 24/7/2013.Seed rate was (7kg/fed).All plots were irrigated at sowing Weed were controlled by hand, the first weeding was done ten days after sowing (5/8/2013)and the second weeding on 20/8/2013.

3.3. Data collection

The following characters were taken for five plants at each plot randomly selected and tagged and from them data for the following growth and yield characters were measured

3.3.1 Growth characters

3.3.1.1 Plant height (cm)

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

3.3.1.2 Stem diameter (cm)

It was determined at maturity on the stalk at 10/cm above the ground level.

3.3.1.3 Number of leaves/plant

It was counted for the five tagged plants and the average was determined.

3.3.1.4 Leaf area (cm^2)

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

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

3.3.1.5 Plant dry weight (g)

It was calculated as average for the dry weight of the five tagged plans.

3.3.2 Yield Characters

3.3.2.1 Panicle length (cm)

It was measured from the base of the panicle to its tip using the meter tape.

3.3.2.2 Grain yield/plant (g)

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

3.3.2.3 100 grain weight (g)

The weight of 100 grains was determined by weighing 100 grains obtained randomly from the five selected panicles using asensitive balance.

3.3.2.4 Grain yield (ton /ha)

After harvesting, all the covered heads from an area of 0.7 m^2 in the middle ridges of each plot were cut and then stored for four weeks to minimize change in weight due to moisture content, then manually threshed ,cleaned and weighed by using the sensitive balance and the grain yield (ton/ /ha) was determined as follows:

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

3. 4phosphors analysis;

For available phosphorus,Olsen*et al* (1954) method was used using spectrophotometer modal (6305)and phosphorusin thetissuswas determined using astandardanalytical method (Ryan el al.,1996).

3.5 Phosphorus Useefficiency (PUE):

In general one term is used in relation to (PUE).These are:

$$\text{PE (kg grain .kgg P taken upby crop)} = \frac{\text{yf}-\text{yc}}{\text{PUf}-\text{PUC}}$$

In the above expression, yf and yc are the yields(kg /ha) in fertilizer and control(no fertilizer) plots, respectively PUF and PUC are the amounts of phosphorus taken up by a crop in fertilized and control plots, receptivity and Pa refers to the amount applied (k/ha). PUE is productivity index used by FAO (1989).

3.5. Statistical Analysis

The collected data for growth and yield was subjected to analysis of variance for a randomized complete block design (RCBD).The means were separated using MSTAT-C

Coefficient of variation (C. V) for each character was determined according to the following formula.

$C.V = \frac{\sqrt{(\mathrm{MSE})}}{(G)} \times 100$ Where

MSE = mean square of Error, G= Grand mean

CHAPTER FOUR

RESULTS

4.1Productivity of sorghum clutivars in phosphorus utilization:

In soil analysis the percentage of phosphorus in the soil was 17% and the percentage after sowing using phosphorus fertilizer and without using it was 3% and 7% respectively, which means that the uptake of phosphorus by the plant from soil increased after adding the fertilizerArafagadamak cultivar has the highest yield productivity (12.74 T/ha) though its phosphorus uptake was the lowest (19.169ppm) and this implies that the utilization of phosphorus fertilizer was excellent because of its high physiological efficiency (10.37) compared to the other cultivars.

Although Botana had the highest uptake of the fertilizer (40.462ppm), but its productivity was equal to Titron, alloughTitron itself had an uptake of (28.735ppm), knowing that the physiological efficiency of both was almost equal (Botana 8.70, Titron 8.69).

4.2 Growth characters:

4.2.1 Plant height (cm):

Statistical analysis revealed significant differences between phosphorus treatments and highly significant differences (0.05) among the fivecultivars of sorghum (Table2). However, the interaction between phosphorus and the five of cultivarssorghum were not significant. The taller plants were attained in plants which weretreated t with phosphorus (131.66cm) while the shortest were obtained at contact treatment (124.09cm) (Table3).As shown in (Table4) Titron gave significantly taller plants (185.50cm) than the other four varieties. The interaction between phosphorus and the fivcultivarse of sorghum revealed that Titron with phosphorus and without phosphorus gave either ways significant taller plants (188.85cm) or (182.15) respectively than the other comparisons while Wadahmed without phosphorus gave significantly lower plant height (99.97cm) as shown on Table (5).

Table (1) Productivity of sorghum cultivars in relation to phosphorus utilization

Cultivars	Yield (T/ha)		P Content In Sorghum (ppm)			P In The Soil (%)			P Use Efficienc
	P-	P+	Before Sowing	After Sowing P-	After Sowing P+	Before Sowing	After Sowing P-	After Sowing P+	(P-)-(P+)
Arafagadamak	7.45	12.75	1.565	15.789	19.169	17%	7%	3%	10.37
Botana	7.90	10.70	1.730	23.952	40.462	17%	7%	3%	8.70
Titron	7.65	10.70	1.740	15.789	28.735	17%	7%	3%	8.69
Tabat	7.50	10.0	1.800	15.763	27.624	17%	7%	3%	6.96
Wad Ahmd	6.90	6.90	1.620	19.663	30.075	17%	7%	3%	6.74

4.2.2 Number of Leaves/Plant:

The highly significant differences were shown in phosphorus but there is a significant difference (0.05) among the five of cultivarssorghum (Table2). However the interaction between phosphorus and the fivecultivarsof sorghum was not significant. The highest number of leaves was attained in plants treated with phosphorus (12.3) while the lowest was obtained in plants without phosphorus (11.2) (Table3). As shown in (Table4) Wadahmed gave asignificantly high number of leaves per plants (12.9) than the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Wadahmed with phosphorus had significantly the highest number of leave per plant (13.3) than the other comparisons while Arfagadamk without phosphorus had the significantly the lowest number (10.7) as shown in (Table 5).

4.2.3 Stem diameter (cm):

Statistical analysis revealed high significant differences between phosphorus treatments and the five cultivarsof sorghum (Table2). However, the interaction between phosphorus and the fivecultivarsof sorghum was not significant. The highest stem diameter was attained in plants treated with phosphorus (12.0cm) while the lowest was attained in plants without phosphorus (11.2) (Table3). As shown in (Table4) Butana gave significantly the highest stem diameter (11.9 cm) than the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Butana with phosphorus had a significantly highest stem diameter (12.6cm) in comparison with the others, while Wadahmed without phosphorus had the significantly the lowest stem diameter (10.3cm) as shown in (Table5).

Table (2): F- Values of different characters of Sorghum:

SOURCE	DF	F. value									
		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	Number of panicle
REP	3	-	-	-	-	-	-	-	-	-	
phosphorus	1	9.79*	248.57**	244.16**	33.92*	13.15*	1.28^{NS}	10.05*	133.58**	34.94**	10.16*
ERROR a	3	-	-	-	-	-	-	-	-	-	-
Cultivars	4	123.11**	3.76*	2.39*	51.27**	4.52**	0.86^{Ns}	2.83**	1.06^{Ns}	0.92 ^{Ns}	2.82*
A TREAT*VAR	4	0.37 ^{Ns}	1.12 ^{Ns}	0.26 ^{Ns}	0.17 ^{Ns}	1.12 ^{Ns}	1.72 ^{Ns}	1.49 ^{Ns}	0.21 ^{Ns}	1.07 ^{Ns}	0.29 ^{Ns}
ERROR b	24	-	-	-	-	-	-	-	-	-	-
TOTAL	39	-	-	-	-	-	-	-	-	-	-
EMS	-	80.79	0.95	0.49	32.59	0.01	0.16	0.26	9.67	2.85	21.06
CV	-	7.03	8.27	6.21	4.10	24.35	32.88	16.75	13.88	8.25	8.67
SE±	-	1.17	0.5	0.05	0.74	0,02	0.26	0.07	0.37	0.51	0.67

CV = Coefficient of Variation. *=significant **=highly significant NS=non significant

SE = Standard Error

4.2.4 Leaf Area (cm^2):

The significant differences were shown between phosphorus treatments and highiy significant differences were among the five cultivars s of sorghum (Table2). The interaction between phosphorus and the five genotypes of sorghum was not significant. The highest leaf area was attained in plants treated with phosphorus (142.2cm^2) while the lowest was obtained in plants without phosphorus (136.0cm^2) (Table3). As shown in (Table4),Tabat gave significantly the highest leaf area (162.6cm^2) than the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Tabat with and without phosphorus hadsignificantly the highest leaf area (165.1cm^2), (160.1cm^2) respectively comparing to the other. Cultivars,while tiron without phosphorus had significantly the lowest leaf area (123.1cm^2) as shown in(Table 5).

4.2.5 Plant fresh weight (g):

Statistical analysis exposed significant differences between phosphorus treatment throughout the five cultivars of sorghum- and the interaction between phosphorus and the five cultivars ofsorghum (Table2). The highest weight was reached in plant which treated with phosphorus (0.60g) while the lowest was reached in plants without phosphorus (0.47g) (Table3). As shown in (Table4) Titron gave significantly the highest weight (0.60g) among the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Wadahmed with phosphorus hadsignificantly the highest weight (0.67g) among the varieties,while Butana treated without phosphorus had significantly the lowest weight (0.75g) as shown in(Table 5).

Table (3): Effect of Phosphorus on different parameters of Sorghum:

Parameter / Treat	plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf Area (cm^2)	Plant fresh weight (g)	Plant dry weight (g)	Length of panicle (cm)	Weight of seed panicle(g)	Weight of 100 seeds(g)	Number of panicle
P+	131.66	12.34	11.99	142.17	0.50	0.40	21.63	25.50	3.42	54.50
P-	124.09	11.22	10,69	136.02	0.47	0.36	19.32	2.76	19.29	51.40
Mean	127.87	11.78	11,34	13.09	0.53	0.36	20.47	22.39	3.09	52.95
LSD	5.74	0.58	0.43	3.56	0.08	0.08	1,14	1.93	0.32	1.47

(p+): With phosphorus

(P-): Without phosphorus

4.2.6 Plant dry weight (g):

There were no significant differences in phosphorus treatments, among the fivecultivars of sorghum and in the interaction between phosphorus and the five cultivars of sorghum (Table2). The highest dry weight was attained in plant which treated with phosphorus (0.40g) while the lowest was attained in plants without phosphorus treatment (0.36g) (Table3).As shown in (Table4),Butana gave significantly the highest dry weight (0.5612g) than the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Butana with phosphorus had the highest significant weight (0.5625g) among all othercultivars,while Titron treated with phosphorus had significantly the highest weight (0.43g), and lowest weight whennot treated with phosphorus (0.33g) as shown in(Table5).

4.3 Grain yield characters:

4.3.1 Length of panicle (cm):

Statistical analysis showed significant differences in phosphorus treatments and highly significant differences (0.01) among the five cultivars(table2)However, the interaction between phosphorus and the five of cultivarssorghum was not significant. The tallest panicle was attained in plants treated with phosphorus (21.6cm) while the shortest was in plants without phosphorus (19.3cm)(Table3). As shown in (Table4) Titron gave significantly taller panicles (22.0cm) than the other four varieties. The interaction between phosphorus and the fivecultivars of sorghum revealed that Titron with phosphorus had a significantly taller panicle (24.2cm) than the other while cultivars,Wadahmed treated without phosphorus had significantly the shortest panicle (18.6cm) as shown in(Table5).

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

Parameter / Cultivar	Yield (/T/ha)	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(g)	Number of panicles
Titron	9.17	185.50^{A}	11.65^{B}	11.32^{AB}	127.55^{D}	0.60^{A}	0.38^{A}	22.00^{A}	22.81^{A}	2.87^{A}	52.25^{B}
Butana	9.30	138.00^{B}	11.15^{B}	11.90^{A}	128.90^{CD}	0.36^{B}	0.46^{A}	19.81^{B}	23.93^{A}	3.05^{A}	57.62^{A}
Arfagad amk	10.10	107.04^{C}	11.82^{B}	11.16^{B}	142.93^{B}	0.57^{A}	0.37^{A}	19.50^{B}	21.53	3.06^{A}	50.500^{B}
Tabat	8.75	107.04^{C}	11.40^{B}	11.46^{AB}	162.60^{B}	0.55^{A}	0.35^{A}	20.93^{B}	22.67^{A}	3.12^{A}	52.12^{B}
Wad ahmed	8.17	101.66C	12.88^{A}	10.85^{B}	133.51^{c}	0.57^{A}	0.37^{A}	20.15^{B}	21.05^{B}	3.36^{A}	52.12^{B}
Means	9.09	127.84	11.78	11.33	139.09	0.53	0.38	20.47	22.39	3.09^{A}	52.92
LSD	0.5	9.07	0.94	0.68	5.63	0.13	0.12	1.81	3.06	0.51^{A}	4.55

Means followed by the same letter for each parameter are not significantly different at 5% Level according to LSD

4.3.2 Weight of seeds/panicle (g):

In these particular results, highly significant differences (0.05) were seen in phosphorus treatment but there were no significant differences among the five of cultivarssorghum or the interaction between phosphorus and the five cultivars(Table2). The highest weight was attained in plants treated with phosphorus (25.5g) while the lowest was obtained in plants treated without phosphorus (19.2g) (Table3). As shown in (Table4),Butana gave a significantly higher weight (23.9g) than the other four varieties. The interaction between phosphorus and the five genotypes of sorghum revealed that Butana with phosphorus had significant higher weight (27.5g) than the other cultivars,while Wadahmed without phosphorus had significantly the lowest weight (17.8g) as shown in (Table 5).

4.3.3 Weight of 1000 Seeds (g):

Statistical analysis revealed highly significant differences in phosphorus treatment among the of sorghum cultivars, but no significant differences in phosphorus with interaction between the fivecultivars of sorghum (Table2). The highest weight was attained in plants treated with phosphorus (3.4g) while the lowest weight was obtained in plant treated without phosphorus (2.7g) (Table3). As shown in (Table4) Wadahmed gave significantly higher weight (3.3g) than the other four varieties. The interaction between phosphorus and the five of scultivarsorghum revealed that Btana with phosphorus had a significantly highest weight (3.7g),while Tiron treated with phosphorus had significantly the lowest weight (3.0g) as shown in (Table 4).

Table (5): Interaction between phosphorus and Sorghum Cultivars for different parameters:

Cultivars	Phosphorus	Characters measured									
		Plant height (cm)	Leaf number	Stem diameter	Leaf area(cm^2)	Plant Fresh Weight (g)	Plant Dry Weight (g)	100 Seeds Weight (g)	Panicle Weight (g)	Panicle Length (cm)	Number of Panicles
Titron	P+	188.85 A	12.60 ABC	12.05 AB	131.97 DE	0.582 ABC	0.435 ABC	3.00 BCD	25.90 A	24.25 A	53.50 ABC
	P-	182.15 A	10.70 D	10.60 DE	123.13 F	0.625 ABC	0.332 B	2.75 CD	19.72 CD	19.75 BCD	51.00 BC
	Mean	185.5	11.65	11.32	127.55	0.60	0.38	2.87	22.81	22.00	52.25
Butana	P+	141.75 B	11.65 BC	12.60 A	131.88 D	0.45 D	0.56 A	3.75 CD	20.5 B	20.62 BCD	55.50 A
	P-	134.25 B	10.65 D	11.20 BCD	125.92 DC	0.27 D	0.36 B	2.72 CD	20.32 B	19.00 CD	55.75 AB
	Mean	138.00	11.15	11.9	128.9	0.60	0.46	3.23	23.93	19.18	5.62
Arfagadmak	P+	141.13 C	12.70 AB	11.95 AB	145.18 B	0.63 AB	0.31 B	3.42 AB	32.80 ABC	20.25 BCD	52.25 BC
	P-	100.20 D	10.95 D	10.3 E	140.68 BC	0.51 ABC	0.42 AB	2.70 CD	19.27 D	18.5 D	48.50 C
	Mean	107.16	11.82	11.15	142.93	0.57	0.36	3.06	26.03	19.50	50.37
Tabat	P+	110.22 CD	11.45 DC	11.92 AB	165.13 A	0.64 AB	0.35 B	3.75 CD	25.97 A	21.37 C	52.25 bc
	P-	100.30 CD	11.35 CD	11.00 CDE	160.07 A	0.47 BC	0.35 B	2.50 D	19.37 D	20.50 B	52.00 BC
	Mean	105.26	11.40	11.46	162.60 24	0.55	0.35	3.12	22.6	20.93	52.12
Wad Ahmed	P+	103.35 CD	13.32	11.45	136.7	0.67 A	0.38 AB	3.57 AB	24.32 AB	21.67 B	54.50 ABC

			A	BC	2^{CD}						
	P-	99.97^{D}	12.45 AB	1026 E	130.3 0^{C}	0.47^{B} C	0.37^{B}	3.15 ABC	17.77 D	18.62 D	49.75 BC
	Mean	101.66	12.88	10.85	133.5 1	0.57	0.37	3.36	21.04	20.14	52.12

Means followed by the same letter for each parameter were not significantly different at 5% level

4.3.4 Number of panicles /plant:

Significant differences were shown in phosphorus treatments but there were highly significant differences (0.05) among the five cultivarsof sorghum (Table2). However, the interaction between phosphorus and the five cultivarsof sorghum was not significant. The highest number of panicles was attained in plants treated with phosphorus (51.4) while the lowest was obtained in plants with not without phosphorus (48.5) (Table3). As shown in (Table4) Butana gave significantly ahigher number of paniclesper plants (57.6) than the other four varieties. The interaction between phosphorus and the five cultivarsof sorghum revealed that Wadahmed with phosphorus had significantly the highest number of paniclesper plants (54.5),while Arfagadamk without phosphorus had significantly the lowest number (49.5) as shown in (Table 5).

4.3.6 Yield(t/ha):

Arafagadamak cultivar gave the highestyield (12.74),while Tiron, Botan,Tabat recorded (10.7),(10.7),(10.0).respectively and Wadahamed gave lowest yield (6.90)as show in(Table4).

CHAPTER FIVE

Discussion

Phosphorus fertilizer was added to five cultivars of sorghum in order to study the physiological phosphorus use efficiency and its effect on productivity. According to this the soilwas analyzed before and after phosphorus fertilizer addition as well as analyzing the percentage of phosphorus in the grains of the five cultivars before and after adding the phosphorus.

Plant height was increased with the addition of phosphorus, because it helped in the process of cells division. This result is not similar to the findings of Gasim (2001), who reported that phosphorus did notaffect the plant height.

On the other hand, leaf area has also increased because of phosphorus which affected thephotosynthesis significantly. The increment of seed weight was due to the role which the phosphorus plays in composition of carbohydrates, proteins and seeds. This result agreed with Charles et.al (2006) who stated that yield increase is expected from phosphorus application. Samuel et.al (2012) also stated that grain yield was increased significantly by added Nitrogen and Phosphorus only. The increment of the fresh weight of the plant was a result of the addition of phosphorus, because it has affectedon some physiological processes. Arafagadamak cultivar has the highest yield productivity (12.74 T/ha) though its phosphorus uptake was the lowest (19.169ppm) and this implies that the utilization of phosphorus fertilizer was excellent because of its high physiological efficiency (10.37) compared to the other cultivars.

Although Botana had the highest uptake of the fertilizer (40.462ppm), but its productivity was equal to Titron, alloughTitron itself had an uptake of

(28.735ppm), knowing that the physiological efficiency of both was almost equal (Botana 8.70, Titron 8.69).

Apparently, Titron utilized the fertilizer in the growth characters while Botana utilization was balanced between all yield components and productivity. The uptake percentage of Tabat was (27.624ppm), however its physiological efficiency was low, thus indicating that it utilized the fertilizer in some of the vegetative growth (leaf area, fresh weight), and other parts went to yield components (100 seeds weight). Wadahmed took a high percentage of the fertilizer (30.075ppm), however it had the lowest productivity and the lowest physiological efficiency, (9.45 t/ha productivity) and (6.74 physiological efficiency), showing that it utilized its fertilizer in yield growth (fresh weight and 100 seeds weight mostly).

CHAPTER SIX

SUMMARY AND CONCULUSION

6.1 Summary:

To study the effect of phosphorus fertilizer on growth and productivity of five cultivars ofsorghum, and to evaluate phosphorus use efficiency, a field experiments was conducted during(2014), summer season in the Demonstration Farm of the Collage of Agricultural Studies at Shambat, Sudan University of Science and Technology .A randomized complete block design under split trial arrangement with addition of phosphorus as the main plot(with and without) and five sorghum cultivars (Butana, Tabat , Arfagadamak , Wad Ahmed , Tetron) as the sub-plot, with four replications was used for this purpose.

The results revealed that phosphorus effected yield and growth characters.Arfagadamakreveatedthe best use, therefore the highest productivity (12.75 tan/h), and Wadahmed showed the lowest use of phosphorus and therefore the lowest productivity (9.45 tan/h).

6.1 Conclusion:

According to this study phosphorus affected the productivity and the growth characters, and therefore it is suggested that this study can be use in the Sudan to increase grains and forages production.It is alsorecommendrepeating this experiment is to be repeated next year to can finer these these results.

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