Sudan University of Science and Technology

College of Graduate Studies

Effect of Sowing date, Irrigation Intervals and Fertilization On Growth, Seed and Oil Yield of Safflower (*Carthamus tinctorius* L),

أثر تاريخ الزراعه ، فترات الري والتسميد علي نمو وانتاجيه الحبوب والزيت في ال قرطم

A thesis submitted in fulfillment of the requirement for the Degree of (Ph.D) in Agronomy

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DEDICATION

To my parents for giving birth to me at the first place and supporting me spiritually throughout my life

To my brother and my sisters
With love.

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First of all this Thesis would not have been possible unless the care and conciliation of ALLAH to whom I am greatly indebted.

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ABSTRACT

Despite importance of safflower in the world, this crop has received only little research attention in Sudan. Therefore, a field experiment was conducted at the College of Agricultural Studies, Sudan University of Science and Technology in Khartoum, during winter season in 2010/2011 and 2011/2012, to study the effects of sowing date, irrigation intervals and fertilizers on seed , and oil yield, of safflower (***Carthamus tinctorius*** L.).The cultivar used was Geeza. The experiment designed in split-split plot arrangement, with four replications. The main plots were two sowing dates on 13^{th} (S1) and on 28^{th} November (S2). Subplots were three irrigation intervals (7, 14 and 21 days) and sub-subplots were three types of fertilizer (urea 190 kg ha^{-1}, compound fertilizer (pellet granules) 250 kg ha^{-1} and farm yard manure 4800 kg ha^{-1}).

Growth parameter which studied were plant height, stem diameter , number of leaves / plant ,number of branches / plant, leaf area index and plant population. In addition, yield components were, number of seeds / head, thousand seed weight ,seed yield, pigment yield ,shoot dry weight , harvest index , oil , protein and fiber content,

The general trend was that sowing date had significant effect on all growth parameters in two seasons, also on seed, pigment yield and shoot dry weight. Irrigation intervals displayed significant difference on plant height, stem diameter, leaf area index, seed yield and harvest index in season one, pigment yield and oil content in season two.

Generally application of fertilizers resulted in significant affect on plant height and oil content in both seasons.

ملخص الدراسه

رغم اهمية الا قرطم في العالم ,هذا المحصول تلـ قي قليل من البحث في السودان , وبالتالي اجريت تجربه حـ قليه بكليه الدراسات الزراعيه .جامعة السودان للعلوم والتكنولوجيا في الخرطوم في موسم الشتاء في عامي 2010-2011 و2011-2012 ,لدراسه تاثير تاريخ الزراعه, فترات الري والتسميد علي انتاجية البذور, والزيت للا قرطم , استخدم الصنف جيزة وصممت التجربه بطريـ قة الا قطع المنشـ قه -المنشـ قه في اربعه مكررات , احتوت الا قطع الرئيسة علي تاريخي الزراعه13نوفمبر و28 نوفمبروالا قطع الفرعيه علي ثلاثه فترات ري 14,7و21 يوم ,والا قطع الفرعيه -الفرعيه علي ثلاثه انواع اسمدة, اليوريا 190 كيلوجرام للهكتار,السماد المركب الحبيبي 250 كيلو جرام للهكتار و سماد المزرعة 4800 كليوجرام للهكتار .

معايير النمو التي تمت دراستها كانت طول النبات , قطر الساق ,عددالاوراق علي النبات ,عدد الافرع علي النبات, دليل مساحة الور قه والكثافه النباتيةومكونات الانتاجيه كانت عدد البذور بالراس ,وزن 1000 بذره ,انتاجيه البذوروالصبغه,دليل الحصاد,وزن النبات الجاف ,محتوي الزيت , البروتين والالياف .

الملامح العامة اشارت ان تاريخ الزراعة له اثر معنوي غلي كل معايير النمو في الموسمين وكذلك غلي انتاجية البذوروالصبغة ووزن النبات الجاف.

الري اظهر ان هنالك فرو قات معنوية في طول النبات , قطر الساق و دليل مساحة الور قة بالاضافه لانتاجية البذورو دليل الحصاد في الموسم الاول والصبغه في الموسم الثاني.

عموما اضافة الاسمده نتجت عنه اختلافات معنويه علي طول النبات و محتوي الزيت.

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CHAPTER ONE

INTRODUCTION

Safflower (*Carthamus tinctorius* L), has been grown for countries from China to the Mediterranean region and all along the Nile valley up to Ethiopia. Recently, it is grown commercially in India, U.S. A, Mexico, Ethiopia, Kazakhstan, Australia, Argentina, Uzbekistan, China, the Russian Federation. Pakistan, Spain, Turkey, Canada, and Iran. Safflower is a native crop of Iran with high tolerance to drought stress and good oil quality.It has an important role in expansion of cultivation area. Commercial production of safflower in Iran was started in the 2000s, and the area rapidly increased to 10000/ha mainly in the province of Isfahan (Omidi, 2009)

At presant safflower production in Sudan is negligible. However it has been suggested for inclusion in rotation of a number of new large scale rain fed mechanized schemes in the central clay plain , is also grew well on pump schemes between Wad Madani and Sennar. Gurtum as winter crop .is adapted to moderate temperatures to achieve high percentage of oil (Khiddir1981) .Thus, the temperature during November – January was found to be more sutiable than in June for sowing of safflower as seed crop. The crop can be grown successfully in arid and sunny regions. (Khiddir1981).

Safflower contributes partially in the world edible and industrial oil market, the by-products of oil extraction, whole seed or kernel meal, is available for stock feed. All the plant can be grazed or stored as hay or silage (Bar-Tal 2008). The forage is palatable and its feed value and yield are similar to or better than oats or alfalfa (Smith, 1996; Wichman, 1996). In China safflower is grown as a medicinal plant (Singh, 2007)

Safflower is considered an important winter crop in some semiarid regions due to its deep roots and its drought tolerance (Rafey, 1991; Blachshow, 1992). Zaman and Choudhuri (1998) reported deeper water extraction from sandy loam soils under dry land than under irrigated cultures. Leaf area and evapotranspiration rate reduction, osmotic adjustment and increments in the cell density are other adaptative mechanisms of safflower plants to water stress conditions (Guerra Sanz 1982). Since safflower is known by its efficient use of soil moisture, because of its deep tab root, the crop is suitable for arid regions. Therefore, the crop is recommended for new large scale rain fed mechanized schemes. Safflower may be the alternative or rather the supplement for other oil seed crops because of its spiny nature which makes the crop more resistant to bird attack and pest or diseases .

Crop response to nitrogen has generally been more pronounced than to other fertilizers, and it would appear that nutrients affects not only the total yield of seed but also seed composition .Nitrogen is important in plant chemical compounds such as protein, nucleic acid, chlorophyll and enzymes structure. It has an important role in the tissues structure of plants (Heidari 2004)Despite many uses of safflower, the crop remained minor importance , neglected and no enough agronomic information of the crop. Thus the study aim to achieve the following objectives:

1- Determine the optimum sowing date of the crop.
2- Determine the optimum irrigation interval.
3- Determine the best type of fertilizers to maximize seed and oil yield.

CHAPTER TWO

LITERTURE REVIEW

2.1 History

Safflower (*Carthamus tinctorius* Li) is a plant that has been cultivated since ancient times (Breitschneider, 1870).It has been known under many names: asfiore, asper, aspir, assfore, azafrancillo, bastard saffron, benibana, benihana, brarta, cartamo, cartham, carthami flos, carthamo, carthamos, cnecus, cnicus, cnikos, cusumba, dikken, dyer’s saffron, false saffron, flase, ghurtom, golbar aftab, golzardu, hong hua, hubulkhortum, hung hua, kafsha, kafshe, kahil, kajena-goli, kajireh, kamal lotarra, kardi, kariza, kasumbha, kazhirak, khardam, khariah, kharkhool, khartum, khasdonah, kosheh, kouchan-gule, kusum, kusuma, kusumba, laba torbak, maswarh, muswar, onickus, ostur, qurtum, saffiiore, safflor, snecus, suff, thistle saffron, ssuff, usfar, usfur, and zafaran-golu, (Weiss, 1971; Salunkhe, 1992) among others.

2.2 Botany description

Safflower is a member of the Compositae (*Cynaraae*) family, which includes several important crop plants, such as Artichoke, (*Cynara scolymus*), Sunflower (*Heliamthus annus*), Niger seed (*Guizotia abyssinica*), and Chrysanthemum (*Chrysanthemum*)(Smith, 1985).

The plant is a highly branched, herbaceous, thistle-like annual varying in height from 30 to 150 cm. It has a strong, somewhat thickened tap-root, and numerous thin laterals. The stem is stiff, solid, and circular in section, thick at the base and tapering with height, smooth and glabrous. The plant has many branches, each terminating in a flower, and the extent of branching within a variety depends mainly on environment. However, Abel (1976), has shown that yield is not correlated to plant height. This has been proven in practice many times; safflower that is 24 inches tall can yield just as well as safflower that is 40–50 inches tall if other conditions particularly moisture are satisfactory.

The leaves are simple, usually dark green, sessile and glabrous, estipulate, deciduous, with short spines scattered along the margins. Width between 2.5 to 5 cm and length from 10 to 15 cm with acuminate (pointed) tips. The midrib projects slightly from the tip. Most leaves have serrated edges and are lanceolate in shape but can be ovate to obovate. Leaves become shorter and stiffer on the upper reaches of the plant until reaching the terminal bud branches where the leaves become still shorter, ovate to obovate shapes, getting closer and closer together until they crowd on each other in a involucral whorl around the flower head. The lower leaves on most safflower types are spineless, on the upper leaves the degree of spines varies from spineless to horrible. Spines are controlled by multiple genes. The number of spines per leaf varies from zero to 24 and length can be from 1 to 6 mm (Claassen, 1950; Ashri, 1964).

Sharifmoghaddasi and Omidi (2009) reported that most people who work around safflower learn to wear leather pants, chaps, or at least heavy blue jeans when they need to walk through safflower in its later stages, or better yet, they avoid walking through it. Leaves have acuminate tips and a pronounced midrib. They are cauline, alternate, penastichous, with aphyllotaxy of two-fifths (144°).

The inflorescence is a dense capitulum of flowers, invested with an involucre of green ovoid bracts, the outer bracts separate, foliaceous, sometimes spinescent, the inner becoming fused, ovate, often covered with short white hairs. The involucre is conical, with a small apical opening through which the corolla tubes of the flowers protrude. The receptacle is broad, flat or slightly curved, and densely bristled from the numerous floral bracts. There are numerous flowers in the inflorescence. Each floret has its own set of bracts in the form of small hairs. The number of florets varies from 20 to 180, depending on the genotype involved and also any environmental effects particularly plant population(Wu, et al.,1982) .The florets are tubular, sessile, regular epigynous, and grow out through the apical opening of the involucre, the calyx is rudimentary. The ovary is unilocular, with a simple basal ovule, which is composed of two united carpels, and is inferior (Smith, 1985).

The heads at the ends of main branches bloom first, followed by the heads on the secondary branches. Within a given head, blooming starts on the periphery and moves toward the center in a centripetal or whorling manner, two rows at a time. This goes on for 3–7 days, depending on the variety and environmental factors. It may take 10–40 days for all heads on a plant to bloom. Head size, number of heads per plant, and number of seeds per head is affected by varietal difference and environmental factors. There can be 3–50 flower heads (capitulum) per plant, and head size is 1.25–4 cm in diameter (Weiss, 1971).

The fruit of safflower is an achene, which are the seeds. The modern types of safflower seed are normally free of pappus, although it sometimes occurs on some seeds in the center of the head. Claassen (1950) reported that one gene and some modifiers control the attached pappus phenomenon .Safflower seeds consist of a tough, fibrous hull that protects a kernel made up of two cotyledons and an embryo. The hull makes up 18–59% of the seed weight.

The color of safflower seeds is generally creamy to white, but in the last 30 years a number of color variations have occurred as researchers have striven for higher oil contents by modifying the thick hull. Normal-hull seed, thin-hull, and gray-, purple-, and brown-striped hull seeds have combined into a variety of hues. The seed is dicotyledonous, oleaginous and exalbuminous . Weiss, (1971) reported that there are spineless varieties of safflower. The crop produces flowers about 45 days before harvest with beautiful yellow, orange, or red flower colors for a period of approximately 2–4 weeks. The collection of the florets and/or the heads for use in medicine or as source of dye or food coloring is one of the oldest uses of safflower. Florets are classified by color (white, light yellow, yellow, yellow-orange, red-orange, red, purple, or other) with yellow-orange being the most common color. The color of the florets after flowering may vary from the color during flowering. Claassen ,(1952) found that inheritance of flower color is due to four independently inherited pairs of genes.

Red florets are the source of two coloring materials, a water-soluble yellow and bright red dye. Yellow florets contain little or no red pigment. The red dye is carthamin, the component that was highly prized in ancient times. In order to extract the red coloring matter, the yellow dye must first be removed. The yellow component (C16H20O11) has a molecular weight of 558.48. The red component, carthamin, (C43H42O22) has a molecular weight of 910.81 and a chemical structure as shown:

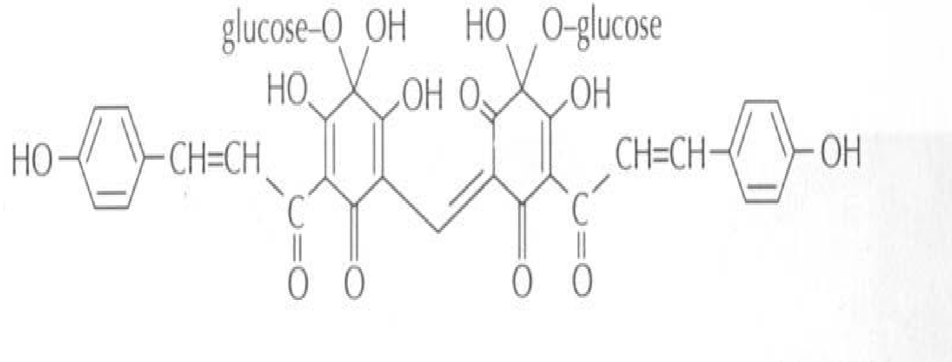


Plate 2.1. Chemical structure of safflower pigment (Claassen, 1952).

Cultivated safflower is part of the 12-pair group. Some wild species are closely related: *Carthamus flavescens* Spreng, is usually a wheat field weed found in Lebanon, Syria, and continental Turkey. Other species is a very serious weed in the area from western Iraq to northwestern India (Knowles, *et al.1989*) *Carthamus tinctoriu* and *C.flaverscens* are self incompatible (Imrie, and Knowles 1970).

C. palaestinus is self-compatible,and *C. oxyacantha* is mixed self-compatible and self-incompatible (Knowles, *et al*.1989). These species readily cross with

C. tinctorius to produce fertile progeny in the F1 and F2 generations (Imrie, and Knowles 1971) Two other species, *C. gypsicolus* Ilj. and *C. curdicus* Han., seem to belong to the 12-chromosome group. *Carthamus gypsicolus* Ilj. is similar to *C. oxyacantha* but is found only in some of the republics of the former U.S.S.R., while *C. curdicus* Han, is similar to both *C. gypsicolus* and *C. flavescens* and is restricted to northern Iraq, . (Hanelt, 1961).

2.3 Origin and usage

Nobody knows exactly how long ago or where safflower originated. Salunke *et al*. (1992) call it the world's oldest crop whereas others in *Evolution of Crop Plants* indicate that olives, dates, and sesame may be older . In any case, over 4,000 years ago safflower was grown in Egypt; it is possible that it was grown earlier in the Euphrates region. Weiss, (1971) uncovered a number of Egyptological references showing that safflower was prized as a source of red-yellow and orange dyes for cotton and silk. The dyes were derived from safflower flowers, and this use continues to this day. Safflower orange dye was used to dye the bindings of mummies found in ancient tombs(Pfister, 1937), and was used to color ceremonial ointments used to anoint mummies. Safflower flowers were woven into mummy wreaths, while safflower seeds were found in temple offerings, and representations of the flower have been found in early Egyptian wall-paintings.

Initially, safflower oil was used as a source of oil for the paint industry, now its edible oil is used for cooking, making margarine and salad oil (Pascual and Alburquerque, 1996). It is also grown for its flowers which are used as cut flowers, coloring and flavoring foods, making dyes for the textile industry, livestock forage, vegetable, making herbal teas and medicinal purposes. In China, safflower is grown as a medicinal plant (Singh, 2007) for the treatment of cardiovascular diseases, male and female sterility, lowering blood cholesterol, release of retained placenta and still birth, induction of labour in expectant women, delayed, heavy and painful various types of rheumatism (sciatica, thorax, arthritis), respiratory diseases (whooping cough, chronic bronchitis), gastritis. In addition to their medicinal uses, safflower flowers are also highly nutritious. Safflower has gained the reputation of being an edible oil of superior quality containing high levels of unsaturated fatty acids associated with the reduction of cholesterol level in the human blood (Chaturvedi *et al.*, 2001). It is also a source of important biochemical's like tocopherol in oil and carthamin in flowers (Ramaswamy, 2001).

2.4 Crop Adaptation

Safflower is a winter annual that belongs to the family Compositae, a diverse group of flowering plants that grow in many parts of the world. Sunflower, *Helianthus annuus*, and niger, *Guizotia abyssinica*, are two other oil-bearing members of the family. Except for its flower color, safflower resembles a thistle, and the commercial genus, *C. tinctorius*, is not a weed since it exists only as a cultivated crop .When farmed in the United States, safflower is an annual that grows 1.5–6feet tall. If planted when soil temperatures are barely above the 40°F, safflower seedlings can take up to 3 weeks to emerge. If planted when temperatures are above 60°F, seedlings emerge in 3–4 days. After emergence, safflower grows slowly for a period, forming many leaves in a rosette form. If safflower is planted in late fall or early winter it can remain in this form for 2–3 months, while plants that emerge in late spring will stay in this form only 4 weeks or less. During this period competing plants can gain a foothold, and later in the season will tower over the safflower (Smith, 1985).

Safflower has high adaptability to low moisture conditions. Therefore, its production all over the world is mainly confined to areas with scanty rainfall. *Carthamus* Has 25 species, of which only *C. tinctorius* is the cultivated type, having 2n = 24 chromosomes (Knowles, 1989; Ekin, 2005). Adaptability to varied conditions and to be exploited for various purposes, the area under safflower around the world is limited largely due to the lack of information on its crop management and product development (Li and Mundel, 1996).

The research and development on different aspects of safflower, despite its adaptability to varied growing conditions with very high yield potential and diversified uses of different plant parts, have not received due attention. This probably is the main reason for its status as a minor crop around the world in terms of area and production, compared to the other oilseed crops. However, interest in this crop has been rekindled in the last few years due to three major reasons:

1. A huge shortfall in oilseed production in countries having a sizable area with scanty rainfall, to which safflower is most suited.
2. The preference of consumers for healthy oil with less amounts of saturated fats, for which safflower is well known.
3. The medicinal uses of flowers in China and extraction of edible dyes from flowers have become more widely known (Singh 2007).

Safflower is a day neutral plant .However the origin of varieties is very important because summer crop varieties from temperate regions,are planted during short days as a winter crop in subtropical and tropical regions. Safflower is grown throughout the semiarid region of the temperate climates in many areas of the world (Weiss, 2000; Johnston *et al*., 2002). Plant density varies greatly among countries .The plant density adopted is influenced by the variety, climatic factors and cultural practices .When soil moisture is not limiting, safflower compensates for low plant density by increased branching and other yield components adjustments. The seeding rate is 10-45kg/ha (Mundel , 1969). During the rosette stage of growth, safflower is a poor competitor with weeds. Therefore, weed control at this stage is very important for yield optimization (Blackshaw *et al*., 1990). The crop is well adapted to dry and salty land conditions since it is a strongly tap-rooted annual plant which is resistant to saline conditions, drought stress and can reach the deep-lying water (Aira *et al.,* 2002). Therefore safflower grows well in welldrained, deep, fertile sandy loam soils. In heavy clay soils, crusting may reduce seedling emergency. Safflower seed yield is affected by cultural practices (Siddiqui and Oad, 2006; Nikabadi *et al*., 2008), cultivar (Arslan2007; Pahlavani 2005; Mahasi *et al*, 2006) and climatic factors (Kolte 1985; Abdualhi *et al.*, 2007). The crop has long rosette stage, it harvested directly when crop is at 9 to 13% moisture, about one to two months after flowering and when most leaves have turned brown, and seeds should rub freely from the heads. Bird damage may be a problem. (Petrie, *et al*., 2008).

2.5 Sowing Date

Safflower growth as well as composition and quality of seeds are influenced by many factors like genotype, environment and agronomic practices (Nagaraj, 1993; Weiss, 2000). One of the key points for optimizing safflower productivity in a given location is the choice of the appropriate sowing date (Esendal, 1997). Sowing date usually has a big and predominant influence on yield. There is a little information about the summer sowing of crops especially safflower. A study in Cyprus showed that fall/winter sowings gave higher seed yield than spring sowings (Hadjichristodoulou,1985). Spring sowing does not appear to be utilizing the available rainfall effectively. (Singh,.2007:Heidari, 2004) in their study of safflower reported postponing the sowing date in addition to temperature increase in developmental stages of germination to flowering which shortening this period cause to yield component production period encounter with high temperature and reduced the total plant dry weight, although number of heads per plant, 1000 seeds weight and seed yield were more affected by it in comparison to biomass yield. Yau (2007) , in his study to find the optimal winter sowing month, for rain-fed safflower in a semiarid, high-elevation Mediterranean site, found out that November sowing gave the highest yields, but yields from December and January sowings were not significantly different. Furthermore, plant height dropped from late November sowing to December sowing to January sowing. In addition there were no effect of sowing date on leaf area index

.Also he pointed out that dry matter yield at maturity under the November sowing was higher than that in February and March sowings .These results was in the same magnitude as those reported for safflower in southern Italy (Cazzato *et al*., 1997; Corleto *et al*., 2001).Studies suggested that farmers in Lebanon and in other areas of West Asia and North Africa with cool climatic conditions should change their traditional spring sowing of safflower to fall or early-winter sowing just like small grains. The lower seed yield with later sowing-dates can be attributed to unfavorable conditions for crop growth, smaller biomass production resulting from a shorter vegetative growth period, and later flowering which was correlated with the day length. The day-length sensitivity of safflower, as shown by the finding that days to flowering are delayed by only 12 days when sown later, strongly restricted pre-anthesis growth. The much-reduced growth and plant height of safflower in February and March sowing suggests that adequate roots may not have been formed to extract water stored deep in the soil profile. Besides, it is known that safflower transferred a large percentage (65–92%) of its pre-anthesis storage of assimilates to the seed (Koutroubas *et al*., 2004). A low pre-anthesis growth led to low seed yield consequently. Early sowing may have two beneficial effects on environment protection. First, early sowing is expected to provide a crop cover earlier than later sowing, thereby helping to reduce soil erosion. Second, the earlier and better growth under early sowing is expected to capture more residual soil N and reduce nitrate leaching into ground water.

2.6 Irrigation

Safflower respond to different irrigation regimes which plays an important role in safflower seed yield. Moreover, seed and oil quality and yield are both dependent upon the genotype of the crop and its interaction with the environment (Jalilian *et al*., 2012). Among the factors responsible for increasing crop yield and quality is irrigation (Blum, 1997). Suitable irrigation regime increases seed yield primarily through its effect on the number of heads per plant. (Omidi, 2010 a) suggested that maintainace of soil moisture at an adequate level produce more seed and oil yield 0f safflower. Water deficit prior to anthesis can decrease crop biomass and insufficient growth leads to lower seed yield, because seeds number per unit area is closely related to biomass at anthesis (Fischer 1985). In Iran, a common concept among farmers is that early season drought stress encourages root growth and thus, crops can better withstand drought stress that may occur later in the season. Therefore, farmers try to increase irrigation intervals during the vegetation growth stages. Tomar, *et al.* (1995) showed that with increasing drought stress percentage of protein increased significantly.

Excessive rainfall during flowering causes several leaf and flower head diseases resulting in yield reduction (Kolte 1985). Prolonged rainfall during flowering interferes with pollination and seed set, so does high temperatures greater than 32^{o} C.

The best irrigation regimes must be determined precisely in local conditions. according to Ozturk,(2008); Hayashi and Hanada,(1985) reported that water stress reduces LAI and number of seeds per plant. Seed oil concentration is poorly affected by drought stress and was shown to highly depend on the genotype. Omidi,(2010b) demonstrated that interrupting irrigation significantly affected the number of days to maturity, seed , oil yields, number of seed per head and number of branches. He reported that the highest seed and oil yields belonged to Padideh cultivar (2300, 667 Kg/ha) in non-stress conditions. Amir (2011) in his study applying 7,15,22 and 28 days irrigation intervals on safflower , pointed out An increase in the irrigation interval up to 15 days after the six-leaf stage had no significant effects on grain yield, but grain yield did decrease by 18 and 29.8% with increased irrigation intervals to 22 and 28 days, respectively. Among yield components, number of capitulums per plant and number of primary branches were negatively affected by an increased irrigation interval greater than15 days.

Other studies have shown that drought stress during reproductive growth stages reduced seed and/or flower number per capitulum (Steer *et al*, 1986; Saini *et al* 2000), but in that study number of seeds per capitulum was not significantly affected by irrigation intervals. This was most likely due to the drought stress stage in the study. Also thousand-grain weight was not significantly different among treatments. This component is usually constant and does not change with environmental and management factors. (Kasper *et al*. 1990) reported that there was no significant difference among irrigation intervals for harvest index. Similarly, Lovelli *et al*. (2007) showed that the harvest index of safflower did not change significantly at five irrigation regimes 0, 25, 50, 75 and 100%, based on maximum evapotranspiration. On the other hand, no significant differences in seed oil percentage were observed for different irrigation intervals, but regarding grain yield in these treatments, oil amounts in the 7, 15, 22 and 28 days irrigation intervals were increased by decreased irrigation intervals. That results were similar to the findings of Abel (1975) and Ozturk *et al*. (2008) who found that irrigated in all stages and non-irrigated in rosette stage , safflower had similar oil contents. By contrast, Ashrafi and Razmjoo (2010) reported that the amount and composition of safflower oil was affected by irrigation. In their study, drought stress reduced the palmitic, stearic, oleic and linoleic acid contents by 13, 63, 60, 14 and 10%, respectively.

2.7. Nitrogen Fertilizers

Nitrogen is one of the most important nutrients for crop production because it affects dry matter production by influencing leaf area development and maintenance as well as photosynthetic efficiency. Siddiqui and Oad (2006), reported that application of 120kg N/ha significantly increased safflower branches number, plant height and seed yield but delayed maturity. Nitrogen increases seed yield primarily through its effect on the number of heads per plant and the increase is greater in tertiary and to a lesser extent in secondary heads (Weiss, 2000). Surprisingly, safflower was reported to accumulate 5 kg N ha^{-1} to produce 100 kg of seeds (M¨undel, 2004), while the same figure for sunflower is only 3.7 kgNha^{-1} (Merrien, 1992).

The researchers declared that increasing nitrogen increased seed yield but seed oil content decreased (Chkerol hosseini, (2006). In the context of plant nutrition, nitrogen deficiency represents the most important factor affecting safflower production, which is also true for most other crops (Dordas and Sioulas, 2008).Despite of the important role of N in the productivity of crops, the use of N fertilizer is associated with economic and environmental risks, especially with poor N fertilizer management is employed (Sylvester-Bradley, 1993).

Nitrogen is the most important element that increase protein of grain.(Abou khadrah, 2002; Mohamed 2003; Awad, 2004*)* they reported that the application of nitrogen rate up to 45 kg N/fed. significantly increased dry matter accumulation, plant height, head diameter, LAI, stem diameter, 100 seed weight and seed yields as well as oil yields/fed of safflower. They reported also that increasing N- level tended to decrease seed oil content. Gorttappeh, *et al*.(2000). In iran they showed that increases in application rates of nitrogen fertilizers and manure increased seed and biological yields, 100- seed weight, plant height, as well as oil percentage and yield. The highest seed and oil yields were obtained with 200 kg N/ha and with organic fertilizer of 30 t/ha.

For an optimal yield, the N supply must be available according to the needs of the plant. Thus, nitrogen deficiency generally results in stunted growth and chlorotic leaves caused by poor assimilate formation that leads to premature flowering and shortening of the growth cycle (Hamza *et al*., 2010). Proper nitrogen (N) management optimizes seed yield, farm profit, and N use efficiency while minimizing the leaching of N beyond the crop rooting-zone Shapiro (2005).N deficiency can speed up the time plants require to reach maturity and thus can decrease significantly the grain filling period. When the grain filling period is longer this leads to higher yields and also to better quality (Yau, 2007and.Mündel *et al*., 2004) reported that safflower requires 5 kg/ha of N to produce 100 kg/ha of seed. Soleimani (2010) reported that appling of 100 and 125 kg/ha nitrogen produce higher 1000 seed weight, seed yield and number of seed /head that results were in agreement of Haby *et al*., (1982) reported that seed yield of safflower increased with increasing fertilizer nitrogen rates of 135 and 180 kg ha^{-1}. Singh *et al*., (1994) reported that application of 40 kg ha^{-1} for increase of heads per plant and oil yield of safflower was the best treatment.

Research by Mahey *et al*. (1989) indicated that the highest biomass yield was in treatment of application of 60 kg ha^{-1} of nitrogen. Also, Nasr *et al*., (1978) reported that the best nitrogen application for ideal grain and oil yield was 70 kg ha^{-1}. Rajput *et al*., (1992) reported that plant growth was increased by nitrogen application, and the highest seed yield was at treatment of 60 kg ha^{-1}. Dordas *et al*,, (2008), to rainfed safflower, reported that application of 100 kg nitrogen/ha increased grain by an average of 19% and the grain weight per plant by 60% compared with control (without nitrogen application). Aowad.,(2009) showed that the highest safflower grain yield (1750 kg ha^{-1}) was obtained from a nitrogen application rate of 80 kg ha^{-1} from a urea source.

2.8. Farm Yard Manure

Due to energy crisis, escalating cost of fertilizers and poor purchasing capacity of dry land farmers, it is becoming difficult to meet the demand of the plant nutrients only through chemical fertilizers. Intensive cultivation and growing of exhaustive crops have made the soil deficient in macro-as well as in micro nutrients. Now days use of only nitrogenous and phosphatic fertilizers also creates nutrient imbalance in soil(Tolanur 2009).

Organic fertilizers are a source of plant nutrients and makes marked changes in the soil properties. It contains significant amounts of macro-nutrients (i.e., N, Pand K). Many organic materials contain other components that can contribute significantly to an increase in crop yields, including secondary nutrients and micro-nutrients. On the other hand, application of animal waste is a common practice which when conducted judiciously can provide a cost-effective strategy for recycling organic matter and essential plant nutrients as well as assisting in solid waste disposal. The production benefits garnered from animal sludge has been extensively documented (Adegbidi and Briggs, 2003; Yang *et al*., 2004; Hiltbrunner *et al*.,2005 and Zhou *et al*., 2005).

Many investigators indicated that the application of organic fertilizer increased the nutrient contents in the soil, their uptake and consequently increased the productivity of crops. Dahiya and Singh (1980) showed that the concentration of P in the soil was significantly increased with increasing in the level of FYM over the control. Also, Poonia *et al.,* (1986), found that increasing the rate of FYM application to calcareous soils in India increased K by soils over Ca. Several concepts have been advanced to explain the improvement of nutrient availability as a result of the application of organic manure availability of nutrient and their uptake by the crop. Due to the reduction in soil pH Abd El-Moez, (1999) or through improvement of physical and chemical properties of the suitable package of fertilizer management. (Orlando *et al*., 1991; Sikora *et al*., 1993). Application of organic manures on safflower plant had a significant influence on the plant to height, number of leaves per plant, number of primary branches per plant, number of capitula per plant, seed weight per plant, 1000 seed weight total dry matter production and seed yield per hectare. Application of organic manures had significant influence on the plant height, number of leaves per plant, number of primary branches per plant, total dry matter production at harvest and leaf area. Among the different organic manures Nakhlawy, *et al.,* (1991); Naik, *et al.,* (2007), To address issues of crop environment and crop productivity the over all management system of crop culture needs to be improved especially the nutrients management of crops. The application of organic and bio fertilizers sustain the fertility of the soil for a long time. On the other hand, the farmers add rarely sufficient amount of organic manure to the soil against the removal. Under this condition there is need to explore the possibilities of using the expanding native sources of plant nutrition, such as organic and bio fertilizers. Several investigators showed the effect of mineral and organic fertilizers application on sunflower as; Abou khadrah *et al*., (2002); Mohamed (2003);Awad, (2004) they reported that the application of nitrogen rate up to 45 kg N/fed. Significantly increased dry matter accumulation, plant height, head diameter, LAI, stem diameter, 100 seed weight and seed yield as well as oil yield/fed. They reported also that increasing N- level tended to decrease seed oil content and increasing mineral nitrogen rate with bio and FYM significantly increased dry matter acumulation , LAI,stem diamter, head diamter , 100-seed weight, seed yield and oil yield. Keshta and El-Kholy (1999*)* indicated that organic manure application increased the efficiency of both mineral nitrogen and biofertilizers of nitrogen as well as organic matter content..Increasing mineral nitrogen rate with bio nitrogen and FYM significantly increased dry matter accumulation , LAI, stem diameter , head diameter , 100-seed weight, seed yield and oil yield.

Mohamed *et al* (2009) reported that application of farm yard manure alone at rate 20 and 30 m3/fed was less effective on seed oil content and oil yeild than applying mineral nitrogen alone or with them. Similar results were reported by Mohamed. 1997; Keshta 1999; Gorttappeh *et al*., 2000), Soleimani (2010) indicated that application of manures increased yield and straw of safflower that results were in full agreement of these obtained by Abdel-Sabour (1999); Basha (2000); Ahmed (2001); Darwish *et al*., (2002) and Abou Youssef *et al.*, (2003). Moreover, Faiyad (1999) suggested that the increasing effect of organic manures may be due to the ability of organic matter in rendering soil nutrients more available and chelating of these elements by humic substances.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study site

A field experiment was conducted in the experimental farm of the Department of Agronomy, College of Agricultural Studies, Sudan University of Science and Technology, Shambat, Khartoum, during winter of 2010/11 and 2011/12 seasons to study the effect of sowing date, water intervals and fertilizers on growth and yield of Safflower (*Carthamus tinctorius L*).

The area lie, at 15^0 40'N and 32^0 32' E. The climate is described as tropical semi-arid. Annual rainfall ranges from 750-800 mm, occurring during July to September. Relative humidity ranges between 31-51% during wet season and14-27%during dry season. Mean maximum and minimum temperature in Khartoum are 41.7^0C and 15.3^0C, respectively. The winter season extend from November to March and is relatively cool and dry. The summer season is hot and dry. The soil is clay loam with physical and chemical properties which make it ideal for vegetable and crop production. Pumping water from the river Nile is common, in addition, subsoil water used as supplementary source of irrigation (Sayed 2012).

3.2. Land preparation

The experimental area was tilled adequately to prepare a suitable seedbed. The implements used were disk plough, disk harrow and leveler to make easy movement and uniform running of irrigation water. The field then was divided to four blocks (replications) each one contained 18 equal plots of 4x3m size. Prior to sowing, soil samples were collected randomly from depth 0-30 cm using an auger that was done before sowing and after harvesting in the two seasons to determine soil PH, P, and Na content in Soil Laboratory of the Department of Soil, College of Agricultural Studies .(table 3.1 appendix.).

3.3. Experimental design

The experiment was RCBD lied out in split-split arrangement, with four replications. The main plots were two sowing dates on 13th (S1) and on 28th (S2) November in two seasons. Subplots were three irrigation intervals (7, 14 and 21 days) and sub-subplots were three levels of fertilizers, urea (U 46%N) (190.5 kg ha^{-1}), pellet granules (P)(250 kg ha^{-1}) and farm yard manure (F)(4800 kg ha^{-1}).Urea was obtained from the market, Pellet granules from the Ministry of Agriculture new in Sudan ,while Farm yard manure was obtained from Animal Production Department, College of Agricultural Studies. All fertilizers were added before sowing. Safflower variety Geeza obtained from Egypt and then released under local sowing conditions. After testing the germination percentage of the seeds, planting was done manually with the in-row spacing of 30cm and 60cm between rows at the depth of 4 cm at 3-4 seeds per hole.

3.4. Cultural Practices

3.4.1. Irrigation

Immediately after sowing irrigation was applied then every week for four weeks then irrigation scheduling was arranged until the end of season.

3.4.2. Weed control

Weed control was done by hand 30, 45 and 60 days after sowing (DAS). No herbicides were used to control weed in this study. In season two serious infestations with *Orobanche crenata* occurred in the experiment which could not be controlled by herbicides (Plate 3.1). It was the first record in Sudan.

Plate 3.1 *Orobanche crenata* growing with Safflower plants.

3.4.3. Pest and diseases

Helicoverpa armigera attacked the plant in early stages of growth, in two seasons and controlled by spraying with monochrotophos at750 ml/ha in 600-800 liters of water per hectare and was repeated twice after 30 and 45 days after sowing.

3.5. Parameters Studied

3.5.1. Vegetative growth parameters

Data were collected from the central part of each plot. Five safflower plants were randomly selected and tagged and used for following observations:

3.5.1.1. Plant height (cm)

Mean plant height was determined by measuring height from the tip of the stem to the ground level which was done every 30, 45, 60 and 75 (DAS).

3.5.1.2. Stem diameter (mm)

The stem circumference was measured and the stem diameter was determined using the following formula

$$\text{Stem diameter} = \frac{\text{Circumference}}{2x3.14}$$

3.5.1.3. Number of leaves

Number of leaves was counted and determined every 30, 45, 60 and 75 days (DAS) and mean leaf number was calculated.

3.5.1.4. Number of branches

Number of branches of five plants was counted every 30, 45, 60, and 75 (DAS and the mean was obtained).

3.5.1.5. Leaf Area Index (LAI)

Leaf area was measured using Leaf Area Meter (Plate 3.2) in Striga Research Laboratory, College of Agricultural Studies then the following equation was used to determine LAI

$$\text{LAI} = \frac{\text{Mean of LAX Mean of number of leaves /plant X Number of plants/m}^2}{\text{M}^2}$$

LAI was determine three times throughout the growing seasons.

Plate. 3.2. Leaf Area Meter.

3.5.1.6. Plant population density

Numbers of plants were counted from one meter^2 in center of the each plot after 30 and 45 (DAS).

3.5.2. Yield components

3.5.2.1. Number of heads / plant

Number of heads mean determined by counting heads in five plants selected randomly from each plot and the mean was obtained.

3.5.2.2. Number of seeds / head

Five heads were selected randomly from each plot and seeds numbers was counted then mean was taken.

3.5.2.3. Thousand seed weight (gm)

Seed weight in grams was obtained by weighting 1000 seed selected randomly from each plot.

3.5.2.4. Seed yield (t/ha)

To measure seed yield one meter square in center of each plot was harvested, the plants were dried in open air. Their seeds were separated and weighed. Then, seed weight per unit area and per hectare was determined.

3.5.2.5. Pigment leaves yield (gm)

Safflower petals contains about yellow (30%) and red pigment (0.83%) Nagaraj *et al* (2001) and Kulkarni *et al* (2001), obtained from plants in one meter^2 each plot and weighed, then converted kg/ha.

3.5.2.6. Harvest Index (%)

Plants from one meter^2 area harvested, dried and weighed, seed yield weight was recorded. Harvest index was calculated according to following equation

$$\text{Harvest Index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6. Porometer data

Porometer type AP4 (Plate 3.3) was used to measure the differential temperature, relative humidity, leaf stomatal resistance and conductance. Prior to start of reading , porometer need calibration. To avoid errors it was calibrated in the lab and field at 6 positions. Data obtained was used to compare between water intervals in histograms.

Plate. 3.3. porometer

3.7. Oil extraction

Oil percentage of the seed samples was determined by Sechelt method. The seed was cleaned and dried in the oven at a temperature of 105^O C for an hour and then crushed into smaller particles in a iron mortar. The oil was then extracted in a soxhlet apparatus with n-Hexane for about 8 hours and by hydraulic pressing (2000 psi). The solvent was removed by a rotary vacuum evaporator and the percentage of oil contain was calculated. The crude oil thus obtained was purified in a column (neutral alumina in pet.-ether) using petroleum ether- diethyl ether (70: 30) as the eluting solvent. The purity of the oil was checked by normal TLC, and oil yield was calculated by multiplying grain yield by oil content.

3.8. Proximate analysis

Crude protein and crude fiber contents were determined following the standard methods of the Association of Official Analytical Chemists (AOAC1990). The organic nitrogen content was quantified using the micro Kjeldahl method, and an estimate of the crude protein content was estimated by multiplying the organic nitrogen content by a factor of 6.25 (Sosulski &Imafidon, 1990). Two different samples were analyzed in triplicate.

3.9. Statistical analysis

Prior to analysis of variance (ANOVA), data were subjected for normality and homogeneity of variance test using Shapiro-Wilk-W test and the Levene test, respectively.

The ANOVA directive of SAS package was used to perform the analysis of variance. Mean separation were made by Duncan Multiple Rang Test (DMRT) and Tukey test. Statistical significance was accepted at a level of $P < 0.05$ (Statgraphics 1985–1989).

CHAPTER FOUR

RESULTS

4.1 Vegetative Growth:

4.1.1 Plant height (cm):

Statistical analysis showed significant effect of sowing dates on plant height in 45, 60 and 75 days after sowing (DAS) in the two seasons, but in season 1 sowing had no significant effect after 45, 60 (DAS).(P<0.05) (Table 4.1appendex).Sowing date at 13^{Nov} gave the highest plant height in the two seasons 119.1cm compare to 53.0 cm at 28 ^{Nov} in season 2(Table4. 2).

There was high significant effect of water intervals on plant height of 60 and 75 (DAS) in the two seasons. Irrigation every 7days obtained greater plant height 124.9 and 105.0 cm in season 1 and 2 respectively. In the first season application of 4800 kg/ha of farm yard manure increased the height by 0.1% over urea and 0.04% on pellet granules compared to 0.06% and 0.04% in second season (Table4. 2). The differences between the interactions of the factors were significantly only in the first season (Fig 4.1 2.3)

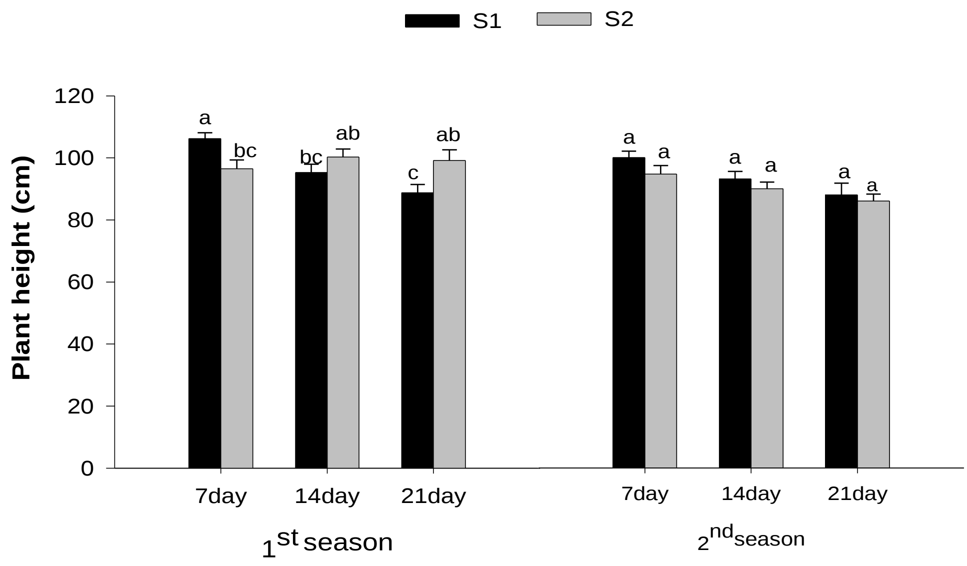


Fig.4.1.Effect of sowing date and water intervals on plant height of 60(DAS).Error bars represent the standard error of the means. Bars marked with the same letters are not statistically significantly different at $P<0.05$ (Tukey test).

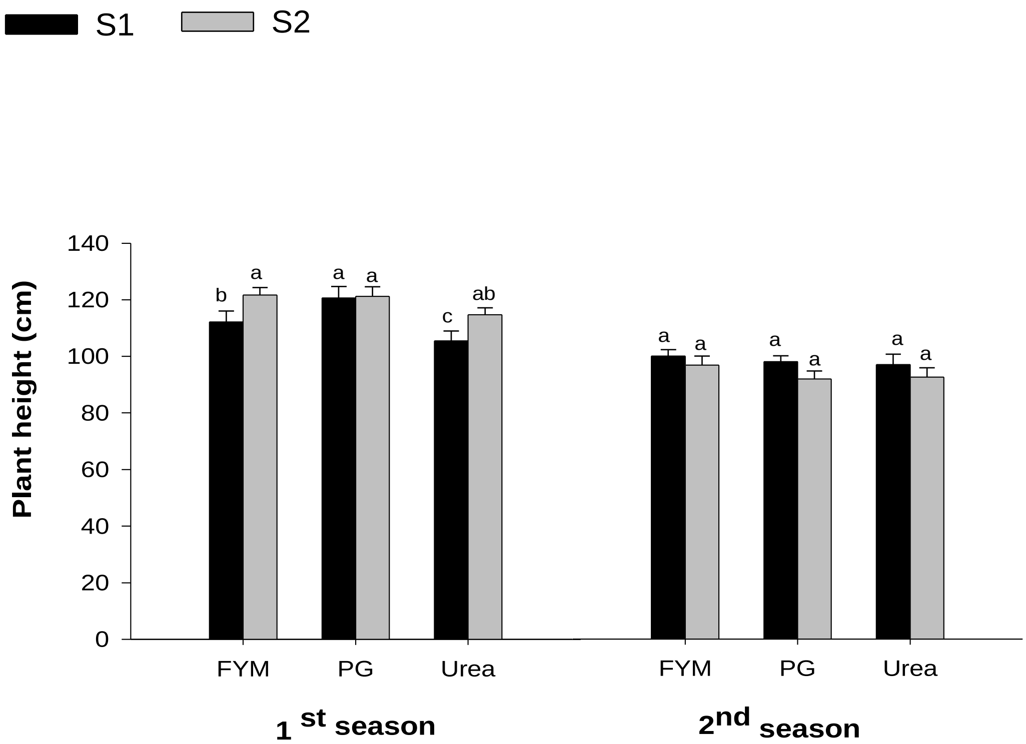


Fig.4.2. Effect of sowing date and fertilizers on plant height at 75 (DAS). Error bars represent the standard error of the means. Bars marked with the same letters are not statistically significantly different at $P<0.05$ (Tukey test).

7 day 14 day 21 day

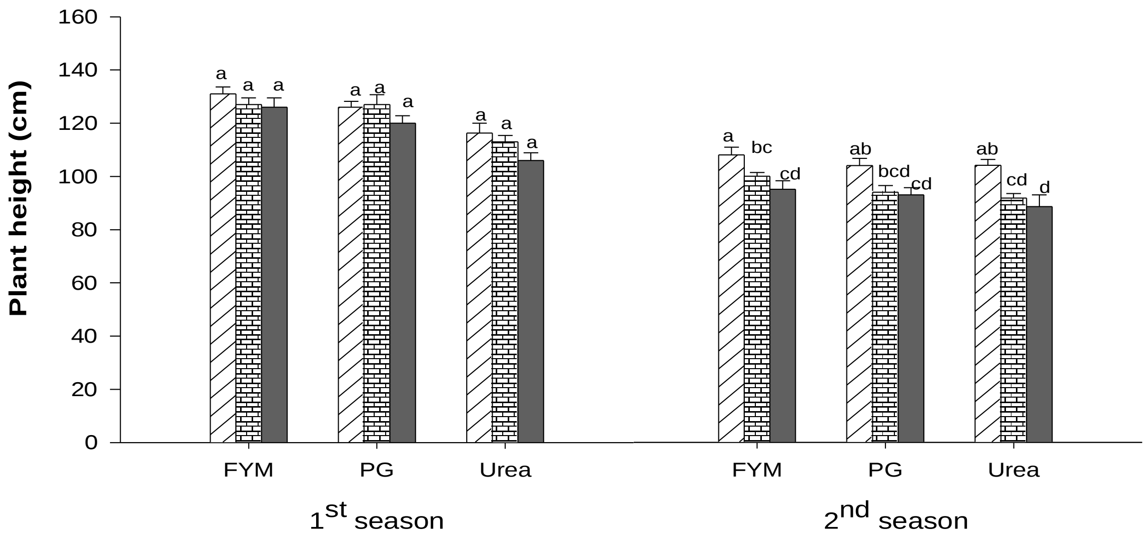


Fig 4.3 Influences of the interaction of water intervals and fertilizers on plant height 60 (DAS).Error bars represent the standard error of the means. Bars marked with the same letters are not statistically significantly different at P<0.05 (Tukey test).

4.1.1.2 Stem diameter (mm):

Effect of sowing date on stem diameter was highly significant in season two (P<0.001) where S1 gained larger stem diameter than S2 at 45 (DAS) and in the two seasons aT 60 and 75(DAS). On the other hand , the effect of water intervals were not significant in the first season .Irrigation every 7 days achieved the largest stem diameter in 2 nd season (Table 4.2). (Table4.1.appendex)

Differences between fertilizers on stem diameter were not significant in both seasons. Also the differences of the treatments interactions were not significant in the two seasons (table 4.1 appendix), but interaction of sowing date and water intervals showed highly effect in 2nd season (Table 4.4)

4.1.3 Number of leaves /plant:

According to statistical analysis it was clear that sowing date had significant effect on the number of leaves /plant in both seasons when S1, sowing date 1gaved highest number of leaves in both seasons (Table 4.1 and2). Number of leaves/plant statistically was not significant affected by water intervals and fertilizers application in both seasons (Table 4.1, appendix). The interaction of sowing dates and water intervals had marked effect on this parameter (Fig 4.4) and (Table 4.4).

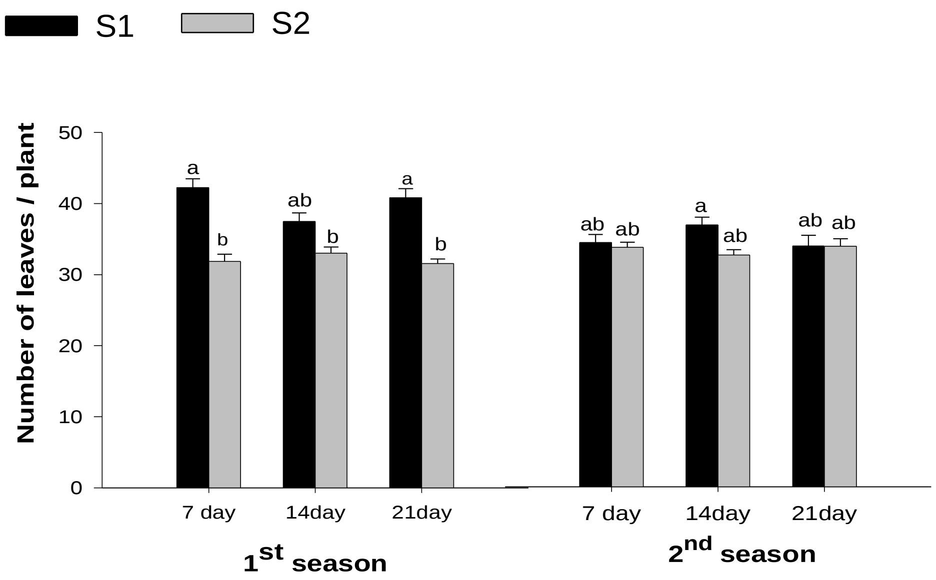


Fig 4.4 Effect of sowing date and water intervals on number of leaves /plant at75 (DAS).

Table (4.2). Effects of sowing date , water intervals and fertilizers on the vegetative growth parameters at45.60 and 75(DAS)

Treatments	**Plant height(cm)**		**Stem diameter(mm)**		**No of Leaves/plant**	
Sowing dates	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
			45(DAS)			
S1	42.8 a	22.5a	0.9 a	0.9a	22.9b	22.5a
S2	41.6 a	19.7b	0.8 a	0.7b	25.9a	19.6b
Water interval						
7	43.0 a	33.7 a	0.9 a	0.8 a	24.5 a	20.3 a
14	43.3 a	33.5 a	0.8 a	0.7 a	24.0 a	20.9 a
21	43.6 a	32.4 a	0.9 a	0.8 a	25.0 a	21.0 a
fertilizers						
F	43.5 a	34.8 a	0.8 a	0.7 a	24.7 a	21.5 a
P	43.2 a	32.8 a	0.9 a	0.7 a	24.0 a	21.2 a
U	41.9 a	32.8 a	0.9 a	0.8 a	24.1 a	20.6 a
			60(DAS)			
S1	99.8a	94.4a	1.1a	0.8a	34.3a	41.5a
S2	96.7a	88.0b	0.6b	0.6b	31.2b	37.1b
Water interval						
7	101.3a	100.9a	1.0a	0.8a	33.9a	37.8a
14	97.8ab	91.5b	0.9a	0.7a	33.2a	38.1a
21	93.5b	85.9b	0.9a	0.6a	32.1a	40.3a
fertilizers						
F	98.4a	94.4a	0.9a	0.8a	32.6a	41.2a
P	98.7a	94.0a	1.0a	0.7a	33.2.a	39.6a
U	97.1a	90.9a	0.9a	0.7a	32.9a	39.8a

	75(DAS)					
S1	119.1a	101.8a	0.9a	0.9a	35.0a	39.9a
S2	112.3b	53.0b	0.9a	0.7b	33.0b	31.8b
Water levels						
7	124.9a	105a	0.9a	0.9a	34.0a	37.0a
14	110.2b	95.0b	0.8a	0.8ab	34.7a	36.1a
21	112.2b	93.0b	0.9a	0.7b	33.8a	36.4a
fertilizers						
F	120.3a	100.9a	0.1a	0.8a	34.7a	36.1a
P	116.9ab	96.9ab	0.9a	0.8a	34.7a	36.0a
U	110.1b	94.5b	0.9a	0.8a	33.0a	35.7a

Means in columns followed by different letters are significantly different at p<0.5 (Duncan test).

Key S1= Sowing date at 13 Nov S2=28 Nov, W1, W2 and W3 Irrigation every 7, 14 and 21 days respectively, F=Farm yard manure, P=Pellet granules and U =Urea.

Table (4.4) Stem diameter and number of leaves /plant as influenced by sowing date(S1,S2), (water intervals W1, W2 and W3 every 7, 14 and 21 days respectively and their interactions at 45,60 and 75(DAS).,

Treatments		**Stem diameter(mm)**		**No of leaves/plant**	
		2010/11	2011/12	2010/11	2011/12
		45(DAS)			
Sowing	Water interval				
S1	7	0.9±(0.1)a	0.9±(0.02)a	23.8±(0.6)bc	22.8±(0.9)a
	14	0.9±(0.1)a	0.8±(0.02)ab	22.9±(1.0)bc	23.1±(0.9)a
	21	0.8±(0.1)a	0.9±(0.02)a	21.9±(0.7)c	21.7±(0.7)ab
S2	7	0.9±(0.1)a	0.7±(0.01)bc	25.8±(1.3)ab	19.1±(1.0)bc
	14	0.8±(0.1)a	0.7±(0.01)bc	24.5±(1.3)bc	18.7±(0.6)c
	21	0.8±(0.1)a	0.6±(0.02)c	27.7±(1.4)a	21.2±(0.3)ab
		60(DAS)			
S1	7	1.2±(0.1)a	0.9±(0.02)a	35.3±(1.4)a	36.9±(1.4)b
	14	1.1±(0.1)ab	0.7±(0.03)bc	31.3±(0.9)abc	43.1±(4.2)ab
	21	0.9±(0.1)b	0.8±(0.02)b	34.9±(0.8)ab	45.2±(2.9)a
S2	7	0.2±(0.1)c	0.7±(0.01)c	31.0±(1.0)c	37.1±(1.0)b
	14	0.2±(0.1)c	0.7±(0.01)c	32.6±(0.7)abc	37.3±(0.8)b
	21	0.9±(0.1)b	0.7±(0.01)c	32.1±(1.1)bc	38.9±(0.9)ab

75 (DAS)					
S1	7	1.0±(0.1)a	0.9±(0.02)a	41.4±(1.2)a	33.5±(1.8)ab
	14	0.9±(0.1)a	0.8±(0.01)b	39.2±(1.2)ab	36.1±(0.8)a
	21	0.9±(0.4)a	0.7±(0.01)c	39.4±(1.5)a	35.6±(0.7)ab
S1	7	1.0±(0.03)a	0.7±(0.01)c	31.7±(0.8)b	34.4±(1.0)ab
	14	1.0±(0.03)a	0.7±(0.01)c	31.7±(0.3)b	33.5±(0.8)ab
	21	1.0±(0.04)a	0.7±(0.02)c	32.2±(0.9)b	32.5±(0.8) ab

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at $P< 0.05$ (Duncan test).

4.1.4 Number of branches /plant:

The influence of sowing date on number of branches/plant was significant in 1st season only at 60(DAS) and in2 nd season at 45 and75 (DAS). S1 increased number of branches from 13.4 to 17.2 in season one .On the other hand in 2nd season sowing two produced higher number of branches. The interaction between treatments was significant in season one and two (Table 4,5).Interaction of sowing date and water intervals 45 and 60 (DAS) illustrated in (Fig 4.5)

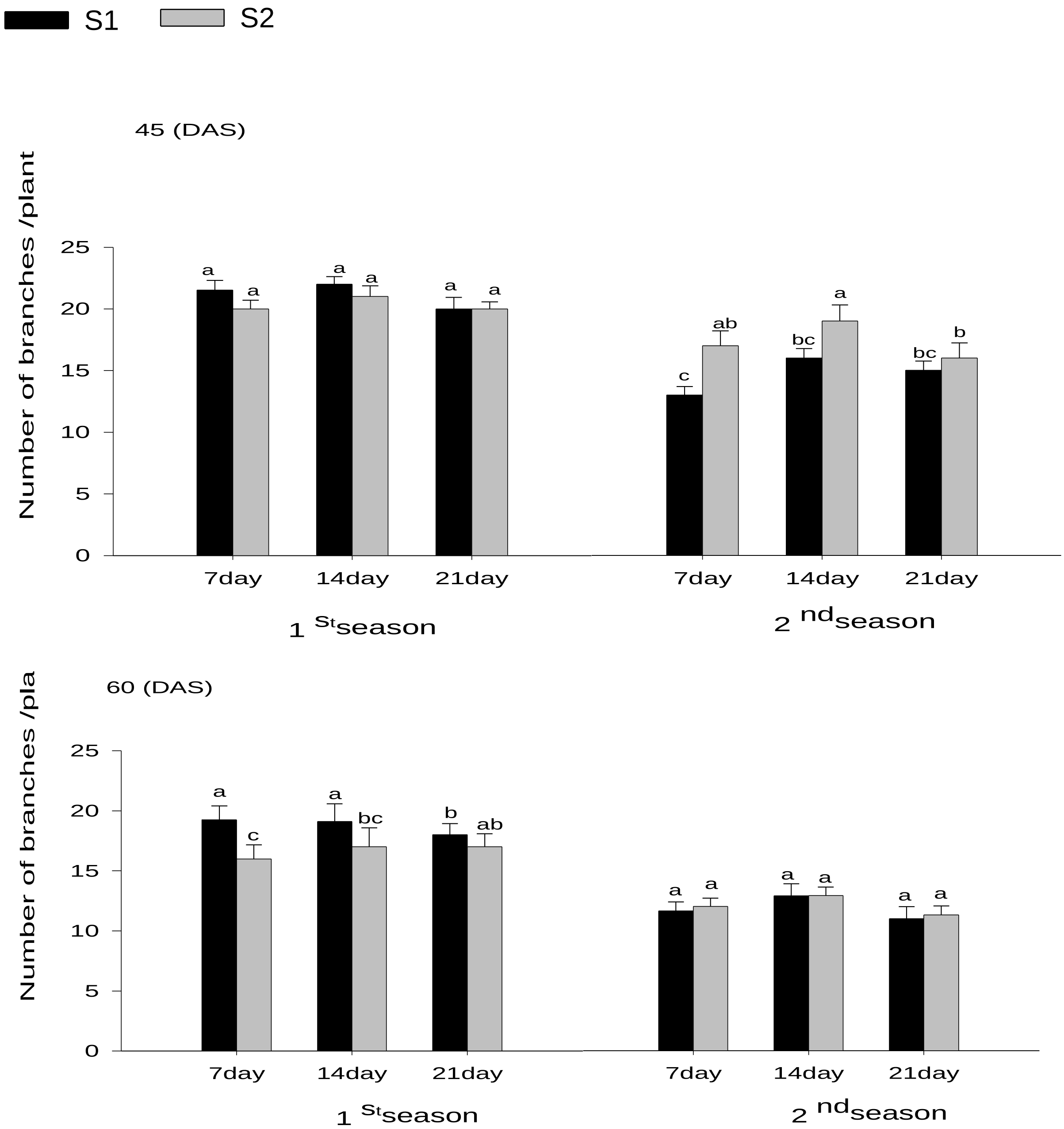


Fig 4.5. Effect of sowing date and water intervals interactions on number of branches /plant.

The differences of the interactions between sowing date, water intervals and fertilizers on number of branches /plant disappeared with the development of the plant .However it was significantly in the 2nd season 45(DAS)(Data not shown, appendix table 4.6)

Table(4.5). Effects of sowing date , water intervals and fertilizers on means of the vegetative growth parameters at 45.60 and 75(DAS)

Treatments	**No of branches/plant**		**Leaf area index**		**Plant population/m²**	
	2010/11	2011/12	2010/1	2011/12	2010/11	2011/12
Sowing date			45days			
S1	3.6 a	4.4b	2.9a	1.0b	19.2a	6.3b
S2	3,5 a	8.3a	1.9b	1.6a	16.4b	11.9a
Water interval						
7	3.9 a	6.2 a	2.5 a	1.4 a	17.8 a	9.0 a
14	3.5 a	6.5 a	2.1 b	1.3 a	17.5 a	9.3 a
21	3.1 a	6.0 a	1.9 b	1.2 a	18.3 a	8.9 a
fertilizers						
F	3.8 a	6.3 a	2.3 a	1.3 a	18.0 a	8.9 a
P	3.9 a	6.4 a	2.0 a	1.3 a	17.7 a	9.1 a
U	3.0 a	6.5 a	2.1 a	1.3 a	17.9 a	9.0 a
Sowing date			60 days			
S1	17.2a	12.7a	3.1b	2.8a	18.5a	12.6a
S2	13.4b	12.0a	4.2a	2.7a	16.3b	13.2a
Water interval						
7	16.0a	11.5a	3.7a	2.9a	17.6a	12.6a
14	14.7a	12.3a	3.6a	2.8a	17.2a	12.9a
21	14.5a	12.7a	3.7a	2.5a	18.1a	13.2a
fertilizers						
F	14.3a	11.4a	3.4a	3.1a	17.8a	13.3a
P	16.5a	11.2a	4.0a	2.7a	17.6a	13.6a
U	15.2a	13.2a	3.6a	2.9a	17.1a	12.1a
Sowing date			75days			
S1	13.8a	10.7b	5.0a	1.9a	19.6a	11.6a
S2	13.7b	20.4a	4.0b	1.1b	16.b	6.8b
Water interval						
7	14.2a	17.0a	5.2a	1.7a	18.0a	9.0a
14	14.0a	15.0a	4.2b	1.5a	17.5a	8.6a
21	13.8a	13.0a	4.2b	1.6a	18.3a	8.7a
fertilizers						
F	14.3a	15.5a	4.8a	1.5a	18.0a	8.3a
P	14.0a	15.1a	4.5a	1.5a	18.1a	8.0a
U	13.9a	16.0a	4.2a	1.6a	17.7a	9.1a

Means in columns followed by different letters are significantly different at p<0.5 (DMRT).

4.1.5. Leaf area index:

Sowing at 13 Nov resulted in a significant increase in leaf area index in both seasons at 45 and 75 (DAS) (Table 4.5), estimated by 0.01 % more than sowing at 28 Nov. The same result was found from water intervals only in 1st season at 45 and 75(DAS), decreasing of water intervals (7days) gained huge leaf area compare to irrigation every 14 and 21days respectively. The application of fertilizers had no effect on that parameter (Table 4.4 and 4.5). Interaction of sowing date and water intervals was significant only in 1st season 60 (DAS) (Data not shown, appendix table 4.7), however a considerable interactions of the factors occurred in 2nd season 45(DAS). (Fig 4.6) (Table 4.8 appendix)

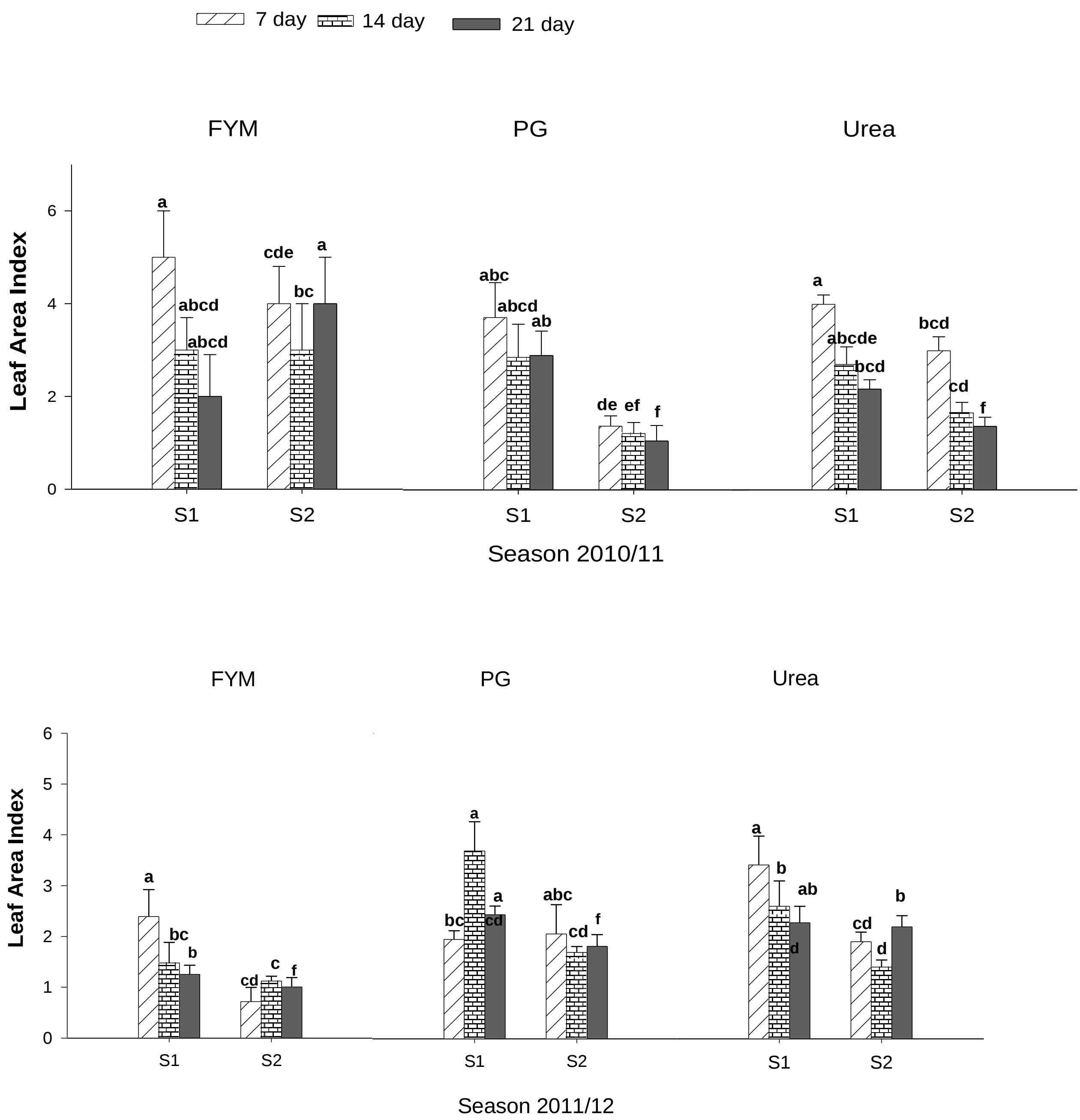


Fig 4.6 .Leaf area index response to sowing date S1,S2.water intervals 7 ,14 and 21 days and fertilizers applications FYM = Farm yard manure ,PG= Pellet granules and U=Urea .Bars marked with different letters are significantly different at P<0.05 (Tukey test).Bars represent means(N=4).Error bars are standard error of mean.

4.1.6 Plant population density:

Analysis of variance showed no significant effect (p=0.01) of treatments on plant population except sowing date in both seasons (table 4.4and 4.5) Sowing date at 13 Nov increased number of plans /m^2 over sowing at 28 Nov .In addition the interaction of the treatments responsible significant in the early stage of the crop in season two at 45(DAS) (Fig 4.7).

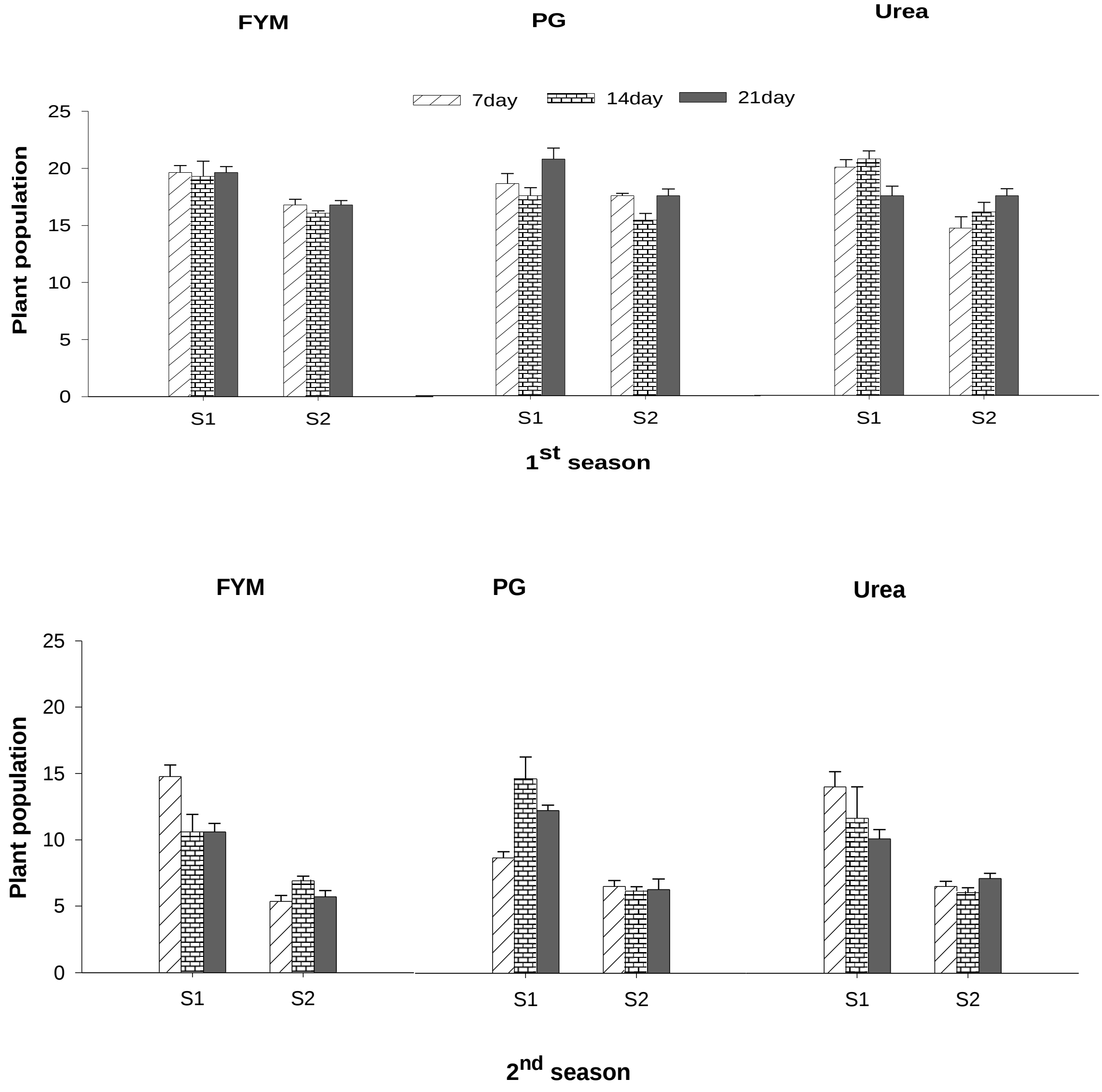


Fig 4.7 .Plant population as affected by sowing date ,.water intervals and fertilizers applications Bars represent means(N=4).Error bars are standard error of mean.

4.2 YEILD AND YEILD COMPONENTS:

4.2.1 Number of seeds/head:

Generally, two sowing dates, three water intervals and three types of fertilization, statistically resulted in no significant effect nor their interactions on number of seeds/head in the two seasons (Fig4.8). The same trend was occurred on thousand seed weight (Table4.9).

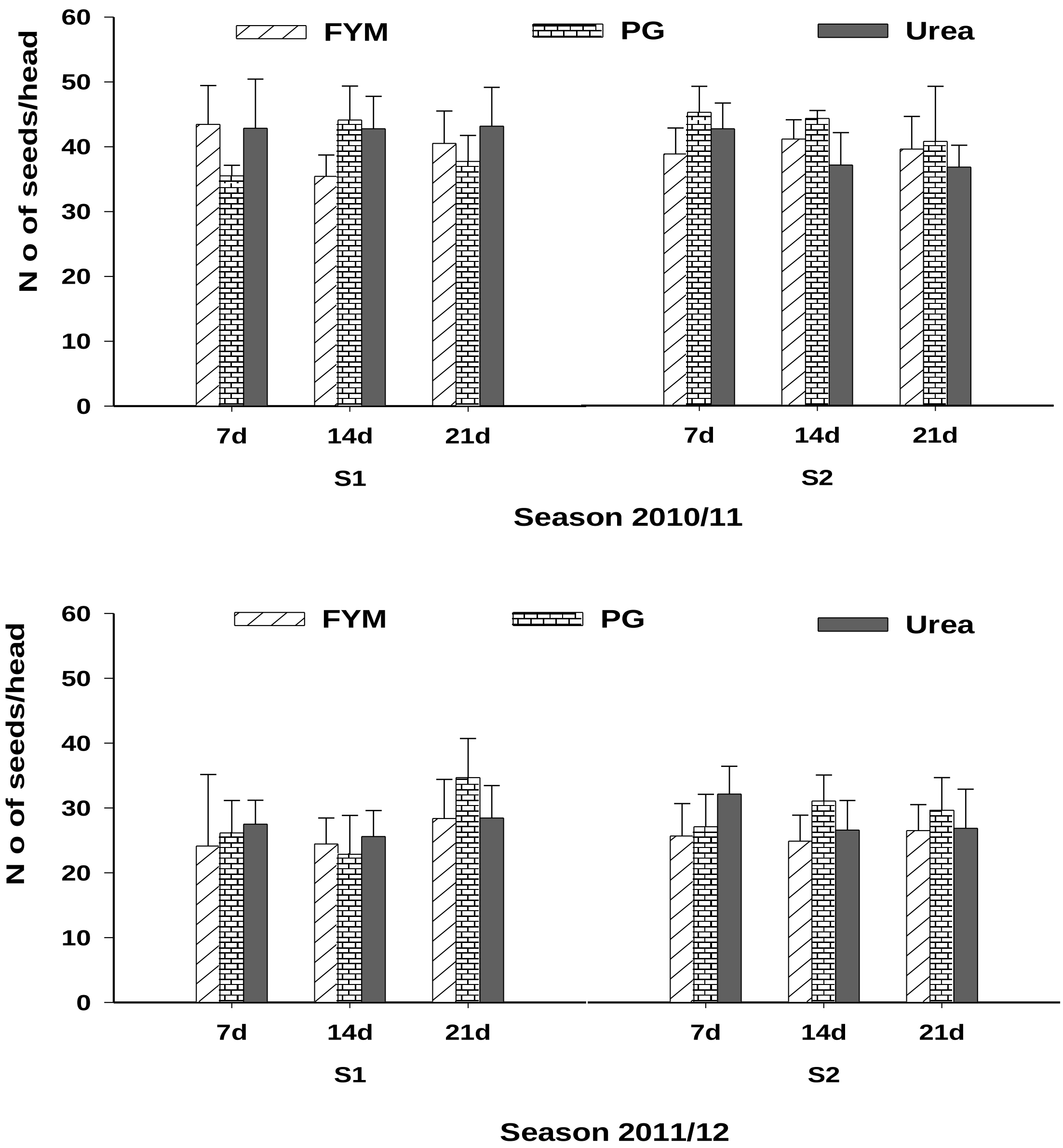
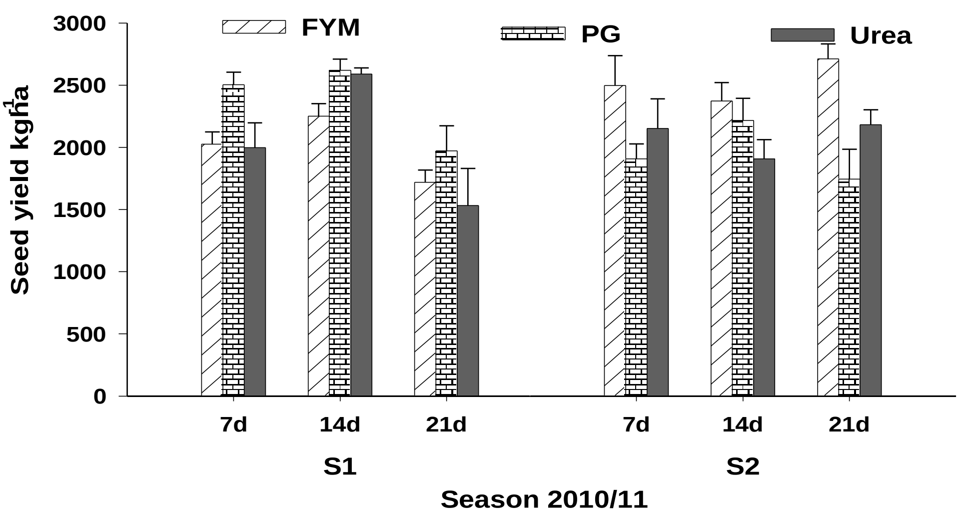


Fig 4.8. Number of seeds/head as influence by sowing date, water intervals and fertilization.

4.2.2 Seed yield (kg/ha):

There was obvious different of sowing dates on seed yield in both seasons. However early sowing date (13 Nov) achieved highest yield 2134.1 and 854.6 kg / ha compared to 1923.2 and 663.0 kg /ha when planted later in November in both seasons respectively (Table 4.10).Irrigation every 14 days increased seed yield by 1.47% and 3.53% over irrigation every 7 and 21 day respectively in season one. It was evident that there was no effect of fertilization on seed yield in both seasons. Nevertheless, farm yard manure slightly increased the yield at late planting date in 1st season. (Fig 4.9).



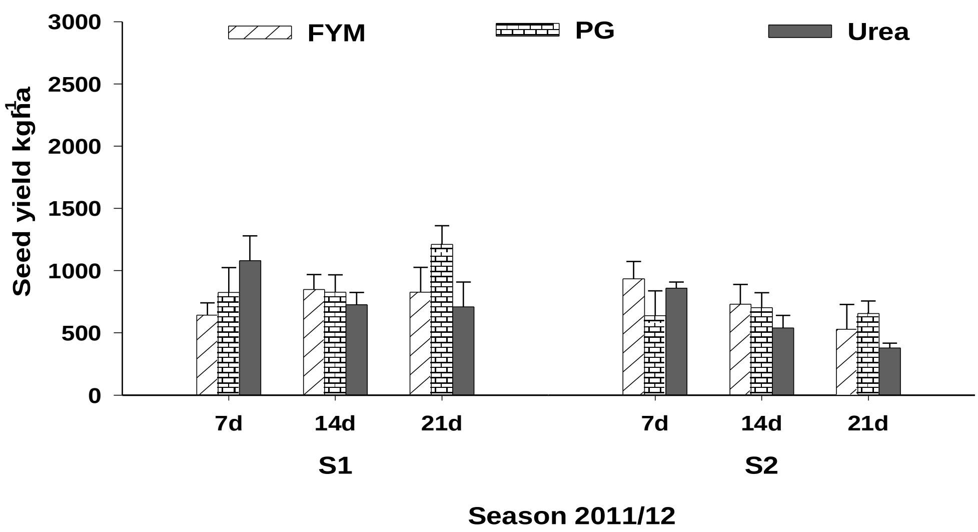


Fig 4.9. Effect of sowing date, water intervals and fertilization on seed yield.

The results showed that there were significant effect on seed yield by (sowing date x water intervals) in both seasons and by (sowing date x fertilizers) at season one only,(Table4. 9) .Generally seed yield was extremely low in 2nd season due to *Orobanchi cernate* infestation .

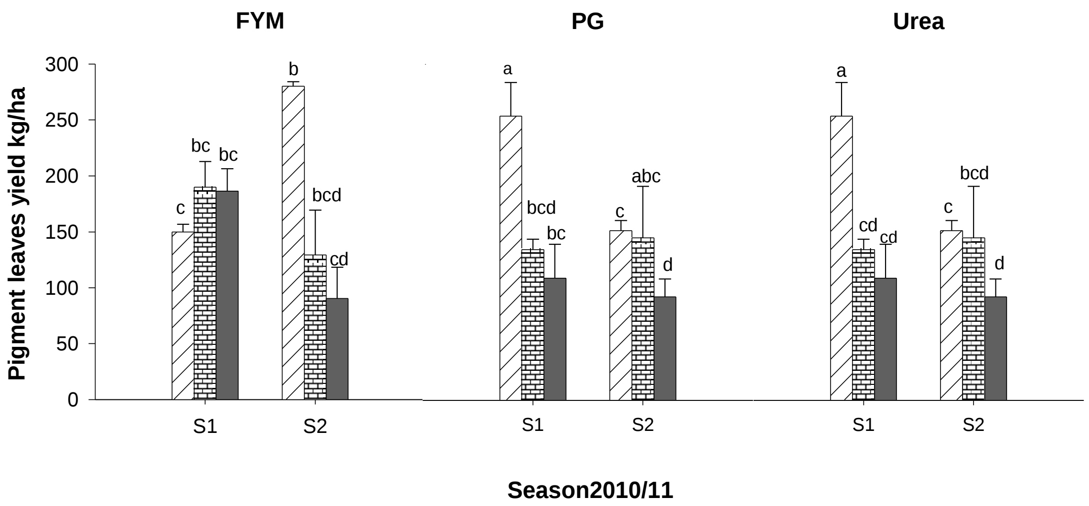
4.2.3 Pigment leaves yield (kg/ha):

There was no apparent effect of sowing dates in term of pigment yield in the first season ($P<0.05$).Planting later in November decreased pigment yield by 0.35% in 2nd season, furthermore irrigation intervals followed the same pattern in season two , applied water every 14 day increased pigment leaves yield (Table 4.10). Adding of farm yard manure or pellet granules and urea fertilization resulted in non significant increase of pigment leaves yield except in 2nd season .However significant interaction between (sowing date x water intervals x fertilization) (Fig 4.10) occurred in season 2.(P= 0.001 table 9) (Table 4.12 appendix).

4.2.4 Shoot dry weight:

There was no obvious effect of treatments in both seasons except sowing date in 2nd season (P= 0. 01). Increment of shoot dry weight in season 2 due to early sowing in November. The treatments responsible for the significant three- way interaction (water x fertilization) in the both seasons (Table4.9). Application of 7 days intervals incorporating with 105 kg/ha farm yard manure gaved greatest weight in 1st season (Table 4.13 appendix)

7day 14day 21day



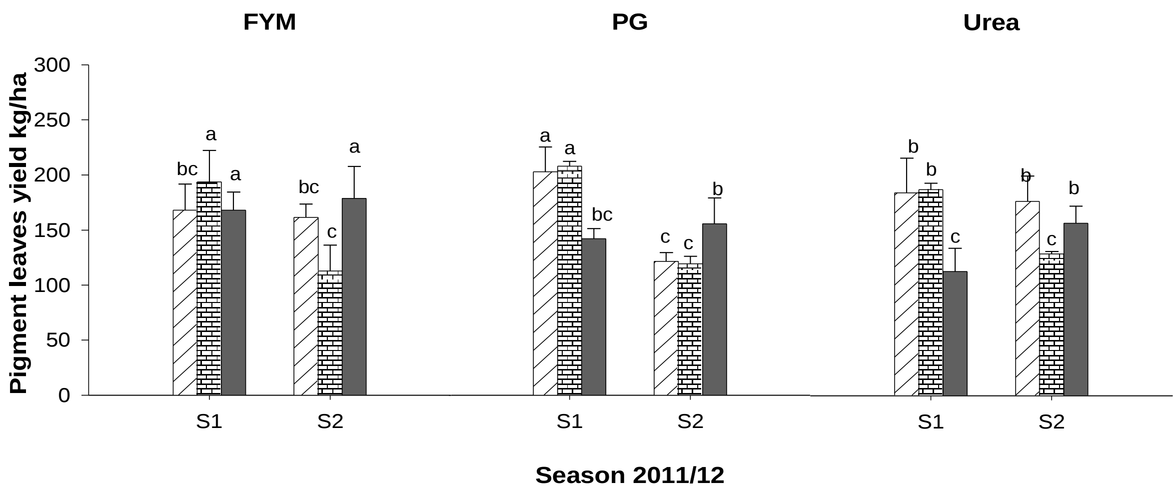


Fig4.10. Sowing date ,water intervals and fertilization interactions as influence on pigment leaves yield .

4.2.5 Harvest index (%):

The effect of the treatments on harvest index was not significant (P=0.01) equally in both seasons excluding water intervals in 1st

season. Applied of 7day water interval gained huge weight of dry shoot. Also their interactions followed the same trend, except (sowing x water) in the second season effect significantly (Fig 4.11)

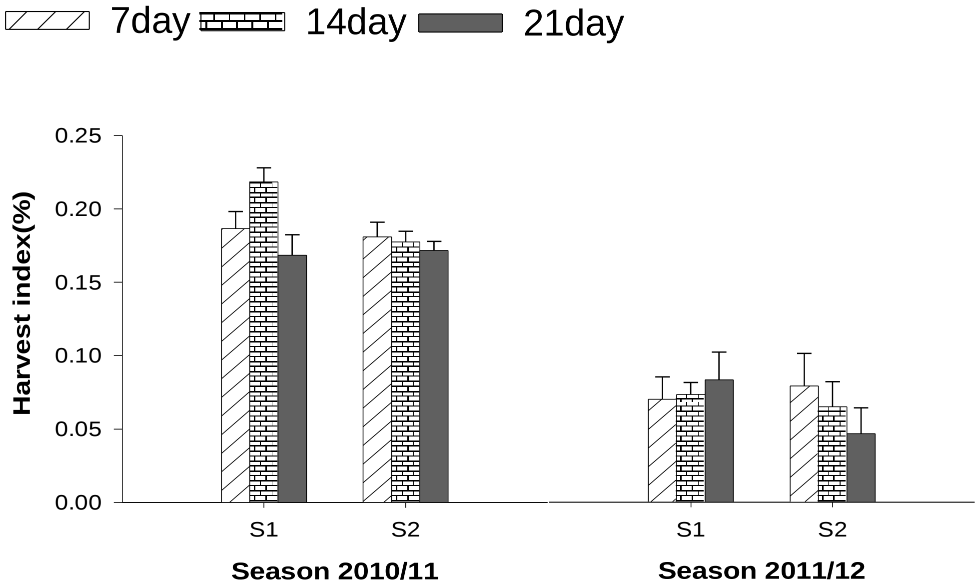


Fig 4.11. Harvest index response to sowing date and water intervals.

Interaction of (water intervals x fertilization) statistically showed significant effect only in season 2 (Table 4.11 appendix).

Table 4.10. Effect of sowing date and water intervals on some yield components.

Treatments	Seed Yield kg/ha		Pigment leaves Yield kg/ha		Shoot dry weight	
	2010/11	**2011/12**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
Sowing						
S1	2134.1a	854.6a	147.1a	169.2a	0.7a	1.7a
S2	1823.2b	663.2b	145.6a	137.6b	0.6a	1.0b
Water						
7	1998.3ab	830.0a	169.0a	189.1a	0.8a	1.2a
14	2145.4a	729.1a	159.2a	149.2ab	0.7a	1.1a
21	1792.3b	718.2a	153.3.a	121.3b	0.6a	1.1a

Means followed the same letters are not significant at P<0.01 (Duncan test) .

4.3. Chemical composition:

4.3.1. Oil content (%):

Statistical analysis showed that water intervals had significant effect on oil content in the seeds. Irrigation every 14 days increased oil content (Fig 4.12).Application of 4t/ha farm yard manure resulted in great amount of the oil among others fertilizers 41.92% compared to 30.80and 33.11% from pellet granules and urea respectively (Table 4.15).There was no significant influence of (water X fertilizers) on oil content.

4.3.2 Crude protein (%):

Effect of treatments on protein content was not significant, nor there interaction except fertilization which was highly significant (P=0.001). Farm yard manure increased protein content (35.66). (Fig 4.12).

Table 4.14. Effect of water intervals and fertilizers on oil, crude protein and fiber (%).

Treatments	Oil (%)	Crude protein (%)	Crude fiber (%)
Water intervals	8.92*	1.21	0.08
Fertilizers	8.30**	25.60***	8.13**
Water* Fertilizers	0.73	1.30	0.10
CV	14.03	7.25	8.75

P<0.05;**=P<0.01;***=p<0.001=* .

4.3.3. Crude fiber (%):

There was no obvious effect of water intervals on fiber content. Nevertheless, applied of fertilizers had high effect .Pellet granules achieved 41.02 % fiber content compared to farm yard manure and urea (Table 4.15).

Table 4.15 Effect of water intervals and fertilization on oil, crude protein and crude fiber%.

Treatments	Oil (%)	Crude protein (%)	Crude fiber (%)
Water intervals			
7day	30.24b	31.01a	36.82a
14day	38.37a	32.21a	36.22a
Fertilizers			
FYM	41.92a	35.66a	34.71b
PG	30.80b	25.22b	41.02a
Urea	33.11b	33.53a	34.35b

Means followed the same letters are not significant at P<0.01 (DMRT) .

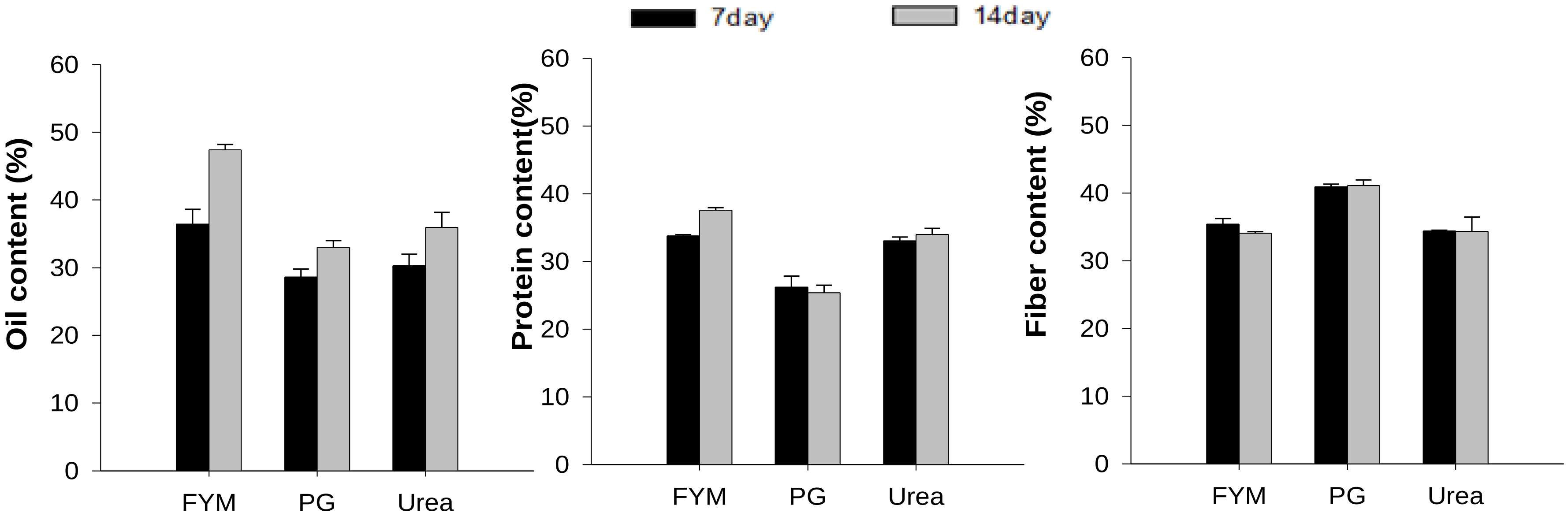


Fig 4.12 . Effect of water intervals and fertilization on oil, protein and fiber content (%).

CHAPTER FIVE

DISSCUTION

The general trend is sowing date had significant effect on all growth parameters in two seasons, also on seed, pigment leaves yield and shoot dry weight. Irrigation intervals displayed significant different on plant height, stem diameter ,leaf area index, seed yield and harvest index in season one, pigment leaves yield in season two and chemical composition . However, application of fertilizers resulted in significant augment on plant height in both seasons and oil content.

Sowing earlier at 13 Nov increased all vegetative attributes and yield components compared to sowing later in November in both seasons , temperature was generally similar in both growing seasons. Decrease of all assessed morphologic traits, Plant height, number of branches/plant, leaf area index, stem diameter and number of seeds /head, 100 seed weight and seed yield at delayed sowing dates can be attribute to unfavorable climatic conditions during vegetative growth, flowering and seed filling stages .Moreover The day-length sensitivity of safflower, as shown by the finding of Tomar,(1995), delays days to flower by only 12 days when sown later in winter, which strongly restricted pre-anthesis growth and the much-reduced plant height of safflower in December.

In the second year huge problem with *Orobanchi cernata* infestation was occurred which greatly reduce all growth characters and yield components.

Reduction of seeds number per head and seed weight due to delayed planting date has been shown by other authors (Cazzato, *et,al*., 1997. Cholak,I ,1993. Dadashi, 2004), .It seems that in early planting date due to longer vegetative period, more branches were produced. The number of heads in each branch increases with increasing reproductive period. It is clear that correspondence of flowering period with more optimum temperature and better pollination are the reasons for high number of grain per head at early sowing dates.

Reduction of number of grains per head can be attributed to shorten vegetative growth period, lower amounts of carbohydrates and reduce translocation of assimilation to grains. Movahhedy *et a.*,(2009). Hocking, *et al* .,(2001) , suggested that reduction of canopy size less than ideal limit and short growth periods are the most important reasons for low grain yield in delayed planting dates . The studies by other researchers in delay planting date (Omidi,.*et al*., (2010) and Peppwr,.*et al* (1988)) compared to different sowing dates resulted in low grain yield . Omidi and Sharifmogadas 2010 reported that plant height became shorter in late planting time. (Hocking and Stapper (2001) ;Miralles *et al*. (2001);Yau (2007), considered shortening of vegetative growth as a factor in reduced plant height. Seed yield was directly related to plant growth duration since with long plant growth duration the rate of radiation absorbed by plant increased and therefore seed yield enhanced..

Mirzakhani, *et al*.,(2009) and Koutroubas *et al*., (2004) confirmed that safflower transferred a large percentage (65–92%) of its pre-anthesis storage of assimilates to the seed. Low pre-anthesis growth will lead to low seed yield consequently. The meteorological data recorded during the trial period in each growing season are given in Table (5.1. appendix).

Safflower is known to be xerophytes crop tolerant to drought ,it is considered to be the most drought-resistant of all annuals oil-seeds in India (Arnon,1972). Morphological characters (plant height, stem diameter and leaf area index) were increased by decreasing water intervals (7days) , as the increment associated with developing growth stages. This result was in agreement with Amir. (2011) in his study using 7, 15, 22 and 28 days water intervals on safflower, found that number of primary branches and stem diameter were negatively affected by an increased irrigation interval of more than15 days. Also grain yield was decreased by 18 and 29.8% with

increased irrigation intervals to 22 and 28 days, respectively. Among yield components, number of capsules / plant were more sensitive to increasing water intervals. Previous studies have shown that drought stress during reproductive growth stages reduced seed capsules and/or flower number per plant. Steer and Harrigan 1986; Saini and Westgate 2000; found that among yield components that seed yield, pigment yield and harvest index were more affected by water intervals in their study. Moderate water interval (14day) resulted in highest seed yield (2.145t/ha). Increasing irrigation intervals (21day) accelerated flower production more than others. On the other hand, physiologically plant exposed to prolong irrigation interval may decrease seed set by increasing ovary abortion due to the lowering of the photosynthetic supply to ovaries during their development. Other studies (Zinselmeier *et al*. 1995, (1999);Clément *et al*. (1994)) pointed out that sucrose was artificially fed to replace the photosynthetic missing during the exposure to low water potentials which will overcome the negative effect of drought. Moreover, starch is considered a major energy source for pollen development and germination; hence the absence of this energy source could lead to pollen sterility. In contrast, Mosallayi,*et al* (2011) in their study of evaluation of irrigation regimes levels (5, 10, 15, 20 days) showed that irrigating every 5 days had the highest grain yield (1263Kg /ha) while the highest oil yield (410Kg /ha),1000 seed weight (34.3g), number of head/plant(13.6) and number of seed/head(31.6) were obtained from D1(irrigating every 5 days **)**.At the same time, irrigation every 20 days D4 stage, was grouped in the lowest class. In this stage (D4) leaves were damaged by water deficiency and damaged cells caused redcution of CO_2 absorption and photosynthesis rate
.

Differential sensitivity of expansive growth and photosynthesis to water deficits leads to reduced biomass production under long term water interval due to a reduction in canopy size and in radiation interception. For this reason, dry matter partitioning is usually affected and then harvest index could be directly affected in many determinate crops, particularly when the post-anthesis fraction of total transpiration is too low (Fischer, 1979). An enormous pigment leaves (petals) yield (199.0 kg/ha) was produced when water was added every 7days. (Saini and Westgate 2000) indicating that plant subjected to water regime interferes with flower period, flower opening, nectar production, and turgor maintenance of floral organs and subsequently leads to reduce flower size , mean petal size, nectar secretion and pollen production. In support of this finding Al-Ghzawi *et al (* 2009); McLaughlin and Boyer (2004); Zinselmeier *et al*. (1995, 1999) suggested that drought stress might reduce flower size nectar production and nectar sucrose content compared to non-stressed flowers produced with supplemental watering which increased nectar volume and increased nectar sucrose content.

Oil content of seeds is a very important economic trait for safflower and is considered one of the most important factors affecting the success of safflower introduction in new areas. Oil yield is a combination of seed yield and oil content. Since the highest seed yield was obtained from 14 days interval, it seems that seed yield / hectare was the reason for the increase in oil yield / hectare. Results revealed that, the highest grain oil yield under studying condition was from applying water every 14 days. Ensiye and Khorshid 2010) studied the response of safflower to irrigation regimes and reported that the oil content and oleic and linoleic acid percentage were reduced by drought stress significantly. Whereas, Flagella *et al.* (2000) concluded that stopping irrigation from flowering to physiological maturity increased the percentage of oleic acid in sunflower seeds compared to those irrigated at all growth stages.

The interactions between sowing date and water intervals were not significant on all assessed growth attributes except plant population. The same trend was observed on seed yield, pigment yield and harvest index.

There is abundant evidence of effect of fertilizers on growth and yield of safflower .The results of this study demonstrated that the differential effect between three types of fertilizers was not significant on all studied growth characters, as well as yield components. Generally, farm yard manure had increase on plant height in both seasons. (Zamil et al. (2004) reported that farm yard manure is the best organic manure, through its effect of soil physical and chemical properties. Muhammad Sharif (1992)., explained that FYM increased the N, P, K, S, and Zn contents by 25, 10, 27.5, 7.5, and 0.23 kg ha $^{-1}$ respectively. Thus the FYM treatments contained 115 kg N//ha in addition to other nutrients Farm yard manure provide lots of organic matter to the soil, have high available nitrogen content and conversion of mineral nutrients into more plant-available forms but should only be used composted because the fresh manure can burn the roots of tender seedlings.

The effect of N on seed yield may be a consequence of N influence on photosynthesis, on the amount of photo assimilates that are produced by the plant, on dry matter partitioning, and on organ development (Dordas and Sioulas, 2008, 2009; Dordas *et al*., 2008). The effect of N on photosynthesis may also affect the yield components (Dordas and Sioulas, 2008, 2009). The seed yield that was obtained in their experiments was much lower than has been reported in other experiments (Lafond *et al.*, 2008; Grant *et al*., (1993) ;Dordas and Sioulas (2009) reported that nitrogen fertilization increased seed yield by an average of 19%. However, Strasil and Vorlicek (2002). reported that there was no yield increase with N fertilization. Siddiqui and Oad (2006) reported, under field conditions in Pakistan, an increase in N rates significantly prolonged crop maturation and increased plant height**.**

Sowing dates and fertilizers interactions significantly increased plant height and seed yield in season one .Moreover, the effect of water intervals and fertilizers interaction was significant on plant height and shoot dry weight. The interaction of three factors affected stem diameter, leaf area index and plant population as morphological charcters, as well as on pigment leaves yield .

In this study oil and protein content resulted from applied 105 kg / ha farm yard manure were 41.92% and 35.66% respectively which was much more than other fertilizers .On the other hand, pellet granules increased fiber content over others. Özer, *et al***.**(2004) in their study pointed out that Increased N rates led to decline in oil concentrations of the sunflower seeds. Similar responses have been reported in other studies (Steer *et al*. (1986); Geleta *et al.* (1997); Scheiner *et al*. (2002).

The increase in oil and protein content in safflower seed is seemed to be as a result of subjection of samples to temperature of roasting and boiling techniques. These results are in agreement with those indicated by different authors (Damame *et al*., 1990; El-Badrawy *et al*., 2007) who reported that the oil and protein content of raw peanut increased whereas fiber decreased as a result of roasting proce. In the present study, there was no clear effect of water intervals and fertilizers interactions on oil, protein and fiber content. Analysis of variance showed there was significant differences between the two seasons.

CHAPTER SIX

SUMMARY, CONCLUTIONAND RECOMMENDATIONS

A field experiment was undertaken in 2010/11 and 2011/12 winter seasons at the College of Agricultural Studies, Sudan University of Science and Technology in Khartoum, to study the effects of sowing date, irrigation intervals and different types of fertilizers on growth, yield, yield components ,pigment leaves and oil of safflower (***Carthamus tinctorius*** L.) .Sowing in mid November significantly increased all growth parameter assessed (plant height ,stem diameter ,number of leaves, number of branches, leaf area index) and yield components(seed yield, pigment yield and shoot dry weight) in both seasons . Irrigation every 7 days resulted in great plant height, increased stem diameter leaf area index and pigment yield while seed yield and oil percentage improved through 14 days intervals .Safflower displayed the same response to application of different types of fertilizers . However, addition of 4800kg /ha farm yard manure resulted in slight increased in seed yield , oil yield and protein content.

According to the results of the present study, in order to cultivate safflower as oil crop under conditions similar to the region of this experiment, it is recommended that safflower should be sown as soon as possible in mid November. It is a potential candidate for breeding safflower varieties (non- spiny) capable of adapting to our climatic range via long-term experiments of breeding and engineering programs to facilitated cultivating and harvesting. , as well as, further investigations with other treatments are required to provide farmers with essential information about this crop.

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APPENDIX

Table 3.1 nutrients content in the soil of the experiment site before sowing and after sowing in both seasons. (5-25cm) depth

	2010/11				2011/12			
fer	Before		After sowing		Before		After sowing	
	P	Na	P	Na	P	Na	P	Na
F	5.7	33	4.3	15	8.3	24.	8.0	13.
P	4.4	27	4.1	14.	6.8	21	7.6	13.
U	5.9	34	4.2	15.	8.7	19	9.4	17.

Table (4.1) Three way ANOVA and Fvalues of growth parameters (Plant height, stem diameter and number of leaves /plant) 45,60 and75 (DAS)

	Plant height(cm)		Stem diameter(mm)		No of leaves/plant	
Treatments	**2010/11**	**2011/12**	**22010/11**	**2011/12**	**2010/1**	**2011**
			45days			
Sowing dates, S	1.3	60.6***	2.3	83.1***	24.0***	33.1**
Water	0.5	0.9	1.4	1.2	4.5	1.9
Fertilizers, F	1.2	1.0	1.5	0.6	0.3	1.0
S* W	1.7	3.1	0.3	7.5**	0.2	3.3*
S* F	1.2	0.1	1.3	0.1	1.3	1.7
W* F	1.9	2.2	2.1	0.3	1.1	0.6
S* W* F	0.5	1.0	0.8	1.2	1.9	0.7
			60 days			
Sowing dates, S	0.9	19.8***	72.3***	65.1 ***	10.2**	6.5*
Water interval	4.6*	24.3**	6.7	5.7**	1.8	0.3
Fertilizers, F	0.9	2.1	3.3	0.8	0.9	1.4
S* W	9.3**	2.3	21.7**	5.9**	5.2*	1.6
S* F	0.1	0.4	0.1	0.9	0.7	0.8
W* F	3.2	0.4	0.7	1.9	0.7	0.3
S* W* F	1.4	0.2	0.6	0.4	0.1	0.7
			75 days			
Sowing dates,S	20.5***	34.7***	3.5*	51.9***	5.9*	102.2*
Water	40.3**	37.5**	1.5	14.6**	0.6	0.
Fertilizers,F	19.9**	7.7*	0.7	0.5	2.7	1.

S* W	1.6	0.8	0.1	4.3*	3.8*^	5.5
S* F	4.3*	1.8	0.4	2.1	0.6	3.
W* F	3.4*	0.6	0.9	1.0	1.9	1.
S* W* F	0.5	0.7	0.3	0.5	1.8	0.

P<0.05;**=P<0.01;***=p<0.001=* .

Key S= Sowing date, W= Water interval and F= Fertilizers.

Table 4.3.Plant height (cm) as influence by sowing dates, water intervals and fertilization interactions.

Plant Height(cm)			
Treatments		75 (DAS)	
Sowing dates	**Fertilize**	**2010/11**	**2011/12**
S1	**F**	114.9±(6.7)b	102.4±(3.9)a
	P	119.4±(5.6)ab	102.3±(3.7)a
	U	103.7±(5.6)c	97.0± (6.4)b
S2	**F**	120.7±(4.5)ab	101.8±(4.3)a
	P	123.7±(5.3)a	93.7±(4.7)b
	U	115.5±(2.0)b	91.1±(2.4)b
Water intervals	**Fertiliz**		
7	**F**	111.4±(7.1)a	104.9±(5.2)a
	P	102.2±(4.6)a	104.0±(3.3)ab
	U	104.5±(6.6)a	102.3±(3.2)ab
14	**F**	106.9±(3.1)a	99.9±(1.8)bc
	P	108.3±(8.4)a	93.9±(3.1)bcd
	U	110.4±(4.4)a	92.9±(2.1)cd
21	**F**	112.6±(3.9)a	94.4±(5.4)bcd
	P	102.9±(2.4)a	92.9±(3.4)cd
	U	115.0±(8.1)a	88.6±(5.5)d

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at P< 0.01 (Duncan test).

Table (4 .5) Three way ANOVA and F values of growth parameters 45,60 and75 (DAS)

Treatments	No of branches/plant	Leaf area index	Plant population/ m^2

	2010/11	2011/12	2010/1	2011/12	2010/1	2011/12
45days						
Sowing dates,S	0.1	100.7***	85.2***	23.9***	22.1***	101.3***
Water interval,W	0.5	0.6	3.8 *	0.9	0.6	0.6
Fertilizers,F	1.8	0.1	0.3	0.1	0.08	0.1
S* W	3.5	0.9*	0.9	2.5	0.5	0.9
S* F	0.7	0.1	0.8	0.5	0.4	0.12
W* F	1.2	2.4	0.3	1.5	1.1	2.4
S* W* F	0.4	3.9*	2.0	3.3*	1.3	3.4*
60days						
Sowing date,S	13.4***	0.3	12.5**	0.1	5.9*	1.5
Water interval,W	2.3	0.3	0.1	1.8	0.1	0.8
Fertilizers,F	1.4	1.6	1.8	1.6	0.1	3.1
S* W	9.2**	0.6	5.8*	1.7	0.2	1.47
S* F	1.9	1.3	2.9	1.4	1.2	2.1
W* F	1.5	0.4	0.3	2.6	1.6	1.5
S* W* F	0.1	0.5	2.8	0.7	0.8	0.4
75days						
Sowing date,S	0.1	77.9***	17.2***	41.8***	20.8**	87.8***
Water interval ,W	1.4	4.3	8.3**	0.1	0.5	0.9
Fertilizers, F	0.9	0.3	1.9	0.2	0.2	2.6
S* W	1.5	2.2	2.1	1.8	0.4	1.7
S* F	0.1	0.2	0.3	1.8	0.1	1.8
W* F	0.5	1.8	1.7	1.4	0.7	3.8*
S* W* F	0.8	0.8	1.8	1.8	1.4	1.2

*=P<0.05;**=P<0.01;***=P< 0.001.

Table 4.6.No of branches as influence by sowing date and water interactions

Treatments	**No of branches/plant**
	45 (DAS)

Sowing dates	Water intervals	2010/11	2011/12
S1	7	4.4±(0.8)a	4.0±(0.3)c
	14	3.9±(0.5)a	4.5±(0.2)bc
	21	2.6±(0.4)a	4.5±(0.4)bc
S2	7	3.4±(0.8)a	8.1±(0.8)ab
	14	3.1±0.7)a	9.4±(1.1)a
	21	4.2±(1.1)a	7.5±(0.5)b
		60 (DAS)	
S1	7	19.3±(1.2)a	11.3±(0.8)a
	14	a(1.5)19.3±	12.6±(1.7)a
	21	13.5±(1.0)	13.6±(3.1)a
S2	7	10.3±(1.2)	11.7±(0.5)a
	14	14.8±(1.6)	12.8±(0.8)a
	21	15.4±(1.1)	11.1±(0.8)a

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at P< 0.01 (Duncan test).

Table 4.7 . Effect of sowing date and water intervals interaction on plant height and leaf area index 60(DAS).

Treatments		Plant height (cm)		Leaf area index	
Sowing	**Water intervals**	**2010/11**	**2010/12**	**2010/11**	**2011/12**
S1	**7**	106±(1.9)a	107.7±(1.9)a	3.9±(0.6)ab	2.8±(0.2)a
	14	95.3±(2.6)bc	93.1±(2.4)b	2.9±(0.4)b	3.1±(0.4)a
	21	88.7±(2.4)c	90.2±(3.8)bc	3.0±(0.5)b	2.6±(0.2)a
S2	**7**	96.5±(2.9)bc	95.1±(3.0)b	3.6±(0.5)ab	3.3±(0.2)a
	14	100.3±(2.6)ab	90.1±(2.2)bc	4.6±(0.5)a	2.7±(0.3)a
	21	99.2±(3.5)ab	81.7±(2.3)c	4.5±(0.5)a	2.6±(0.3)a

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at P< 0.01 (Duncan test)

Table 4.8.Main effects of interaction of sowing date S1=13[Nov] S2=28 [Nov],water levels W1W2 and W3 Irrigation every 7, 14 and 21 days respectively and fertilizers F=Farm yard on no of branches and leaf area index.

No of branches/plant

Treatments		FYM		PG		Urea	
Sowing dates	**Water**	**2010/11**	**2011/12**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
	7	4.3±(1.6)a	3.7±(0.6)e	3.8±(1.3)a	4.6±(0.6)cde	5.1±(14)a	4.5±(0.3)cde
S1	**14**	4.1±(0.3)a	4.6±(0.5)cde	3.8±(0.7)a	4.4±(0.5)cde	3.7±(1.0)a	4.7±(0.5)cde
	21	2.8±(0.5)a	4.0±(0.6)de	3.6±(1.2)a	4.1±(0.6)de	1.4±(0.4)a	5.0±(0.5)cde
	7	3.9±(1.4)a	7.0±(2.4)bcde	3.9±(1.8)a	7.5±(1.9)bc	2.6±(1.0)a	7.4±(0.5) cde
S2	**14**	2.9±(1.1)a	7.4±(1.6)bcde	3.6±(1.3)a	10.3±(2.0)ab	3.0±(1.5)a	11.6±(1.3)a
	21	5.2±(2.5)a	7.6±(1.0)bcd	4.0±(2.1)a	7.9±(1.0)bc	2.4±(0.6)a	8.1±(0.6)bc

Leaf area index

Treatments		FYM		PG		Urea	
Sowing date	**Water**	**2010/11**	**2011/12**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
	7	3.7±(0.8)a	0.7±(0.3)d	3.1±(0.8)abc	1.2±(0.3)bcd	3.6±(0.9)a	1.1±(0.2)cd
S1	**14**	2.9±(0.7)abcde	1.1±(0.1)cd	2.6±(0.6)abcdef	1.0±(0.1)d	2.7±(0.8)abcdef	0.8±(0.1)d
	21	2.9±(0.5)abcd	1.0±(0.2)d	3.2±(0.9)ab	1.1±(0.2)cd	2.2±(0.6)abcdef	1.3±(0.2)bcd
	7	1.4±(0.2)cdef	2.2±(0.5)a	2.2±(1.0)abcdef	1.1±(0.1)cd	1.1±(0.3)ef	2.0±(0.6)abc
S2	**14**	1.2±(0.2)def	1.5±(0.4)bcd	1.3±(0.1)def	2.3±(0.6)ab	1.7±(0.4)bcdef	1.5±(0.5)abcd
	21	1.0±(0.3)f	1.3±(0.2)bcd	0.9±(0.2)f	1.4±(0.1)bcd	1.7±(0.4)cdef	1.3±(0.3)bcd

Data between parentheses are the standard error of the mean .Date followed by the same letters are not significantly at P< 0.01 (Duncan test)

Data between parentheses are the standard error of the mean .Date followed by the same letters are not significant

Table 4.9 .F values of yield components response to sowing date, water intervals and fertilizations.

	No of seeds /head		1000 seed weight		Seed Yield kg/ha		Pigment Yield kg/ha		Shoot dry weight(kg/ha)		Harvest index	
Treatments	**2010/11**	**2011/12**	**2010/11**	**2011/12**	**2010/11**	**2010/11**	**2010/11**	**2011/12**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
Sowing date,S	0.1	0.3	0.3	0.2	10.0**	5.6***	3.1	4.5*	1.2	6.8*	2.1	2.3
Water interval ,W	0.3	1.4	0.6	1.0	4.4*	3.7	4.3	7.0**	0.4	1.2	2.6*	0.5
Fertilizers, F	0.2	1.2	0.7	18	1.0	0.5	0.3	0.2	2.4	1.3	1.0	0.2
S* W	0.2	1.4	1.2	0.9	5.4**	2.4*	2.6	2.9*	0.8	0.2	1.8	2.9*
S* F	1.0	0.1	0.5	0.1	6.2**	0.9	0.7	1.2	0.1	0.3	4.4	0.8*
W* F	0.6	0.7	1,0	0.2	0.5	1.9	0.6	0.9	2.9**	5.4*	0.7	3.2
S* W* F	1.0	0.5	1.0	0,1	1.0	0.4	1.9	3.6*	0.8	2.0	1.6	0.8
CV	18.5	24.0	33.0	12.0	21.0	33.7	25.0	24.6	20.3	30.0	23.2	45.0

P<0.05;**=P<0.01;***=p<0.001=* .

Key S= Sowing date, W= Water interval and F= Fertilizers.

ble 4.11. Seed yield ,pigment yield and harvest index response to sowing date ,water intervals and fertilizations interactions.

Treatments		Seed yield kg/ha		Pigment yield kg/ha	
Sowing	**Water**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
S1	7	2286.3±(127.0)ab	849.3±(153.8)ab	185.0±(21.7)ab	204.5±(28.7a
	14	1740.8±(157.5)c	800.2±(89.1)ab	196.2±(14.0)a	144.0±(12.3)bc
	21	2375.0±(158.5)a	915.2±(158.7)a	140.2±(13.9)bc	151.8±(19.9)b
S2	7	1834.3±(181.4)c	810.6±(87.2)ab	166.5±(19.3)abc	136±(20.7)c
	14	1892.2±(137.9)b	657.8±(73.3)ab	120.2±(11.5)c	155.1±(32.5)ab
	21	1741.3±(132.6)c	521.1±(71.5)b	163.6±(19.2)abc	83.5±(15.1)d
		Seed yield kg/ha		**Harvest index**	
Sowing	**fertilizers**	**2010/11**	**2011/12**	**2010/11**	**2011/12**
S1	F	2167.9±(184.9)a	772.2±(119.5)a	0.187±(0.011)a	0.076±(0.015)a
	P	2066.8±(157.9)a	954.1±(154.4)a	.0.218±(0.009) a	0.071±(0.015)b
	U	2167.5±(166.5)a	838.2±(140.1)a	0.168±(0.013) a	0.0.83±(0.01)a
S2	F	1600.4±(163.1)b	730.3±(99.7)a	0.180±(0.010) a	0.079±(0.02)ab
	P	1811.4±(153.5)a	666.1±(75.2)a	0.177±(0.007) a	0.065±(0.017)
	U	2055.8±(106.0)a	593.2±(73.7)a	0.171±(0.008) a	0.046±(0.018)d

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at P< 0.01 (Duncan test)

Table 4.12.Pigment yield response to sowing date ,water intervals and fertilizations interactions.

Treatments	Pigment yield kg/ha					
	FYM		PG		Urea	
Sowing*water	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
S1*W1	167.9±(42.2)a	132.1±(12.0)bcd	202.9±(40.0)a	227.5±(33.9)a	254.2±(53.2)a	184.3±(55.7)a
S1*W2	193.6±(50.7)a	139.7±(40.0)bcd	207.9±(7.9)a	158.1±(12.7)	187.1±(10.0)a	134.9±(16.2)
S1*W3	167.9±(29.3)a	186.4±(21.6)bcd	142.2±(16.5)a	181.3±(16.6)abcd	112.9±(37.2)a	109.2±(53.5)bcd
S2*W1	161.5±(21.5)a	235.5±(7.6)a	121.4±(14.3)a	134.4±(25.0) c	176.4±(40.0)a	151.8±(16.1)
S2*W2	112.9±(41.5)a	129.3±(69.3)bcd	119.3±(12.2)a	195.5±(43.2)ab	128.6±(4.3)a	145.1±(82.0)
S2*W3	178.4±(51.5)a	90.4±(43.9)cd	155.7±(41.4)a	68.0±(28.4)d	156.5±(27.9)a	92.4±(28.5)cd

Data between parentheses are the standard error of the mean .Date followed by different letters are significantly at P< 0.01 (Duncan test).

Table 4.13.Effect of interaction between water intervals and fertilization on shoot dry weight.

Shoot dry weight			
Water intervals	**Fertilization**	**2010/11**	**2011/12**
7day	**F**	0.9±(0.1)a	1.0±(0.1)a
	P	0.7±(0.1)ab	1.2±(0.1)a
	U	0.8±(0.2)ab	1.0±(0.1)a
14day	**F**	0.7±(0.1)ab	1.0±(0.1)a
	P	0.7±(0.1)ab	1.2±(0.1)a
	U	0.7±(0.1)ab	1.1±(0.1)a
21day	**F**	0.6±(0.2)ab	1.3±(0.1)a
	P	0.4±(0.1)b	1.0±(0.1)a
	U	0.4±(0.1)b	1.0±(0.1)a

Means followed by standard errors between parentheses.

Date followed by different letters are significantly at P< 0.01 (Duncan test).

Table5.1..Mean temperature and relative humidity during growing seasons.

Months	Mean temperature	Relative humidity
November 2010	30.05	29
December 2010	24.8	30
January 2011	21.55	29
February 2011	25.9	21
March 2011	26.85	18
April 2011	30.5	14
November 2011	24.7	25
December 2011	24.5	33
January 2012	21.8	29
February 2012	26.45	26
March 2012	26.55	19
April 2012	29.85	17