Sudan University Of Science and Technology

College of Graduate Studies

Effects of Water Intervals and Nitrogen Levels On Growth and Sugar Content of Sweet *Sorghum bicolor L Moench*

تأثير فترات الري ومستويات النتروجين في صفات النمو ومحتوى السكر في الذرة السكرية

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

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DEDICATION

To My:

Family,

Teachers

And every Friends.

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First and last I thanks Allah for this gracious, Merciful and innumerable bounties.

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TABLE OF CONTENTS

ملخص الدراسة

أجريت هذه الدراسة بالمزرعة التجريبية لكلية الدراسات الزراعية جامعة السودان للعلوم والتكنلوجيا (شمبات). خلال الموسم الصيفي (2014) ,لدراسة نوع من الذرة السكريه (عنكوليب) تم تقييم صفات النمو لها تحت تأثير فترات الرى كل 7 أيام 14 و21 يوم بين الريات والتسميد النتروجيني N0, شاهدN1 (43كجم للفدان) وN2 (86 كجم للفدان) استخدم في هذه التجربة تصميم القطاعات العشوائية الكاملة اربعه مكرارات للمعاملة الرئيسية الري والمنشقة النتروجين .تم تجميع البيانات لتسع صفات وهي طول النبات عدد الاوراق , سمك الساق, مساحة الورقة, عدد السلاميات ,الوزن الرطب, الوزن الجاف, ومسافة ورقة العلم وتحليل نسبة السكر. فقد أظهرت النتائج فروقات معنوية بين صفات النموفي المعاملات مقارنة ببعضها. سجلت أعلى درجة لمعاملة الري7 ايام لصفة مساحة الورقة(390.26سم) وطول النبات(159.86سم) وعدد الاوراق (13.31) ونسبة السكر (2N) 11.99% في 7 ايام .و سجلت أعلى درجة لمعاملة النتروجين الثاني لصفات مساحة الورقة (404.9سم) وطول النبات(159.11سم) وعدد الاوراق (14.12) ونسبة السكر(10.11%) وأوضحت الدراسة أن هذه الصفات قد تأثرت بفترات الري ومستويات النتروجين.

Abstract

The experiment was conducted (during summer season of 2014), in the Demonstration Farm of the College of Agricultural Studies at Shambat , Sudan University of Science and Technology, to study the response of sweet sorghum (Ankolib) to three different water (7,14 and 21days) and nitrogen fertilizer as (urea) levels control(N0) ,43kg/ha (N1) and 86 kg/ha (N2) in asplit plot arrangement with the three water interval as the main plot and the nitrogen levels as a sub .plot in Randomized Complete Block Design (RCBD) with four replications.

The data collected in this study encompass nine characteristics, viz: plant height, number of leaves per plant, stem diameter, leaf area, flag leaf (exersion), internodes length, plant fresh weight, plant dry weight, and Sugar content. The results showed that there were significant differences among most of the characters studied. The best results recorded for water interval of 7 days were in leaf area (390.26 cm^2 , plant height (159.86 cm), number of leaves (13.31), and sugar content (11.99%). The best results recorded for nitrogen treatment of N2 were for leaf area (404.9 cm^2), plant height (159.11cm), leaf number (14.12) and sugar content (10.11%).

The study showed that most characters were affected by the two treatments, water regimes and nitrogen levels.

CHAPTER ONE
INTRODUCTION

Sweet sorghum (S*orghum* *bicolor* L Monech) belongs to the family Poaceae. at believed that the crop originated in Africa, and its spread to other parts of the world is credited to the activities of man. It is grown in Sudan in small areas of traditionally farming in Kordofan, Darfur, Sennar and White Nile states and the local name for sweet sorghum in these areas is “Ankolib”. The area of this crop increasing with climatic changes. Where annual rain full is (200-450mm).Drought is a multidimensional stress, often coupled with heat stress affecting plants at various levels of their metabolic mechanisms (Blum, 1996), and is generally accepted as the most widespread abiotic stress experienced by crop plants (Quarrie *et al*., 1999). If plants are to survive this abiotic stresses they must have a range of morphological, biochemical and physiological mechanisms that enable them to grow and reproduce despite water limitations (Turner, 1997). Drought tolerance is defined as the relative ability to sustain plant function under dehydrated state and achieving an economic yield potential (Blum, 2005). Many studies were conducted to investigate sweet sorghum as a drought-tolerant crop. Sweet sorghum is an annual warm season crop similar to grain sorghum in grain production and almost like sugarcane for sugar-rich stalk and high sugar accumulation (Ratnavathi *et al*., 2004). As a C4 crop, sweet sorghum features rapid growth, low water requirement, high biomass production and wide adaptation. As a multi-purpose crop, it has a great potential for food, fodder, feed, sugar, jaggery, syrup and most importantly fuel alcohol production. Other putative roles of osmotic adjustment in sweet sorghum have been recently assembled under the term of "osmoprotection" which reserves high relative water content in leaves (Rontein *et al*., 2002). Numerous reports provide evidence on the association between high rate of osmotic adjustment and sustained yield or biomass under drought-stress by cellular turgor and yield-forming processes during drought-stress conditions (Ali *et al*., 1999). Many studies showed that stem and leaf sheath of cereal crops are the organs where photosynthesis takes place while accumulating the photosynthetic assimilates in the pre-flowering and post-flowering stages (Slafer and Savin, 1994; Yang *et al*., 2007). Sweet sorghum a sustainable and profitable crop, there is need to be standardized for the best agronomic practices, apart from breeding high-yielding cultivars, which can contribute to increased yields. The various agronomic practices include use of optimum nitrogen fertilizer rate, plant population rate, use of plant growth regulators and chemical sterility for getting maximum millable stalk yield. Nitrogen (N) is one of the expensive nutrients to supply; simultaneously, it is an important factor that limits crop productivity. Approximately 85 to 90 million metric tons of nitrogenous fertilizers are added to soil worldwide each year. Worldwide, N use efficiency for the production of cereals approximately 33%, and the remaining 67% goes as loss (Raun and Johnson, 1999). Furthermore, producers are looking for ways to improve their ability to manage N fertilizers more effectively because of recent sharp increases in N fertilizer prices. Generally, sweet sorghum responds well to N (Turgut *et al.*, 2005). Hence, to hypothesize that application of N fertilizer will enhance the vegetative biomass resulting in higher yield.

Sweet sorghum is highly recognized for forage production, but research in standardizing agronomic practices especially water and nitrogen is scantly. Therefore, the main objective of this work is to study the effects of different nitrogen levels and different water regimes on sweet sorghum growth and sugar content.

CHAPTER TWO
LITERATURE REVIEW

2-1General 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). Global cultivation of sorghum covers an area of 43.73 million hectares with annual production of 64 million tons (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, *and Shi.2008*). It is remarkable ability to reliably produce grains under adverse conditions makes sorghum important "fail-safe" sources of food, feed and fuel (Addissu, 2011).

2-2 Importance of sorghum in Sudan:

In Sudan, grain sorghum is the most important cereal crop and is considered the main food for more than 70% of the population. The stalks are used as building material and the straw is used as animal feed or as a source of fuel. Sorghum is undoubtedly the nutritional backbone of the country. The areas under crop is estimated to be (6-7 million ha), and constitutes 74% of the area under cereal and 45% of the total cultivated area in Sudan (Hamdoun and Babiker, 1989). Sorghum grain has limited use for livestock. Its use is limited, however, because the starch and protein in sorghum is more difficult for animals to digest than the starches and protein in corn. Sorghum is traditionally processed to remove fibrous and often colored per carp and testa layers and to reduce the grain into flour used to prepare a variety of traditional foods and beverages.

2-3A daptability and uses

Sweet sorghum has a wide adaptability. It can be grown in different types of soils with pH 5-8.5. The drought resistance of sweet sorghum is much higher than that of maize. Sweet sorghum has the character of water logging tolerance, if the plant of sweet sorghum has been immersed in flood for a week, it can re-grow quickly after the flood retreats .Sweet sorghum can be grown in tropical, subtropical and temperate zones as long as the accumulated temperature reaches 2.6-4.5c of above 10c. “Ankolib”, is the general term used for sweet sorghum in the Sudan . Rao and Mengesh (1979) conducted a germplasm collection expedition in eastern Sudan .They reported that “Ankolib” is a durra –bicolor characterized by sweet stalk just like sugarcane. It is a mixed land race variety grown mainly for chewing the juicy sweet stem (Kambal, 1972). ”Ankolib” was rarely mentioned in the literature as a forage crop. However ,sweet sorghum is highly recognized for forage and syrup production in other parts of the world (Dwayne *et al*.1999).According to (Zhu 1998) sweet sorghum is a type of grain sorghum belonging to Graminaceae and its stem is full of sweet juice. The crop is cultivated widely throughout the world and stalk is used for producing syrup and the livestock feed.

2-4Irrigation and Water Requirements

It has been documented that forage sorghums have the potential to produce as much, and in some cases more, dry matter than corn when grown with the same amount of water (Anderson and Guyer, 1986; Teutsch, 2002). Sorghums have a lower transpiration ratio than corn and require less water per unit of dry matter produced (Martin, *et.al,*. 1976). Forage sorghums have the ability to maintain high yields under water stress conditions and resume growth after drought (Sanderson, *et al*., 1992).

2-5Drought as production limiting factor:

Drought response in sorghum has been classified into two distinct stages pre-flowering and post-flowering. Resistance to water deficit at both of these stages has been reported to occur in the existing germplasm. However, many genotypes with a high level of resistance at one stage are susceptible at the other stage. The effect of drought on crop production and over economy is well known (Singh, 1990). In sorghum, water stress decreases seed filling duration, seed size and number, thus leading to strong yield reduction or even total crop loss (Tuinstra *et al*., 1997). Sorghum avoids dehydration by enhanced water uptake through its deep and extensive root system, and tolerates dehydration by osmotic regulation (Singh and Curr, 1990). Soil moisture deficiency may also affect the growth of the root apparatus, which is responsible for establishing the soil-plant-atmosphere continuum in the flow of water (Kuchenbuch *et al*., 2006). Previous studies in sorghum have shown that total leaf area and specific leaf area decrease under water stress (Munamava *and Riddoch,* 2001). Plant diameter and plant height were highest at 7 days irrigation interval and lowest at 21 days irrigation interval. (Stone *et al*., 2001 and Pandey *et al*., 2000). Earlier, several researchers have reported reduction of plant diameter and plant height which were strongly related to drought conditions (Inman-Bamber and Smith, 2005; Ramesh, 2000; Ramesh and Mahadevaswamy, 2000; Da Silva and Da Costa, 2001).

Rate of shoot and leaves expansions are sensitive to irrigation, which affects plant height and plant diameter (Da Silva and Da Costa, 2001). Biomass was not significantly different between 7 and 10 days irrigation intervals. However, it significantly decreased as irrigation intervals delayed. Biomass at 14 and 21 days irrigation intervals caused reduction of yield components (stalk height and stalk diameter) under water stress conditions. It seems that under water stress, reduction of soil water potential causes stomata to close and consequently leaf surface was reduced using less solar energy which decreases photosynthesis efficiency and reduce biomass. Although brix was not significantly different at 7 and 10 days irrigation intervals (18.6 %), is was higher than 14 days irrigation nterval (16.6 %) and 21 days irrigation interval (15.7 %) It seems that drought stress reduced brix significantly. Tsuchihashi and Goto (2004) reported that sweet sorghum brix was significantly reduced in dry season compared to wet season. The reduction of brix under water stress could be due to the transition of shoot carbohydrate to seed as observed in wheat (Blum, 1998). Sucrose content was higher at 7 and 10 days irrigation intervals (11.35 %) than 14 and 21 day irrigation intervals (9.35 %), although it was not significantly different between 7 and 10 days or 14 and 21 days irrigation intervals. Drought did not affect sugar percentage in sugar beet (Mui *et al*., 1996). Contrary to sucrose, invert sugar was higher at 14 and 21 days irrigation intervals (2 %) than 7 and 10 days irrigation intervals (1.55%). It seems as irrigation intervals increased sucrose content decreased while invert sugar increased significantly. The conversion of sucrose to invert sugar under drought stress could be due to the metabolic compatibility of plant. One of the compatibilities of plant under drought stress is osmotic adjustment that plant protects turgid pressure via increasing solution elements such as sugar, organic acids, ions etc. Kellerm and Ludlow (1993) and Palleschi *et al*. (1997) reported that corn drought stress leads to increased acidic invertase activity and consequently increased invert sugar formation. On the other hand, Mui *et al*. (1996) reported that drought did not affect sugar percentage in sugar beet. Juice volume was significantly lower at 21 days irrigation interval than the other three irrigation intervals. Even though juice volume was not significantly different at 7, 10 and 14 irrigation intervals, but juice volume decreased as the irrigation intervals increased. There is a relationship between dry matter, sugar yield and the quantity of applied water.

2-6**Mechanisms of drought tolerance:**

The crop grown under unfavorable environments withstands the stress through different modifications. Drought stress is a serious agronomic problem contributing to severe yield losses worldwide. This agricultural constraint may, nevertheless, be addressed by developing crops that are well adapted to drought prone environments. Drought tolerance depends on the plant developmental stage at the onset of the stress syndrome, which in sorghum may happen during the early vegetative seedling stage, during panicle development and in post-flowering, in the period between grain filling and physiological maturity (Rosenow and Clark 1995; Rosenow *et al*. 1996).

2-7Drought escape:

Drought escape is particularly an important strategic phonological development with the period of soil moisture availability to minimize the impact of drought stress on crop production in environments where the growing season is short and terminal drought stress predominates (Truner, 1986). Also later flowering can be beneficial in escaping early season drought that is followed by rains (Ludlow and Muchow, 1990).

2-8Drought avoidance:

Drought avoidance is defined as the ability of plants to retain a relatively high level of hydration under conditions of soil and atmospheric water stress. Plants can exhibit dehydration avoidance through increasing water uptake and reducing water loss by means of morphological or physiological modifications (Blum, 1998).

2-9 Drought tolerance:

Drought is the major important constraint on crop production in the world today. Drought tolerance is one of sorghum most important traits, allowing it to be grown in harsh environments. Complexity of inheritance pattern of drought resistance encouraged breeders to adopt alternative strategies to improve stress resistance (Borrell *et al.,* 2006). Plant tolerates drought by ability of their tissue to withstand water stress. The mechanism of drought tolerance is maintenance of turgor through osmotic adjustment (a process which induces solute and decreased accumulation in cell), increase in elasticity in cell and decrease in cell size and desiccation tolerance by protoplasmic resistance (Ugherughe, *et al.,* 1996).

2-10 Effect of drought on yield and yield components:

The effect of water deficit on yield and yield components has been the subject of many investigations. Moisture deficit was found to account for 65% of variation in grain yield of sorghum and pearl millet (Mahalkshmi and Rao, 1990). Timing of water supply generally has a larger effect on grain yield than total water for many crops (Show, 1998). Both pearl millet and grain sorghum productivity are most sensitive to water stress during flowering and grain filling (Garrity *et al.*, 1993 and Hattendorf *et al.,* 1998). Unger (1991) indicated that in sorghum grain mass was the most affected grain yield component by water stress, followed by seed per unit area. Harvest index of sorghum was also reported to be significantly affected by water stress. Field trials with sorghum, irrigated and rainfed, showed significant differences between those two moisture regimes in grain yield, time to 50% flowering, time to maturity, and number of heads per unit area, (Osmanzai, 1992).

2-11Methods of determining drought tolerance:

Identification and understanding the mechanisms of drought tolerance in sorghum have been major goals of plant physiologists and breeders including prolific root system, ability to maintain stomata opening at low levels of water potential and high osmotic adjustment and various seedling parameters (Rajendran *et al*. 2011). Only a few of the many techniques reported for measuring drought stress have been mentioned, but it is believed that selection and use of combinations of methods will give necessary information and three types of measurements are suggested .

1- Desiccations tolerance tests or related heat tolerance tests that give information on how much tissue drying can be tolerated before severe injury occurs.

2- Field measurements of water potential (or relative water content) that show how far the internal water status is kept above the critical point during the drought period.

3- Diffusive observation indicated if the internal water potential is kept up by related transpiration or of water is efficient to root and conducting systems that keep the plant shoot supplied with water.

Accordingly, many yield – based parameters were suggested to evaluate drought tolerance. Many of them were contracted in forms of indices, e.g., stress susceptibility index (SSI) suggested by Fisher and Maurer (1978). The stress susceptibility index is a ratio of relative reduction in yield of genotypes due to drought compared to the mean relative reduction in yield of all tested genotypes. This (SSI) is found to be equivalent to the ratio of yield under stress to yield under non – stress yd/yw. Heringa *et al*., 1984. considered the ratio of absolute reduction (AR) in yield due to stress to yield under non - stress (yw), AR/Yw what is again equivalent to a ranking of genotypes according to their ratios Yd / Yw. A further yield – based parameter of drought tolerance is geometric mean (GMP), (Fernandez, 1993) which is the square root of the product of yield under stress times under non stress. The geometric mean is often used by breeders, who are interested in performance under favorable and stress conditions, since drought stress can vary in severity in field environments over years.

2-12Fertilizer Requirements

Nitrogen and phosphorus are two nutrients that will most likely need to be added to the soil for forage sorghum silage production (Bolsen and Kuhl, 1996). Mortvedt, *et al*., (1996) reported that zinc and iron may also be limiting nutrients in some soils. Marsalis (2006) stated that forage sorghums will remove large amounts of nutrients from the soil, so it is imperative that producers test their soils frequently in order to accurately assess their fertilizer needs. Mortvedt, *et al*., (1996) reported that sorghum roots quickly grow into the soil between the rows. As such, side dressing nitrogen fertilizers early in the growing season will help avoid root pruning. Dryland nitrogen requirements will be lower than those necessary for irrigated. Addition of one dose of P,(2N+P)gave about 54% increase over that of the control. The application of 2N resulted in a significant increase of 40% over the control (0N) (Ali, 1982).Nitrogen fertilizer, on the other hand, increased the dry matter yield, (Naik *et al*., 1979). Nitrogen (N) is one of the expensive nutrients to supply; simultaneously, it is an important factor limiting crop productivity. Approximately 85 to 90 million metric tons of nitrogenous fertilizers are added to soil worldwide each year. Worldwide, N use efficiency for the production of cereals such as wheat (*Triticum aestivum*), rice (*Oryza sativa*), corn (*Zea mays*), barley (*Hordeum vulgare*), sorghum, pearl millet (*Pennisetum glaucum*), oat (*Avena sativa*), and rye (*Secale cereal*) is approximately 33%, and the remaining 67% goes as loss (Raun and Johnson, 1999). Furthermore, producers are looking for ways to improve their ability to manage N fertilizers more effectively because of recent sharp increases in N fertilizer prices. Generally, sweet sorghum responds well to N (Turgut *et al.,* 2005). Hence,it was hypothesized that application of N fertilizer will enhance the vegetative biomass resulting in higher millable cane yield. The plant population provides the best chance to produce the most biomass per given area. It is common to think that in narrower row spacing, the more plants can that be grown in that area would result in more biomass.

Sugar content is one of the most important traits of sweet sorghum. There are large variations in sugar contents of stem among sweet sorghum varieties. For example, the Brix in two hundred and six cultivars ranged from 8.0% to 19.1% (Zhao *et al*., 2008). Sucrose (Suc) is the predominant sugar, and the total Suc content is lowest at the boot stage and highest at the soft dough stage (Lingle, 1987). The Sucrose contents at different intermodal region of sorghum stem showed that the sugar content had an up-down tendency with the intermodal number increasing (from top to base) (Subramanian *et al.,* 1987). Hoffmann-Thoma *et al*., (1996) also reported that the upper most internodes represent strong ‘utilization sinks’until final development of the peduncle during anthesis. However, at the physiological maturity stage, how sugar is accumulated in different internodes is not clear.

Suc in the stem can be catabolized by either sucrose synthase ,(SS)or invertase (INV), which is located in apoplast and vacuoles of young internodes, soluble acid invertase (.SAI) is bound to the cell wall and vacuole in tissues of all ages, and neutral (NI) exists low in the cytoplasm of young tissues and high in mature tissues(Guti Orrez-Miceli *et al*., 2002). After entering the parenchyma cells, the hexoses may be metabolized into Callose for plugging or resynthesized into Suc by sucrose phosphate synthase (SPS) (Koch, 2004).Sucrose synthase(SS)may also be involved in Suc synthesis, but the equilibrium is usually in the direction of degradation(Goldner *et al.,* 1991).

Sweet sorghums are typically characterized by low grain yields, but high biomass production. The stalks contain 10-25% sugars (mainly sucrose, glucose, and fructose) at maturity (Byrt *et al.*, 2011). Sweet sorghum has advantages in ethanol production processing because it requires fewer chemical reaction steps and less energy from feedstock to the end product than grain and forage sorghums. Furthermore, the cost to cultivate sweet sorghum can be as little as three times lower than that of sugarcane Reddy*et al.,* 2005; Audilakshmi*et al.,* 2010; Xin *and Wang,* 2011). Sweet sorghum contains approximately equal quantities of soluble (glucose and sucrose) and insoluble carbohydrates (cellulose and hemicellulose) and has been considered as an important source for the production of fuel ethanol (Mamma *et al.,* 1995). However, its potential as a source of ethanol production has not been fully exploited. To make sweet sorghum a sustainable and profitable crop, there is a need for standardizing the best agronomic practices, apart from breeding high-yielding cultivars, which can contribute to increased yields. The various agronomic practices include use of optimum nitrogen fertilizer rate, plant population rate, use of plant growth regulators and chemical sterilants for getting maximum millable stalk yield.

CHAPTER THREE
MATERIALS AND METHODS

3.1.1 Field experiments location:

The experiment was carried out in the summer of 2014 under irrigation system at the Demonstration farm for CAS, SUST, Shambat. Sudan University of Science and Technology, College of Agricultural Studies, Shambat (15^0 40N, 32^0 32E and altitude 288meters above sea level). Climate of the area is semi arid (Oliver, 1965).The range of temperature is 42.6-35..3 /27.2-18.1 day and night .Humidity 15-55% and rainfall 0.1-24.7mm.(The Meteorological Station at Shambat) . The soil at Shambat site is heavy clay with pH 7.5-8 as described by Abdelgader (2010).

3.2.2 Design and Description of the experiments.

The experiments were laid out in a Randomized Complete Block Design (RCBD) with four replications. The treatments were assigned in a split plot arrangement. The water intervals (7days, 14days and 21days) were considered as the main plost and the nitrogen levels as sub plots. The experimental field was disc ploughed; disc harrowed, leveled and ridged up north - south, 70cm apart. The land was divided into 3 x $3.5m^2$ plots, each composed of 3 ridges, 3 meters long. Seeds were sown on the 25^{th} of July 2014 in low than the top of the ridge at 20cm spacing between holes. Nitrogen fertilizer (urea 46% N) was applied at N1(43g/fedan) andN2(86g/fedan) dose three weeks after planting,. Hand weeding was done when needed. Irrigation was conducted at aweek's intervals and tow weeks for wet and three weeks intervals for drought stress. The field was affected by Stem borer and FALEMAT 800 was used to control the stem borer.

3.2 Data collection

When the plants reached physiological maturity, five plants from the two inner ridges at each plot separately were randomly selected and tagged and from them data for the following growth and yield characters, except days to 50% flowering and days to maturity, were collected as following:

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 using a meter tape.

3.3.1.2 Stem diameter (mm)

It was determined at maturity on the stalk at 10cm above the ground level, using (vernier caliper)

3.3.1.3 Number of leaves/plant

Leaves were 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 Internodes length (cm) It was calculated as average for the internodes length measured by a normal tape.

3.3.1.6 Plant fresh weight (g)

The tagged fresh plants were weighed and the average was calculated.

3.3.1.7 Plant dry weight (g)

The tagged plants were dried using natural drying and then weighed and the average was obtained.

3.3.1.8 Flag leaf (leaf exersin) (cm) Flag leaf was measured for the five tagged plants and the average was determined.

3.3.2 Sugar content :

The stalks of sweet sorghum were crushed and the percent sugar for the juice was determined in the Animal laboratory Khartoum university Faculty of Agriculture at shambat .

3.4 Statistical Analysis:

The data collected were subjected to statistical analysis to obtain the ANOVA and the means were separated by Least Significance Different (LSD) Using STATISTIX8 computer package.

CHAPTER FOUR
RESULTS

4.1 Growth characters

4.1.1 Plant height (cm)

Statistical analysis revealed no significant differences among water levels but highly significant differences (0.01) for nitrogen levels were observed (Table4- 1). However the interaction between water and nitrogen levels was not significant. The taller plants were attained at 7 days interval (159.86cm) while the shortest were obtained at 21 days water interval (139.15cm) (Table 2). As shown in Table 3 .N2 nitrogen levels gave significantly taller plants (159.11cm) than N0 and N1 nitrogen levels. The interaction between water and nitrogen levels revealed that7days water interval with 1N nitrogen had a significant taller plants (171.28cm) than the other combirations while 21days interval with 0N had the significantly lower plants height (122.50cm) as shown in Table 4.The trend of growth at 30, 60, and 90 days showed the normal exponential type (Fig 1) and the highest plants were obtained at 90 days of growth for 1N at 21 days water interval.

4.1.2 Number of leaves /plant

No significant differences were shown among water levels but there were highly significant differences (0.01) for nitrogen levels (Table 1). However, the interaction between water and nitrogen levels was not significant. The higher number of leaves was attained at 7 days interval (13.308) while the lowest were obtained at 21 days water interval (12.967) (Table 2).As shown in Table 3 .N2 nitrogen levels gave a significantly higher number of leaves (14.117) in comparison to nitrogen at 0N and 1N nitrogen levels. The interaction between water and nitrogen levels revealed that 14 days water interval with 2N nitrogen had a significantly higher number of

Table (1): F .values of different characters of sweet sorghum:

F. value

source	Df	Plant height (cm)	Number of leaves	Stem diameter (cm)	Interrede length (cm)	Flag leaf(cm)	plant fresh weight (g)	Plant dry weight (g)	Le Ar (cı
REP	3	-	-	-	-	-	-	-	-
WATER	2	**2.82 NS**	0.06 **NS**	4.59*	2.42 **NS**	0.29 **NS**	2.32 **NS**	1.62 **NS**	16
ERROR A	6	-	-	-	-	-	-	-	-
NITORGEN	2	***8.28*****	6.06**	1.41 **NS**	4.09*	0.52 **NS**	1.46 **NS**	1.02 **NS**	5.0
WATER*NITROGEN	4	1.21 **NS**	0.67 **NS**	2.40*	0.045 **NS**	1.07 **NS**	1.06 **NS**	0.83 **NS**	1.4
ERROR B	18	-	-	-	-	-	-	-	-
TOTAL	35	-	-	-	-	-	-	-	-
EMS		247.20	1.5684	3.9318	3.0045	18.0402	0.01191	0.00405	77
CV(RRP*WATER*NITROGEN	-	**10.71**	**9.55**	**13.19.**	**15.36**	**14.30**	**34.38**	**45.15**	**26**

* Significant

**Highly Significant

Ns: not Significant

Table (4-2): Effects of water intervals on different parameter of sweet sorghum:

parameter / water	plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf Area (cm^2)	Internodes length (cm)	Flag leaf **(cm)**	Plant fresh weight (g)	Plant dry weight (g)	Sugar **content (%)**
7days	159.86	13.308	17.061	390.26	10.263	29.775	0.3500	0.1549	11.995
14 days	141.38	13.050	14.158	337.64	11.768	30.717	0.3442	0.1458	7.230
21 days	139.15	12.967	13.867	287.82	11.825	28.628	0.2583	0.1222	11.649
Mean	146.79	13.108	15.028	338.573	11.255	29.706	0.3175	0.1409	10.291
LSD	**23.411**	**2.5389**	**2.8529**	**43.533**	**1.7007**	**6.7400**	**0.1165**	**0.0460**	3.1405
SE±	**9.5675**	**1.0376**	**1.1659**	**17.791**	**0.8095**	**2.7545**	**0.0476**	**0.0446**	1.2834

Table (4-3): Effects of Nitrogen levels on different parameter of sweet sorghum:

	plant height (cm)	Number of leaves	Stem diameter (cm)	Leaf Area (cm^2)	Internodes length (cm)	Flag leaf **(cm)**	Plant fresh weight (g)	Plant dry weight (g)	Sugar **content (%)**
N0	133.10	12.775	14.348	308.37	10.521	30.383	0.3025	0.1363	9.778
N1	148.18	12.433	15.031	302.49	10.902	28.711	0.2892	0.1258	10.986
N2	159.11	14.117	15.707	404.86	12.433	30.25	0.3608	0.1613	10.111
Mean	**146.79**	**13.108**	**15.28**	**338.573**	**11.285**	**29.781**	**0.3175**	**0.1411**	10.291
LSD	**13.485**	**1.07422**	**1.7007**	**75.748**	**1.4867**	**3.6430**	**0.0936**	**0.0546**	2.629
SE±	**6.4187**	**0.5113**	**0.8095**	**36.055**	**0.7076**	**1.7340**	**0.0446**	**0.0260**	1.2514

Table (4-4): Interaction of water intervals and nitrogen for plant height (cm):

	0N	1N	2N	Mean
7days	144.07 **BCD**	171.28 **A**	164.23 **AB**	159.86
14 days	132.73 **CD**	135.80 **CD**	155.63 **ABC**	141.38
21 days	122.50 **D**	137.47 **CD**	157.47 **ABC**	139.14
Mean	133.1	148.18	159.11	146.80

Means followed by the same letter were not significant according to LSD at 5%

Table (4-5): Interaction of water intervals and nitrogen for Number of leaves:

	0N	1N	2N	Mean
7days	12.800 **AB**	12.975 **AB**	14.150 **A**	13.308
14 days	12.975 **AB**	11.700 **B**	14.475 **A**	13.05
21 days	12.550 **AB**	12.625 **AB**	13.725 **AB**	12.966
Mean	12.775	12.433	14.116	13.108

Means followed by the same letter were not significant according to LSD at 5%

Table (4-6): Interaction of water intervals and nitrogen for Stem diameter (cm):

	0N	1N	2N	Mean
7days	15.350 **AB**	17.747 **A**	18.085 **A**	17.06
14 days	15.127 **AB**	12.370 **B**	14.977 **AB**	14.158
21 days	12.567 **B**	14.975 **AB**	14.060 **B**	13.867
Mean	14.348	15.03	15.707	15.02

Means followed by the same letter were not significant according to LSD at 5%

leaves (14.47) than the other combinations, while 14days interval with 1N had the significantly the lowest number of leaves (11.70) as shown in Table 5.The trend of growth at 30, 60, and 90 days showed the normal exponential type (Fig 2) and the higher number of leaves was obtained at 90 days of growth for 1N at 14 days water interval.

4.1.3 Stem diameter (cm)

Statistical analysis revealed significant differences among water levels but no significant differences for nitrogen levels (Table4-1). However, the interaction between water and nitrogen levels was significant. The highest stem diameter was attained at 7 days interval (17.06cm) while the lowest was obtained at 21 days water interval (13.87cm) (Table 4-2).As shown in (Table 4-3) . Nitrogen at N2 gave the highest stem diameter (15.71cm) in comparison to other level and N1 nitrogen levels. The interaction between water and nitrogen levels revealed that 7 days water interval with 2N nitrogen had a significant higher Stem diameter (18.09cm) than the other combinations while 14 days interval with 1N had the significantly lowest stem diameter (12.370cm) (Table 4-6).The growth of stem diameter at 30, 60, and 90 days showed the normal exponential type of growth (Fig 3) and the highest stem diameter was obtained at 60 days of growth for 3N at 14 days water intervals.

4.1.4 Leaf area (cm^2)

Highly significant differences (0.01) were shown among water intervals but only significant differences (0.05) for nitrogen levels were observed (Table4-1). However, the interaction between water and nitrogen levels was not significant. The highest leaf area was attained at 7 days interval (390.26 **cm^2**) while the lowest was obtained at 21 days water interval (287.82 **cm^2**) (Table 4-2).As shown in (Table 4-3), N2 nitrogen level gave a significantly higher leaf area (404.86 **cm^2**) than N0 and N1 nitrogen levels. The interaction between water and nitrogen levels revealed that 7days water interval with N2 nitrogen had a significant higher leaf area (454.10 **cm^2**) than the other combinations while 14 days interval with N1 had the significantly lower Leaf area (236.59 **cm^2**) as shown in Table (4-7).

4.1.5 Internodes length (cm):

No significant differences were noticed among water levels but significant differences (0.05) for nitrogen levels were observed (Table4- 1). However, the interaction between water and nitrogen levels was not significant. The highest length was attained at 21 days interval (11.83 **cm**) while the lowest was obtained at 7 days water interval (10.26**cm**) (Table 4-2).As shown in (Table 4-3) .N2 nitrogen levels gave significantly higher internode length (12.43 **cm**) than N0 and N1 nitrogen levels. The interaction between water and nitrogen levels revealed that 14days water interval with 2N nitrogen had a significant higher Internode length (13.45cm) than the other combinations while 7 days interval with 1N had significantly the lowest Internode length (9.95cm) as shown in Table(4-8).

4.1.6 Flag leaf (cm) (leaf exersion)

This were no significant differences among flag leaf length for nitrogen levels, water levels nor the interaction between water and nitrogen levels (Table 4-1).The longest flag leaf was obtained for 14 days water interval (30.72cm), 0N fertilization (30.38cm) and 14 days and 2N interaction (32.95cm)as shown in Tables(4- 2,4-3 and 4-9) respectively.

4.1.7 Plant fresh weight (g):

There were nor significant differences among plant fresh weights for nitrogen levels, water levels or the interaction between water and

Table (4-7): Interaction of water intervals and nitrogen for Leaf Area (cm^2):

	0N	1N	2N	Mean
7days	330.13 **BCD**	386.55 **ABC**	454.10 **A**	390.26
14 days	330.80 **BCD**	236.59 **D**	445.53 **AB**	337.64
21 days	264.20 **D**	284.32 **CD**	314.95 **CD**	287.82
Mean	308.376	302.486	404.86	338.574

Means followed by the same letter were not significant according to LSD at 5%

Table (4-8): Interaction of water intervals and nitrogen for Internodes length (cm):

	0N	1N	2N	Mean
7days	10.012 **C**	9.950 **C**	10.825 **BC**	10.262
14 days	10.375 **C**	11.480 **ABC**	13.450 **A**	11.435
21 days	11.175 **ABC**	11.275 **ABC**	13.025 **AB**	11.825
Mean	10.520	10.90	12.433	11.285

Means followed by the same letter were not significant according to LSD at 5%

Table (4-9): Interaction of water intervals and nitrogen for Flag leaf (cm): EXersion

	0N	1N	2N	Mean
7days	28.875 **A**	30.450 **A**	30.000 **A**	29.775
14 days	31.725 **A**	27.475 **A**	32.950 **A**	30.716
21 days	30.550 **A**	28.207 **A**	27.125 **A**	28.627
Mean	30.383	28.710	30.025	29.706

Means followed by the same letter were not significant according to LSD at 5%

nitrogen levels (Table 4-1).The highest plant fresh weight was obtained for 7 days water interval (0.35g), N2 fertilization (0.36g) and 14 days and N2 interaction (0.45g)as shown in Tables (4-2,4-3and 4-10) respectively.

4.1.8 Plant dry weight (g):

There were no significant differences among plant dry weights for nitrogen levels, water levels nor the interaction between water and nitrogen levels (Table 4-1).The highest plant dry weight was obtained for 7 days water interval (0.15g), N2 fertilization (0.16g) and 14 days and N2 interaction (0.19g)as shown in Tables (4-2,4-3and 4-11) respectively.

4.1.9 Sugar content%:

Statistical analysis revealed significant differences among water levels but no significant differences (0.05) for nitrogen levels were observed (Table 4-1). However the interaction between water and nitrogen levels was not significant. The highest sugar content was attained at 7 days interval (11.99%) while the lowest was obtained at 14 days water interval (**7.23**) (Table 4-2).As shown in Table (4-3), N1 nitrogen level gave a higher Sugar content (**10.99%**) than N0 and N2 nitrogen levels. The interaction between water and nitrogen levels revealed that 7 days water interval with N1 nitrogen had a significantly higher sugar content (**13.31**%) than the other combinations while 14 days interval with 2N had significantly the lowest sugar content (**5.64**) as shown in Table(4-12).

Table (4-10): Interaction of water intervals and nitrogen for plant fresh weight (g):

	0N	1N	2N	Mean
7days	0.3225 **AB**	0.3800 **AB**	0.3475 **AB**	0.35
14 days	0.3300 **AB**	0.2575 **B**	0.4450 **A**	0.344
21 days	0.2550 **B**	0.2300 **B**	0.2900 **AB**	0.258
Mean	0.3025	0.289	0.360	0.317

Means followed by the same letter were not significant according to LSD at 5%

Table (4-11): Interaction of water intervals and nitrogen for plant dry weight (g):

	0N	1N	2N	Mean
7days	0.1390 **AB**	0.1708 **AB**	0.1550 **AB**	0.1549
14 days	0.1375 **AB**	0.1048 **B**	0.1950 **A**	0.1457
21 days	0.1325 ***AB***	0.1000 **B**	0.1340 **AB**	0.1221
Mean	0.1363	0.1252	0.1613	0.1409

Means followed by the same letter were not significant according to LSD at 5%

Table (4-12): Interaction of water intervals and nitrogen for Sugar content (%):

	0N	1N	2N	Mean
7days	10.454**ABC**	13.310 **A**	12.223 **ABC**	11.995
14 days	8.244 **BCD**	7.808 **CD**	5.638 **D**	7.23
21 days	10.636 **ABC**	11.840 **ABC**	12.472 **AB**	11.649
Mean	9.778	10.986	10.111	10.291

Means followed by the same letter were not significant according to LSD at 5%

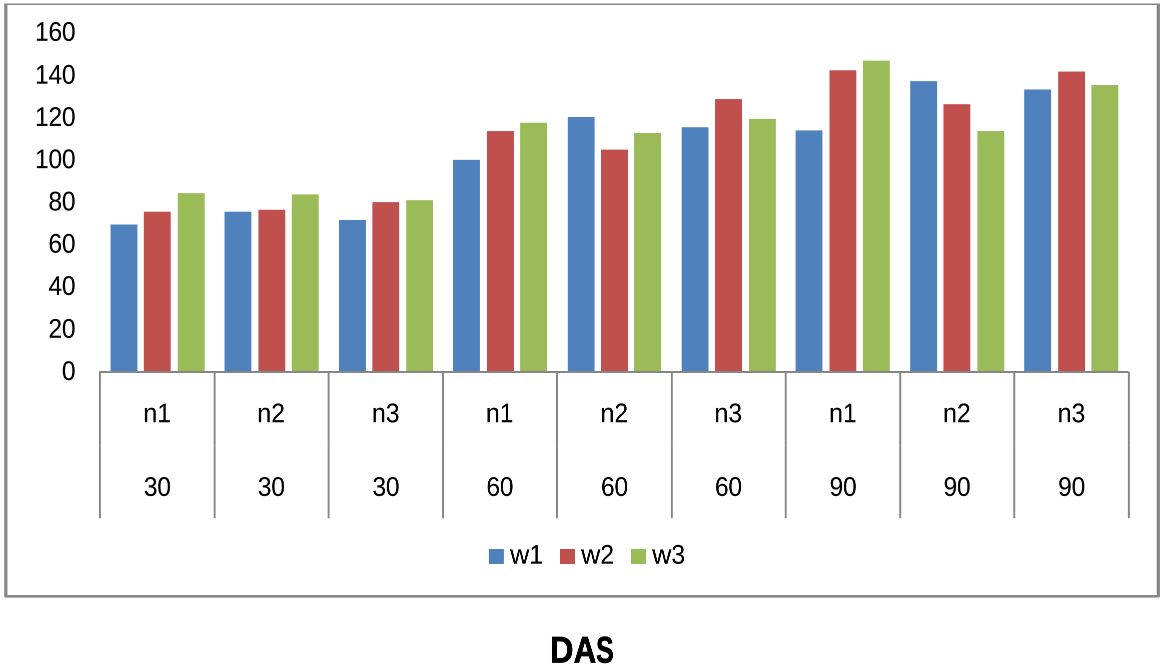
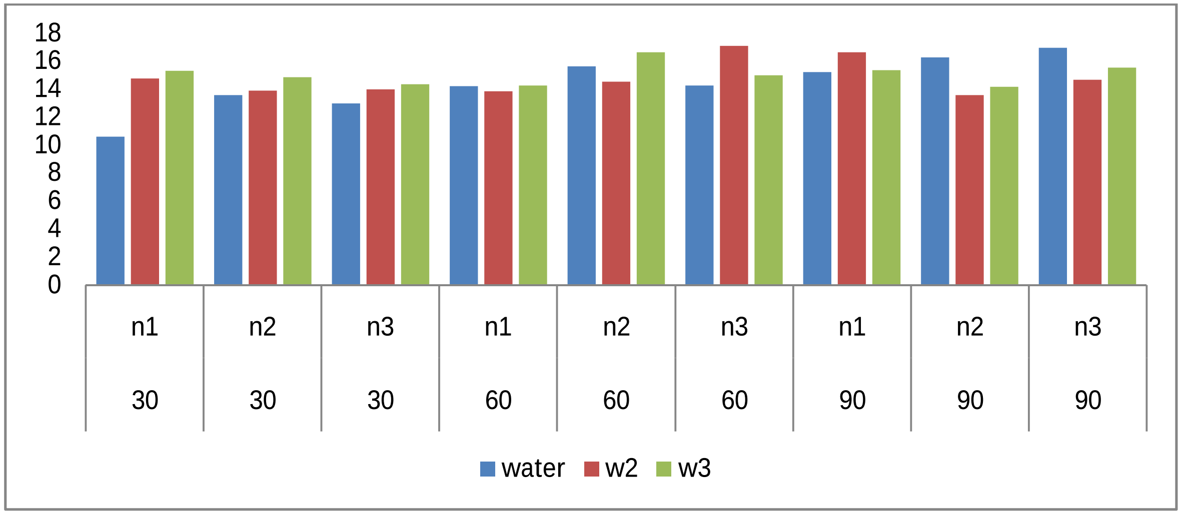


Fig .1.Effects of water intervals and nitrogen levels on plant Height during different growth stages



DAS

Fig .2.Effects of water intervals and nitrogen levels on stem diameter during different growth stages

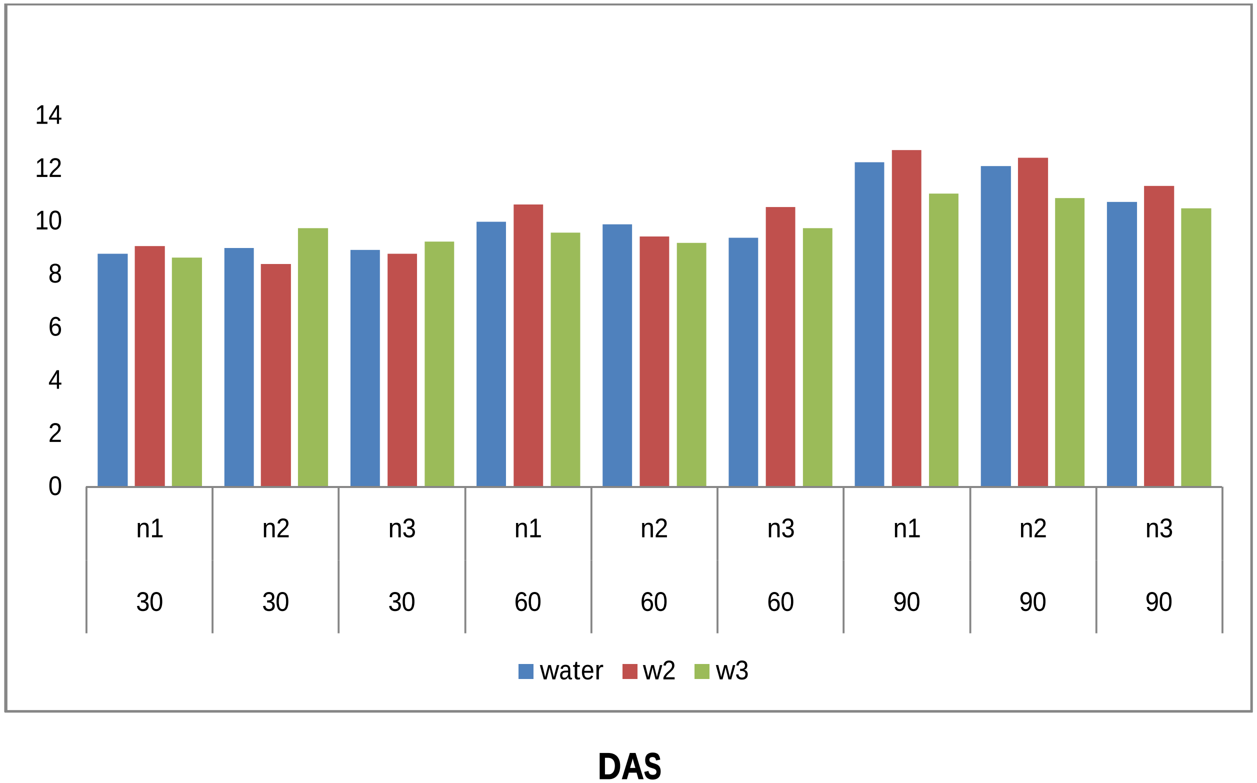


Fig .3.Effects of water intervals and nitrogen levels on number leaves during different growth stages

CHAPTER FIVE
DISCUSSION

5.1 Effects of water on growth characters

Most of the growth characters were sensitive to water stress. Stem diameter, leaf area, sugar content were significantly affected.. Similar finding were shown by (Rauf , 2008; Khayatnezhad*, et al.* ,2010) who found that effect of water stress coincided with various growth stages such as germination; seedling and shoot length. On the other hand, stem diameter, leaf area and number of leaves were also highly significantly decreased due to stress. Generally, all of these characters were highest in (7days) watering and lowest in (21days). (Tables 4-1and 4-2). Most characters were higher in the interaction between 7 days water interval and nitrogen.

Plant diameter and plant height in the present study were highest at 7 days irrigation interval and lowest at 21 days irrigation interval. It seems that increasing irrigation intervals reduced plant height and stem diameter (Stone et al., 2001; Pandey et al.,(2000). Earlier, several researchers have reported reduction of plant diameter and plant height and strongly related that to drought conditions (Inman-Bamber and Smith, 2005; Ramesh, 2000; Ramesh and Mahadeva swamy, 2000; Da Silva and Da Costa, 2001).

Rate of shoot and leaves expansions are sensitive to irrigation which affects plant height and plant diameter (Da Silva and Da Costa, 2001), Stalk height and stalk diameter under water stress conditions which caused biomass to decrease. It seems that under water stress, reduction of soil water potential causes stomata to close and consequently leaf surface reduced, using less solar energy which decreases photosynthesis efficiency and reduce biomass.

. Drought did not affect sugar percentage in sugar beet (Mui *et al*., 1996). Contrary to sucrose, invert sugar was higher at 14 and 21 days irrigation intervals (2 %) than 7 and 10 day irrigation intervals (1.55%). It seems as irrigation intervals increased, sucrose content decreased while invert sugar increased significantly. The conversion of sucrose to invert sugar under drought stress could be due to the metabolic compatibility of the plant. One of the compatibilities of plants under drought stress is osmotic adjustment that plant protects turgid pressure via increasing solution elements such as sugar, organic acids, ions etc. Kellerm and Ludlow (1993) and Palleschi *et al*. (1997) reported that corn drought stress leads to increased acidic invertase activity and consequently increased invert sugar formation. Juice volume was significantly lower at 21 days irrigation interval than the other three irrigation intervals. Even though juice volume was not significantly different at 7, 10 and 14 irrigation intervals, but juice volume was decreased as the irrigation intervals increased.. There is a relationship between dry matter, sugar yield and the quantity of applied water.

5.2 Effects of nitrogen on growth characters

Nitrogen affects plant height, leaf area, number of leaves and internodes length significantly, which increased with increasing N levels. Generally, all of these characters were highest under (N2) and lowest in (N0).Nitrogen increased most of the parameters measured as it affected most of the physiological parameters and increased photosynthate production. This was in agreement with (Ali, (1982). Solar energy increase photosynthesis efficiency. Application of 2N resulted in a significant increase of 40% over the control (N0) Nitrogen fertilizer, and increased the dry matter yield, (Naik *et al* ,1979). However, stem diameter, flag leaf, plant fresh weight, and plant dry weight and sugar content were not significantly affected. because they were attacked by stem borer. Most characters were higher in (N2) and 7 days water levels with sole effect of nitrogen and this trend was in agreement with the results stated before for water levels.

CONCLUSINS

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

The crop under the study was significantly different in growth characters.

7 days, water interval was found to be the best.

N2 level for most of the character was the best.

The interaction revealed best results for 7 days interval with N2 nitrogen.

The experiment should be repeated for another season and for locations to confirm the result different.

The best percentage of sugar content in N1 and 7day water interval.

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