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# Effect of Irrigation, Foliar Spray with Nano-fertilizer (Lithovit) and N-levels on Productivity and Quality of Durum Wheat under Toshka Conditions

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## Abstract

Tow field experiments were carried out at the Experimental Farm of the Water Studies and Research Complex (WSRC) Station, National Water Research Center, in Abu Simbel, Toshka Region, Egypt during two winter seasons 2015-16 and 2016-17. The main objectives were to study the effect of different irrigation levels [$A_1$=100% of crop water requirements ($ET_{crop}$), $A_2$=80% $ET_C$ and $A_3$=60% $ET_C$], three rates of nano-fertilizer (lithovit) ($B_1$=0, $B_2$= 200 and $B_3$=400ppm), three levels of nitrogen fertilizer ($C_1$=60, $C_2$=80 and $C_3$=100 kg N fed$^{-1}$) and their interactions on yield and its component, water use efficiency (WUE), fertilizer use efficiency (FUE) and quality of durum wheat plants. The experimental design was a strip-split plot with three replications. The tested agronomic traits were: plant height, No. of tillers m$^{-2}$, spike length, No. of grains spike$^{-1}$, 1000-grain weight, grain yield, water use efficiency (WUE), irrigation use efficiency (IWUE), fertilizer use efficiency (FUE) as well as protein and ash content, hectoliter weight and Hegberg falling number. The results indicated that the irrigation levels, nano-fertilizer concentrations and N-levels had significant effects on most yield component, water parameters, fertilizer use efficiency and quality of wheat plants in both seasons. Increasing irrigation levels from 60% to 100% increased all agronomic traits and FUE, but WUE, IWUE and falling number were decreased. The treatment of 400 ppm nano-fertilizer produced high values of all yield parameters, water relation, FUE except falling number. Increasing N-levels from 60 to 100 kg N fed$^{-1}$ increased all studied traits, but FUE and falling number were deceased. The maximum grain yield (2192.4 and 2251.6), (2026.8 and 2075.7) and (1904.3 and 1964.3 kg fed$^{-1}$) were produced when 100% of irrigation water, 400ppm of lithovit and 100 kg N fed$^{-1}$ were applied in the two seasons, respectively.

Based on the obtained results, it could be concluded that highest irrigation level of 100%, nano-fertilizer concentration of 400 ppm in combination with N-level of 100 kg fed$^{-1}$ is suitable for Toshka climatic conditions to increase the grain yield and quality of wheat (*Triticum durum* L.).

**Keywords:** *Toshka, Wheat, Irrigation levels, Nano-lithovit and N-levels, WUE, IWUE, FUE, yield and Quality.*

## Introduction

Wheat (*Triticum durum* L.) belong to the family Poaceae and genus Triticum. It is an annual, self-pollinated and long-day cereal crop. It is God's unique gift to mankind as it produces an excellent source of human nutrition in terms of carbohydrates, calories, minerals and proteins in the most developing countries including Egypt.

Durum wheat is resistant under hot climatic condition, hence, it is intensively cultivated in Upper Egypt due to its good heat tolerance. Egypt occupies an advanced position among the countries of the world in the productivity of the areal unit, it is preceded only by the countries where the wheat growing season lasts for about ten months, such as Germany, France, Holland and England, which is characterized by a cold climate, which gives the grain the full opportunity for growing and the quality of filling. In Egypt, wheat covers 1,368,767 ha of area harvested with an annual production 9,000,000 ton, according to (FAO, 2016). The produced wheat in Egypt is locally consumed and is not enough for the population needs. Egypt imports the necessities for local consumption. Farmers and scientists in Egypt are making good efforts to close the gap between production (about 9.0 million tons) and consumption, which are estimated by 50-60% with increasing the cultivated area of wheat as well as the increasing of unit area productivity and the reduction of loss in production, processing, and consumption. Wheat researchers, instead of milling industry, need to perform experiments regarding quality and determine the important constituent's *i.e* protein, falling number and acidity, because the ingredients dictate the intended use of flour (Glevitzky *et al*., 2011 and Petrenko *et al*., 2015).

Irrigation is the most important factor necessary for optimum growth and development of wheat especially in arid and semi-arid areas. Wheat production is influenced by different factors *i.e.* soil fertility, climatic condition and irrigation treatments. The influences of the implemented amount of sprinkler irrigation water, irrigation frequency and water use are particularly in order to obtain higher yields. Suitable scheduling of sprinkler irrigation is critical for operative water management in crop production, particularly under conditions of water scarcity (Pereira *et al.,* 2002). Decreasing the irrigation requirements from 100% to 50% significantly decreased most of growth characters, yield and its components, protein while, water use efficiency significantly increased (Abdelraouf *et al*., 2013, Mansour *et al*., 2016 and Gangwar and Lodhi, 2018). Increasing irrigation amounts up to 100% of irrigation requirement significantly increased grain yield (Teama *et al*., 2016), while WUE and IWUE decreases with increasing amount of irrigation water (Beyenesh and Nigussie, 2017 and Eissa *et al*., 2018). Grain yield and its components of wheat increased when wheat plants were irrigated to field capacity (Sarkar *et al*., 2017). Abdrabbo *et al.* (2016) showed that the 1.2 of water requirements gave the highest grain yield and vegetative growth while, the 0.6 of water requirements gave the highest water use efficiency, increasing irrigation water above 0.6 from water requirements led to decrease water use efficiency.

Nano-technology is the most novel field of the twenty-one century.

Modern technologies improved production and food quality, which can meet ever-increasing world food demand in environment-friendly way (Wheeler, 2005). Nanoparticles are defined as the materials (atomic aggregates) with size range of 1 to 100 nm (nm=$10^{-9}$) in at least one dimension (Liu and Lal, 2015).

Nanotechnology such as using nano-scale particles is expected to play a vital role in developing improved systems for increasing the ability of crops to absorb nutrients. Rameshaiah and Jpallavi, (2015) found that nano formulated fertilizers can be easily noticed by plants and they perhaps exhibit prolonged effective duration of nutrient supply in soil or on plant.

Use of Nano-fertilizers instead of common fertilizers may have properties that are valuable to crops which releases the nutrients requirement, discharge of chemicals fertilizers in a controlled way that standardize plant growth and improve activity of target (Farooqut *et al*., 2016). Furthermore, nanoparticles enhance crop yield, photosynthetic activity, nutrient use efficiency, grain quality and nitrogen metabolism (Sekhon, 2014).

Lithovit is a natural calcium carbonate (nano-$CaCO_3$) foliar fertilizer made from limestone deposits by tribodynamic activation, micronization to levels of 10-20 microns and remain as thin layer on the surface of leaves and penetrate frequently when they get wet by dew at night. Foliar spray with lithovit at 500 mg $L^{-1}$ caused significant increases in yield parameters of soybean *i.e*., No of setted pods $plant^{-1}$, pods yield $plant^{-1}$, No of seeds $pod^{-1}$, weight of seeds $pod^{-1}$, 100 seeds weight (g) and weight of seeds $plant^{-1}$ (g) compared with the control treatment in both seasons (Abd El-Aal and Rania, 2018). In the respect (Hanafey *et al*., 2014) on wheat, (Hamoda *et al*., 2016) on cotton, (Gomaa *et al*., 2018) on wheat and (Malgorzata, 2018) on maize illustrated that foliar application of Lithovit improved the growth and yield of the plants.

Nitrogen is the core component of protein and many plant structures and for both their internal and external metabolic processes. It is necessary for the formation of amino acids which are the building blocks of plant proteins, important in the growth and development of vital plant tissues and cells. Nitrogen is essential in plant processes like photosynthesis and plant cell enlargement. Plant height, grain weight $spike^{-1}$, grain weight $m^{-2}$, 1000-grain weight, straw yield and grain yield were increased with increasing nitrogen levels (Osman *et al*., 2008). Kandil *et al.* (2016) found that application of 262 kg N $ha^{-1}$ produced the highest values of spike length, No. of grains $spike^{-1}$, 1000-grain weight and straw and grain yields than the other levels (214 and 166 kg N $ha^{-1}$).

Therefore, this research aims to evaluate the effect of irrigation treatments, nano-fertilizer (Lithovit), nitrogen fertilizer and its combination on the productivity, quality and water use efficiency of durum wheat cultivar (Baniswef 1).

## Materials and Methods

### Experimental site:

Tow field experiments were carried out during 2015-16 and 2016-17 growing seasons at the agricultural experimental station farm of Water Studies & Research Complex (WSRC), National Water Research Center, located in Abu-Simbel, Toshka, at the most southern part of Egypt, about 1300 south from Cairo and 280 Km. from Aswan at latitude 22-25° north, 31 longitude east and elevation 181m above the sea level.

**Experimental details:**

The treatments used in the experimental composed of three irrigation levels ($A_1$=100%, $A_2$=80% and $A_3$=60% of irrigation requirement ($A_1$=2700, $A_2$=2160, $A_3$=1620 $m^3$ $fed^{-1}$, respectively), three rates of lithovit nano-fertilizer ($B_1$=control, $B_2$= 200ppm and $B_3$=400ppm) and three levels of N-fertilizer ($C_1$=60, $C_2$=80 and $C_3$=100 Kg N $fed^{-1}$) on durum wheat local cultivar (Baniswef 1) total number of plots were 81 plots= A:3× B:3× C:3× replication:3). Analysis of Lithovit according to Hamoda *et al*. (2016) were illustrated in Table 1.

**Table 1. Structure of Lithovit (Nano-particles) used in the experiment.**

| Component % | $CaCO_3$ | $MgCO_3$ | Silica | Sulphate | N | P | K oxide | Iron | Trace amount of Al, Ba, Mg, Na and Zn |
|---|---|---|---|---|---|---|---|---|---|
| **Value** | 80.08 | 8.91 | 7.82 | 0.34 | 0.07 | 0.03 | 0.22 | 1.31 | 1.22 |

Lithovit as nano-particles which used in this investigation was obtained from Agrolink Company, Cairo, Egypt

Treatments were arranged in a strip-split plot design under RCBD with three replications. The horizontal plots were devoted for irrigation levels, the vertical plots were assigned for foliar spraying with nanomaterials (Lithovit) and sub-plots were allocated for N-levels. Fixed spray irrigation system was used with the use of water meter to estimate irrigation water quantities. Soil and water samples were collected and routinely analyzed according to Klute (1986) and Page *et al*. (1982) Tables 2 and 3.

**Table 2. Some mechanical and chemical properties of the study area.**

| Particle size distribution (%) | | | | OM (%) | $CaCo_3$ (%) | pH (1:1) Soil extract | EC dS $m^{-1}$(1:1) Soil extract | Bulk density (g $cm^{-3}$) | Field Capacity (%) |
|---|---|---|---|---|---|---|---|---|---|
| Sand | Silt | Clay | Texture class | | | | | | |
| 82.19 | 13.16 | 4.65 | Loamy sand | 0.61 | 4.0 | 7.89 | 0.50 | 1.53 | 11.8 |
| Ions (meq $L^{-1}$ ) | | | | | | | | Available water (%) | Wilting Point (%) |
| Cations | | | | Anions | | | | | |
| $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ | $Cl^-$ | $CO_3^{--}$ + HCO3- | | $SO_4^{--}$ | | |
| 3.70 | 0.1 | 6.10 | 0.43 | 2.8 | 0.2 | | 7.33 | 8.00 | 3.8 |

**Table 3. Some chemical analysis of the irrigation water.**

| Date | pH | EC dS $m^{-1}$ | Ions meq $L^{-1}$ | | | | | | | | Sodium adsorption ratio (SAR) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $Na^+$ | $K^+$ | $Ca^{++}$ | $Mg^{++}$ | $Cl^-$ | $CO_3^{--}$ | $HCO_3^-$ | $SO_4^{--}$ | |
| **April 2016** | 6.85 | 0.70 | 4.56 | 0.23 | 1.58 | 0.86 | 3.53 | 0.0 | 2.56 | 1.07 | 4.15 |
| **April 2017** | 6.82 | 0.70 | 4.75 | 0.29 | 1.60 | 0.88 | 3.56 | 0.0 | 2.61 | 1.10 | 4.28 |

**Weather data:**

Monthly means of maximum and minimum temperature (C°), relative humidity (%), wind speed (m $sec^{-1}$), and pan evaporation (mm $day^{-1}$) were collected from Meteorological WSRC station, National Water Research Center, Abu Simbel city, Toshka Egypt during the two growing seasons as shown in Table 4.

**Table 4. Some meteorological data for Toshka during the two growing seasons (2015-16 and 2016-17).**

| Month | 2015-16 season | | | | | 2016-17 season | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature (C°) | | Relative Humidity % | Wind speed (m $sec^{-1}$) | E pan | Temperature (C°) | | Relative Humidity % | Wind speed (m $sec^{-1}$) | E pan |
| | Max. | Min. | | | | Max. | Min. | | | |
| December | 27.20 | 6.50 | 44.50 | 2.60 | 4.55 | 30.40 | 5.30 | 38.60 | 2.20 | 5.22 |
| January | 22.32 | 9.89 | 38.28 | 2.93 | 5.96 | 24.76 | 10.08 | 43.22 | 2.77 | 6.22 |
| February | 27.98 | 11.78 | 30.64 | 2.88 | 8.12 | 29.75 | 11.93 | 28.90 | 3.13 | 7.81 |
| March | 33.45 | 16.63 | 24.35 | 3.29 | 11.74 | 31.11 | 14.44 | 26.12 | 2.95 | 12.13 |
| April | 38.08 | 19.25 | 14.73 | 2.79 | 12.36 | 37.70 | 20.33 | 11.98 | 3.10 | 12.95 |

Max = maximum, Min = minimum, Ep = pan evaporation (mm $day^{-1}$)

The preceding crop was soybean in both seasons. Plot area was 144 $m^2$ (12 m length and 12 m width = 1/29 fed). Sowing dates were 5 and 7 December in the 1st and 2nd seasons, respectively with a seeds rate of 60 kg $fed^{-1}$ wheat (*var.* Baniswef 1) using planting planter machine under sprinkler irrigation system. While wheat Plants were harvested on 5th May 2016 and 7th May 2017 in the first and second seasons, respectively. Nano-fertilizer was sprayed at two times *i.e.*, after 40 and 60 days from sowing. Nitrogen fertilizer levels were applied manually in the form of ammonium nitrate (33.5% N) at four equal doses, the first dose was applied after 20 days from sowing and the final dose before flowering stage time.

All the culture practices for growing wheat were adopted as recommended by the Ministry of Agriculture (in the area and region of the study), except the experimental treatments.

**The data collected were as follows:**

**A- Yield and some yield attributes:**

At harvest time, ten random plants were chosen randomly from each plot to estimate the following characters:

| | |
|---|---|
| 1-Plant height (cm) | 4- Number of grains $spike^{-1}$ |
| 2-Spike length (cm) | 5- 1000-grain weight (gm) |
| 3-Number of tillers $m^{-2}$ | 6-Grain yield (kg $fed^{-1}$) |

Grain yield: at maturity, whole experimental units were harvested and the total weight of grain per plot was measured and then converted to kg $fed^{-1}$.

**B- Water parameters:**

WUE and IWUE were calculated with following equations by (Howell, 1990).

1- Crop water use efficiency (WUE, kg $m^{-3}$)

$$WUE = \frac{\text{Grain yield (kg fed}^{-1})}{\text{Actual evapotranspiration (m}^3\text{ fed}^{-1})}$$

The obtained actual evapotranspiration [(actual water consumptive use (C.U)] was calculated according to Doorenbos and Pruitt, (1984) as follows:

$$C.U = (Q_2 - Q_1) \times Bd \times D / 100 \ ..... (1)$$
$$C.U = (1) \times Er$$

Where: C.U = actual evapotranspiration (mm), $Q_2$ = the percent of soil moisture at field capacity, $Q_1$ = the percent of soil moisture before irrigation, D= the irrigated soil depth, Bd = bulk density of soil (g $cm^{-3}$), Er = irrigation system efficiency (%) {Sprinkler irrigation system assumed to be 75%}.

2- Irrigation water use efficiency (IWUE, kg $m^{-3}$)

$$IWUE = \frac{\text{Grain yield (kg fed}^{-1})}{\text{Amount of applied irrigation water (m}^3\text{ fed}^{-1})}$$

Irrigation water requirements of wheat crop for Toshka region is calculated using CROPWAT 8.0 software computer program for irrigation planning and management which was devolved by the FAO land and water development division (FAO, 1992). CROPWAT was utilized for estimating reference crop evapotranspiration, crop water requirements and scheduling irrigation.

**C- Crop-Fertilizer use efficiency (FUS):** was calculated according to (Ali, 2010) by using the following formula:

$$FUE = \frac{\text{Grain yield (kg fed}^{-1})}{\text{Total fertilizer added (kg fed}^{-1})}$$

**D- Chemical and technological characters:**

1- Protein content %, total N content in grains was determined by using the micro-Kjeldahl method and the protein% was calculated by multiplying N content by 6.25 (FAO, 2002).
2- Hectoliter weight (Kg $hl.^{-1}$), it was determined according to the method outlined by AACC, (2000), one sample was taken from every plot (was manually cleaned from impurities, such as crushed grains and foreign matters ... etc) to calculate the hectoliter weight. It was determined as grains weight in grams for container of one-liter volume then weight was converted to hectoliter.
3- Hegberg falling number (Sec.), soundness of whole grain was tested by AACC, (2000). Approved methods 56-81 B for falling number. Minimally duplicates were completed on all analysis.
4- Ash content %, two grams of each sample were ashed for 2 hours at 600 C° to determine grain ash concentration according to the standard method of the AACC (2000).

**E- Statistical analysis:**

The collected data were analyzed using analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means separation was carried out using the least significance difference (LSD) test at 5% level to test for significant differences among treatment means of the two growing seasons 2015-16 and 2016-17.

## Results and Discussion

The obtained results of this investigation are will be discussed in the following order:

**A-Yield and some yield attributes:**

**Plant height (cm):**

The effects of irrigation, nano-fertilizer, nitrogen levels and their interaction on plant height are illustrated in Table 5. Data showed that significant effect was found on plant height due to irrigation levels in both seasons. The highest plant height was 80.0 cm 2015/2016 season and 80.2

cm 2016/2017 season was obtained at 100% irrigation requirements, on the other hand the lowest wheat plant height was 76.3 cm in the first season and 77.0 cm in the second season recorded by 60% irrigation requirements. The tallest plants due to water increased at 100% compared to the 80% and 60% could be discussed on the basis growth stages which are highly sensitive to the plenty of water, which was reflected on increasing length of the internodes. The previous results are in full agreement with those reported by Osman *et al.* (2008), Ahmed and Sherif (2014), Abdelkhalek *et al.* (2015) Teama *et al.* (2016), Abdrabbo *et al.* (2016) and Attia *et al.* (2018).

Foliar application of nano-fertilizers significantly affected plant height, (Table, 5). The tallest and shortest plants belonged to the 400 ppm nano-fertilizer foliar application (79.8 and 80.2 cm) and control treatment (76.0 and 76.8 cm) in the first and second seasons, respectively. The increase in plant height due to the role nano-fertilizer increasing cell division and enlargement both longitudinal and transversely, and subsequently plant growth and develop wheat plants. Hamoda *et al.* (2016), reported that increasing Lithovit concentrations from 0.0 to 7.5 g $L^{-1}$ significantly increased plant height in both seasons. Also, Hanafey *et al*, (2014), Kandil and Eman, (2017) and Abd El-Aal and Rania (2018) who revealed that using Lithovit increased plant height.

**Table 5. Effect of irrigation treatments, foliar spraying with nano lithovit, N-levels and their interaction on plant height (cm) of durum wheat during 2015-16 and 2016-17 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700$m^3$ $fed^{-1}$) | Control | 76.1 | 77.2 | 81.3 | 78.2 | 77.0 | 78.0 | 80.0 | 78.3 |
| | 200ppm | 77.0 | 79.0 | 84.4 | 80.1 | 78.1 | 79.1 | 85.7 | 80.9 |
| | 400ppm | 77.0 | 80.2 | 87.7 | 81.6 | 78.6 | 79.4 | 85.7 | 81.2 |
| **Mean of A1** | | **76.7** | **78.8** | **84.5** | **80.0** | **77.9** | **78.8** | **83.8** | **80.2** |
| 80% (2160$m^3$ $fed^{-1}$) | Control | 74.0 | 77.1 | 78.4 | 76.5 | 75.6 | 76.0 | 79.7 | 77.1 |
| | 200ppm | 76.7 | 78.7 | 79.7 | 78.3 | 76.0 | 78.3 | 81.7 | 78.7 |
| | 400ppm | 77.7 | 79.7 | 80.0 | 79.1 | 77.3 | 80.7 | 83.0 | 80.4 |
| **Mean of A2** | | **76.1** | **78.5** | **79.3** | **78.0** | **76.3** | **78.3** | **81.5** | **78.7** |
| 60% (1620$m^3$ $fed^{-1}$) | Control | 70.7 | 74.0 | 75.0 | 73.2 | 73.4 | 74.7 | 77.0 | 75.0 |
| | 200ppm | 74.6 | 75.0 | 80.8 | 76.8 | 74.7 | 76.8 | 79.6 | 77.0 |
| | 400ppm | 75.0 | 78.0 | 83.3 | 78.8 | 75.0 | 78.8 | 82.9 | 78.9 |
| **Mean of A3** | | **73.4** | **75.7** | **79.7** | **76.3** | **74.4** | **76.8** | **79.8** | **77.0** |
| Mean of BC | Control | 73.6 | 76.1 | 78.2 | 76.0 | 75.3 | 76.2 | 78.9 | 76.8 |
| | 200ppm | 76.1 | 77.6 | 81.6 | 78.4 | 76.3 | 78.1 | 82.3 | 78.9 |
| | 400ppm | 76.6 | 79.3 | 83.7 | 79.8 | 77.0 | 79.6 | 83.9 | 80.2 |
| **Mean of C** | | **75.4** | **77.7** | **81.2** | **78.1** | **76.2** | **78.0** | **81.7** | **78.6** |
| $LSD_{0.05}$ | | A: 1.90 B: ns C:1.46 AB: ns AC: 2.53 BC: ns ABC: ns | | | | A: 1.67 B: ns C: ns AB: ns AC: 1.76 BC: ns ABC: ns | | | |

Data in Table 5 showed that the effect of N fertilizer was significant on plant height. The highest value of plant height were 81.2 and 81.7 cm obtained when plants were fertilized with 100 kg N $fed^{-1}$, followed by 80 kg N $fed^{-1}$ were 77.7 and 78.0 cm in both seasons, respectively. The shortest plants were 75.4 cm and 76.2 cm in the first and second season were recorded when plots were fertilized with 60 kg N $fed^{-1}$. Yadav and Dhanai (2017) and Attia *et al*. (2018) stated that plant height increased significantly with the increasing doses of N fertilization. These findings are consonance with the reports of Amjed *et al*. (2011), Chibsa *et al*. (2016) and Gangwar and Lodhi (2018). The interaction between irrigation and N-levels on plant height had a significant effect in both seasons. The tallest plants of 84.467 and 83.787 cm were obtained from plots when irrigated with 2700 $m^3$ $fed^{-1}$ combined with 100 kg N $fed^{-1}$ in $1^{st}$ and $2^{nd}$ seasons, respectively.

**Spike length (cm):**

Data in Table 6 indicate that irrigation levels, nano-fertilizer concentration and N-levels had a significant effects on wheat spike length in the two growing seasons. Regarding to irrigation treatments, decreasing amount of irrigation water applied to wheat plants from 100 to 80 or 60% decreased spike length from 8.3 to 8.1 or 7.9 cm in (season 1), being 8.3 to 8.1 or 8.0 cm in (season 2) in the same order. The increase in spike length may be attributed to the better utilization of nutrients using the adequate moisture, which helps the crop to better utilize the nutrient and made the plant more efficient to express its potential in photosynthesis activity and effect to increase length of spike. Many authors reported that spike length increased by increasing available soil moisture (Ahmed and Sherif, 2014, Teama *et al*., 2016, Beyenesh and Nigussie, 2017, Attia *et al*., 2018 and Gangwar and Lodhi, 2018).

In addition, the application of Lithovit significantly affected spike length in both seasons. Foliar applied by 400ppm increased spike length 8.3 and 8.5 cm as compared with control treatment of 7.9 and 7.8 cm in the two growing seasons, respectively. The lithovit components *i.e.* $CaCO_3$, $MgCO_3$, may penetrate rapidly into plant tissues through the stomata and play vital roles in biological and physiological processes of wheat plants which reflected on increasing growth parameters. These results were in line with Mardalipour *et al*. (2014).

**Table 6. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on spike length (cm) of durum wheat during 2015-16 and 2016-17 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700m$^3$ fed$^{-1}$) | Control | 7.7 | 8.0 | 8.3 | 8.0 | 7.6 | 8.0 | 8.1 | 7.9 |
| | 200ppm | 7.8 | 8.2 | 8.9 | 8.3 | 7.8 | 8.2 | 8.5 | 8.2 |
| | 400ppm | 8.0 | 8.4 | 9.1 | 8.5 | 8.0 | 8.9 | 9.1 | 8.7 |
| Mean of A1 | | 7.8 | 8.2 | 8.8 | 8.3 | 7.8 | 8.4 | 8.6 | 8.3 |
| 80% (2160m$^3$ fed$^{-1}$) | Control | 7.5 | 7.8 | 8.2 | 7.8 | 7.4 | 7.8 | 8.0 | 7.8 |
| | 200ppm | 7.8 | 8.1 | 8.6 | 8.2 | 7.8 | 8.1 | 8.3 | 8.1 |
| | 400ppm | 7.9 | 8.2 | 8.5 | 8.2 | 7.9 | 8.6 | 9.0 | 8.5 |
| Mean of A2 | | 7.7 | 8.0 | 8.5 | 8.1 | 7.7 | 8.2 | 8.4 | 8.1 |
| 60% (1620m$^3$ fed$^{-1}$) | Control | 7.3 | 7.8 | 8.2 | 7.8 | 7.3 | 8.0 | 8.2 | 7.8 |
| | 200ppm | 7.5 | 8.1 | 8.3 | 8.0 | 7.6 | 8.0 | 8.2 | 7.9 |
| | 400ppm | 7.8 | 8.1 | 8.2 | 8.1 | 7.7 | 8.4 | 8.7 | 8.3 |
| Mean of A3 | | 7.5 | 8.0 | 8.2 | 7.9 | 7.5 | 8.1 | 8.4 | 8.0 |
| Mean of BC | Control | 7.5 | 7.9 | 8.2 | 7.9 | 7.4 | 7.9 | 8.1 | 7.8 |
| | 200ppm | 7.7 | 8.1 | 8.6 | 8.1 | 7.7 | 8.1 | 8.3 | 8.0 |
| | 400ppm | 7.9 | 8.2 | 8.6 | 8.3 | 7.9 | 8.6 | 8.9 | 8.5 |
| Mean of C | | 7.7 | 8.1 | 8.5 | 8.1 | 7.7 | 8.2 | 8.5 | 8.1 |
| $LSD_{0.05}$ | | A: 0.08 B: 0.10 C: 0.08 AB: ns AC: 0.14 BC: ns ABC: ns | | | | A: 0.11 B: 0.06 C:0.08 AB:0.10 AC: ns BC: 0.14 ABC: ns | | | |

Spike length of wheat was significantly affected by N-levels in two growing seasons. In case of 100 kg N fed$^{-1}$ (8.5 and 8.5 cm) length of spike was recorded, which was significantly higher than the spike length observed by 80 and 60 kg N fed$^{-1}$ in both seasons, respectively. In the concern, Yadav and Dhanai (2017) and Gangwar and Lodhi (2018) who observed that the increasing N-level increased the spike length. It is mainly due to more utilization of plant nutrients. The results are in agreement with the findings of Beyenesh and Nigussie (2017) and Haque *et al*. (2017) and Attia *et al*. (2018).

Spike length of wheat was significantly influenced by the interaction effect of irrigation levels × N-levels in season 1, and foliar spraying with lithovit × N-levels in season 2. The treatment where nitrogen was applied at the level of 100 kg N fed$^{-1}$ and irrigated with 100% level ($A_1C_3$) increased spike length by about 17.33% compared to ($A_3C_1$) Table 6. Regarding the interaction effect of lithovit nano-fertilizer concentration and N-levels on spike length, there was a significant effect in the second season only. The highest length of spike of 8.6 and 8.9 cm was obtained from the combination of 400 ppm × 100 kg N fed$^{-1}$ ($B_3C_3$) in the first and second seasons, respectively. However, the lowest length of 7.5 and 7.4 cm were gained from ($B_1C_1$) for the same respective seasons.

**Number of tillers m$^{-2}$:**

Generally, wheat yield is dependent on many contributing yield agents. No. of tillers m$^{-2}$ is one of the most important contributions in final yield, which varies considerably with variation in environmental conditions (availability of soil moisture at planting, seed-bed preparation and nutrition managements, etc.). The result presented in Table 7 indicated that the irrigation levels had a significant effect on the No. of tillers $m^{-2}$ in both seasons. Thus, No. of tillers $m^{-2}$ was decreased with decreasing amount of water applied to wheat plants. Decreasing irrigation water amount from $A_1$ to $A_2$ or $A_3$ resulting in decrease in No of tillers $m^{-2}$ reached about 18.55 and 34.98 %, respectively, in the 2015-16 season, being 21.08 and 35.57 %, in the 2016-17 season, respectively. This may be due to better soil moisture conditions under increased irrigation levels. Thus, the general effect of moisture stress depends on intensity and length of stress (Bukhut, 2005). Shahid and Ram (2017) also noticed an increase in No of tillers $m^{-1}$ as irrigation was increased. These results are supported by results reported by Ram, *et al.* (2013) and Gangwar and Lodhi (2018).

Lithovit significantly affected No. of tillers $m^{-2}$ (Table 7). The highest rate of nano-fertilizer application (400 ppm) increased No. of tiller $m^{-2}$ by 6.68 % (season 1) and by 5.38 % (season 2) compared to the control treatment. This may be attributed to the increase of photosynthetic pigments and the absorption of mineral nutrients. In this regard, on soybean plants, (Hanafey *et al.*, 2014 and Abd El-Aal and Rania, 2018) whom found that spraying soybean plant with Lithovit (micronized $CaCO_3$) significantly increased No. of tillers $m^{-2}$ compared with control.

Data also revealed that No. of tillers $m^{-2}$ was significantly affected by the different N levels in both seasons. It is evident from the data that during 2015-16 and 2016-17 seasons that the maximum No. of tillers $m^{-2}$ (200.7 and 199.0) were noted when plots were fertilized with 100 kg N $fed^{-1}$ ($C_3$), while minimum No. of tillers $m^{-2}$ (178.7 and 174.8) were recorded with 60 kg N $fed^{-1}$ ($C_1$), respectively. The increase in the No. of tillers with an increase in N-levels might be due to the well accepted role of N in enhancing the vegetative growth of wheat plants.

Shah (2012) stated that No. of tillers $m^{-2}$ resulted in the highest value from 120 kg N $ha^{-1}$. These results are quite in line with those of Shahid *et al.* (2017), Beyenesh and Nigussie (2017), Haque *et al.* (2017) and Gangwar and Lodhi (2018).

The data also indicated that the interaction between irrigation and N-levels was significant in both seasons. The maximum No. of tillers (243.9 and 248.3 $m^{-2}$) were noted when water was used at the level of 2700 $m^3$ $fed^{-1}$ and applied 100 kg N $fed^{-1}$ ($A_1C_3$) and minimum No. of tillers (141.0 and 141.4 $m^{-2}$) were observed in those treatments where irrigated 60% and N was applied at the level of 60 kg N $fed^{-1}$ ($A_3C_1$), in the first and second seasons, respectively. Shah (2012) also reported that irrigation and N-levels favorably affected No. of tillers of wheat.

**Table 7. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on number of tillers $m^{-2}$ of durum wheat during 2015-16 and 2016-17 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700$m^3$ $fed^{-1}$) | Control | 214.6 | 228.1 | 240.4 | 227.7 | 209.3 | 223.7 | 244.4 | 225.8 |
| | 200ppm | 217.0 | 230.1 | 244.6 | 230.6 | 212.0 | 229.9 | 249.0 | 230.3 |
| | 400ppm | 219.7 | 235.0 | 246.8 | 233.8 | 218.0 | 236.6 | 251.4 | 235.3 |
| **Mean of A1** | | **217.1** | **231.1** | **243.9** | **230.7** | **213.1** | **230.0** | **248.3** | **230.5** |
| 80% (2160$m^3$ $fed^{-1}$) | Control | 173.7 | 182.5 | 189.4 | 181.9 | 164.2 | 180.0 | 185.5 | 176.6 |
| | 200ppm | 178.4 | 183.1 | 195.2 | 185.6 | 170.7 | 182.0 | 195.7 | 182.8 |
| | 400ppm | 182.0 | 199.0 | 207.5 | 196.2 | 175.0 | 184.4 | 199.2 | 186.2 |
| **Mean of A2** | | **178.0** | **188.2** | **197.4** | **187.9** | **170.0** | **182.1** | **193.5** | **181.9** |
| 60% (1620$m^3$ $fed^{-1}$) | Control | 135.2 | 138.0 | 156.1 | 143.1 | 136.2 | 146.0 | 149.0 | 143.8 |
| | 200ppm | 139.6 | 144.7 | 158.4 | 147.6 | 140.2 | 145.9 | 157.0 | 147.7 |
| | 400ppm | 148.0 | 162.6 | 167.6 | 159.4 | 147.7 | 154.8 | 159.5 | 154.0 |
| **Mean of A3** | | **141.0** | **148.4** | **160.7** | **150.0** | **141.4** | **148.9** | **155.2** | **148.5** |
| Mean of BC | Control | 174.5 | 182.9 | 195.3 | 184.2 | 169.9 | 183.3 | 193.0 | 182.0 |
| | 200ppm | 178.3 | 186.0 | 199.4 | 187.9 | 174.3 | 185.9 | 200.5 | 186.9 |
| | 400ppm | 183.2 | 198.9 | 207.3 | 196.5 | 180.2 | 191.9 | 203.4 | 191.8 |
| **Mean of C** | | **178.7** | **189.2** | **200.7** | **189.5** | **174.8** | **187.0** | **199.0** | **186.9** |
| $LSD_{0.05}$ | | A:14.42 B:3.71 C:2.97 AB: ns AC:5.15 BC: ns ABC: ns | | | | A: 5.16 B: 3.54 C: 4.01 AB: ns AC: 6.95 BC: ns ABC: ns | | | |

## Grain characters:

### Number of grains $spike^{-1}$ and 1000-grain weight

Effect of irrigation levels, nano-fertilizer and N-levels on No. of grains $spike^{-1}$ and 1000-grain weight of wheat are presented in Tables 8 and 9. The grain characters were significantly affected by irrigation, nano-fertilizer and nitrogen.

In general, the decrease irrigation levels caused significant decrease in grain characters. During 2015-16 and 2016-17, irrigation with 100% ASM produced the highest No. of grains $spike^{-1}$ of 58.6 and 57.5 and 1000-grain weight of 42.4 and 42.5 g compared with minimum No. of grain $spike^{-1}$ (55.6 and 54.6) and 1000-grain weight (37.2 and 37.1 g) produced by $A_3$, respectively. These results were agreement with the previous studies (Osman *et al.*, 2008; Shah, 2012; Teama *et al.*, 2016 and Gangwar and Lodhi 2018). Availability of water during the vegetative phase and during the shooting stage is very important and may be the main growth factor.

Lithovit as nano-fertilizer applied at 400 ppm produced significantly greater grain $spike^{-1}$ of 59.1 and 57.2 and 1000-grain weight of 41.5 and 41.5 g, while the lowest grain $spike^{-1}$ of 54.0 and 54.9 and 1000-grain weight of 37.2 and 37.3 g were recorded with the control treatment, in first and second seasons, respectively. Increase in grain characters were observed when applying Lithovit as foliar spray on wheat plants (Hanafey *et al.*, 2014).

The grain characters were significantly affected by the different N-levels in both growing seasons (Table 8 and 9). The data recorded during 2015-16 showed that maximum of 59.3 grain spike$^{-1}$ and of 41.0 g for 1000-grain weight were produced by 100 kg N fed$^{-1}$, while the minimum of 53.1 grain spike$^{-1}$ and of 37.3 g for 1000-grain weight were obtained with adding 60 kg N fed$^{-1}$. The same trend was observed during 2016-17. Shah (2012) noticed that grain characters were affected by increasing N-level from $N_0$ to 120 kg N ha$^{-1}$. The increase in grain characters by increasing N-levels might be attributed to saving N in suitable time and maximizing the N utilization through minimizing losses of the applied N which led to high photosynthesis rates and increased the amount of carbohydrate in the grains, which reflected to increase grain characters. These findings were similar to those obtained by Osman *et al*. (2008), Teama *et al*. (2016), Shahid *et al*. (2017), Attia *et al*. (2018) and Gangwar and Lodhi (2018).

**Table 8. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on number of grains spike$^{-1}$ of durum wheat during 2015-16 and 2016-17 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700m$^3$ fed$^{-1}$) | Control | 52.0 | 56.5 | 57.9 | 55.5 | 52.9 | 56.4 | 59.3 | 56.2 |
| | 200ppm | 55.6 | 61.0 | 61.2 | 59.3 | 54.0 | 58.3 | 60.8 | 57.7 |
| | 400ppm | 56.1 | 63.0 | 64.2 | 61.1 | 55.5 | 59.7 | 60.8 | 58.7 |
| Mean of A1 | | 54.6 | 60.2 | 61.1 | 58.6 | 54.1 | 58.2 | 60.3 | 57.5 |
| 80% (2160m$^3$ fed$^{-1}$) | Control | 50.4 | 54.9 | 55.7 | 53.7 | 51.7 | 55.3 | 57.4 | 54.8 |
| | 200ppm | 53.4 | 59.8 | 60.3 | 57.8 | 53.6 | 57.0 | 59.6 | 56.7 |
| | 400ppm | 54.4 | 60.4 | 61.4 | 58.7 | 54.6 | 58.2 | 59.8 | 57.5 |
| Mean of A2 | | 52.7 | 58.3 | 59.1 | 56.7 | 53.3 | 56.8 | 58.9 | 56.4 |
| 60% (1620m$^3$ fed$^{-1}$) | Control | 50.0 | 54.2 | 54.1 | 52.8 | 50.7 | 53.6 | 56.5 | 53.6 |
| | 200ppm | 52.2 | 58.2 | 59.1 | 56.5 | 52.1 | 54.6 | 57.4 | 54.7 |
| | 400ppm | 53.3 | 59.3 | 59.9 | 57.5 | 53.1 | 55.9 | 57.5 | 55.5 |
| Mean of A3 | | 51.8 | 57.3 | 57.7 | 55.6 | 52.0 | 54.7 | 57.1 | 54.6 |
| Mean of BC | Control | 50.8 | 55.2 | 55.9 | 54.0 | 51.7 | 55.1 | 57.7 | 54.9 |
| | 200ppm | 53.7 | 59.6 | 60.2 | 57.9 | 53.2 | 56.6 | 59.3 | 56.4 |
| | 400ppm | 54.6 | 60.9 | 61.8 | 59.1 | 54.4 | 57.9 | 59.4 | 57.2 |
| Mean of C | | 53.1 | 58.6 | 59.3 | 57.0 | 53.1 | 56.6 | 58.8 | 56.2 |
| $LSD_{0.05}$ | | A:0.43 B:0.73 C:0.52 AB: ns AC:ns BC: 0.91 ABC: ns | | | | A:0.64 B: 0.48 C:0.44 AB: ns AC: ns BC: ns ABC: ns | | | |

Data in Table (8) revealed that foliar application of nano-lithovit × N-levels affected significantly on the number of grains spike$^{-1}$ during 2015-16 only. Also, the data show that more (61.8 and 59.4) grains spike$^{-1}$ were obtained from high nano-lithovit concentration × 100 kg N fed$^{-1}$ ($B_3 \times C_3$), while less No. grains spike$^{-1}$ (50.8 and 51.7) were noted from plots ($B_1 \times C_1$) in the first and second seasons, respectively.

**Table 9. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on 1000 grain weight (gm.) of durum wheat during 2015/2016 and 2016/2017 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700$m^3$ $fed^{-1}$) | Control | 39.5 | 40.6 | 41.1 | 40.4 | 40.5 | 41.0 | 41.1 | 40.9 |
| | 200ppm | 40.3 | 41.2 | 44.0 | 41.9 | 41.0 | 41.3 | 43.7 | 42.0 |
| | 400ppm | 42.0 | 45.4 | 47.7 | 45.0 | 42.0 | 44.6 | 47.0 | 44.5 |
| Mean of A1 | | 40.6 | 42.4 | 44.3 | 42.4 | 41.2 | 42.3 | 43.9 | 42.5 |
| 80% (2160$m^3$ $fed^{-1}$) | Control | 33.2 | 37.3 | 38.2 | 36.2 | 35.7 | 36.2 | 37.4 | 36.4 |
| | 200ppm | 35.0 | 38.0 | 41.0 | 38.0 | 36.2 | 38.5 | 41.8 | 38.8 |
| | 400ppm | 38.0 | 41.1 | 42.0 | 40.4 | 37.3 | 41.6 | 42.7 | 40.5 |
| Mean of A2 | | 35.4 | 38.8 | 40.4 | 38.2 | 36.4 | 38.8 | 40.6 | 38.6 |
| 60% (1620$m^3$ $fed^{-1}$) | Control | 33.2 | 35.0 | 37.0 | 35.1 | 32.0 | 34.0 | 37.3 | 34.4 |
| | 200ppm | 36.4 | 37.3 | 38.5 | 37.4 | 36.0 | 37.0 | 39.3 | 37.4 |
| | 400ppm | 38.0 | 39.3 | 39.7 | 39.0 | 37.6 | 40.0 | 40.4 | 39.3 |
| Mean of A3 | | 35.9 | 37.2 | 38.4 | 37.2 | 35.2 | 37.0 | 39.0 | 37.1 |
| Mean of BC | Control | 35.3 | 37.6 | 38.8 | 37.2 | 36.1 | 37.1 | 38.6 | 37.3 |
| | 200ppm | 37.3 | 38.9 | 41.2 | 39.1 | 37.7 | 38.9 | 41.6 | 39.4 |
| | 400ppm | 39.3 | 41.9 | 43.2 | 41.5 | 39.0 | 42.0 | 43.4 | 41.5 |
| Mean of C | | 37.3 | 39.5 | 41.0 | 39.3 | 37.6 | 39.4 | 41.2 | 39.4 |
| $LSD_{0.05}$ | | A:0.68 AC:ns | B:0.57 BC: ns | C:0.62 | AB: ns ABC: ns | A: 0.65 AC: ns | B: 0.86 BC: ns | C: 0.76 | AB: ns ABC: ns |

## Grain yield (kg $fed^{-1}$):

Grain yield is usually a product of an organized interplay of its several components which contributes to the overall yield. Presented data in Table 10 indicated that the studied irrigation levels, nano-fertilizer and N-levels had a significant effect on the grain yield in the two seasons. Decreasing irrigation water amount from 2700 to 2160 or 1620 $m^3$ $fed^{-1}$ resulted in decrease in grain yield reached about (18.41 and 30.70%) and (18.84 and 30.19%) in the first and second seasons, respectively. These results reflect the importance of soil water to increase plant nutrient availability in soil solution and enhancement of all vegetative growth factor (increase cell divison, elongation and enlargement) and yield components, which contribute to increased production of grain yield, moreover, increase spikelet fertility and decrease sterility. Grain yield was reported to increase with increasing irrigation levels (Osman *et al*., 2008 and Attia *et al*., 2018). Similar results were reported by Teama *et al*. (2016), Beyenesh and Nigussie, (2017), Hossain and Hasan, (2018) and Gangwar and Lodhi, (2018).

Maximum grain yield (2026.8 and 2075.7 kg $fed^{-1}$) was recorded by foliar application with lithovit nano-fertilizer treatment as compared with other treatments in both seasons, respectively. Nanoparticles induced enhancement photosynthesis and nutrient use efficiency leading to more production of grain yield. Furthermore, nanoparticles like Lithovit availability may increase the leaf area index and duration, and decreased leaves senescence that increase grain yield. Razzaq *et al*. (2016), Kandil and Eman, (2017), Singh *et al*. (2017) and Malgorzata, (2018) support these trend.

The data recorded during 2015-16 and 2016-17 showed that maximum grain yield (1904.3 and 1964.3 kg fed$^{-1}$) was produced with adding 100 kg N fed$^{-1}$, while minimum grain yield (1763.9 and 1818.3 kg fed$^{-1}$) was produced with the application of 60 kg N fed$^{-1}$. The application of N at a level of 100 kg N fed$^{-1}$ increased the wheat grain yield by 7.96 and 8.03% in the first and second seasons, respectively, compared to the low treatment 60 kg N fed$^{-1}$. Attia *et al.* (2018) who stated that treated wheat plants with 80 kg N fed$^{-1}$ resulted in higher grain yield as compared at 40 and 60 kg N fed$^{-1}$. These results might be due to adequate supply of nutrients during grain filling duration. Many researches have shown that increasing N-level properly can increase the grain yield of wheat (Chibsa, *et al*., 2016; Rekaby, *et al*., 2016; Haque, *et al*., 2017; Yadav and Dhanai, 2017; Gangwar and Lodhi, 2018 and Hossain and Hassan, 2018).

The data further showed that grain yield was significantly affected by the interaction between A×B in both seasons and A×C in the first season. The highest value of grain yield (2490.0 and 2547.2 kg fed$^{-1}$) in 1st and 2nd seasons respectively, were obtained from plots when irrigated with 2700 m$^3$ fed$^{-1}$ and 400ppm lithovit ($A_1 \times B_3$). The maximum value of grain yield was recorded from plots when irrigated 2700 m$^3$ fed$^{-1}$×100 kg N fed$^{-1}$ (2290.4 kg fed$^{-1}$) in 1st season ($A_1 \times C_3$).

**Table 10. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on grain yield (kg fed$^{-1}$) of durum wheat during 2015/2016 and 2016/2017 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (B) 60 | 80 | 100 | Mean of AB | N- level (kg N fed$^{-1}$) (B) 60 | 80 | 100 | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | First season | | | | Second season | | | |
| 100% (2700m$^3$ fed$^{-1}$) | Control | 1839.0 | 1896.0 | 1994.6 | 1909.9 | 1923.5 | 1931.0 | 2064.0 | 1972.8 |
| | 200ppm | 2080.5 | 2191.1 | 2260.5 | 2177.3 | 2148.0 | 2237.0 | 2319.5 | 2234.8 |
| | 400ppm | 2382.5 | 2470.5 | 2617.1 | 2490.0 | 2435.0 | 2534.6 | 2672.0 | 2547.2 |
| Mean of A1 | | 2100.6 | 2185.9 | 2290.7 | 2192.4 | 2168.8 | 2234.1 | 2351.8 | 2251.6 |
| 80% (2160m$^3$ fed$^{-1}$) | Control | 1597.5 | 1606.1 | 1710.0 | 1637.9 | 1649.6 | 1640.0 | 1748.6 | 1679.4 |
| | 200ppm | 1734.0 | 1786.1 | 1825.1 | 1781.7 | 1767.5 | 1811.0 | 1877.0 | 1818.5 |
| | 400ppm | 1878.0 | 1941.5 | 2021.0 | 1946.8 | 1899.0 | 1992.0 | 2062.5 | 1984.5 |
| Mean of A2 | | 1736.5 | 1777.9 | 1852.0 | 1788.8 | 1772.0 | 1814.3 | 1896.0 | 1827.5 |
| 60% (1620m$^3$fed$^{-1}$) | Control | 1325.6 | 1467.5 | 1467.0 | 1420.0 | 1399.1 | 1458.0 | 1546.1 | 1467.7 |
| | 200ppm | 1449.5 | 1488.5 | 1545.0 | 1494.3 | 1514.6 | 1526.6 | 1615.5 | 1552.2 |
| | 400ppm | 1589.0 | 1643.0 | 1698.5 | 1643.5 | 1629.0 | 1683.5 | 1774.1 | 1695.5 |
| Mean of A3 | | 1454.7 | 1533.0 | 1570.2 | 1519.3 | 1514.1 | 1556.0 | 1645.2 | 1571.8 |
| Mean of BC | Control | 1587.3 | 1656.5 | 1723.8 | 1655.9 | 1657.4 | 1676.3 | 1786.2 | 1706.6 |
| | 200ppm | 1754.6 | 1821.9 | 1876.8 | 1817.8 | 1810.0 | 1858.2 | 1937.3 | 1868.5 |
| | 400ppm | 1949.8 | 2018.3 | 2112.2 | 2026.8 | 1987.7 | 2070.0 | 2169.5 | 2075.7 |
| Mean of C | | 1763.9 | 1832.2 | 1904.3 | 1833.5 | 1818.3 | 1868.1 | 1964.3 | 1883.6 |
| $LSD_{0.05}$ | | A:64.5 B:27.1 C:17.7 AB:46.9 AC:30.7 BC: ns ABC: ns | | | | A:78.3 B:55.9 C:50.4 AB:96.8 AC: ns BC: ns ABC: ns | | | |

### B- Water parameters:

### Water use efficiency (WUE) and irrigation use efficiency (IWUE) (kg m$^{-3}$):

Data in Tables 11 and 12 present the effect of irrigation levels, nano-fertilizer, N-levels and their interactions on WUE and IWUE in 2015-16 and 2016-17 seasons. WUE and IWUE were significantly affected by irrigation levels in the two growing seasons. Values of WUE and IWUE as recorded indicate that irrigation at 60% from irrigation requirement gave the maximum WUE and IWUE of 1.25 and 0.94 kg grains m$^{-3}$ water in 2015-16 season, respectively, while minimum values were 1.08 and 0.81 kg grains m$^{-3}$ were recorded at 100% ASM. In the 2016-17 season the maximum values were 1.29 and 0.97 kg grains m$^{-1}$ from 60% ASM treatment, whereas the minimum values were 1.11 and 0.83 kg grains m$^{-3}$ obtained with 100% ASM. WUE and IWUE were increased with decreasing irrigation requirement (irrigation levels) during growing season according to irrigation at 60% ASM. This may be attributed to soil conditions, agriculture practices *i.e.* (irrigation and fertilization) and environmental factors. Moreover, deficit irrigation reduces grain yield, yet increases WUE and IWUE. In the respect, Ahmed and Sherif (2014) found that the maximum WUE value for wheat was achieved when irrigation water was applied at 40% ASM for grain. These results are agreement with Osman *et al.* (2008), Abdelkhalek *et al.* (2015), Beyenesh and Nigussie (2017) and Eissa *et al.* (2018).

Increasing Lithovit concentrations from 0 ppm to 400ppm significantly increased WUE and IWUE of wheat cultivar (Baniswef 1) in both seasons, however, it caused about (21.15 and 20.56%) and (20.51 and 19.75%) increase in WUE and IWUE where, WUE increased from (1.26 to 1.04 and from 1.29 to 1.07 kg m$^{-3}$) and IWUE increased from (0.94 to 0.78 and from 0.97 to 0.81 kg m$^{-3}$) for nano-fertilizer concentrations 0 ppm (control) and 400ppm, respectively (Tables 11 and 12).

**Table 11. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on water use efficiency (WUE, kg m$^{-3}$) of durum wheat during 2015/2016 and 2016/2017 seasons.**

| Irrigation levels (A) (actual water consumptive use) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (C) 60 | 80 | 100 | Mean of AB | N- level (kg N fed$^{-1}$) (C) 60 | 80 | 100 | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | First season | | | | Second season | | | |
| 100% (2025m$^3$ fed$^{-1}$) | Control | 0.91 | 0.94 | 0.98 | 0.94 | 0.95 | 0.95 | 1.02 | 0.97 |
| | 200ppm | 1.03 | 1.08 | 1.12 | 1.08 | 1.06 | 1.10 | 1.15 | 1.10 |
| | 400ppm | 1.18 | 1.22 | 1.29 | 1.23 | 1.20 | 1.25 | 1.32 | 1.26 |
| **Mean of A1** | | **1.04** | **1.08** | **1.13** | **1.08** | **1.07** | **1.10** | **1.16** | **1.11** |
| 80% (1620m$^3$ fed$^{-1}$) | Control | 0.98 | 0.99 | 1.06 | 1.01 | 1.02 | 1.01 | 1.08 | 1.04 |
| | 200ppm | 1.07 | 1.10 | 1.13 | 1.10 | 1.09 | 1.12 | 1.16 | 1.12 |
| | 400ppm | 1.16 | 1.20 | 1.25 | 1.20 | 1.17 | 1.23 | 1.27 | 1.22 |
| **Mean of A2** | | **1.07** | **1.10** | **1.15** | **1.11** | **1.09** | **1.12** | **1.17** | **1.13** |
| 60% (1215m$^3$ fed$^{-1}$) | Control | 1.09 | 1.21 | 1.21 | 1.17 | 1.15 | 1.20 | 1.27 | 1.21 |
| | 200ppm | 1.19 | 1.23 | 1.27 | 1.23 | 1.25 | 1.26 | 1.33 | 1.28 |
| | 400ppm | 1.31 | 1.35 | 1.40 | 1.35 | 1.34 | 1.39 | 1.46 | 1.40 |
| **Mean of A3** | | **1.20** | **1.26** | **1.29** | **1.25** | **1.25** | **1.28** | **1.35** | **1.29** |
| Mean of BC | Control | 0.99 | 1.05 | 1.08 | 1.04 | 1.04 | 1.05 | 1.12 | 1.07 |
| | 200ppm | 1.10 | 1.14 | 1.17 | 1.14 | 1.13 | 1.16 | 1.21 | 1.17 |
| | 400ppm | 1.22 | 1.26 | 1.31 | 1.26 | 1.24 | 1.29 | 1.35 | 1.29 |
| **Mean of C** | | **1.10** | **1.15** | **1.19** | **1.15** | **1.14** | **1.17** | **1.23** | **1.18** |
| $LSD_{0.05}$ | | A:0.04 B:0.02 C:0.02 AB:0.03 AC:NS BC:NS ABC:NS | | | | A:0.02 B:0.0.03 C:0.02 AB:0.05 AC:NS BC:NS ABC:NS | | | |

The addition of N to irrigation levels of wheat significantly affected on WUE and IWUE in the two seasons (Tables 11 and 12). In both seasons, WUE and IWUE increased with increasing N levels, and were recorded the highest values (1.19 and 1.23) and (0.89 and 0.92) kg grain $m^{-3}$ $fed^{-1}$ were obtained with applying 100 kg N $fed^{-1}$, and the lowest values (1.10 and 1.14) and (0.83 and 0.85) were recorded with applying 60 kg N $fed^{-1}$ for both growing seasons. This may due to the fact that grain yield obtained is higher with 100 kg N $fed^{-1}$ as compared to other levels. Martin *et al*. (2010) who stated that increasing WUE requires increasing photosynthetic capacity, thus, more N will be required. WUE of wheat increased with increasing N-rates (Rekaby, *et al*., 2016). These results agree with findings of Abdelraouf, *et al*., (2013), Abdelkhalek *et al*., (2015) and Beyenesh and Nigussie (2017).

Data presented in Tables 11 and 12 showed that the interaction between irrigation levels and nano-fertilizer concentrations on WUE and IWUE where significant differences among treatments were observed in both seasons. The treatment irrigation levels at 60% ASM + 400 ppm nano-fertilizer recorded the highest WUE (1.35 and 1.40) and IWUE (1.01 and 1.05) followed by the treatment irrigation levels at 60% ASM + 200 ppm nano-fertilizer.

**Table 12. Effect of irrigation levels, foliar spraying with nano lithovit, N-levels and their interaction on irrigation water use efficiency (IWUE, kg $m^{-3}$) of durum wheat during 2015/2016 and 2016/2017 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N $fed^{-1}$) (C) 60 | 80 | 100 | Mean of AB | N- level (kg N $fed^{-1}$) (C) 60 | 80 | 100 | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | First season | | | | Second season | | | |
| 100% (2700$m^3$ $fed^{-1}$) | Control | 0.68 | 0.70 | 0.74 | 0.71 | 0.71 | 0.72 | 0.76 | 0.73 |
| | 200ppm | 0.77 | 0.81 | 0.84 | 0.81 | 0.80 | 0.83 | 0.86 | 0.83 |
| | 400ppm | 0.88 | 0.92 | 0.97 | 0.92 | 0.90 | 0.94 | 0.99 | 0.94 |
| Mean of A1 | | 0.78 | 0.82 | 0.85 | 0.81 | 0.80 | 0.83 | 0.87 | 0.83 |
| 80% (2160$m^3$ $fed^{-1}$) | Control | 0.74 | 0.74 | 0.79 | 0.76 | 0.76 | 0.76 | 0.81 | 0.78 |
| | 200ppm | 0.80 | 0.83 | 0.84 | 0.82 | 0.82 | 0.84 | 0.87 | 0.84 |
| | 400ppm | 0.87 | 0.90 | 0.94 | 0.90 | 0.88 | 0.92 | 0.95 | 0.92 |
| Mean of A2 | | 0.80 | 0.82 | 0.86 | 0.83 | 0.82 | 0.84 | 0.88 | 0.85 |
| 60% (1620$m^3$ $fed^{-1}$) | Control | 0.82 | 0.91 | 0.91 | 0.88 | 0.86 | 0.90 | 0.95 | 0.91 |
| | 200ppm | 0.89 | 0.92 | 0.95 | 0.92 | 0.93 | 0.94 | 1.00 | 0.96 |
| | 400ppm | 0.98 | 1.01 | 1.05 | 1.01 | 1.01 | 1.04 | 1,10 | 1.05 |
| Mean of A3 | | 0.90 | 0.95 | 0.97 | 0.94 | 0.93 | 0.96 | 1.02 | 0.97 |
| Mean of BC | Control | 0.75 | 0.78 | 0.81 | 0.78 | 0.78 | 0.79 | 0.84 | 0.81 |
| | 200ppm | 0.82 | 0.85 | 0.88 | 0.85 | 0.85 | 0.87 | 0.91 | 0.88 |
| | 400ppm | 0.91 | 0.94 | 0.99 | 0.94 | 0.93 | 0.97 | 1.01 | 0.97 |
| Mean of C | | 0.83 | 0.85 | 0.89 | 0.86 | 0.85 | 0.88 | 0.92 | 0.88 |
| $LSD_{0.05}$ | | A:0.02 B: 0.01 C:0.01 AB:0.03 AC:NS BC:NS ABC:NS | | | | A:0.02 B:0.02 C:0.02 AB:0.03 AC:NS BC:NS ABC:NS | | | |

**C- Crop-Fertilizer use efficiency (FUS):**

Data presented in Table 13 showed that irrigation levels, nano-fertilizer concentration, N-levels and their interactions involved here had a significant effects on fertilizer use efficiency (FUE) in both seasons, except the effect of interaction of three factors in the two growing seasons. Therefore, FUE was increased significantly with increasing amount of water applied to wheat plants. The highest values of FUE (28.033 and 29.199 kg grain $kg^{-1}$ N applied) in $1^{st}$ and $2^{nd}$ seasons, respectively, were estimated from 100% ASM treatment, while, the lowest values of FUE (19.703 and 20.381 kg grain $kg^{-1}$ N applied) in $1^{st}$ and $2^{nd}$ seasons, respectively, were obtained from 60% ASM.

This is the same trend was obtained with regard to grain yield. In this study, FUE as revealed by response ratio of wheat to applied nano-fertilizer (Table 13) was better with 400ppm concentration (26.283 and 26.901 kg grain $kg^{-1}$ N applied) in both seasons, respectively, compared to with 0.0 and 200ppm. FUS in crop production can be enhanced with the effective application of nano-fertilizers (Singh, *et al.*, 2017).

Regarding the main effect of N in both seasons, the highest value (29.414 and 30.307 kg grain $kg^{-1}$ N applied) when N applied at 60 kg N $fed^{-1}$ and the lowest value (19.043 and 19.646 kg grain $kg^{-1}$ N applied) found when the plants received 100 kg N $fed^{-1}$, in the two seasons, respectively. Generally, fertilizer efficiency assigned as the amount of increase in yield of the harvested portion of the crop per unit N applied. Haque *et al.* (2017) observed that decrease in FUE with increasing N-rates is due to less increase in grain yield in comparison to N supply in wheat.

Considering the interaction of irrigation levels and different nano-fertilizer concentration (Table 13), highest FUE during the two growing seasons (31.067 and 32.995 kg grain $kg^{-1}$ N applied) observed by 100% ASM + 400 ppm nano-fertilizer, the minimum (18.369 and 19.001) FUE was found from 60% ASM with control nano-fertilizer, respectively.

Also, the interaction among nano-fertilizer and N-levels had a significant effect on FUE in the two growing seasons. Thus, the highest mean values of FUE (32.497 and 33.130 kg grain $kg^{-1}$ N applied) in first and second seasons respectively, were obtained from 400 ppm nano-fertilizer with 60 kg N $fed^{-1}$.

**Table 13. Effect of irrigation levels, foliar spraying with nano lithovit, N- levels and their interaction on fertilizer use efficiency (FUE) of durum wheat during 2015/2016 and 2016/2017 seasons.**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB | N- level (kg N $fed^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | First season | | | | Second season | | | |
| 100% (2700$m^3$ $fed^{-1}$) | Control | 30.7 | 23.7 | 19.9 | 24.8 | 32.1 | 24.1 | 20.6 | 25.6 |
| | 200ppm | 34.8 | 27.4 | 22.6 | 28.3 | 35.8 | 28.0 | 23.2 | 29.0 |
| | 400ppm | 39.7 | 27.3 | 26.2 | 31.1 | 40.6 | 31.7 | 26.7 | 33.0 |
| Mean of A1 | | 35.1 | 26.1 | 22.9 | 28.0 | 36.1 | 27.9 | 23.5 | 29.2 |
| 80% (2160$m^3$ $fed^{-1}$) | Control | 26.6 | 20.1 | 17.1 | 21.3 | 27.5 | 20.5 | 17.5 | 21.8 |
| | 200ppm | 28.9 | 22.3 | 18.3 | 23.2 | 29.5 | 22.6 | 18.8 | 23.6 |
| | 400ppm | 31.3 | 24.3 | 20.2 | 25.3 | 31.7 | 24.9 | 20.6 | 25.7 |
| Mean of A2 | | 28.9 | 22.2 | 18.5 | 23.2 | 29.5 | 22.7 | 19.0 | 23.7 |
| 60% (1620$m^3$ $fed^{-1}$) | Control | 22.1 | 18.3 | 14.7 | 18.4 | 23.3 | 18.2 | 15.5 | 19.0 |
| | 200ppm | 24.2 | 18.6 | 15.5 | 19.4 | 25.2 | 19.1 | 16.2 | 20.2 |
| | 400ppm | 26.5 | 20.5 | 17.0 | 21.3 | 27.2 | 21.0 | 17.7 | 22.0 |
| Mean of A3 | | 24.2 | 19.2 | 15.7 | 19.7 | 25.2 | 19.5 | 16.5 | 20.4 |
| Mean of BC | Control | 26.5 | 20.7 | 17.2 | 21.5 | 27.6 | 21.0 | 17.9 | 22.1 |
| | 200ppm | 29.3 | 22.8 | 18.8 | 23.6 | 30.2 | 23.2 | 19.4 | 24.3 |
| | 400ppm | 32.5 | 25.2 | 21.1 | 26.3 | 33.1 | 25.9 | 21.7 | 26.9 |
| Mean of C | | 29.4 | 22.5 | 19.0 | 23.7 | 30.3 | 23.4 | 19.6 | 24.4 |
| $LSD_{0.05}$ | | A:0.92 B:0.37 C:0.25 AB:0.64 AC:0.43 BC:0.43 ABC:NS | | | | A:0.67 B:0.51 C:0.36 AB:0.88 AC:0.63 BC:0.63 ABC:NS | | | |

## D- Chemical and technological characters:

### Protein and ash contents %:

Data presented in Table 14 revealed that protein and ash content % in grains was significantly affected by various irrigation levels, nano-fertilizer, N-levels and their interaction in the average of the two seasons. The irrigation levels had a significant effects on protein and ash content% in average two seasons. Thus, protein and ash content were decreased significantly with decreasing amount of water applied to wheat plants. Decreasing irrigation water amount from 100% to 80% or 60% resulting in the decrease in protein and ash content reached about (2.03 and 8.56%) and (2.59 and 8.81%) respectively in the average of the two seasons. (Erekul *et al*., 2012 and Shah, 2012) stated that protein content decreased with increasing irrigation level.

The results are shown in Table (14), also, demonstrated that wheat plants sprayed by lithovit nano-fertilizer produced the highest mean values of protein and ash content. High values of (13.724 and 1.90%) were recorded with foliar application of 400ppm nano-fertilizer in the average of the two seasons, respectively. One the other hand, the lowest values for grain protein and ash (13.153 and 1.82%) were obtained from control treatments in the average of the two seasons, respectively.

Protein and ash content in wheat grain were significantly affected by levels of N in the average of the two seasons. Higher value of protein and ash content in grain (13.791 and 1.90%) was noticed when wheat crop was fertilized with 100 kg N $fed^{-1}$, while the lowest (12.890 and 1.79%) were recorded when fertilized with 60 kg N fed$^{-1}$. The favorable effect of N-levels on two characters might be explained in the light of the direct influence of this essential element in increasing photosynthesis activity and subsequently chemical contents. Plescuta and Panayotova, (2016) reported that higher N-levels usually results in increased wheat protein content and thereby improved end use quality. This was agreement with the findings of many authors (Shah, 2012, Harasim and Wesolowski, 2013, Chibsa *et al*., 2016, Haque *et al*., 2017 and Hossain and Hasan, 2018).

Regarding the interaction between A × B on protein and ash content%, there was significant effect in average two seasons. The maximum values of 14.278 and 1.97% were obtained from the interaction between 100% ASM × 400ppm nano-fertilizer ($A_1$×$B_3$) in average two seasons, respectively. However the lowest values of 12.322 and 1.70% obtained from the interaction between 60% ASM × control ($A_3$ × $B_1$) for the same respective in average two seasons. When the interaction between A × C studied it was noted that ash content% was significantly affected only. The data showed that the maximum 1.97% ash content% were obtained for irrigated according to 100% ASM combined with 100 kg N fed$^{-1}$ ($A_1$×$C_3$), while the minimum 1.67% ash content% were obtained from $A_3$×$C_1$.

**Table 14. Effect of irrigation levels, foliar spraying with nano lithovit, N- levels and their interaction on Protein and ash content % of durum wheat (Average 2015-16 and 2016-17 seasons)**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | Protein content % | | | | Ash content % | | | |
| 100% (2700m$^3$ fed$^{-1}$) | Control | 13.137 | 13.827 | 14.000 | 13.653 | 1.86 | 1.91 | 1.93 | 1.90 |
| | 200ppm | 13.467 | 13.930 | 14.030 | 13.811 | 1.86 | 1.93 | 1.94 | 1.91 |
| | 400ppm | 13.700 | 14.433 | 14.700 | 14.278 | 1.89 | 1.99 | 2.03 | 1.97 |
| Mean of A1 | | 13.434 | 14.064 | 14.243 | 13.914 | 1.87 | 1.94 | 1.97 | 1.93 |
| 80% (2160m$^3$ fed$^{-1}$) | Control | 12.970 | 13.620 | 13.860 | 13.483 | 1.79 | 1.88 | 1.91 | 1.86 |
| | 200ppm | 13.203 | 13.767 | 13.867 | 13.612 | 1.82 | 1.90 | 1.91 | 1.88 |
| | 400ppm | 13.333 | 13.990 | 14.070 | 13.798 | 1.84 | 1.93 | 1.95 | 1.91 |
| Mean of A2 | | 13.169 | 13.792 | 13.932 | 13.631 | 1.82 | 1.90 | 1.93 | 1.88 |
| 60% (1620m$^3$ fed$^{-1}$) | Control | 11.567 | 12.500 | 12.900 | 12.322 | 1.60 | 1.73 | 1.78 | 1.70 |
| | 200ppm | 12.103 | 13.083 | 13.167 | 12.784 | 1.67 | 1.81 | 1.82 | 1.77 |
| | 400ppm | 12.533 | 13.223 | 13.530 | 13.096 | 1.73 | 1.83 | 1.87 | 1.81 |
| Mean of A3 | | 12.068 | 12.936 | 13.199 | 12.734 | 1.67 | 1.79 | 1.82 | 1.76 |
| Mean of BC | Control | 12.558 | 13.316 | 13.586 | 13.153 | 1.75 | 1.84 | 1.88 | 1.82 |
| | 200ppm | 12.924 | 13.594 | 13.689 | 13.403 | 1.79 | 1.88 | 1.89 | 1.85 |
| | 400ppm | 13.189 | 13.882 | 14.100 | 13.724 | 1.82 | 1.92 | 1.95 | 1.90 |
| Mean of C | | 12.890 | 13.597 | 13.791 | 13.426 | 1.79 | 1.88 | 1.90 | 1.86 |
| $LSD_{0.05}$ | | A:0.23 B:0.15 C:0.14 AB:0.25 AC:NS BC: NS ABC: NS | | | | A:0.03 B:0.02 C:0.02 AB:0.03 AC:0.19 BC: NS ABC: NS | | | |

**Hagberg falling number HFN (Sec.) and hectoliter weight HLW (kg $hl^{-1}$):**

HFN is a measure of the degree of weather damage that results in sprouting. A result of sprouting from weather damage is the development of α-amylase activity which is detrimental to wheat quality and an indicator of poor grains.

Data presented in Table (15) indicated that irrigation levels had no significant effect on falling number in average of the two seasons. Falling number decreased with irrigation (Torrion and Stougaard, 2017). The data further revealed that the falling number of wheat flours is significantly influenced by nano-fertilizer levels (Table 14). The highest falling number was observed in 0.0 nano-fertilizer (451.16 s), while the lowest value was recorded for sample $B_3$ (395.65 s). Generally, the filling number (α-amylase) of all treatments were relatively high. N-levels had a significant effect on the HFN in average seasons. The data recorded that the maximum HNF (442.77 s) was noted for pots treated with 60 kg N $fed^{-1}$ ($C_1$) while minimum HFN (396.55 s) was obtained by 100 kg N $fed^{-1}$. The effects of N on HFN may, therefore, have been more closely related to the rate of grain drying, rather than just grain size, as has been suggested for the effects of N (Clarke *et al*., 2004). N fertilization reason a sharp decline on HFN Gashaw *et al*. (2013). The decline of HFN in response to N fertilization might be associated with its effect on delaying grain maturation and grain protein concentration. Corroborating the results of this study, Leta *et al*. (2013) reported the effect of N fertilization on grain quality.

Hectoliter weight is a measure of grain shape, the grain density which appertain to the chemical and biological composition as immature or shrunken grain have specific weight lower than plumpness and hard grain. Results of Table (15) revealed that hectoliter weight of durum wheat was significantly affected by different irrigation levels. The maximum increase in HLW of grains wheat (75.37 kg $hl^{-1}$) was recorded when plots were irrigated with 2700 $m^3$ $fed^{-1}$ water ($A_1$), while minimum (70.85 kg $hl^{-1}$) was produced from those plots treated with 1620 $m^3$ $fed^{-1}$ water ($A_3$). HLW decreased as the severity of the water stress increased (Guler, 2003). Supplemental irrigation throughout the growing season improves HLW and increases dry matter accumulation in the grain and that leads to plumpness of the grain increase. High HLW will have a low ratio of the barn and high semolina yield. HLW of grain wheat is an important indicator of flour milling quality wherein higher HLW is favorite (Torrion and Stougaard, 2017). In harmony with the present result, (Erekul *et al*., 2012) and EL-Hag and Shahein (2017).

Concerning the effect of Lithovit on HLW of wheat grains, Table (15) shows that HLW increased with foliar application of 400ppm nano-fertilizer (77.02 kg $hl^{-1}$). These results may be attributed to the promoting effects of lithovit.

It is worthy to mention that, the results of Table (15) show that nitrogen addition increased significantly hectoliter weight in average two seasons. The maximum increase in HLW was obtained by applying 100 kg N fed$^{-1}$ (77.95 kg hl$^{-1}$). In general, high test weight indicates sound grain and higher correlations are found between hectoliter weight and flour yield. Harasim and Wesolowski (2013) demonstrated that the higher rate of N increased grain test weight of wheat. These results are found by EL-Hag and Shahein (2017), EL-Temsah (2017). Table (14) shows that all interactions had no significant effect on Hagberg falling number and hectoliter weight in average seasons.

**Table 15. Effect of irrigation levels, foliar spraying with nano lithovit, N- levels and their interaction on Hegberg falling number (Sec.) and hectoliter weight (kg hl$^{-1}$) of durum wheat (Average 2015-16 and 2016-17 seasons).**

| Irrigation levels (A) | Nano-fertilizer (B) | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB | N- level (kg N fed$^{-1}$) (C) | | | Mean of AB |
|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 80 | 100 | | 60 | 80 | 100 | |
| | | Hagberg falling number (Sec.) | | | | Hectoliter weight (kg hl$^{-1}$) | | | |
| 100% (2700m$^3$ fed$^{-1}$) | Control | 475.46 | 443.52 | 429.32 | 449.43 | 68.16 | 71.00 | 74.86 | 71.34 |
| | 200ppm | 418.68 | 408.02 | 386.74 | 404.48 | 71.61 | 76.52 | 78.85 | 75.66 |
| | 400ppm | 411.57 | 393.83 | 369.00 | 391.47 | 73.25 | 76.84 | 87.24 | 79.11 |
| Mean of A1 | | 435.24 | 415.12 | 395.02 | 415.13 | 71.01 | 74.79 | 80.32 | 75.37 |
| 80% (2160m$^3$ fed$^{-1}$) | Control | 474.68 | 449.67 | 425.72 | 450.02 | 66.10 | 69.31 | 73.00 | 69.47 |
| | 200ppm | 429.31 | 404.45 | 375.83 | 403.20 | 68.46 | 72.34 | 76.94 | 72.58 |
| | 400ppm | 415.10 | 404.46 | 379.65 | 399.74 | 71.57 | 76.34 | 82.75 | 76.89 |
| Mean of A2 | | 439.70 | 419.53 | 393.73 | 417.65 | 68.71 | 72.66 | 77.56 | 72.98 |
| 60% (1620m$^3$ fed$^{-1}$) | Control | 482.17 | 443.51 | 436.38 | 454.02 | 61.72 | 67.04 | 72.74 | 67.17 |
| | 200ppm | 459.34 | 400.94 | 393.80 | 418.03 | 65.47 | 70.22 | 75.24 | 70.31 |
| | 400ppm | 418.62 | 396.09 | 372.50 | 395.74 | 69.44 | 75.88 | 79.89 | 75.07 |
| Mean of A3 | | 453.38 | 413.51 | 400.89 | 422.60 | 65.54 | 71.05 | 75.96 | 70.85 |
| Mean of BC | Control | 477.44 | 445.57 | 430.47 | 451.16 | 65.33 | 69.12 | 73.53 | 69.33 |
| | 200ppm | 435.78 | 404.47 | 385.46 | 408.57 | 68.51 | 73.03 | 77.01 | 72.85 |
| | 400ppm | 415.10 | 398.13 | 373.72 | 395.65 | 71.42 | 76.35 | 83.29 | 77.02 |
| Mean of C | | 442.77 | 416.05 | 396.55 | 418.46 | 68.42 | 72.83 | 77.95 | 73.07 |
| $LSD_{0.05}$ | | A: NS B: 11.02 C: 7.72 AB: NS<br>AC: NS BC: NS ABC: NS | | | | A: 2.88 B: 1.41 C: 1.50 AB:NS<br>AC: NS BC: NS ABC: NS | | | |


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**تأثير معاملات الرى وسماد النانو (الليثوفيت) ومستويات التسميد النيتروجينى على إنتاجية وجودة قمح الديورم تحت ظروف توشكى**

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**الملخص**

اجريت هذه الدراسة بمزرعة تجارب الأبحاث بمجمع الدراسات والبحوث المائية بتوشكى خلال موسمى ٢٠١٦/٢٠١٥ و ٢٠١٧/٢٠١٦ لدراسة تأثير إستخدام مستويات الرى (١٠٠% - ٨٠% - ٦٠% من إحتياجات الرى) وثلاث تركيزات من أسمدة النانو ( صفر - ٢٠٠ - ٤٠٠ جزء فى المليون) مع تطبيق ثلاث مستويات من التسميد النتروجينى (٦٠ - ٨٠ - ١٠٠ كجم نتروجين للفدان) على المحصول ومكوناته والعلاقات المائية لمحصول قمح المكرونة (صنف بنى سويف ١) وكفاءة إستخدام التسميد تحت الظروف المناخية لمنطقة توشكى. نفذت التجارب بإستخدام تصميم الشرائح المتعامدة فى ثلاث مكررات. وقد أوضحت النتائج التالى:

مستويات الماء، تركيزات النانو ومستويات السماد النيتروجينى أثرت معنوياً على جميع الصفات بالدراسة وهى إرتفاع النبات ، طول السنبلة ، عدد الفروع بالمتر المربع ، عدد السنيبلات بالسنبلة، وزن ١٠٠٠ حبة ، ومحصول الحبوب والقش وقراءات الماء وكفاءة إستخدام النيتروجين بالموسمين وأيضاً النسبة المئوية للبروتين والرماد ورقم السقوط ووزن الهيكتوليتر لمتوسط الموسمين.

زيادة مستويات الماء من ٦٠% إلى ١٠٠% من إحتياجات الرى زادت جميع الصفات المحصولية وكفاءة إستخدام النيتروجين ولكن علاقات الماء ورقم السقوط بالثوانى نقصت بزيادة مستوى الماء. عند أعلى مستوى ماء رى سجلت أعلى القيم لمحصول الحبوب وكانت (٢١٩٢,٤ و ٢٢٥١,٦ كجم لكل فدان) بالموسم الأول والثانى على التوالى.

سجلت أعلى تركيزات سماد النانو الليثوفيت أعلى القيم بجميع الصفات محل الدراسة ، وكانت أعلى القيم لمحصول الحبوب (٢٠٢٦,٨ و ٢٠٧٥,٧ كجم لكل فدان) خلال موسمى الدراسة على التوالى.

إستخدام ١٠٠ كجم نتروجين للفدان أعطى زيادة لجميع الصفات ماعدا كفاءة إستخدام النيتروجين ورقم السقوط بالثوانى نقصت عند ذلك المستوى ، وسجل محصول الحبوب (١٩٠٤,٣ و ١٩٦٤,٣ كجم للفدان) خلال الموسمين على التوالى.

فى النهاية وإستناداً إلى النتائج المتحصل عليها تبين أن إستخدام مستوى مائى ١٠٠% (٢٧٠٠ م$^3$/فدان) من إحتياجات الرى وسماد النانو الليثوفيت بتركيز ٤٠٠ppm وتطبيق ١٠٠ كجم نيتروجين للفدان كان مناسب لظروف منطقة توشكى كما سبب زيادة فى محصول الحبوب للقمح الديورم ( صنف بنى سويف ١).