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***Corresponding author**

Ali Abdalla Mohammed, National Institute of Desert Studies, University of Gezira, Wad Medani, Sudan

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Research Article

# Effect of Irrigation Intervals, Irrigation Method and Different Nitrogen Fertilizer Rates on Wheat Performance and Water use Efficiency in Northern State of Sudan

**Ali Abdalla Mohammed* and Imran Ali Ahmed**

*National Institute of Desert Studies, University of Gezira, Wad Medani, Sudan*

## Abstract

Most soils under arid conditions have extremely low quality due to poor physical conditions, low organic matter and water retention capacity, soil fertility and consequently both low water and fertilizer use efficiencies. The present study was planned to investigate the effects of irrigation interval (II), irrigation methods (IM) and nitrogen fertilizer rates (NF) on wheat performance (yield and its components) and water use efficiency. The experiment was conducted at National Institute of Desert Studies Research Farm for two consecutive winter seasons of (2020/21) and (2021/22) in a sandy soil of North Sudan. The experiment design was complete randomized block in factorial arrangement with four replications. Factor (A) was irrigation methods with two types (furrow and basin), factor (B) was irrigation interval with three rates (7, 10, 13 days) and factor (c) was assigned to nitrogen with three rates (43, 86 and 129 Kg/fed). The results showed that irrigation methods had not significant p (≤.05) effect on wheat yield and its components and water use efficiency, irrigation interval affected significantly p (≤.05) on plant height, biomass, spike per meter square, grain yield and water use efficiency in both seasons Nitrogen fertilizer were effective highly significant p (≤.05) in improving biomass p (≤.05) and significantly p (≤.05) effect on plant height, number of spike per meter square, grain yield and water use efficiency in both seasons. Both irrigation interval and nitrogen fertilizer rates were not significant p (≤.05) effect on plant per meter. Maximum yield and high water use efficiency were obtained when irrigated every 7 days and added nitrogen fertilizer in rate of 129 Kg per fedan.

## Introduction

More than 60% of Sudan area lies in the arid and semiarid region which is characterized by low and erratic rainfall. Salih [1] stated that the desert extends from north to south at an alarming rate and he also mentioned that about 13 states out of the 26 states of the Sudan are affected by desertification but now after separation this ratio was increased. The desert plain soils of Northern State of Sudan are characterized by high amount of sand and low chemical soil fertility and mostly are deficient in nitrogen, phosphorus and organic carbon for optimum yield production of different cultivated crops [2,3], In many of the arid and semi-arid regions of the world including Sudan water is likely to become the most critical resource and the most limiting factor in the production of food [4].

Profitability of producing irrigated crops is directly related to water management. Applying too much or too little water at the wrong time is a common problem. Applying too much water causes leaching of nutrients, erosion, high water tables and salinity problems. Too much water at the wrong time can retard plant growth and production. Too little water at critical crop stages can significantly reduce production. Irrigation water management is managing soil moisture so that an optimum quantity of irrigation water is applied at appropriate times. Good water management can both increase crop production and reduce costs. [5]. This present study was planned to investigate the effects of irrigation interval, irrigation methods, and nitrogen fertilizer on wheat performance (yield and its components) and water use efficiency.

## Materials and Methods

Field experiments were carried out during two consecutive winter seasons (2011/12 and 2012/13) at the National Institute of Desert Studies Research Farm, New Hamdab Scheme, Northern State of Sudan (latitude 17°55' N and longitude 31°10' E). The climatic zone of the area is described as desert, which is characterized by high temperature in summer, low temperature in winter and low rainfall (Habiballa and Ali, 2010). The soil of the study area belongs to El Multaga soil series which classified as Vertic Haplocambids, fine loamy, mixed, supper active, hyperthermic. The soil structure is moderate sub angular blocky. It is non-saline and non-sodic (Table 1) [2]. Generally, the soil chemical fertility is low and mostly these soils deficient in nitrogen, phosphorus and organic carbon for optimum yield production of different cultivated crops. The physical properties of the soil are shown in Table 1.

**Table 1:** Some soil properties of the experimental site.

| Soil properties | Soil depth (cm) | | | | |
|---|---|---|---|---|---|
| | 0-23 | 23-65 | 65-80 | 80 – 105 | 105 - 125 |
| FS (%) | 40 | 23 | 22 | 21 | 24 |
| CS (%) | 37 | 33 | 43 | 42 | 40 |
| Silt (%) | 15 | 25 | 11 | 19 | 8 |
| Clay (%) | 8 | 19 | 24 | 18 | 28 |
| Texture | LS | SL | SL | SL | SCL |
| H (paste) | 7.5 | 7.3 | 8.1 | 7.8 | 7.5 |
| Ece | 0.35 | 0.37 | 0.42 | 1.1 | 3.2 |
| ESP | 3.0 | 3.0 | 4.0 | 5.0 | 8.0 |
| CaCO3 (%) | 0.8 | 2.6 | 10.4 | 0.2 | 27.5 |
| O.C (%) | 0.052 | 0.066 | 0.078 | 0.061 | 0.052 |
| C/N ratio | 4 | 4 | 5 | 5 | 5 |

L S = loamy sand, SL = sandy loam, SCL= sandy clay loam

## Treatments and Experimental Design

The treatments were arranged in completely randomized in factorial arrangement with four replicates. The area of each sub- sub plot was 42m$^2$ (6 × 7 m). The experimental units were two meter apart from each other. The experimental procedures were the same for both seasons. Treatments and their abbreviations are illustrated in Table 2.

**Table 2:** Treatments Application and their Abbreviations.

| Treatment | Operation | Abbreviation |
|---|---|---|
| Irrigation Interval Factor A (II) | 7 Days | I1 |
| | 10Days | I2 |
| | 13Days | I3 |
| Irrigation Methods Factor B(IM) | Furrow | F |
| | Basin | B |
| Nitrogen Fertilizer Factor C (NF) | 43 Kg fed$^{-3}$ | NF1 |
| | 86 Kg fed$^{-3}$ | NF2 |
| | 129 Kg fed$^{-3}$ | NF3 |

## Cultural practices

Wheat variety Wadi Elneel was used in this study. Sowing was done manually by digging on 20$^{th}$ of November for both seasons, with seed rate of 120 kg ha$^{-1}$, at 0.2 m inter-row spacing.

## Collection of data

Plant samples were collected randomly from each experimental unit (sub- sub plot) and then growth and yield parameters were determined. A number of thousand seeds were picked randomly from each plot. The seeds were weighed, and mean 1000-seeds weight (g) was obtained.

Plants of the net area of one meter square (using steel frame of one meter square) were cut at the soil surface at harvest time in three different positions in each plot, tied in bundles and left to dry by air. After drying, they were weighed, then the mean biological yield (kg ha$^{-1}$) (dry matter plus grain) was determined.

The experimental units consisted main plots irrigation interval, sub- plots irrigation methods and sub-sub- plots nitrogen levels. The sub-sub- plot size will be 6 × 7 meters. The experiment was designed in spilt- spilt block design.

Wadi Elneel wheat verity was grown under three irrigation intervals 7, 10 and 13 days, (factor A), with two irrigation methods Basin and furrow as (factor B) and three levels of nitrogen fertilizer were applied 43 Kg/fed, 86 Kg/ fed and 129 Kg/ fed (factor C). Measurement of the soil moisture in the root zone (0 -25 cm, 25 -50 cm, 50 -75 cm soil depths) for each irrigation was calculated using the following formula:

$$MC = \frac{WW - DW \times 100}{DW}$$

Where:
MC = moisture content (%).
WW = wet weight of soil sample (g).
DW = dry weight of soil sample (g).

Then the total moisture applied in each irrigation was calculated using Michael's (1978) formula to convert to volumetric values as follows:

$$S = G.D\ (M1 - M2)/100$$

Where:
S= Change in soil moisture storage (mm).
G = Bulk density (g cm$^{-3}$).
D = Soil depth (cm).
M1= Initial moisture content % before irrigation.
M2= Final moisture content% after irrigation.

Bulk density was determined with the help of core sampler and soil moisture with gravimetric method. Samples for determination of moisture contents were regularly taken from different locations and at three depths i.e. 0-25, 25-50 and 50-75 cm.

Potential Evapotranspiration (ETo) was determined by using CROPWAT soft program and metrological data was obtained from national institute metrological station.

## Results and Discussion

Table 3 showed the effect of irrigation intervals on wheat yield, related agronomy and water use efficiency, Results indicated that irrigation intervals had no a significant p (≤.05) effect plant per meter, 1000 seeds weight and significant p (≤.05) effect in improving Biomass, spike/m$^2$, grain yield and water use efficiency. Maximum wheat yield was obtained when irrigated every 7 days although there was no difference in wheat yield when irrigated every 10 days so it's better to irrigate every 10 days to decrees amount of water and increase water use efficiency. The highest water use efficiency (2.4 kg fed$^{-1}$) was obtained when crop was irrigated after seven days interval, this is can be attributed to high wheat yield when irrigated every seven days. This result is in agreement with that of mohammad et al. [6] who concluded that irrigation interval affected significantly on wheat yield and water use efficiency.

**Table 3:** Average of growth, yield and water use Efficiency of wheat influenced by different irrigation interval.

| Irrigation Intervals | Plant No/ m$^2$ | Biomass (Kg/ Fed) | Spike/ m$^2$ | Plant height (Cm) | 1000 Seed weight (gm) | Grain Yield (Kg/ Fed) | WUE (Kg/ m$^3$) |
|---|---|---|---|---|---|---|---|
| 7 | 157a | 3836.28a | 224a | 88.2a | 34.6a | 1307.04a | 2.4a |
| 10 | 153a | 3331.02a | 210a | 79.0b | 33.5a | 1223.88a | 2.2a |
| 13 | 152a | 3044.58b | 173b | 78.8b | 31.0a | 971.04b | 1.3b |
| Mean | 154 | 3403.96 | 202.3 | 79.7 | 33.03 | 1167.32 | 1.9 |
| SE± | 0.04 | 100.38 | 8.3 | 0.64 | 0.5 | 54.6 | 0.58 |
| Sig. Level | NS | * | * | * | NS | * | * |

Means within columns followed by the same letter(s) are not significantly different at P<0.05 level according to Duncan's Multiple Range Test. * indicate at P ≤ 0.05.

## Irrigation Methods

Table 4 illustrated the effect of irrigation methods on wheat yield and related agronomy and water use efficiency in both seasons. Results showed that there were no significant p (≤.05) differences between basin and furrow irrigation methods in wheat yield, its components and water use efficiency.

**Table 4:** Average of growth, yield and water use Efficiency of wheat influenced by irrigation methods

| Irrigation Methods | Plant No/ $m^2$ | Biomass (Kg/ Fed) | Spike/ $m^2$ | Plant height (Cm) | 1000 Seed weight (gm) | Grain Yield (Kg/ Fed) | WUE (Kg/$m^3$) |
|---|---|---|---|---|---|---|---|
| Basin | 146 | 3404.5 | 198 | 79.3 | 32.0 | 1129.8 | 2.1 |
| Furrow | 147 | 3768.8 | 197 | 79.8 | 33.7 | 1148.3 | 2.2 |
| Mean | 146.5 | 3586.7 | 197.5 | 79.6 | 32.9 | 1139.05 | 2.15 |
| SE± | 2.93 | 70.6 | 3.3 | 0.82 | 1.04 | 14.7 | 0.04 |
| Sig. Levels | NS | NS | NS | NS | NS | NS | NS |

## Nitrogen Fertilizer

Table 5 illustrated the effect of nitrogen levels on plant No/ $m^2$, plant height, Biomass, spike/$m^2$, 1000 seed weight, grain yield and water use efficiency. Results indicated that nitrogen levels had no significant p (≤.05) effect on plant per meter, but there were a significant p (≤.05) effect on spike per meter, plant height, thousand seeds weight grain yield and water use efficiency and had highly significant p (≤.05) effect in improving wheat biomass. This results is in online with that of Amjed et al [7] and Halepyati [8], Yang et al [9] and Halepyati et al. [8] those mentioned that high dose of nitrogen fertilizer resulted in high wheat yield.

**Table 5:** Average of growth, yield and water use Efficiency of wheat influenced by different nitrogen rates

| Nitrogen (Kg/ Fed) | Plant No/ $m^2$ | Biomass (Kg/ Fed) | Spike/ $m^2$ | Plant height (Cm) | 1000 Seed weight (gm) | Grain Yield (Kg/ Fed) | WUE (Kg/ $m^3$) |
|---|---|---|---|---|---|---|---|
| 43 | 154a | 3134.0c | 192c | 66.0c | 34.0b | 1059.2b | 2.0c |
| 86 | 151a | 3543.5b | 192b | 78.9b | 34.3b | 1187.3b | 2.1b |
| 129 | 150a | 3644.8a | 194a | 80.7a | 36.2a | 1301.2a | 2.2a |
| SE± | 3.6 | 104.2 | 0.8 | 0.9 | 0.79 | 69.5 | 0.1 |
| Sig. Levels | NS | ** | * | * | * | * | * |

Means within columns followed by the same letter(s) are not significantly different at P<0.05 level according to Duncan's Multiple Range Test.
* and ** indicate significance at P ≤ 0.05 and 0.01, respectively.

## Reference evapotranspiration and accumulated water at Root zone

Results in Table 6 showed the values of reference evapotranspiration from sowing up to harvesting in (mm/day) every ten days using maximum temperature, minimum temperature humidity, wind speed, sun shine and radiation by using software package (CROPWAT). Results showed that high reference evapotranspiration of 6.39mm/ day was obtained after three month of crop sowing in summer and the lower on was 4.29 in winter, this is can be attributed to the highest values of temperature in summer compare to winter which is characterized by low temperature. Results in Table 7 revealed that the highest amount of accumulated total moisture applied in the root zone was 653.4 mm, when irrigated every seven days using furrow irrigation method, and the lowest moisture applied was 334.6mm for irrigated every thirteen days using basin method. Generally, the grand mean was 504.6 mm. Also results indicated that the amount of water accumulate in root zone is high when using furrow irrigation method, this is may be due to the shape of furrow which allows to collect and concentrated water in root zone more than water is collected when use basin.

**Table 6:** Calculation of Reference evapotranspiration (mm/day).

| DAS | Min Temp °C | Max Temp °C | Humidity % | Wind km/ day | Sunshine hour | Rad MJ/$m^2$/ day | Eto mm/ day |
|---|---|---|---|---|---|---|---|
| 10 | 4.4 | 27.7 | 56 | 234 | 9.9 | 19.6 | 4.29 |
| 20 | 6.0 | 28.8 | 53 | 185 | 10.2 | 21.5 | 4.71 |
| 30 | 8.3 | 29.2 | 59 | 159 | 10.2 | 23.5 | 4.86 |
| 40 | 8.3 | 30.1 | 54 | 164 | 10.2 | 25.1 | 5.48 |
| 50 | 8.0 | 27.7 | 63 | 185 | 9.85 | 25.2 | 5.20 |
| 60 | 5.2 | 23.8 | 65 | 210 | 9.85 | 25.0 | 4.61 |
| 70 | 8.4 | 28.3 | 57 | 191 | 9.85 | 24.4 | 5.19 |
| 80 | 11.6 | 31.9 | 56 | 147 | 9.65 | 24.4 | 5.34 |
| 90 | 15.2 | 34.3 | 51 | 226 | 9.65 | 23.6 | 6.39 |
| 100 | 13.6 | 30.9 | 53 | 256 | 9.65 | 21.7 | 5.71 |
| 110 | 13.7 | 30.3 | 57 | 215 | 10.2 | 19.7 | 5.09 |
| Average | 9.3 | 29.4 | 56.7 | 197.5 | 9.9 | 23.1 | 5.20 |

(Source: National Institute of desert studies metrological station).

**Table 7:** Average accumulated water at the active root zone affected by irrigation intervals and method on wheat.

| Treatments | Water applied (mm) for season |
|---|---|
| I1 B | 634.2 |
| I1 F | 653.4 |
| I2 B | 499.4 |
| I2 F | 523.3 |
| I3 B | 382 |
| I3 F | 334.6 |
| Mean | 528.5 |
| SD± | 141.1 |

$I_1$ =irrigation interval (7) days, $I_2$= irrigation interval (10) days, $I_3$= irrigation interval (13) days, B= Basin irrigation method, F=Furrow irrigation method and SD± standard deviation.

## Conclusion

It can be concluded that irrigation methods had not significant effect in both wheat yield and water use efficiency. Irrigation interval and nitrogen fertilizer doses were affected in improving wheat groth, yield and water use efficiency of the poor sandy soil of Northern State of Sudan

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