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Growth, Yield and Quality of Winter Wheat under Different Cropping Sequences and Fertilization Treatment

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Abstract: Two field experiments were conducted in the Experimental Research Station, National Research Centre, Nubaria District, Behaira Governorate located about 150 km from the National Research Centre and about 13 km east of Cairo/Alexandria desert road (30°91 N latitude, 29° 96 E longitude and almost at an altitude of 14m above the sea). The objective of the experiments was to evaluate the effect of crop sequence and nutrient management on wheat yield and yield components, as well as quality traits. The experiments included three preceding crops *i.e.*(peanut-wheat), (maize-wheat) and (sunflower-wheat) as well as ten fertilizer treatments. The fertilizer treatments were three N levels 40, 60 and 80 kg Nfed.$^{-1}$ alone or combined with ZnNPs applied once or twice compared with the control treatment. The results showed that there were significant differences among preceding crops on wheat growth characters. Growing wheat after peanut gave significant taller plants, more tillering, heavier dry weight and greater chlorophyll content compared to wheat grown after sunflower or maize. Reducing the dose of application of N levels 40 or 60 kg N fed.$^{-1}$ with ZnNPs as foliar application once or twice application surpassed the sole application of N at highest N level sole in plant height, number of tillers plant^{-1}, dry weight of plants m^{-2} and leaf chlorophyll content. Also, results showed significant interactions between preceding crop and fertilization treatments on the same growth characters. Similar trends were also noticed by the preceding crops on wheat yield and yield components. The results showed that (peanut-wheat) >(sunflower-wheat)>(maize-wheat) crop sequences on their effect on wheat yield and yield components *i.e.,* plant height, spike length, spike weight, spike number, biol. yield fed.$^{-1}$, straw yield fed.$^{-1}$, grain yield fed.$^{-1}$ and weight of 1000 grains. Significant differences were found among fertilization treatments on wheat yield and yield components. Spike weight, spike number, biol. yield fed.$^{-1}$, straw yield fed^{-1}, grain yield fed.$^{-1}$ and weight of 1000 grains. The combined application of the reduced dose of N levels 40 or 60 kg N fed.$^{-1}$ in combination with ZnNPs foliar application once or twice surpassed sole application of Nat the highest N level alone in yield components *i.e.,* plant height, spike length, spike weight, spike number, biological yield fed^{-1}, straw yield fed.$^{-1}$, grain yield fed^{-1} and weight of 1000 grains. Furthermore, a significant interaction between preceding crop and fertilizer treatments on studied yield characters was also found. The results revealed that when peanut was preceding crop and wheat plants were sprayed with ZnNPs once or twice application, the highest values of yield and yield components characters were attained compared with sunflower or maize as preceding crops for wheat.

Key words: Preceding crop · Nutrient management Nano zinc particles · Nitrogen levels wheat yield

INTRODUCTION

Wheat (*Triticum aestivum* L.) considered as the main cereal crop in the world and in Egypt. It represents the main source of food for more than one third of the world population; in Egypt wheat provides 37% of the total calories for the people and 40% of the protein in the Egyptian diet [1]. It is also represent a major source of straw for animal feeding. Under Egyptian conditions a great attention is being devoted to reduce the high

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rates of mineral fertilizers by using new techniques. Also, beneficial role of modification some agronomic practices such as cropping sequences and use of nanotechnology applications are evident to rationalize the use of mineral fertilizers and add an effective mean for sustainable cultivation of the desert, less environmental pollution, diminishing farming expenses, enhancing crop productivity. One of the most important factors of sustaining crop productivity is crop sequence [2] considered cropping sequences and nutrient management are the most important agronomic practices for maximizing the yield potential of wheat. With regard to current and future agronomic challenges *viz.,* climate change, sustainable crop production, food security and maintaining zero poverty for a growing world population, it is becoming increasingly important to evaluate the effects of different strategies on the stability of crop yields in the long term beside developing resilient crop production systems for the future [5, 6]. Crop rotation type may share in maintaining nutrient statues and soil characteristics. In divergent studies, found that maize growth, yield and yield attributes increased when growing after legumes, in contrast, reversal trend was obtained when maize was preceded by wheat [7-9]. In addition, Khalil *et al*. [10] reported that sunflower growth increased with increase of legumes percent and the proximity of legume to sunflower in crop sequence. Sustainable crop rotation achieve crop yield advantage [11, 12]. The inclusion of perennial leys in crop rotations is regarded as an important tool to increase soil fertility due to the positive effect of leys on soil organic matter (SOM) [13]. Wheat yield was relatively lower in rotations where two summer crops are involved (four-year rotations) compared with one summer crop (three-year rotations) [14]. Cultivation of legumes results in an increased mobility of phosphorous compounds in the soil and enriches the soil with organic matter too [15]. Nanotechnology can be identified as a science, technology carried out using materials, atoms, or molecules in dimensions ranged 1-100 nm [16]. The inclusion of nanoscience in biotechnology applications such as bio pesticides and fertilizers contributes to a rapid progress in field of food safety and quality [17-20]. Nanotechnology can revolutionize the agricultural sector by providing innovative strategies for understanding and conquering stress phenomena in the environment and assists in increasing food production [21]. Nowadays, there is a growing interest in the beneficial application of Nano-fertilizers in consolidate crops to withstand biotic and abiotic stresses [22-25]. Nano-fertilizers are fertilizers produced in nanoscale by chemical, physical or biological methods that enhance their characteristics and improve their performance compared to conventional fertilizers [26]. That drew the attention toward the nutritional advantage of elevating Zn content in the basic food crops [27]. It exists in the plant tissues as ions or as an essential component assimilating into protein. Zn ion and its components played a vital role in plants metabolism and biomass production. It is among other elements that played a direct or indirect role in carbohydrate breakdown and involved in protein synthesis [28, 29]. It is performed as a regulatory factor for many enzymes and incorporated in several activities such as gene expression, hydrogenase and carbonic anhydrase and energy production, along with chlorophyll and cytochrome synthesis [30-34]. Further, zinc has a crucial function in plant's strategies against salinity, drought and pathogens [35-39]. Accordingly, the deficiency of this nutrient led to several physiological processes disruptions, reducing crop production and yield quality. Thus, the supply of soils and field crops by zinc fertilizers is crucial for crop productivity [40].

MATERIALS AND METHODS

Two field experiments were conducted at the Agricultural Experiments and Research Station of the National Research Centre, Nubaria District, Behaira Governorate, the location is located about 150 km from the National Research Centre and about 13 km east of Cairo/Alexandria desert road, (30°91 N latitude, 29° 96 E longitude and almost at an altitude of 14m above the sea). During the two successive winter seasons of 2019/20 and 2020/21. The surface soil sample (0-30 depth) of the experimental area was subjected to laboratory analysis to determine some of its physical and chemical properties according to the method described by [41] in Table (1).

Phosphorus fertilizer was added before sowing at the rate of 31 kg P_2O_5 fed.$^{-1}$ as calcium superphosphate (15.5% P_2O_5), while potassium was added at the rate of 24 kg K_2SO_4 fed.$^{-1}$ as potassium sulphate (48% K_2SO_4), nitrogen fertilizer was applied at three levels according to the experimental design *i.e.,* N levels 40, 60 and 80 kg fed.$^{-1}$. Zn NPs (Nano-1) was applied once (after 40 days from sowing) or (Nano-2) applied twice(after 40 days from sowing and15 days later) at the rate of (5 g l^{-1}) while the control treatment, sprayed with tap water.

Table 1: Physical and chemical properties of the experimental soil

Soil property	Value	Soil property	Value
Particle size distribution %		pH (1:2.5 soil suspension)	7.70
Sand	92.65	EC (dS m^{-1}), soil paste extract	1.60
Silt	5.07	Soluble ions (mmol L^{-1})	
Clay	2.28	Ca^{++}	8.02
Texture	Sandy	Mg^{++}	3.23
$CaCO_3$ %	2.20	Na^{+}	3.92
Saturation percent %	22.50	K^{+}	0.91
Organic matter%	0.11	CO_3^{-}	nd
Available N (mg kg^{-1})	20.2	HCO_3^{-}	2.20
Available P (mg kg^{-1})	3.50	Cl^{-}	3.98
Available K (mg kg^{-1})	66.4	SO_4^{-}	9.90

The Experimental Design was a split plot design with four replications, the main plots included three preceding crops *i.e*., (peanut-wheat), (maize-wheat) and (sunflower-wheat), whereas subplots occupied the fertilization treatments were as follows:

- Control
- 40 Kg N fed.$^{-1}$
- 60 Kg N fed.$^{-1}$
- 80 Kg N fed.$^{-1}$
- 40 Kg N fed.$^{-1}$ + Nano 1
- 40 Kg N fed.$^{-1}$ + Nano 2
- 60 Kg N fed.$^{-1}$ + Nano 1
- 60 Kg N fed.$^{-1}$ + Nano 2
- 80 Kg N fed.$^{-1}$ + Nano 1
- 80 Kg N fed.$^{-1}$ + Nano 2

The normal agronomic practices of growing wheat in the local area were practiced till harvest as recommended by Wheat Research Department A.R.C., Giza. At 80 days from sowing. Plant samples were taken from each subplot (0.25 m^2) to record the following characters: maim stem height (cm), number of spikesm^{-2}, blades area (cm^2 m^{-2}), flag leaf area (cm^2) and dry weight of plants (gm^2). Photosynthetic pigments content were determined by SPAD meter according to [42]. At harvest, one square meter of the central of subplots were harvested and the following characters were recorded: number of grainsspike^{-1}, dry weight of grainsspike^{-1} (g), 1000 grains weight (g), grain yield (kg fed.$^{-1}$), straw yield (kg fed.$^{-1}$), biological yield (kg fed.$^{-1}$) and harvest index (economical yield/biological yield × 100).

The obtained data were subjected to the proper statistical analysis according to [43]. Since the trends were similar in both seasons, the homogeneity test was carried out according to Partlet's test and the combined analysis of the data was applied .Treatment means were compared using LSD test at 5% level.

RESULTS AND DISCUSSION

Wheat Growth: Data presented in Table (2) show significant differences among preceding crops on wheat growth characters. Growing wheat plants after peanut gave significant taller plants, more tillering, heavier dry weight and greater chlorophyll content compared to wheat grown after sunflower or maize. This could be attributed to the crop rotations which enable to avoid yield depressions under monoculture which increase populations of microorganisms that are pathogenic and decrease population of antagonistic microorganisms in the crop root rhizosphere [44] and reduce production of phytotoxic allelopathic chemicals and improve the physical and chemical conditiothe ns of soil. [45], indicated that both the previous crop and N fertilization treatments significantly affected all components of the winter wheat

Data presented in Table (3) show significant differences among fertilization treatments on wheat growth after 80 days from sowing. Successive increases in main stem length, tillering dry weight of plants m^{-2} and leaf chlorophyll contents (expressed as SPAD reading). The combined application of reduced N levels 40 or 60 kg N fed.$^{-1}$ with ZnNPs foliar applied once or twice application surpassed the application of the highest level of N application alone in main stem height, number of tillers, dry weight of plants $m^{-2}$and leaf chlorophyll content (SPAD). This may be due to zinc is directly absorbed in excessive amounts into the plant tissues, which inhibits the metabolic functions and causes absorption competition between zinc and other essential nutrients such as iron and phosphorus, reducing the growth and the yield [46-48].

Data presented in Table (4) reveal significant interaction between preceding crop and fertilizer treatments on studied growth characters *i.e*., main stem height, number of teller's, dry weight of m^{-2} and

Table 2: Effect of preceding crop on wheat growth characters

Preceding crop	Main stem height (cm)	Number of tillers	Dry weight of m^{-2} (g)	Total Chl. SPAD value
Sunflower	64.7	2.3	30.5	24.2
Maize	62.0	2.4	22.0	21.9
Peanut	70.3	3.1	42.0	26.8
LSD at 0.05	0.5	0.2	1.5	0.4

Table 3: Effect of managing fertilization treatments on wheat growth characteristics

Fertilizer Treatment	Main stem length, (cm)	Number of tillers	Dry weight of plants m^{-2} (g)	Total Chl. SPAD value
Control	55.7	1.2	17.2	22.0
40 Kg N fed.$^{-1}$	60.2	1.8	23.4	23.8
60 Kg N fed.$^{-1}$	63.1	2.1	27.1	23.6
80 Kg N fed.$^{-1}$	65.6	2.3	30.2	23.8
40 Kg N fed.$^{-1}$+ Nano 1	63.6	2.5	30.2	23.8
40 Kg N fed.$^{-1}$+ Nano 2	65.3	2.7	32.1	24.7
60 Kg N fed.$^{-1}$ + Nano 1	66.7	2.9	34.5	24.7
60 Kg N fed.$^{-1}$ + Nano 2	69.2	3.4	37.6	24.7
80 Kg N fed.$^{-1}$ + Nano 1	71.5	3.4	40.8	26.0
80 Kg N fed.$^{-1}$ + Nano 2	75.5	3.7	43.1	26.1
LSD at 0.05	1.0	0.4	0.5	0.7

Table 4: Effect of the interaction between preceding crop and fertilizer treatments on wheat growth characteristics

Preceding crop	Fertilizer treatment	Main stem height (cm)	Number of tillers	Dry weight of m^{-2}(g)	Total Chl. SPAD value
Sunflower	Control	55.7	1.1	18.5	22.7
	40 Kg N fed.$^{-1}$	57.9	1.5	24.0	24.6
	60 Kg N fed.$^{-1}$	61.6	2.2	27.5	24.2
	80 Kg N fed.$^{-1}$	62.0	2.2	31.0	23.5
	40 Kg Nfed.$^{-1}$ + Nano 1	61.6	2.2	29.5	23.8
	40 Kg N fed.$^{-1}$ + Nano 2	63.1	2.2	33.0	24.9
	60 Kg N fed.$^{-1}$ + Nano 1	66.0	2.2	33.0	23.5
	60 Kg N fed.$^{-1}$ + Nano 2	69.3	3.3	35.0	23.5
	80 Kg N fed.$^{-1}$ + Nano 1	73.7	3.3	36.5	25.3
	80 Kg N fed.$^{-1}$ + Nano 2	75.9	3.3	38.5	26.4
Maize	Control	52.9	1.4	14.0	19.3
	40 Kg N fed.$^{-1}$	57.8	1.8	17.5	20.7
	60 Kg N fed.$^{-1}$	59.5	1.8	19.5	21.4
	80 Kg N fed.$^{-1}$	63.0	2.1	19.5	21.0
	40 Kg N fed.$^{-1}$ + Nano 1	60.6	2.1	21.0	21.4
	40 Kg N fed.$^{-1}$ + Nano 2	62.0	2.5	21.0	22.8
	60 Kg N fed.$^{-1}$ + Nano 1	64.1	3.2	24.5	23.1
	60 Kg N fed.$^{-1}$ + Nano 2	65.1	3.2	26.5	23.1
	80 Kg N fed.$^{-1}$ + Nano 1	65.8	3.2	26.5	23.8
	80 Kg N fed.$^{-1}$ + Nano 2	69.0	3.2	31.5	23.1
Peanut	Control	58.7	1.2	19.0	24.2
	40 Kg N fed.$^{-1}$	64.8	2.3	29.0	26.1
	60 Kg N fed.$^{-1}$	68.2	2.3	34.5	25.3
	80 Kg N fed.$^{-1}$	71.7	2.7	40.5	26.8
	40 Kg N fed.$^{-1}$ + Nano 1	68.6	3.1	40.5	26.1
	40 Kg N fed.$^{-1}$ + Nano 2	70.9	3.5	42.0	26.5
	60 Kg N fed.$^{-1}$ + Nano 1	70.2	3.5	46.0	27.6
	60 Kg N fed.$^{-1}$ + Nano 2	73.2	3.8	52.0	27.6
	80 Kg N fed.$^{-1}$ + Nano 1	75.1	3.8	59.5	28.8
	80 Kg N fed.$^{-1}$ + Nano 2	81.7	4.6	59.5	28.8
LSD at 0.05		3.4	0.9	4.4	2.6

chlorophyll content of leaves. The results revealed that when peanut was preceding crop and wheat plants sprayed with ZnNPs once or twice application, the highest values of these criteria were attained compared with the case of sunflower or maize as preceding crops for wheat. The promotive interaction between Nitrogen fertilizers at low levels with ZnNPs could be attributed to Nano-fertilizers as fertilizers produced in nanoscale by chemical, physical or biological methods that enhance their characteristics and improve their performance compared to conventional fertilizers [26]. That drew the attention toward the nutritional advantage of elevating Zn content in the basic food crops [27]. It exists in the plant tissues as ions or as an essential component assimilating into protein. Zn ion and its components played a vital role in plants metabolism and biomass production. It is among other recommended elements plays a direct or indirect role in carbohydrate breakdown and involved in protein synthesis [28, 29]. It is performed as a regulatory factor for many enzymes and incorporated in several activities such as gene expression, hydrogenase and carbonic anhydrase and energy production, along with chlorophyll and cytochrome synthesis [30].

Yield and Yield Components: Data presented in Table (5) revealed significant effects due to cropping sequences on yield and yield components. The results showed that (peanut-wheat) >(sunflower-wheat)>(maize-wheat) crop sequences on their effect on wheat yield and yield components *i.e.*, main stem height, spike length, spike weight, spike number, biological yield fed.$^{-1}$, straw yield fed.$^{-1}$, grain yield fed.$^{-1}$ and weight of 1000 grains. Fig. (1), also illustrated that biological straw and grain yields fed.$^{-1}$ could be arranged in the following order of crop sequences: peanut-wheat> sunflower-wheat >maize-wheat. Some of the general purposes of crop rotation are: supplying plants with a stable and balanced nutrient source; not jeopardizing soil health; maintaining soil structure, increasing soil organic matter, increasing water use efficiency, reducing soil erosion, reducing the pest infestation, reducing reliance on agricultural chemicals and improving crop nutrient use [49, 50]. The influence of preceding crop on the N uptake of the following crop has long been recognized by several researches. Rahimizadeh *et al*. [51] reported that, different crop sequences have differences between preceding crops were observed. In the same domain, Hefny [52] manifested that there were significant differences between crop sequences with wheat for main stem height, number of spikesm^{-2}, number of grainsspike^{-1}, grains weightspike^{-1}, 1000-grain weight, grainyield, straw and biological yieldsfed.$^{-1}$. Also, Zaheer *et al*. [53] noticed that plots grown with mung bean (sole) had higher N content at both occasions (before sowing 0.41 g kg^{-1} and after harvest 0.38 g kg^{-1}) as compared with other cropping sequences.

Data presented in Table (6)show significant differences among fertilizer treatments on wheat yield and yield components. Successive increases in main stem height, spike length, spike weight, spike number, biological yield fed.$^{-1}$, straw yield fed.$^{-1}$, grain yield fed.$^{-1}$ and weight of 1000 grains. The combined application of reduced N levels 40 or 60 kg N fed.$^{-1}$ with ZnNPs foliar applied once or twice application surpassed the highest N level application alone in components *i.e.,* main stem height, spike length, spike weight, spike number, biological yield fed^{-1}, straw yield fed.$^{-1}$, grain yield fed^{-1} and weight of 1000 grains were clearly shown in Fig. (2), whereas data in Fig. (3), illustrate the relative yield increase of wheat grains (%)over the control treatment) as combined mean of two seasons. The data showed that the combined application of reduced N levels 40 or 60 kg N fed.$^{-1}$ with ZnNPs foliar applied one application surpassed the highest N level application alone in grain yield increase. The response of wheat yield and yield components to the combined application of N and ZnNPs could be attributed to the proper fertilization method and rate which are the basis of any efficient agricultural management system and also the nutritional advantage of elevating Zn content in the basic food crops [28]. It exists in the plant tissues as ions or as an essential component assimilating into protein. Zn ion and its components played a vital role in plants metabolism and biomass production. It is among other elements that played a direct or indirect role in carbohydrate breakdown and involved in protein synthesis [29, 30]. It is performed as a regulatory factor for many enzymes and incorporated in several activities such as gene expression, hydrogenase and carbonic anhydrase and energy production, along with chlorophyll and cytochrome synthesis [31].

Data presented in Table (7) reveal significant interaction between preceding crop and fertilizer treatments on studied yield characters *i.e.*, in main stem height, spike length, spike weight, spike number, biological yield fed^{-1}, straw yield fed.$^{-1}$, grain yield fed.$^{-1}$ and weight of 1000 grains. The combined application of reduced N levels 40 or 60 kg N fed.$^{-1}$with ZnNPs foliar applied once or twice application surpassed the highest N level application alone in components *i.e.,* main stem height, spike length, spike weight, spike number,

Table 5: Effect of preceding crop on wheat yield and yield components

Preceding crop	Main stem height (cm)	Spike length, (cm)	Spike weight m^{-2} (g)	Spike number m^{-2}	Biol. yield $fed.^{-1}$ (kg)	Straw yield $fed.^{-1}$ (kg)	Grain yield $fed.^{-1}$ (kg)	Weight of 1000 grain, (g)	Protein %	Protein yield $fed.^{-1}$ (kg)
Sunflower	102.4	21.3	430.3	204.4	3363.7	1670.5	1693.2	39.7	12.3	208.3
Maize	94.4	18.8	356.0	189.4	2800.4	1397.8	1402.5	36.3	11.4	159.7
Peanut	110.8	23.7	471.1	219.1	3960.0	1943.0	2016.9	43.6	11.5	231.9
LSD at 0.05	5.4	33.0	6.9	1.3	30.0	13.7	16.4	0.4	ns	39.3

Table 6:Effect of fertilizer treatments on wheat yield and yield components

Fertilizer treatment	Main stem height (cm)	Spike length (cm)	Spike weight m^{-2} (g)	Spike number m^{-2}	Biol. yield $fed.^{-1}$ (kg)	Straw yield $fed.^{-1}$ (kg)	Grain yield $fed.^{-1}$ (kg)	Weight of 1000 grain (g)	Protein %	Protein yield $fed.^{-1}$ (kg)
Control	91.7	16.1	308.2	171.3	2739.2	1353.1	1386.1	34.5	12.54	173.7
40 Kg N $fed.^{-1}$	100.4	19.8	341.9	191.7	3106.5	1539.7	1566.7	37.3	10.81	169.4
60 Kg N $fed.^{-1}$	101.6	20.6	366.4	198.3	3246.1	1609.2	1636.9	38.5	11.96	195.8
80 Kg N $fed.^{-1}$	104.1	21.4	377.7	206.2	3486.5	1722.0	1764.5	39.2	11.27	198.9
40 Kg N $fed.^{-1}$ + Nano 1	101.4	20.9	382.3	198.3	3188.3	1584.8	1603.5	39.0	12.77	204.7
40 Kg N $fed.^{-1}$ + Nano 2	102.0	21.7	397.3	205.0	3359.8	1664.0	1695.8	39.7	11.73	198.9
60 Kg N $fed.^{-1}$ + Nano 1	103.6	22.4	437.9	210.2	3447.2	1708.6	1738.6	41.0	11.27	195.9
60 Kg N $fed.^{-1}$ + Nano 2	104.5	22.5	462.5	214.7	3572.3	1767.2	1805.1	41.8	11.39	205.5
80 Kg N $fed.^{-1}$ + Nano 1	107.2	23.2	513.9	221.3	3744.0	1852.1	1891.8	43.3	12.19	230.6
80 Kg N $fed.^{-1}$ + Nano 2	109.0	23.9	603.4	226.1	3856.9	1903.5	1953.4	44.6	11.27	220.1
LSD at 0.05	0.9	0.5	23.0	4.9	51.2	24.6	26.8	0.7	ns	12.3

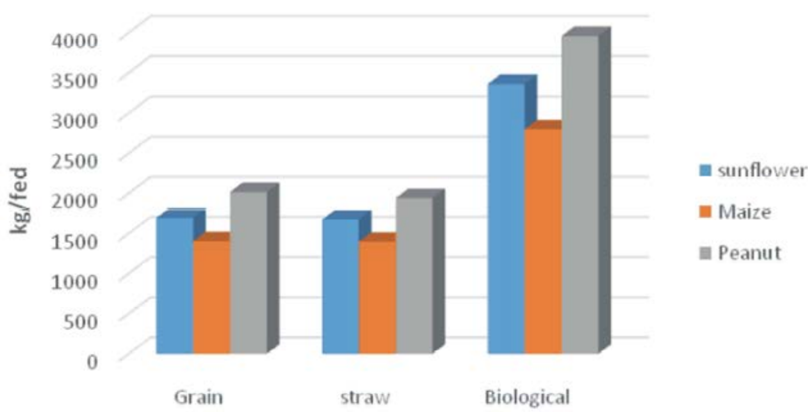

Fig. 1: Effect of preceding crop on wheat straw, grains and biological yields ($kgfed.^{-1}$)

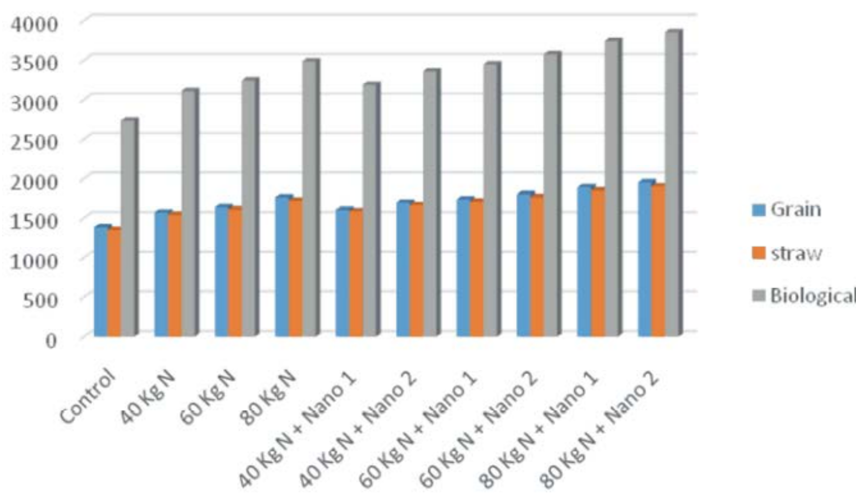

Fig. 2: Effect of fertilizer treatment on wheat straw, grains and biological yields ($kgfed.^{-1}$)

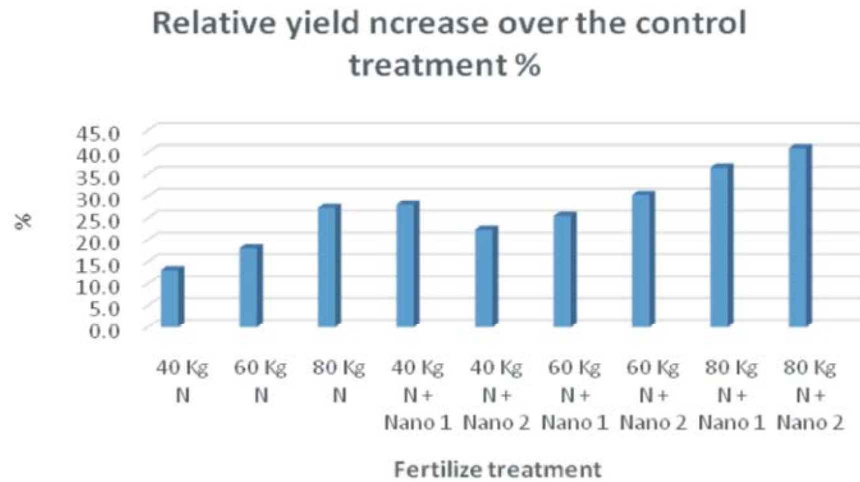

Fig. 3: Relative yield increase of wheat grains (%over the control treatment), combined mean of two seasons

Table 7: Effect of the interaction between preceding crop and fertilizer treatments on wheat yield and yield components

Preceding crop	Fertilizer treatment	Main stem height (cm)	Spike length (cm)	Spike weight m^{-2} (g)	Spike number m^{-2}	Biol. yield fed.$^{-1}$ (kg)	Straw yield fed.$^{-1}$ (kg)	Grain yield fed.$^{-1}$ (kg)	Weight of 1000 grain (g)	Protein %	Protein yield fed.$^{-1}$ (kg)
Sunflower	Control	92.4	15.4	314.6	169.8	2805.9	1388.8	1417.1	34.1	10.7	182.5
	40 Kg N fed.$^{-1}$	100.5	20.2	364.8	198.7	3349.5	1658.3	1691.2	38.5	12.9	241.7
	60 Kg N fed.$^{-1}$	101.6	20.9	379.5	205.7	3542.0	1749.3	1792.7	39.2	10.1	208.9
	80 Kg N fed.$^{-1}$	103.4	21.6	383.2	198.7	3187.8	1591.1	1596.7	39.2	13.5	234.1
	40 Kg N fed.$^{-1}$ + Nano 1	100.8	20.9	403.3	206.1	3311.0	1649.3	1661.7	39.6	13.1	199.5
	40 Kg N fed.$^{-1}$ + Nano 2	101.9	21.6	449.9	210.5	3457.3	1718.1	1739.2	41.1	14.1	228.9
	60 Kg N fed.$^{-1}$ + Nano 1	103.8	22.0	478.5	214.1	3557.4	1768.2	1789.2	40.7	11.5	210.2
	60 Kg N fed.$^{-1}$ + Nano 2	104.9	22.4	539.0	221.8	3588.2	1787.1	1801.1	43.3	12.8	201.5
	80 Kg N fed.$^{-1}$ + Nano 1	106.7	23.1	641.7	225.9	3688.3	1834.0	1854.3	44.4	11.7	133.1
	80 Kg N fed.$^{-1}$ + Nano 2	108.5	24.6	257.3	158.6	2344.7	1163.4	1181.3	32.6	10.9	166.3
Maize	Control	83.0	15.4	286.0	176.1	2579.9	1289.0	1290.9	34.7	11.3	155.9
	40 Kg N fed.$^{-1}$	93.1	17.5	330.1	183.1	2668.1	1332.2	1335.8	35.4	12.9	133.5
	60 Kg N fed.$^{-1}$	94.5	18.6	339.5	191.8	2763.6	1381.7	1381.9	35.4	11.7	135.6
	80 Kg N fed.$^{-1}$	96.3	19.3	351.8	184.8	2690.1	1343.0	1347.2	35.4	9.7	150.1
	40 Kg N fed.$^{-1}$ + Nano 1	94.9	18.6	360.5	190.1	2807.7	1400.8	1406.9	35.7	10.1	152.6
	40 Kg N fed.$^{-1}$ + Nano 2	94.9	18.9	379.8	196.0	2859.2	1428.5	1430.7	36.8	10.7	164.9
	60 Kg N fed.$^{-1}$ + Nano 1	96.3	20.0	397.3	199.9	2925.3	1462.0	1463.4	37.8	10.7	198.0
	60 Kg N fed.$^{-1}$ + Nano 2	96.6	20.0	420.0	204.1	3167.9	1581.0	1586.9	38.9	11.3	209.4
	80 Kg N fed.$^{-1}$ + Nano 1	97.0	20.0	438.2	209.7	3197.3	1596.6	1600.7	40.6	12.5	185.2
	80 Kg N fed.$^{-1}$ + Nano 2	98.0	20.3	352.7	185.5	3067.1	1507.2	1559.9	36.8	13.1	216.1
Peanut	Control	99.7	17.6	391.0	206.2	3590.3	1770.0	1820.4	39.9	11.9	200.9
	40 Kg N fed.$^{-1}$	107.7	21.9	404.4	213.1	3720.7	1837.2	1883.6	41.8	11.9	268.7
	60 Kg N fed.$^{-1}$	108.9	22.2	414.0	221.2	4153.8	2034.9	2118.9	42.9	10.7	199.1
	80 Kg N fed.$^{-1}$	112.7	23.4	412.1	211.2	3686.9	1820.4	1866.6	42.6	12.7	272.2
	40 Kg N fed.$^{-1}$ + Nano 1	108.5	23.4	428.2	218.9	3960.6	1941.9	2018.7	43.7	10.7	267.6
	40 Kg N fed.$^{-1}$ + Nano 2	109.3	24.5	484.2	224.3	4025.0	1979.1	2045.9	45.2	13.5	208.9
	60 Kg N fed.$^{-1}$ + Nano 1	110.8	25.3	511.8	230.0	4234.3	2071.6	2162.7	46.8	13.1	230.2
	60 Kg N fed.$^{-1}$ + Nano 2	111.9	25.3	582.7	238.1	4475.8	2188.3	2287.5	47.9	9.7	304.9
	80 Kg N fed.$^{-1}$ + Nano 1	118.1	26.5	730.3	242.7	4685.1	2280.0	2405.1	48.7	10.1	243.0
	80 Kg N fed.$^{-1}$ + Nano 2	110.4	26.8	730.3	230.3	4685.1	2280.0	2405.1	48.7	10.3	234.8
LSD at 0.05		3.8	2.8	51.4	ns	366.4	126.7	133.9	10.7	ns	42.4

biological yield fed.$^{-1}$, straw yield fed^{-1}, grain yield fed^{-1}and weight of 1000 grains under the cropping sequence (peanut-wheat) than the other two cropping sequences. The results revealed that when peanut was preceding crop and wheat plants sprayed with ZnNPs once or twice application, the highest values of yield and yield components characters were attained compared with sunflower or maize as preceding crops for wheat. In this respect, considerable volume of the literature addresses the effects of preceding crop on wheat. Kirkegaard *et al.* [54] carried out a survey of the literature on the effects of break crops, that is, crops interrupting the sequence of continuous wheat and showed mean yield benefits of up to 20% or more, the magnitude of response depending on site, weather conditions and other aspects of crop management.

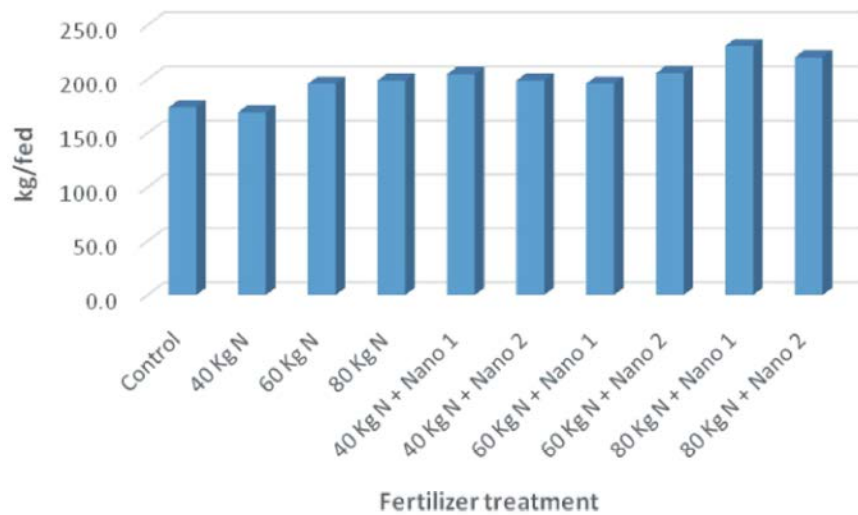

Fig. 4: Effect of fertilizer treatments on wheat protein yield (kgfed.$^{-1}$)

Protein Yield: Data presented in Tables (4, 5 and 6) show that there were not significant differences in protein percentage in wheat grains due to preceding crop, fertilizer treatments and their interaction. However, reversal magnitude was reported for protein yield (kg fed.$^{-1}$). Data presented in Fig. (4) show that the combined application of N and foliar applied ZnNPs once or twice compared with the other treatments recorded higher protein yield (kg fed.$^{-1}$). Rahimizadeh *et al*. [51] noticed that wheat yield interaction between preceding crops and N fertilizer may be contributed to NUE, NUpE, NUtE, NHI and grain protein content of wheat. The highest NUE, NUpE and NUtE were obtained for potato-wheat, while continuous wheat recorded the lowest NUE indices. Nitrogen fertilizer rates had a significant effect on NUE, NUpE and grain protein content in each rotation, but NUtE and NHI were not significantly affected by N fertilizer rate. This study showed that NUE decreased with increasing N rate. Thus, a potato-wheat cropping system planted on beds with low N supply is better than other double cropping systems wheat based. Return of crop residue had no significant effect on NUE indices expect NHI. Dogan and Bilgili [45] indicated that both the previous crop and N fertilization treatments significantly affected all components of the winter wheat cultivars.

CONCLUSION

It could be concluded from this study the importance of choosing the proper preceding crop for wheat to improve growth, yield and quality in similar sandy soils. Also, using nano technology fertilizers could effectively correct Zn deficiency in such soils which reflects directly on wheat growth and yield.

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