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Impact of Preceding Crop, Sowing Methods and Nano-Fertilizer (Amino mineral) on Bread Wheat Production and Quality in Toshka Region, Egypt

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THE CURRENT study was carried out at the Experimental Farm of the Water Studies and Research Complex (WSRC) Station, National Water Research Center, in Abu Simbel, Toshka Region (laying out in the part of the south valley of Egypt, about 1300 and 280km. south from Cairo and Aswan, respectively) during 2018-19 and 2019-20 seasons to study the effect of preceding crop (PC_1: fallow, PC_2: soybean and PC_3: sunflower), sowing methods (SM_1: drilling and SM_2: broadcasting) and nano-fertilizer (NF_1: 0.0 Nano (control), NF_2: 125, NF_3: 250 and NF_4: 500mL fed^{-1}) on the growth, yield and its quality of bread wheat *cv.* Giza 171 in sandy-loam soil. The experiment was carried out in (RCBD) using strip-split plot design with three replications. Results showed that plant height, number of spike plant^{-1}, number of leaves plant^{-1}, flag leaf area, spike length, number of grains spike^{-1}, 1000-grain weight, grain yield, protein content, hectoliter weight, wet and dry gluten traits were significantly affected by preceding crops, sowing methods and nano-fertilizer in both seasons. Wheat preceded by soybean shows an increase in all studied wheat traits than those preceded by sunflower crop and fallow. The drilling method showed remarkably superior performance for all studied traits, except the plant height and hectoliter weight which was recorded the highest mean values with the broadcasting method. Increasing nano-fertilizer concentration from 125 to 500mL fed^{-1} resulted in an increased significance in all previous traits, except for hectoliter weight trait which was decreased by increasing nano-fertilizer concentration in both seasons. Also, all interactions involved in this respect had significant influences on the majority of the traits, and the highest mean value of grain yield was (3.480 and 3.553 ton fed^{-1}) in the 1st and 2nd seasons, respectively which were resulted from planting wheat after soybean (PC_2) with drilling method (SM_1) and spraying with 500 ml fed^{-1} nano-fertilizer (NF_4) at three times.

Keywords: Preceding crops, Sowing methods and Nano-fertilizer, Wheat, Yield and its Quality.

Introduction

Wheat (*Triticum aestivum L.*) is an important cereal crop all over the world as well as it is considered the major cultivated, most consuming staple food in Egypt and for millions of people worldwide. Egypt remains a highly importer of wheat despite it was the first crop to be planted. To obtain high production of wheat under Egyptian agriculture is one of the main targets of food production increase in order to reduce the food gap as a result of the continuous population increase. Land reclamation is one of the important solutions for this reason which is the most important strategic aim to reduce the gap between production and consumption.

It is known that the sandy soils are poor in

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the macro and micro-elements, especially the available N, because of their low organic matter.

Therefore, crops grown in previous years especially legumes play an important role in the increase of nutrients available for subsequent plant growth and facilitate better utilization of growth resources to improve soil quality and increased productivity of crops. Residual benefits of legumes are often equivalent to the addition of 50-100kg N ha^{-1} as fertilizer, low of N is one of the major yield-limiting factors for cereals (Phoomthaisong et al., 2003; Shah et al., 2003). Also, Hamd Alla et al. (2015) illustrated that planting cereals on the same piece of land annually leads to an imbalance in soil fertility and a decline in productivity of crops. Hamdany et al. (2016) indicated that the highest values of cereal units, economic evaluation, net return and improved physical and chemical properties of soil for the next planting resulted from the crop sequence corn followed by fahal berseem one cut followed by wheat compared the other treatments in both seasons. Growing wheat after soybean and clover (as legume crops) increased plant height, number of spikes m^{-2}, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, spike length, grain weight $spike^{-1}$, 1000-grain weight, straw yield, and grain yield (Abomarzoka & Hamadny, 2017; Gad et al., 2018; Abd Allah et al., 2020). Likewise, Andrii et al. (2021) indicated that after the preceding crop soybean, wheat crop gained the maximum yield (5.77ton ha^{-1}).

Using suitable methods of sowing for wheat plays a crucial role in increasing productivity and enhance resource availability e.g. moisture, sunlight capture and nutrient availability, etc. (Harishankar & Tomar, 2017). So, the farmer selects the proper method depending on soil type and the preceding crop which leads to facilitating plants to utilize the land, and optimum plant population in the field, and good subsequent crop growth (Singh & Sharma, 2019; Angelique et al., 2020). In Egypt, most farmers prefer the broadcasting method because it saves time, whereas progressive farmers and research scientists use the drilling sowing method due to uniform seed distribution in the field and sowing at desired depth which results in higher germination, to save the labor in controlling weeds and increases the utilization efficiency of light, water, fertilizer and other resources (Tao et al., 2017), but only 27% of the farmers currently practice drill sowing (Abdelmageed et al., 2019).

The different sowing methods resulted in changes in grain yield that were mainly attributed to the effects of number of spike (Ding et al., 2021).

Several researchers found that wheat sown by drilling method gave the highest values for plant height, number of tillers m^{-2}, number of spikes m^{-2}, number of spikelets $spike^{-1}$, number of grains $spike^{-1}$, spike length, grain weight $spike^{-1}$, 1000-grain weight, straw yield, grain yield and protein percentage compared to the other sowing methods (Chauhdary et al., 2016; Khatri et al., 2019; Al-Zahy et al., 2020; Bakhsh et al., 2020; Singh et al., 2020; Hassanein et al., 2020; Tamirat & Mekides, 2020). Latif et al. (2018) concluded that poor results were obtained in the method of broadcast single 1 as compared to the other methods.

The use of Nano-fertilizers (NF_S) based on nanoparticles (NP_S) has unique various traits that make them more beneficial than synthetic fertilizers. NF_S have high surface areas, minimum losses, high reactivity, and their ability to enter stomata when applied as a foliar due to their small particle size (Seleiman et al., 2021). Nano-technology is the most novel field of the twenty-one century and could be considered as smart fertilizers or eco-friendly technology and it's towards saving of nutrients, in particular N element (Yaseen et al., 2020; Yogendra et al., 2020). Furthermore, the application of NP_S improves carbon balance in crops, accelerates plant growth, can increase the efficiency of micro and macronutrients of plants, and reducing the use of chemical fertilizers per unit area which causes environmental problems (Mahil & Kumar, 2019; Hasan & Saad, 2020). Most of the researches conducted globally on nano-fertilizers suggest that these materials have a greater role in crop production with environmental safety, ecological sustainability and economic stability, the same as reported by Abdel-Aziz et al. (2016) on wheat, El-Habbak et al. (2019) on maize, Basim & Turki (2019) on wheat, Burhan & AL-Hassan (2019) on wheat, Hayyawi et al. (2019) on wheat, Makarem et al. (2019) on wheat, Khalil et al. (2019) on maize, Abou-Baker et al. (2020) and Gomaa et al. (2020) on sorghum, Mayyadah & Abdullah (2020) on wheat. Astaneh et al. (2018) found that Nano Chelated N is the best fertilizer due to the significant yield increase of wheat in lesser doses. Fertilization with NPK NPs produced an increase in yield for wheat (Abdelsalam et al., 2019).

Hence, the main target of the current study is to elucidate the impact of preceding crop, sowing methods and nano-fertilizer on the growth, production and quality of bread wheat *cv.* Giza 171 at Toshka region-Aswan Governorate.

Materials and Methods

Field experiment

The current study was carried out at the Experimental Farm of the Water Studies and Research Complex (WSRC) Station, National Water Research Center, in Abu Simbel, Toshka Region (laying out in the part of the south valley of Egypt, about 1300 and 280 Km. south from Cairo and Aswan, respectively on latitude 22-25° north, 31 longitude east and elevation 181m above the sea level) during 2018-19 and 2019-20 seasons to defined the effect of preceding crop, sowing methods and nano-fertilizer on the growth, yield and its quality of bread wheat *cv.* Giza 171 under the Sandy-loam soil.

Soil analytical procedures

The soil type of the experimental field was sandy-loam textured. Composite soil samples were taken before planting a crop to depth (0-30cm) for physical and chemical analysis according to Rowell (1995). Details of soil properties and available nutrients after preceding crops are shown in Table 1.

The experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD) using a strip-split plot arrangement with three replication. Treatments included three preceding crops (PC_1: Fallow, PC_2: Soybean and PC_3: Sunflower) were allocated vertically, while, amino mineral (nano-fertilizer was foliar spraying with four concentration, i.e. NF_1= Control, NF_2= 125mL, NF_3= 250mL and NF_4= 500mL fed^{-1}) were arranged horizontally and two sowing methods (MS_1: Drilling and MS_2: Broadcasting) were arranged in sub-plots. Control plants were sprayed with water (without amino mineral). Amino mineral® was used as Nano-major and microelements with amino acids obtained from (BIO NANO TECH for fertilizers development, Egypt). It contained amino acids (5%), algal extract (5%), vitamins (1%), N (8%), P_2O_5 (5%), K_2O (3%), microelements 10% (Fe, Zn, B, Mn, Co, Cu and Mo).

All agriculture practices from sowing wheat until harvest as recommended for the wheat crop were done in both seasons. Table 2 shows the sowing and harvest of summer field crops in the two growing seasons.

Foliar application of Nano-fertilizer was done at three times, i.e. after 21, 45 and 65 days from sowing. Each sub-plot area was 10.5m^2 (3m length and 3.5m width= 1/400fed). Sowing dates of wheat were 7 and 5 December in the 1st and 2nd seasons, respectively with a seeds rate of 60kg fed^{-1} wheat *cv.* Giza 171 under sprinkler irrigation system where water was added every 5 days.

TABLE 1. Some soil properties of the study area and available N, P and K after soybean and sunflower in growing seasons

Particle size distribution (%)				OM (%)	$CaCo_3$ (%)	pH (paste extract)	EC dS m^{-1}	Bulk density (g cm^{-3})	Field capacity (%)
Sand	Silt	Clay	Texture class						
82.19	13.16	4.65	Sandy-loam	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^-		$CO_3^{--} + HCO_3^-$	SO_4^{--}		
3.70	0.1	0.61	0.43	2.8		0.2	1.84	8.00	3.8

Preceding crops	2018-19 season			2018-19 season		
	N	P	K	N	P	K
Soybean	45.00	8.80	223.00	46.00	8.90	225.00
Sunflower	25.00	6.00	160.00	25.05	6.50	163.00

(Some available nutrients (ppm) after preceding crops)

TABLE 2. Sowing and harvest dates of crop sequence in the two growing seasons

Crops	2018-19 season		2019-20 season	
	Sowing date	Harvest date	Sowing date	Harvest date
Soybean	15th May	20th August	13th May	19th August
Sunflower	26th April	10th September	28th April	11th September
Wheat	7th December	25th April	5th December	25th April

All the other agricultural practices were carried out for each crop according to the recommendations of the province by the Ministry of Agriculture.

The studied traits as follow

A- Vegetative growth traits

Samples of one square meter were taken from at random the middle area from each plot after 90 days from sowing to measure traits given below:

1- Plant height (cm).
2- Number of spike plant^{-1}.
3- Number of leaves plant^{-1}.
4- Flag leaf area (cm^2): was calculated using the following equation of Palamiswamy & Gomex (1974):

Leaf area (L.A) = K (L × W).

where: L= Leaf length, W = Maximum width of the leaf, K= factor of 0.75

B- Yield and its components

At harvest time, ten random plants were chosen at random from each sub plot from the three replicates to study the following traits:

1- Spike length (cm)
2- Number of grains spike^{-1}
3- 1000-grain weight (g)
4- Grain yield (ton fed^{-1}): At maturity, whole experimental units were harvested then threshed and the total weight of grain per plot was measured and then converted to ton fed^{-1}.

C-Quality characteristics

1- Protein content %, total N content in grains were determined by using the micro-Kjeldahl method and the protein% was calculated by multiplying N content by 5.75 (AOAC, 2010).

2- Hectoliter weight (kg hectoliter^{-1}), was used one-quarter liter apparatus to determine the hectoliter weight of grains and expressed in kg hl^{-1}. (AACC, 2005).

3- Wet and dry gluten %: Gluten content was determined according to the standard method described by, AACC (2005) as follows, twenty grams of each sample from the flour was placed in a container. Ten cm^3 water were added and mixed then the dough pieces were rolled into balls by hand then it was placed in glass water on hour washed down using a little water and grabs starch and stayed then wet gluten was dried for 48 hours at 70°C to determine dry gluten.

Statistical analysis

The data gathered were subjected to statistically analyze using the SAS program and LSD test at a 5% level of probability was used to compare the treatments means according to Gomez & Gomez (1984).

Results and Discussion

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

Vegetative growth traits

Effect of preceding crops

Results in Table 3 indicated that the growth characters were significantly affected by preceding summer crops in both seasons. The highest mean values of plant height (90.17 and 90.41cm), number of spike plant^{-1} (5.17 and 5.30), number of leaves plant^{-1} (18.47 and 18.29) and flag leaf area (42.26 and 41.89cm^2) in the two respective seasons were achieved when wheat plants are sown after soybean PC_2 followed by those after sunflower (PC_3), and the lowest values were when growing wheat plants after fallow for the previously mentioned traits. Growing soybean following wheat increased plant height by 6.27 and 7.01%, number of spike plant^{-1} by 25.48 and 24.71%, number of green leaves plant^{-1} by 14.36 and 12.90% and flag leaf area by 9.68 and 9.89%, in the 1st and 2nd second seasons, respectively, compared with sowing wheat after sunflower. The positive impact when grown wheat after soybean is attributed due to the improved total count of rhizobia that increased soil N levels and availability of microelements which ultimately affected growth traits of wheat plants. These results coincided with those obtained by Dilsher (2012), Abomarzoka & Hamadny (2017), Gad et al. (2018) and Abd Allah et al. (2020).

Effect of sowing methods

The sowing methods showed a remarkable effect on vegetative growth characters of wheat plants including plant height, number of spike plant^{-1}, number of leaves plant^{-1} and flag leaf area (Table 3). In both seasons, seeding wheat by drilling method (SM_1) gave the greatest increase for all studied growth traits. It might be attributed to drilling is an advisable planting method due to uniform seed distribution in the field and seeding at desired depth which ensures higher emergence and good subsequent crop growth as well as increases the utilization efficiency of light, water, fertilizer and higher root growth, which lead to enhance plant growth (Tao et al., 2017; Abdelmageed et al., 2019). Tamirat & Mekides (2020) indicated that the drilling planting method has able a good leaf length, the highest mean values of leaf number and is a better way to maximize the productivity of wheat. This result is supported by the study of Latif et al. (2018), Angelique et al. (2020), Karim et al. (2020) and Singh et al. (2020).

Effect of nano-fertilizer

Treatment of wheat plants with nano-fertilizer led to significant progressive increase for all growth traits. In Table 3 foliar application of nano-fertilizer (NF_4) with 500mL fed^{-1} gave the highest mean values for plant height (90.29 and 89.91cm), number of spike plant^{-1} (5.28 and 5.44), number of leaves plant^{-1} (19.31 and 19.23) and flag leaf area (42.50 and 41.98cm^{-2}) in 2018-19 and 2019-20 seasons, respectively. While, the lowest mean values of plant height (82.94 and 82.75cm), number of spike plant^{-1} (3.70 and 3.95), number of leaves plant^{-1} (14.68 and 14.53) and flag leaf area (37.01 and 36.77cm^{-2}) were achieved by sprayed wheat plants with water (NF_1: Control treatment) in both seasons, respectively. The increments in previous traits may be due to used nano-fertilizer have an essential role in physiological and biochemical processes of plants by increasing availability of nutrients which increase photosynthesis rate caused by an expansion in surface area of the leaves, higher apical growth, chlorophyll formation, dry matter production and subsequently improve growth and develop the wheat plant (Singh et al., 2017; Mahil & Kumar, 2019). These results are in line with those obtained by Burhan & AL-Hassan (2019), Hayyawi et al. (2019), Mayyadah & Abdullah (2020) and Yogendra et al. (2020).

TABLE 3. Means of vegetative growth traits of wheat as affected by preceding crops, sowing methods, nano-fertilizer and their interactions during 2018-19 and 2019-20 seasons

Treatments	Plant height (cm)		Number of spike plant^{-1}		Number of leaves plant^{-1}		Flag leaf area (cm^2)	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Preceding crops (PC)								
PC_1: Fallow	86.62	85.95	4.24	4.47	16.70	16.42	39.17	38.67
PC_2: Soybean	90.17	90.41	5.17	5.30	18.47	18.29	42.26	41.89
PC_3: Sunflower	84.85	84.49	4.12	4.25	16.15	16.20	38.53	38.12
LSD at 5%	**0.24**	**0.34**	**0.11**	**0.07**	**0.12**	**0.10**	**0.17**	**0.20**
Sowing methods (SM)								
SM_1: Drilling	86.21	86.05	4.59	4.73	17.61	17.38	40.20	39.70
SM_2: Broadcasting	90.21	89.85	3.42	3.62	15.60	14.76	36.76	37.42
LSD at 5%	**1.06**	**0.25**	**0.11**	**0.03**	**0.29**	**0.27**	**0.14**	**0.10**
Nano-fertilizer (NF)								
NF_1: 0.0 control	82.94	82.75	3.70	3.95	14.68	14.53	37.01	36.77
NF_2: 125mL fed^{-1}	86.86	86.58	4.09	4.21	16.59	16.33	39.35	38.74
NF_3: 250mL fed^{-1}	88.77	88.57	4.96	5.10	17.86	17.79	41.18	40.75
NF_4: 500mL fed^{-1}	90.29	89.91	5.28	5.44	19.31	19.23	42.50	41.98
LSD at 5%	**0.28**	**0.34**	**0.06**	**0.05**	**0.17**	**0.07**	**0.19**	**0.21**
LSD at 5% for Interactions								
PC×SM	**NS**	**NS**	**NS**	**NS**	**NS**	**0.10**	**NS**	**NS**
PC×NF	**0.48**	**0.58**	**0.11**	**0.10**	**0.30**	**0.13**	**0.33**	**0.36**
SM×NF	**0.39**	**0.41**	**NS**	**NS**	**0.25**	**0.10**	**NS**	**NS**
PC×SM×NF	**NS**	**NS**	**NS**	**NS**	**0.43**	**0.18**	**NS**	**NS**

Yield and yield components

Effect of preceding crops

Data in Table 4 and Fig. 1 show that the preceding crop had a significant effect on yield and its components traits of wheat during 2018-19 and 2019-20 seasons. In general, cultivating wheat after soybean crop produced the maximum yield and its components as compared with planting wheat after sunflower. When the previous crop was soybean wheat plants gave the highest mean values of mentioned traits (13.86cm, 63.10 grains spike^{-1}, 53.33gm and 3.316ton fed^{-1} of spike length, number of grains spike^{-1}, 1000-grain weight and grain yield, respectively, in the 2018-19 season. The corresponding mean values in 2019-20 season were 13.96cm, 63.54 grains spike^{-1}, 52.56gm and 3.291ton fed^{-1} in the same order. The increase in grain yield grown after soybean were (25.08 and 34.63%) as well as (23.03 and 30.75 %) compared with grown wheat after fallow and sunflower in the first and second seasons, respectively. The superiority of yield and its components traits could be ascribed to increased fertility of the soil after sowing soybean due to its ability to fix atmospheric N2, and enhance the photosynthesis process and leading to more assimilate production and translocation to the sinks thus, increases the yield components traits and consequently increase grain yield.

Andrii et al. (2021) indicated that wheat crop sown after soybean, gained the maximum yield (5.77ton ha^{-1}). Similar results were obtained by Hamdany et al. (2016), Abomarzoka & Hamadny (2017), Gad et al. (2018) and Abd Allah et al. (2020).

TABLE 4. Means of yield and its components of wheat as affected by preceding crops, sowing methods, nano-fertilizer and their interactions during 2018-19 and 2019-20 seasons

Treatments	Spike length (cm)		Number of grains spike^{-1}		1000-grain weight (gm)		Grain yield (ton fed^{-1})	
	2018-19	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**	**2018-19**	**2019-20**
Preceding crops (PC)								
PC_1: Fallow	12.14	12.43	58.98	59.31	47.93	48.19	2.651	2.675
PC_2: Soybean	13.86	13.96	63.10	63.54	53.33	52.56	3.316	3.291
PC_3: Sunflower	11.95	12.22	58.23	58.60	48.24	47.67	2.463	2.517
LSD at 5%	**0.09**	**0.11**	**0.27**	**0.28**	**0.40**	**0.26**	**0.03**	**0.04**
Sowing methods (SM)								
SM_1: Drilling	12.74	12.97	60.44	60.80	51.13	50.84	2.955	2.982
SM_2: Broadcasting	11.57	10.77	56.77	57.17	46.54	47.11	2.611	2.674
LSD at 5%	**0.07**	**0.06**	**0.32**	**0.42**	**0.27**	**0.22**	**0.10**	**0.03**
Nano-fertilizer (NF)								
NF_1: 0.0 control	10.80	11.05	56.81	57.31	47.63	46.90	2.253	2.267
NF_2: 125mL fed^{-1}	12.17	12.39	59.62	59.78	49.32	48.93	2.546	2.571
NF_3: 250mL fed^{-1}	13.37	13.58	61.20	61.77	50.47	50.32	2.858	2.925
NF_4: 500mL fed^{-1}	14.29	14.46	62.78	63.09	51.92	51.75	3.277	3.190
LSD at 5%	**0.17**	**0.10**	**0.25**	**0.24**	**0.23**	**0.18**	**0.04**	**0.02**
LSD at 5% for Interactions								
PC×SM	**0.21**	**NS**	**NS**	**NS**	**0.37**	**0.39**	**NS**	**NS**
PC×NF	**0.24**	**0.17**	**0.43**	**0.41**	**0.40**	**0.30**	**0.06**	**0.05**
SM×NF	**0.21**	**0.14**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.04**
PC×SM ×NF	**NS**	**0.23**	**NS**	**0.58**	**NS**	**0.43**	**0.09**	**0.07**

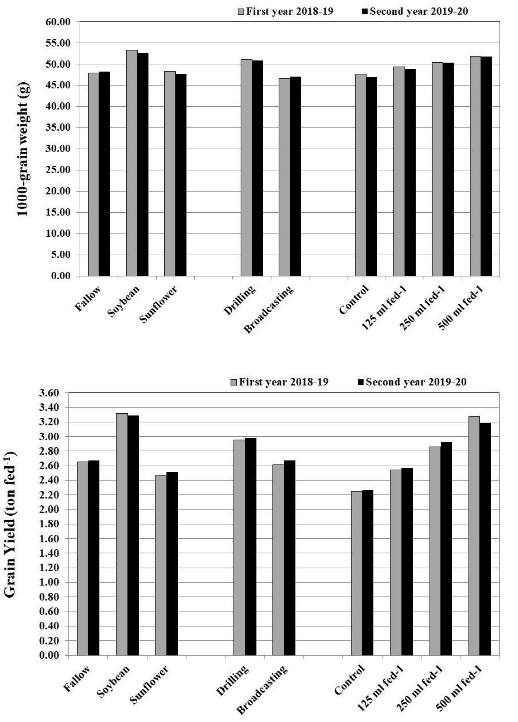

Fig. 1. Means of 1000-grain weight and grain yield of wheat as affected by preceding crop, sowing methods and nano-fertilizer during 2018-19 and 2019-20 seasons

Effect of sowing methods

The obtained data reveal that all the studied yield and its components traits significantly affected by sowing methods in both seasons (Table 4, Fig. 1). Drilling method (SM_1) was given the highest mean values of spike length (12.74 and 12.97cm), number of grains spike^{-1} (60.44 and 60.80), 1000-grain weight (50.13 and 50.84gm) and grain yield (2.955 and 2.982ton fed^{-1}) in the 1st and 2nd seasons, respectively while, the lowest mean values of mentioned traits were recorded by broadcasting method (SM_2). Grain yield was reduced by about 11.64 and 10.33% in the two respective seasons when planting wheat with broadcasting compared to drilling method. Our results were in the same respect of Al-Zahy et al. (2020) and Meleha et al. (2020) who found that lowest 1000-grain weight and grain yield were recorded with the broadcasting method. These results may be due to the drilling method could resolve the several problems regarding the nutrient addition, water losses, disease infestation, poor grain filling besides to the better field air circulation and finally could contribute to attaining as well straight plants standing can harvest more solar light and such impacts increased vegetative growth. El-Temsah (2017), Latif et al. (2018), Angelique et al. (2020), Karim et al. (2020), Singh et al. (2020) and Tamirat & Mekides (2020) supported these results.

Effect of nano-fertilizer

The data in Table 4 and Fig. 1 indicate that sprayed wheat plants by nano-fertilizer had a significant effect on all yield and its components traits in both growing seasons. The foliar spray of wheat plant by 125 or 250 or 250mL fed^{-1} of nano-fertilizer led to an increases in spike length by 12.69, 23.80 and 32.31%, number of grains spike^{-1} by 4.95, 7.73 and 10.51%, 1000-grain weight by 3.55, 5.96 and 9.01% and grain yield by 13.00, 26.85 and 45.45% as compared to control treatment (without nano-fertilizer plants) in the first season. The corresponding increase in the second season were 12.13, 22.90 and 30.86%, 4.31, 7.78 and 10.08% , 4.33, 7.29 and 10.34% and 13.41, 29.03 and 40.71% in the same order compared to control treatment (NF_1). Application of 14, 27 and 41kg ha^{-1} nano-fertilizer led to 31, 44 and 98% increase in seed yield compared to control (Astaneh et al., 2018). Fertilization with NPK NPs produced an increase in yield for wheat (Abdelsalam et al., 2019). This can be attributed to foliar application nano-fertilizer directly on to leaves led to reducing the time lag between application and uptake by the plant during the rapid growth phase as well can improve the efficiency and rapidity of the utilization of a nutrient urgently required by the plant for maximum growth and yield. Basim & Turki (2019) indicated that the superiority of nano-fertilizer in grain number, 1000-grain weight and grain yield.

Quality traits

Effect of preceding crops

The demonstrated data in Table 5 reveal that the studied preceding crops influenced significantly quality traits in the two growing seasons. Wheat preceded by soybean resulted in significantly higher protein (12.21 and 12.64%), wet gluten (35.31 and 35.42%) and dry gluten (11.58 and 11.68%) in the two respective seasons, followed by that preceded by sunflower which was gained protein content (11.06 and 11.11%), while wet gluten (32.11 and 32.60%) and dry gluten (10.59 and 10.70%) resulted from the sequence of fallow land/wheat in the 1st and 2nd seasons, respectively. These results could be due to the high residue of N into the soil and low C/N ratio in the residual influence of soybean compared to sunflower. In addition to, gluten content depends on grain protein composition. Our results were obtained by Abd EL-Zaher et al. (2009). The crop sequence of fallow land/wheat (84.84 and 84.96kg hl^{-1}) produced the heaviest hectoliter weight followed by the sequence of sunflower/wheat (81.73 and 82.11kg hl^{-1}) and the lowest value in this respect resulted from the sequence of soybean/wheat (80.53 and 80.42kg hl^{-1}) in the two respective seasons. Hectoliter weights are performed to determine the degree of the size of the grains and the producer of flour yield that can be obtained when milling wheat grain are accepted as the main quality factors by the industry (Mut et al., 2010).

Effect of sowing methods

Data illustrated in Table 5 show that the percentages of protein, wet gluten and dry gluten were affected significantly by studied sowing methods in both seasons. Wheat plants obtained from the planting method by drilling gave the higher mean values of protein (12.32 and 12.37%), wet gluten (33.15 and 33.46%) and dry gluten (10.91 and 11.03%) in the first and second seasons, respectively. The positive influence was observed by the drilling method may be mainly due to uptake of N and cumulating of Co_2 accrue to excellent plant distribution in the field (Al-Zahy et al., 2020). In the same table, hectoliter weight was affected significantly by sowing methods. The highest average values of test weight (85.11 and 85.32kg hl^{-1} in the two respective seasons) were obtained from the broadcasting method. The hectoliter weight is a major predictor of the milling yield and is used as an indicator of the general grain quality. In this study, the hectoliter weight ranged from 82.63 to 85.32kg L^{-1}, which is in agreement with the standard hectoliter weight in the U.S. grading system more than 77.23kg L^{-1} for all wheat, as well for the milling process and the production of fine flour (Angelique et al., 2020). El-Temsah (2017) is a corresponding with our results.

Effect of nano-fertilizer

The effect of foliar spraying by nano-fertilizer on percentages for both protein, wet and dry gluten in grain wheat. Giza 171, was shown in Table 5. Percentages of protein and gluten increased with increasing nano-fertilizer. In both seasons, the grains produced from the plants which were sprayed by 250mL fed^{-1} nano-fertilizer gave the highest mean values of protein (12.45 and 12.69%), wet gluten (35.03 and 35.23%) and dry gluten (11.55 and 11.69%) in the first and second seasons, respectively**.** The increment in percentages of protein, wet and dry gluten can be due to the improvement in the vegetative growth and grain yield as a result of spraying a high number of nutrients in nano-fertilizer. Consequently, controlled release of N from that by nano-fertilizer application and availability of N throughout the crop growth period. Burhan & AL-Hassan (2019) showed that increases in protein% (27.24%) and gluten (58.45%) when fertilized with 100% nano-fertilizer compared with the control treatment. In addition, application of 125, 250 and 500 ml fed^{-1} nano-fertilizer led to (4.47 and 5.30%), (3.18 and 3.95%) and (1.35 and 2.31%) increase in hectoliter weight compared to control treatment in the first and second seasons, respectively. In agreement with our results, Ahmed et al. (2018) illustrated that the tested zinc oxide nanoparticles had a significant effect on hectoliter weight trait in both seasons.

Effect of interactions

The interaction between PC and SM were not significantly on most growth, yield and quality of wheat traits, while were significant for number of green leaves plant in 2nd season, spike length in 1st season, 1000-grain weight in both seasons, wet gluten in the 2nd season and dry gluten in both seasons (Table 6). The highest values of the mentioned previously traits were achieved when wheat is preceded by soybeans and its plantation by drilling method (PC2×SM1).

Regarding the interaction between PC and NF had a significant effect on all growth characters in both seasons Table 7. The highest plant height (93.51 and 93.75cm), number of spike $plant^{-1}$ (5.79 and 5.97 spikes), number of leaves $plant^{-1}$ (20.40 and 20.32 leaves) and flag leaf area (45.29 and 44.85cm^2) were obtained by planting wheat after soybean and sprayed with 500 ml fed^{-1} nano-fertilizer (PC_2×NF_4) in the 1st and 2nd seasons, respectively.

Data in Table 8 indicated that the interaction between SM×NF was significant, it is clear from data that the best treatment for plant height (91.43 and 91.07cm) and hectoliter weight (87.81 and 88.78kg hl^{-1}) were obtained by when planting wheat on broadcasting method and adding 500mL fed^{-1} from nano-fertilizer (SM_2×NF_4) in both seasons, respectively. Also, data cleared that application of 500mL fed^{-1} nano-fertilizer with planting wheat by drilling method produced (SM_1×NF_4) the highest values of number of leaves $plant^{-1}$ (20.00 and 19.87 leaves) and spike length (14.87 and 14.64cm) in the 1st and 2nd seasons, respectively, grain yield (3.317ton fed^{-1}) and dry gluten (11.74%) in the 2nd season only.

Data presented in Table 9 and Fig. 2 revealed that number of leaves plant^{-1} (21.66 and 21.51 leaves) and grain yield (3.480 and 3.553ton fed^{-1}) in both seasons, respectively and spike length 16.31 cm, number of grain spike^{-1} 67.31 grains, 1000-grain weight 56.66 g and wet gluten 37.44% in the second season as well as protein 13.69% in the first season were significantly affected by the interaction between PC×SM×NF. The wheat plants preceded by soybean, planted by drilling method and fertilized with 500mL fed^{-1} nano-fertilizer recorded the highest values $PC_2 \times SM_1 \times NF_4$. Hectoliter weight recorded the heaviest value (87.42kg hl^{-1}) when wheat plants sowed after soybean on the broadcasting method and fertilized with 125mL fed^{-1} nano-fertilizer $PC_2 \times SM_2 \times NF_2$.

TABLE 5. Quality properties of wheat as affected by preceding crops, sowing methods, nano-fertilizer and their interactions during 2018-19 and 2019-20 seasons

Treatments	Crude protein %		Hectoliter weight (kg hl^{-1})		Wet gluten %		Dry gluten %	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Preceding crops (PC)								
PC_1: Fallow	10.70	10.60	84.84	84.96	32.11	32.60	10.59	10.70
PC_2: Soybean	12.21	12.64	80.53	80.42	35.31	35.42	11.58	11.68
PC_3: Sunflower	11.06	11.11	81.73	82.11	31.43	31.59	10.34	10.47
LSD at 5%	**0.05**	**0.32**	**0.21**	**0.28**	**0.20**	**0.14**	**0.07**	**0.08**
Sowing methods (SM)								
SM_1: Drilling	12.31	12.37	82.63	82.67	33.15	33.46	10.91	11.03
SM_2: Broadcasting	11.53	11.62	85.11	85.32	31.75	31.90	9.77	9.87
LSD at 5%	**0.06**	**0.12**	**0.38**	**0.34**	**0.05**	**0.29**	**0.05**	**0.14**
Nano-fertilizer (NF)								
NF_1: 0.0 control	9.45	9.92	80.80	80.18	30.37	30.64	10.03	10.15
NF_2: 125mL fed^{-1}	11.40	11.59	84.41	84.43	32.39	32.78	10.63	10.75
NF_3: 250mL fed^{-1}	11.99	12.06	83.37	83.35	34.00	34.17	11.14	11.21
NF_4: 500mL fed^{-1}	12.45	12.69	81.89	82.03	35.05	35.23	11.55	11.69
LSD at 5%	**0.08**	**0.12**	**0.21**	**0.18**	**0.17**	**0.13**	**0.05**	**0.06**
LSD at 5% for Interactions								
PC×SM	**NS**	**NS**	**NS**	**NS**	**NS**	**0.14**	**0.05**	**0.09**
PC×NF	**0.13**	**0.20**	**0.26**	**0.31**	**0.30**	**0.22**	**0.08**	**0.11**
SM×NF	**NS**	**NS**	**0.30**	**0.25**	**NS**	**NS**	**NS**	**0.09**
PC×SM×NF	**0.19**	**NS**	**0.52**	**NS**	**NS**	**0.31**	**NS**	**NS**

TABLE 6. Effect of interaction between preceding crops × sowing methods on wheat traits during 2018-19 and 2019-20 seasons

Treatments \ Traits		Number of leaves plant^{-1}	Spike length (cm)	1000-grain weight (g)		Wet gluten %	Dry gluten %	
		2nd season	1st season	1st season	2nd season	2nd season	1st season	2nd season
		Preceding crops × Sowing methods (PC×SM)						
PC1	SM1	16.77	12.26	48.10	48.31	32.79	10.64	10.73
	SM2	15.05	11.03	45.76	46.07	32.41	10.45	10.46
PC2	SM1	18.96	14.05	53.93	53.27	35.62	11.95	11.87
	SM2	16.62	12.67	50.72	50.85	35.22	11.21	11.34
PC3	SM1	16.40	12.00	49.37	48.93	31.96	10.45	10.61
	SM2	15.00	10.89	46.12	45.41	31.21	10.12	10.23
LSD at 5%		**0.10**	**0.21**	**0.37**	**0.39**	**0.14**	**0.05**	**0.09**

- PC1: Fallow, PC2: Soybean, PC3: Sunflower.
- SM1: Drilling, SM2: Broadcasting.

TABLE 7. Effect of interaction between preceding crops × Nano-fertilizer on growth traits of wheat plants during 2018-19 and 2019-20 seasons

Treatments \ Traits		Plant height (cm)		Number of spike plant^{-1}		Number of leaves plant^{-1}		Flag leaf area (cm^2)	
		2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
		Preceding crops × Nano-fertilizer (PC×NF)							
PC1	NF1	82.70	82.10	3.38	3.78	14.30	14.05	36.26	36.14
	NF2	86.23	85.61	3.65	3.84	16.08	15.70	38.63	38.21
	NF3	88.05	87.48	4.78	4.96	17.33	17.09	40.36	39.62
	NF4	89.51	88.62	5.12	5.28	19.08	18.82	41.42	40.73
PC2	NF1	84.67	84.95	4.36	4.58	15.89	15.62	38.76	38.63
	NF2	90.18	90.31	5.09	5.14	18.24	18.02	41.41	40.89
	NF3	92.31	92.64	5.42	5.53	19.35	19.21	43.59	43.20
	NF4	93.51	93.75	5.79	5.97	20.40	20.32	45.29	44.85
PC3	NF1	81.45	81.19	3.34	3.50	13.82	13.92	36.01	35.53
	NF2	84.16	83.81	3.51	3.63	15.44	15.27	37.73	37.14
	NF3	85.95	85.59	4.69	4.82	16.91	17.06	39.58	39.44
	NF4	87.84	87.37	4.92	5.05	18.44	18.56	40.80	40.37
LSD at 5%		**0.48**	**0.58**	**0.11**	**0.10**	**0.30**	**0.13**	**0.33**	**0.36**

- PC1: Fallow , PC2: Soybean, PC3: Sunflower.
- NF1: 0.0 Nano, NF2: 125mL fed^{-1}, NF3: 250mL fed^{-1}, NF4: 500mL fed^{-1}.

TABLE 8. Effect of interaction between sowing method × Nano-fertilizer on wheat traits during 2018-19 and 2019-20 seasons

Treatments \ Traits		Plant height (cm)		Number of leaves plant^{-1}		Spike length (cm)		Grain yield (ton fed^{-1})	Hectoliter weight (kg hl^{-1})		Dry gluten %
		1st season	2nd season	1st season	2nd season	1st season	2nd season	2nd season	1st season	2nd season	2nd season
		Sowing methods × Nano-fertilizer (SM×NF)									
SM1	NF1	81.44	81.26	15.09	14.78	11.09	10.84	2.330	79.71	80.01	10.27
	NF2	84.74	84.69	16.96	16.61	12.45	12.17	2.641	81.69	82.03	10.84
	NF3	86.53	86.51	18.37	18.25	13.54	13.27	2.942	83.04	83.19	11.27
	NF4	88.14	87.76	20.00	19.87	14.87	14.64	3.317	84.00	84.05	11.74
SM2	NF1	83.44	83.23	13.25	13.27	10.09	10.74	2.103	81.90	81.36	10.02
	NF2	87.97	87.46	15.21	15.06	11.32	11.17	2.300	83.09	84.03	10.65
	NF3	90.02	89.63	16.35	16.32	12.63	12.41	2.608	85.70	86.50	11.16
	NF4	91.43	91.07	17.62	17.60	13.05	12.95	3.083	87.81	88.78	11.53
LSD at 5%		**0.39**	**0.41**	**0.25**	**0.10**	**0.21**	**0.14**	**0.04**	**0.30**	**0.25**	**0.09**

- SM1: Drilling, SM2: Broadcasting.
- NF1: 0.0 Nano, NF2: 125mL fed^{-1}, NF3: 250mL fed^{-1}, NF4: 500mL fed^{-1}.

TABLE 9. Effect of interaction between preceding crops × sowing method × Nano-fertilizer on wheat traits during 2018-19 and 2019-20 seasons

Treatments		Traits	Number of leaves plant^{-1}		Spike length (cm)	Number of grain spike^{-1}	1000-grain weight (gm)	Grain yield (ton fed^{-1})		Protein %	Hectoliter weight (kg hl^{-1})	Wet gluten %
			1st season	2nd season	2nd season	2nd season	2nd season	1st season	2nd season	1st season	1st season	2nd season
			Preceding crops × Sowing method × Nano-fertilizer (PC×SM×NF)									
PC1	SM1	NF1	14.59	14.20	10.92	56.87	46.03	2.263	2.293	9.14	78.65	30.52
		NF2	16.40	16.05	12.17	59.37	48.04	2.673	2.613	10.92	81.27	32.24
		NF3	17.84	17.73	12.96	60.20	48.92	2.907	2.887	11.32	80.99	33.77
		NF4	19.47	19.10	14.14	62.04	50.26	3.077	3.097	11.96	79.61	34.63
	SM2	NF1	14.00	13.89	10.52	56.75	45.39	2.163	2.167	8.89	78.85	30.33
		NF2	15.75	15.36	12.02	58.62	47.72	2.367	2.393	10.56	83.07	32.08
		NF3	16.81	16.45	12.84	59.74	49.20	2.840	2.950	11.13	81.81	33.15
		NF4	18.70	18.54	13.87	60.88	45.00	2.917	3.003	11.66	79.99	34.07
PC2	SM1	NF1	16.52	16.07	12.01	60.25	49.68	2.570	2.540	10.21	81.46	32.92
		NF2	18.68	18.35	13.09	62.09	52.78	2.950	3.010	12.46	86.98	35.53
		NF3	20.06	19.91	15.03	65.89	53.96	3.103	3.190	12.92	85.44	36.60
		NF4	21.66	21.51	16.31	67.31	56.66	3.480	3.553	13.69	82.35	37.44
	SM2	NF1	15.27	15.17	11.93	59.51	49.27	2.347	2.363	10.14	81.78	32.72
		NF2	17.81	17.69	12.94	61.74	50.89	2.787	2.837	12.40	87.42	34.63
		NF3	18.63	18.51	15.15	65.37	52.46	2.930	3.010	12.75	86.00	36.16
		NF4	19.15	19.13	15.21	66.19	54.76	3.220	3.227	13.09	82.67	37.38
PC3	SM1	NF1	14.17	14.08	10.09	56.10	45.97	2.133	2.157	9.21	78.69	29.03
		NF2	15.80	15.43	12.11	58.58	47.18	2.283	2.300	11.16	83.76	31.37
		NF3	17.20	17.11	12.63	59.81	48.84	2.700	2.750	11.96	82.14	33.17
		NF4	18.88	19.00	14.17	61.14	49.75	2.923	3.000	12.20	81.38	34.27
	SM2	NF1	13.47	13.75	10.80	54.40	45.07	2.040	2.080	9.11	79.38	28.31
		NF2	15.08	15.12	11.98	58.26	46.99	2.213	2.270	10.93	83.95	30.85
		NF3	16.62	17.01	12.88	59.59	48.51	2.670	2.763	11.87	82.85	32.17
		NF4	18.01	18.12	13.06	60.95	49.07	2.743	2.820	12.063	81.72	33.51
LSD at 5%			**0.34**	**0.18**	**0.23**	**0.58**	**0.43**	**0.09**	**0.07**	**0.19**	**0.52**	**0.31**

- PC1: Fallow , PC2: Soybean, PC3: Sunflower.
- SM1: Drilling, SM2: Broadcasting.
- NF1: 0.0 Nano, NF2: 125mL fed^{-1}, NF3: 250mL fed^{-1}, NF4: 500mL fed^{-1}.

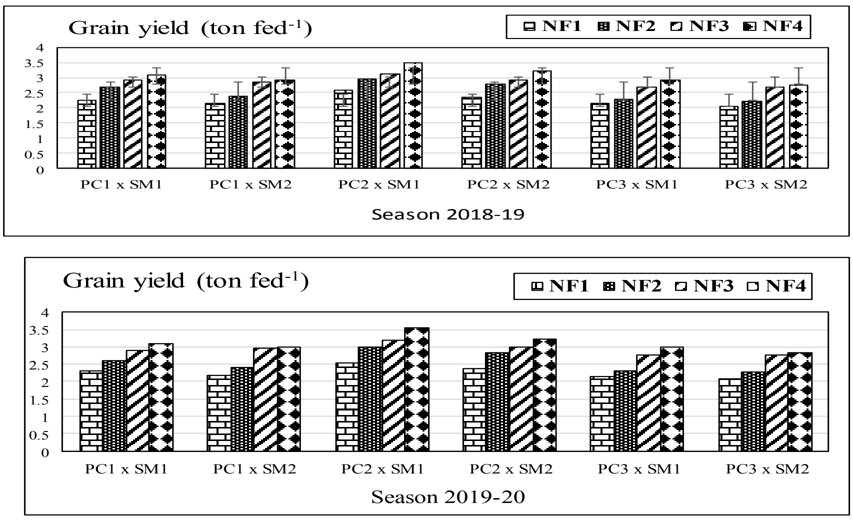

Fig. 2. Grain yield of wheat as affected by interaction among preceding crop, sowing method and nano-fertilizer during 2018-19 and 2019-20 seasons

Conclusion and Recommendations

From the obtained results it concluded that planting wheat plants after summer legumes (soybean) on drilling method and sprayed it by 500mL fed^{-1} nano-fertilizer at three times as a safe, eco-friendly and sustainable agricultural approach to improvement growth, production and quality of the wheat crop and tolerated the climatic conditions of Toshka-Aswan Governorate, Egypt.

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تأثير المحصول السابق وطرق الزراعة وسماد النانو على إنتاج وجودة قمح الخبز بمنطقة توشكى، مصر

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إجريت هذه الدراسة بمزرعة تجارب الأبحاث بمجمع الدراسات والبحوث المائية بتوشكى خلال موسمى 2018-19 و2019-20 لدراسة تأثير المحصول السابق (أرض بور، فول صويا، عباد شمس) وطريقة الزراعة (تسطير و بدار) وتركيزات النانو (صفر، 125، 250، 500 مللى للفدان) على المحصول ومكوناته وجودة الحبوب لمحصول قمح الخبز (جيزة 171) تحت الظروف المناخية لمنطقة توشكى. نفذت التجربة بإستخدام تصميم الشرائح المنشقة فى ثلاث مكررات.

وقد أظهرت النتائج أن إرتفاع النبات، عدد السنابل للنبات، عدد الأوراق للنبات، مساحة ورقة العلم، طول السنبلة، عدد الحبوب بالسنبلة، وزن 1000 حبة، محصول الحبوب، محتوى البروتين، وزن الهكتوليتر، الجلوتين الرطب والجلوتين الجاف تأثرت معنوياً بالمحاصيل السابقة وطرق الزراعة وسماد النانوي خلال موسمى الزراعة.

أدت زراعة القمح بعد فول الصويا إلى تحسين خصوبة التربة مما أدى بدورة إلى زيادة جميع الصفات محل الدراسة بالمقارنة بالزراعة بعد عباد الشمس أو بعد بور فى كلا الموسمين.

أظهرت الزراعة بالتسطير تفوقًا ملحوظاً فى جميع الصفات السابقة عدا إرتفاع النبات والوزن النوعى والتى سجلت أعلى قيم لهما من الزراعة البدار.

أدت زيادة تركيز السماد النانوي من 125 إلى 500 مللى للفدان إلى زيادة معنوية في جميع الصفات السابقة، فيما عدا صفة الوزن النوعى التى إستجابت عكسياً مع زيادة التركيز فى كلا الموسمين.

أحدثت التفاعلات بين عوامل الدراسة المختلفة تأثيرات معنوية على معظم الصفات المدروسة وكان أعلى متوسط لقيم محصول الحبوب (3.480 و 3.553 طن للفدان في الموسمين الأول والثاني على التوالي) نتج عن زراعة القمح بعد فول الصويا بطريقة التسطير والرش الورقى بأعلى تركيز لسماد نانو 500 مللى للفدان على ثلاث مرات.