بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Response of Genotypes of faba bean (*Vicia faba* L) to Water Stress during flowering and podding stages

استجابة اصناف من الفول المصري للإجهاد المائي خلال فترة الإزهار و تكوين القرون

A thesis Submitted in full Fulfillment for the Requirement of the Degree of M.Sc. in Agronomy

By

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B. Sc. Agronomy

Sudan University of Science and Technology 2015

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March 2019

الاية

بسم الله الرحمن الرحيم

قَالَ تَعَالَىٰ:

﴿ وَٱللَّهُ أَنزَلَ مِنَ ٱلسَّمَآءِ مَآءً فَأَحۡيَا بِهِ ٱلۡأَرۡضَ بَعۡدَ مَوۡتِهَآۚ إِنَّ فِي ذَٰلِكَ لَأٓيَةً

لِّقَوۡمٍ يَسۡمَعُونَ ٦٥ ﴾ النحل: ٦٥

صدق الله العظيم

سورة النحل الأية (65)

Dedication

To my mother,

My father's

My brothers and sisters,

And my friends

To my family ….. With love

Esra

Acknowledgements

Above all I render my thanks to the Merciful ALLAH who offers me all things to accomplish this study.

I wish to express my sincere gratitude and appreciation to my supervisors: **Dr. Samia Osman Yagoub** for their invaluable guidance and help during the stages of the practical work and preparation of the study.

My full thanks are to my mother and father and colleagues for their continuous support during the study period. Lastly, I would like to express my great appreciation to the members of the Department of Agronomy, College of Agricultural Studies, Sudan University of Science and Technology for their unlimited help during teaching period and experimental work.

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Abstract

The experiment was conducted during the 2017-2018 season at the Demonstration Farm, Sudan University of Science and Technology .The objective of this study was to determine the effect of water stress on growth and yield of different varieties of faba beab (*Vicia faba* L).The experimental design used was randomized complete block in split plot replicated three times .The main plot consisted of five water intervals during flowering and podding stages (7,15,21days) and the subplots consisted of four varieties (Basabeer, Selaum, ALdamer and ,Huduba).

The vegetative and reproductive growth parameters studied were plant height, fresh weight of plant, dry weight of plant, fresh weight of root, dry weight of root, number of flower50%, number of flower100%, and number of nodes. Yield and yield components were number of pods, number of seeds, hundred seeds weight, weight of seeds, and hard seeds. Water use efficiency parameters were; drought tolerance index (DTI), stress susceptibility (SSI) and stress tolerance index (STI).

The results revealed that water stress significantly affected all vegetative growth parameters except dry weight of plant, fresh weight and plant height at the first reading. On the other hand, faba bean varieties were not significantly affected except plant height at reading four. Water stress significantly affected all yield and yield components except seed weight.There were no significant differences among faba bean varieties.

Water use efficiency is presented in from of tolerance index, (DTI) stress stability index (SSI) and stress tolerance index (STI). The results showed that water stress and faba bean varieties had no significant difference

concerning drought tolerances index and stress tolerance index, while stress susceptibility index was affected significantly.

It can be concluded that water stress during flowering and podding stages had significant differences for all growth, yield, yield components, and water use efficiency for the cultivars of faba bean. No clear variation was observed among all parameters studied for water stress, which means that flowering and podding stages are critical stages under semi-arid conditions of Sudan.

المستخلص

أجريت هذة التجربة خلال الموسم 2017- 2018 بالمزرعة التجريبية لكلية الدراسات الزراعية جامعة السودان للعلوم والتكنولوجيا. هدفت الدراسة إلي تحديد تأثير الاجهاد المائي على النمو والإنتاجية لأربعة أصناف من الفول المصري .إستخدم تصميم القطاعات العشوائية الكاملة في توزيع القطع المنشقة بثلاثة مكررات و شملت القطع الرئيسية خمسة مستويات من الري خلال فترة الإزهار وتكوين القرون (7,15,21) بينما وزعت أصناف الفول المصري (بسابير, سليم ,الحديبة ,الدامر).على القطع المنشقة

شملت مقايس النمو الخضري والثمري طول النبات ,والوزن الرطب للنبات , والوزن الرطب للجذور , والوزن الجاف للنبات و الوزن الجاف للجذور , وعدد الازهار عند50% , وعدد الازهار عند 100%, وعدد العقد, بينما شملت الانتاجية ومكوناتها عدد القرون,وعدد البذور,ووزن البذور,و وزن المائة بذرة ,وصلابة القشرة .

كان تأثير الاجهاد المائي معنوياً في كل صفات النمو الخضري ماعدا الوزن الجاف والرطب للنبات لم يكن هناك تأثير معنوي لأصناف الفول المصري على كل صفات النمو الخضري عداطول النبات في القراءة الرابعة, .الاجهاد المائي كان له تأثير معنوي على كل صفات الانتاجية ومكوناتها ماعدا وزن البذور . لم يكن هناك تأثير معنوي لأصناف الفول المصري على كل صفات الانتاجية ومكوناتها ما عدا وزن المائة بذرة و صلابة القشرة .

كفاءة الري ,كفاءة استخدام الماء تم تقسيمها حسب الجفاف الي معامل الجفاف ومعامل الإجهاد ومقاومة الجفاف .واوضحت النتائج عدم وجود فروقات معنوية لمعامل الجفاف ومقاومة الجفاف في حين اوضح معامل الاجهاد فرقاً معنوياً بالنسبة للاجهاد الامائي كما اوضحت النتائج عدم وجود أي فروقات معنوية بين الأصناف.

يستنتج من هذة الدراسة ان الإجهاد المائي خلال مرحلة الإزهار وتكوين القرون أظهرت إختلافاً معنويًا في كل من النمو ,والإنتاجية ومكونات الإنتاجية وكفاءة إستخدام الماء لأربعة أصناف من الفول المصري ,ولم تظهر الأصناف أي إختلاف معنوي في كل القياسات للأجهاد المائي. مرحلة الإزهار وتكوين القرون هي المرحلة الحرجة للإستجابة للإجهاد المائي تحت ظروف المناطق شبه الجافة في السودان.

CHAPTER ONE

INTRODUCTION

Faba bean (*Vicia faba.L*) belongs to the family Fabaceae. Knowledge of the wild progenitor and area of origin of the genus, and subsequent steps in the domestication of its most important species, is scarce and disputed (Shiran *et al*.,2014). It is well known as faba bean, field bean, and horse bean (Zohary, 2000). *Vicia faba* is an important legume crop worldwide, ranking as the fourth most important grain legume after dry bean, dry peas and chick peas (Lopez Bellido *et al*, 2005). It is one of the oldest and the most important grain legumes grown in the Mediterranean region, where it is used for human consumption and animal feed, (Kharrat and Ouchari, 2011, Prolea 2014) moreover, it is used for improving crop rotation (Kharrat and Ouchari, 2011). Faba bean and broad bean are good source of carbohydrate and protein, low in fat, and is mainly starch (GRDC, 2016), it can be also used in the bakery industry (Belghith *et al.*, 2016).

Faba bean consuming countries are Egypt, Morocco and Sudan (FAO, 2016).The Faba bean world production is approximately 2.4 million metric tons with China being the largest producer with 60% of the total world production (FAO, 2005). Its global acreage declined from 3.7 to 2.1 million ha between 1980 and 2014, and yields are highly variable within specific countries (FAO, 2017). Despite the decreasing acreage however, productivity per area has tended to increase, due to reduced susceptibility to abiotic and biotic stresses. The global production of Faba bean grain in 2014 was 4.1 million tons, which is approximately 21% greater than in 1994 (FAO, 2017). In Sudan production of faba bean was 138 thousand tons in year 2006 (FAO, 2008).The Northern State produces about 20% of the crop.

Drought stress is a main constraint to agricultural production, including terminal stresses observed in low rain fall areas of the world where dry bean is an important crop .Soil water deficits that occur during the reproductive growth are considered to have the most adverse effects on crop yield (Costa *et al* 2000). Drought is an important environmental factor,which induced significant alteration in plant physiology and biochemistry (Kamal, 2012). Drought affects many aspects of plant physiology including net photosynthesis, relative water content, chlorophyll content and photosystem activity (Pandey and Shukla 2015).

Faba bean is more sensitive to drought than some other seed legumes including common bean pea and chick pea (Amede and Schabert 2003). Selecting adapted genotypes under environmental stress condition helps to improve adaptation and stress tolerance in cultivars (Lopes *et al*., 2012). The reaction of plant to drought stress depends on the intensity and duration of stress as well as the plant species and its stage of growth (Parameshwarappa and salimath 2008).

This study aimed at knowing the effect of water stress during flowering and pod filling stage on growth and yield of four cultivars of faba bean.

CHAPTER TWO

LITERATURE REVIEW

2-1General :-

Faba bean (*Vicia faba L*) is considered one of the most important legumes in Sudan, it has become one of the strategic crops due to its income to the farmers, and also, it is important for soil fertility, human nutrition as good source of vegetarian protein and industry purpose. The world production of faba bean was3.3 million tones, which reported by (FAO,2000). The 5 top producing countries are China, Ethiopia, Australia, France and United kingdom and account for more than 75% of world production, China alone produced 34%of all faba bean in 2013(FAO,2014). Faba bean production has declined considerably from 523,000 tones in1998 to158, 000 tons in 2014 (FAO, 2015).Often a result of susceptibility to foliar diseases, the effects of parasites (Abdelmonaim 2013). Faba bean production has been shown to contribute in reducing carbon footprint of cereal based agricultural production systems through its ability in fixing nitrogen that can be used by the succeeding cereal crop and by breaking the cycle of biotic stresses (Jensen,*et al* 2010). Faba bean is one of the most efficient nitrogen-fixing legumes and Faba bean plants can meet all of their N need through biological nitrogen fixation (Hirridge, 2008)

2-2Adaptation:-

Faba bean is a cool season, annual legume (Bilalis *et al.*, 2003), and generally suited to the medium to high-rain fall, the ideal soil type is a deep, well-drained loam, clay soil. The suitable soil pH will ideally range from neutral to alkaline, it grows best in soil with a pH ranging from 6.5to 9.0

(Jensen *et a.*, 2010). The optimal temperature for faba bean growth is 15c-20c, especially during the reproductive phases of flower and pod development. Weed infestation is a major constraint in faba bean production, and can reduce yield by up to 50 %(Frenda *et al.,* 2013).

2-3Cultivars:

Evolution of the species was accompanied by intensified cultivation, with selection for different traits. The genotypes of faba bean are commonly classified into three main botanical varieties according to seed size (a) . Faba var .major with large seeds, (b) . Faba var minor with small seeds, and (c) . Faba var equine with medium seeds (Crepon et al., 2010; Pietrzak *et al.*, 2016) the first two of which are relevant in European agriculture. However, faba bean germplasm is also grouped into spring and winter types, according to target climatic zone, and sowing time, and according to the ability of adaptation to oceanic or continental climates (Link *et al*., 2010; Flores *et al*., 2013, Zhao *et al.*, 2018).

Faba bean has a long history of cultivation. A broad gene pool has therefore been developed over several centuries, including local landraces, mass selections from landraces, open-pollinated populations, inbred lines, and cultivars (*Duc et al*., 2010). In addition, socioeconomic changes have led to decreases in cultivation and the disappearance of local genetic resources, with only small farms continuing to grow different landraces selected for their adaptation to local environmental conditions (Karaköy *et al*., 2014). Most of faba bean cultivars grown in Sudan were reported to have considerable degree of auto fertility (Gasim, 2011).

Previously, local faba bean growers only accessed crop inputs through village merchants which turned out to be very expensive. In Sudan the moneylenders often grant the loan through asystem which is an exploitive informal loan there are no ways to avoided, most of the farmers look at it as a trap used by money lenders to exploit them forever (Abdalla, 2008).

Vicia faba has a large genetic diversity. According to (Duc *et al*., (2010, 2015) accessions of faba bean germplasm are conserved globally in numerous gene banks, as well as at the International Center for Agricultural Research in Dry Areas (ICARDA). Research conducted by the EUROLEGUME consortium has shown that potentially many more genotypes are available locally in Europe, at farms and in breeders' collections (Lepse *et al*., 2017). The genetic diversity of *V. faba* accessions has been assessed in various studies and marker systems (Zeid *et al*., 2003; Zong *et al.*, 2009; Oliveira *et al*., 2016; Sallam *et al*., 2016; Göl *et al*., 2017)

2-4Drought in faba bean:

Drought, is one of the environmental stresses, it is the most significant factor restricting plant production in the majority of agricultural fields of the world (Hasan and Tacettin 2010). Drought causes significant damaging for plant growth, productivity and mineral nutrition losses to crop yield (Chaves *et al*., 2003, Shao *et al* 2009). Drought severely affects plant growth, grain yield and quality, and causes morphological, biochemical and molecular changes in plants (Zaraf shr *et al.*, 2014). According to (Amede and Schubert,(2003), drought severely affects plant biomass production. Shao *et al*.,(2008), stated that different plant species can vary in their sensitivity and response to water shortages, and modifies their morphological components through a decrease in height leaf area, number of leaves and consequently plant biomass production. Furthermore, yield constituents such as grain number and size are decreased in faba bean (Ammar *et al*.,2014). Siddiqui *et al*., (2015), found that water stress also decreased stem extension of faba bean. Water deficit during the reproductive growth is considered to have the most adverse effect on crop productivity (Baigorri, *et al.*, 1999 Costa *et al* 2000).

2-5 Effect of water stress at flowering stage:

Water stress during flowering severely depressed nitrogenase activity and yield formation in all cultivars. Yield was affected to the same extent as with permanent stress from pre flowering until harvest, indicating that flowering is extremely sensitive to water stress. Water stress during pod filling hardly affected nitrogenase activity and biomass production of the cultivars tested (Hegab *et al.*,2014) Bryla *et al.*, (2003) reported that faba bean production is usually increased by irrigating spring crops during the flowering stage and early podding. Between 231 and 297 mm of water is required to produce 3–4.4 t ha^{-1}, faba bean dry biomass.

Drought and heat are considered major- constraints in faba bean growth and production in Europe. The most drought –sensitive growth stages are flowering, early podding, and grain filling (Mwanamueng *et al*., 1999; Katerji *et al* 2011). The most drought-sensitive growth stages are flowering, early podding, and grain filling (Katerji *et al*., 2011). However faba bean varieties differ widely in drought-tolerant varieties or genotypes is praline accumulation (Migdadi *et al*., 2016; Abid *et al*., 2017). Waterlogging during flowering limits faba bean growth and yield (Pampana *et al*., 2016). Faba bean is considered the most tolerant to waterlogging of the cool-season grain legumes (Solaiman *et al*., 2007)

2-6 Effect of deficit irrigation on faba bean yield:

Faba bean is well known for its susceptibility in growth, flowering and pod set, and yield when suffering from limited water supply (Ricciardi *et al*., 2001). Stresses to the plant can affect its ability to produce grain; flower and pod, retention is sensitive to transient stress (GRDC, 2016). Water stress is considered as a detrimental factor for the production of crop worldwide, globally; more than 50% of the average yield of most major crops is lost due to drought stress (Zlatev and Lidon, 2012). Khan *et al.* (2010) confirmed that pod development and seed filling stages were the most drought sensitive stage.

2-7 Efficiency of water use:

Siddique *et al* ., (2001) found that in the earlier flowering species, faba bean and field pea, a greater proportion of total water use occurred after flowering and this assisted pod filling and increased harvest index. Enhancing water use efficiency ,both under rain-fed and irrigated agriculture is a high priority for agricultural improvement in developing countries (Canone *et al.*,2015).The effect of this irrigation mode on increasing water use efficiency (WUF) and maintaining yield has been extensively verified (Davies and Hartung,2004).

Reduction in fresh and dry weight of plant organs, and in leaf area and early maturity, to mitigate the effect of drought on plants (Farooq *et al.*,2009).

In semiarid regions, climate change can affect water use efficiency and growth in faba bean (Guoju *et al*., .2016), given its sensitivity to drought (Ghassemi-Golezani *et al*., 2009; Alghamdi *et al*., 2015). Thus, production is highly dependent on the amount and variation in rainfall during the growing season (Oweis *et al.*, 2005).

2-8Drought tolerance:

Drought as an interval of water deficiency leading to a significant reduction in yield is widely considered to be the most important environmental constraint to crop productivity (Borlaug and Dowswell, 2005). Variation in the amount and distribution of rainfall is generally considered as the major reason for variability in grain yield of faba bean (Siddique *et al*., 2001).Although genotypic variation in the response of faba bean to drought has been documented, the development of drought –tolerant cultivars is essential to improve its yield stability. Plant breeders evaluate and select breeding material empirically for adaptation to drought under experimental conditions based on grain yield at drought-prone sites (Maalouf *et al*., 2015). Some studies have reported physiological traits associated with drought, such as carbon isotope discrimination, leaf temperature and stomatae conductance (Khan *et al*., 2007).

2-9Drought tolerance of the faba bean varieties:

The drought tolerance of faba bean varieties was studied by application of different irrigation treatments. The variety which gave unstable or variable results through the different drought stress treatments was considered as drought susceptible variety according to (Cattivelli *et al*., 2008, Khan *et al*., 2010).

The development of drought-tolerant faba bean varieties is a key challenge in achieving increased and more stable production levels (Khan *et al.*, 2010; Siddique *et al., 2013*). Several genotypes are considered tolerant to drought and can be exploited in breeding programs in order to develop drought-tolerant varieties (Ali, 2015). Recently, some varieties have been evaluated as tolerant to water stress (Girma and Haile, 2014).

CHAPTER THREE

MATERIALS AND METHODS

3-1The experimental site:

The experiment was carried out at the Farm of the College of Agricultural Studies ,Sudan University of Science and Technology at Shambat during the winter season of 2017_2018 to study the effect of five interval water stress during flowering and podding stages on growth and yield of four varieties of Faba bean crop (Basaber,_Huduba,_Selaum, andALdamer).

3-2Source of seed:

The source of seeds was from Khartoum University, faculty of Agriculture.

3-3Land preparation

The experimental area was tilled adequately to prepare a suitable seed bed. The implements used included a chisel (cross plough) to break and loosen the soil and a leveler (scraper) to level the experimental area for the easy movement and uniform distribution of irrigation water. The field was then divided into three blocks (replication), each plot size was 2×2 the space was each plant equal 25(cm).

Sowing was done on mid-November; the seeds were sown manually at the rate of two seeds per hole. The distance between holes was 25 cm .each genotype was grown as single plot. Weeding was done every two weeks after sowing .The plants were sprayed by Actara immediately when aphids appeared in the field.

3-4Experimental design and treatments:

The experimental design was a randomized complete block in split plots arrangement with three replications. The main plot contains irrigation and varieties in sub plots.

3-5The experiment included the following:

3-5-1Treatments:

Factor (A) five irrigation intervals during flowering and pod filling;

w1= irrigated every 7days (control).

w2 = irrigated every 15 days during flowering.

w3= irrigated every 21days during flowering.

w4 = irrigated every 15 days during pod filling.

w5= irrigated every 21days during pod filling.

Factor (B) four Faba bean varieties; v1, (Basaber), v2, (Huduba), v3, (Selaum) , v4 (ALdamer).

3-5-2Parameters studied:

3-5-2-1 vegetative growth parameters:

Plant height (cm): five randomly selected plant were measured using ruler from the soil surface to the tip of the plant and the mean plant height was determined.

3-5-2-2Number of flowers at50% flowering:

Five randomly selected plants from the each plot, were used obtain the number of flowers at 50% flowering.

3-5-2-3Number of flowers at100 % flowering:

Five randomly selected plants from the each plot, were used obtain the number of flowers at 100% flowering.

3-5-2-4 Fresh weight of plant (g):

Three plants were randomly selected from each plot, then weighed using sensitive balance.

3-5-2-5Dry weight of plant (g):

The same plant taken for fresh weight were levied in an oven for 48 hours at 80 degree then weighted using a sensitive balance.

3-5-2-5Root fresh weight (g):

The mean root fresh weight was determined from the same plants of fresh weighed using a sensitive balance.

3-5-2-7Dry weight of root (g):

The above mentioned root were dried at 80c for 48 hours and then weighted to obtain the dry weight.

3-5-2-8Number of nodes:

Three plants were randomly selected from each plot, and the number of nodes was calculated

3-5-2Yield components:

3-5-2-1Number of pods:

Five randomly plants were selected from each plot, and the average number of pods was counted.

3-5-2-2Number of seeds:

Five randomly selected plants from each plot, and the average number of seeds was counted.

3-5-2-3Hundred seed weight (g):

100 seed samples were randomly selected from each plot, and Seeds weighted using a sensitive balance.

3-5-2-4Hard seed: 100 seeds were randomly selected from each plot, wetted in water for 24 hours and hard seed were determined and calculates.

3-5-2-5Seed yield (t/ha):

When signs of maturity were clear on the plant (complete yellowing of leaves), one meter length in each plot was harvested for yield, weighed and then seed yield per plot was converted to seed yield in ton/hectare (t/ha).

3-5-3Water use efficiency (WUE):

3-5-3-1Drought tolerant index (DTI) =grain yield under low irrigation/grain yield under normal water (yl/yh).

3-5-3-2Stress susceptibility index (SSI) =

$$\frac{1-Ysi/Ypi}{1-Ys/Yp}$$

YSI=grain yield of each genotype under stress

Ypi =grain yield of each genotype under optimal condition

Ys=mean of grain yield under stress

Yp= mean of grain yield under optimal condition

3-5-3-3Stress tolerance index (STI) =

$$\frac{YSI.YPI}{Y2P}$$

Where:

Ysi= grain yield of each genotype under stress

Ypi= grain yield of each genotype under optimal condition

Y2p= square of mean grain yield in all genotypes under optimal conditions.

3-6Statistical analysis:

The data collected in this study were statistically analyzed using STATISTIX8.0 software. Aanalysis of variance ANOVA and least significant different (LSD) were used to separate the treatment means.

CHAPTER FOUR

RESULTS

4-1Vegetative Growth:

4-1-1Plant height (cm): The results of plant height of four cultivars of faba bean as affected by watering interval were presented on (Tables 1, 2,3 and 4). Four reading were taken every 15 days (15, 30, 45and 60 days) after application of watering interval The statistical analysis showed no significant difference among plant height of cultivars, but irrigation indicated significant difference in all reading expect reading one (Table 1, 2 3 and 4). In reading one, W4 gave the highest plant height(37.8cm)and W2 the lowest value (34.6cm) (Table 1), in reading two W1, gave the highest value (51.2 cm) andW3, the lowest value(46. cm) (Table 2), in reading three W1, gave the highest value(74 cm) and W3, the lowest value(62 cm) (Table 3), in reading four W1, gave the highest value (85.9cm) and W3, the lowest value(68.2)cm (Table 4). Interaction between cultivars and watering interval revealed no significant difference for all reading.

4-1-2Flower 50%: Table (5) showed the analysis of variance of 50% flowering, the results revealed no significant difference among cultivars. Irrigation indicated significant difference W1 gave the highest value,(37) and W5 gave the lowest value (12), interaction of cultivars and watering intervals showed no significant differences.

4-1-3Flower 100%: The statistical analysis of 50% flowering in Table 6 indicated no significant difference among cultivars. Irrigation obtained significant difference W1 gave the highest value(293) and W4 the lowest value (148), interaction of cultivars and watering intervals, observed no significant difference.

4-1-4 Fresh weight: Fresh weight of faba bean presented in (Table 7), **the** analysis of variance had no significant difference among cultivars. Irrigation showed no significant difference W1 had the highest value (36.1) and W3 the lowest value (23.5). Interaction of cultivars and watering intervals, showed no significant difference.

4-1-5 Dry weight: In Table (8) the data of the results of dry weight were presented and statistical analysis revealed no significant difference among cultivars. Irrigation indicated no significant difference, W1 gave the highest value (36.1)and W3 the lowest value (23.5). Interaction of cultivars and watering intervals indicated no significant difference.

4-1-6 Root fresh weight: The analysis of variance of root fresh weight (Table 9) indicated no significant difference among cultivars. Irrigation showed significant difference W1 gave highest value 5 and W3 the lowest value 3. Interaction of cultivars and watering intervals observed no significant difference.

4-1-7Root dry weight: In (Table 10) the results of root dry weight showed no significant difference among cultivars. Irrigation observed highly significant difference W1 gave the highest value 2.9 and W4, W3 the lowest value, 1.4. Interaction of cultivars and watering intervals, revealed no significant difference.

4-1-8Number of nods: The statistical analysis of number of nodes (Table 11), showed no significant difference among cultivars. Irrigation obtained significant difference; W1 gave the highest value (73.5)and W3 the lowest value (40.3). Interaction of cultivars and watering intervals, noticed no significant difference.

Table1. Effect of water stress during flowering and podding stages on plant height of cultivars of *Vicia faba* (first reading; after 15 days of watering intervals):

	V1	V2	V3	V4	X
W1	38.8a	35.0adc	34.7abc	35.6abc	36.0ab
W2	36.0abc	35.2abc	33.5bc	33.7bc	34.6b
W3	33.0c	34.2abc	37.6abc	36.7abc	35.3ab
W4	37.4abc	38.7a	36.6abc	38.4ab	37.8a
W5	35.9abc	36.4abc	37.2abc	37.6abc	36.8ab
X	36.4a	35.9a	35.9a	36.4a	
C.V	8.32				
L.S.D	2.4				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer.

Table2. Effect of water stress during flowering and podding stages on plant height of cultivars of *Vicia faba (*second reading)

	V1	V2	V3	V4	X
W1	54.0 a	49.5 abc	50.7 abc	50.6 abc	51.2 a
W2	48.0abc	50.1abc	45.4c	49.7abc	48.3ab
W3	44.3c	45.0 c	48abc	46.7bc	46.0b
W4	50.2abc	52.6ab	48.9 abc	51.0 abc	50.7a
W5	49.1abc	47.7abc	50.6 abc	50.6 abc	49.5a
X	49.1a	49.0a	48.7a	49.7a	
C.V	8.64				
L.S.D	3.4				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling podW5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table3. Effect of water stress during flowering and podding stages on plant height of cultivars of *Vicia faba (third reading)*:

	V1	V2	V3	V4	X
W1	75.4 a	72.9 ab	75.4 a	72.3 ab	74.0 a
W2	70.4 abc	64.5bc	69.0 abc	63.4 bc	66.8b
W3	52. ab	65.4 abc	66.5 abc	66.9abc	62.9b
W4	67.1abc	70.3abc `	67.4 abc	64.6bc	67.3b
W5	63.6bc	62.2cd	69.1abc	68.5abc	65.8b
X	65.8a	67.0a	69.5a	67.0a	
C.V	9.04				
L.S.D	4.9				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling podW5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer.

Table4. Effect of water stress during flowering and podding stages on plant height of cultivars of *Vicia faba(* four reading):

	V1	V2	V3	V4	X
W1	83.6 ab	84.2 ab	87.7 a	88.2a	85.9 a
W2	74.4bcde	77.0abcd	80abc	75.7bcd	76.7b
W3	62.2 f	81.5 abc	77.4abcd	81.7 abc	75.7b
W4	75.1 bcd	78.5abc	72.9bcdef	77.6 ab	76.0b
W5	63.4 ef	66.1def	71.7cdef	71.1cdef	68.1c
X	71.7 b	77.4 a	77.9a	78.8a	
C.V	9.06				
L.S.D	5.6				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table5. Effect of water stress during flowering and podding stages on 50%days of viciafaba:

	V1	V2	V3	V4	X
W1	46.6a	37.0abc	44.6ab	19.6abc	37.0 a
W2	30.00 abc	28.3 abc	17.3abc	45.0ab	30.1ab
W3	19.2 abc	32.6abc	47.3a	20.3abc	29.8 ab
W4	16.3abc	13.00 bc	28.0 abc	11.0 c	17.0 bc
W5	20.6abc	8.3c	11.6 c	9.3c	12.5c
X	26.5 a	23.8a	29.8a	21.0 a	
C.V	77.2				
L.S.D	15.9				

W1=7daycontro,lW2=14day during flowerW3=21day during flowerW4=14day duringfillingpodW5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table6. Effect of water stress during flowering and podding stages on flowering 100% of cultivars of vicia faba

	V1	V2	V3	V4	X
W1	387.3a	308.3ab	320.6ab	157.3bc	293.4a
W2	28.16cab	172.00bc	183.3bc	165.6bc	200.6ab
W3	174 bc	160.0 bc	298 abc	162 bc	198.5 ab
W4	179.3 bc	133.6 bc	137.6 bc	143.3bc	148.5b
W5	299.3 abc	107 c	162.3 bc	203.0 abc	192.9 b
X	264.3 a	176.2 b	220.4 ab	266.2 b	
C.V	7.2				
L.S.D	96.6				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table7. Effect of water stress during flowering and podding stages on fresh weight of plants of *Vicia faba:*

	V1	V2	V3	V4	X
W1	62.6ab	52.0ab	68.4a	61.2ab	36.1a
W2	43.2ab	58.2ab	47.5ab	63.3ab	30.4ab
W3	34.0b	42.4ab	58.6ab	48.8ab	23.5b
W4	71.1a	52.8ab	32.2b	51.5ab	26.8ab
W5	46.5ab	43.0ab	61.2ab	43.9ab	30.1ab
X	27.7a	30.7a	30.5a	28.7a	
C.V	36.8				
L.S.D	15.6				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table8. Effect of water stress during flowering and podding stages on dry weight (g) of plants of *Vicia faba:*

	V1	V2	V3	V4	X
W1	36.5ab	30.0abc	43.7a	34.1abc	36.1a
W2	25.9abc	35.1ab	27.5abc	33.3abc	30.4ab
W3	15.1c	23.1bc	31.1bc	25.00abc	23.5b
W4	38.7ab	28.3abc	14.9c	25.2abc	26.8ab
W5	22.4bc	36.9ab	35.3ab	25.9abc	30.1ab
X	27.7a	30.7a	30.5a	28.7a	
C.V	40.35				
L.S.D	9.6				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table9. Effect of water stress during flowering and podding stages on fresh root weight (g) of plants of *Vicia faba:*

	V1	V2	V3	V4	X
w1	5.3ab	4.4abc	5.6a	4.6abc	4.9a
W2	3.0bcd	4.1abcd	3.0bcd	3.8abcd	3.4bc
W3	2.5cd	3.5abcd	3.6abcd	2.5cd	3c
W4	4.4abc	3.5abcd	1.9d	2.6cd	3.1bc
W5	3.0bcd	5.6a	4.5abc	4.0abcd	4.2ab
X	3.6a	4.2a	3.7a	3.5a	
C.V	39.2				
L.S.D	1.2				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table10. Effect of water stress during flowering and podding stages on root dry weight (g) of plant of *Vicia faba:*

	V1	V2	V3	V4	X
W1	2.8abc	2.3abcd	3.0ab	3.3a	2.8a
W2	1.6bcd	1.9abcd	1.9abcd	1.4bcd	1.7bc
W3	0.9d	2.2abcd	1.4bcd	1.1d	1.4c
W4	2.4abcd	1.3cd	0.9d	1.2d	1.4bc
W5	1.2d	1.9abcd	2.1abcd	1.4bcd	1.6ab
X	1.7a	1.9a	2a	1.6a	
C.V	54				
L.S.D	0.8				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table11. Effect of water stress during flowering and podding stages on number of nodes of plants of *Vicia faba:*

	V1	V2	V3	V4	X
W1	65.1abc	66.2abc	76.5ab	86.5a	73.5a
W2	44.8bc	37.3bc	31.9c	52.2bc	41.5b
W3	31.4c	46.7abc	47.3abc	35.8c	40.3b
W4	77.4ab	34.2c	28.0c	32.6c	43.0b
W5	39.4bc	48.2abc	57.6abc	52.8abc	41.5b
X	51.6a	46.5a	48.2a	52.0a	
C.V	49.3				
L.S.D	19.9				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdame

4-2Yield and yield components:-

4-2-1Number of pods: In (Table 12) the analysis of variance revealed no significant differences among cultivars .Irrigation resulted in highly significant differences, W1 had the highest number(37.5), and W5 showed the lowest record(19.4). Interaction between cultivars and watering intervals had no significant difference.

4-2-2Number of seeds: From (Table 13) the statistical analysis showed no significant differences among cultivars. Irrigation indicated significant differences ,where W1 revealed the highest value (84.8), and W5, the lowest number(47.9). Interaction revealed no significant differences.

4-2-3 Hundred seeds weight (g): As presented on (Table 14) the analysis of variance revealed no significant differences among cultivars. Irrigation showed significant differences. The highest value of (54.3) was observed in W1where W5 gave the lowest value(49.1). Interaction had no significant difference.

4-2-4Weight of seeds (g) : The analysis of variance of weight of seeds showed on (Table 15). The results revealed no significant differences among cultivars .Irrigation revealed no significant differences W1,W2 and had the highest value(2.5g), while W4 the lowest value(2.2g). Interaction observed no significant difference.

4-2-5Hard seeds: The results of hard seeds data (Table 16) are presented on The statistical analysis showed no significant differences among cultivars. Irrigation showed no significant difference W2, gave the highest records (24.), and W5 had the lowest value (7.7). Interaction showed no significant differences.

4-3Water use efficiency parameters:

4-3-1Drought tolerantce index (DTI): The analysis of variance of drought tolerance index (Table17) revealed no significant differences among cultivars. Irrigation showed no significant differences W2 gave the highest value (0.83) W3 the lowest value (0.64). Interaction had no significant differences.

4-3-2Stress susceptibility index (SSI): From (Table 18) the statistical analysis of stress susceptibility showed no significant difference among cultivars. Irrigation resulting in significant differences W4 gave the highest record (1.16) and W2 had the lowest value (0.5) Interaction of cultivars and watering intervals obtained no significant difference.

4-3-3Stress tolerance index (STI): Table (19) presented the analysis of variance of stress tolerance index which revealed no significant differences among cultivars. Irrigation showed no significant difference, butW2 gave the highest value(0.81) W5 the lowest value(0.56). Interaction had no significant differences.

Table12. Effect of water stress during flowering and podding stages on number of pods of cultivars of *Vicia faba*

	V1	V2	V3	V4	X
W1	29.8abcd	42.6ab	44.4a	33.2abc	37.5a
W2	27.0bcde	27.0bcde	28.8abcde	23.0cde	26.4b
W3	15.7de	23.0de	27.1bcde	27.3bcde	23.3b
W4	25.4cde	26.0cde	26.8bcde	25.2cde	25.8b
W5	13.0e	20.1cde	25.2cde	19.4cde	19.4b
X	22.2b	27.7ab	3o.4a	25.6ab	
C.V	36.8				
L.S.D	7.9				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table13. Effect of water stress during flowering and podding stages on number of seeds of cultivars of *Vicia faba*

	V1	V2	V3	V4	X
W1	70.9abcd	74.4abc	110.6a	83.6ab	84.8a
W2	69.6bcd	71.6abcd	67.2bcd	69.1bcd	69.4ab
W3	35.3cd	56.2bcd	67.0bcd	74.4abc	58.3bc
W4	59.8bcd	69.0bcd	74.4abc	60.4bcd	65.9abc
W5	32.3d	46.7bcd	60.0bcd	52.4bcd	47.9c
X	53.6b	63.5ab	75.8a	68.0ab	
C.V	37.1				
L.S.D	19.7				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table14. Effect of water stress during flowering and podding stages on weight of 100 seeds(g) of cultivars of *Vicia faba:*

	V1	V2	V3	V4	X
W1	51.1abc	54.3abc	57.9ab	53.1abc	54.1a
W2	48.0bc	56.1abc	51.3abc	57.0abc	53.1a
W3	49.5bc	55.1abc	57.7abc	46.7c	52.2a
W4	49.4bc	50.1bc	56.2abc	61.7a	54.3a
W5	48.7bc	50.5bc	55.5abc	49.1bc	49.1bc
X	49.3b	53.2ab	55.7a	53.2ab	
C.V	12.6				
L.S.D	5.4				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table15. Effect of water stress during flowering and podding stages on weight of seeds(g) of cultivars of *Vicia faba:*

	V1	V2	V3	V4	X
W1	2.7abcd	2.6abcde	2.3abcdef	2.2abcdef	2.5a
W2	1.3ef	3.01abcde	3.1abc	2.5abcdef	2.5a
W3	2.1bcdef	2.4abcdef	3.6a	2.09bcdef	2.5a
W4	1.2f	2.7abcd	1.7def	3.3ab	2.2a
W5	3.01abcd	2.4abcdef	2.2def	1.8cdef	2.3a
X	2.09a	2.6a	2.6a	2.4a	
C.V	34.3				
L.S.D	0.6				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table16. Effect of water stress during flowering and podding stages on hard seeds% of cultivars of *Vicia faba:*

	V1	V2	V3	V4	X
W1	23ab	22ab	21ab	21ab	21.7a
W2	19ab	34b	22ab	23ab	24.5ab
W3	18a	17a	18ab	14a	16.7bc
W4	22ab	22ab	16a	11a	21bc
W5	13a	19ab	14a	17a	15.7c
X	19a	22.8a	18.2a	17.2a	
C.V	11.9				
L.S.D	7.9				

W1=7 day controlW2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table17. Effect of water stress during flowering and podding stages on drought tolerant index (DTI) of cultivars of *Vicia faba*

	V1	V2	V3	V4	X
W2	0.976a	0.88c	0.875abc	0.611abc	0.835a
W3	0.400c	0.756abc	0.655abc	0.753abc	0.641ab
W4	0.698abc	0.953a	0.617abc	0.688abc	0.739ab
W5	0.45bc1	0.813abc	0.502abc	0.579abc	0.657b
X	0.631a	0.851a	0.662a	0.657a	
C.V	40.7				
L.S.D	0.23				

W2=14 day during flowerW3=21day during flowerW4=14day during filling podW5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table18. Effect of water stress during flowering and podding stages on stress susceptibility index (SSI) of cultivars of *Vicia faba*

	V1	V2	V3	V4	X
W2	0.179d	0.918abcd	0.429bcd	0.648bcd	0.543b
W3	1.65a	0.323cd	0.968abcd	0.939abcd	0.972ab
W4	1.18abc	1.08abcd	1.15abc	1.24abc	1.168a
W5	1.36ab	0.583bcd	1.19abc	0.799abcd	0.984ab
X	1.096a	0.727a	0.937a	0.908a	
C.V	62.7				
L.SD	0.4				

W2=14 day during flowerW3=21day during flowerW4=14day during filling pod

W5=21day during filling podV1=BasaberV2=HudubaV3=SelaumV4=ALdamer

Table19. Effect of water stress during flowering and podding stages on stress tolerance index (STI) of cultivars of *Vicia faba*

	V1	V2	V3	V4	X
W2	0.873ab	0.746abc	1.05a	0.593bc	0.817a
W3	0.366c	0.713abc	0.806abc	0.763abc	0.662ab
W4	0.610abc	0.746abc	0.760abc	0.713abc	0.707ab
W5	0.393c	0.683abc	0.603bc	0.593bc	0.568b
X	0.560b	0.722ab	0.806a	0.665ab	
C.V	39.1				
L.S.D	0.22				

W2=14 day during flower , W3=21day during flower, W4=14day during filling pod, W5=21day during filling pod. V1=Basaber, V2=Huduba, V3=Selaum, V4=ALdamer

CHAPTER FIVE

Discussion

There are many biotic and a biotic factors that lead to great reduction in yield of crops. Drought is one of this major a biotic stress factors that affect almost all plant function and reflect directly on yield of crops (Anjum et al.,2011). On another site, bean plant showed a great magnitude of intra specific variation (Hirich, 2012).

Faba bean varieties showed no significant difference of all vegetative growth. On the other hands, interaction between cultivars and watering intervals revealed no significant differences for all growth parameters taken. Emam *et al.*,(2010) studied the effects of water stress on two common bean cultivars with contrasting growth habits, the result showed that plant height, number of pods, dry weight responded significantly to water stress condition. EL tyayeb and Hassanein, (2000) and Schutze *et al*., (2002) studied the effect of drought on seed germination and stated that the most common symptom of water stress injury is the decrease in seed germination. By Siddigui *et al*., (2015), revealed that faba bean growth performance was affected significantly and depends on the level of water deficit stress. Drought drastically decreased shoot and root fresh weight and reduced growth of crop plant (Saeidi and Abdoli 2015).

In this study, water stress had highly significant differences in weight of seed. Also, water stress had highly significant differences in number of pods. Meanwhile, the cultivars and the interaction of cultivars and watering intervals showed no significant difference for all yield and yield components studied.

Dewey *et al* (2004) showed similar findings that the mean number of pods per plant decreased with increasing water interval. Oweis *et al*., (2005). showed that faba bean can give high yield if its water requirements were met by winter rainfalls. This result was confirmed by Ganupathy ,(2011) who showed a wide range of variation and no significant differences for all characters under study Bolanos and Edmedes,(1993) indicated that the reproductive characters were more significantly affected by water regime than the growth characters. EL-Gindy *et al.*,(2003)found that irrigation at 25%of available soil moisture depletion significantly increased Faba bean plant height number of pods/plant. This worke showed no response of faba bean to water deficit in contrast to Ghassen and Abid .,(2017) ,also Eco recommended that to identifiy tolerant cultivar can be utilized as a source for water stress tolerance in faba bean breeding program aimed at improving drought tolerance.

Result in the form of tolerance indices (TOI), stress sustainability indices (SSI) and stress tolerance index (STI) showed no significant differences between water interval on tolerance indices and stress tolerance index. The statistical analysis also showed no significant differences among faba bean varieties on tolerace indices and stress stability index and stress tolerance index. However, difference in yield potential could be caused by factors related to adaptation, rather than to drought tolerance by itself (Golabadi *et al*., 2006). The effects of drought on yield of crops depend on their severity and stage of plant growth during which they occur (Rauf *et al*., 2007)

RECOMMEDATION

From the result of the study main recommendation is to avoid any watering stress during flowering and podding stage of Faba bean cultivar under Khartoum North condition to maintain good growth and yield

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Appendices

Analyses of variance (ANOVA) table –growth and yield components

Table (1) effect of water stress during flowering and podding on vegetative Growth:

Source of variation	Plant height (1)	Plant height (2)	Plant height (3)	Plant height (4)	Flower 50%	Flower 100%	Fresh weight of plant	Dry weight of plant	Root fresh weight	Root dry weight	Number of nod
V	O.881 Ns	2.7 Ns	37.1 Ns	155.7*	208.7 Ns	30372 Ns	55.6 Ns	30.2 Ns	1.4 Ns	o.12 Ns	105.5 Ns
W	18.4 Ns	52.1*	200.3**	483.6**	1237.7*	33602*	391.9 Ns	262.1 Ns	8.5*	4.4**	2303.9*
V×W	8.1 Ns	10.9 Ns	52.2 Ns	50.2 Ns	355.5 Ns	10303 Ns	410.3 Ns	174.08 Ns	2.1 Ns	o.83 Ns	597.6 Ns
Error	9.04	18.05	37.1	48.05	382.1	14004	368.9	140.9	2.2	0.99	599.6

*= significant   v=varites

**= highly significantw=water

Ns= not significantv×w=interaction

Table (3) effect of water stress during flowering and podding on yield and yield component

Source of variation	Number of pod	Number of seed	Weight of hundred seed	Weight of seed	Drought tolerant index	Stress susceptibility index	Stress tolerant index
V	182.09 Ns	1287.2 Ns	105.2 Ns	o.99 Ns	0.123 Ns	0.27 Ns	0.127 Ns
W	546.7**	2247.7*	23.2 *	o.18*	o.145 Ns	0.83*	0.128 Ns
V×W	37.8 Ns	278.9 Ns	44.4 Ns	1.54 Ns	0.059 Ns	0.43 Ns	0.056 Ns
Error	95.5	587.2	45.23	0.704	0.081	0.331	0.072

*= significant v=varites

**= highly significantw=water

Ns= not significantv×w=interaction