Enhancement of Wheat Productivity Under Different Levels of Tillage, Seeding Rate and Nitrogen Sources in An Arid Region

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ABSTRACT

A two year field experiment was conducted during the winter season of 2018/2019 and 2019/2020, to evaluate grain yield and some agronomic traits of the Egyptian local wheat cultivar (Shandaweel 1) under three tillage practices; conventional (CT), partial (PT) and zero tillage (ZT), three nitrogen fertilizer treatments (180 kg mineral N ha^{-1} (N1), 144 kg N ha^{-1} + humic acid (N2) and 108 kg N ha^{-1} + humic acid + halex (N3) as well as three seeding rates (95 (S1), 119 (S2) and 143 (S3) kg ha^{-1}). Conservation tillage practices showed significantly higher yield or at least equal to partial tillage, highlighting 1.6 ton ha^{-1} increase over conventional tillage in 2019 season, emphasizing the suitability of conservation tillage for agriculture in arid regions. Averaged over the two growing seasons, the non-significant 0.6 ton ha^{-1} difference in yield between N1 and N3 suggests the replacement of part of the mineral nitrogen fertilizer with more environmentally friendly forms without yield penalty. The intermediate seeding rate offered an adequate balance between resources and number of plants/unit area, thus minimizing competition and outperforming the lowest and highest seeding rate with a 0.5-0.7 ton ha^{-1} over the two growing seasons.

Keywords: wheat, tillage, mineral nitrogen, biofertilizer, seeding rate.

INTRODUCTION

Wheat is one of the major food resources worldwide providing 20 % of total consumed calories, grown globally on more than 218 million hectares with total production of 772 million tons in 2019 (FAO, 2020). Wheat production faces the challenge of accelerated water evaporation from the soil upper layer in arid and semi-arid regions hindering the yield potential (FAO, 2020), this challenge is more profound in Northwestern Egypt as it is coupled with fast drainage from light soils, amplifying the mineral nitrogen fertilizer losses. This implies the need to adopt less conventional agronomical practices including tillage, nitrogen fertilizers source and seeding rate, to mitigate the effects of such adverse environments. Reduced tillage (RT) and no-till (NT) as conservation tillage practices can be applied to mitigate the negative impacts of accelerated water loss, as they result in surface residues retention which proved to increase water use efficiency and water storage (Hemmat and Eskandari, 2006). Carter, 2005 defined conservation tillage as any tillage system that retains not less than 30 % of the residue as soil surface cover in order to reduce soil erosion by water.

Conservation tillage practices range from zero tillage (No-till), reduced (minimum) tillage to ridge tillage. No tillage (NT) is proposed as field cultivation with almost no soil surface disturbance except that happens during planting, while minimum tillage implies reduction of soil disturbance such as ploughing (Busari et al., 2015). Ridge tillage is disturbing one-third of the soil surface and restricted to raising ridges Carter (2005). Conservation tillage practices showed the potential to enhance crops growth by improving soil water holding capacity (Abdullah, 2014), chemical and physical properties of the soil (Gao et al., 2017; Wang et al., 2019; Yang et al., 2020) Thus, studies on the effect of tillage practices on the production of wheat in the semi-arid conditions of northern Egypt have important significance.

Tillage affects root growth and development both directly through changes in physical properties such as aggregation and compaction and indirectly through altered chemical conditions as a result of residues incorporation and mulching (Qian et al., 2018; Hamed et al., 2019). Gozubuyuk et al. (2015) found that no tillage practice showed significant increase in soil water content in the 0-90 cm soil profile compared to conventional tillage in a three years study carried out in a semiarid region. By contrast, Ren et al. (2018) reported limited root expansion in the upper soil layers due to mechanical impediment under no tillage practice.

Several reports indicated significant increase in yield accompanied by conservation tillage practices adoption. Mokrikov et al. (2019) compared the yield of winter wheat under no tillage to conventional tillage (CT) over 5 years, where the yield/year varied significantly. No tillage wheat yields outperformed CT significantly by 26-114 %. Under Mediterranean conditions, barley yield

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was doubled under No- tillage compared to CT in a dry year (El-Sadek et al., 2020).

No tillage induced better root growth and distribution as well as faster crop establishment of dryland sorghum when compared to tillage practice by significant reduction of soil drying rate and increase in surface soil water content, thus, offering favorable conditions for crop establishment (Schwartz et al., 2010). Hemmat and Eskandari (2006) evaluated wheat yield and yield components under three tillage levels; conventional, reduced and No tillage. Grain yield and number of spikes per square meter decreased significantly from No tillage to conventional tillage. No tillage profound increase in yield (70 %) compared to CT in a dry year. Increase in soil organic carbon, available soil nitrogen and nitrogen uptake efficiency were found associated with minimal tillage compared to CT and caused improved yield and yield components in wheat (Hou et al., 2018; Fernandez et al., 2019; Shiwakoti et al., 2019; Liu et al., 2020; Yang et al., 2020).

In the wheat production process, seeding rate is a key factor for obtaining maximum yield since it is a controlled factor that can be accurately determined. Applying the proper seeding rate ensures optimum wheat yield through establishing the desired plant density, which in turn will determine the number of spikes /m^2, number of grains/spike and 1000 grain weight (Spink et al., 2000). Using different seeding rates was reported to affect several agronomic traits and yield components such as number of productive tillers, grain number on main and side tillers and grain weight (Kiss et al., 2018). Increasing seeding rate led to increasing the number of spikes/unit area associated with a smaller number of grains/head (Lollato et al., 2017). Also maximizing the gain from increased seeding rate in wheat was obtained in narrow rows rather than wider rows spacing (Chen et al., 2008).

Identifying the optimum seeding rate for wheat is principally defined as number seeds per ha not as seed weight per ha, because the latter will vary among cultivars following the variation in grain size and weight (Walsh and Walsh, 2020). Many factors were reported to affect the seeding rate such as, the variety tillering potential which inversely correlates to seeding rate, late seeding and reduced tillage system which require increased seeding rate to compensate expected reduced germination in the former and poorly placed seeds in the latter (Mcvay et al., 2010). Bio-fertilizers are reported to activate a wide range of growth regulators including auxins, cytokinins and gibberellins, in addition to their active role in N_2-fixation, which is reflected in better growth and improved yield (El-Kased et al., 1996). The use of biofertilizers to replace a proportion of the mineral nitrogen fertilizer is gaining its importance as an environmentally friendly approach, as it reduces soil pollution by accumulations of using the chemical fertilizers (Abd El Ghany, 1994). Humic acid and organic fertilizer improve yield through enhancing plant growth parameters, as well as increasing stress tolerance by amending soil physical properties and soil pH which is directly reflected on improved root growth and nutrients uptake (Zandonadi et al., 2007; Karakurt et al., 2009; Khan et al., 2010; Asal et al., 2015).

The aim of the present investigation was to study the response of yield and yield components of spring wheat (*Triticum aestivum L.*) Egyptian cultivar ‘Shandaweel 1’ to mineral and bio-fertilizer nitrogen sources and different seeding rate under different tillage practices in arid environmental conditions, represented by the northwest coast of Egypt.

MATERIALS AND METHODS

Experimental site characteristics

The spring wheat (*Triticum aestivum L.*) Egyptian cultivar ‘Shandaweel 1’ was grown in two seasons (2018/2019 and 2019/2020) in field experiments conducted at the Agricultural Research Station, Faculty of Desert and Environmental Agriculture, Matrouh Governorate, Egypt. The experimental site is located at the Northwest Coast of Egypt (N= 31 o 04 ', E= 27 o 54 '), where the experimental site is characterized by a Mediterranean climate with cold winters. Average monthly temperature (°C) and humidity (%) for the two seasons are illustrated in Table 1. Physical and chemical properties of the upper 30 cm layer of soil in the experimental site for the two seasons are presented in Table 2.

Table 1. Climatic conditions during the two studied seasons of the experimental site*

Months	Average Temperature (ºC)		Precipitation (mm)		Wind Speed (m/sec)	
	2018-2019	2019-2020	2018-2019	2019-2020	2018-2019	2019-2020
November	19.31	19.69	1.53	0	5.83	4.25
December	15.35	15.36	1.63	0.96	8.09	7.25
January	12.07	12.35	0.53	0.71	9.65	8.48
February	13.04	13.75	0.94	0.56	7.9	7.89
March	14.96	15.21	0.52	0.69	7.98	8.52
April	17.61	16.15	0.11	0	8.25	7.02
May	21.42	20.95	0	0	8.26	6.93

* Source: Marsa Matrouh Research Station, Agricultural Research Central (ARC), Egypt.

Table 2. Physical and chemical soil properties during 2018 and 2019 seasons

Soil properties	2018 season	2019 season
1- Particles size distribution (%)		
Texture	**Sandy loam**	
Clay	10.30	9.53
Silt	1.29	1.32
Sand	88.41	89.15
2- Chemical analysis		
pH	8.18	8.21
EC (ds/m)	2.24	2.30
Total N (%)	0.29	0.31
P (ppm)	81.5	80.4
Ca^{++} (meq/l)	3.9	4.1
Mg^{++} (meq/l)	3.6	3.4
Na^{+} (meq/l)	16.6	17.0
K^{+} (meq/l)	0.5	0.4
CO_3^{--}	0.0	0.0
HCO_3^{-}	5.6	5.9
Cl^{-}	14.3	15.1
SO_4^{--}	4.7	5.2
$CaCO_3$ (%)	12.04	12.82
Organic matter (%)	0.53	0.50

Treatments and Experimental Design

Wheat was sown on 27 October 2018 and 24 October 2019 under three tillage levels (conventional, partial and zero tillage), as follow, Conventional tillage (CT, 2 chisel ploughs followed by harrowing at 15-20 cm to remove weeds crop residues), whereas partial tillage (PT, harrowing with tooth-harrow to remove weeds and crop residues) and zero tillage (ZT, seeds were sown directly into the residues of the preceding summer crop *Zea mays L)*, three nitrogen fertilizer treatments (180 kg mineral N ha^{-1} (N1), 144 kg N ha^{-1} + humic acid (N2) and 108 kg N ha^{-1} + humic acid + halex (N3) and three seeding rates (95, 119 and 143 kg ha^{-1}. Weeds were initially controlled, before sowing, by applying a non-selective herbicide Baron 48 % SL (Glyphosate Isopropylammonium), that was sprayed at a rate of 6 L/ha. Nitrogen, in the form of ammonium nitrate (33.5 % N), were applied to the experimental plots at sowing, booting and before heading stages in three equal doses.

These treatments were arranged in a three replicate split-split plot design according to El-Nakhlawy (2010), the whole plots assigned for the tillage practices, the subplots assigned for nitrogen fertilizer treatments and the sub-sub plots dedicated for the seeding rates. Plot size was 5.4 m^2 (9 rows X 0.2 m between rows X 3.0 m row length). Phosphorus fertilizer was applied as calcium monophosphate (15.5 % P_2O_5), during soil preparation, at the rate of 37 kg P_2O_5 ha^{-1}. Potassium fertilizer was added 30 days after sowing (DAS) as potassium sulphate (48 % K_2O) at the rate of 60 K_2O ha^{-1}. Humic acid (in a powder form and dissolved in water) was sprayed at 40 DAS at the rate of 9.6 kg ha^{-1}. Halex biofertilizer (powder) was mixed with wheat seeds before sowing. It is a mixture of growth promoting N-fixing bacteria of *Azotobacteriaceae*, *Azospirillum* and *Klebsiella* registered under the commercial name Halex and was provided by the Biofertilization unit, Plant Pathology department, Alexandria University. Control of annual weeds, broad and narrow leaves were performed by spraying with Panther 55 % Sc at the 2-4 leaves stage. All other practices were applied as recommended for wheat production in the studied region.

Seeds were drilled according to the treatments and were maintained free of weeds and disease with the appropriate herbicides and fungicides. Irrigation was applied using a sprinkler irrigation system at the amount of 6500 m^3 ha. Number of irrigations and quantity depended on the environmental conditions, particularly air temperature, but generally irrigation was applied each 5 to 7 days.

Agronomic, yield and its components characteristics

At anthesis, random samples, each of five plants, were taken from each sub sub plot to measure flag leaf area (cm^2). Plant height (cm) was determined at maturity. At harvest, one square meter random sample was taken from each sub sub plot to measure the number of fertile spikes per m^2. Five random spikes were collected from each experimental plots to determine spike length (cm), spike weight (g) and number of grains $spike^{-1}$. Two random 1000 grain samples were taken from each sub sub plot to measure 1000 grain weight (TGW). Grain yield (GY) was determined by harvesting the inner seven rows of each sub sub plot and converted to tons ha^{-1}. Finally, the harvest index (%) was calculated as grain yield/ biomass yield and expressed as percentage.

Statistical analyses

R software R 3.3.4 (R development core team, 2017) was used to calculate means and standard deviations, bar charts and interaction plots were done using the R package “ggplot2” (Wickham, 2009) and analysis of variance (ANOVA) was performed using the “lmerTest” R package (Kuznetsova et al., 2017). Within the ANOVA, tillage, nitrogen fertilizer treatments and seeding rate were defined as fixed effects, while replicates were treated as random. Whenever the three factors interaction was significant, the main effects and two-way interactions were not presented or discussed (El-Nakhlawy, 2010).

The statistical model:

$$Y_{ijkl} = \mu + B_j + T_i + e_{ij} + N_k + TN_{ik} + eijk + S_l + TS_{il} + NS_{kl} + TSN_{ikl} + e_{ijkl}$$

where μ is overall mean, B_j is blocks effect, T_i is the tillage practice effect, eij is the main plot error, N_K is the nitrogen treatment effect, TN_{ik} is the tillage*nitrogen interaction effect, eijk is the subplot error effect, S_l is the seeding rate effect, TS_{il} is the tillage*seeding rate interaction effect, NS_{kl} is the nitrogen treatment * seeding rate interaction effect, TSN_{ikl} is the three-factors interaction effect and eijkl is the sub-subplot error effect.

RESULTS

The significance levels of measured traits responses under the effects of the three studied factors and their interactions are presented in tables 3 and 4, The main effect of tillage practice, nitrogen treatment and seeding rate were significant on all measured traits except spike length in the two seasons. Tillage practice effect was not significant on number of spikes m^{-2} in the first season. The significance of first order interactions varied according to their different combinations and between the two growing seasons. Over the two seasons, no significant effects for first order interactions were found for spike weight, grain yield and harvest index. The three-way interactions effects (Supplementary material, Table S1) were significant over the two seasons for spike length and number of grains $spike^{-1}$, and significant in 2018 season only for plant height and flag leaf area.

Data in figure 1 revealed that plant height had the highest significant value in 2018 season under zero tillage combined with seeding rate S3 and N1, followed by N3, with a 14.8 cm difference in height, while the shortest plant were recorded for CT combined with N2 and S1 revealing 25.33 cm difference in height from the ZT combined with seeding rate S3. In the 2019 season, nitrogen treatment effects varied within tillage practices (Fig. 2), with superiority observed in the combination of CT and N1, while ZT coupled with N3 resulted in the lowest plant height differing from the best combination with 11.48 cm. In the 2019 season, seeding rate acted independently from the other two factors, marking the highest seeding rate S3 to outperform the two other insignificantly different seeding rates by an average of 2.79 cm increase in plant height.

Partial tillage outperformed the other two tillage practices in significantly inducing larger flag leaf area across the different nitrogen treatments and seeding rate in 2018 season (Fig.1), where the best results were obtained from PT, N1 and seeding rate S2 showed significant increase of 1.59 % and 2.38 % compared to the following two combinations S1 and S3, respectively, and 5.76 % increase over the lowest treatment combination; ZT, N2 and S1. The two and three-way interactions were not significant in the 2019 season (Table 3), however the means presented in table 5 show flag leaf area to be statistically equal in PT and ZT, and both significantly higher than CT by an average of 0.5

%. Considering the 2019 season independent effect of nitrogen treatments, N1 treatment resulted in the significantly highest flag leaf area followed by N3 then N2 and seeding rate S2 was superior to the other two statistically equal seeding rate, which coincides with the same pattern of 2018 season for both factors.

The significantly tallest spike length was obtained at seeding rate S1 followed by S3 combined with N3 treatment and PT and CT for 2018 and 2019 seasons, respectively (Fig. 1).

The effect of the three tested factors was clear on the spike weight (Table 5). Tillage practices had the most profound effect among the three factors, however, its effect followed opposite trends between the two growing seasons, the 2018 season marked CT and PT to significantly outperform ZT with an increase of spike weight by 7.82 % and 8 %, respectively. The 2019 season significantly heaviest spike was noticed in ZT followed by PT, with an increase of 5.18 % and 5.05 % over CT, respectively. N1 and N3 induced significantly heavier spikes with average increase over the two seasons of 4.27 % and 2.25 % over N2. The least effect was attributed to variation seeding rate, as S2 showed a significant increase of 3.17 % and 2.85 % over S1 and S3, respectively.

Noticeably, 2018 growing season marked no significant effect for tillage practices on number of spikes m^{-2}, but the 2019 season showed a distinguished impact of tillage practices, where ZT and PT resulted in more spikes m^{-2} compared to CT by 16.91 % and 8.44 %, respectively. Nitrogen treatment and seeding rate effects were consistent across the two seasons, with N3 giving intermediate values while N1 yielded 10 % more spikes m^{-2} than N2. Seeding rate of S1 and S3 effects didn’t differ significantly, but S2 resulted in significantly more spikes m^{-2} than both by 8.8 % and 11 %, averaged over the two seasons. Figure 2 illustrates that the effect of nitrogen treatments in the 2019 season varied significantly following the seeding rate, marking N1 coupled with S2 as the highest combination while the lowest was N2 and S3, with a significant difference between them of 70.07 spikes m^{-2}.

Similarly, tillage practices had an opposite effect on the number of grains $spike^{-1}$ between the two seasons while nitrogen treatment and seeding rate were consistent. During the 2018 season, CT and PT were significantly equivalent and resulted in an increase in grains $spike^{-1}$ by 6.4 % and 5.6 %, respectively over ZT. However, in 2019, both PT and ZT induced an increase in grains $spike^{-1}$, compared to CT, by 6.13 % and 5.5 %, respectively. The three seeding rates varied significantly in their effects, with highest grains $spike^{-1}$ at S2 followed by S3, exceeding S1 and S3 by 12.6 % and 6.2 %, respectively. Figure 1 illustrates how the three way interaction significantly alters the number of grains $spike^{-1}$,with the lowest combination in 2018 season was ZT*N2*S1 and best resulting combinations were ZT*N1*S2 and CT*N1*S2, with 46 % increase between the lowest and highest combinations, whereas in 2019 season the lowest combination was ZT*N2*S1 and highest combinations similar to 2018 season were CT*N1*S2 and ZT*N1*S2, with a significant difference between them of 45 %. The consistency between the results reveals the negative combination of N2 when coupled with lowest seeding rate.

Over the two growing seasons, nitrogen treatment effects on TGW varied among tillage practices (Fig. 2), with superiority attributed to nitrogen treatment N1 as highest values were found in PT*N1 (45.3 g) and ZT*N1 (43.8 g), while lowest TGW was observed in ZT*N2 (36.87 g) and CT*N2 (37.4 g) in 2018 and 2019 seasons, respectively. Seeding rate effect was independent from the other two factors as shown in table 4, the intermediate seeding rate S2 significantly outperformed the other two levels, by average increase of 4.7 % and 3.2 % over S3 and S1, respectively.

Tillage practices' effects on grain yield were high, i.e., 1.3 t ha^{-1} and 1.6 t ha^{-1} difference between the highest and lowest yielding tillage practices in 2018 and 2019 seasons, respectively. The ranking of tillage practices varied between the two seasons as shown in table 6, where, in the 2018 season, PT resulted in the highest grain yield with no significant difference from CT, while in the 2019 season, ZT gave the highest yield with no significant difference from PT. Nitrogen treatment effects were less than tillage practices, i.e., 1.2 t ha^{-1} and 0.6 t ha^{-1} difference between the highest and lowest yielding nitrogen treatment in 2018 and 2019 seasons, respectively, but treatments effect was consistent across the two seasons and ranked as N1 followed by N3 then N2. Seeding rate impact was significant, but the least profound among the three factors, i.e., 0.5 t ha^{-1} and 0.7 t ha^{-1} difference between the highest and lowest yielding seeding rate in 2018 and 2019 seasons, respectively, with consistent trend over the two growing seasons, highlighting the intermediate seeding rate S2 as superior to the other two seeding rate.

As might be expected, the harvest index response to the studied factors followed the same trend of grain yield regarding the ranking of levels within each factor as well as the magnitude effect of each factor. PT induced an increase of 24.5 % compared to ZT in the 2018 season, while the 2019 season marked ZT to outperform CT by 27.5 %. N1and N3 were insignificantly different and on average caused 17 % increase in harvest index relative to N2 and seeding rate of S2 resulted in 10.4 % increase in harvest index compared to the highest and lowest seeding rate.

Table 3. Levels of significance of plant height, flag leaf area, number of spikes m^{-2}, spike length, spike weight, as affected by tillage practices, nitrogen fertilizer treatment and seeding rate in 2018-2019 and 2019-2020 seasons

Sources of variation	df.	Plant height (cm)		Flag Leaf area (cm^2)		No. of spikes m^{-2}		Spike length (cm)		Spike weight (g)	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Tillage practices (T)	2	0.013 *	0.003 **	<0.001 ***	0.032 *	0.304	0.006 **	0.149	0.107	0.003 **	0.018 *
Nitrogen fertilizer treatment (N)	2	0.002 **	0.009**	<0.001 ***	0.002 **	0.018 *	0.041 *	0.436	0.367	<0.001 ***	0.001 **
Seeding rate (S)	2	<0.001 ***	0.043*	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	0.54	0.504	<0.001 ***	0.002 **
T X N	4	0.032*	0.028 *	<0.001 ***	0.6296	0.18	0.273	<0.001 ***	<0.001 ***	0.075	0.148
T X S	4	<0.001 ***	0.726	0.153	0.159	0.556	0.078	0.040 *	0.032 *	0.817	0.127
N X S	4	0.001 **	0.737	0.031 *	0.302	0.268	0.003 **	0.544	0.474	0.436	0.45
T X N X S	8	<0.001 ***	0.685	<0.001 ***	0.586	0.384	0.065	<0.001 ***	<0.001 ***	0.395	0.866

NS: non significant at $p \leq 0.05$, * Significant at $p \leq 0.05$, ** Significant at $p \leq 0.01$, *** significant at $p \leq 0.001$.

Table 4. Levels of significance for number of grains spike^{-1}, TGW, grain yield and harvest index as affected by tillage practices, nitrogen fertilizer treatment and seeding rate in 2018-2019 and 2019-2020 seasons

Sources of variation	df.	No. of grains spike^{-1}		TGW (g)		Grain yield (t ha^{-1})		Harvest index (%)	
		2018	2019	2018	2019	2018	2019	2018	2019
Tillage practices (T)	2	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	0.047 *	0.003 **	0.050 *	0.005 **
Nitrogen fertilizer treatment (N)	2	0.010 *	0.003 **	<0.001 ***	<0.001 ***	<0.001 ***	0.035 *	<0.001 ***	0.050*
Seeding rate (S)	2	<0.001 ***	<0.001 ***	<0.001 ***	<0.001 ***	0.003 **	<0.001 ***	<0.001 ***	<0.001 ***
T X N	4	<0.001 ***	<0.001 ***	0.001**	0.006**	0.0888	0.457	0.109	0.602
T X S	4	<0.001 ***	<0.001 ***	0.733	0.466	0.859	0.724	0.47	0.667
N X S	4	0.679	0.529	0.407	0.942	0.994	0.938	0.779	0.942
T X N X S	8	<0.001 ***	<0.001 ***	0.065	0.889	0.996	0.393	0.782	0.425

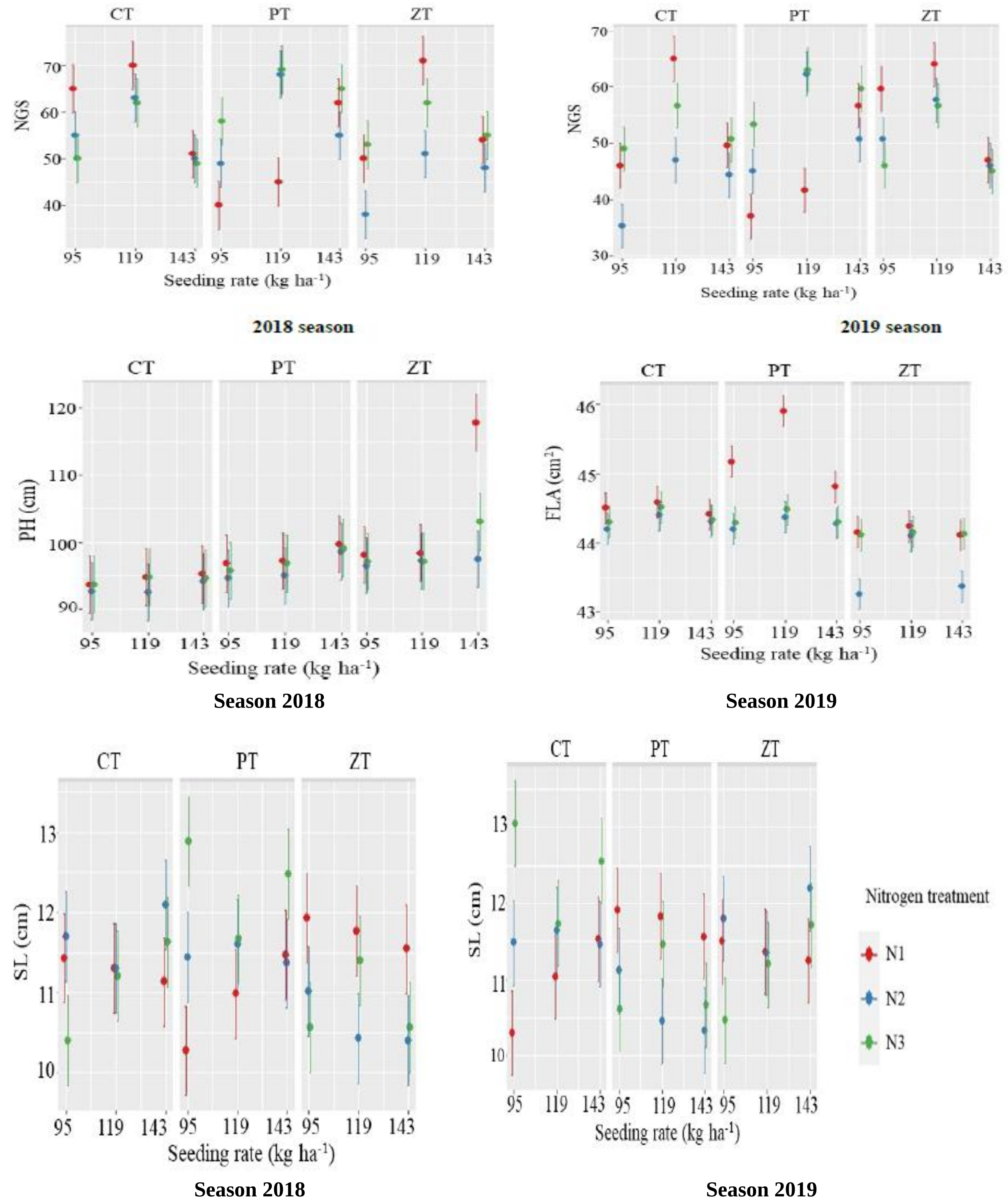

Fig.1. Variations in number of grains spike^{-1}, plant height, flag leaf area and spike length as affected by the significant interaction between three treatments during 2018 and 2019 growing seasons

Table 5. Mean values for plant height, panicle length, flag leaf area, number of spike m^{-2}, spike length and spike weight as affected by tillage practices, nitrogen fertilizer treatment and seeding rate in 2018-2019 and 2019-2020 seasons

	Plant height (cm)		Panicle length (cm)		Flag leaf area (cm^2)		No. of spikes m^{-2}		Spike length (cm)		Spike weight (g)	
Treatment	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
Tillage practices												
Conventional tillage (CT)	94.02 b	99.57 a	94.02 b	99.57 a	44.39 b	45.02 b	258.07 a	235.40 c	11.35 a	11.64 a	4.19 a	4.60 b
Partial tillage (PT)	97.08 b	99.81 a	97.08 b	99.81 a	44.64 a	45.27 a	277.45 a	257.12 b	11.57 a	11.10 a	4.20 a	4.85 a
Zero tillage (ZT)	100.31 a	94.33 b	100.31 a	94.33 b	43.95 c	45.26 a	249.09 a	283.34 a	11.06 a	11.42 a	3.86 b	4.85 a
LSD $_{0.05}$	**3.16**	**2.14**	**3.16**	**2.14**	**0.13**	**0.18**	**44.68**	**19.9**	**0.55**	**0.52**	**0.13**	**0.15**
Nitrogen fertilizer treatment (kg ha^{-1})												
180 kg N ha^{-1} (N1)	99.09 a	99.72 a	99.09 a	99.72 a	44.65 a	45.26 a	275.81 a	271.58 a	11.31 a	11.36 a	4.21 a	4.83 a
144 kg N ha^{-1}+ humic (N2)	95.45 b	97.79 b	95.45 b	97.79 b	44.05 c	45.10 b	249.18 b	243.18 b	11.26 a	11.31 a	3.96 c	4.70 c
108 kg N ha^{-1} + humic + halex (N3)	96.91 b	96.20 b	96.91 b	96.21 b	44.28 b	45.19 ab	259.62 ab	261.11 ab	11.42 a	11.49 a	4.08 b	4.77 b
LSD $_{0.05}$	**1.74**	**2.04**	**1.74**	**2.04**	**0.13**	**0.07**	**17.33**	**21.6**	**0.26**	**0.27**	**0.05**	**0.06**
Seeding rate (kg ha^{-1})												
95 (S1)	95.43 b	97.02 b	95.43 b	97.02 b	44.24 b	45.15 b	255.46 b	252.71 b	11.29 a	11.36 a	4.02 b	4.72 b
119 (S2)	96.00 b	96.93 b	96.00 b	96.93 b	44.52 a	45.26 a	280.24 a	276.91 a	11.29 a	11.34 a	4.20 a	4.83 a
143 (S3)	99.97 a	99.77 a	99.97 a	99.77 a	44.22 b	45.14 b	248.90 b	252.71 b	11.40 a	11.47 a	4.03 b	4.75 b
LSD $_{0.05}$	**1.27**	**2.60**	**1.27**	**2.6**	**0.09**	**0.06**	**13.69**	**8.07**	**0.24**	**0.24**	**0.06**	**0.06**

Means followed by different letter(s) within the same studied parameter and experimental season for each treatment are significantly different According to LSDF at $p \leq 0.05$.

Table 6. Mean values number of grains m^{-2}, TGW, grain yield and harvest index as affected by tillage practices, nitrogen fertilizer treatment and seeding rate in 2018-2019 and 2019-2020 seasons

Treatment	No. of grains spike^{-1}		TGW (g)		Grain yield (t ha^{-1})		Harvest index (%)	
	2018	2019	2018	2019	2018	2019	2018	2019
Tillage practices								
Conventional tillage (CT)	57.22 a	49.29 b	40.65 b	38.36 c	4.80 ab	4.00 b	36.66 ab	31.02 b
Partial tillage (PT)	56.77 a	52.14 a	43.22 a	40.64 b	5.48 a	5.14 a	42.46 a	39.09 a
Zero tillage (ZT)	53.55 b	52.51 a	38.20 c	42.73 a	4.19 b	5.63 a	32.05 b	42.79 a
LSD $_{0.05}$	**0.88**	**0.73**	**0.81**	**0.62**	**0.95**	**0.58**	**7.87**	**4.78**
Nitrogen fertilizer treatment (kg ha^{-1})								
180 kg N ha^{-1} (N1)	56.44 a	51.85 a	42.40 a	41.86 a	5.32 a	5.16 a	41.14 a	39.13 a
144 kg N ha^{-1}+ humic (N2)	53.00 b	48.77 b	39.72 b	39.91 b	4.07 b	4.52 b	30.87 b	34.79 b
108 kg N ha^{-1} + humic + halex (N3)	58.11 a	53.33 a	39.95 b	39.96 b	5.09 a	5.09 a	39.16 a	38.96 a
LSD $_{0.05}$	**3.05**	**2.33**	**0.43**	**0.49**	**0.43**	**0.5**	**3.14**	**3.9**
Seeding rate (kg ha^{-1})								
95 (S1)	50.88 c	46.88 c	40.38 b	40.46 b	4.76 b	4.74 b	36.72 b	36.39 b
119 (S2)	62.33 a	57.11 a	41.98 a	41.45 a	5.12 a	5.35 a	39.68 a	40.66 a
143 (S3)	54.33 b	49.96 b	39.71 c	39.82 b	4.59 b	4.68 b	34.78 b	35.85 b
LSD $_{0.05}$	**2.16**	**1.66**	**0.65**	**0.66**	**0.3**	**0.28**	**2.27**	**2.17**

Means followed by different letter(s) within the same studied parameter and experimental season for each treatment are significantly different According to LSDF at $p \leq 0.05$.

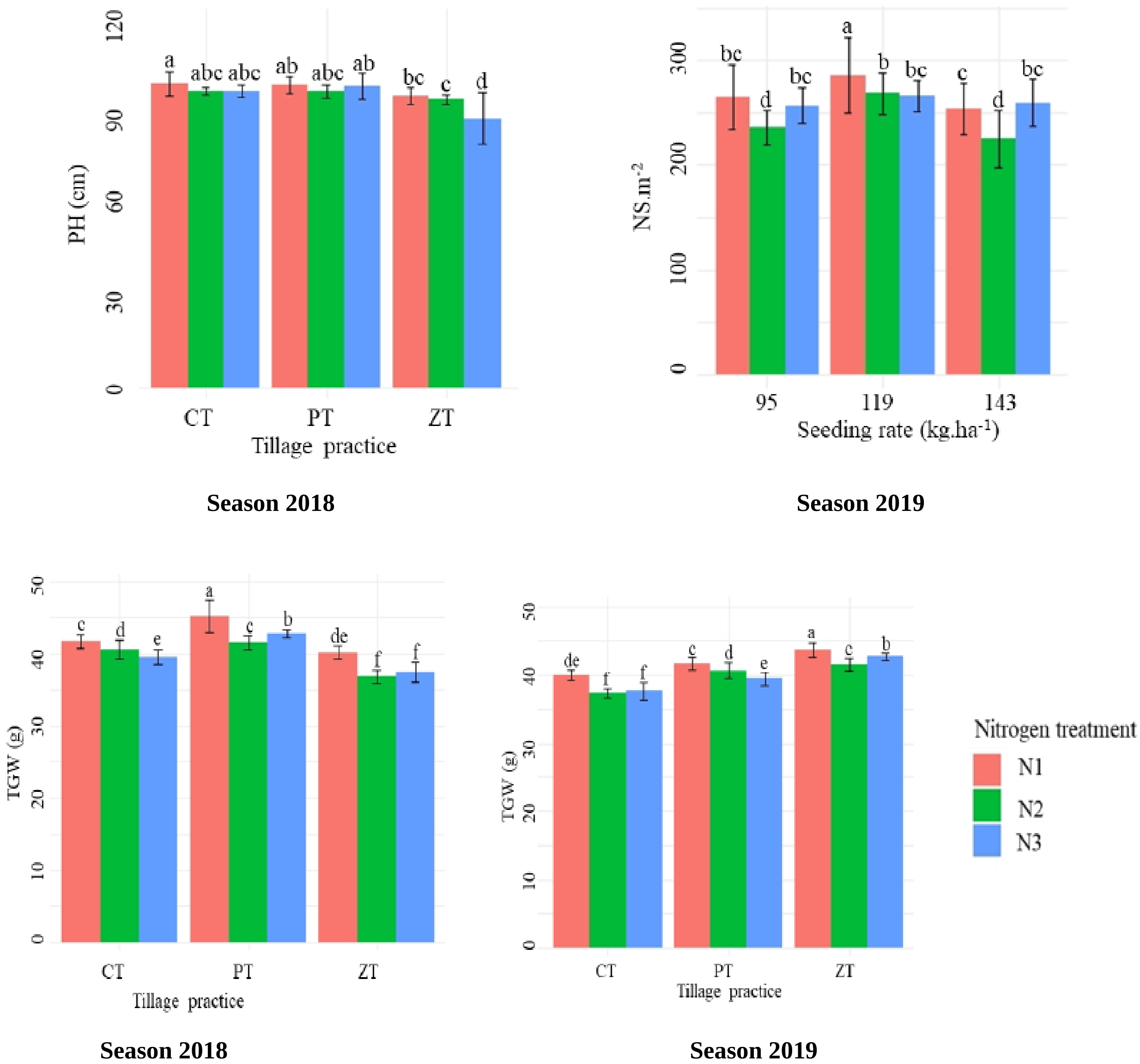

Fig. 2. Variations in plant height, number of spikes m^{-2} and Thousand grain weight as affected by the significant interaction between tillage practices or nitrogen fertilizers and seeding rate during 2018 and 2019 growing seasons

DISCUSSION

The results of this research study showed significant increase in plant height as plant density increased, this response might be due to the competition on sun light among plants (Melash et al., 2019). The 2018 season marked ZT with the significantly tallest plants when combined with high seeding rate, this enhancing effect in plant height with reduced and conservation tillage practices was confirmed by Alijani et al. (2012) and Honsdorf et al. (2020).

CT resulted in the highest increase in plant height in the 2019 season, which could be caused by possible increased water run-off in ZT (due to increased residuals) in the second year, leading to loss in nitrogen fertilizer. Busari et al. (2015) found this to be attributed to decline in macro pores in ZT especially in the second year. That was reflected in the nitrogen treatments effect where N1 treatment revealed superiority in 2018 with ZT and in 2019 with CT.

PT and ZT significantly outperformed CT in their impact on flag leaf area, a finding that may be confirmed with the results of Cheng-yan et al. (2014) which reported that reduced tillage was found to be associated with higher chlorophyll content and net photosynthetic rate of the flag leaf. N1 and intermediate seeding rate resulted in the significantly highest flag leaf area, as mineral nitrogen is readily dissolved in water and absorbed with plant roots leading to enhanced growth and biomass. The same finding was reported by Niedziński et al. (2021) who found 55 % increase in nitrogen release from mineral fertilizers compared to the organic ones. The intermediate seeding rate allows sufficient balance between resources and growing space, resulting in maximum vegetative growth (Ma et al., 2018; Shah et al., 2020; Fazily, 2021).

In the second season, the study results revealed that ZT and PT yielded significantly more spikes m^{-2} than CT, agreeing with the findings of (Xie et al., 2005; Su et al., 2007; Zhang et al., 2015; Yin et al., 2017; Peng et al., 2020) who reported that tillage practices showed significant positive effect on the number of spikes m^{-2}, favoring conservation over conventional tillage.

The same trend was observed in the flag leaf area, where N1 and intermediate seeding rate resulted in the significantly highest number of spikes m^{-1} and can be explained by availability of resources, reduced competition and the potential to produce spikes bearing tillers (Holman et al., 2021; Wang et al., 2021)

Main effects of the studied factors on spike length were not significant (Table 3), however their three-way interaction was significant, highlighting best treatments combination as seeding rate S1 combined with N3, while tillage practice varied, PT and CT for 2018 and 2019 seasons, respectively. The negative effect of increasing seeding rate on spike length was found to result from decreased number of grains $spike^{-1}$ and TGW, similar to the results of Naveed et al. (2014) and Melash et al. (2019).

CT and PT yielded significantly more grains $spike^{-1}$ than ZT in 2018 season, agreeing with (De Vita et al., 2007) who reported no significant impact for conservation tillage in semi-arid conditions on yield. However in 2019 season, results showed superiority of ZT, in agreement with other reports. (Xie et al., 2005; Su et al., 2007; Zhang et al., 2015). Intermediate seeding rate outperformed the high density one which might be explained by negative effect of plants competition and reduced spike length (Naveed et al., 2014; Kühling et al., 2017; Melash et al., 2019), as well as boosting the duration of spikelet primordia production, but might even increase more grains $spike^{-1}$ with low seeding rate (Whaley et al., 2000). Over the two growing seasons, N3 treatment resulted in the highest number of grains $spike^{-1}$ which could be due to the presence of humic acid (added and released biologically) that reduces sterility in wheat (Enan et al., 2016, Kandil et al., 2016; Hafez et al., 2021).

Paradoxical findings were found for spike weight between the two growing seasons, with CT and ZT dominating the 2018 and 2019 seasons, respectively. N1 resulted in the heaviest spikes, so did the intermediate seeding rate. The pattern of the three factors effect on spike weight followed the TGW response, which is its main contributor. The intermediate seeding rate yielded highest TGW. Naveed et al. (2014), Abdulkerim et al. (2015) and Melash et al. (2019) reported negative effects of increased seeding rate on yield components due to the competition between plants on growth resources.

The other two factors interacted, showing the best combination of N1 with conservation tillage (PT and ZT) in the two seasons respectively, while the lowest TGW was found in ZT and CT treatments combined with N2 and N3. Moreover, other researchers found improved TGW to be associated with increased humic acid concentration (Al-zubaidy et al., 2020).

The effect of tillage practices varied in yield production between the two seasons, as ZT resulted in lowest yield in 2018 season and highest yield in 2019 season. The effect of conservation tillage was reported to occur especially in the long term (Alijani et al., 2012). Increasing yield under ZT may be associated with reduced soil water evaporation (Iqbal et al., 2005; Guo et al., 2021) or increasing water use efficiency (Du et al., 2008; Lei et al., 2008).

Since roots grow in the undistracted channels formed by the previous crop rather than investing energy in penetrating the tilled soil, this energy is directed to forming assimilates (Lawrence et al., 1994), also ZT is associated with enhanced mineralization of organic nitrogen especially at top soil layers (Huang et al., 2009), increased soil total nitrogen content (Liu et al., 2020), increased leaves chlorophyll content and photosynthesis rate (Li and Wei, 1999) and cooler temperatures due to residue cover (Honsdorf et al., 2020).

On the other hand, inferiority of yield under ZT was found to be linked to inefficient weed control, poor establishment, nutritional elements shortage and diseases spread (Lai, 1989) compared to better soil texture and properties under CT (Iqbal et al., 2005).

The harvest index performance followed the same pattern found in yield under the three tested factors, which in a sense indicates no preference for differential translocation in grains associated with increased biomass under different treatments as well as pointing to higher translocation of assimilates in sink organs due to increased photosynthesis rate (Li and Wei, 1999).

CONCLUSION

The finding of the present study revealed the adequacy of conservation tillage, i.e., partial and zero-tillage for the arid land environments since they gave comparable or significantly higher grain yield compared to the conventional tillage. Application of reduced mineral nitrogen accompanied with biofertilizer or humic acid resulted in comparable grain yield production to application of the highest level of mineral nitrogen thus it is recommended to use 108 kg N ha^{-1} + humic acid + halex to limit the pollution of the environment and enhance the microbiological activities in the soil. Intermediate seeding rate of 119 kg ha^{-1} proved to be superior to lower or higher seeding rate due to the balance between number of plants per unit area and the available growth resources, both added and indigenous. The combination of conservation tillage, mineral nitrogen accompanied with biofertilizer and humic acid and seeding rate of 119 kg ha^{-1} could be recommended for spring wheat cultivation in Northwest coast of Egypt.

Statements and Declarations

Author Contributions:

Conceptualization, Hassan E. Khalil; methodology, Ahmed M. Shaalan and Samer Amer; validation, Ahmed M. Shaalan; data curation; Samer Amer, writing the manuscript, Ahmed M. Shaalan and Samer Amer; editing, Ahmed M. Shaalan and Samer Amer; supervision, Hassan E. Khalil. All authors have read and agreed to the published version of the manuscript.

Declarations

Conflict of interest the authors declare no conflict of interest.

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Table. S1. Mean values for plant height, flag leaf area, spike length and Number of grains.spike^{-1} as affected by the significant three-way interaction

Plant height (cm)		Flag leaf area(cm^2)		Spike length(cm)				Number of grains.spike^{-1}			
2019		2019		2019		2020		2019		2020	
3:1:3	117.83 a	2:1:2	45.90 a	2:3:1	12.88 a	1:3:1	13.05 a	3:1:2	71 a	1:1:2	65.00 a
3:3:3	103.03 b	2:1:1	45.17 b	2:3:3	12.48 ab	1:3:3	12.56 ab	1:1:2	70 a	3:1:2	64.00 ab
2:1:3	99.7 bc	2:1:3	44.81 c	1:2:3	12.10 bc	3:2:3	12.2 bc	2:3:2	69 ab	2:3:2	63.00 ab
2:3:3	99.15 cd	1:1:2	44.59 cd	3:1:1	11.93 bcd	2:1:1	11.92 bcd	2:2:2	68 abc	2:2:2	62.33 abc
2:2:3	98.6 cde	1:3:2	44.51 de	3:1:2	11.77 bcde	2:1:2	11.83 bcde	1:1:1	65 abc	2:3:3	59.67 bcd
3:1:2	98.4 cdef	1:1:1	44.5 de	1:2:1	11.70 cdef	3:2:1	11.80 cde	2:3:3	65 abc	3:1:1	59.67 bcd
3:1:1	98.1 cdef	2:3:2	44.48 def	2:3:2	11.67 cdef	1:3:2	11.73 cdef	1:2:2	63 bcd	3:2:2	57.67 cde
3:2:3	97.5 cdefg	1:1:3	44.41 defg	1:3:3	11.63 cdef	3:3:3	11.72 cdef	1:3:2	62 cd	1:3:2	56.67 de
2:1:2	97.26 cdefg	1:2:2	44.4 defgh	2:2:2	11.60 cdef	1:2:2	11.65 cdef	2:1:3	62 cd	2:1:3	56.67 de
3:2:2	97.26 cdefg	2:2:2	44.37 defghi	3:1:3	11.54 cdef	2:1:3	11.57 cdef	3:3:2	62 cd	3:3:2	56.67 de
3:3:2	97.15 cdefg	1:3:3	44.33 defghi	2:1:3	11.47 cdef	1:1:3	11.53 cdef	2:3:1	58 de	2:3:1	53.33 ef
3:3:1	97.1 cdefg	1:2:3	44.31 defghi	2:2:1	11.44 cdef	3:1:1	11.50 cdef	1:2:1	55 ef	1:3:3	50.67 fg
2:1:1	96.81 cdefg	1:3:1	44.3 defghi	1:1:1	11.43 cdef	1:2:1	11.48 cdef	2:2:3	55 ef	2:2:3	50.67 fg
2:3:2	96.81 cdefg	2:3:3	44.3 defghi	3:3:2	11.40 cdef	1:2:3	11.47 cdef	3:3:3	55 ef	3:2:1	50.67 fg
3:2:1	96.46 cdefgh	2:3:1	44.29 efghi	2:2:3	11.37 def	2:3:2	11.47 cdef	3:1:3	54 efg	1:1:3	49.67 fgh
2:3:1	95.76 defghi	2:2:3	44.28 efghi	1:1:2	11.30 def	3:1:2	11.37 defg	3:3:1	53 efg	1:3:1	49.00 fghi
1:1:3	95.21 efghi	3:1:2	44.24 efghi	1:2:2	11.30 def	3:2:2	11.35 defgh	1:1:3	51 fgh	1:2:2	47.00 ghi
2:2:2	95 efghi	1:2:1	44.20 fghi	1:3:2	11.21 efg	3:1:3	11.25 defgh	3:2:2	51 fgh	3:1:3	47.00 ghi
1:1:2	94.81 efghi	2:2:1	44.20 fghi	1:1:3	11.13 efgh	3:3:2	11.2 defghi	1:2:3	50 fgh	1:1:1	46.00 ghij
1:3:2	94.8 efghi	3:1:1	44.15 ghi	3:2:1	11.02 fghi	2:2:1	11.12 efghij	1:3:1	50 fgh	3:2:3	46.00 ghij
1:3:3	94.66 fghi	3:3:2	44.15 ghi	2:1:2	10.98 fghij	1:1:2	11.03 fghijk	3:1:1	50 fgh	3:3:1	46.00 ghij
2:2:1	94.62 fghi	3:3:3	44.13 ghi	3:3:1	10.57 ghij	2:3:3	10.67 ghijk	1:3:3	49 fgh	2:2:1	45.00 hij
1:2:3	94.1 ghi	3:1:3	44.11 hi	3:3:3	10.57 ghij	2:3:1	10.62 hijk	2:2:1	49 fgh	3:3:3	45.00 hij
1:3:1	93.7 ghi	3:3:1	44.11 hi	3:2:2	10.43 hij	3:3:1	10.47 ijk	3:2:3	48 gh	1:2:3	44.33 ij
1:1:1	93.68 ghi	3:2:2	44.10 i	1:3:1	10.40 ij	2:2:2	10.45 jk	2:1:2	45 hi	2:1:2	41.67 jk
1:2:1	92.7 hi	3:2:3	43.37 j	3:2:3	10.40 ij	2:2:3	10.33 k	2:1:1	40 ij	2:1:1	37.00 kl
1:2:2	92.51 i	3:2:1	43.26 j	2:1:1	10.27 j	1:1:1	10.30 k	3:2:1	38 j	1:2:1	35.33 l

Means followed by different letter(s) within the same studied parameter and experimental season for each treatment are significantly different at $p \leq 0.05$.

For each treatment, the 3 way combination goes as follow; fertilization treatment:tillage practice: seeding rate

Tillage practice 1, Conventional tillage, 2,partial tillage and 3 zero tillage

Nitrogen fertilization sources. 1 Mineral,2, humic acid, 3 biofertilizer

Seeding rate 1, 95kg.ha^{-1}, 2, 119kg.ha^{-1} and 143 kg.ha^{-1}

الملخص العربي

تحسين إنتاجية القمح تحت مستويات مختلفة من الحرث ، معدل التقاوى ومصادر نيتروجين في المناطق الجافة

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أجريت تجربة حقلية لمدة عامين خلال فصلى الشتاء لعامى ٢٠١٨/٢٠١٩ و ٢٠١٩/٢٠٢٠ ، لتقييم محصول الحبوب وبعض الصفات المحصولية لصنف القمح المصرى المحلى المسمى (شندويل ١) نتيجة تأثير ثلاثة معاملات من الحرث تشمل تقليدي وجزئي وبدون حرث ، ثلاثة تطبيقات للأسمدة النيتروجينية تشمل: (١٨٠ كجم نيتروجين/هكتار تسميد معدنى، ١٤٤ كجم نيتروجين معدنى / هكتار + حمض هيوميك و ١٠٨ كجم نتروجين/ هكتار + حمض هيوميك + هاليكس) مع تأثير ثلاثة معدلات من التقاوى هى ٩٥ كجم/هكتار ، ١١٩كجم/هكتار، ١٤٣كجم/ هكتار . وقد بينت نتائج الدراسة تفوق معاملة تجهيز التربة المحافظة فى المحصول إذا كان معنويًا أو على الأقل مساوى للحرث الجزئي ، مع وجود زيادة ١,٦ طن/هكتار عن الحراثة التقليدية في موسم ٢٠١٩ . وبمعدل متوسط على مدار موسمي الزراعة، مما يؤكد على ملاءمة الحرث التقليدى للزراعة في المناطق الجافة. وتوضح النتائج إلى تحسين فى محصول الحبوب مع تطبيق معاملات النيتروجين المعدنى مضافًا إليه المركبات العضوية مقارنة بإستخدام النيتروجين المعدنى فقط وبمعدلات مرتفعه وهذا له أهمية فى تقليل استخدام الاسمدة المعدنية وتحسين البيئة. يوفر معدل التقاوى المتوسط توازنًا مناسبًا بين الموارد وعدد النباتات / وحدة المساحة ، مما يقلل من المنافسة، إذ بينت النتائج تفوق معدل التقاوى المتوسط على أدنى وأعلى معدل التقاوى بمتوسط ٠,٥ – ٠,٧ طن/هكتار في موسمي النمو.

الكلمات المفتاحية: القمح ، حرث التربة، النيتروجين المعدني ، الأسمدة الحيوية ، معدل التقاوى