EFFECT OF DIFFERENT QUANTITIES OF IRRIGATION WATER ON GROWTH AND YIELD OF WHEAT
(*Tritcum aestivum* L.)

By

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DEDICATION

TO MY FAMILY

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I am greatly thankful to Alla who bestowed me with good health and enabled me to accomplish this work.

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ABSTRACT

A study was conducted in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat area for two successive seasons 1999/2000 and 2000/200. The objectives were to study the effects of the quantity of irrigation water and varieties on wheat (*Triticum aestivum* L.) growth and yield.

The different water amount treatments used were 300, 400, 500 and 600 mm. The irrigation treatments were calculated through calibration of the pump, using a stop watch. The varieties of wheat used were: El Neilein, Condor and Deibira.

Data collected included crop growth and yield parameters of wheat. A split plot design was adopted for analyzing the parameters, with the irrigation treatments as main plots and the varieties as sub-plots.

Differences in season 1999/2000 were due in wheat to uncontrollable weather conditions.

Irrigation water amount significantly affected yield, the high yields were obtained from 500 and 600 mm, while the lowest was recorded by the 300 mm treatment.

There were slight difference effect on growth and yield components except El Neilein which showed high grain yield with high amount of water (500 and 600 mm). Also there were differences in plant height between the two seasons, this could be attributed to the high temperatures that prevailed in the 1999/2000 season.

الخلاصـــة

نفذت هذه الدراسة بالمزرعة التجريبية بكلية الزراعة ، جامعة الخرطوم بمنطقة شمبات خلال الموسمي المتعاقبين 2000/1999 و 2001/2000 بغرض دراسة أثر كميات مختلفة من مياه الري على ثلاثة أصناف من محصول القمح .

كميات مياه الري التي أعطيت هي 300 ، 400 ، 500 و 600 ملم وقد حولت هذه الكميات الى زمن عن طريق معايرة المضخة وذلك لكي تساعد في حساب كميات المياه . أما أصناف القمح فهي النيلين ، كندور ودبيره .

شملت العوامل التي تمت دراستها عوامل نمو وإنتاجية المحصول ، الري وأصناف القمح .

استخدم تصميم القطع المنشقة لتحليل عوامل التجربة ، كان هنالك اختلافات غير معنوية وهي تعزى للظروف المناخية التي لا يمكن التحكم فيها .

كان لمعاملات الري تأثير إيجابي فقط على الإنتاجية النهائية حيث سجلت أعلى إنتاجية في معاملات الري 500 و 600 ملم . كذلك ظهر هنالك إختلافات في نسبة رطوبة التربة حيث تزداد الرطوبة مع إزدياد كمية مياه الري .

عند استخدام أصناف القمح المختلفة لم يظهر هنالك أي إختلافات أو أثر معنوي عدا صنف النيلين حيث سجل أعلى إنتاجية عند زيادة كمية مياه الري .

وقد ظهر إختلاف غير معنوي في طول النباتات بين الموسمين حيث كان طول النبات أقصر في موسم 2000/1999 منه في موسم 2001/2000 وهي تعزى لدرجة الحرارة العالية في الموسم الأول .

CHAPTER ONE

INTRODUCTION

Wheat, *Triticum* sp., of the family Poceae (Graminae), is the second most important cereal in human diet in the world after rice. It occupies over 30% of the world area devoted to grains. The heading producing areas are these of the temperate Europe, Asia and North America. In Africa, wheat production is confined mainly in the Northern areas, and Egypt is considered the major producing country, where yields of up to 5.00 tons/ha where reported under irrigation (Sied Ahmed, 1992).

In the Sudan, wheat ranks the second in Sudanese diet after sorghum (Farah, 1995). Faki (1995) reported that, expansion of consumption in the Sudan was from little over 229,000 tons in 1970/71 to over 800,000 tons in 1990/91. On the other hand, the area devoted to wheat was about 300,000 hectares annually (Farah, 1995). The crop is grown entirely under irrigation, water supplies to irrigation an either from rivers, as in the major irrigated schemes (Gezira, Rahad, New Halfa, etc.), or from wells as in the Northern and Nile States.

Al Ahmadi (1993) stated that, the crop has been grown in Sudan from early time. It has been restricted to the Banks of the Nile, North of Khartoum, and grown during the short cool reason (Nov. – March). Toxtures of cultivars known as (baladi) were grown, which probably were introduced from Egypt. Ageeb (1993) and Al Ahmadi (1993) stated that introduction of wheat to other points of the Sudan was first attempted in 1918 at Gezira. Interest in wheat and wheat research resumed after World War II due to food shortage. However, the scarcity of land and high cost of production in the Northern state, with the increase in demand for wheat consumption, led to the expansion of wheat growing areas south wards to warmer regions.

Ahmed *et al.* (1989) reported that, in the Gezira Scheme 400 m^3 of irrigation water/fed was assumed the best practice for all crops. However, saving of water without harming crop yield and quality can be obtained. Drewitt (1974) stated that varietal differences exist in the response of wheat to irrigation.

Ahmed *et al.* (1989) demonstrated that wheat crop yields in the Gezira were reduced significantly when the crop was water stressed at booting stage. On the other hand, irrigation scheduling has a direct effect on wheat grain yield.

Although the Northern and Nile States represent the most favourable environment for growing wheats, however, the scarcity of land necessitates that recent expansions in wheat areas to be confined to the Central and Eastern parts of the country despite the fact that thesis areas are characterized by their relatively high mean temperatures during a shorter growing season from November to March (Khalifa, 1973).

Solh (1995) reported that major factors known to affect wheat productivity include weather, cultivar and irrigation. Ageeb and Abd-ElShafi (1993) reported that developing high yielding wheat varieties tolerant to heat stress is a very important objective to increase wheat productivity in the Sudan.

Farah (1995) reported that water relations and water requirements studies of wheat dates back to 1960's. It was based on either ommitting irrigations at one of the major stages of crop development, or irrigating at fixed intervals throughout the season. He also stated that the usual trend in irrigating wheat, was applying 400 m^2/fed/irrigation at all stages of crop development. Soil and climate conditions, should be further investigated.

Studies based upon subjecting different wheat cultivars to different soil moisture depletions and stresses, heat and environmental stresses, using different techniques, revealed successful tools for selecting cultivars on the basis of their water use efficiency (WUE), moisture stress and heat tolerance as well as field potentialities.

The objectives of this study are:-

1- To study the effect of different levels of irrigation on the yield of three cultivars of wheat, namely; Condor, Debeira and El-Nilein.

2- To study the interaction effect of water amount and cultivar response.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic importance of cereals

Cereals, members of the grass family Poaceae (Gramminae), are the most widely adapted crop species. The most important members of its group are wheat, maize, rice, barley, sorghum, etc. which are grown mainly for their characteristic fruit, the caryopsis, which has been the most important source of the world food. If only a single food crop can be grown in a given environment, it's usually a cereal. Cereals are both warm-season as well as cool-season crops.

Even though yield may be low, but cereals can be grown under adverse conditions; as conditions improve, yields increase. Thus, with modern technology, cereals respond favorably to intense field management, including an increased use of commercial fertilizers and irrigation.

Cereal products comprise 80% or more of the average diet of Asia and Africa, 50% of Central and Western Europe, and between 20 - 25% of the U.S.A. cereals can supply sufficient quantities of carbohydrates, proteins, fats, many minerals and vitamins, but they are not a perfect food because they don't supply the dietary balance required for proper nutrition. Diets that consist primarily of cereals are too high in carbohydrates and deficient in vitamins.

2.2 Wheat Recognition and Adaptation

Onwueme and Sinha (1990) stated that wheat, *Triticum* spp. is the world's most widely cultivated plant. Different wheat species have originated in various localities in the area adjoining Southern Turkey, Iraq and Syria, Iran and USSR. It's then spread to India, Pakistan and China in the East, to the Mediterranean Countries in the West, and Europe in the North. It reaches Ethiopia by the early imigrants. In the very recent past, the crop was introduced to America and Australia. Today wheat is grown in most temperate, tropical and subtropical countries of the world.

Onwueme and Sinha (1991) reported that, although wheat is the number one cereal of the temperate regions of the world, which are climatically suitable for its cultivation, it's also grown on a large scale on the subtropical and tropical regions of the world. They also stated that, wheat is grown from the tropics to 60^{o}N and 40^{o}S. In the tropics it's grown at higher attitudes or where suitable conditions exist in the low land during winter. It grows successfully in hot climates if the humidity is not too high to avoid rapid development of diseases. Because most wheat is produced on dry land, the availability of moisture is a major factor in wheat production. The ideal temperature for different stages of wheat plant varies considerably between 16 - 20^{o}C at tillering, and 20 – 25^{o}C for germination. Wheat can be grown successfully under a wide range of soil conditions, but it is best adapted to fertile, well drained, silt and clay soils.

Major producers are U.S.S.R., China, the U.S.A., India, Canada, France, Turkey, Australia, and Pakistan, Africa produces only 2.46%

of the total world production. Major producers in Africa are Zimbabwy, Ethiopia, Sudan and Kenya, (Onwueme and Sinha, 1991).

2.3 Utilization of Wheat

Onwueme and Sinha (1991) stated that the whole plant of wheat contains approximately 70% carbohydrates, 8.15% protein, 2% fat, 2% fibre, 1.5% ash and 13% water. The flour is used for bread, cake, macaroni, etc .. The straw provides available fodder.

2.4 Botanical Description

Onwueme and Sinha (1991) reported that the temperate cereals (wheat, barley, rye and oats) all have the morphological and anatomical featured which characterize the family Poaceae. The leaves have no petioles. They are arranged alternately at the nodes. No tap root is formed, but 3 –6 seminal rots from the need are followed by fibrous root system which develops deventitiously from the basal nodes of the stem and its main branches. Tillers arise from buds in the oxils of the basal leaves of the main stem, and secondary laterals a rise from the basal nodes of the primary ones. Normally 2 – 3 tillers are produced, however, on fertile soils with enough space, 30 – 100 tillers may be produced. The young influences on carried upwards by the developing stems or culms, and finally emerge from within the sheath of the last leaf at the head or panicles of flowers. The flowers consist of lemma and palea, which enclose three stamens, and a unilocular gynaelium which has one ovule, and a style with a fearthery stigma. The own a rises dorsally on the tip of the lemma. The florets are arranged in spikelets.

The cereal grain is a one-seeded fruit with dry indehescent pericarp known as caryopsis.

In wheat, the starchy endosperm constitutes about 82 – 86% of the dry weight of the grain. The average spike (head) of common wheat contains 25 – 30 grains in 14 – 17 spikes. However, up to 70 grains are known (Onwueme and Sinha, 1991). The principle wheat of commerce belongs to the species *T. aertivum, T. durum,* and *T. coupactum.* On the other hand, one of the greatest developments in modern times has been the production of dwarf cultivars suited to the warmer countries. They are very responsive to high doses of fertilizers and high level of management. They are high fielding cultivars.

2.5 Wheat Cultivation

Onwueme and Sinha (1991) reported that in tropical Africa, wheat is commonly grown during the dry season (Nov. – April) with irrigation when winters are mild and water is assured. Much care should be given to the control of perennial weeds in land preparation.

Rajaram and Nelson (1984) stated that approximately 241 million hectares of wheat are planted in the world; of these, 105 million hectares are distributed in the developing world. Of the total areas of all developing countries, 37% are semi-arid, where moisture is the biggest constraint on wheat production.

Climate is largely determining the optimum time of sowing. However, the effective wheat growing season may vary even in different regions of the same country. For high-yielding cultivars a seed rate of up to 125 kg/ha has been found desirable. However, when some climatic restrictions and/or shorter growing seasons, were encountered higher seed rates of more than 125 kg/ha are recommended. In row sowing, on the other hand, wide spacing of up to 22.5 cm for cultivars of high tillering capacities is reasonable, while a narrower spacing of up to 20.0 cm is recommended for cultivars that are of less tillering capacities (Onwueme and Sinha, 1991). They also reported that sowing of up to 5 –6 cm deep doesn't have any adverse effect on the emergence percentage for both dwarf and tall cultivars. However, sowing beyond this depth might result in a marked reduction in emergence percentage. With modern high yielding cultivars, there is almost always a response to fertilizers. Unlike the tall cultivars which lodge severely at nitrogen rates higher than 40 kg/ha, the dwarf wheats have shown a better response to nitrogen of up to 120 kg/ha, depending on economic of the operation. Generally, 100 – 120 kg/ha can be safely recommended. On the other hand, Bhandari *et al.* (1989) reported a significant increase in wheat yield with the increase in nitrogen level of up to 190 kg/ha (80 kg/fed). Onwueme and Sinha (1991) reported that the areas for 1961-65 and 1979 seasons were 210 and 239 million hectares, showing an increase of 13.8%, while production increase from 254 to 455 million tonnes, showing an increase of 79%. This was mainly due to the increased use of fertilizers and high yielding cultivars, as well as improved husbandry. On the other hand, there was slight decrease in area (5%) but the best further increase in production (19%) was from 1979 – 1989.

In medium – to heavy – textured soils, the application of nitrogen either all at sowing, or in two splits (half at sowing and half at crown root initiation, i.e 20 – 25 days after sowing), or in three splits (one third at sowing, one third at crown root initiation, and one third about 3 weeks after the second) has given similar results.

In modern high yielding cultivars, the crown root initiation stage has been found to be the most critical stage as far as water use is concerned. This is the stage when the first irrigation has to be applied. This stage is reached about 3 weeks after sowing. A delay in the development of crown roots results in a delay in the development of tillers and finally lower grain yield (Onwueme and Sinha, 1991). On the otheer hand, Singh and Hundal (1988) stated that at the stage of crown root initiation, only small amount of irrigation water should be applied to avoid excessive losses from deep percolation. Narayan and Misra (1989) stated that, under moisture stress conditions, the roots of some wheat varieties penetrated comparatively deeper. Greater depths of root were advantageous because the roots could extract more water from deeper soil layers, and satisfied the demand of evapotranspiration. They concluded that, total root-length density of a variety was not as much important as its root penetration depth, and that under soil-moisture stress a plant having low root-length density, but having deep root penetration can fulfill the evapotranspiration demand for satisfactory grain yield. Sied Ahmed (1992) stated that an adequately long vegetative period is needed to establish the root system, leaf and tiller number together with a large apex capable of forming a big spike primordium. Heitholt (1989) stated that, WUE and the distribution of dry matter to the roots in wheat are potential selection criteria for improving yield under water stress conditions. He concluded that shoot: root ratio was consistently reduced by nitrogen stress, but not by water stress.

Rajaran and Nelson (1984) reported that the primary climatic components of interest are the yearly available water for irrigation or precipitation, the relative humidity, the average temperature, and the type and depth of soil. In many areas in the semi-arid regions, the relatively low average temperatures during the growing season in tract with low soil moisture deficits to alleviate the effects of drought, through reduced growth and evapo-transpiration. They concluded that, the response of plant to moisture stress depends, to some extent, on the type and depth of the soil. On heavy clays, soil moisture is held with progressively increasing tension as soil moisture content is reduced below field capacity (F.C.). As the tension progresses towards the permanent witting point (PWP), plant growth continues for longer periods on clays than on sands.

Onwueme and Sinha (1991) reported that wheat is harvested some where in the world every month of the year. It usually ripen, about 30 days after blooming. The kernels are completely filled, leaves, stalks and spikes begin to lose their colour and become golden yellow. Average moisture of the kernel about 10 – 12% for sake storage. Harvesting may be done by hand with sickles, or by machine. There is great variation in the average yield of wheat in different parts of the world. Yields are usually higher in temperate regions than in tropical and subtropical regions. The average yield of wheat in the world is about 2.3 ton/ha whereas it is about 1.5 ton/ha in Africa, with a possibility for increasing yields in tropical Africa.

Common diseases of wheat constitute; rust, smuts, while the main insect pests include aphids, white flies, worms, fassids, etc ..

2.6 Water Requirements of Wheat

It's synonymously called consumptive use of water (CUW) or evapotranspiration, and is defined by Israelsen and Hansen (1962) as the sum of evaporation and transpiration. The former constitutes the water entering plant root and used to build plant tissues or passed to the atmosphere through leaves, while the latter is the water evaporation from the vegetative parts of the plant and the surroundings. It's expressed as volume of water per unit area e.g m^3/ha, litre/fed.

Onwueme and Sinha (1991); and Prasad *et al.* (1988) stated that, the most practical criterion commonly adopted for scheduling irrigation to wheat is the one based on the physiological growth stages critical in demand for water. The moisture available in a soil is the difference of moisture contents at the PWP and FC, levels which is available to the plant in the root zone. Irrigation requirement is the quantity of water needed above the existing moisture level. The difference between available moisture and irrigation requirements lies in the losses in conveyance, evaporation 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 evapo-transpiration during crop-growth period was higher when more irrigations were given. Apart from applied irrigation, soil profile also contributes a sizeable quantity (0-2 – 43.5%) of water to the crops.

Passiowra (1977) suggested that, the yield could be a production of three factors viz, usable water, WUE and the harvest index (HI). 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 arthesis. Similar results were reported by French and Schultz (1984).

Koshata and Raghn (1983) stated that, frequent irrigation increased grain yield and weight, increased consumptive use, but reduced WUE. Cooper (1980) and Protiff *et al.* (1985) reported an increased WUE with frequent irrigation. In contrast, Rathore and Singh (1977); and Rao (1981) reported reduced WUE with frequent irrigation.

El Nadi (1969) reported that, under different climatic regions, different varieties of wheat require different amounts of water to produce a unit of dry matter i.e transpiration ratio or CUW. Transpiration ratio for wheat ranges from 225 to 359 in temperate climates, and from 513 to 1006 in mediterranean climates, while in tropical regions, as in Sudan, it ranges between 691 and 2011.

Bhandari *et al.* (1989); and Entz and Fowler (1991) stated that WUE of wheat crop in the dry land a near can be improved by the use of fertilizers and reduction of water loss due to evaporation from the soil, or by applying water according to growth stage of the crop.

Onweue and Sinha (1991) stated that, in sandy soils and in areas where summer starts early, the practice of irrigation at the different growth stages may not be adequate as the number of irrigations required may be more than the number of growth stages. Onwueme and Sinha (1991) reported that, the measuring of soil moisture is important in the scheduling of irrigation and in estimating the amount of water to be applied in each irrigation.

2.7 Effect of Water Stress on Wheat Production

2.7.1 Growth components

2.7.1.1 Plant height

Ghuman and Maurya (1986) found that, the height of wheat crop was not significantly affected by the depth of irrigation in a given season. Similar results were reported by Farah (1999). However, 100% crop water requirements produced the tallest plants. Singh *et al.* (1979) reported increased plant height with increasing soil water storage of up to 30 cm in the season. Nimir (1986) reported that, the shorter the irrigation interval, the taller the plant. On the other hand, increased irrigation amount, irrespective of interval showed a highly significant difference in plant height. Similar results were reported by

Moursi *et al.* (1979) in Egypt. However, number of stems was not affected.

2.7.1.2 Tillering

A significant response of wheat to wetting was reported by Reddy and Bhardwe (1983). Tiller height was affected positively by irrigation as mentioned by Rahman *et al.* (1981). Number of tillers increases significantly with depth of water (Singh and Brar, 1979; Rahman *et al.,* 1981; Gajry and Prihar, 1983). Singh *et al.* (1979) reported increased tiller number with increasing soil water storage beyond 30 cm in the season. Cannel *et al.* (1980) stated that water logging caused reduced tillering and finally poor yields, which was most likely due to poor grain set associated with poor pollination or poor pollen development. Nimir (1986) reported that, a significantly higher number of productive tillers were obtained at shorter intervals of irrigation and with higher irrigation amounts. Cooper (1980) and Shanahan *et al.* (1985) reported greater number of spicke bearing tillers with frequent irrigation. They concluded that, number of grains/unit area was the major yield determinant under adequate irrigation. Farah (1999) reported no significant effect of irrigation amount on number of tillers, although a positive response with increased wetting was predicted. Moursi *et al.* (1979) stated that, number of fertile tillers/m^2, yield of protein, grain and straw yields/ha, all increased with increased number of irrigations.

2.7.2 Yield components

2.7.2.1 Number of spikelets, grains/spike and 1000-grain weight

Reddy and Bhardwaj (1983) reported that both variables were positively affected by water amount. They also stated that, moisture stress before booting reduces the number of grains per ear. However, stress after ear emergence tend to lower grain weight. Both 1000-grain weight and number of grain per spike tend to increase significantly by irrigation. Similar observations were reported by Gajri and Prihar (1983). Entz and Fowler (1991) reported that, higher grain yields of winter wheat were attributed mainly to the production of higher kernels' number/m^2. On the other hand, wheat grown under cooler winters has a slower development rate which often resulted in a higher kernel set, and finally higher yields. Singh *et al.* (1980); Ibrahim (1980) and Martin (1982) reported increased grain weight (1000-grain weight) with frequent irrigation.

Talukder (1985) reported that, soil moisture stress during the crop growth periods affects height, number of leaves, number of tillers, leaf area, spike size, grains/ spike and grain filling before the organs reach their final size. Moursi *et al.* (1979) reported a significant increase in spike length and weight, spike grain weight and 1000-grain weight with increasing number of irrigations and fertilizer level in Egypt. However, number of spikes/plant was affected only by increased fertilizer level. Farah (1999); Prihar *et al.* (1976) and White (1987) reported no significant differences in number of spikes due to irrigation amount. They further stated that spike emergence was more rapid for plants under low soil water. However, Drewitt (1974) stated that shallow fibrous roots of wheat need a large volume rather than great root zone depth to perform well.

Gajri and Prihar (1983); Reddy and Bhardwaj (1983) and Farah (1999) agreed that no increase in number of grains/spike is expected with increased water regime. They observed no significant gain in 1000-grain weight due to increased irrigation amounts.

2.7.2.2 Harvest index (HI) and total dry matter

HI is the ratio of seed weight to the total crop weight. It shows how far the plant is able to convert total dry matter into economic yield. Although Jamal *et al.* (1996) reported that HI decreases severely with water stress, Rahman *et al.* (1981) reported contrasted results. Talukoler (1985) observed that, the total dry matter decreased considerably in all his moisture stress treatments and the effect was more severe during the vegetative stage, mainly by affecting the leaf and stem. Similar results were reported by Gajri and Prihar (1983), who observed that a considerable number of late tillers was developed when the moisture stress or drought was terminated at an early and intermediate phase, allowing a compensation of the earlier losses in total dry matter. Fully irrigated crops produced greater dry matter due mainly to increased number of stems, leaves/stem, and area/leaf, and in turn increased leaf-area index. Moisture stress increases the number of wilted leaves, beside decreasing the previous variables, and hence led to a decrease in dry matter. Similar results were reported by Choudhury and Kumar (1980) except in the intermediate drought phases.

Entz and Fowler (1989, 1991) reported that, dry matter production tend to decrease as water stress between tillering and an thesis increases. Moreover, water stress during flowering and grain filling has a negative effect on grain yield and harvest index, particularly when coupled with high temperatures.

2.7.2.3 Grain and straw yields

Ghuman and Maurya (1986) stated that application of 180-270m^3 of water per irrigation (assuming 70% efficiency for surface irrigation), resulted in a higher grain yield than 360 m^3, with using 7 day interval. Singh and Brar (1979) stated that lower yields of wheat were obtained when a given quantity of water is applied at shallower depths than at deeper depths, Saxena and Singh (1979) detected a positive response of wheat to both irrigation amount and interval. Similar findings were reported by Gajera and Patel (1984) and Babn and Singh (1984).

Singh and Brar (1979) and Shukla *et al.* (1984) reported no significant differences in straw yield of wheat due to irrigation regime. While Rahman (1981) detected a linear trend between straw yield and water regime.

Singh *et al.* (1979); Ghudhary and Bhatnagar (1980); Tamor (1981); Mallic *et al.* (1981); Profitt (1984) and Shanaham (1985) stated that, frequent irrigation, applied in different countries, was reported to give higher grain yields than less frequent irrigation. Souza *et al.* (1982) and Gajri and Prihar (1983) found that grain yields were highly responsive to irrigation 30 – 39 days from sowing, whatever the soil type and the amount of water applied, provided that soil was not saturated and aeration was not impeded.

Omer (1983) found reduced straw and grain yields with increasing moisture depletion by decreasing amount of irrigation progressively from spike -emergence to harvest.

Choudhury and Kumar (1980); Gajri and Prihar (1983) and Talukder (1985) reported that water stress at any stage of crop growth and development reduced the grain and straw yield.

Hochman (1982) found that water stress from tillening to an thesis reduced grain weight. Grain yield was 28% lower them the unstressed wheat. Stress from booting to grain filling reduced grain number and 1000-grain weight, while grain yield was reduced by 36%. Stress during grain filling reduced 1000-grain weight, while grain yield was 16% lower. On the other hand WUE was reduced and was lowest for stress between booting and grain filling. He concluded that, in a semi-arid environment leaf water potential is significantly sensitive to soil moisture deficits during grain filling. This undesirable response may be remedied for varieties which are less resistive to soil moisture deficits at grain filling.

Mazumder (1976) stated that, the timely application of irrigation water is more important than the depth of water applied. Untimely irrigation may not only result in the wastage of water and nutrients, but also in reduced crop yields. On the other hand, too little water to moisture the root zone and too much water, both produce undesirable effects and wasted water that might be used for other purposes in other places. As common practice among farmers is to watch plants for signs of moisture deficiency as a basis for supplying water. However, by time plants start to show some signs of water stress and finally yield will be reduced. Therefore, soil should be watched for water deficiency rather than the plants. Prasad and Sharma (1984) stated that water requirements vary from year to year due basically to climatic factors. Bergmann (1973) reported that satisfactory yields, not far below the optimum, could be obtained using about two-third or three quarter of the quantities calculated as water requirements. On the other hand, excessive water application tend to produce profuse vegetative growth which in turn resulted in poor yields. Clemmens (1987) stated that yield response to over or under irrigation was not linear, and that slight amounts under both conditions usually had insignificant impacts on yield. However, large deficits or over application were found to have proportionally large impacts.

2.8 Wheat in Sudan

Wheat is growing in the Sudan as a winter crop under irrigation. The Northern region, having a longer and cooler growing season, is considered more suitable for its production, compared to other parts of the country. 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.

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 temperatures at early and late crop growth stages contribute greatly to the low wheat productivity. In the Sudan, wheat cultivation was recently expanded into latitudes lower than 15^{o}N as a winter crop. The minimum temperature for wheat growth is about 3 – 4^{o}C, optimum is about 25^{o}C, and the maximum is about 30 – 32^{o}C.

Ageeb (1993) stated that until 1988, Sudan imported 75% of its annual local needs estimated at 0.8 to 1.0 million tonnes. From 1988 – 1992 wheat production has been increased by 350%. However, wheat productivity is affected by a number of stresses, the most important of which are temperature, soils, pests and diseases, and weeds, as well as adequate seedbed preparation, poor seed and fertilizer distribution, irregular irrigation schedules, and delayed harvest, similar views were mentioned by Salih *et al.* (1993).

Ageeb (1991) reported that, previous research findings showed that yield losses, due to weed, are small. However, in recent years, findings showed that wild sorghum at a population densities of 3 – 10 plants/metre of row can reduce wheat yields by 18 – 35%.

Farah *et al.* (1996) reported that, the volume of water needed to produce optimum grain yields was around 10000 m^3/ha (4200 m^3/fed). less or more than this amount tended to decrease yields.

Farah *et al.* (1993) stated that, research findings showed that there was some cultivar x irrigation interaction; yield gaps between cultivars were minimal under favorable moisture regimes, but become very wider under stress conditions. Farah (1995) also stated that skipping one irrigation showed that moisture stress would have very little adverse effects on the economic yield of wheat when the second or the final irrigation was not given.

Ageeb, (1993) stated that, irrigation water and irrigation practices are factors which have always limited wheat productivity. The recommended number of waterings and irrigation regimes at the vegetative and the reproductive stages need to be applied properly and timely for better yields. Fadl (1974); Ageeb (1991); Adam and Ageeb (1991); and Ahmed (1992) stated that estimates of daily water consumption for wheat varied over a wide range, from 3.5 – 8.0 mm within and between seasons. The causes of this variability can be related to prevailing weather, the stage of crop development and level of the vegetative vigour. Maximum soil moisture change under wheat occurs in the top 40 cm. Peak demand for water occurs during stem elongation, heading, and grain formation (Mid December – the end of January), when mean temperatures are 24.1^{o}C and 23.6^{o}C respectively (average of 1951 – 80), and average of 500 mm of water (375 m^3/fed/irrig.) at the Gezira, and 640 mm (487 m^3/fed/irrig.) at the Northern state were applied per season. However, Ageeb (1991) stated that research recommendations showed that more water for irrigation should be applied during the reproductive stage, and that a minimum of (8) irrigations are needed.

Farah (1993) reported that, at New Halfa, farmers believe that, reducing number of irrigations by delaying the second irrigation by up to 4 weeks, increases yields, root depth and tillering capacity.

However, results did not reported any significant increases on these parameters.

El Nadi (1969) stated that, both flowering and grain filling stages as well as maturation phases were more sensitive to drought than vegetative stage. More than 70% of total water use occurred at anthesis, at Shambat soils. Similar observations were stated by Ishag and Ageeb (1993); and Al Ahmadi (1993).

Nimir (1986) reported that, wheat is poorly adapted to acid or strongly leached soils. It's classified as medium salt tolerant with pH range of 7.0 – 8.5.

Valencia *et al.* (1991) reported that experiments on the improved variety Condor at the Gezira scheme during 1986-87 revealed that, lower yields were obtained due mainly to irrigation problems. However, up to 5.2 tonne/ha. They also obtained 3.2 tonnes/ha from Condor, in farmers fields during 1989/90 compared to 3.3 and 3.1 tonne/ha for Elneelein and Debeira, respectively.

Salih *et al.* (1993) tested both Debeira and Condor at the Gezira scheme and reported that, the former had a small yield advantage over Condor (2.3g tonne/ha and 2.21 tonne/ha respectively). Data showed that areas sown in mid-November significantly out yielded those sown in the latter part of December, and that, areas received more irrigations (8) have significantly out yielded those received fewer irrigations (5 or 6).

Hassan *et al.* (1993) reported that both Debeira and Condor are relatively short-maturing and semi-dwarf wheat cultivars. Planting should be between 12 – 26 November, so that the coolest part of the growing season (December and January) coincide with the reproductive stages (flowering and grain filling), which are the most sensitive to high temperatures. Similar results were reported by El Nadi (1969); Al Ahmadi (1993); and Ishag and Ageeb (1993).

Ali (1982) reported that, 15% increase in yield were obtained when seed rates of common wheat varieties were increased from 41 to 95 kg/ha. High seed rates hastened maturity which is considered an advantage in short growing seasons as most grain filling period takes place in a relatively cool weather. Akasha (1966-76); and Ageeb (1974-76) found no significant differences in yield when sowing at a range of 48 – 190 kg/ha, and 11.9 – 190.4 kg/ha, respectively. They attributed these results to the survival of productive tillers.

Ibrahim (1995) reported that in many studies, different wheat cultivars showed differential response to sowing dates. Optimum range of sowing dates (ORSD) for wheat in the Sudan was 3 Nov. – 12 Dec. In the various growth environments of wheat in the Sudan, the cultivars showed differential response to sowing time. Condor, being the most sensitive genotype to heat stress, gave lower grain yields than Debeira when sown before the ORSD. However, the reverse was true when sown after the ORSD.

Ali (1982) and Nimir (1986) reported that, all experiments conducted since mid-sixties to study the optimum sowing dates at Hudeiba, Gezira and Khashm El Girba indicated that sowing during the two weeks of Nov. were the most suitable. Examples of such experiments are those of Rogner, (1965-67); Khalifa (1962-68); Absha (1960-67); Dafalla and Gabbar (1966-69) and Ishag (1993) tested Condor, Deberia and El Nilein against three sowing dates (9^{th}, 23^{rd} Nov. and 14^{th} Dec.) at the Gezira Research Farm. They concluded that, November sowing resulted in higher yields. Ishag *et al.* (1992) found 14% decrease in yield of Debeira when water stressed during tillering (skipping one irrigation) as compared to full irrigation. However, the lowest yield was obtained when the crop was stressed at both head emergence and dough stage. The decrease was attributed to reduction in grains/spike as a result of infertile grains at both tip and base of spikes. Ahmed (1992) also reported considerable reduction in grain yield at Hudeiba when irrigation was skipped during heading and early grain filling stage. This was attributed to reduction in grain size. Farah *et al.* (1994) found that the lowest yields were obtained when Deberia was water-stressed at time of the initiation of the reproductive tillers and formation of grains. The highest WUE (0.27 kg/m^3/ha) was obtained when (9) irrigations were applied, amounting to 8615 m^3/ha (400 m^3/fed/irrig.). However, closer values of WUE (0.25 – 0.26 kg m^3/ha) were obtained when irrigation was skipped once during the dough stage, with only (8) irrigations amounting to 8100 and 8080 m^3/ha (425 m^3/fed/irrig.) respectively.

Ahmed (1993) studied the effect of different irrigation regimes on the performance of both Deberia and El Nilein. He obtained a significant reduction in grain yield (23%) when the crop was water-stressed after heading stage (30% water deficiency from the conventional amount). The highest grain yield was obtained from El Nilein, followed by Debeira. When that water deficit was applied prior to heading, El Nilein scored the highest WUE at all levels of his irrigation treatments which was attributed to its ability to maintain the highest relative turgidity values at these levels.

Ahmed (1993) and Farah *et al.* (1993) reported that, a water stress at the Northern state and Gezira, did not significantly reduce grain yield when imposed during the vegetative stage or grain filling stage, where as considerable reduction in grain yield occurred when the stress coincided with the heading and anthesis stages. Similar results were observed by Salih *et al.* (1995).

Studies by Ibrahim (1995) in the Northern state revealed that, highest grain yields were obtained when only 50% of water requirements were applied during the first stage of growth, and 130% was applied during the subsequent stages. He concluded that wheat can tolerate long irrigation intervals during early vegetative stages, provided that shorter intervals were used during the reproductive stages.

Farah *et al.* (1993) obtained the highest grain yields (30 – 54% higher), with Debeira and El Nilein when irrigating every 10 days throughout than every 14 days or 21 days throughout. Ahmed (1993) subjected Condor, El Nilein, Giza 164 and Wadi ElNil to different irrigation regimes involving moisture depletion (MD) based on scheduling, at Hudeiba. He obtained 10% and 24% decrease in yield when irrigating at 50% MD prior to anthesis, and 75% MD thereafter, or vise versa, respectively, than irrigating at 50% MD throughout. The highest yields were obtained from El Nilein, followed by Candor, with highly significant differences. However, El Nilein out yielded all other cultivars, when the same experiment was repeated at the Gezira, and differences between cultivars were highly significant.

Farah (1986) reported that, Candor yields were highest when 400 m^3/fed/irrig. were applied throughout the development cycle, at the Gezira. More adverse effects on yield were observed when that quantity was partially applied (30% decrease), particularly during the second stage of crop growth.

Salih *et al.* (1993) stated that, the effective rooting depth of Candor, Debeira and El Nilein did not exceed 26 cm. Total root length and average rate of extension into the soil was highest for Candor, and to some extent, El Nilein, and finally Debeira. The former two cultivars were also able to extract more water from the deeper soil profile and attain greater grain yields than Debeira. On the other hand Salih *et al.* (1994) revealed that, the rooting depth of all three cultivars did not exceed 19 cm under both wet and dry treatments (50 and 75% WD) at the Gezira. El Nilein gave the highest grain yield under the dry treatments (75% WD), which has also accumulated more straw than the others under the wet treatments. However, all cultivars used similar amounts of water under the wet treatments, while El Nilein used more water under the dry treatments (75% MD).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site and climate:

The experiment was carried out during two successive seasons; 1999/2000 and 2000/2001 at the Demonstration Farm, Faculty of Agriculture, Shambat, University of Khartoum (Latitude 15^o 40`N and Longitude 32$^o$ 32`E) (Oliver, 1965).

The climate of the locality, as described by Oliver (1965), was a tropical, semi-arid one with low relative humidity (R.H). The daily mean maximum temperature was more than 40^{o}C in summer, with its peak being during May and June, compared to only about 21^{o}C during winter. The daily mean minimum temperature ranged between 15 and 25^{o}C during winter and summer, respectively. The mean daily solar radiation ranged between 400 – 581 per cm per day. The total amount of rainfall amounts to only about 158 mm per annum, resulting from few to moderate showers.

Saeed (1968) described the soil of the site as heavy montmorillonitic clay with 48 – 54% clay, 25 – 29% silt and 17 – 25% sand. The soil reaction was moderately alkaline (pH 7 – 8).

3.2 Treatments and design

The experiment was laid in a split-plot design comprising two factors viz. water amounts as main-plot factor and wheat varieties as sub-plot factor. The main-plot factor has four (4) levels, namely; 300, 400, 500 and 600 m^3 per feddan per irrigation, assigned as Q_1, Q_2, Q_3 and Q_4 respectively (Q_2 as control). The sub-plot factor, on the other hand comprises three (3) levels, namely; Condor, Debeira and ElNilein, assigned as V_1, V_2 and V_3 respectively. The experiment was replicated four (4) times.

Wheat seeds were brought from Shambat Research Station (SRS):

Total treatment combinations	= 4x3x4 = 48
Gross experimental area	= 1050 m^3 (¼ fed.)
Sub-plot area	= $\frac{4x4}{4200}$ = …… fed
Net experimental area	= $\frac{16x48}{4200}$ = ….. fed

Each sub-plot constitutes only six (6) furrows with 0.60 m between adjacent furrows.

3.3 Land preparation

Land preparation started at mid October. A local hand tool "Toria", was used for working the land, constructing the furrows, shaping and levelling of the experimental plot. Tractors with conventional land preparation attachments, were avoided due to the presence of a permanent irrigation net work comprising inflexible pipes at the site.

3.4 Planting

Planting started one week after land preparation. Two lines at each side of the furrow were made using "Khulal".

For optimum seed germination and seedling establishment, a seed rate of 60 kg/fed was adopted. Quantity of seeds actually used for each sub-plot was calculated as follows:

$$\text{Seed rate/sub-plot (kg)} = \frac{60 \times 16}{4200} = 0.23 \text{ kg approx.}$$

Seeds were manually drilled and thoroughly covered. Replanting was done after the second irrigation i.e. 20 days from planting.

3.5 Irrigation

An ordinary, medium size electric pump was used to deliver water from a field ditch to the experimental area through a fixed water distribution net work comprising a number of lateral pipe lines permanently constructed at the site. A number of risers were set equidistantly at the laterals. Portable flexible hoses were used to direct the irrigation water into the sub-plots. Each experimental unit (sub-plot) was irrigated separately by connecting a given hose to the corresponding riser on the lateral on the vicinity. When the required amount of water at a given sub-plot is reached, the hose can easily be disconnected from the riser and tilted to irrigate subsequent plots.

Volumetric method, stated by Michael (1978) was used to estimate the amount of water to be applied according to the treatment requirements. An ordinary bucket, of a known capacity (16 litres; 0.016 m^3) was used to assess the flow rate (m^3/sec.) of the individual hose. The average time (t_1) in seconds required to fill the bucket (or to attain that volume of 0.016 m^3) was recorded. This procedure was used to estimate the time (secords) required do add a given amount of water to the sub-plot as follows:

- Volume of water (m^3) required/sub-plot (v) =

$$V (m^3 / 16\ m^2) = \frac{16\ m^2 \times Q_s\ m^3}{4200} \quad \ldots\ldots\ldots\ldots\ldots.. \quad (3.1)$$

Where:

Q_s = Volume of water required for treatment

(x) i.e. 300, 400, 500 or 600 m^3.

- Time (seconds) required for a given amount of water (m^3) to be added to the sub-plot (t_2) =

$$t_2\,(\text{seconds}) = \frac{16\ m^3 \times Q_s\ m^3 \times t_1}{4200} / 0.016\ m^3 \quad \ldots\ldots\ldots\ldots \quad (3.2)$$

Where:

t_1 = average time (seconds) required to add 0.016 m^3.

Two irrigation intervals were adopted, 10 days' interval for the first and second preliminary irrigations to guarantee good seedling emergence and establishment, and 12 days' interval for the remaining irrigations. A total of eight (8) irrigations were applied each reason.

3.6 Fertilizer application

Urea was added immediately after weeding (45 days after sowing, DAS) at a rate of 45 kg/fed (1 N) as one dose. The material was placed manually at the vicinity of the growing seedlings, and perpendicular to the planting line before the fourth irrigation was applied. Actual amount of fertilizer added (X kg) per sub-plot was calculated as follows:

$$X\,(\text{kg}) = \frac{45\ \text{kg/fed}}{4200} \times 16 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

3.7 Weeding

Weeding was done only once, 45 DAS, using sickle.

3.8 Harvesting

One square metre from each plot was precisely measured, and the plants were carefully uprooted. Seeds were further threshed manually and cleaned before they are finally weighed (x mg) using a sensitive balance. The yield per m^2 was determined as a guide for calculating net yield/plot (Y_1 kg), as well as yield/fed. (Y_2 kg) as follows:

$$Y_1 (kg) = \frac{X (mg) \times 16}{1000} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

$$Y_2 (kg) = \frac{Y_1 X 4200}{16} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

3.9 Agronomic and physical parameters

Different parameters related to plant and soil were determined and processed as follows:

3.9.1 Plant height (cm)

An ordinary woody scale (50 cm ruller) was used to measure plant height from soil surface (base of the stem) to the apex of the upper leaf (above the spike base). Four (4) readings were determined throughout the crop development cycle viz. 30, 44, 58 and 72 days after sowing.

Five (5) plants were randomly selected from each sub-plot, labelled, and their heights were periodically determined for each specific stage of growth as mentioned previously. Average plant height at each stage was then recorded.

3.9.2 Number of tillers per plant

The same plants (five) examined above were used, and the number of tillers at the same sequence of stage was determined. Average number of tillers for each stage of growth was then recorded.

3.9.3 Number of leaves/plant

The same bunch of plants were used, and the number of leaves per plant at the same sequence of stage were then determined, totalled, averaged and recorded.

3.9.4 Leaf turgidity (R.T.)

Twenty leaves from twenty random plants, including the labelled ones described earlier, from each sub-plot were carefully taken just before each effective irrigation (i.e excluding the first and second preliminary ones). Leaves were kept immediately in previously labelled plastic bags to prevent loss of moisture (Drying). They were carefully transferred to the laboratory and weighed in a sensitive balance to predict fresh weight (F.W.). leaves were then soaked in tap water for 4 hours to attain their maximum saturation before they were weighed again (Turgid weight, T.W.). Leaves were then oven-dried for 24 hours at 80^{o}C before they are finally weighed (oven-dry weight, O.W.). Relative turgidity (R.T.) was then calculated using the following formula:

$$R.T. = \frac{F.W - O.W}{T.W - O.W} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.6)$$

3.9.5 Number of spikelets/spike

Ten (10) plants from each sub-plot were randomly selected, excluding the bunch of plants described at articles; 3.9.1, 3.9.2, and

3.9.3, and their spikes were carefully detached and taken to the laboratory. The spikelets of the sample were carefully separated, counted and averaged.

3.9.6 Biological yield (%)

One square metre in each sub-plot was carefully determined with an aid of a woody stick, carefully worked to a one – metre length. The whole bunch of plants were carefully uprooted and taken to the laboratory, left to dry thoroughly for a week, before they were weighed (W_1). Spikes were then carefully separated and thoroughly threshed and weighed (W_2). The biological yield was then determined as follows:

$$\text{Biological yield (\%)} = W_2/W_1 \times 100 \quad \ldots\ldots\ldots\ldots\ldots \quad (3.6)$$

3.9.7 1000-seed weight (mg)

1000 seeds were carefully counted from the same sample examined in article 3.9.6. The weight of the sample was precisely determined with an aid of a sensitive balance, to the nearest 3rd decimal.

3.9.8 Yield (kg)

As described in article 3.8.

3.9.9 Soil moisture determination (%)

The method described by Gardner (1965) was used. Before each effective irrigation (i.e excluding the two preliminary irrigations), an anger was used to provide soil samples from three depths in succession with 15 cm increment upto 60 cm depth. One sub-plot was randomly considered for each replicate at a time. Soil samples were carefully placed in a polythene bags and labelled before they were transferred to the laboratory. Three sub-samples were then prepared in small cans to make a total of nine (9) sub-samples for each sub-plot. Sub-samples were oven-dried for 24 hrs at 100^{o}C before they are weighed again (W_2). Moisture content (M.C) on wet weight basis was then calculated as follows:

$$M.C\ (\%) = \frac{(W_1 - W_2)}{W_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots.. \quad (3.7)$$

CHAPTER FOUR

RESULTS

4.1 Effect of variety and irrigation water on growth attributes

4.1.1 Plant height (cm)

Variety had no significant effect (P > 0.05) on plant height in both seasons (Table 1). Generally, plant height 30 days after sowing was higher in season 2000/2001, while in the first season the tallest plant were obtained from 75 days after sowing.

Irrigation water amount had no significant effect on plant height in the two seasons (P > 0.05) as presented in (Table 2). However, irrigation water amounts of 500 mm and 600 mm produced the tallest plants in the first and second seasons, respectively. On the other hand, the shortest ones were obtained from irrigation water amount of 300 mm.

The variety x water amount interaction had no significant effect on plant height (Table 1 and 2). However, under Condor, with 500 mm and 600 mm in the second season 75 days after sowing in the two seasons. Debeira, El Nilein and Condor with 300 mm had the shortest plants at 75 days after sowing in the first season, whilst El Nilein with 300 mm at 75 days after sowing produced the shortest plants.

4.1.2 Length of leaves (cm)

Table (3) revealed the results of leaf length as affected by variety. In both seasons, variety had no significant effect on this parameter. However, Debeira variety recorded the greater leaf length of 20.975 cm and 24.863 cm in the first and second seasons, respectively.

Irrigation amounts had no significant effect on leaf length during the two seasons (Table 4). In the second season, the irrigation amount of 300 mm resulted in shorter length of leaves.

Table (3 and 4) showed that no significant effect among variety x water amount interaction on this parameter during both seasons. In the second season, the greatest length was obtained by El Nilein x 300 mm, Condor x 500 mm and Debeira x (400 mm and 600 mm) respectively. While the shortest leaf length was obtained under Condor x 300 mm in the first season and El Nilein x 300 mm in the second season.

4.1.3 Number of leaves/plant

Table (5) revealed that variety had no significant effect on number of leaves/plant in the two seasons. However, El Nilein variety recorded the highest number of leaves/plant during both seasons.

Amounts of irrigation water had no significant effect on number of leaves/plant in both seasons (Table 6). Number of leaves/plant was not significantly affected by the interaction of variety and water amount during both seasons (Table 5 and 6).

However, the highest number of leaves/plant was obtained under El Nilein x 600 mm in the first season and with 400 mm in the second season. While the lowest number of leaves/plant was obtained under Condor x 300 mm in the first season and Debeira x 400 mm in the second season.

4.1.4 Leaf turgidity

The analysis of variance showed that no significant effect of variety on leaf turgidity during the two seasons (Table 7 and 8). However, in the first season the highest value of leaf turgidity was obtained from El Nilein variety.

As shown on Table (7 and 8), the effect of irrigation water amount treatments on leaf turgidity was not significant in both seasons.

Variety x irrigation water interaction had no significant effect on leaf turgidity in the two seasons (Table 7 and 8). The highest value of leaf turgidity was obtained from El Nilein x 400 mm in the two seasons.

4.1.5 Number of tillers/plant

Results of number of tillers/plant, as affected by variety, are presented on (Table 9 and 10). Variety had no significant effect on number of tillers/plant in both seasons ($P > 0.05$). However, El Nilein variety gave the highest number of tillers/plant, (3.4 and 2.2 in the first and the second season, respectively). Whereas Debeira gave the lowest number of tillers/plant (1.8 and 1.0 in the two seasons respectively).

Irrigation water amount had no significant effect on number of tillers/plant for both seasons. The amount 300 mm produced the highest number of tillers/plant (4.0) in the first season, while the amount 400 mm produced the lowest number of tillers/plant (2.2) in the second season. On the other hand, the lowest number of tillers/plant was obtained with 600 mm in the first season (1.6) Table (9) and with 500 mm in the second season (1.0) (Table 10).

Variety x irrigation water amount interaction had no significant effect on the number of tillers/plant for both seasons. The highest number of tillers/plant was produced under El Nelein x 300 mm in the first season. While the lowest number was obtained under Debeira x 600 mm in the first season and Condor x 300 mm in the second season (Table 9 and 10).

4.2 Effect of variety and irrigation water amount on yield and yield components

4.2.1 Number of spikelets/spike

As shown in Table (11) varieties had no significant effect on number of spikelets per spike ($P > 0.05$). However, El Nelein produced the highest number of spikelets/spike (16.3 and 16.4) in the two seasons, respectively, whereas the lowest number was obtained from Condor (14.8 and 15.0) for both seasons, respectively.

Irrigation water amount had no significant effect on number of spikelets/spike during two seasons. Water quantity of 600 mm watering produced the highest number of spikelets/spike in both seasons. While the lowest number of spikelets/spike was obtained under 300 mm during the two seasons (Table 11).

It is evident that there was no significant effect of variety x irrigation water amount interaction on number of spikelets/spike in the two seasons ($P > 0.05$). The highest number of spikelets/spike was obtained under Debeira and El Nelein x 600 mm, while the lowest number was obtained under Condor x 500 mm in both seasons.

4.2.2 1000 – grain weight

In both seasons, variety had no significant effect on 1000- grain weight ($P > 0.05$). However, the highest weight was obtained by Debeira (28.387 g and 30.003 g), in the first and second seasons, respectively. On the other hand, Condor produced the lowest weight (26.934 g and 28.208 g) for both seasons, respectively (Table 12).

It is obvious that 1000-grain weight was not significantly affected by irrigation water amount in both seasons 1000- grain weight increased with increasing the level of irrigation water in the two seasons.

Variety x irrigation water amount interaction had no significant effect on 1000- grain weight in both seasons. Debeira x 500 mm produced the highest weight in the first season while El Nelein x 600 mm produced the highest weight in the second season.

4.2.3 Grain Yield (ton/ha)

As shown on Table (13), variety had no significant effect on grain yield ($P > 0.05$). Yields of season 2000/2001 were higher than those of season 1999/2000. The highest grain yields of 2.9 and 3.3 ton/ha were obtained from El Nelein variety during the two seasons,

respectively, where as, the lowest values of 2.5 and 3.0 ton/ha were obtained from Condor and 2.9 and 3.0 ton/ha from Debeira in the two seasons respectively.

Grain yield (ton/ha) was significantly affected by the amount of irrigation water in the two seasons (Table 13). As the level of irrigation water increased, the grain yield increased in both seasons.

Variety x irrigation water amount interaction had no significant effect on wheat grain yield ($P > 0.05$) in the two seasons (Table 13). However, the superior combination was Debeira with 600 mm in the first season as it gave the highest yield, and El Nilein with 600 mm in the second season. While the lowest yield was obtained under Condor and Debeira with 300 mm in the first season, and El Nilein with 300 mm in the second season.

4.2.4 Biological yield (ton/ha)

Variety had no significant effect on biological yield ($P > 0.05$) in both seasons (Table 14).

The amount of irrigation water had no significant effect on the biological yield ($P > 0.05$). However, the highest biological yields of 54.9 and 55.8 ton/ha were obtained under 600 mm in the two seasons, respectively. Also the biological yields of 51.1 and 54.8 ton/ha were obtained under 500 mm in both seasons. While the lowest yields were obtained under 300 mm and 400 mm in the two seasons, giving 40.5 and 42.8 ton/ha and 14.8 and 43.7 ton/ha respectively (Table 14).

In Table (14) variety and irrigation water amount interaction had no significant effect on this parameter. El Nelein x 600 mm gave higher values than the other combinations in the two seasons. While the lowest values were obtained under El Nelein x 300 mm and 400 mm in the two seasons respectively.

4.3 Soil moisture content

Table (15) depicts soil moisture content (w/w%) under three depths during the two seasons. In all sampling depths, the moisture content was higher in 15 and 30 cm depths in the two seasons.

In all treatments, the soil moisture content increased with increasing water quantity.

CHAPTER FIVE

DISCUSSION

Generally most of the growth and yield components had not been significantly effected by varieties and amount of irrigation water in both seasons. This may be attributed to the fact that all varieties received similar amounts of water before the commencement of the treatments.

This is in agreement with findings of Salih *et al.* (1994) who showed that the rooting depth did not exceed 16 cm under both wet and dry treatments, for this all cultivars used similar amount of water under the wet treatments. The results of the effect of varieties on growth components were not significant in the three varieties, from sowing to maturity. This may be attributed to the poor establishment of wheat crop. This agrees with Ageeb (1994) who found that wheat crop establishment is a result of many factors. These include seed germination soil tillage, irrigation water management and the effect of the environment.

In the first season, plant height was greater than that in the second season. This could be attributed to the high temperature that prevailed during the first season, which enhanced the rate of plant growth during that particular period (Appendix 1). The tallest plants were produced by greater quantities of irrigation water, while the shortest ones were obtained from plots receiving less quantities of irrigation water. These results agreed with those obtained by Ghuman and Maurya (1986) who found that the height of wheat crop was not significantly affected by the depth of seasonal irrigation water.

El Nilein variety scored the tallest plants and leaves at 75 days from sowing when the irrigation amount applied was 500 mm and the shortest plants were, when the quantity of water applied was 300 mm. This may be due to the fact that El Nelein scored the highest water use efficiency at all levels of irrigation which was attributed to its ability to maintain the highest relative turgidity values at these levels.

Number of tillers/plant decreased with increasing water amount. These results are in agreement with the findings of Reddy and Bhardway (1983), who found that the change of soil moisture regime from dry to wet, showed a positive response in respect to tiller production. Also, Gajri and Prihar (1983), obtained similar results.

Wheat yield increased as applied water increased. This disagreed with the findings of Steianer *et al.* (1985) who reported that irrigation significantly affected dry matter production, grain yield and yield components of wheat crop, and that more than 70% of the crop requirements were taken at an thesis. Furthermore, Ayars (1991) mentioned that excessive water application leads to consequently poor yield on excessive vegetative growth and consequently poor yield. On the other hand, Ageeb (1994) concluded that poor crop establishment of wheat was a major cause for low yield on heavy clay soils of the Sudan. Also the results were in agreement with Saxena and Singh (1979) who found a positive response of grain yield to irrigation level. Kragman and Lutwich (1961) also found higher yields with irrigation level based on 83% ETc and 100 ETc than 70% ETc level.

Irrigation water amount had no significant effect on number of spikelets per spike. These results are comparable with those obtained by White (1987) who also mentioned that spike emergence was more rapid for plants under low soil water. However, Prihar *et al.* (1976) found no response. This may be ascribed to the difference in amount of water in treatment, this emphasizes the positive effect of water amount on the number of spikelets per spike.

The results of 1000-grain weight was not significantly affected by irrigation water amount. The weight of thousand grains was found to increase with increased level of irrigation water, and these results were in agreement with those obtained by Prihar *et al.* (1976) who found no significant effect on 1000-grain weight due to varied irrigation levels, but their results conflicted with the findings of Gajri and Prihar (1983) who reported significant differences due to different water regimes. Yet, a positive response was observed to increased levels of irrigation water up to a certain limit.

Biological yield was not affected by increasing the water amount. These results were confirmed with those reported by Singh and Brar (1979) who found no significant differences in biological yield of wheat due to the depth of water stored in the soil profile. Also, similar results were reported by Sheikh *et al.* (1983). However, Rahman (1981) reported a trend of linear positive relationship between fresh and dry matter production and soil moisture.

Soil moisture content increased with increased water quantity. The highest moisture content was obtained at 5, 30 and 45 cm depth.

This may be due to the fact that upper depth contained the highest amount of water as mentioned by Baeumer and Bakermans (1973).

The variety x irrigation water amount interaction had no significant effect on both growth and yield components in this study. This may be attributed to the fact that each factor separately had no significant effect among those parameters and consequently the interaction of two factors also had no significant effect. Besides that, there was a slight increment in the yield of the variety El Nilein which may be due to high moisture in treatments 500 mm and 600 m. This agrees with Salih *et al.* (1994) who reported that El Nelien used more water under the dry treatment to increase its yield.

CHAPTER SIX
SUMMARY AND CONCLUSION

In this study, a field experiment was conducted during 1999/2000 and 2000/2001 seasons to investigate the effect of different quantities of irrigation water on growth and yield of three varieties of wheat, namely Condor, Debeira and El Nilein. The results showed that irrigation water amount significantly affected yield. High yields were obtained from 500 mm and 600 mm water quantities, while the low yield was recorded by the 300 mm treatment.

The varieties have no significant effect on yield and growth components. However, El Nilein gave higher yields with 500 mm and 600 mm.

The irrigation also affected soil moisture, which increased with increased irrigation water. There were differences in plant height between the two seasons, due to temperature variation.

It can be concluded that:

1. Increased irrigation water amount increased yield of wheat and soil moisture content.
2. El Nilein variety gave higher seed yield and greater values of leaf turgidity with increasing irrigation water.
3. The amount of 400 mm showed lower yield in all varieties as compared to the 500 mm and 600 mm of irrigation water.

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Appendix 1. Mean monthly temperature (^oC), relative humidity (%) and total rainfall (mm) at Shambat during seasons 1999/2000 and 2000/2001.

Months	1999/2000			2000/2001		
	Mean temp. (^oC)	RH (%)	Total rainfall (mm)	Mean temp. (^oC)	RH (%)	Total rainfall (mm)
November	28.3	25	-	26.7	27	-
December	25.0	30	-	22.5	29	-
January	25.0	30	-	22.7	26	-
February	24.1	30	-	23.3	23	-

Table 1. The effect of water amount and variety on plant height (cm) for season 1999/2000.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	19.98	20.23	19.38	19.86[b]	27.75	32.03	32.08	30.62[b]	41.70	41.38	44.98	42.68[b]	55.95	55.70	55.70	55.63[c]
Q_2	17.65	19.28	20.10	19.01[bc]	33.20	33.58	36.23	34.33[ab]	47.65	48.10	54.33	50.03[a]	61.55	61.45	65.73	62.91[b]
Q_3	21.40	21.63	19.80	20.94[a]	42.73	37.90	41.98	40.87[a]	54.90	52.00	57.68	54.86[a]	69.65	66.13	65.40	67.06[a]
Q_4	17.95	18.68	18.03	18.05[c]	42.15	39.83	39.65	40.54[a]	62.15	47.33	49.88	49.68[a]	65.43	66.45	65.73	65.88[ab]
Mean	19.12[a]	19.95[a]	19.33[a]		36.46[a]	35.83[a]	37.48[a]		49.10[a]	47.68[a]	51.71[a]		63.15[a]	62.43[a]	63.15[a]	
CVa =	7.66				12.89				11.99				5.90			
CVb =	5.49				19.52				13.45				5.39			
SEa = ±	0.43				1.36				1.71				1.07			
SEb = ±	0.27				1.79				1.66				0.85			
SEab = ±	0.53				3.57				3.32				1.69			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 2. The effect of water amount and variety on plant height (cm) for season 2000/2001.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	32.46	37.53	30.44	33.47[a]	42.10	42.45	44.10	42.87[a]	50.10	44.15	47.85	47.37[a]	53.93	52.75	59.40	55.36[b]
Q_2	30.95	28.55	34.00	31.17[a]	41.83	38.93	50.65	43.80[a]	49.26	45.98	45.85	47.03[a]	56.15	60.55	54.75	57.15[ab]
Q_3	30.21	31.10	36.34	32.55[a]	43.95	42.31	45.26	43.84[a]	50.28	46.38	43.30	46.65[a]	56.03	63.65	59.60	59.76[ab]
Q_4	31.13	31.95	30.45	31.17[a]	42.78	45.10	45.45	44.44[a]	50.91	49.60	47.08	49.20[a]	60.55	63.45	58.63	60.88[a]
Mean	81.19[a]	32.28[a]	32.80[a]		42.66[b]	42.20[b]	46.36[a]		50.14[a]	46.53[b]	46.02[b]		56.66[a]	60.10[a]	58.09[a]	
CVa =	16.92				11.33				9.97				9.21			
CVb =	24.67				12.97				9.89				9.07			
SEa = ±	1.57				1.43				1.37				1.55			
SEb = ±	1.98				1.42				1.18				1.32			
SEab = ±	3.96				2.84				2.35				2.64			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 3. The effect of water amount and variety on leaf length (cm) for season 1999/2000.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	14.55	16.80	16.70	16.02	19.88	21.70	20.58	20.72[a]	19.28	19.28	20.38	19.51[a]	16.48	17.28	20.60	18.12[a]
Q_2	18.35	18.03	17.05	17.81	16.65	16.38	18.18	17.07[b]	20.48	20.93	18.63	20.01[a]	17.48	19.70	20.35	19.18[a]
Q_3	18.45	17.23	16.13	17.27	21.55	17.55	21.20	20.10[a]	19.15	18.68	23.03	20.28[a]	18.50	16.73	19.33	18.18[a]
Q_4	16.83	17.03	15.68	16.51[a]	15.68	17.33	17.28	17.91[ab]	23.75	22.23	21.88	22.62[a]	17.60	18.08	19.95	18.54[a]
Mean	17.04[a]	17.27[a]	16.39[a]		18.85[a]	18.23[a]	19.77[a]		20.66[a]	20.18[a]	20.98[a]		17.51[b]	17.94[b]	20.06[a]	
CVa =	7.32				11.92				10.50				13.13			
CVb =	10.84				16.58				21.77				19.56			
SEa = ±	0.36				0.65				0.62				0.70			
SEb = ±	0.46				0.79				1.12				0.91			
SEab = ±	0.92				1.57				2.24				1.81			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor   D = Debeira   N = El Nilein

Table 4. The effect of water amount and variety on leaf length (cm) for season 2000/2001.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	18.60	17.68	19.83	18.70[a]	21.78	18.90	22.40	21.02[a]	20.75	20.34	21.30	20.80[a]	20.03	16.33	18.49	18.28[b]
Q_2	18.79	19.18	21.70	19.89[a]	22.50	19.26	25.26	22.34[a]	21.00	18.92	26.32	22.08[a]	19.43	16.98	25.00	20.47[b]
Q_3	19.31	19.59	21.58	20.16[a]	20.97	21.68	23.90	22.18[a]	22.14	21.65	25.47	23.09[a]	23.79	20.45	25.18	23.14[a]
Q_4	18.54	19.84	20.38	19.46[a]	20.20	21.80	24.01	22.00[a]	22.10	23.56	26.38	24.01[a]	21.70	20.33	25.00	22.34[ab]
Mean	18.81[b]	18.98[b]	20.87[a]		21.36[ab]	20.42[b]	23.89[a]		21.50[b]	21.12[b]	24.86[a]		21.23[ab]	18.52[b]	23.42[a]	
CVa =	11.05				16.20				15.88				18.13			
CVb =	19.91				24.30				17.37				21.22			
SEa = ±	0.62				0.85				1.03				1.10			
SEb = ±	0.97				0.74				0.98				1.12			
SEab = ±	1.95				1.47				1.95				2.23			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor   D = Debeira   N = El Nilein

Table 5. The effect of water amount and variety on number of leaves plant for season 1999/2000.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	6.13	7.45	6.65	6.74[a]	6.00	6.63	6.48	6.37[a]	6.48	7.25	7.00	6.91[a]	6.10	6.98	6.85	6.64[ab]
Q_2	6.45	7.33	6.68	6.82[a]	6.40	7.08	6.45	6.64[a]	6.90	6.25	7.00	6.72[a]	6.35	6.63	6.53	6.50[b]
Q_3	6.68	6.98	6.33	6.66[a]	6.45	7.08	7.20	6.91[a]	7.80	7.40	6.85	7.35[a]	6.68	6.90	6.48	6.68[ab]
Q_4	6.95	7.65	6.70	7.10[a]	7.28	7.70	6.30	7.09[a]	7.20	6.95	8.68	6.94[a]	6.98	7.48	6.48	6.98[a]
Mean	6.55[b]	7.35[a]	6.59[b]		6.53[b]	7.12[a]	6.61[b]		7.09[a]	6.96[a]	6.88[a]		6.53[b]	6.99[a]	6.58[b]	
CVa =	12.04				7.87				14.56				7.61			
CVb =	14.54				11.61				13.76				2.83			
SEa = ±	0.26				0.15				0.29				0.15			
SEb = ±	0.25				0.20				0.24				0.11			
SEab = ±	0.50				0.39				0.48				0.22			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 6. The effect of water amount and variety on number of leaves plant for season 2000/2001.

Water	Days 30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	6.85	6.85	6.70	6.80[a]	6.45	6.95	6.85	6.75[a]	6.75	6.90	6.55	6.73[a]	6.80	7.15	6.75	6.90[a]
Q_2	6.90	6.75	6.05	6.57[a]	6.60	7.35	7.00	6.98[a]	6.55	7.10	6.65	6.77[a]	6.95	7.00	6.85	6.93[a]
Q_3	6.70	6.60	6.35	6.55[a]	6.75	7.20	6.80	6.92[a]	6.55	6.75	6.55	6.62[a]	6.55	6.80	6.90	6.75[a]
Q_4	6.95	6.90	6.75	6.87[a]	6.50	7.20	6.35	6.68[a]	6.85	6.33	6.90	6.69[a]	6.70	7.10	6.55	6.78[a]
Mean	6.85[a]	6.78[a]	6.46[a]		6.58[b]	7.18[a]	6.75[b]		6.68[a]	6.77[a]	6.66[a]		6.75[b]	7.01[a]	6.76[b]	
CVa =	8.54				4.36				10.72				4.28			
CVb =	14.18				6.39				13.09				6.87			
SEa = ±	0.16				0.08				0.21				0.08			
SEb = ±	0.24				0.11				0.22				0.12			
SEab = ±	0.47				0.22				0.44				0.24			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 7. The effect of water amount and variety on leaf turgidity (%) for season 1999/2000.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	49.55	51.98	43.62	48.38[a]	59.42	76.99	65.59	67.33[a]	69.95	79.37	74.67	74.66[a]	66.61	75.03	68.99	70.21[a]
Q_2	52.13	53.01	52.16	52.43[a]	65.71	80.34	75.85	73.97[a]	62.89	74.81	69.39	69.03[a]	59.08	69.76	62.04	63.63[ab]
Q_3	50.00	54.11	52.48	52.20[a]	64.68	66.13	65.68	65.50[a]	62.21	60.00	62.96	61.72[a]	51.30	54.35	46.90	50.85[b]
Q_4	54.37	59.32	50.49	54.73[a]	69.60	77.99	71.10	72.89[a]	56.13	56.13	55.89	56.06[a]	51.27	54.27	53.62	53.05[b]
Mean	51.51[a]	54.60[a]	49.68[a]		64.85[b]	75.36[a]	69.55[ab]		62.79[b]	67.72[ab]	65.72[ab]		57.07[b]	63.35[a]	57.89[b]	
CVa =	13.71				13.04				9.44				7.15			
CVb =	14.58				26.97				33.13				24.93			
SEa = ±	2.05				2.63				1.78				1.23			
SEb = ±	1.89				4.71				5.41				3.70			
SEab = ±	3.79				9.43				10.83				7.41			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 8. The effect of water amount and variety on leaf turgidity (%) for season 2000/2001.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	52.05	54.62	46.21	50.96[a]	58.85	63.83	58.81	60.50[a]	58.46	40.40	64.02	54.29[b]	58.30	51.87	52.18	54.12[a]
Q_2	50.76	54.01	57.76	54.18[a]	54.86	64.68	75.93	65.16[a]	60.61	62.31	57.00	59.97[ab]	56.91	53.55	51.35	53.94[a]
Q_3	50.57	54.97	53.85	53.13[a]	61.94	63.41	65.91	63.75[a]	64.63	67.30	70.94	67.62[a]	49.36	53.68	57.62	53.54[a]
Q_4	54.28	51.70	50.47	52.15[a]	70.37	76.02	70.83	72.41[a]	67.79	60.13	69.23	65.72[ab]	59.36	66.90	55.61	60.62[a]
Mean	51.92[a]	53.82[a]	52.07[a]		61.51[a]	66.98[a]	67.87[a]		57.53[a]	62.87[a]	65.30[a]		55.97[a]	56.50[a]	54.19[a]	
CVa	8.65				17.70				19.77				8.85			
CVb	14.42				24.53				20.29				14.43			
SEa = ±	1.31				3.34				3.53				1.42			
SEb = ±	1.90				4.01				3.14				2.00			
SEab = ±	3.79				8.03				6.28				4.01			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 9. The effect of water amount and variety on number of tillers for season 1999/2000.

Water	Days															
	30				45				60				75			
	Variety															
	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	3.30	4.08	3.70	3.69^{a}	3.18	3.70	3.30	3.39^{a}	3.55	4.45	3.88	3.96^{a}	2.15	1.85	2.05	2.02^{ab}
Q_2	3.23	3.60	3.15	3.33^{ab}	2.83	3.80	3.85	3.49^{a}	3.68	4.23	3.48	3.79^{a}	2.65	2.30	2.25	2.40^{a}
Q_3	2.25	3.25	2.50	2.67^{b}	2.48	2.65	2.25	2.46^{b}	2.68	2.80	2.35	2.61^{b}	2.05	2.10	1.80	1.98^{ab}
Q_4	1.88	1.63	1.75	1.75^{c}	2.13	2.40	2.38	2.30^{b}	1.83	2.03	2.15	2.00^{b}	1.65	2.05	1.15	1.62^{b}
Mean	2.66^{a}	3.14^{a}	2.78^{a}		2.65^{a}	3.14^{a}	2.94^{a}		2.93^{b}	3.38^{a}	2.96^{ab}		2.13^{a}	2.08^{a}	1.81^{a}	
CVa	24.13				24.06				18.51				23.87			
CVb	25.06				21.41				33.84				31.30			
SEa = ±	0.20				0.20				0.17				0.14			
SEb = ±	0.18				0.16				0.26				0.16			
SEab = ±	0.36				0.31				0.52				0.31			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 10. The effect of water amount and variety on number of tiller for season 2000/2001.

	Days															
	30				45				60				75			
	Variety															
Water	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean	C	N	D	Mean
Q_1	2.00	2.65	1.05	1.90^{a}	0.60	1.85	1.40	1.28^{b}	1.75	1.25	0.65	1.22^{a}	1.15	0.85	1.05	1.02^{a}
Q_2	2.15	2.55	1.95	2.22^{a}	1.90	1.30	1.40	1.53^{ab}	1.10	1.60	1.25	1.32^{a}	1.65	1.30	1.20	1.38^{a}
Q_3	2.30	1.55	1.20	1.68^{a}	2.15	1.83	1.45	1.81^{a}	1.05	1.25	0.90	1.07^{a}	0.90	1.45	0.75	1.03^{a}
Q_4	2.00	1.85	1.55	1.80^{a}	1.60	1.50	1.70	1.80^{ab}	1.20	1.80	1.55	1.52^{a}	0.85	1.55	1.00	1.13^{a}
Mean	2.11^{a}	2.15^{a}	1.44^{b}		1.56^{a}	1.62^{a}	1.49^{a}		1.28^{a}	1.48^{a}	1.09^{a}		1.14^{a}	1.29^{a}	1.00^{a}	
CVa	33.62				49.91				45.86				47.95			
CVb	41.71				30.23				77.31				48.18			
SEa = ±	0.18				0.22				0.17				0.16			
SEb = ±	0.20				0.12				0.25				0.14			
SEab = ±	0.40				0.24				0.49				0.28			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 11. The effect of water amount and variety on number of spiklets/spike for seasons 1999/2000 and 2000/2001

Water	First season 1999/2000				Second season			
	Variety							
	C	N	D	Mean	C	N	D	Mean
Q_1	14.42	14.55	14.93	14.63[a]	14.15	14.95	15.45	15.05[a]
Q_2	14.50	16.10	15.20	15.27[a]	14.95	16.20	15.90	15.68[a]
Q_3	14.43	17.33	17.08	16.28[a]	14.05	16.95	16.70	15.90[a]
Q_4	15.90	17.20	17.20	16.77[a]	16.08	17.35	17.35	16.93[a]
Mean	14.81[b]	16.29[b]	16.10[a]		14.96[b]	16.36[a]	16.35[a]	
CVa =	9.12				9.50			
CVb =	18.42				14.68			
SEa = ±	0.41				0.44			
SEb = ±	0.72				0.58			
SEab = ±	1.45				1.17			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 12. The effect of water amount and variety on 1000-grain weight (g) for seasons 1999/2000 and 2000/2001

Water	First season 1999/2000				Second season			
	Variety							
	C	**N**	**D**	**Mean**	**C**	**N**	**D**	**Mean**
Q_1	22.94	23.84	24.60	23.79[c]	25.14	22.39	25.32	24.28[c]
Q_2	26.84	26.96	26.92	26.91[b]	26.40	26.76	28.53	27.23[b]
Q_3	29.69	29.77	31.32	30.26[a]	31.65	33.18	33.04	32.62[a]
Q_4	28.27	30.02	30.72	29.67[a]	29.65	34.25	33.14	32.34[a]
Mean	26.93[b]	27.65[ab]	28.39[a]		28.21[b]	29.15[ab]	30.00[a]	
CVa =	6.27				5.62			
CVb =	8.58				9.88			
SEa = ±	0.50				0.47			
SEb = ±	0.59				0.72			
SEab = ±	1.19				1.44			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 13. The effect of water amount and variety on grain yield (ton/ha) for seasons 1999/2000 and 2000/2001

Water	First season 1999/2000				Second season			
	Variety							
	C	N	D	Mean	C	N	D	Mean
Q_1	2.13	2.46	2.16	2.25[c]	2.62	2.21	2.46	2.43[c]
Q_2	2.28	2.73	2.73	2.58[b]	2.99	2.99	2.82	2.93[b]
Q_3	2.78	3.21	3.20	3.06[a]	2.02	3.71	3.46	3.40[a]
Q_4	2.84	3.26	3.36	3.16[a]	3.43	4.17	3.50	3.70[a]
Mean	2.51[b]	2.91[a]	2.86[a]		3.01[b]	3.27[a]	3.06[b]	
CVa =	10.95				8.43			
CVb =	10.21				13.34			
SEa = ±	0.09				0.08			
SEb = ±	0.07				0.10			
SEab = ±	0.14				0.21			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor   D = Debeira   N = El Nilein

Table 14. The effect of water amount and variety on biological yield for seasons 1999/2000 and 2000/2001

Water	First season 1999/2000				Second season			
	Variety							
	C	**N**	**D**	**Mean**	**C**	**N**	**D**	**Mean**
Q_1	41.65	39.55	40.17	40.45[b]	43.92	41.50	42.86	42.76[b]
Q_2	43.26	39.45	42.83	41.85[b]	44.84	41.42	44.95	43.74[b]
Q_3	49.20	51.88	52.36	51.15[a]	52.38	55.89	56.11	54.78[a]
Q_4	53.23	56.40	55.03	54.88[a]	54.03	58.58	54.87	55.83
Mean	46.84[a]	46.82[a]	47.59[a]		48.79[a]	49.34[a]	49.70[a]	
CVa =	7.72				7.75			
CVb =	17.92				14.03			
SEa = ±	1.05				1.10			
SEb = ±	2.11				1.73			
SEab = ±	3.44				3.46			

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm

C = Condor D = Debeira N = El Nilein

Table 15. The effect of water irrigation and depth on soil moisture.

Water	First season 1999/2000			Second season		
	Depth					
	0-15	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Q_1	11.93	15.03	11.07	9.96	12.41	9.12
Q_2	12.92	15.68	11.64	10.34	13.20	9.22
Q_3	13.98	18.22	12.25	11.52	17.37	10.5
Q_4	11.8	19.79	12.93	12.47	17.82	11.75
Error	0.69			0/83		
Mean	4.79			6.89		

Q_1 = 300 mm Q_2 = 400 mm Q_3 = 500 mm Q_4 = 600 mm