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EFFECT OF SEEDING RATE AND NITROGEN FERTILIZER ON GRAIN YIELD AND ITS COMPONENTS OF MISR 3 BREAD WHEAT CULTIVAR UNDER TWO TILLAGE SYSTEMS

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ABSTRACT: Climatic changes characterized by unusually heavy rainfall during wheat land preparation in the Nile Delta. Farmers were compelled to adopt zero-tillage (ZT) practices instead of traditional methods due to these conditions. To address this issue, two field experiments were conducted at El-Gemmeiza Agricultural Research Station during the 2023/2024 and 2024/2025 growing seasons to evaluate the effects of seeding rate and nitrogen fertilization under two tillage systems. Two separate experiments were established: one under conventional tillage (CT) and the other under zero tillage (ZT). A split-plot design was applied, assigning three seeding rates (71, 107, and 143 kg ha^{-1}) to main plots and four nitrogen levels (60, 120, 180, and 240 kg N ha^{-1}) to sub-plots. Increasing the seeding rate improved spike density and grain yield, particularly under ZT. The highest rate (143 kg ha^{-1}) was found to be optimal for both tillage systems. Nitrogen fertilization had a noteworthy effect on yield and its components, with 180 kg N ha^{-1} resulting in the highest grain yield (6.62 and 6.49 t ha^{-1} for CT and ZT, respectively). No further significant improvements were obtained at 240 kg N ha^{-1}, suggesting diminishing returns. A significant interaction was detected, where the combination SR3 × N3 (143 kg ha^{-1} × 180 kg N ha^{-1}) achieved maximum productivity (7.14 and 7.19 t ha^{-1} under CT and ZT, respectively) and the highest harvest index. Soil analyses demonstrated that ZT maintained higher organic matter content (1.26–1.62%), whereas CT improved bulk density and infiltration rate. Overall, integrating a high seeding rate (143 kg ha^{-1}) with moderate nitrogen fertilization (180 kg N ha^{-1}) under ZT provided the most effective balance between productivity and soil sustainability in the Nile Delta.

Keywords: Wheat, tillage system, Seeding rate, Nitrogen fertilization, Yield components

INTRODUCTION

Wheat is a fundamental food crop worldwide, supplying nearly 20% of total dietary calories. In 2025, the global harvested area exceeded 215 million hectares, with production projected to reach about 795 million tons (FAO, 2025). Despite this stability, wheat productivity in arid and semi-arid regions remains constrained by rapid soil moisture evaporation, which limits yield potential. To mitigate these challenges, conservation practices such as zero tillage (ZT) are increasingly adopted, as retaining crop residues on the soil surface has been shown to enhance soil water storage, improve water- and nutrient-use efficiency, and reduce erosion (Hemmat & Eskandari, 2006; Carter, 2005; FAO, 2025).

Conservation tillage has the potential to promote crop growth by improving soil water retention (Abdullah, 2014). Because tillage practices exert physical, chemical, and biological effects on the soil, their outcomes may be beneficial or harmful depending on the system adopted. This underscores the importance of studying the impacts of tillage on wheat production in Egypt's Delta region (Gao *et al.*, 2017; Wang *et al.*, 2019; Yang *et al.*, 2020; and Euteneuer & Butt, 2025).

Physical effects such as enhanced aggregate stability, greater infiltration rates, and improved soil and water conservation play a decisive role in sustaining soil productivity and long-term

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agricultural viability (Euteneuer *et al*., 2024). Evidence further indicates that tillage systems significantly influence soil physical and chemical attributes, with many studies reporting increases in soil organic matter (SOM) under diversified cropping systems (Qian *et al*., 2018; El-Ramady *et al*., 2019; and Amer *et al*., 2023). (Gozubuyuk *et al*., 2015) documented higher soil water content in the 0–90 cm profile under no-tillage compared to conventional tillage in a three-year semi-arid field study. In contrast, Ren *et al.* (2018) noted that no-tillage could restrict root penetration in upper soil layers due to mechanical impedance. Conservation tillage practices have been consistently associated with yield gains in wheat. In a five-year comparison, Mokrikov *et al.* (2019) demonstrated that no-tillage outperformed conventional tillage (CT) by 26–114%.

Equally important, seeding rate plays a decisive role in determining wheat yield potential, as it regulates plant density, tiller formation, and canopy structure. An optimal rate ensures adequate crop establishment and directly influences major yield components, including spikes per unit area, grains per spike, and 1000-grain weight (Spink *et al*., 2000). Deviations from the optimum, such as excessive or insufficient seeding, can reduce yield potential through heightened interplant competition or inadequate stand establishment (Lollato *et al.*, 2017; Ma *et al*., 2018).

Nitrogen (N) fertilization is considered the most important yield-limiting nutrient for wheat production, especially under the nitrogen-deficient soils that prevail in arid and semi-arid regions. Nitrogen is a fundamental component of chlorophyll, enzymes, and proteins, and thus it plays a vital role in biomass accumulation and grain filling. Proper nitrogen management enhances yield and improves grain quality, but its efficiency is significantly influenced by the tillage system, soil fertility, and crop density. Moreover, inappropriate use of nitrogen may lead to environmental concerns such as nitrate leaching and greenhouse gas emissions.

The interaction between seeding rate and tillage system has been widely recognized as a critical factor in determining wheat productivity. Under zero tillage (ZT), higher seeding rates are often recommended to compensate for reduced seed–soil contact and potential emergence constraints, thereby ensuring adequate stand establishment (Erenstein *et al*., 2012; Jat *et al*., 2019). Conversely, in conventional tillage (CT), moderate seeding rates may be sufficient due to improved seedbed conditions and greater uniformity of plant emergence (Khan *et al*., 2021). These findings highlight the importance of tailoring seeding strategies to the tillage environment to optimize crop performance.

Moreover, seeding rate interacts strongly with nitrogen (N) fertilization, as plant density directly affects N uptake efficiency and biomass partitioning. Higher seeding rates can accelerate canopy closure and increase early N demand, whereas low seeding rates may limit N use efficiency by reducing the crop's capacity to capture available resources (Lollato *et al*., 2019; Li *et al*., 2020). The balanced integration of an optimum seeding rate with appropriate N fertilization has been shown to improve spikes per unit area, grain number, and final yield under diverse wheat production systems (Zhang *et al*., 2017; Ma *et al*., 2018).

Understanding the interactions among seeding rate and nitrogen fertilization under tillage systems is crucial for optimizing bread wheat performance and advancing sustainable, high-yielding cropping systems. Optimizing these factors can help maximize yield and its components, improve nitrogen use efficiency, and ensure the sustainability of wheat production under varying environmental conditions, particularly in resource-constrained and nutrient-poor soils such as those found in many Egyptian agroecosystems. Evaluate the interaction between seeding rates and nitrogen fertilizer levels on the productivity of bread wheat under two different tillage practices.

MATERIALS AND METHODS

Experimental site characteristics

The new Egyptian bread wheat cultivar 'Misr 3' was grown during two seasons (2023/2024 and 2024/2025) at the Agricultural Research Center, El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt. The experimental site is located in the Central Delta region of Egypt (31°07′N, 30°48′E), characterized by a Mediterranean climate. The average monthly temperatures (°C), rainfall (mm), and humidity (%) for the two seasons are illustrated in Table 1. Physical and chemical properties of the topsoil layer (0–30 cm) in the experimental site for the two seasons are given in Table 2. Bulk density and some hydrodynamic constants of the studied soil are summarized in Table 3.

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

Months	Average Temperature (°C)		Rainfall (mm)		Humidity (%)	
	2023/2024	2024/2025	2023/2024	2024/2025	2023/2024	2024/2025
November	21	19	8.38	6.82	59	61
December	17	15	4.03	3.12	65	62
January	14	15	11.07	3.12	60	67
February	15	13	9.00	1.6	64	59
March	17	18	1.09	0.61	55	56
April	22	20	0.43	0.31	55	52
May	25	25	0	1.56	46	45

*Source: *https://www.worldweatheronline.com/tanta-weather-averages/al-gharbiyah/eg.aspx*

Table 2: Chemical and physical properties of the experimental soils.

Season	PH Suspension (1:2.50)	EC dS m^{-1}	NPK available (mg kg^{-1})			OM (%)	CEC (C mol (+) kg^{-1} soil)
			N	P	K		
2023/2024	8.14	0.87	38.05	4.05	405.20	1.19	49.05
2024/2025	8.11	0.76	40.05	5.35	348.30	1.11	46.33

Season	Particle size distribution (%)				Tex. class	HC (cm hr^{-1})	IR	BD (g cm^{-3})	TP (%)
	C. sand	F. sand	Silt	Clay					
2023/2024	8.91	11.63	29.11	50.35	Clay	1.21	13.05	1.25	52.83
2024/2025	7.73	12.05	32.19	48.03	Clay	1.10	10.39	1.29	51.23

EC: Electrical conductivity, Bd: bulk density, HC: Hydraulic conductivity, OM: organic matter, CEC: Cation Exchange Capacity, and IR: Infiltration rate

Table 3: Bulk density and some hydrodynamic constants of the studied soil.

Depth	Season 2023/2024				Season 2024/2025			
	FC (%)	WP (%)	AW	BD (g cm^{-3})	FC (%)	WP (%)	AW	BD (g cm^{-3})
0-15 cm	45.33	23.01	22.32	1.25	42.90	22.39	20.50	1.29
15-30 cm	43.85	22.71	21.14	1.26	41.80	22.03	19.70	1.31
30-45 cm	40.05	20.63	19.42	1.29	39.40	20.09	19.30	1.32
45-60 cm	38.63	19.65	18.98	1.33	37.10	19.58	17.50	1.36
Average	41.97	21.50	20.47	1.28	40.27	21.02	19.25	1.32

FC: field capacity, WP: water point, AW: available water, and BD: bulk density

Treatments and Experimental Design

Wheat was planted on 25 November 2023 and 15 November 2024 under the two tillage systems: complete tillage (CT) and zero tillage (ZT). In CT, the soil was prepared using two passes with a chisel plough followed by harrowing at a depth of 15–20 cm to incorporate crop residues and control weeds. In ZT, wheat seeds were directly drilled into the residues of the preceding summer crop (*Zea mays* L.).

The experiment included three seeding rates (71, 107, and 143 kg ha^{-1}) and four nitrogen fertilizer levels: N1 (60 kg N ha^{-1}), N2 (120 kg N ha^{-1}), N3 (180 kg N ha^{-1}), and N4 (240 kg N ha^{-1}). Nitrogen was applied as urea (46% N) in three equal splits: at sowing, at booting, and just before heading.

Two separate experiments were conducted. One experiment represented complete tillage (CT) and the other represented zero tillage (ZT). A split–plot arrangement in a randomized complete block design with three replications was used for each experiment. The seeding rates were arranged in the main plots, while nitrogen treatments were randomly arranged in the subplots. The area of the subplot was 10.5 m^2 (18 rows × 0.20 m spacing × 3.0 m length). Standard agronomic practices recommended for wheat production in the region were applied.

Yield and its components characteristics

At harvest, a random sample from one square meter was taken from each subplot to count the no. of spikes m^{-2}. Randomly, 10 spikes were taken to determine the number of grains per spike. Three random samples of 1000 grains (TGW) were taken from each subplot and weighted. Grain yield (GY) was recorded by harvesting each subplot. Finally, the harvest index (%) was calculated by dividing the grain yield by the biomass yield and expressed as a percentage.

Soil samples were collected from a depth of 0-30 cm in all plots. They were air-dried in the shade, ground, and passed through a 2 mm sieve. Physical properties, including bulk density, total porosity, infiltration rate, and hydraulic conductivity, were measured and related to crop production over a two-year period, following the methods of Klute (1986). Soil samples were analyzed for certain chemical properties according to the A.O.A.C. (2012). Soil pH was measured in a 1:2.5 soil-to-water suspension. Electrical conductivity (EC) was determined in the saturated paste extract at 25 °C and expressed as ds m^{-1} to indicate the level of soluble salts. Organic matter (OM) was estimated using the Walkley and Black method. Available nitrogen (N), phosphorus (P), and potassium (K) were extracted using KCl (2M), $NaHCO_3$ (0.5 M), and CH_3COONH_4 (1M), respectively. Particle size distribution was determined by the pipette method described by Sheldrick and Wang (1993). Bulk density was measured using the core method (Blake & Hartge, 1986). Soil water content was assessed gravimetrically, and field capacity and permanent wilting point were estimated at 0.3 and 15 bars, respectively, as described by Klute (1986).

Statistical Analysis

Data from each tillage system were analyzed individually for each season using analysis of variance (Gomez & Gomez, 1984). The Levene test (1960) was performed prior to the combined analysis to test the homogeneity of individual errors. Accordingly, a combined analysis of variance was conducted over the two seasons (S). The statistical analyses were performed using GenStat 19th Edition software (VSN International, 2017).

RESULTS AND DISCUSSIONS

Analysis of variance

The results of the analysis of variance (Tables 4 and 5) revealed that the growing season significantly influenced several traits, including the number of grains per spike, 1000-grain weight, grain yield, and harvest index, although the extent of the effect varied across tillage systems.

Table 4. Levels of significance of No. of grains spike^{-1}, No. of Spike m^{-2} and 1000-grain weight (g) as affected by seasons, seeding rate, and nitrogen fertilizer treatment under complete and zero tillage practices

Sources of variation	d.f	No. of grains spike^{-1}		No. of Spike m^{-2}		1000-grain weight (g)	
		CT	ZT	CT	ZT	CT	ZT
Seasons (S)	1	0.161	0.038*	0.071	0.07	0.003**	0.037*
Seeding rate (SR)	2	0.003**	0.001**	<.001***	<.001***	0.391	<.001***
Nitrogen (N)	3	<.001***	<.001***	<.001***	<.001***	<.001***	<.001***
S X SR	2	0.097	0.599	<.001***	<.001***	0.037*	0.002**
S X N	3	0.077	<.001***	<.001***	<.001***	<.001***	<.001***
SR X N	6	0.109	0.014*	0.002**	<.001***	<.001***	<.001***
S X SR X N	6	0.001**	0.276	<.001***	<.001***	<.001***	<.001***

CT: Complete tillage, ZT: Zero tillage, NS: non-significant at $P \leq 0.05$, * Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$, and *** significant at $P \leq 0.001$.

Table 5. Levels of significance of Grain Yield (t ha^{-1}) and Harvest Index (%) as affected by seasons, seeding rate, and nitrogen fertilizer treatment under complete and zero tillage practices

Sources of variation	d.f	Grain Yield (t ha^{-1})		Harvest Index (%)	
		CT	ZT	CT	ZT
Seasons (S)	1	<.001***	0.006**	0.016*	0.111
Seeding rate (SR)	2	<.001***	<.001***	<.001***	0.004**
Nitrogen (N)	3	<.001***	<.001***	0.013*	<.001***
S X SR	2	0.008**	<.001***	0.008**	0.02*
S X N	3	0.085	0.299	0.404	0.02*
SR X N	6	0.008**	<.001***	0.468	0.993
S X SR X N	6	<.001***	<.001***	0.624	0.983

CT: Complete tillage, ZT: Zero tillage, NS: non-significant at $P \leq 0.05$, * Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$, and *** significant at $P \leq 0.001$.

Results in Table 6, particularly for the first season (S1), outperformed those of the second season (S2) in terms of grain yield (6.77 and 6.52 t ha^{-1} under CT and ZT, respectively) and 1000-grain weight, indicating that the environmental conditions during S1 were more favorable. This reduction in the second season could be attributed to fluctuations in temperature and rainfall, as shown in Table 1, which are critical for grain filling and kernel weight. Such seasonal variations have also been reported by Ali *et al.* (2022), who noted that wheat yield is highly sensitive to climatic factors during the reproductive stage. The observed seasonal variability highlights the importance of adopting resilient management practices, such as optimized seeding rates and nitrogen fertilization, to buffer environmental stresses.

Seeding rate had a pronounced and consistent impact on spike density, grain yield, and harvest index (Table 6). Increasing seeding rate from SR1 (low rate) to SR3 (high rate) significantly increased the number of spikes m^{-2} (from 324 to 390 under CT, and from 282 to 335 under ZT) and grain yield (from 5.85 to 6.80 t ha^{-1} under CT, and from 5.48 to 6.67 t ha^{-1} under ZT). These results clearly indicate that a higher plant population ensures greater spike production, which is a decisive yield component, particularly under ZT, where soil compaction and reduced seed-soil contact may hinder germination and tillering.

Interestingly, the effect of high seeding rate was more evident under zero tillage. This aligns with the findings of Singh *et al.* (2023), who emphasized that in conservation agriculture, increasing plant density can compensate for poor crop establishment. Moreover, Zhang *et al.* (2024) highlighted that higher seeding density improved canopy closure, reduced weed competition, and stabilized yields under low-disturbance systems. Thus, SR3 appears to be the optimum strategy, especially for farmers practicing ZT.

Nitrogen fertilization exhibited the strongest effect among all factors studied, significantly affecting all traits at $P \leq 0.001$ in most cases (Tables 4 and 5). Mean values (Table 6) showed that grain yield increased progressively with increasing nitrogen application up to N3 (150 kg N ha^{-1}), which recorded the highest yield (6.62 and 6.49 t ha^{-1} under CT and ZT, respectively). Although N4 (200 kg N ha^{-1}) also improved spike number and 1000-grain weight, the yield increase over N3 was marginal and not statistically significant, suggesting diminishing returns at higher nitrogen levels

Table 6. Mean values for No. of grains $spike^{-1}$, No. of Spike m^{-2}, 1000-grain weight (g), Grain Yield (t ha^{-1}), and Harvest Index (%) as affected by seasons, seeding rate, and nitrogen fertilizer treatment under complete and zero tillage practices

Treatments	No. of grains $spike^{-1}$		No. of Spike m^{-2}		1000-grain weight (g)		Grain Yield (t ha^{-1})		Harvest Index (%)	
	CT	ZT	CT	ZT	CT	ZT	CT	ZT	CT	ZT
Seasons										
(S1)	56	60	360	312	47.98	44.25	6.77	6.52	30.26	30.00
(S2)	56	59	350	301	41.75	42.13	5.88	5.69	28.43	28.99
L.S.D. 0.05	ns	1.2	ns	ns	1.383	1.818	0.027	0.269	1.023	ns
Seeding rate (kg ha^{-1})										
(SR1)	54	57	324	282	44.67	39.63	5.85	5.48	28.14	29.33
(SR2)	56	60	351	302	44.61	43.98	6.33	6.16	29.23	28.99
(SR3)	58	61	390	335	45.32	45.96	6.80	6.67	30.67	30.17
L.S.D. 0.05	1.90	1.70	6.00	10.00	1.25	1.54	0.12	0.12	0.87	0.58
Nitrogen treatment (kg ha^{-1})										
(N1)	52	56	340	295	44.14	40.69	6.13	5.70	28.54	27.75
(N2)	57	58	364	317	43.42	44.11	6.24	6.11	29.33	29.49
(N3)	58	62	357	318	46.55	43.84	6.62	6.49	29.88	30.47
(N4)	59	62	358	296	45.36	44.13	6.30	6.12	29.63	30.29
L.S.D. 0.05	ns	1.40	7.80	9.00	0.96	0.90	0.11	0.11	ns	ns

CT: Complete tillage, ZT: Zero tillage

This trend aligns with the findings of Abd El-Moneim *et al.* (2021), who discovered that nitrogen rates exceeding 150 kg ha^{-1} under Egyptian conditions did not result in proportional yield increases, primarily due to leaching and volatilization losses. Similarly, Hafez & Abou El-Hassan (2022) reported that moderate-to-high nitrogen levels enhanced nitrogen-use efficiency and grain yield more effectively than excessive applications. Hence, N3 emerges as the most economical and agronomically sound treatment.

The interaction effects (Table 7) clearly demonstrated that the combination of SR3 and N3 produced the highest grain yield (7.14 and 7.19 t ha^{-1} under CT and ZT, respectively), along with superior harvest index values (31.11 and 31.28%). This indicates a synergistic effect, where high plant density ensured maximum spike production and nitrogen availability supported adequate grain filling and kernel development.

Table 7. Interaction effects of seeding rate and nitrogen fertilizer on the number of grains spike^{-1}, the number of spikes m^{-2}, 1000-grain weight, grain yield, and harvest Index under complete and zero tillage systems

Treatments		No. of grains spike^{-1}		No. of Spike m^{-2}		1000-grain weight (g)		Grain Yield (t ha^{-1})		Harvest Index (%)	
		CT	ZT	CT	ZT	CT	ZT	CT	ZT	CT	ZT
SR1	(N1)	49	53	316	290	42.03	34.5	5.81	5.21	27.07	27.57
	(N2)	54	55	330	295	44.03	42.79	5.6	5.24	27.92	29.41
	(N3)	56	61	336	268	46.46	46.3	6.08	5.93	28.36	30.31
	(N4)	58	60	315	276	46.15	34.94	5.89	5.56	29.21	30.04
SR2	(N1)	53	58	329	271	44.09	44.77	6.12	5.49	28.38	27.45
	(N2)	56	58	360	326	42.02	43.41	6.32	6.46	29.26	28.8
	(N3)	57	63	352	321	47.93	40.2	6.65	6.36	30.17	29.81
	(N4)	58	62	363	288	44.4	47.52	6.23	6.34	29.11	29.92
SR3	(N1)	53	56	376	323	46.3	42.81	6.47	6.41	30.17	28.21
	(N2)	60	60	404	329	44.22	46.12	6.8	6.62	30.81	30.26
	(N3)	61	62	383	364	45.25	45.01	7.14	7.19	31.11	31.28
	(N4)	60	66	397	324	45.52	49.91	6.79	6.48	30.59	30.92
L.S.D. 0.05		ns	2.60	12.70	16.10	1.81	1.94	0.20	0.19	ns	ns

CT: Complete tillage, ZT: Zero tillage, SR: Seeding rate, and N: Nitrogen treatments

Under zero tillage, the combination SR3xN3 was particularly beneficial, as it minimized the typical yield gap observed between CT and ZT without significant differences among SR3N4; these results highlight the importance of increasing seeding rates under ZT. Further confirming that applying nitrogen beyond 150 kg ha^{-1} does not justify the extra cost and environmental risk. These results align with those of Zhang *et al.* (2024) and Singh *et al.* (2023), who reported that optimizing seeding density in conjunction with moderate nitrogen fertilization enhances productivity and sustainability in reduced tillage systems.

Soil analyses conducted after harvest (Table 8) revealed that nitrogen fertilization increased the availability of N, P, and K, with the highest values observed at N4. However, soil organic matter was consistently higher under zero tillage than under complete tillage, regardless of nitrogen level. For instance, organic matter under ZT ranged between 1.41% and 1.62% in the first season and 1.26% and 1.45% in the second season, compared to 1.29% and 1.47% under CT. This demonstrates the capacity of zero tillage to preserve crop residues and enhance soil carbon sequestration.

In addition, the nitrogen effect (Table 8) clearly demonstrated that increasing levels from N1 to N4 resulted in a gradual rise in available N, P, and K, as well as soil organic matter, highlighting the complementary role of nitrogen fertilization and tillage management in improving soil fertility.

Table 8: Effect of tillage and nitrogen fertilizer on soil chemical properties after wheat harvesting.

Tillage	Nitrogen Treatments	Season 2023/2024						Season 2024/2025					
		pH (1:2.50)	EC (dS m^{-1})	Available NPK (mg Kg^{-1})			Organic Matter (%)	pH (1:2.50)	EC (dS m^{-1})	Available NPK (mg Kg^{-1})			Organic Matter (%)
				N	P	K				N	P	K	
CT		7.94	0.74	38.31	4.74	444.84	1.37	7.92	0.71	29.09	6.47	423.75	1.27
ZT		7.91	0.84	40.83	5.51	483.75	1.53	7.86	0.75	44.32	6.80	442.92	1.36
L.S.D. 0.05		ns	0.31	2.54	0.42	22.67	0.08	0.035	ns	1.9	ns	7.45	0.07
N	N1	7.98	0.77	33.33d	4.63	448.00c	1.35	7.94	0.69	36.20d	6.37	418.33c	1.24
	N2	7.95	0.79	38.44c	4.98	448.33c	1.43	7.93	0.73	39.86c	6.42	430..00 b	1.28
	N3	7.90	0.80	41.94b	5.27	466.67b	1.47	7.86	0.72	44.02b	6.76	435.00b	1.33
	N4	7.88	0.82	44.54a	5.62	494.17a	1.54	7.84	0.76	46.73a	6.99	450.00a	1.41
L.S.D. 0.05		0.40	0.026	1.94	0.30	17.58	0.053	0.024	0.026	1.13	0.28	11.50	0.050
CT	N1	7.99	0.70	32.02	4.19	439.33	1.29	7.97	0.68	35.44	6.16	405.00	1.22
	N2	7.97	0.74	37.40	4.56	436.67	1.35	7.95	0.71	38.60	6.40	423.33	1.23
	N3	7.92	0.76	40.52	4.92	441.67	1.35	7.89	0.71	0.65	6.55	428.33	1.26
	N4	7.88	0.77	43.28	5.27	461.67	1.47	7.87	0.74	41.65	6.75	438.33	1.37
ZT	N1	7.96	0.84	34.65	5.06	456.67	1.41	7.90	0.70	36.96	6.58	431.67	1.26
	N2	7.92	0.84	39.48	5.40	460.00	1.51	7.92	0.74	41.12	6.44	436.67	1.33
	N3	7.88	0.83	43.37	5.62	491.67	1.58	7.82	0.77	47.40	6.96	441.67	1.40
	N4	7.87	0.86	45.80	5.97	526.67	1.62	7.80	0.77	51.81	7.23	461.67	1.45
L.S.D. 0.05		ns	ns	ns	ns	19.03	ns	ns	ns	1.35	ns	ns	ns

CT: Complete tillage, ZT: Zero tillage, EC: Electrical conductivity, and N: Nitrogen treatments

These findings are consistent with those of Page *et al*. (2020), who emphasized that conservation tillage improves soil organic matter and nutrient retention. Moreover, maintaining higher organic matter under ZT is critical for smallholder farmers facing fertility decline, as it reduces dependency on external inputs.

Soil physical properties (Table 9) were markedly influenced by tillage. Complete tillage resulted in lower bulk density (1.14–1.19 g cm^{-3})

and higher infiltration rates (17.86–19.21 mm) compared with ZT (11.16–14.78 mm). This suggests that CT initially improves soil porosity and water movement. However, ZT gradually enhanced soil structure over time, as indicated by stable bulk density values and moderate infiltration rates.

Table 9: Effect of tillage and nitrogen fertilizer on soil physical properties after wheat harvesting.

Tillage	Nitrogen Treatments	Season 2023/2024				Season 2024/2025			
		BD (g cm^{-3})	Tp (%)	HC (cm hr^{-1})	IR (mm)	BD (g cm^{-3})	Tp (%)	HC (cm hr^{-1})	IR (mm)
CT		1.19	55.27	2.00	18.03	1.21	54.31	1.64	16.72
ZT		1.25	52.83	1.24	13.38	1.26	52.28	0.99	11.85
L.S.D. 0.05		0.04	1.42	0.20	0.67	0.01	0.38	0.30	0.99
N	N1	1.23	53.71	1.48	15.46	1.25	53.01	1.23	13.78
	N2	1.22	54.09	1.58	15.75	1.24	53.40	1.28	14.65
	N3	1.21	54.34	1.66	15.95	1.23	53.77	1.47	14.63
	N4	1.18	55.60	2.00	17.00	1.20	54.59	1.61	15.56
L.S.D. 0.05		0.03	1.03	0.21	0.57	0.014	0.51	0.22	0.97
CT	N1	1.19	55.09	1.82	17.86	1.21	54.34	1.53	16.40
	N2	1.18	55.47	1.93	18.05	1.21	54.34	1.61	17.07
	N3	1.18	55.47	2.02	18.36	1.19	55.09	1.82	17.03
	N4	1.14	56.98	2.42	19.21	1.18	55.47	1.98	17.53
ZT	N1	1.26	52.45	1.14	13.06	1.28	51.70	0.93	11.16
	N2	1.25	52.83	1.23	13.45	1.26	52.45	0.95	12.23
	N3	1.24	53.21	1.31	13.53	1.26	52.45	1.11	12.22
	N4	1.21	54.34	1.58	14.78	1.23	53.58	1.23	13.77
L.S.D. 0.05		ns	ns	ns	ns	ns	ns	ns	1.06

CT: Complete tillage, ZT: Zero tillage, N: Nitrogen treatments, Bd: bulk density, TP: Total porosity, HC: Hydraulic conductivity, and IR: Infiltration rate

Nitrogen fertilization also contributed to significant variation in soil properties. Increasing nitrogen from 60 to 240 kg N ha^{-1} progressively decreased bulk density (from 1.23 to 1.18 g cm^{-3} in 2023/24 and from 1.25 to 1.20 g cm^{-3} in 2024/25), while enhancing total porosity and infiltration rate. For instance, the highest N level (240 kg ha^{-1}) improved infiltration to 17.0 and 15.6 mm in the two seasons, respectively, compared with 15.5 and 13.8 mm under 60 kg N ha^{-1}. These improvements suggest that adequate N supply enhances root growth and soil aggregation, thereby promoting better water movement.

While CT may provide short-term benefits for root penetration, ZT ensures long-term sustainability by conserving organic matter and reducing erosion. These outcomes confirm earlier reports by Cooper and Galdos (2021), who noted that soil structure under ZT improves progressively, providing resilience against degradation.

CONCLUSION

This study demonstrates that optimizing seeding rates and nitrogen fertilizer application can significantly enhance wheat productivity across both tillage systems. For farmers employing zero tillage, the integration of a high seeding rate (SR3 ≈ 400 kg ha^{-1}) with a moderate nitrogen application (N3 ≈ 150 kg N ha^{-1}) demonstrated the greatest efficacy. This treatment enhanced grain yield, improved harvest index, and maintained elevated organic matter levels, which are essential for long-term fertility and sustainability. Conversely, excessive nitrogen application (N4) did not yield substantial benefits and may exacerbate environmental pollution. Consequently, implementing SR3N3 through zero-tillage offers a mutually beneficial outcome: enhanced productivity for farmers and improved soil health for the environment.

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تأثير معدل التقاوي والتسميد النيتروجيني على محصول الحبوب ومكوناته لصنف قمح الخبز مصر ٣ تحت نظامين من الحرث

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الملخص العربى

لقد تعرضت دلتا النيل مؤخرًا لتقلبات مناخية تمثلت في هطول أمطار غزيرة بشكل غير معتاد أثناء تجهيز أرض القمح للزراعة، مما أجبر المزارعين إلي اللجوء إلى الزراعة بدون حرث (ZT) ولحل هذه المشكلة، أُجريت تجربتان حقليتان بمحطة البحوث الزراعية بالجمّيزة خلال موسمي ٢٠٢٤/٢٠٢٣ و٢٠٢٥/٢٠٢٤ بهدف تقييم تأثير معدل التقاوي والتسميد النيتروجيني تحت نظامي حرث مختلفين. وقد تمت إجراء تجربتان منفصلتان: إحداهما تحت نظام الحرث التقليدي (CT) ، والأخرى تحت نظام الزراعة بدون حرث (ZT) . استُخدم تصميم القطع المنشقة، حيث وُزعت ثلاثة معدلات للتقاوي (٧١، ١٠٧، ١٤٣ كجم/هكتار) على القطع الرئيسية، بينما وُزعت أربعة مستويات من السماد النيتروجيني (٦٠ ، ١٢٠، ١٨٠، ٢٤٠ كجم ن/هكتار) على القطع المنشقة. أظهرت النتائج أن زيادة معدل التقاوي عمل علي زيادة كثافة السنابل ومحصول الحبوب، خاصةً تحت نظام عدم الحرث، حيث كان أفضل معدل للتقاوي هو (١٤٣ كجم/هكتار) تحت كلا نظامي الزراعة، كما كان للتسميد النيتروجيني تأثير واضح على محصول الحبوب ومكوناته، حيث أعطى مستوى ١٨٠ كجم ن/هكتار أعلى محصول حبوب (٦,٦٢ و٦,٤٩ طن/هكتار تحت CT وZT على التوالي). كما أوضح التفاعل أن المعاملة SR3 × N3 (١٤٣ كجم/هكتار × ١٨٠ كجم ن/هكتار) حققت أعلى إنتاجية (٧,١٤ و٧,١٩ طن/هكتار تحت CT وZT على التوالي) واعلي معامل حصاد. أظهرت تحليلات التربة أن الزراعة بدون حرث حافظت على نسبة أعلى من المادة العضوية (١,٢٦–١,٦٢%)، بينما حسّن الحرث الكامل الكثافة الظاهرية ومعدل الرشح. وبوجه عام، يُعد الجمع بين معدل تقاوي مرتفع (١٤٣ كجم/هكتار) مع تسميد معتدل (١٨٠ كجم ن/هكتار) تحت الزراعة بدون حرث أفضل خيار لتحقيق التوازن بين الإنتاجية واستدامة التربة في دلتا النيل.