بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Effect of Nitrogen Rates on Growth and Yield of Some Wheat Genotypes Under Post- anthesis Water Stress Levels

تأثير معدلات النتروجين علي نمو وإنتاجية بعض انواع القمح في ما بعد مستويات الإجهاد المائي بعد مرحلة طرد السنابل

A thesis Submitted in full Fulfillment for the Requirements of the Degree of Ph.D. in Agronomy

By

Azza Al Tag Al Khalil Mohammed Ali

B.Sc. (Honors) Field Crop Science

Sudan University of Science and Technology 2005

M.Sc. field crop science

Sudan University of Science and Technology 2010

Supervisor: Prof. Dr. Yassin Mohammed Ibrahim Dagash

Co- Supervisor: Dr. Sami Abdel Gaffar Mahagoub

2017

الآية

بسم الله الرحمن الرحيم

قال تعالى:

الأَرْضَ فِ(رَاشًا وَالسَّمَاءَ بِنَاءً وَأَنْزَلَ السَّمَاءِ مَاءً

رِزْقًا لَكُمْ فَأَخْرَجَ فَلَا تَجْعَلُوا لِلَّهِ أَنْدَادًا وَأَنْتُمْ تَعْلَمُونَ)

صدق الله العظيم

سورة البقرة الآية (22)

Dedication

To the soul of my grandfather and grandmother

To my uncle Saif Edein
To the soul of my Wisal Abass Makkawi

To my mother, father, husband and my kid " Dina"

To all the family ….with love.

Azza

Acknowledgments

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

I wish to express my sincere gratitude and appreciation to my supervisors: **Prof. Dr. Yassin Mohammed Ibrahim Dagash** and **Dr. Sami Abdel Gaffar** and **Dr. Samia Osman Yagoub** for their invaluable guidance and help during the stages of the practical work and preparation of the study.

Thanks are extended to the Dongola Agricultural Research for supporting me.

My full thanks to my mother and husband and colleagues for their

continuous support during the study period.

Table of Contents

List of Tables

Abstract

The experiment was conducted during the seasons of 2013/2014 and 2014/2015 at Dongola research station farm high terrace. Dongola, Northern State, Sudan. The objective of this study was to determine the effect of nitrogen levels, verities and irrigation intervals on growth and yield of wheat. Experimental design used was randomized complete block in split-split plot arrangement with three replications. The main plot consisted of three water intervals (7,14 and 21days) and the subplots consisted of two varieties (Wadi El Neil and EL Neileen) while the sub-sub plot consisted of four nitrogen levels (43, 86 and 129 kg N/ha) .

The vegetative and reproductive growth parameters studied were plant height, number of tillers /meter square, leaf area index. Yield and yield components parameters were spike length, number of grains/spike, thousand grain weight, spike index, grain yield, biological yield and harvest index. Water use efficiency parameters were drought tolerance index. stress susceptibility and stress tolerance index. Nitrogen use efficiency parameter was used as the efficiency of nitrogen.

Nitrogen significantly affected all vegetative growth parameters in both seasons with the exception on leaf area index which exhibited significant differences in the second season only. Irrigation intervals affected all vegetative growth in both seasons. Wheat varieties significantly affected leaf area index in both seasons and plant height in the first season.

Nitrogen fertilizer significantly affected all yield and yield components parameters in both seasons with the exception of spike length which exhibited significant in the second season only. Irrigation intervals affected significantly some of the yield components in both seasons as biological yield , yield and harvest index. There were significant differences among wheat varieties in number of grains /spike and harvest index in both seasons and thousand grain weight and biological weight in the first season and yield in the second

season. Water use efficiency are presented in from of tolerance index, (TI) stress stability index and stress tolerance index for all treatments in tolerance index and stress stability.

Mean while stress tolerance showed significant difference for both season and application of 129 kg N/ ha gave the greatest values.

Nitrogen use efficiency significantly decreased with the increase of nitrogen rate in both seasons.

المستخلص

أجريت هذه التجربة خلال موسمي 2013-2014 و 2014-2015 بالمزرعة التجريبية لمحطة البحوث الزراعية- تربة التروس العليا دنقلا- الولاية الشمالية – السودان. هدفت الدراسة إلي تحديد تأثير السماد النيتروجين وفترات الري علي النمو الخضري والإنتاجية لصنفين من القمح.

استخدم تصميم القطاعات العشوائية الكاملة في توزيع القطع المنشقة المنشقة بثلاثة مكررات, شملت القطع الرئيسية ثلاثة مستويات من الري (7، 14 ، 21 يوماً) بينما وزعت أصناف القمح (وادي النيل والنيلين) علي القطع المنشقة في حين شملت القطع المنشقة المنشقة أربعة مستويات من السماد النيتروجيني هي (0 ، 43 ، 86 و 129 كجم نيتروجين للهكتار).

مقاييس النمو الخضري والثمري شملت طول النبات، عدد الخلف/ المتر المربع ودليل مساحة الورقة بينما شملت الإنتاجية ومكوناتها طول السنبلة، عدد الحبوب / السنبلة، دليل السنبلة، وزن الألف حبة، الإنتاجية، المحصول البيولوجي ودليل الحصاد. كفاءة استخدام الماء شملت دليل الجفاف, تحمل الإجهاد ومقاومة الإجهاد. بينما شملت كفاءة السماد كفاءة استخدام النيتروجين.

كان تأثير السماد النيتروجيني معنوياً في كل صفات النمو الخضري في كلي الموسمين ماعدا دليل مساحة الورقة والتي كان لها تأثير معنوي في الموسم الثاني فقط, فترات الري كان لها تأثير معنوي علي كل صفات النمو الخضري في كلي الموسمين ماعدا عدد الخلف/ المتر المربع والتي كانت معنوي في الموسم الثاني فقط. أصناف القمح كان لها تأثير معنوي في دليل مساحة الورقة في كلا الموسمين وطول النبات في الموسم الأول فقط. السماد النيتروجيني كان له تأثير معنوي علي كل صفات الإنتاجية ومكوناتها في كلا الموسمين ماعدا طول السنبلة والتي كانت معنوية في الموسم الثاني فقط. فترات الري كان لها تأثير معنوي علي بعض صفات الإنتاجية ومكوناتها والتي تتمثل في المحصول البيولوجي والإنتاجية ودليل الحصاد. اختلفت أصناف القمح معنويا في عدد الحبوب /السنبلة ودليل الحصاد في كلا الموسمين ووزن الألف حبة والمحصول البيولوجي في الموسم الأول والإنتاجية في الموسم الثاني. كفاءة الري كفاءة استخدام الماء تم تقسيمها حسب الجفاف إلى معامل الجفاف (TI) ومعامل الاجهاد (SSI) ومقاومة الجفاف (STI). وأوضحت النتائج عدم وجود فروقات معنوية لمعامل الجفاف ومعامل الاجهاد في حسين أوضح معامل الجفاف فرقا معنويا للموسمين مع ألإضل النتائج عند 129 كلجم نتروجين/ هكتار. قلت كفاءة استخدام النيتروجين معنويا كلما زاد مستوى السماد النيتروجيني في كلا الموسمين.

CHAPTER ONE

INTRODUCTION

Wheat (*Triticum aestivum* L.) covers most of the earth's surface compared to other food crops. It is the third largest cereal in terms of production worldwide, after maize and rice (Wang 2009). It can be cultivated in a wide range of agricultural environments .Whereas, in terms of dietary intake, wheat comes second to rice as a main food crop (FAO, 2013). In 2010, world production of wheat was 651 million tons, making it the third most- produced cereal after maize (844 million tons) and rice (672 million tons).Wheat production at 2012 was 656.5 million tons and at (2013/ 14) was 716.82 million tons. USDA, (2014) estimates that the World wheat production 2014/ 2015 will be 726.45 million tons that could represent an increase of 9.63 million tons or a 1.34% in wheat production around the globe. One of the most important abiotic stresses of wheat is heat, which is considered as a major environmental stress limiting wheat productivity in most cereal growing areas of the world (Mohammadi *et al.*, 2008). In addition, terminal heat stress can be a problem in up to 40% of the irrigated wheat- growing areas in the developing world. With the climate changes, threatening food crops across the world, (IPCC's) predictions of increasing drought spells disaster for half of the developing world's wheat growing areas (Pfadma, 2008). Global warming effects are expected to increase the probability and intensity of droughts and heat waves, thus exacerbating the existing conditions. Other effects of the global warming include changes in agricultural yields. Wheat is an especially critical "staff of life" for approximately 1.2 billion "wheat-dependent" to 2.5 billion "wheat-consuming" poor-men, women and children-who live on less than $US 2/day (FAOSTAT, 2010). IFPRI, projections indicate that the world demand for wheat will rise from 552 million tons in 1993 to 775 million tons by 2020, and 60% in total by 2050 (Rosegrant and Agcaoili, 2010). At the same time, climate change-induced temperature increases are likely to reduce wheat production by 20-30% in developing countries, where around 66% of all wheat is produced (Esterlirig *et al.*, 2007; Lobell *et al.*, 2008; Rosegrant and Agcaoili, 2010). Wheat is the second most important cereal crop in the Sudan after sorghum. Its importance increased during the last decade due to increased demand in the country. Wheat is exclusively produced under irrigation during the period from November to March. This period is shorter and has relatively higher temperature than those of traditional wheat producing regions of the world. In the Northern region the constraints are scarcity of both land and water, as wheat is in direct competition with other valuable winter crops such as beans and vegetables. FAO, (2000) indicated that main problems of irrigation in Northern Sudan were emanating from unavailability of water. Genotypes that maximize productivity under these stresses and express high yield under normal conditions, need to be identified to improve wheat production.

Results indicated that irrigation, nitrogen and cultivars were significantly affective on yield. Increased nitrogen levels and irrigation water coincided with improved chlorophyll content and other nutrients in leaves and seed (Pakhashan, 2010). For water stress, severity, duration and timing of stress as well as response of plants after stress removal and interaction between stress and other factors are extremely important (Estrada *et al.*, 2008). Deficit irrigation has been widely investigated as a valuable and sustainable production strategy in dry regions (Akram,2011). Water demand for irrigation can be reduced and water saved can be diverted for alternative uses. Decreased soil water potential increases the total resistance in the soil- plant system, which leads to reduced photosynthetic activity and growth (Ali *et al.*, 2013). At high terrace, (North Sudan), Yagoub *et al.*, (2012) studied the effect of different watering regimes on growth of two cultivars; the results revealed significant difference in dry weight, plant height and number of tillers/ plant due to the effect of watering regimes and cultivars but interaction of watering regime had no clear effect on all parameters of growth. Water and nutrient availability are major limiting factors of wheat production in the world (Curtis, 2002).Strategies of regulated irrigation and fertilization are one of the most practical ways in saving irrigation water and N. fertilizer of farmland in arid and semi-arid regions (Abdelkhalek 2015). Fakadu *et al.*, (2016) reported that poor soil management and low water and nutrient inputs lead to reduction in yield of wheat. The varieties are generating stable yields up to six tons per hectare (ICARDA,2015). Nitrogen use efficiently (NUE) of wheat decreased with increasing nitrogen fertilizer levels (Ali *et al.*,2013). Availability of N to the plants during growing season and weather condition specially rain fall affected NUE of the crop (Hafield *et al.*, 2004) and (Bertic, *et al.*, 2007). Many researchers in different studies reported that application of nitrogen of 75 and 150 kgN/ha,(Mandic *et al.*,2015). 180kgN/ha Nouraldin (2013) and 240 kgN/ha (Abadi and Kazemeini, 2011), to wheat increased grain yield and its components. Based on the results, farmers should be advised to use of the larger amounts of nitrogen although they increase production costs and reduce benefits. Crop production in arid and semi-arid region is restricted by soil deficiency in moisture and plants, nutrient especially nitrogen. Consequently, adequate levels of irrigation and nitrogen are needed.

The goal of this research is to develop high yielding wheat cultivars suitable for the high terrace soils of the Northern State with the following specific objectives:

1- To determine the effects of nitrogen levels on growth and yield of wheat.

2- To evaluate performance of wheat cultivars under different irrigation levels and fertilization.

CHAPTER TWO

LITERATURE REVIEW

2.1 Wheat History

The development of agriculture and cultivation of wheat(*Triticum spp*) occurred approximately 9,000 to 10,000 years ago (Katz, 2003). The first identifiable bread wheat (*Triticum aestivum* L.) with sufficient gluten for yeast breads has been identified using DNA analysis in samples from a granary dating to approximately 1350 BC at Assiros in Greek Macedonia (Sheffield, 2011).Genetic analysis of wild einkorn wheat suggests that it was first grown in the Karacadag Mountains in southern Turkey. The cultivation of emmer reached Greece, Cyprus and India by 6500 BC, Egypt shortly after 6000 BCE, Germany and Spain by 5000 BC (Diamond, 1997). The early Egyptians were the developers of bread and the use of the oven, developing baking into one of the first large- scale food production industries (Grundas, 2003). By 3000 BC, wheat had reached England and Scandinavia and a millennium later it reached China.

2.2 Wheat Adaptation

Wheat, like most grains, thrives in cool climates and tends to do poorly in warm, humid climates, which often ruins the crop through disease. Although wheat prefers cool climates, it does not grow as far north as heavier grains, such as rye and oat (Kipel and Kriemhild, 2000). The growing period of wheat lasts approximately 90 days and requires little attention other than a period of dry, sunny weather (Katz, 2003). Wheat also ideally requires land free of competition, which could draw its water supply and potentially block sunlight; however, it is known for readily growing in the presence of weeds (Kipel and Kriemhild, 2000).

Wheat is easily cultivated due to its ability to grow in regions of sparse rainfall, for their roots have the ability to take up nutrients from dry upper soil as long as they have access to moist lower soil (Bowden, Ma, and Rengel, 2006). Another function of their roots, which makes wheat particularly adaptable to drought and nutrient deficiency, is the ability to extend their roots into deep soil to gain access to nutrient-rich patches which would be normally unreachable (Bowden, Ma, and Rengel, 2006).

2.3 Importance of wheat

Accounting for a fifth of humanity's food, wheat is second after rice. Wheat production at 2012 was 656.5 million tons and at (2013/ 14) was 716.82 million tons. USDA, (2014) estimates that the World wheat production 2014/ 2015 will be 726.45 million tons that could represent an increase of 9.63 million tons or a 1.34% in wheat production around the globe.

Wheat was the second most- produced cereal in 2009; world production in that year was 682 million tons, after maize (817 million tons) and with rice as a close third (679 million tons); (World Wheat, Corn and Rice, 2015).

Wheat is mainly used as food crop for its relatively high protein 17% content. Sometimes it may be used as a fodder crop, a source of calories in the diets of consumers in developing countries and is first as a source of protein (Braun *et al*., 2010). Wheat is a major staple crop for several countries and is an imported commodity in all Africa. It steadily increased during the past 20 years as a result of increased population, changing food world's preference and socioeconomic change associated with urbanization (Harlod, 2015).

Wheat germs may help to decrease the body's absorption of dietary cholesterol and may also, inhibit the growth of some cancers (Wheat Germ, 2007). Bread wheat, primarily hard wheat, has the highest level of glutenin and gliadin which, when moistened and kneaded, combine to create gluten. Gluten provides a network of fibers that traps carbon dioxide and steam, allowing for a light, porous break by creating small pockets during baking (Smith, 2004).

2.4 Wheat production in Sudan

Ageeb *et. al*. (1993) stated that, wheat is the second most important cereal crop in the Sudan after sorghum. As a single crop, it occupies the largest area in the irrigated schemes. Average yields are generally low as affected by many production and environmental factors. The short wheat growing season (90- 100 days) and the excessively high temperature at early and late crop growth stages contribute greatly to low wheat productivity in the Sudan.Wheat, although has been grown North of Khartoum during the short cold season, introduction of wheat to other parts of the Sudan was the first attempted in1918at Gezira (El Ahmadi, 1994).Wheat production under semi-arid conditions of Sudan is no success. Grain yield of over 5 tons/hectare were obtained with high technology use. However, lack of yield stability over seasons and location has remained a great challenge to both research and production management (Babiker and Faki, 1994).Wheat cultivation in Dongola area and the Northern part of the Northern State has been practiced for hundreds of years. The crop is considered the main suitable cereal food crop for the people of that area compared to the rest of the country. Dongola area is considered the most favorable site for production of wheat. Selaim farmers grow traditional varieties, 52%, Condor 22% and Wadi El Neil 26% (Ahmad and Mohammad, 1992).

Wheat is the main winter cereal crop in the Northern State in terms of areas and production. Its area amounted to about 98000 feddans (1 feddan = 0.42 ha) in 1995 season, producing a total of 145500 tons with an average of 1.5 tons/ faddan. The whole area that was sown under surface-irrigation either on the old land near the Nile or the newly upper terrace (Northern State-Ministry of Agriculture, 1995). However, due to high costs of production and limited area, the crop was expanded to the Central and Eastern parts of the Sudan

(Nimir, 1986). (Disougi *et. al*., 1983) stated that, irrigation water and local cropping systems are basic limitations for the horizontal expansion.

Wheat research in Sudan found great attention in last years as a result of introducing new cultivars, change in climate, and encouragement of cultivation in high terrace soil of Northern Sudan, to give high production (El Hawary, and Yagoub 2011,Yagoub *et al*., 2012, Asayim *et al*., 2013, and Eltony, 2016.

2.3 Crop water requirement

Factors influencing crop production can be divided into three groups. Firstly, yield-defining factors such as radiation; secondly, yield-limiting factors which include soil moisture, nutrient availability and length of growing season; and thirdly, yield-reducing factors which encompass disease, insects and weeds. Amongst the factors limiting the uniform stand establishment; poor quality seed (Radford, 1983), poor seedbed preparation (Joshi, 1987), low moisture (Harris, 1996), conventional sowing (Radford, 1983), late sowing and sub- optimum temperature at sowing (Farooq *et al.*, 2008) are more important in our region.

FAO (1984) defined crop water requirements as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease-free, growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment'.

Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. Irrigation water requirement basically represents the difference between the crop water requirement and effective precipitation.

The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application.

Knowledge of crop-water requirements is crucial for water resources management and planning in order to improve water-use efficiency (Hamdy and Lacirignola, 1999; Katerji and Rana, 2008).

Sirelkhatim *et. al*. (2007) estimated the crop water requirements for different sowing dates as the product of either E_o or ET_o by the appropriate crop factor (coefficient) at Gezira scheme, the studied crops were cotton, wheat, sorghum, groundnuts, sesame, summer fodder, sugar cane, vegetables, fruit trees, and forests. The highest seasonal amount required was by sugar cane (12410-12490 m^3/fed) followed by that of extra-long staple cotton ELS *(Gossypium barbadense)*, (5110-5320 m^3/fed) and medium staple cotton MS *(Gossypium hirsutum)*, (3645-3680 m^3/fed). The lowest amount was required by sorghum, (2265-2310 m^3/fed). Wheat requires (2555-2760 m^3/fed) while summer fodders require (3205-3430 m^3/fed). Long and short-term groundnut water requirements are estimated at (3325-3420) and (2430-2600) m^3/fed, respectively. Irrigated sesame requires about (2470-2570) m^3/fed. For crops grown during the rainy season, expected rainfall should be subtracted from estimated crop water requirements. Estimated crop water requirements do not include planting water requirements.

2.4 Irrigation efficiencies

Water requirements of a crop are dependent on the botanical characters of the crop, its stage of growth and the prevailing weather conditions, different criteria based on soil, plant and meteorological factors were used for estimation of crop water needs.

To express which percentage of irrigation water is used efficiently and which percentage is lost, the term irrigation efficiency is used. The scheme irrigation efficiency (e in %) is that part of the water pumped or diverted through the scheme inlet which is used effectively by the plants. The scheme irrigation efficiency can be sub-divided into: the conveyance efficiency (ec) which represents the efficiency of water transport in canals, and the field application efficiency (ea) which represents the efficiency of water application in the field.

The conveyance efficiency (ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals. In large irrigation schemes more water is lost than in small schemes, due to a longer canal system. From canals in sandy soils more water is lost than from canals in heavy clay soils. When canals are lined with bricks, plastic or concrete, only very little water is lost. If canals are badly maintained, bund breaks are not repaired properly and rats dig holes, a lot of water is lost.

Soil management practices affect the processes of evapotranspiration by modifying the available energy, the available water in the soil profile, or the exchange rate between the soil and the atmosphere. Plant management practices, e.g., the addition of Nand P, have an indirect effect on water use through the physiological efficiency of the plant. A survey of the literature reveals a large variation in measured WUE across a range of climates, crops, and soil management practices. It is possible to increase WUE by 25 to 40% through soil management practices that involve tillage. Overall, precipitation use efficiency can be enhanced through adoption of more intensive cropping systems in semiarid environments and increased plant populations in more temperate and humid environments. Modifying nutrient management practices can increase WUE by 15 to 25%. Water use efficiency can be increased through proper management, and field-scale experiences show that these changes positively affect crop yield. (Jerry *et al*., 2001).

2.5 Deficit Irrigation

To cope with scarce supplies of water Fereres and Soriano, (2007)stated that deficit irrigation is defined as the application of water below full crop water requirements. Deficit irrigation has been widely investigated as a valuable and sustainable production strategy in dry regions.

Higher grain weight of well-watered plants are associated with longer grain filling duration and faster grain filling rate (Li *et al.*, 2000). Water stress induced accelerated senescence after anthesis, shortens the duration of grain filling by causing premature desiccation of the endosperm and by limiting embryo volume, has also been reported (Westage, 1994).

Increasing the yield of wheat in most areas requires more water for wheat sowing. Taha *et al.*, (1986) stated that less frequent irrigation was carried out in neighboring farmer's field than in participating farmer's plots in Northern Sudan. Elsir and Abdu Allah (2003), and Elsir (2002, 2004a), indicated the main problems of irrigation in Northern Sudan were emanating from unavailability of water. Ahmed (2005) cited that the problem of irrigation in the Gezira Scheme was associated with canals for passing water. Canals were not fully opened or were invested with weeds or were not linked to the blocks resulting in shortage of water and to poor distribution.

The grain yield was viewed by some research workers as a product of biological yield and harvest index (Donald and Hamblina, 1976). Passioura (1977) suggested that the yield could be a product of three factors via, usable water, water use efficiency and the harvesting index. The effect of water deficit on yield and total or economic yield is the integral part of its effects on the growth and other physiological processes (Farah, 1996). Onwueme and Sinha (1991); and Prasab *et al*. (1988) stated that, the most practical criterion commonly adapted for scheduling irrigation of wheat is the one based on the physiological growth stage. The moisture available in a soil is the difference of moisture contents at the permanent witting point and FC level which is available to the plant in the root zone. Irrigation requirement the quantity of water needed above the existing moisture level. The difference between available moisture anti irrigation requirements lies in the losses in conveyance and seepage which must be taken into consideration when computing the irrigation requirements. Prasad *et al*. (1988) further added that, available soil moisture is commonly used to determine the exact date and the quantity of water applied. They also reported that WUE, was generally higher in lower frequencies of irrigation. They found maximum WUE when two irrigations were applied at crown-root initiation and flowering because these are the most critical stages of irrigation, and therefore, water utilization was most efficient leading to high WUE. Total crop evapotranspiration during crop-growth period was higher when more irrigation was given. Apart from applied irrigation, soil profile also contributes a sizeable quantity (43.5%) of water the crop. Steiner *et al*. (1985) reported that irrigation significantly affected dry matter production, grain yield and yield components of wheat crop, and that more than 70% of the crop water requirements were taken at anthesis. Similar results were reported by France and Schultz (1984). Koshata and Raghn (1983) stated that, frequent irrigation increased grain yield and weight, increased consumptive use, but reduced WUE.

Hailk and Melegy, (2005). Khabir, *et al*., (2009), Yagoub *et al*., (2012), Eltony (2016) reported positive effect of irrigation on plant height, total tillers/plant, biological yield and harvest index. Hailk and Melegy, (2005) attributed this result to the effect of irrigation that encouraged cell elongation, cell division which consequently increased meristimatic growth. On the other hand, Ashraf *et al*., (2002) showed that many important physiologyical and morphological processes such as leaf enlargement, stomata conductance and photosynthetic activity are directly affected by leaf turger potential. Under water stress conditions, plants lose their turger and thus cell expansion and growth reduced.

Bukhat, (2005) stated that moisture stress reduced biomass, tillering and number of grain per spike and overall effect of moisture stress depends on intensity and length of stress. Hassan, (2002), Pierre *et al*., (2008), Malik, (2010), Elhawary, (2011) and Yagoub, (2012), revealed that wheat can tolerate intervals of up to 12 days during the vegetative growth stage, but during the time of booting and antheise moisture stress should be avoided.

2.6 Drought in wheat

Drought is one of the most important phenomena which limit crop production and yield. Crops demonstrate various morphological, physiological, biochemical, and molecular responses to tackle drought stress. Plants' vegetative and reproductive stages are intensively influenced by drought stress. Drought tolerance is a complicated trait which is controlled by polygenes and their expressions are influenced by various environmental elements (Nezhadahmadi, 2013).

Many studies have used drought indices to select stable genotypes according to their performance under favorable and stress conditions (Moosavi *et al.* (2008), Farshadfar *et al.* (2013), Mursalova *et al.* (2015). Examples of such indices are stress susceptibility index (SSI) (Fischer and Maurer 1978), tolerance (TOL) (Rosielle and Hamblin 1981), stress tolerance index (STI) (Fernandez, 1992), stress susceptibility percentage index (SSPI) (Moosavi *et al.* 2008), and modified stress tolerance index (MSTI) (Farshadfar and Sutka 2002).

The effects of drought on yield of crops depend on their severity and the stage of plant growth during which they occur. Seed germination is the first stage of growth that is sensitive to water deficit. Under semiarid regions, low moisture is often a limiting factor during germination. The rate and degree of seedling establishment are extremely important factors to determine both yield and time of maturity (Rauf *et al*.,2007).

Among all the stress factors either biotic or abiotic factors, drought plays a significant role for reduced wheat production and performance upon a great extent. It is recognized that almost 50% of wheat cultivated land in the developing world is under rainfed condition (Renolds *et al*.,2001). Drought is a worldwide problem constraining global crop production seriously (Comas *et al.*, 2013 and Rabbani, *et al*,.2011). There was high variability among genotypes in response to drought(Soleimani, *et al*,.2014).

Drought tolerance is defined as the relative yield of a genotype compared to other genotypes, subjected to the same drought stress. Blum (1988) measured drought susceptibility in each genotype as reduction in yield under drought stress, whilst the mentioned values are baffled with different yield potential of genotypes (Ramirez and Kelly, 1998). However, difference in yield potential could be caused by factors related to adaptation rather than to drought tolerance by itself (Golabadi *et al.*, 2006).

Drought induces significant alterations in plant physiology and biochemistry. Some plants have a set of physiological adaptations that allow them to tolerate water stress conditions. The degree of adaptations to the decrease of water potential caused by drought may vary considerably among species (Save *et al.*, 1995) .Plant response to water stress includes morphological and biochemical changes and later as water stress becomes more severe to functional damage and loss of plant parts (Sangtarash, 2010). Researchers linked various physiological responses of plant to drought with their tolerance mechanisms, such as: pigment content and stability and high relative water content (Clarke and McCaig, 1982). Drought tolerant wheat species can be characterized by growth response, changes in water relations of tissues exposed to low water potential, stomatal conductance, ion accumulation and changes in the fluorescence induction parameters under water stress (Blum, 1988),

2.7 Nitrogen Fertilization

Establishing effective N management systems, updating N application guidelines, and improving NUE are the key challenges that must be addressed to sustain and enhance the sustainability of wheat production. Sustaining global food security and minimizing the negative impact of agriculture intensification on environmental quality are the most challenging issues the researchers and crop growers are facing today (Wash, 2012).

Nitrogen along with carbon and oxygen is the most complex and crucial factors essential for life. Supplementing grain and grass forage crops with organic and inorganic N fertilizers has long been recognized as a key to improving crop yields and economic returns. Globally, N fertilizer is largely used for cereal grain production and accounts for an estimated 40% of the increase in per capita food production in the past 50 years (Mosier *et al*, 2001). Nitrogen comprises about 16%of the weight of the plant protein. It is essential in many other components including chlorophyll. Nitrogen uptake by plants can mainly be when it is in anon organic form, that is as ammonium (NH4) or nitrate (N03). The commonly available sources of nitrogenous fertilizer are urea, ammonium nitrate and ammonium sulphate. Dawelbeit *et al* (2007) reported that the importance of nitrogen fertilization was recognized for most crops, such as wheat, cotton and sorghum. With these findings research concentrated in testing the effect of different nitrogen forms starting with ammonium sulphate as N**.**

Addition of nitrogen fertilizer to wheat is required to ensure that nitrogen is available throughout the growing season due to the important role in promoting both vegetative and reproductive growth Wheat requirements for nitrogen depends on season, soil type, soil moisture and yield potential.

Generally heavy rates of nitrogen were used with higher seed rates when there is abundant moisture. Grain and straw yield were found to increase significantly with the increase in nitrogen levels (Akasha, 1968; Khalifa, 1968; Dahiya, *et al*. 1980).

Many researches showed that N application increased grain yield of wheat (Subedi *et al.*, 2007; Gorjanovic and Kraljevic-Balalic, 2008). Marino *et al.* (2009) concluded that increase N rate increased number of spikes m^{-2} (NS m^{-2}) kernels m^{-2}; decreased 1000 grain weight and in some cases no differences were noticed among fertilized treatments for plant height and number of spikelets per spike. Increasing nitrogen levels significantly increased the effective tillers, ear length, grains per ear and plant height (Sharma *et al*. 1970; Singh, 1987). Yield increased significantly with the increase in nitrogen rate (Nehra-AjitetaI; 2001, Singh and Sharma, 2001, Mohammad *et al*; 2003). Iqtidar *et al*. (2006) reported that increasing the N level from 50 to 200 kg ha^{-1} significantly increased total number of plants m^{-2}, spike weight, and grain yield compared to 0 kg N ha^{-1}. Asif *et al*. (2012) concluded that number of fertile tillers per unit area, number of grain per spike , and harvest index were significantly increased by increasing N fertilization levels. Abedi *et al*. (2011) reported that higher grain yield (8230 kg ha^{-1}) was produced in treatment receiving 240 kg N ha^{-1} than in control (3930 kg ha^{-1}), 120 kg N ha^{-1} (4400 kg ha^{-1}), and 360 kg N ha^{-1} (6530 kg ha^{-1}).

Akasha (1972), made an experiment to study the response of various wheat cultivars to nitrogen fertilizer in the Gezira Scheme. The result showed that early application of nitrogenous fertilizer gave the best response and that the variation in grain yield was mainly due to the effect of the leaf area. Ibrahim (1987, 1989) at Hudeiba, Mohamed (1989) at Shendi, and Ibrahim and Mohamed (1988) investigated the response of three wheat cultivars, namely, Condor, Wadi El Niel and Debira to different rates of N application (0,43 and 129 kg N/ha) at different sites representing the three major soil types in the River Nile State, i.e., Gurier, Karu and High Terrace soils. Generally, N application increased grain and straw yields considerably on the Karu and High Terrace soils. Khalifa (1973) reported that grain yield was unaffected by either source of nitrogen or method of application. Most agricultural soils of the Northern State are alkaline in reaction and very low in organic matter. Such conditions bind the micronutrients to the soil particles and render them unavailable to the crop. Foliar application of micronutrients was found to increase wheat grain yield up to 110 %unless of soil in the Northern state revealed that Terrace soil contained the least amount of available micronutrients (Ishag, *et. al*., 1993). In a factorial experiment carried out on a (Terrace soil) in El-Damer area. The results indicated that the optimum doze for wheat production on the high terrace soil of the Northern region is 80 kg, N and 21.5 kg, per hectare (Ibrahim, 1990).

2.8 Nitrogen use efficiency (NUE)

NUE parameters are high under low nitrogen levels and decrease with increasing nitrogen level. Decreased NUE at high nitrogen is attributed to higher losses because the plant is unable to absorb all of nitrogen applied (Giambalvo *et al*. 2009 and EL Toum 2016). Noureldin *et al*. (2013) reported that increasing N up to 180 kg ha^{-1} increased grain yield and its components. Raun and Johnson (1999) reported that globally, N use efficiency (NUE) in grain production is 33%. Sieling *et al*. (1998) and Li *et al*. (2013) concluded that the NUE of wheat decreased with increasing N fertilization levels. Hatfield and Prueger (2004) and Bertic *et al*. (2007) concluded that NUE by the crop depends on the weather conditions, especially rainfall and availability of N to the plants during growing season.

2.9 Wheat varieties

The presence of differential genotypic responses in different environments, known as the interaction of genotypes with environments (GE), is a natural phenomenon and part of the mechanism of species evolution. The adaptability of a variety is usually tested by the degree of its interaction with different environments. A variety or genotype is considered to be more adaptive or stable if it has a high mean yield with low degree of fluctuation in yielding ability grown over diverse climatic conditions. The relative yield performance of genotypes in drought stressed and favorable environment seems to be a common starting point in the identification of desirable genotypes for unpredictable rain-fed conditions. Jobet and Warren (2000) and Rashid *et al* (2004) found that significant differences between wheat cultivars were observed for plant height., Ishag (1991); Carr *et al*. (2003) and Nader Khan *et al*. (2004) reported that significant differences between cultivars were detected in tillers. Ishag (1973) reported that there were considerable differences between cultivars such as Wadi El Neil, El Neileen, Debiera, and Condor in number of grain per spikelet and number of grains per plant. Carr *et. al*., (2003), Nader Khan *et. al*.,. (2004) and Rashid *et. al*., (2004) found that significant variation was observed among different wheat genotypes for number of grains per spike. Ibrahim (1993) and Jobet and Warren, (2000) found that significant differences between cultivars were observed for grain yield. Significant difference between cultivars were observed furring weight (Gobbet and Warren, 2000; Carr *et. al*, 2003; Nader khan *et al*., 2004 and Rashid, *et al*., 2004). Naseri *et.al*., (2010) found that grain yield and its components were significantly different among cultivars due to effect by different levels of irrigation at different growth stages.

Cultivars can differ in NUE as a result of differences in the absorption of nitrate (Rodgers and Barneix, 1988) and N remobilization (Van Sanford and MacKown, 1986). However, improved varieties are often developed without considering their ability to grow and yield under low soil nutrient status, and have been selected for high yields under high nutrient input conditions (Wissum *et al*., 2009). Feil (1992) indicated that varieties producing large amounts of biomass seemed to have more NUPE, which could decrease NUTE thereby also decreasing total NUE of modern varieties. Genetic variation highly influences NUTE (Singh and Arora, 2001), which particularly depends on harvest index (HI) and N biomass production efficiency.

.

CHAPTER THREE

MATERIALS AND METHODS

3-1 The Experimental Site and the Climate

Two field experiments were conducted during season 2013/2014 and 2014/2015 at Dongola research station farm in the Northern State, Sudan (16 and 22^{o}N; 25 and 32^{o}E). It is bordered by Khartoum State and Northern Kordfan in the South, the River Niles State in the East, Egypt to the North and Lybia and North Darfur State on the West. The State of desert and semi desert climate. Its climate is characterized with relatively cold and long winters. The average annual rain fall varies from nil in the north to 100mm in the south. Maximum and minimum temperatures recorded were found to be as high as 48^{o}C during summer and as low as5^{o}C during winter.

3.2 Land preparation, sowing and the layout of the experiment:

The experimental area was tilled adequately to prepare a suitable seed bed. The implements used included a chisel (Cross Plough) to break and loosen the soil and a leveler (scraper) to level the experimental area for the easy movement and uniform distribution of irrigation water. The field was then divided into three blocks (replications) each contained 24 equal plots of 2½m × 4m size. Sowing was done on the first of December for both seasons in rows 20 cm apart at seed rate of 90 kg/h or 48.6 g/plot of 11 rows (3m long).

Weed control was done by hand weeding ten days after sowing and then as needed throughout the growing season.

3.3 Experimental Design and treatments

Experimental Design is a randomized complete block in split – split plots arrangement with three replications. The main plot contains irrigation and varieties in sub plot and nitrogen levels as sub subplot.

The experiment included the following treatments:

Factor (A): Three irrigation intervals during pod anthesis (W1: 7 days, W2: 14 days and W3: 21 days).

Factor (B): Two wheat varieties (V1: Wadi El Neil and V2: EL Neileen).

Factor (C): Four nitrogen levels (N0: zero, N1: 43kgN/ha, N2: 86kg N/ha and N3: 129 N kg/ha).

The treatment combinations are shown below.

No.	Treatment symbol	No.	Treatment symbol
1	W1V1N0	13	W2V2N0
2	W1V1N1	14	W2V2N1
3	W1V1N2	15	W2V2N2
4	W1V1N3	16	W2V2N3
5	W1V2N0	17	W3V1N0
6	W1V2N1	18	W3V1N1
7	W1V2N2	19	W3V1N2
8	W1V2N3	20	W3V1N3
9	W2V1N0	21	W3V2N0
10	W2V1N1	22	W3V2N1
11	W2V1N2	23	W3V2N2
12	W2V1N3	24	W3V2N3

3.4 Parameters studied

3.4.1 Vegetative growth parameters

3.4.1.1 Plant height (cm)

The mean plant height was determined from ten randomly selected plants from the middle rows in each plot, measured in centimeters (cm) from the soil surface to the tip of the spike.

3.4.1.2 Number of tillers/m^2

Mean number of tillers per meter square was obtained from the middle rows in each plot.

3.4.1.3 Leaf area index (LAI)

From ten randomly selected plants from the middle rows in each plot, the area of individual green leaves (LA) was determined by measuring their length (L) and maximum width (W) and multiplying by a factor of 0.75 (Bueno and Atkins; 1981).

$LA = L \times W \times 0.75$

$$LAI = \frac{\text{LA} \times \text{Number of leaves per plant} \times \text{Number of plants/m2}}{(\text{m}^2)}$$

3.4.2 Yield components

3.4.2.1 Spike length (cm)

The mean spike height was determined from ten randomly selected spikes from the middle rows in each plot, measured in centimeters (cm) from the base to the tip of the spike.

3.4.2.2 Number of grains/spike

The average number of grains per spike was counted from ten randomly selected spikes from the middle five rows of each plot and the mean number of grains per spike was calculated.

3.4.2.3 Spike index

The average spike weight was counted from ten randomly selected spikes from the middle five rows of each plot and the mean yield of grains per spike was calculated.

$$\text{Spike index} = \frac{\text{Grain yield/ spike}}{\text{Spike weight}}$$

3.4.2.4 Thousand grain weight (TGW)

Grain weight in grams was obtained by weighing two 1000- grain samples selected at random from each plot, using a sensitive balance.

3.4.2.5 Grain yield (t/ha)

When signs of maturity were clear on the plant (complete yellowing of leaves and spikes) one meter square of the five central rows in each plot was harvested for yield. Grain yield per plot was converted to grain yield (t/ha). (Show in detail)

3.4.2.6 Biological yield (t/ha)

From the middle rows of each plot, plants in one meter square area were cut at soil surface and dried then weighted and recorded as yield (t/ha).

3.4.2.7 Harvest index (%)

One meter square of the five central rows were cut from the surface of the ground and dried then weighed and the harvest index was recorded as:

$$\text{Harvest index} = \frac{(\text{Economic yield}) \times 100}{(\text{Biological yield})}$$

3.4.3 Water use efficiency (WUE)

3.4.3.1 Drought tolerant index (DTI) = grain yield under low irrigation/ grain yield under normal water (yl/yh)

3.4.3.2 Stress susceptibility index (SSI) =

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

Ysi = grain yield of each genotype under stress

Ypi = grain yield of each genotype under optimal condition

Ys = mean of grain yield under stress

YP = mean of grain yield under optimal condition

3.4.3.3 Stress tolerance index (STI) =

$$\frac{Ysi.Ypi}{Y^2P}$$

Where:

Ysi = grain yield of each genotype under stress

Ypi = grain yield of each genotype under optimal condition

Y^2P = square of mean grain yield in all genotypes under optimal conditions.

3.4.4 Nitrogen use efficiency (NUE) = (kg/ha) / Actual amount of nitrogen added.

3.5 Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) appropriate for randomized complete block design (Gomez and Gomez, 1984). Duncan's Multiple Range Test (DMRT) was applied for the separation of treatment means. All statistical analyses were performed using M-STAT-C program computer package.

CHAPTER FOUR

RESULTS

4.1 Vegetative Growth

4.1.1 Plant height (cm)

The statistical analysis revealed that Nitrogen had highly significant differences (P =0.01) in plant height in both seasons (Tables 1).

In the first season the application of 129 kg N/ha gave higher plant height. On the other hand, there were no differences between the application of 86 and129 kg N/ha. In the second season the application of 86 kg N/ ha gave greater plant height than control. (Table 2).

Wheat varieties had higher significant differences in plant height (P = .01) in the first season but there were no significant differences in the second seasons (Table 1). In the first season ELNeileen gave higher plant height than Wadi Elneil (Table 3).

Irrigation intervals had higher significantly (P =0.01) in plant height in both seasons (Table 1). Irrigation intervals after 7 days gave higher plant height than 14 and 21 days in both seasons (Table 4).

The interaction of irrigation interval and wheat varieties had significant differences (P=0.05) in plant height in the first season (Table 1).

4.1.2 Leaf area index (LAI)

The analysis of variance showed that nitrogen had significantly affected leaf area index in the second season but there were no significant differences in the first season (Table 1). In the second season the application of 129 Kg N/ha gave higher leaf area index on the other hand, there were no different between 43, 86 and control (Table 2).

Wheat varieties had higher significant differences (P= 0.01) leaf area index in the first season and significant differences (P = 0.05) in the second season (Table 1). In both seasons Wadi El Neil gave higher leaf area index than El Neileen (Table 3).

Irrigation intervals had significantly affected leaf area index in both season (Table 1). In the first season, irrigation interval 7 days gave higher leaf area index than 21 days, on the other hand, there were no difference between irrigation intervals 7 and 14 days and between 14 and 21 days. In the second season, irrigation interval 7 days gave higher leaf area index than 14 and 21 days, on the other hand, there were no different between 14 and 21 days (Table 4).

There were no significant differences among treatments interactions in both seasons, (Tables 1).

4.1.3 Number of tillers per meter square

The analysis of variance indicated that nitrogen levels had highly significant differences (P = 0.01) in number of tillers per meter square in both seasons (Table 1). Application of 129 kg N/ha increased number of tillers per meter square than 43, 86 and control in both seasons, on the other hand, there were no significant differences between the application of 43 and 86 kg N/ha in number of tillers per meter square in both seasons (Table 2).

There were no significant differences between wheat varieties in number of tillers per meter square in both seasons (Table 1).

There were highly significant differences (P = 0.01) between irrigation intervals in number of tillers per meter square in the second season and significant differences (P = 0.05) in the first season (Table 1). In the first season irrigation interval at seven days gave greater number of tillers per meter square, on the other hand, there were no significant differences in number of tillers/ m^2 between irrigation intervals 14 and 21 days. In the second season irrigation interval at seven days gave greater number of tillers/ m^2 and there were no significant differences in number of tillers/ m^2 between irrigation intervals 7 and 14 days (Table 4).

Treatment interactions were not affected in number of tillers per meter square in both seasons (Table1).

Table (1): F- value of the vegetative growth parameters for the treatment and their interactions in (2013/2014 and 2014/ 2015) seasons

Sources of variation	Plant height		Leaf area index		Number of tillers/ m^2	
	First season	Second season	First season	Second season	First season	Second season
W	236.72**	18.55**	11.53*	8.38*	13.06*	20.87**
V	87.53**	24.55^{ns}	15.40**	12.40*	1.79^{ns}	0.20^{ns}
W×V	7.70*	0.48^{ns}	0.19 ^{ns}	0.15 ^{ns}	0.68^{ns}	0.47^{ns}
N	13.77**	26.12**	0.99 ^{ns}	3.81*	24.03**	20.17**
W×N	0.94^{ns}	0.72^{ns}	1.86 ^{ns}	0.62 ^{ns}	1.36^{ns}	0.67^{ns}
V×N	1.39^{ns}	0.21^{ns}	0.70 ^{ns}	0.99 ^{ns}	2.40^{ns}	0.30^{ns}
W×V×N	0.69^{ns}	0.27^{ns}	1.40 ^{ns}	0.10 ^{ns}	1.26^{ns}	0.60^{ns}
CV%	5.10	5.09	22.12	26.29	7.37	8.59

Key: N: Fertilizer levels W: irrigation intervals V: wheat varieties

* = Significant at 5% level (Significant).

** = Significant at 1% level (highly Significant).

^{ns} = not Significant.

Table (2): Effect of nitrogen levels on vegetative growth parameters of wheat in (2013/2014 a

Treatments	Plant height (cm)		Leaf area index		Nun
	First season	Second season	First season	Second season	First seas
0N	73.03[c]	73.47[d]	1.178[a]	1.156[b]	250.22
1N	75.73[b]	77.58[c]	1.283[a]	1.472[a]	278.44
2N	78.62[a]	80.31[a]	1.217[a]	1.333[ab]	276.17
3N	80.93[a]	80.02[b]	1.322[a]	1.528[a]	308.17
LSD	2.658	2.722	0.1864	0.2473	13.87
SE±	0.927	0.949	0.6498	0.0850	4.834
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple

Key: N: fertilizer levels (N0:0kg/ha,N1:43 kg/ha, N2: 86 kg/ha, N3: 129 kg/ha).

Table (3): Effect of varieties on vegetative growth parameters of wheat in (2013/2014 and 201

Treatment	Plant height (cm)		Leaf area index		Num
	First season	Second season	First season	Second season	First seas
V1	71.57^{b}	74.74^{a}	1.43^{a}	1.61^{a}	283.00
V2	82.58^{a}	83.54^{a}	1.07^{b}	1.14^{b}	273.50
LSD	2.89	4.34	0.23	0.33	17.47
SE±	0.833	1.244	0.65	0.095	5.021
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple I

Key: V1: Wadi Elneil V2: ELNeileen.

Table (4): Effect of irrigation intervals on vegetative growth parameters of wheat in (201 seasons

Treatment	Plant height (cm)		Leaf area index		Nun
	First season	Second season	First season	Second season	First seas
W1	84.43[a]	83.80[a]	1.42[a]	1.59[a]	295.96
W2	76.20[b]	80.28[b]	1.24[ab]	1.35[b]	272.83
W3	70.60[c]	73.20[c]	1.09[b]	1.17[b]	265.96
LSD	1.776	4.92	0.19	0.29	17.08
SE±	0.452	1.25	0.050	0.78	4.349
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple

Key:

W1: = 7 days interval.

W2 = 14 days interval.

W3 = 21 days interval.

Table (5): Effect of interaction between nitrogen levels and varieties on vegetative growth p (2013/2014 and 2014/2015) seasons

Treatments	Plant height (cm)		Leaf area index		Num
	First season	Second season	First season	Second season	First seas
V1N0	68.43^{e}	70.03^{e}	1.333^{ab}	1.322^{bc}	247.33
V1N1	70.63^{de}	74.37^{d}	1.478^{a}	1.800^{a}	280.33
V1N2	73.37^{d}	74.82^{d}	1.467^{a}	1.622^{ab}	291.00
V1N3	73.83^{d}	79.72^{ec}	1.444^{a}	1.689^{ab}	313.33
V2N0	77.62^{c}	76.90^{cd}	1.022^{c}	0.989^{c}	253.11
V2N1	80.82^{bc}	80.80^{c}	1.089^{bc}	1.144^{c}	276.56
V2N2	83.88^{b}	85.79^{b}	0.967^{c}	1.044^{c}	261.33
V2N3	88.03^{a}	90.32^{a}	1.200^{abc}	1.367^{bc}	303.00
LSD	3.759	3.849	0.2636	0.345	19.61
SE±	1.311	1.342	0.9189	0.120	6.837
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple I

Table (6): Effect of interaction of nitrogen levels and irrigation intervals on vegetative growt in (2013/2014 and 2014/2015) seasons

Treatments	Plant height (cm)		Leaf area index		Num
	First season	Second season	First season	Second season	First seas
W1N0	81.43^{b}	77.75^{def}	1.483^{ab}	1.317^{abc}	258.17
W1N1	80.90^{b}	82.67^{bcd}	1.567^{a}	1.767^{a}	302.50
W1N2	86.92^{a}	85.33^{abc}	1.350^{abc}	1.517^{ab}	287.17^{b}
W1N3	88.48^{a}	89.47^{a}	1.283^{abcd}	1.767^{a}	336.00
W2N0	70.57^{de}	75.55^{f}	1.133^{bcd}	1.183^{bc}	254.33
W2N1	75.62^{cd}	76.67^{ef}	1.267^{abcd}	1.550^{ab}	273.50
W2N2	78.00^{bc}	81.42^{cde}	1.250^{abcd}	1.300^{abc}	268.50
W2N3	80.62^{b}	87.50^{ab}	1.317^{abc}	1.383^{abc}	295.00^{b}
W3N0	67.08^{e}	67.10^{g}	0.917^{d}	0.967^{c}	238.17
W3N1	70.67^{de}	73.42^{f}	1.017^{cd}	1.100^{bc}	259.33
W3N2	70.95^{de}	74.17^{f}	1.050^{cd}	1.183^{bc}	272.83
W3N3	73.70^{cd}	78.10^{def}	1.367^{abcd}	1.433^{abc}	293.50^{b}
LSD	4.604	4.714	0.323	0.422	24.02
SE±	1.605	1.644	0.129	0.147	8.373
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to D test at 5% level.

Table (7): Effect of irrigation intervals and varieties on vegetative growth parameters of wh 2014/2015) seasons

Treatments	Plant height (cm)		Leaf area index		Num
	First season	Second season	First season	Second season	First sea
W1V1	75.80^{bc}	78.28^{b}	1.64^{a}	1.83^{a}	300.33
W1V2	93.07^{a}	89.32^{a}	1.20^{bc}	1.35^{abc}	291.58
W2V1	73.09^{c}	76.84^{b}	1.40^{ab}	1.63^{ab}	282.83
W2V2	79.31^{b}	83.73^{ab}	1.08^{bc}	1.07^{bc}	262.83
W3V1	65.81^{d}	69.08^{c}	1.25^{abc}	1.36^{abc}	265.83
W3V2	75.39^{bc}	77.31^{b}	0.92^{c}	0.98^{c}	266.08
LSD	4.991	7.456	0.39	0.57	30.09
SE±	1.442	2.155	0.11	0.16	8.696
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple

Table (8): Effect of interaction between nitrogen levels and irrigation intervals and varietie parameters of wheat in (2013/2014 and 2014/2015) seasons

Treatment	Plant height (cm)		Leaf area index		Numb
	First season	Second season	First season	Second season	First seas
W1V1N0	72.80^{fghijk}	73.73^{de}	1.60^{ab}	1.40^{abcd}	255.00^{fghi}
W1V1N1	74.86^{fghij}	80.30^{defgh}	1.77^{a}	2.10^{a}	292.00^{bcde}
W1V1N2	78.07^{efg}	77.57^{de}	1.63^{a}	1.77^{ab}	307.33^{bc}
W1V1N3	77.47^{fgh}	81.53^{de}	1.57^{ab}	2.07^{a}	347.00^{a}
W1V2N0	90.07^{bc}	81.77^{cd}	1.37^{abcdef}	1.23^{bcd}	261.33^{fghi}
W1V2N1	86.93^{cd}	85.03^{ab}	1.37^{abcdef}	1.43^{abcd}	313.00^{ab}
W1V2N2	95.77^{ab}	93.10^{a}	1.07^{bcdefg}	1.27^{bcd}	267.00^{efgh}
W1V2N3	99.50^{a}	97.40^{fghi}	1.00^{cdefg}	1.47^{abcd}	325.00ab
W2V1N0	68.33^{ijklm}	72.57^{fghi}	1.40^{abcde}	1.40^{abcd}	253.76^{fghi}
W2V1N1	71.93^{ghijklm}	71.77^{defgh}	1.53^{abc}	2.03^{a}	280.00^{cdef}
W2V1N2	75.87^{ghijkl}	77.70^{cd}	1.33^{abcdef}	1.53^{abc}	289.00^{bcde}
W2V1N3	76.23^{efgh}	85.33^{defg}	1.33^{abcdef}	1.57^{abc}	308.67^{bc}
W2V2N0	72.80^{fgh}	78.53^{de}	0.867^{efg}	0.97^{cd}	255.00^{fghi}

W2V2N1	79.30^{fghijk}	81.57^{cd}	1.00^{cdefg}	1.07^{bcd}	267.00^{efgh}
W2V2N2	80.13^{efg}	85.13^{defg}	$1.17^{abcdefg}$	1.20^{bcd}	248.00^{hij}
W2V2N3	85.00^{cde}	89.67^{de}	1.30^{abcdef}	1.17^{bcd}	281.33^{cdefg}
W3V1N0	64.17^{m}	63.80^{fghij}	1.00^{cdefg}	1.27^{bcd}	233.33^{j}
W3V1N1	65.10^{lm}	71.03^{ij}	1.13^{abcd}	1.57^{bcd}	269.00^{defg}
W3V1N2	66.17^{klm}	69.20^{fghi}	1.43^{abcd}	1.43^{bcd}	276.67^{cdefg}
W3V1N3	67.80^{jklm}	72.30^{hij}	1.43^{abcd}	0.77^{abc}	284.33^{cdef}
W3V2N0	70.00^{hijklm}	70.40^{efghi}	0.83^{fg}	1.43^{abcd}	243.00^{ij}
W3V2N1	76.23^{fgh}	75.80^{def}	0.90^{defg}	0.77^{d}	249.67^{ghi}
W3V2N2	75.73^{fghi}	79.13^{cd}	0.67^{g}	0.93^{cd}	269.00^{defg}
W3V2N3	79.60^{efg}	83.90^{cd}	1.30^{abcdef}	0.80^{d}	302.67^{bcd}
LSD	6.511	6.67	0.465	0.601	33.96
SE±	2.270	2.325	0.159	0.21	11.84
CV%	5.10	5.09	22.12	26.29	7.37

Means within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple

4.2 Yield and yield components

4.2.1 Spike length (cm)

The analysis of variance indicated that fertilizer levels had highly significant differences in spike length in the second season only (Table 9). In the second season application of 129 kg nitrogen per hectare gave 9% greater spike length over the control, on the other hand, there were no significant differences between the application of 86 and 129 kg/ha and between 43 kg and control (Table 10).

There were no significant differences between irrigation intervals and wheat varieties in spike length in both seasons (Table 9). interaction of fertilizer levels X wheat varieties X irrigation intervals had highly significant difference (P= 0.01) in spike length in both seasons (Table 9).

4.2.2 Number of grains/ spike

The statistical analysis showed that nitrogen fertilizer had highly significant effect (P = 0.01) on number of grains per spike in both seasons (Table 9).

Application of 129 kg N/ha gave 13 and 14% greater number of grains per spike over control in the first and second seasons, respectively. In the first season there were no significant differences in number of grains/spike between 43 and 86 kg N/ha. In the second season there were no significant differences in number of grains/spike between 43 and 86 and between 86 kg N/ha and control (Table 10).

Wheat varieties had highly significant effect on number of grains per spike (P = 0.01) in the first season and significant effect (P= 0.05) in the second seasons (Table 9). Wadi Elneil variety gave 7% and 4% greater number of grains/ spike in the first and second seasons, respectively (Table 11).

There were no significant differences between irrigation intervals in number of grains/ spike in both seasons (Table 9).

There were no significant differences between treatments interaction in both season (Table 9).

4.2.3 Spike index

The statistical analysis showed that nitrogen levels had highly significant affect (P = 0.01) in spike index in both seasons (Table 9). In the first season application of 129 kg N/ha gave 10% greater spike index over control while application of 86 kg N/ha gave 11% greater spike index over control in the second season. On the other hand, there were no significant differences between the application of 43, 86 kg N/ha in the first season and between 43, 86 and 129 kg N/ha in the second season (Table 10).

There were no significant differences in spike index between irrigation intervals and wheat varieties (Table 9).

Interaction of nitrogen × irrigation intervals had significant differences (P = 0.05) in spike index in the first season only (Table 9).

4.2.4 Thousand grain weight (TGW)

The analysis of variance revealed that nitrogen had highly significant differences (P= 0.01) in thousand grain weight in both seasons (Table 9). The application of 129 kg nitrogen/ha gave 15% and 12% greater thousand grain weight over control in the first and second seasons, respectively; on the other hand, there were no significant differences between the application of 86 and 129 kg N/ha in both seasons (Table 10).

There were highly significant differences (P = 0.01) among wheat varieties in thousand grain weight in the first season only (Table 9). In the first season El Neilein gave 4% greater thousand grain weight compared to Wadi ElNeil (Table 11).

There were no significant differences between irrigation intervals in thousand grain weight in both seasons (Table 9).

There were no significant differences between treatment interactions in both seasons (Table 9).

4.2.5 Grain yield (t/ha)

The analysis of variance indicated that nitrogen had highly significant effect (P= 0.01) on grain yield of wheat in both seasons (Table 9). The application of 129 kg N/ha gave 40% and 44% greater yield over control in the first and second seasons, respectively, on the other hand, there were no significant differences between the application of 43 kg N/ha and control in the second season (Table 10).

There were highly significant differences (P= 0.01) between irrigation intervals on yield of wheat in both seasons (Table 9).

Irrigation intervals at 7 days gave 50% greater yield compared to irrigation interval at 21 days, in both seasons (Table 12).

There were highly significant differences (P = 0.01) among wheat varieties in yield in the second season only (Table 9).

In the second season wadi El Neil gave 21% greater yield than ELNeilein (Table 11).

Interaction of nitrogen X irrigation had significant differences (P = 0.05) in the second season, while interaction of nitrogen X varieties had significant effect on yield of wheat in the first season (Tables 13 and 14).

4.2.6 Biological yield (t/ha)

Statistical analysis showed that nitrogen had highly significant effect (P = 0.01) on biological yield in both seasons (Table 9).

Application of 129 kg N/ha gave 28% and 18% greater biological yield over control in the first and second seasons, respectively (Table 10).

There were significant differences (P= 0.01) in biological yield between irrigation intervals in both seasons (Table 9).

There were highly significant differences (P = 0.01) among wheat varieties in biological yield in the first season only (Table 9).

In the first season El Neilein had greater biological yield than Wadi ElNeil (10% increase) (Table 11).

Irrigation interval at 7 days gave 25% and 22% greater biological weight compared to irrigation interval at 21 days in the first and second seasons, respectively; on the other hand there were no significant differences between irrigation interval at 7 and 14 days in biological weight in the second season (Table 12).

Interaction of irrigation intervals X varieties had highly significant effect on biological yield in the second season only (Table 9). Also, interaction of nitrogen X irrigation X varieties had highly significant differences (P= 0.01) in biological yield in the first season but there were no significant differences in the second season, (Table 16).

4.2.7 Harvest index

The analysis of variance showed that nitrogen had highly significant differences in harvest index in both seasons (Table 9).

Application of 129 kg N/ha increased harvest index 25% and 20% over control in the first and second seasons, respectively, on the other hand, there were no significant differences between 43 kg N/ha and control and between 86 and 129 kg N/ha in the second season (Table10).

There were highly significant differences (P=0.01) among wheat varieties in harvest index in both seasons (Table 9).

Wadi El Neil increased harvest index 15% and 23% than El Neilein in the first and second seasons, respectively (Table 11).

There were significant differences (P = 0.05) between irrigation intervals in harvest index in both seasons (Table 9). Irrigation interval of 7 days increased harvest index 23% and 21% in comparison with irrigation at 21 days during the first and second seasons, respectively; on the other hand, there were no significant differences between irrigation at 7 days and 14 days and between 14 days and 21 days in harvest index in both seasons (Table 12).

Interaction of nitrogen X varieties had significant effect (P= 0.05) on harvest index in the first season only (Table 9), while interaction of irrigation intervals X varieties gave significant differences in harvest index in the second season only (Table 9).

4.2.8 Water use efficiency parameters

4.2. 8.1 Drought tolerant index (DTI)

The analysis of variance showed that there were no significant differences between nitrogen levels on drought tolerant index in both seasons (Table 18).

The statistical analysis also showed no significant differences among wheat varieties on drought tolerant index in both seasons (Table19).

There were no significant differences between treatment interactions on drought tolerant index in both seasons (Table20).

4.2.8.2 Stress susceptibility index

The analysis of variance showed that nitrogen had not affected stress susceptibility index in both seasons (Table18).

There were no significant differences among wheat varieties on stress susceptibility index in both seasons (Table 19).

There were no significant differences between nitrogen and varieties interaction in both seasons (Table 20).

4.2.8.3 Stress tolerance index

The analysis of variance revealed that there were highly significant differences (P=0.01) between nitrogen levels on stress tolerance index in both seasons (Table17). The application of 129 kg N/ha gave greater stress tolerance index in both seasons (Table18).

There were significant differences among wheat varieties in stress tolerance index in the second season only (Table 19).

Interaction of nitrogen and varieties showed no significant differences in stress tolerance index in both seasons (Table 20).

Table (9): F- value of the yield and yield components parameters for the treatments and their interactions in (2013/2014 and 2014/ 2015) seasons

Sources of variation	Spike length		Grain number/ spike		Spike index	
	First season	Second season	First season	Second season	First season	Second season
W	0.22 ns	0.37 ns	3.95ns	1.48ns	0.71ns	0.41ns
V	1.38 ns	1.14 ns	21.23**	5.83*	4.52ns	2.89ns
W×V	4.09 ns	3.02 ns	0.34ns	2.46ns	1.76ns	1.78ns
N	0.58 ns	5.17**	36.92**	7.79***	12.52**	9.07**
W×N	0.48 ns	0.45 ns	1.04ns	1.62ns	3.16*	0.37ns
V×N	1.97 ns	1.19 ns	2.41ns	0.52ns	0.93ns	0.65ns
W×V×N	3.46**	4.99**	1.18ns	1.96ns	0.77ns	0.14ns
CV%	5.44%	6.57%	3.49	8.17	4.87%	6.65%

* = Significant 5% level (Significant).

** = Significant at 1% level (highly Significant).

ns = not Significant.

Table (9) Cont….:

Sources of variation	TGW		Grain yield (t/ha)		Biological yield (t/ha)	
	First season	Second season	First season	Second season	First season	Second season
W	5.27^{ns}	2.69^{ns}	40.581**	50.72**	234.56**	59.71**
V	17.82**	0.91^{ns}	4.58^{ns}	38.59**	26.54**	4.98^{ns}
W×V	2.05^{ns}	0.83^{ns}	0.48^{ns}	4.55^{ns}	0.500 ^{ns}	18.52**
N	30.09**	4.60**	71.87**	54.26**	153.18**	38.27**
W×N	0.80^{ns}	1.09^{ns}	1.28^{ns}	2.53*	1.56^{ns}	0.82^{ns}
V×N	1.39^{ns}	0.18^{ns}	3.81*	1.31^{ns}	0.52^{ns}	1.59^{ns}
W×V×N	0.80^{ns}	0.65^{ns}	0.23^{ns}	0.52^{ns}	4.51**	0.07^{ns}
CV%	4.77	9.17%	9.04%	9.33%	3.71%	4.89%

* = Significant 5% level (Significant).

** = Significant at 1% level (highly Significant).

^{ns} = not Significant.

**Table (10): Effect of nitrogen levels on yield and yield components parameters of whe
2014/2015) seasons**

Treatments	Spike length (cm)		Grain number/spike		Spike index (%)	
	First season	Second season	Second season	Second season	First season	Second season
0N	6.98[a]	6.99[b]	34.22[c]	33.39[c]	60.84[c]	59.79[b]
1N	6.82[a]	6.89[b]	36.33[b]	36.11[ab]	64.44[b]	64.53[a]
2N	7.22[a]	7.55[a]	37.11[b]	35.00[bc]	65.92[ab]	66.38[a]
3N	6.85[a]	7.59[a]	38.61[a]	37.94[a]	66.79[a]	66.01[a]
LSD	0.245	0.331	0.863	1.968	2.125	2.89
SE±	0.085	0.115	0.301	0.686	0.741	1.001
CV%	5.19	7.04	3.49	8.17	4.87	6.65

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (10 Cont…)

Treatments	Yield (t/ha)		Biological yield (t/ha)		Ha
	First season	Second season	First season	Second season	First seas
0N	2.97^{d}	3.09^{c}	10.33^{d}	10.99^{d}	27.77^{c}
1N	3.63^{c}	3.39^{c}	11.09^{c}	11.70^{c}	30.98^{b}
2N	4.01^{b}	3.88^{b}	12.23^{b}	12.34^{b}	32.13^{b}
3N	4.16^{a}	4.46^{a}	13.22^{a}	12.99^{a}	34.82^{a}
LSD	0.35	0.36	0.44	0.59	2.60
SE±	0.12	0.13	0.15	0.21	0.91
CV%	9.04	9.33	3.71	4.89	8.17

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (11): Effect of varieties on yield and yield components parameters of wheat in (201 seasons

Treatments	Spike length (cm)		Grain number/ spike		Spike index (%)	
	First season	Second season	First season	Second season	First season	Second season
V1	6.844[a]	6.942[a]	37.89[a]	36.39[a]	63.48[a]	63.48[a]
V2	6.997[a]	7.056[a]	35.25[b]	34.83[b]	65.52[a]	64.87[a]
LSD	0.112…	0.101….	1.41	1.58	2.36	2.01
SE±	0.091	0.075	0.405	0.456	0.679	0.577
CV%	5.19	7.04	3.49	8.17	4.87	6.65

Mean within column flowed by the seam letter(s) were not significantly different according to Duncan's Multiple R

Table (11) Cont….

Treatments	Grain yield (t/ha)		Biological yield (t/ha)		Ha
	First season	Second season	First season	Second season	First seas
V1	3.95[a]	4.05[a]	11.15[b]	11.89[a]	33.61[a]
V2	3.66[a]	3.36[b]	12.28[a]	12.13[a]	29.25[b]
LSD	0.341	0.271	0.54	0.255	1.93
SE±	0.18	0.08	0.16	0.07	0.56
CV%	9.04	9.33	3.71	4.89	8.17

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (12): Effect of irrigation intervals on yield and yield components parameters of wh 2014/2015) seasons

Treatments	Spike length (cm)		Grain number/ spike		Spike index (%)	
	First season	Second season	First season	Second season	First season	Second season
W1	7.071[a]	7.891[a]	37.46[a]	36.38[a]	64.04[a]	64.23[a]
W2	6.917[a]	6.987[b]	36.04[c]	35.75[b]	65.53[a]	63.83[a]
W3	6.913[a]	6.888[b]	36.21[b]	34.71[c]	63.94[a]	64.48[a]
LSD	0.871	0.6373	0.152	0.278	14.140	3.430
SE±	0.222	0.1623	0.389	0.692	1.054	0.873
CV%	5.19	7.04	3.49	8.17	4.87	6.65

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (12) Cont:

Treatments	Grain yield (t/ha)		Biological yield		F
	First season	Second season	First season	Second season	First seas
W1	4.56[a]	4.42[a]	12.93[a]	13.00[a]	34.83[a]
W2	3.82[b]	3.76[b]	11.89[b]	12.38[a]	31.12[ab]
W3	3.04[c]	2.94[c]	10.34[c]	10.64[b]	28.33[b]
LSD	0.47	0.41	0.33	0.62	4.335
SE±	0.12	0.10	0.85	0.12	1.107
CV%	9.04	9.33	3.71	4.89	8.17

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (13): Effect of interaction between nitrogen levels and irrigation interval on yield an wheat in (2013/2014 and 2014/2015) seasons

Treatments	Spike length (cm)		Grain number/spike		Spike index (%)	
	First season	Second season	First season	Second season	First season	Second season
W1N0	7.00[ab]	7.03[a]	36.00[e]	33.00[cd]	56.90[d]	59.78[b]
W1N1	6.92[ab]	6.82[a]	37.00[bcde]	37.67[ab]	64.22[abc]	66.32[a]
W1N2	7.25[a]	7.00[a]	37.83[abcd]	36.33[abc]	66.72[ab]	66.10[a]
W1N3	7.12[ab]	6.93[a]	39.00[a]	38.50[a]	68.32[a]	66.22[a]
W2N0	7.12[ab]	7.05[a]	33.17[f]	35.33[abcd]	63.35[bc]	59.53[b]
W2N1	6.62[b]	7.08[a]	36.00[e]	34.17[bcd]	64.21[abc]	64.10[ab]
W2N2	7.30[a]	6.83[a]	36.67[de]	34.50[bcd]	67.00[ab]	65.73[a]
W2N3	6.63[b]	6.98[a]	38.33[abc]	39.00[a]	67.53[ab]	64.80[ab]
W3N0	6.82[ab]	6.90[a]	33.50[f]	31.83[d]	62.28[c]	60.07[b]
W3N1	6.93[ab]	6.78[a]	36.00[e]	36.50[abc]	64.90[abc]	63.18[ab]
W3N2	7.10[ab]	7.00[a]	36.83[cde]	34.17[bcd]	64.05[abc]	67.32[a]
W3N3	6.80	6.95[a]	38.50[ab]	36.33[abc]	64.52[abc]	67.00[a]
LSD	0.511	0.5724	1.495	3.408	3.681	4.998
SE±	0.085	0.120	0.521	1.188	1.283	1.742
CV%	5.19	7.04	3.49	8.17	4.87	6.65

Table (13) Cont….

Treatments	Grain yield (t/ha)		Biological yield (t/ha)		Ha
	First season	Second season	First season	Second season	First seas
W1N0	3.52^{de}	3.58^{cd}	11.25^{de}	11.70^{de}	31.18^{c}
W1N1	4.58^{b}	3.97^{c}	12.22^{c}	12.74^{bc}	36.37^{a}
W1N2	4.72^{b}	4.63^{b}	13.69^{b}	13.50^{a}	34.54^{al}
W1N3	5.43^{a}	5.48^{a}	14.57^{a}	14.08^{a}	37.25^{a}
W2N0	3.02^{fg}	3.20^{def}	10.74^{e}	11.31^{ef}	26.69^{d}
W2N1	3.53^{de}	3.41^{de}	11.24^{de}	12.09^{cd}	30.10^{c}
W2N2	4.08^{c}	3.94^{c}	12.22^{c}	12.74^{bc}	32.29^{b}
W2N3	4.65^{b}	4.49^{b}	13.34^{b}	13.39^{ab}	35.49^{a}
W3N0	2.38^{h}	2.48^{g}	9.00^{g}	9.95^{h}	25.45^{e}
W3N1	26.58^{de}	27.43^{de}	9.82^{f}	10.33^{gh}	2.76^{gh}
W3N2	29.57^{cd}	28.30^{de}	10.78^{e}	10.79^{fg}	3.25^{ef}
W3N3	31.71^{bc}	29.59c^{de}	11.75^{cd}	11.50^{def}	3.75^{cd}
LSD	3.01	3.695	0.509	0.687	0.402
SE±	1.05	1.288	0.145	0.239	0.140
CV%	8.17	10.31	3.71	4.89	9.04

Mean within column flowed by the same letter(s) were not significantly different according to Duncan's Multiple R

Table (14): Effect of interaction between nitrogen levels and varieties on yield and yield co (2013/2014 and 2014/2015) seasons

Treatments	Spike length (cm)		Grain number/spike		Sp
	First season	Second season	First season	Second season	First seas
V1N0	6.91^{abc}	6.78^{a}	35.00^{c}	34.22^{bcd}	60.56^{c}
V1N1	6.81^{bc}	6.90^{a}	37.78^{b}	36.67^{ab}	63.30^{bc}
V1N2	7.14^{ab}	6.91^{a}	39.00^{a}	36.44^{abc}	65.22^{b}
V1N3	6.60^{c}	6.80^{a}	39.78^{a}	38.22^{a}	64.83^{b}
V2N0	7.04^{ab}	7.21^{a}	33.44^{d}	32.56^{d}	61.13^{c}
V2N1	6.83^{bc}	6.89^{a}	34.89^{c}	35.56^{abcd}	65.59^{ab}
V2N2	7.29^{a}	6.98^{a}	35.22^{c}	33.56^{cd}	66.62^{ab}
V2N3	7.10^{ab}	7.11^{a}	37.44^{b}	37.67^{a}	68.74^{a}
LSD	0.346	0.465	1.221	2.783	3.005
SE±	0.121	0.163	0.426	1.188	1.283
CV%	5.19	7.04	3.49	8.17	4.87

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple F

Table (14) Cont…:

Treatments	TGW		Grain yield (t/ha)		Biological yield	
	First season	Second season	First season	Second season	First season	Second season
V1N0	33.78[de]	34.56[ab]	3.00[d]	3.50[c]	9.83[e]	11.12[e]
V1N1	37.00[bc]	36.55[ab]	3.63[c]	3.73[c]	10.46[d]	11.52[d]
V1N2	39.11[a]	37.11[a]	4.24[b]	4.29[b]	11.60[c]	12.08[c]
V1N3	39.44[a]	37.78[a]	4.95[a]	4.68[a]	12.71[b]	12.85[ab]
V2N0	33.56[e]	33.33[b]	2.94[d]	2.68[c]	10.83[d]	10.85[e]
V2N1	35.33[cd]	35.44[ab]	3.62[c]	3.06[d]	11.72[c]	11.92[c]
V2N2	36.56[bc]	36.67[ab]	3.79[c]	3.47[c]	12.86[b]	12.60[b]
V2N3	38.22[ab]	38.00[a]	4.29[b]	4.25[b]	13.72[a]	13.12
LSD	1.670	3.174	0.328	0.331	0.416	0.331
SE±	0.856	1.288`	0.115	0.116	0.145	0.116
CV%	8.17	10.31	9.04	9.33	3.71	4.89

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple R

Table (15): Effect of interaction between irrigation interval and varieties on yield and yield c parameters of wheat in (2013/2014 and 2014/2015) seasons

Treatment	Spike length (cm)		Grain number/spike		
	First season	**Second season**	**First season**	**Second season**	**First**
W1V1	6.84^{a}	6.71^{a}	39.08^{a}	38.00^{a}	61
W1V2	7.30^{a}	7.18^{a}	38.83^{bc}	34.75^{b}	66
W2V1	7.77^{a}	6.87^{a}	37.08^{abc}	36.58^{ab}	64
W2V2	7.07^{a}	7.11^{a}	35.00^{bc}	34.92^{b}	66
W3V1	6.99^{a}	6.97^{a}	37.50^{ab}	34.58^{b}	64
W3V2	6.83^{a}	6.86^{a}	34.92^{c}	34.83^{b}	63
LSD	0.308	0.477	2.427	2.731	4.
SE±	0.105	0.138	0.701	0.789	1.
CV%	5.19	7.07	3.49	8.17	4

Table (15) Cont…

Treatment	TGW		Grain yield (t/ha)		Biological yield (t/ha)	
	First season	Second season	First season	Second season	First season	Second season
W1V1	38.83^{a}	37.83^{a}	4.61^{a}	5.00^{a}	12.33^{b}	12.80^{a}
W1V2	36.58^{bc}	36.00^{a}	4.51^{a}	3.84^{b}	13.53^{a}	13.21^{a}
W2V1	37.08^{b}	36.33^{a}	4.02^{ab}	3.97^{b}	11.21^{c}	11.94^{b}
W2V2	35.67^{bc}	36.50^{a}	3.62^{bc}	3.55^{bc}	12.57^{b}	12.83^{a}
W3V1	36.08^{bc}	35.33^{a}	3.23^{cd}	3.18^{c}	9.92^{d}	10.95^{c}
W3V2	35.50^{c}	35.08^{a}	2.85^{d}	2.70^{d}	10.75^{cd}	10.33^{d}
LSD	1.423	2.838	0.587	0.468	0.932	0.404
SE±	0.411	0.820	0.169	0.135	0.269	0.127
CV%	4.77	9.17	9.04	9.33	3.71	4.89

Mean within column flowed by the seam letter (s) were not significantly different according t Duncan's Multiple R

Table (16): Effect of interaction between nitrogen levels, irrigation interval and varieti components parameters of wheat in (2013/2014 and 2014/2015) seasons

Treatments	Spike length (cm)		Grain number /Spike		Sp
	First season	Second season	First season	Second season	First seas
W1V1N0	6.73^{bcd}	6.70^{bcd}	36.33^{fgh}	37.00^{abc}	54.13^{f}
W1V1N1	6.77^{bcd}	6.90^{bcd}	39.33^{bcd}	37.00^{abc}	61.40^{de}
W1V1N2	7.17^{abcd}	6.63^{bcd}	40.00^{bc}	39.00^{ab}	65.73^{abc}
W1V1N3	6.70^{bcd}	6.60^{bcd}	40.67^{b}	39.00^{ab}	66.37^{abc}
W1V2N0	7.27^{abc}	7.37^{ab}	35.67^{fgh}	29.00^{e}	59.67^{e}
W1V2N1	7.07^{abcd}	7.73^{a}	34.67^{hi}	38.33^{ab}	67.03^{abc}
W1V2N2	7.33^{ab}	7.37^{ab}	35.67^{fgh}	33.67^{abcde}	67.70^{ab}
W1V2N3	7.53^{a}	7.27^{abc}	37.33^{defg}	38.00^{ab}	70.27^{a}
W2V1N0	7.00^{abcd}	6.70^{bcd}	34.33^{hi}	35.33^{abcd}	64.43^{abc}
W2V1N1	6.57^{cd}	6.87^{abcd}	36.67^{efgh}	36.33^{abc}	63.33^{bc}
W2V1N2	7.00^{abcd}	6.83^{abcd}	38.00^{cdef}	35.33^{abcd}	65.67^{abc}
aW2V1N3	6.50^{d}	7.07^{abc}	39.33^{bcd}	39.33^{a}	64.60^{abc}
W2V2N0	7.23^{abc}	7.40^{ab}	32.00^{j}	35.33^{abcd}	62.27^{bc}
W2V2N1	6.67^{bcd}	7.30^{ab}	35.33^{gh}	32.00^{cde}	65.100^{ab}
W2V2N2	7.60^{a}	6.83^{abcd}	35.33^{ch}	33.67^{abcde}	68.33^{ab}
W2V2N3	6.77^{bcd}	6.90^{abcd}	37.33^{defg}	38.67^{ab}	70.47^{a}
W3V1N0	7.00^{abcd}	6.93^{abcd}	34.33^{hi}	30.33^{e}	63.10^{bc}
W3V1N1	7.10^{abcd}	6.93^{bcd}	37.33^{defg}	36.67^{abc}	65.17^{abc}
W3V1N2	7.27^{abc}	7.27^{ab}	39.00^{bcde}	35.00^{abcd}	64.27^{abc}
W3V1N3	6.60^{cd}	6.73^{bcd}	39.33^{a}	36.33^{abc}	63.53^{bc}
W3V2N0	6.63^{bcd}	6.87^{bcd}	32.67^{ij}	33.33^{bcde}	61.47^{cd}
W3V2N1	6.77^{bcd}	6.63^{bcd}	34.67^{hi}	36.33^{abc}	64.63^{abc}

W3V2N2	6.93^{abcd}	6.73^{bcd}	34.67^{hi}	33.33^{bcde}	63.83^{bc}
W3V2N3	7.00^{abcd}	7.17^{abcd}	37.67^{cdefg}	36.33^{abc}	65.50^{abc}
LSD	0.346	0.818	2.114	4.80	5.205
SE±	0.121	0.283	0.737	1.680	1.815
CV%	5.19	7.04	3.49	8.17	4.87

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple R

Table (16) Cont…

Treatments	TGW		Grain yield (t/ha)		Biological weight	
	First season	Second season	First season	Second season	First season	Second season
W1V1N0	35.67^{def}	35.00^{ab}	3.37^{hijk}	4.30^{cde}	10.58^{jkl}	11.77^{efghi}
W1V1N1	38.33^{abcd}	38.33^{ab}	4.48^{cde}	4.53^{cd}	11.30^{hij}	12.30^{cdefg}
W1V1N2	40.33^{ab}	38.67^{ab}	4.93^{bc}	5.37^{a}	13.07^{cd}	13.13^{abcd}
W1V1N3	41.00^{a}	39.33^{ab}	5.67^{a}	5.78^{a}	14.37^{ab}	13.99^{a}
W1V2N0	34.33^{ef}	32.67^{b}	3.67^{fghi}	2.87^{ijklm}	11.92^{fgh}	11.63^{fghij}
W1V2N1	36.33^{cdef}	35.67^{ab}	4.67^{bcd}	3.41^{ghij}	13.13^{cd}	13.17^{abcd}
W1V2N2	38.00^{abcd}	35.00^{ab}	4.50^{cde}	3.90^{defg}	14.32ab	13.87^{ab}
W1V2N3	37.67^{abcde}	40.67^{a}	5.20^{ab}	5.18^{ab}	14.77^{a}	14.17^{a}
W2V1N0	34.00^{ef}	33.33^{b}	3.17^{ijkl}	3.50^{ghi}	10.07^{kl}	11.17^{hijk}
W2V1N1	37.33^{bcde}	37.67^{ab}	3.57^{ghij}	3.58^{fgh}	10.28^{kl}	11.63^{fghij}
W2V1N2	38.67^{abcd}	35.33^{ab}	4.28^{def}	4.17^{cdef}	11.54^{ghi}	12.13^{defgh}
W2V1N3	38.00^{abcd}	39.00^{ab}	5.07^{bc}	4.62^{bc}	12.93^{de}	12.81^{bcde}
W2V2N0	33.00^{fg}	33.33^{b}	2.87^{klmn}	2.90^{ijklm}	11.41^{hi}	11.46^{fghijk}
W2V2N1	35.33^{def}	36.00^{ab}	3.50^{ghijk}	3.23^{hijk}	12.20^{efg}	12.56^{cdef}
W2V2N2	36.00^{cdef}	38.67^{ab}	3.87^{efgh}	3.70^{efgh}	12.90^{de}	13.35^{abc}
W2V2N3	38.33^{abcd}	38.00^{ab}	4.23^{def}	4.37^{cd}	13.75^{bc}	13.97^{a}
W3V1N0	31.33^{g}	35.33^{ab}	2.47^{mn}	2.70^{klm}	8.83^{n}	10.43^{klm}
W3V1N1	35.33^{def}	33.67^{b}	2.85^{klmn}	3.07^{hijkl}	9.80l^{m}	10.63^{jkl}
W3V1N2	38.33^{abcd}	37.33^{ab}	3.50^{ghijk}	3.33^{ghijk}	10.19^{kl}	10.98^{ijkl}
W3V1N3	39.33^{abc}	35.00^{ab}	4.10^{defg}	3.63^{fgh}	10.85^{ijk}	11.75^{efghi}
W3V2N0	33.33^{fg}	34.00^{b}	2.30^{n}	2.27^{m}	9.17^{mn}	9.47^{m}
W3V2N1	34.33^{ef}	34.67^{ab}	2.70^{lmn}	2.53l^{m}	9.83l^{m}	10.03l^{m}
W3V2N2	35.67^{def}	36.33^{ab}	3.00^{jklm}	2.80^{jklm}	11.37^{hi}	10.59^{jkl}

W3V2N3	38.66^{abcd}	35.33^{ab}	3.40^{hijk}	3.20	12.56^{def}	11.24^{ghijk}	2
LSD	2.892	5.497	0.569	0.574	0.728	0.971	
SE±	1.008	1.917	0.198	0.200	0.251	0.339	
CV%	4.77	9.17	9.04	9.33	3.71	4.89	

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple I

Water use efficiency

Drought tolerance indices (DTI); results in form of tolerance indices (TOI), stress susceptibility indices (SSI) and stress tolerance index(STI) were presented in Tables 17, 18 ,19 and 20 for seasons 2013/14-2014/15. The analysis of variance showed that there were no significant differences between nitrogen levels on tolerant indices and stress stability indices in both seasons (Table 18). The statistical analysis also showed no significant differences among wheat varieties on tolerant indices and stress stability index in both seasons (Table 19). There were no significant differences between treatment interactions on tolerant index and stress stability in both seasons (Table 20).

The analysis of variance revealed that there were highly significant differences (P=0.01) between nitrogen levels on stress tolerance index in both seasons (Table 17). The application of 129 kg N/ha gave greater stress tolerance index in both seasons (Table 17).There were significant differences among wheat varieties in stress tolerance index in the second season only (Table 17). Interaction of nitrogen and varieties showed no significant differences in stress tolerance index in second season (Table17).

Table (17): F values of water use efficiency parameters

Parameters	Drought tolerant index (DTI)		Stress susceptibility index (SSI)		Stress tolerance index (STI)	
	First season	**Second season**	**First season**	**Second season**	**First season**	**Second season**
N	0.392^{ns}	0.943^{ns}	0.328^{ns}	1.77^{ns}	69.45^{**}	73.01^{**}
V	0.139^{ns}	2.046^{ns}	0.408^{ns}	0.171^{ns}	0.826^{ns}	25.01^{*}
NV	0.142^{ns}	0.686^{ns}	0.044^{ns}	0.290ns	3.59^{*}	1.00ns
CV%	12.77	17.02	32.30	40.81	10.55	9.06

* = Significant 5% level (Significant).

** = Significant at 1% level (highly Significant).

ns = not Significant.

Table (18): Effect of nitrogen on water use efficiency component

Parameters	Drought tolerant index (DTI)		Stress susceptibility index (SSI)		Stress tolerance index (STI)	
	First season	Second season	First season	Second season	First season	Second season
N0	0.67[a]	0.72[a]	0.96[a]	1.06[a]	1.75[d]	2.06[d]
N1	0.63[a]	0.71[a]	1.09[a]	0.69[a]	2.70[c]	2.56[c]
N2	0.67[a]	0.65[a]	0.92[a]	1.03[a]	3.29[b]	3.27[b]
N3	0.67[a]	0.63[a]	0.97[a]	0.92[a]	4.33[a]	4.27[a]
LSD	0.47	1.26	0.40	0.47	0.40	0.40
SE	0.34	0.047	0.130	0.154	0.130	0.112
CV%	12.77	17.02	32.30	40.81	10.55	9.06

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple Range test at 5% level.

Table (19): Effect of varieties on water use efficiency component

Parameters	Drought tolerant index (DTI)		Stress susceptibility index (SSI)		Stress tolerance index (STI)	
	First season	Second season	First season	Second season	First season	Second season
V1	0.67[a]	0.64[a]	0.97[a]	0.91[a]	3.21[a]	3.66[a]
V2	0.65[a]	0.72[a]	1.00[a]	0.94[a]	2.83[a]	2.42[b]
LSD	0.14	0.14	0.06	0.10	0.75	0.43
SE	0.039	0.041	0.029	0.041	0.294	0.176
CV %	12.77	17.02	32.30	40.80	10.55	9.06

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple Range test at 5% level.

Table (20): Effect of nitrogen and varieties interaction on water use efficiency

Parameters	drought tolerant index (DTI)		Stress susceptibility index (SSI)		Stress tolerance index (STI)	
	First season	Second season	First season	Second season	First season	Second season
V1N0	0.70[a]	0.63[a]	0.92[a]	1.10[a]	1.62[d]	2.64[cd]
V1N1	0.63[a]	0.69[a]	1.12[a]	0.60[a]	2.83[c]	3.15[c]
V1N2	0.68[a]	0.59[a]	0.90[a]	1.11[a]	3.61[b]	4.06[b]
V1N3	0.68[a]	0.63[a]	0.95[a]	0.84[a]	4.78[a]	4.81[a]
V2N0	0.64[a]	0.81[a]	1.00[a]	1.02[a]	1.87[d]	1.48[f]
V2N1	0.63[a]	0.74[a]	1.07[a]	0.78[a]	2.58[c]	1.97[ef]
V2N2	0.67[a]	0.71[a]	0.93[a]	0.95[a]	2.98[c]	2.48d[e]
V2N3	0.65[a]	0.63[a]	0.99[a]	0.99[a]	3.89[b]	3.74[b]
LSD	0.67	1.79	0.56	0.66	9.06	0.55
SE	0.049	0.067	0.184	0.218	0.184	0.159
CV%	12.77	17.02	32.30	40.81	10.55	9.56

Mean within column flowed by the same letter (s) were not significantly different according to Duncan's Multiple Range test at 5% level.

CHAPTER FIVE

DISCUSSION

Like some other crops, if wheat is subjected to many biotic and abiotic stresses, yield will be reduced. The abiotic stresses include drought, heat, water logging, soils and soils with toxic levels of boron. All of these can pose serious problem for wheat farmer, especially in the less favored growing environment. In high terrace soil of Dongla area, where wheat is a very important crop, intensive research should be carried out to improve technical package for high production of wheat.

To study the effect of application of nitrogen and watering stress during post anthesis stage on wheat in this area, an experiment was conducted for two consecutive seasons (2013/14-2014/15). Most of growth attributes showed significant differences to nitrogen levels in both seasons. Nitrogen significantly affected plant height in both seasons, application of 129 kg N/ha gave greater plant height in both seasons. Nitrogen promotes vegetative growth of plants and increases number of nodes and internodes per plant and subsequently increases plant height. This result is similar to that reported by Sharma *et al* (1970), Singh (1987) showed that increasing nitrogen levels significantly increased plant height..

Wheat varieties showed significant differences in plant height in the first season and no significant differences in the second season. This variation may be due to genetic variation between the two wheat cultivar. Similar results were observed by Warren (2000), Rashid *et al* (2004) who showed significant differences between wheat cultivars for plant height.

Irrigation intervals showed significant differences in plant height in both seasons, irrigation interval at seven days gave greater plant height in both seasons. Similar results were found by Hailal and Melegy (2005), Elhawary,

(2011) Yagoub *et al*.,(2012) and Eltony (2016), who reported that shorter irrigation interval gave taller plant.

In this study, nitrogen fertilizer had highly significant differences in number of tillers per meter square in both seasons. Application of 129 kg N/ha gave greater number of tillers per meter square in both seasons. Nitrogen enhances vegetative growth and increases number of branches and tillers per meter square and per plant. Similar results were obtained by Sharma *et al* (1970), Singh (1987) who showed that nitrogen levels significantly increased the number of effective tillers.

Wheat varieties did not differ in number of tillers per meter square in both seasons. This result was in contrast with that reported by Tshag (1996), Carr *et al* (2003) and Nader Khan *et al* (2004) who reported significant differences between cultivars in number of tillers.

Irrigation interval had significant differences in the first season and highly significant differences in the second season. Irrigation interval of seven days gave greater number of tillers per meter square in both seasons. Yagoub *et al*., (2012) and Maqbool *et al*., (2015) agreed with the above results and showed that water stress significantly reduced plant height, number of total tillers per plant, number of fertile tillers per plant, number of nodes per plant, number of spikelets per spike, number of grains per spike, 100-grain weight and dry matter per plant as compared with control. In contrast, Rauf *et al*. (2006) Akram *et al*. (2004), Jaleel *et al*. (2008) and Mirbahar *et al*. (2009) reported that skipping irrigation at different crop growth stages does not significantly affect the spike length of the different varieties of wheat.

In this study, nitrogen levels significantly affected leaf area index in the second season but there were no significant differences in the first season. Nitrogen increased number of leaves and total leaf area and subsequently increased leaf area index. Similar results were observed by Akasha (1972) who showed that nitrogenous fertilizer gave the best response and variation in leaf area.

Wheat varieties differed in leaf area index in both seasons. Wadi El Neil variety gave higher leaf area index in both seasons. This variation could be due to genetic variation among wheat varieties.

In this study, irrigation intervals affected leaf area index in both seasons. Irrigation interval at seven days gave higher leaf area index in both seasons.

5.2 Yield and yield components

Nitrogenous fertilizers have long been recognized as a key to improving crop yields and economic returns **(**Mosier *et al*, 2001**).** In this study**,** nitrogen levels had highly significant differences in spike length in the second season only. Similar results were found by Sharma *et al*. (1970); Singh (1987); they showed that increasing nitrogen levels significantly increased spike length.

Irrigation intervals and wheat varieties were not affected in spike length in both seasons**.** These results were in contrast with Naseri *et.al.*, (2010) who found that grain yield and its components were significantly different among cultivars due to the effect of different levels of irrigation at different growth stages.

In this study, nitrogen levels significantly affected number of grains/spike in both seasons. This result was in line with that found by Sharma *et al*. (1970); Singh (1987**)** who showed that increasing nitrogen levels significantly increased number of grains/spike.

Wheat varieties significantly affected number of grains/spike in both seasons. Similarly, Tshag (1993), Carre *et al* (2003), Nader Khan *et al* (2004) they showed that significant variation was observed among different wheat genotypes for number of grains per spike. Similar results were observed by Carr (203), Nader Khan *et al* (2004) and Rashid *et al* (2004) who showed that grain yield and its components were significantly different among cultivars.

Irrigation intervals affected significantly number of grains/ spike in both seasons. Irrigation interval of seven days gave greater number of grains/ spike in both seasons.

In this study, nitrogenous fertilizers had highly significant differences in spike index in both seasons.

Irrigation intervals and wheat varieties affected spike index.

In this study, nitrogen levels had highly significant differences in thousand seed weight in both seasons. Application of 129 kg N/ha gave greater thousand seed weight in both seasons.

Wheat varieties had highly significant effect on thousand seed weight in the first season only. Similar results were observed by Gobbet and Warren (2000), Carr *et al* (2003), Nader Khan *et al* (2004), Rashid *et al* (2004) and Naseri *et al* (2010) who showed that significant differences were observed between cultivars in thousand seed weight.

There were no significant differences between irrigation intervals in thousand seed weight in both seasons. This result was in contrast with that reported by Reddy and Bhardwaj (1983) who showed that thousand grain weight increased significantly by irrigation intervals.

In this study, nitrogen fertilizer had highly significant effect on yield of wheat in both seasons. Application of 129 kg N/ha gave higher yield in both seasons. This result was similar to that reported by Eppllin (1998), Grant and

Baily (1998), Hotsonyame and Hunt (1998), Nehra Ajitetetal (2001), Singh and Sharma (2001), Mohammad *et al* (2003) and Ali (2007) who showed that yield increased significantly with increase of nitrogen rate.

Wheat varieties differ in grain yield in the second season only. Similar results were observed by Ibrahim (1993), Gobbet and Warren (2000), Carr *et al* (2003), Nader Khan *et al* (2004), Rashid *et al* (2004) and Naseri *et al* (2010). They showed that grain yield and its components were significantly different among cultivars.

Irrigation intervals had highly significant differences in yield in both seasons. Irrigation interval of seven days gave higher yield in both seasons, while there were no significant differences between irrigation intervals of 14 and 21 days in yield in both seasons. Similar results were observed by Koshata and Raghn (1983), France and Schultz (1984) who showed that frequent irrigation increased grain yield and weight. Karrou, (2015), revealed that grain yield might be reduced under induced water stress because of reduction in translocation from the leaves, and as water stress hastens the maturation and in addition to that decrease in photosynthesis caused lower grain yield.

In this study, nitrogen had highly significant effect on biological yield in both seasons. Application of 129 kg N/ha gave higher biological yield in both seasons. Similar results were found by Akasha (1968) and Khalifa (1968). They showed that grain yield and straw yield increased significantly with increase in nitrogen levels. Pierre, (2008) found that, high N fertilization would increase the number of kernels.

Wheat varieties differ in biological yield in the first season only. Irrigation intervals had highly significant differences in biological yield in both seasons.

In this study, nitrogen levels had highly significant effect on harvest index in both seasons. Application of 129 kg N/ha increased harvest index in both seasons. Similar results were reported by Abdel Rahman (1997) who showed that harvest index significantly increase with increased of nitrogen rate.

Irrigation intervals significantly affected in harvested index in both seasons. Similar results were observed by Donald and Hamblina (1976), Passioura (1977) who showed that harvest index significantly differed between irrigation intervals.

Wheat varieties differ significantly in harvest index both seasons. Wadi El Neil cultivar increased harvest index than El Neilein in both seasons. Probably this variation was due to genetic variation among varieties. Beni, *et al*., (2012) reported genetic variability in response to nitrogen fertilization in the cultivars studied. On the other hand, Beni, *et al*., (2012) ensured that the highest increases in yield were observed under a more suitable water regime and the highest performance of yield components was associated with higher nitrogen fertilization levels. Lalelou and Fateh, (2016), reported that water deficit stress had adverse effects on yield of wheat genotypes and nitrogen fertilization had negligible potential to compensate the deteriorative effects of drought condition.

5.3 Water use efficiency

Results in form of tolerance indices (TOI), stress sustainability indices (SSI) and stress tolerance index (STI), showed no significant differences between nitrogen levels on tolerant indices and stress stability indices in both seasons. The statistical analysis also showed no significant differences among wheat varieties on tolerant indices and stress stability index in both seasons. There were no significant differences between treatment interactions on tolerant index and stress stability in both seasons.

The analysis of variance revealed that there were highly significant differences (P=0.01) between nitrogen levels on stress tolerance index in both seasons. There were significant differences among wheat varieties in stress tolerance index in the second season only. Interaction of nitrogen and varieties showed no significant differences in stress tolerance index in both seasons. Reported that SSI, TOI and STI with variable concordance values were found to be inaccurate indices to identified tolerant genotypes in durum wheat. However difference in yield potential could be caused by factors related to adaptation rather than to drought tolerance by itself (Golabadi *et al*.,2006). The effects of drought on yield of crops depend on their severity and the stage of plant growth during which they occur. Rauf *et al*., (2007), stated that seed germination is the first stage of growth that is sensitive to water deficit. Under semiarid regions, low moisture is often a limiting factor during germination. The rate and degree of seedling establishment are extremely important factors to determine both yield and time of maturity.

NUE parameters are high under low nitrogen levels and decrease with increasing nitrogen level. Decreased NUE at high the nitrogen is attributed to higher losses because the plant is unable to absorb all of nitrogen applied. Similar results were reported by Giambalvo *et al*., (2009) who indicated that nitrogen use efficiency decreased with the increase of nitrogen rate because the plants were unable to assimilate all of the nitrogen taken up.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

1. The increase in nitrogen levels significantly increased plant height and number of tillers per meter square in both seasons and leaf area index in the second season only.
2. Irrigation intervals affected all vegetative and reproductive growth characters in both seasons.
3. wheat genotypes differ significantly in leaf area index in both seasons and plant height in the first season.
4. There were no significant differences among wheat genotypes in number of tillers per meter square in both seasons.
5. Interaction of irrigation intervals and varieties had significant differences in plant height in the first season only.
6. Nitrogen levels significantly increased most of yield and yield components in both seasons which included number of grains/spike, spike index, thousand seed weight, yield, biological weight and harvest index and spike length in the second season.
7. Differences between irrigation intervals gave significant differences in yield, biological yield and harvest index.
8. Differences among wheat varieties gave significant differences in number of grains/spike and harvest index in both seasons and thousand seed weight and biological yield in the first season and yield in the second season.
9. There were highly significant differences between nitrogen, varieties and irrigation intervals in spike length in both seasons and between interaction of nitrogen levels and irrigation intervals in spike index and yield characters in the first and second seasons, respectively.

10. Differences between interaction of irrigation intervals and wheat varieties gave significant effect in biological yield and harvest index in the second season.
11. The increase in nitrogen levels significantly increased nitrogen use efficiency in both seasons and NUE decreased with the increase of nitrogen rates.

Recommendations

1. Nitrogen dose of 129 kg/ha increased significantly in yield of wheat, but in some economically cause the use of 86 kg/ha is more suitable.
2. Irrigation interval at seven days gave greater yield in comparison of irrigation intervals after 14 and 21 days.
3. The variety Wad EL Neil performed better in most of yield and yield components characters than El Neilein.
4. Nitrogen use efficiency is more reliable character in the use of fertilizer doses in high terraces soil in the Northern State of Sudan.

REFERENCES

AboElkheir, M. S. A., (2000). Antitranspirant effects on wheat plants grown under two levels of water supply. Annals of Agric., Moshtohor. Vol 38 (2): 823-832. Agric. Sci. 61(10): 709-714.

Ageeb, O. A. A., (1993). Agronomic aspect of wheat production in Sudan. In (Wheat in Heat-Stressed Environments: Irrigated, Dry Areas and Rice Wheat Farming Systems) (ed.I D. A. Saunders and G. P. Hettel). 154-162.

Ageeb, O.A.A. (1993). Agronomic aspect of wheat production in Sudan. in: Wheat in heat stressed envirofl1fle1ts irrigated, d areas and rice wheat fanning systems. Ed. D.A. Saunders and G.P Hettel.. 154-1.62.

Ageeb, Q.A.A. (1993). Agronomic aspect of wheat production in Sudan. In (Wheat in Stressed Environments: Irrigated, Dry Areas and Rice wheat Farming systems) (ed. I D. A. Saunders and G.P Hettel. 154-1.62.

Agriculture. W. H. Freeman and company. San Francisco. 154 - 162.

Agriculture. W. H. Freeman and company. San Francisco. pp. 154 - 162.

Ahmed, A.T. and Mohamed, M.I (1992). Survey of wheat in Dongola area. ICARDA/ARC, Wad Medani, Sudan.

Akasha, M. H., (1968). Wheat variety and N experiment. Annual Rep. of Gezira. Res. Station and Substations. Sudan. Season 1967-1968, 29-30.

Akasha, M. H., (1972). wheat variety and level of N experiment.. Annual rep of Gezira Res. Station and substations, Sudan, season 1971-1972.

Al Ahmadi, A. B., (1993). Development of wheat germ plasm tolerant to heat stress in Sudan. In (Wheat in Heat-Stressed Environments: Irrigated, Dry

Areas and Rice Wheat Farming Systems) (ed./ D. A. Saunders and G. P. Hettel) 48-54.

Arnon, I. (1972). Wheat. In: Crop production in dry regions. Volume II Leonard. Hill. 1-65.

Arnon, I. (1972). Crop production in the dry regions". Vol. 1:208. Leonard. Hill Books, London SWI.

Babiket, E.A. and H. Faki. (1994). Evaluation of farmers' attitudes and their effect on wheat productivity and input use in Rahad Scheme. ICARDA/ARC. Wad Medani, Sudan.

Baeumer, K. and Bakermans, W.A.P. (1973). Zero-tillag In: Advances in Agronomy, 25:77-123.

Bagga, A. K. and Rawson, H. M., (1977). Contrasting responses of morphologically similar wheat cultivars to temperature appropriate to temperate climate with hot summer: A study in controlled environment, Aust. J. Plant Physiol. 4: 877-887.

Bolland, M. D. A., Bowden, J. W., Brennan, R. F., Cartroll, J.W., Mason, M.G. and Porter, W. P., (1991). Wheat nutrition. In: The Wheat Book: a technicalmanual for wheat producers compiled by Michael Perry and Brain Hiliman. 55-76.

Carr, P.M.; Horsley, R.D. and Poland, W.W. (2003). Crop ecology, management and quality tillage and seed rate effects on wheat cultivars. Crop Science, 43:2 10-2 18.

Chapman, S. R., and L. P. Carter., (1976). Wheat. In: Crop production principlesand Practice. Montana State. University press. pp. 290 - 309. Choudhury, P.N. and Kurnar, V. (1980). The sensitivity of growth and yield of dwarf wheat to water stress at three growth stages. irrigation Science, 1: 228-23 1.

Clemmons, A.J. (1987). A statistical analysis of trickle irrigation uniformity.

Cooper, J.L. (1980). The effect of nitrogen fertilization and irrigation frequency on a semi-dwarf wheat in south-east Australia. I. Growth and yield. *Aust. J. Exp. Agric. Anim. Husb*., 20, 359-364.

Dahiva, S. S., Bhatia. B. K and Shukia. U. C. (1980). Note on the effect ofapplication of dilerent ratios of farmyard manure and rice husk will urea on yieldand uptake of nitrogen, phosphorus and potassium by wheat. Indian J. Agric. Sci.50 (1): 89-92.

Dawelbeit, S. E., Salib, F. M., Dahab, O. A. and Ahmid, S. E. H., (2007). Deficit. Aust. J. Exp. Agric. Anin?. Husb., 11:349-351.diLerent tillage systems. M.Sc. Thesis, University of Khartoum.

Disougi, S.M. and Misteam, (1983). Possibility study of northern vertical and horizontal expansion of wheat production in the northern region (in Arabic) Arab Organization for Agric. Develop., Khartoum, Sudan.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index for cereals as all organic plant breeding criteria. *Adv. In Agrun.,* 28:361-401.

Drewtt, E.G. (1974). Irrigation wheat. *New Z. J Agric*., 128('1):44-47.

Elahmadi, **A.; Solh, M., (1998)**. Adoption of improved wheat technology in the Sudan: survey results .No 5 :53 ICARDA Social Science Paper.

Elsir, A. (2004[a]). Monitoring and evaluating improved wheat production technology Northern Sudan. Annual national meeting, ARG, NVRP, Wad Medani, Sudan.

Elsir, A. and Abedalla, I. (2003). Monitoring and evaluating of farmer's Northern Sudan. Annual national meeting, ARG, NVRP, Wad Medani, Sudan.

Epplin, F. M. and Peeper, T. F., (1998). Influence of fertilizer and environment on Oklahoma wheat grain yield trend fflom 1963 to 1995. Canadian J. of Plant Sciences, 78(1).

Evans, L. T. (1976). Wheat In: Crop Physiology. Cambridge University press 101 - 135.

Evans, L. T., (1976). Wheat In: Crop Physiology. Cambridge University press 101-135.

Faki, H.; Aw-Hassan, A.; Ahmed, A.; Elahmadi, A.; Solh, M., (1998). Adoption of improved wheat technology in the Sudan: survey results .No 5 :53pp ICARDA Social Science Paper.

FAO, (2010). Food outlook. Global market analysis. Food and Agriculture Organization of the United Nation. Rome.

Farah, I. A. (1999). Response of wheat to varying irrigation levels (Etc%) under different tillage systems M.Sc. Thesis, University of Khartoum.

Farah, S.M. (1993). Water relations and water requirements of wheat. Gezira. Research Station. P.O. Box 126, Wad Medani, Sudan.

Ferrara, G.Q.; Rajaran, S. and Mosaad, M.G. (1994). Breeding strategies for improving wheat in heat-stressed environment ICARDA, Aleppo, Syria, 24- 32.

Fikishin, A.A.; Shaalan, M.I. and Cad, A.M. (1991). Fundamentals of crop Wheat Farming Systems) (ed./ D. A. Saunders and G. P. Hettel) . 48-54.wheat to water stress at diLerent growth stages. Rachis, Barley and wheat

Friend D. J. C., (1965). Tillering and leaf production in wheat as affected by temperature and light intensity. Can. 3. bot., 43:1063-1076.

Gajri, P.R. and Prihar, S.S. (1983). ELect of small irrigations amount on the yield of wheat. Agric. Water Managt. 6:31-41.

Galal Ahmed El Toum. PhD (2016). Effect of nitrogen and sowing methods on growth, yield and agronomic yield of three maize (*Zea mays* .L) thesis .Sudan University of Science and Technology.

Gardner, B. R. and Jackson, E.P., (1976). Fertilization nutrient composition and yield relationship in irrigated spring wheat. Agron. J. 68:75-78.

Ghuinan, B.S. and Maurya, P.R. (1986). Response of wheat in tropical soils. *Agron.* I, 78a): 791-795.

Giambalvo, D, Ruisi P, Miceli G .D, Frenda A. S, Amato, G. (2009). Nitrogen use efficiency and nitrogen fertilizer recovery of durum wheat genotypes as affected by inter specific competition.

Gomez, K. A and Gomez, A. A., (1984). Statistical procedures for Agricultural Research. John Willy and Sons, New York.

Grant, C.A. and Bailey, L. D., (1998). Nitrogen, phosphorus and zinc management effects on grain Yield and Cadmium concentration in two Cultivars of Durum Wheat. Canadian J. of Plant Sc. 78(1).

Guach, H. G., (1973). Inorganic plant nutrition. Dowden Hulehinson and Ross, Inc. Stroudsburg, 120.

Hanson, H., N. E. Bourlaug, and R. G. Anderson., (1982). Wheat in the thirdworld. Boulder, CO, USA, West view press.

Ibrahiim, H.S. (1990). Effect of different levels of fertilizer nitrogen and phosphor use application on the yield and N and P uptake by wheat under the high terrace soil of the northern region of Sudan. ICARDA/ARC, Wad Medani, Sudan.

Ibrahim, A.A.; Assey, A.A.; Zeidan, EM. and Gomaa, M.A. (1980). Yield and yield components of wheat as influenced by irrigation and cycocel treatments. Field Crop Abstracts, 34, Abstract No. 189.

Ibrahim, H. S. and A. M. Adlan., (1989). Effects of time, rate of N application with Pass on IIe yield and uptake of N and P by wheat under two soil types in the Northern Region. NVRP, annual national wheat co-ordination meeting, 4-7 Sept., ARC, Wad Medani. Sudan.

Ibrahim, O.H. (1995). Effects of sowing time on growth and yield of wheat Annual Report 1994/95. Hudeiba Research Station, Wad Medani, Sudan. improving wheat in heat-stressed environment ICARDA, Aleppo, Syria, 24- in soil cultivated for wheat in South Australia. Aust. 3. Agric. Res. 4:127-149. in Sudan. In (Wheat in Heat-Stressed Environments: Irrigated, Dry Areas and RiceIndian Journal of Agronomy 46(1):1 12-117.

Ibrahirn, H.S., (1987b). Screening of promising wheat lines for P response under two soil types in the Northern region. Paper presented second wheat coordination meeting, 20- 22 July 1987, Agricultural research corporation, Wad Medani, Sudan.

Ibrahirn, H.S., and Mohamed, G. E., (1988). Varietal response to N fertilizer on the major soil types in the Northern region. OF Sudan. Paper presented at third wheat coordination meeting, 4- 6 September 1988, Agricultural research corporation, Wad Medani, Sudan.

Ibrahirn, O.H. (1987a). Varietal response to N fertilizer on IIe major soil types in IIe Northern region. Paper presented IIe second wheat coordination meeting, 20-22 July 1987, Agricultural research corporation, Wad Medani, Sudan.

Ishag, H. M. and Ageeb, O. A. A., (1991). The physiology of grain yield in wheat in an irrigated tropical environment. Experimental Agriculture. 27: 71 - 77.

Ishag, H.M. (1993). The effect of tune of sowing on growth and yield of wheat cultivars in irrigated Gezira. ICARDA/ARC, Wad Medani, Sudan. Cannel, R.Q.; Belford, R.K.; Gales, K.; Dennis, C.W. and Prew, R.D. (1980). Effect of water-logging at different stages of development on the growth and yield of a winter wheat. *J. Sci. Food Agric.*, 31:117-132.

Izzeldin, S. I. M., (1996). The impact of irrigation method and ploughing depth on the reclamation and wheat production in a saline - sodic soil in Dongola area. Ph.D. Thesis, U. of K. Sudan.

Jamal, M.; Nasir, M.S.; Shah, Si-I. and Ahmed, N. (1996). Varietal response of wheat to water stress at different growth stages. Rachis, Barley and wheat newsletters, 15(l-2):38-45. Vicas Publishing House, New Delhi. India.

Janick, J., Schery, R. W., Woods, F. W. and Ruttan, V. W., (1970). Wheat Farming Systems) (ed./ D. A. Saunders and G. P. Hettel) . 48-54.wheat to water stress at diLerent growth stages. Rachis, Barley and wheat

Jobet, C. and K. Warren, (2000). Agronomic and quality performance of Chilean wheat cultivars grown in the Pacific Northern-West. *Agricultural Technique, Chille,* 6O('3):289-294.

Johnson, V. A., Briggle, L. W., Axtel, J. D., Bauman, L. F., Leng, E. R. (1990). Wheat Farming Systems (ed./ D. A. Saunders and G. P. Hettel) . 48-54.wheat to water stress at diLerent growth stages. Rachis, Barley and wheat

Johnstan, T. H., (1978). Grain Crops. In: (M. Nimer, N.S. Scrimshaw and D. I. C.

Karouri, M. O. H. (1968). Long term NPK experiment. Annual Rep. of HudiebaRes. Station, Sudan. Season 1967-68. 223-232.

Khalifa, M. A., (1968). Sowing date and N experiment. Annual Rep. of Gezira Res. Station and Substations, Sudan, Season 1967-68. pp 223-232.

Khalifa, M. A., (1973). Effect of nitrogen on leaf area index, leaf area duration, net assimilation rate and yield of wheat. Agronomy 3. 65..235-256.

Leonard, W.H. and Marten, J. H., (1963). Cereal crops, New York, NY, USA, MacMill and Publishing.

Martin, J.H.; Leonard, D.M. and Stamp, D.L. (1976). Principles of field crop production. Collier Macmillan International, London. 430-490.

Martin, R.J. and Drewitt, E.G. (1982). Irrigation of spring-sown wheat on templet on silt loam. *N.Z.J. Exp. Agric.,* 10:137-146.

Mazurndr, S.K. (1996). Irrigation Engineering Tata ivicGraw Hill Publishing Company Ltd. New Delhi. 7-22.

Mazurndr, S.K. (1996). Irrigation Engineering Tata McGraw Hill Publishing Company Ltd. New Delhi. 7-22.

Mc Master, G. S. and D. E. Smiko. (1988). Estimation and evaluation of winter wheat phenology in the Central Great Plains. Agric. For Moteoro L. A3: 1- 18.

Mohammad, S.C., Au, L. and Akhtar, M., (2003). Wheat following the cotton and rice- based cropping system in Pakistan. Agron. Research Station. Bahawapur, Pakistan.112-113. morphologically similar wheat cultivars to temperature ppropriate to temperate climate with hot summer: A study in controlled environment, Aust. J. Plant Physiol. 4: 877-887.

Mosier, A.R., J.K. Syers, and J.R. Freney., (2001). Nitrogen fertilizer: An essential component of increased food, feed and ffiber production, 3 - 18. In.

Moursi, M.A.; El Bagoury, O.M. and Mohamed, M.A. (1979). The influence of water deficiency on wheat yield and its components. Egyptian J. of Agronomy, 4(1): 1-18.

Nadar Khan; Qasim, M.; Au, S. and Kisana, N.S. (2004). Genotypic variation in wheat genotypes under agro climatic condition of Kaghan, Pakistan. *Asian Journal of Plant Science*, 3(5.) :569-570.

Nehra-Ajit, S., Hoodal, I. S. and Singh K. P., (2001). Effect of Integrated Nutrient management on growth and yield of wheat (Triticumaestivum L.).Indian Journal of Agronomy 46(1):1 12-117.

Nimir, E.E. (1986). Irrigation amount and frequency in wheat production. Thesis, Dept. of Agron., Fac. of Agric., University of Khartoum, Sudan.

Nimir, E.E. (1986). Irrigation amount and frequency in wheat production. Thesis, Faculty of Agriculture, Shambat, University of Khartoum, Sudan.

Nimir, E.F. (1986). Irrigation amount and frequency in wheat production. Thesis, Dept. of Agronomy, Fac. of Agric., University of Khartoum, Sudan.

Northern Region. NVRP, annual national wheat co-ordination meeting, 4-7 Sept.

Northern State Ministry of Agriculture (1995). The ministry plan for the 1995/96 season. Unpublished report. Mins. of Agric. Dongola.

Northern State Ministry of Agriculture, Animal Wealth and Irrigation, (1995).

Nuttons On, M. V., (1955). Wheat — Climate relationships and the use of phenologyin ascertaining the thermal and photo-thermal requirements of wheat Amer. Ins. Crop Eco. Washington. 338.

Nuttonson, M.Y. (1955). Wheat climate relationship and the use of phenology in ascertaining the thermal and photo thermal requirements of wheat. Am. Ins. Crop Eco., Washington, p. 338.

Omer, M.S. and Aziai, M.A. (1993). The effect of spikelet in wheat due to water deficit. *Aust. J. Exp. Agric. Anim. Husb.*, 11:349-351.

Onwuelne, I.C. and Sinha, I.O. (1991). Field crop production in tropical Africa.

Onwueme, I. C. and I. O. Sinha., (1991). Field crop production in tropical Africa.

Onwueme, l.G. and Sinha, T.D. (1991). Field crop production. *Tropical Africa Principles,* 2 15-224.

Parasad, U.K. and Sharma, N.N. (1984). Response of early paddy varieties to different soil moisture regimes in calcareous soil. *Indian J. Agron;*29(3):3 12-316.

Passioura, J.B. (1977). Grain yields harvest index and water use of wheat. *J. Aust. Inst. Agric.* Sci., 43:117-120.

Passioura, J.B. (1977). Grain yields harvest index and water use of wheat. J. Aust. Inst. Agric. Sci., 43:117-120.

Pearson, L. C., (1967). Principles of Agronomy. Reinhold Books in Agricultural Science Washington 323-327.

Pool, R. 1., (1948). Narchingwi grasses, Univ. Nebraska press: Lincoln, Nebraska. Cited by Shellenberger, J. A. In: Wheat chemistry and technology. American Association of Cereal Chemists, INC.1971.

Prasad, U.K.; Prassad. T.N.; Pandey. R.D. and Ehsanullah, M. (1988). Irrigation scheduling methods for wheat Triticuniaestivum L. in calcareous soil of North Bihar. md.J.Agric. Sci., 59 (7):438-341.

Prihar, S.S.; Khera, K.L; Sandhu, KS. and Sandhu, B.S. (1976). Comparion of irrigation schedules based on pan evaporation and growth in winter wheat. *Agron. J*. 68:650-653.

Profit AL, A.B.B.; Berliner, P.R. and Ooster, D.M. (1985). A comparative study of root distribution and water extraction efficiency by wheat grown under high and low frequency irrigation. Agron. J. 77:655-662. Potassium in Saline Soils. Exp. Agric. 3. 37(3): 4 17-427.

Rahman, M., Barma, C. D. and Amin, R., (1993). Wheat breeding strategies in the rice farming systems of BangladiSh. In: (Wheat in heat stressed environments: irrigated, dry areas and rice-wheat farming systems)(ed: D. A. Saunder and G. P. Hettel) 239-246.

Rahman, S.M.; Talukdar, S.U.; Kual, A.K. and Biswas, M.R. (1981). Yield response of semi-arid dwarf wheat variety to irrigation on a calcareous brown flood plain, soil of Bangladesh. Agric. Water Manage., 3(3):217-225.

Rashid, M.H.; Saimiania, S.C.; Biswas, P.; Mannan, M.A. and Zaman, M.M. (2004). Performance of thirty wheat genotypes under late sown Southern Region of Bangladesh. Asian Journal of Plant Science, 3’3):286- 289.

Rathore, S.S. and Singh, R.M. (1977). Water use efficiency and water use pattern as influenced by moisture regimes, N and P fertilization by dwarf wheat. *Indian. J. Agron*., 22:181-182.

Reddy, K.S. and Bhardwaj, R.B.L. (1983). Irrigation requirement of wheat under early, normal and late sown conditions. Agron. Abst. Annual Meetings, 202.

Saxena, K.K. and Singh, P.R. (1979). Effect of irrigation and fertility level on wheat in Bundelkhand region. *Indian J. Agron*., 243:338-339.

Shanahan, J.F.; Dominely, K.L.; Somth, D.H. and Smika, D.E. (1985). Winter wheat shoot development properties associated with grain yield. Crop Sd., 25:770-. 775.

Shulka, N.P.M. and Saxena, D.C. (1984). Effect of soil moisture regimes on water 202. use and forage production by oats, barley and triticale. Indian l Agron., 29(3,) :274-2 76.

Singh, D., M. Singh and K. C. Sharama, (1979). Correlation and path coefficient analysis among flag leaf area, yield and yield attributes in wheat. Cereal Research Communications, 7: 145-152. Transactions of the American Society of Agricultural Engineers, 30(1):169-

Singh, K. and Singh, S., (1991). Different wheat (T. aestivum L.) based cropping.system and their fertilizer requirements, yield and economic returuns. Indian. J. Agric. Sci. 61(10):709-714.

Singh, K. N. and Sharma, D. P., (2001). Response of Wheat to Nitrogen and Wheat Farming Systems) (ed./ D. A. Saunders and G. P. Hettel) . 48-54.wheat to water stress at diLerent growth stages. Rachis, Barley and wheat

Singh, N.T. and Brar, G.S. (1979). Effect of amount and depth of profile stored water on the yield of dry land wheat. *Indain J Agric. Sci*., 294,:26&-269.

Singh, Ringh, R.P.; Singh, R. and Seth, J. (1980). N and P management of wheat under the condition of deyled availability of fertilizer. md. Jo. Agron., 25(3,) :433-440. Stroudsburg, 120. system and their fertilizer requirements, yield and economic returuns. Indian. J.

Singh, Ringh, R.P.; Singh, R. and Seth, J. (1980). N and P management of wheat under the condition of deyled availability of fertilizer. *Ind. Jo. Agron*., 25(3,) :433-440.

Talukdey, M.S.U. (1985). Growth and development of wheat as affected by soil moisture stress. *Ind. I Agric. Sci*., 57('8):559-564.

Tamar, S.S.; Gupta, R.K. and Tamar, A.S. (1981). Water management of wheat in heavy clay soils of Madhya of Pradish. *Ind. I Agron*. 51:493-497.Production. New Maarif Lib., Cairo, Egypt.

Warington, I. R., Dunstan, R. I. and Green, L. M., (1977). Temperature effect on three development stages on IIe yield of the wheat ear. Aust. J. Agric. Res. 28:11- F 27.

White, E.M. (1987). Spring wheat growth at high and low soil water with constricted upper roots. Soil Sci., 143(1) 44-49.

Wolfe, T. K., and Kippes, M. S., (1959). Production of Field Crops. McGrow-Hill Book Company Inc. **Wood** roLe, K. and Williams C. H., (1953). OEe residual effect of superphosphate in soil cultivated for wheat in South Australia. Aust.3. Agric. Res. 4:127-149.