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OPTIMIZING SEEDING RATES FOR MAXIMIZING GRAIN YIELD AND PROFITABILITY OF WHEAT CULTIVARS IN NEW VALLEY

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ABSTRACT

Optimizing seeding rates for specific wheat cultivars are critical for maximizing grain yield and profitability, particularly in new agricultural lands. A field experiment was conducted during 2022/2023 and 2023/2024 seasons at Al Farafra, New Valley, Egypt to evaluate the performance of six wheat cultivars-four bread wheat (Sakha 95, Misr 4, Misr 2 and Giza 171) and two durum wheat cultivars (Bani Suef 5 and Bani Suef 7) differing in 1000-kernel weight- under five seeding rates (250, 325, 400, 475, and 550 grains m^{-2}). The experiment was laid out in a split-plot design with three replications, Where cultivars were assigned to the main plots and seeding rates to sub-plots. Response curve approach was employed to assess yield trends and determine economically optimal seeding rates. Results revealed significant effects of cultivar seeding rate and their interaction on earliness traits, plant height, yield, and yield components. Misr 2 consistently recorded the highest grain yield (26.1 ardab fed^{-1}) across both seasons followed by Bani Suef 7 in the first season. Intermediate yields were recorded for Misr 4 and Sakha 95, While Giza 171 and Bani Suef 5 had the lowest performance. Increasing seeding rates generally reduced days to heading and maturity, number of grains per spike, and 1000-kernel weight, While increasing plant height and number of spikes m^{-2}. The highest yields were achieved at 475 grains m^{-2} in the first season and 400 grains m^{-2} in the second. The average optimal seeding rates (kg fed^{-1}) across both seasons were: Misr 2 (73.10), Sakha 95 (83.29), Misr 4 (85.63), Bani Suef 7 (90.80), Bani Suef 5 (103.02), and Giza 171 (107.87). Economic analysis using a quadratic response model indicated that the most profitable seeding rate was approximately 73 kg fed^{-1}, with maximum yield reaching 26.6 ardab fed^{-1} and net profit exceeding 56,859.23 LE fed^{-1}. The findings emphasize the need to consider 1000-kernel weight when determining optimal seeding rates, as cultivars with larger and heavier kernels often require higher seed rates to achieve maximum yield potential.

Key Words: Bread and durum wheat cultivars, seeding rates, yield components, Response curve, Economic analysis

INTRODUCTION

Wheat is a cornerstone of global food security, serving as a primary staple food for 2.5 billion people across 89 countries. Its strategic importance is particularly pronounced in Egypt, Where it has underpinned the nation's food security for millennia. Despite a domestic production of approximately 9.2 million tons from 1.4 million hectares, Egypt's output is insufficient to meet consumer demand, necessitating the import of around 12.5 million tons annually to bridge the resulting food gap **(FAO, 2024).** Addressing this deficit is a national priority.

One key strategy to enhance self-sufficiency is expanding wheat cultivation to newly reclaimed lands such as the New Valley Governorate, a pivotal region in Egypt's agricultural development plan. The success of this expansion hinges on optimizing a suite of agronomic practices to suit these unique environments. However; many factors like soil type, irrigation methods, and nutrient management are crucial, establishing the optimal seeding rate is a particularly critical and often overlooked component for maximizing both grain yield and economic returns.

A prevalent issue in traditional farming practices is the application of excessive seeding rates often more than the recommended rates. This approach is not only inflates production costs but also incites intense intra-plant competition for resources (light, water, and nutrients). This competition can paradoxically reduce the final grain yield by causing physiological detriments such as shorter spikes and a lower number of grains per spike (**Park *et al.,* 2003; Gab Alla *et al.,* 2019).** Crucially, the optimal seeding rate is not a static value; It is highly dependent on the cultivar's genetic makeup. Key traits like the 1000-kernel weight (TKW) directly influence the number of seeds per kilogram, meaning different cultivars require different seeding rates to achieve the ideal plant population density (**Gab Alla *et al.,* 2019; Abboye and Teto 2020; Öztürk, 2024).**

Therefore, this study was aimed to determine the optimal and economically viable seeding rates for tested wheat cultivars, Based on their thousand-kernel weights under the specific environmental conditions of the New Valley Governorate. By fitting polynomial yield response curves and conducting an economic analysis, This research will provide farmers with practical, data-driven recommendations to reduce seed costs and enhance wheat productivity.

MATERIALS AND METHODS

A field experiment was conducted during the 2022/2023 and 2023/2024 winter growing seasons at a private farm in Abo Huraira village Al Farafra New Valley Governorate Egypt. (Latitude: 27.06° N, Longitude: 27.89° E). The experiments studied were set up using a split-plot design with a Randomized Complete Block Design (RCBD) with three replications. The main plots were assigned to six wheat cultivars: Four bread wheat (*Triticum aestivum* L.) cultivars (Sakha 95, Misr 4, Misr 2, and Giza 171) and two durum wheat (*Triticum durum* Desf.) cultivars (Bani Suef 5 and Bani Suef 7). These cultivars (Table 1) were selected based on their high yield potential and known variations in traits such as grain size and kernel weight. The sub-plots were allocated to five seeding rates: 250, 325, 400, 475 and 550 grains m^{-2}. These seeding rates were chosen to represent a wide range bracketing the current regional recommendation of approximately 400 grains m^{-2}. The objective was to pinpoint the ideal plant density for each cultivar under the specific region conditions of the New Valley.

Table 1. Name and pedigree of the six wheat cultivars under study.

Cultivar	Type	Cross Name/ Pedigree
Sakha 95	bread	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1. CMA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
Misr 4	bread	NS732/HER/3/PRL/ SARA// TSI/VEE 5/6/FRET 2/5/WHEAR/SOKOLL CM SA09Y007125-050Y- 050ZTM-0NJ-099NJ-0B-0EG.
Misr 2	bread	SKAUZ/BAV92 CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
Giza 171	bread	SAKHA 93/GEMMEIZA 9 S.6-1GZ-4GZ-1GZ-2GZ- GZ.
Bani Suef 5	durum	Dipper-2/Bushen-3. CDSS92B128-1M-0Y-0M-0Y-3B-0Y-0SD.
Bani Suef 7	durum	CBC509CHILE//SOOTY_9/RASCON_37/9/USDA595/3/D67.3/ ABI//CRA/4/ALO/5/HUI/YAV_1/6/ARDENTE/7/HUI/YAV79/8/POD_9.C DSS02-Y01233T-0T0PB-0Y-0M-26Y-0Y-0SD

In the first and second seasons, sowing dates were carried out on November 10 and November 13, respectively. The experimental plot area was 4.2 m² comprising six rows, 3.5 m long and 0.2 m apart. Phosphorus fertilizer was applied during seedbed preparation at a rate of 300 kg P_2O_5 fed^{-1}. Nitrogen fertilizer was applied as urea (46.5% N) at a rate of 100 kg N fed^{-1}), split into five equal doses applied with irrigation. The soil of the experimental site was a sandy loam, consisting of 67.7% sand, 21.4% silt, and 10.9% clay, with a pH of 7.8. Meteorological data for the experimental location during both seasons are presented in Table 2. All other standard agronomic practices for wheat production in the New Valley region were followed as recommended.

Table 2. Monthly minimum and maximum of air temperatures (AT ^{o}) and Relative humidity (RH %) in winter seasons of 2022/2023 and 2023/2024 at Al Farafra location.

Month	Temperature 2022/23		Temperature 2023/24		RH%	
	Max.	Min.	Max.	Min.	2022/23	2023/24
Nov.	24.56	12.18	26.53	13.70	48.20	48.52
Dec.	22.23	9.81	21.89	9.42	57.72	60.94
Jan.	20.04	7.13	19.43	6.36	55.10	53.20
Feb.	19.35	5.95	20.56	6.53	52.50	50.60
Mar.	26.50	11.07	25.92	10.42	34.29	36.45
Apr.	30.35	15.23	31.68	15.24	26.26	26.44
May.	34.00	18.67	35.30	19.38	25.56	23.48

* Tmax: Temperature Maximum (C), Tmin: Temperature Minimum (C), RH: Relative Humidity at (%).

Data were recorded for the following traits:

Phonological traits: Days to heading (DH) and days to maturity (DM). The grain filling period (GFP) was calculated as the duration between heading and maturity.

Agronomic traits and yield components: At maturity, plant height (PH, cm), number of spikes m^{-2} (NSM number of kernels per spike (NKS^{-1}), and 1000-kernel weight (TKW, g) were measured.

Grain Yield (GY): Grain yield was determined from the central rows of each plot and converted to ardab fed^{-1} (1 ardab = 150 kg; 1 feddan = 4200 m^2). The grain filling rate (GFR) was calculated as GY (kg fed^{-1}) divided by the GFP (days).

Analysis of variance and mean performance

The collected data were subjected to analysis of variance (ANOVA). Means were compared using the Least Significant Difference (LSD) test at a 0.05 significance level (**Gomez and Gomez, 1984).** Interaction graphs were generated using Minitab 17 Statistical Software.

Response curve analysis:

A variety of models were fitted to the data gathered when multiple seeding rates were used in order to either directly or indirectly estimate the economic seeding rate. In the first and second seasons, the best models were employed to respond the tested seeding rates in terms of grain production (ardab fed^{-1}) for the six cultivars.

Neter *et al*., (1990). The tested models were linear; quadratic and exponential model.

(1): The linear model is defined by the equation; $Y = a + b\,(SR)$

(2): The quadratic model is defined by the equation; $Y = a + b\,(SR) - c\,(SR)^2$

(3): The exponential model is defined by the equation; $Y = a + b^{(SR)}$

Economic analysis

The model that is employed to fit the data determines the economic methods that are employed to ascertain the ideal seeding rates. The cost of seeds and the selling price of the finished grain yield (ardab fed^{-1}) are also directly related to the most economical and efficient seeding rate. Optimizing the overall profit equation could yield the best rate for the data collected annually. **(Engelstad 1985 ; Dillon and Anderson 2012).** The total profit equation in this context reflects the returns for the fixed factors, as we are keeping the levels of all other components constant across all of our experimental plots. Subsequently, we maximize the total profit using calculus techniques.

The total profit equation is: $\pi = P_y\, f(x) - P_x x$

Where:π is the amount of profit, P_y is the price of the product (grain yield ardab fed^{-1}), P_x is the price of input (in this case seeding rate), X is the level of input (in this case seeding rate) and f (x) is the production function. By taking the first derivative of the above profit equation with respect to X and equating that to zero:

$$\frac{\sigma\pi}{\sigma_x} = P_y\ \sigma\ \frac{f(x)}{\sigma x} - P_x = 0$$

Which can be written as:

$$P_y\ \sigma f(x)\sigma_x\ = P_x$$

This provides the first-order requirement for profit maximization, which states that at the optimal price, The product's marginal value must match the grain of seeding rate price. The optimal seeding rate is obtained by solving this first-order condition for the level of X, which is the term unknown. To put it another way, the farmer would keep raising the rate of sowing until the profits from the final unit added were barely equal to the cost of that unit. The price of wheat grains used for the economic analysis were those prevailing in Egypt during both seasons of 2022/2023 and 2023/2024 being i.e. 25 EGP/kg for the price of sowing seeds and 2200 EGP per ardab for commercial wheat yield.

RESULTS AND DISCUSSION

1. Climatic Conditions and their Influence on traits

The climatic results presented in Table 2 indicated the differences between the 2022/2023 and 2023/2024 growing seasons, which likely contributed to the variations observed in some traits. Some growth and crop characteristics such as heading, maturity and 1000-kernel weight were greatly affected by the high and low temperatures. The first season (2022/2023) was characterized by relatively higher average and maximum temperatures, particularly during the critical reproductive and grain-filling stages. High temperature during Dec and Jan in the first season appears to explain the observed acceleration in crop phenology, leading to significantly shorter periods for heading. In accordance, in March , the plants were earlier to matured compared to the second cooler season. This aligns with findings by **Wahid *et al.,* (2007),** who reported that despite exposure of cultivars to heat stress may differ with the stage of plant development, All reproductive and vegetative stages are affected by high temperature.

The temperature in the second season (2023/2024) was favorable for better growth of wheat. The extended grain-filling period allowed for better photosynthesis and translocation of assimilates.Therefore, the year-to-year variation in grain yield and its components observed in this study can be substantially attributed to the distinct temperature regimes of each growing season. This underscores the critical impact of heat stress on wheat productivity in the New Valley and highlights the importance of selecting heat-tolerant cultivars for stabilizing yields under such arid conditions.

2. Earliness characters and plant height

Results indicated significant differences ($P \leq 0.05$) among the six wheat cultivars and five seeding rates for days to heading, days to maturity, grain filling period, grain filling rate and plant height in both growing seasons, with the exception of the effect of seeding rate on the grain filling period in the first season (Table 3).

2.1.Effect of wheat cultivars

The significant variations were observed among the wheat cultivars is primarily attributed to their distinct genetic backgrounds and their interaction with the environment, A principle consistent with numerous studies on wheat (**Darwish *et al.,* 2023; El-Hag, 2023; El Kot *et al.,* 2023; Gab Alla and Hussein, 2025).** The bread wheat cultivar Giza 171 was the earliest one to heading and maturity in both growing seasons (78.60 , 82.20 and 141.4 and 148.67 days, respectively), While exhibiting the longest grain filling period (62.60 and 66.6 days, respectively) and lowest values for grain filling rate. **Gebrel and Ghanem** (**2023**) reported that Giza 171 recorded the lowest values for days to heading and days to maturity than Misr 4 and Sakha 95. **Al-Otayk (2019)** revealed that the earliest wheat genotypes for days to heading might be usually the earliest for days to maturity, Also, indicated that the early maturing genotypes had long grain filling period and the reverse for late genotypes. In contrast, the cultivar Misr 2 was the latest to heading and maturity (84.80, 87.00 and 143.87and 150.73 days, respectively) and had the tallest plants (115 and 117 cm) across both seasons. Furthermore, this cultivar recorded the highest grain filling rate (61.66 and 58.99 kg fed^{-1} day^{-1}) but had the shortest grain filling period. **Gab Alla and Hussein (2025)** reported that Misr 2 recorded significantly higher values for days to heading, maturity, grain filling rate and plant height than Giza 171, Sakha 95, Misr 4, Bani Suef 5, and Bani Suef 7 under the conditions of the New Valley. **Whan *et al.,* (1996)** reported that wheat genotypes that can fill their grain quickly have an advantage under high temperature stress during the grain filling periods.

2.2. Effect of seeding rates

Results in Table (3) showed a significant differences among the five seeding rates for earliness characters and plant height except grain filling period (GFP) in the first growing seasons., specifically, the lowest seeding rate (250 grains m^{-2}) resulted in the longest days to both heading (84.22 and 86.11day) and maturity(144.83, 151.94 day). This can be attributed to the minimal intraspecific competition at low densities. With ample access to resources.i.e. light, water, and nutrients, individual plants experience less stress, allowing them to complete their vegetative growth phase more fully before transitioning to the reproductive stage. However, this extended growth period did not translate into better grain-filling efficiency, as this treatment recorded the lowest grain filling rate (GFR) (48.99 and 41.76 kg fed^{-1} day^{-1}) and shortest plant height (101.94 and 103.33 cm). Whereas earliest traits have shortest days to heading and maturity sowing with 550 seed m^{-2} scored (79.44 and 140.44 day) and (81.72 and 147 day) respectively, in first and second seasons. **Ayalew *et al.,* (2017)** reported that, increasing seed density resulted in increased plant height, due to increasing the competition for light interception between plants and drives upward vegetative growth. **Gab Alla *et al.,* (2019)** showed that increasing seeding rates from 100 to 450 seed m^{-2} decreased days to heading, days to maturity and grain filling rate and increased the plant height.

Table 3. Mean performance of earliness characters and plant height for wheat cultivars evaluated under five seeding rates in 2022/2023 and 2023/2024 seasons and their interaction.

Wheat cultivar (C)	Days to heading (day)		Days to maturity (day)		Grain filling period (day)		Grain filling rate (kg $fed^{-1} day^{-1}$)		Plant height (cm)	
	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Sakha 95	79.93	85.07	141.20	148.93	61.40	63.87	55.11	52.79	112.33	114.00
Misr 4	83.13	84.40	143.40	149.67	60.27	65.27	55.57	51.09	101.67	107.00
Misr 2	84.80	87.00	143.87	150.73	59.07	63.73	61.66	58.99	115.00	117.00
Giza 171	78.60	82.07	141.40	148.67	62.80	66.60	53.70	46.06	111.33	113.00
Bani Suef 5	82.00	83.67	142.73	149.67	60.73	66.00	50.11	49.33	104.33	104.67
Bani Suef 7	82.07	83.33	141.80	149.53	59.73	66.20	61.80	48.37	104.33	105.00
F -Test	**	**	**	**	**	*	**	**	**	**
LSD 0.05	1.10	1.11	1.42	1.90	1.37	2.09	3.82	4.89	3.37	3.00
Seeding Rates (SR) (grain m^{-2})										
250	84.22	86.11	144.83	151.94	60.61	65.83	48.99	41.76	101.94	103.33
325	82.67	85.00	143.11	150.33	60.44	65.33	54.14	50.64	105.28	106.11
400	81.61	84.28	142.22	149.89	60.61	65.61	60.96	56.12	109.17	110.56
475	80.83	83.50	141.50	148.50	60.67	65.00	61.00	55.40	111.11	113.33
550	79.44	82.39	140.33	147.00	60.89	64.61	56.55	51.60	113.33	117.22
F -Test	**	**	**	**	NS	**	**	**	**	**
LSD 0.05	0.67	1.05	0.77	1.31		0.74	4.86	4.04	2.43	1.91
C X SR	*	NS	*	NS	NS	NS	NS	NS	NS	NS
CV	1.22	1.87	0.80	1.13	2.1	3.22	12.88	11.78	3.36	2.59

Abbreviations: LSD compered for wheat cultivars, *,**significant and highly significant and CV Coefficient of Variation 2022/23 and 2023/24.

3. Yield and yield components

Analysis of variance (Table 4) revealed that both cultivars and seeding rates had significant effects on grain yield and its components (spikes m^{-2}, kernels $spike^{-1}$, and 1000-kernel weight) across both growing seasons.

3.1. Effect of wheat cultivars

The bread wheat cultivar Misr 2 gave the highest number of spikes (450.93 and 464.47) in the two-growing seasons. The number of spikes per square meter, which reflects the tillering capacity of a cultivar was a primary determinant of yield potential **(Ayalew *et al.,* 2017).** Misr 2 recorded the lowest values for both kernels per spike and 1000-kernel weight. Where an increase in the number of spikes per area is often accompanied by a reduction in the number of kernels per spike. The results, which show that cultivars with a higher number of spikes m^{-2} tended to have fewer kernels per spike and a lower 1000-kernel weight. Thesis results are consistent with **Fischer, (2007) and Li *et al.,* (2021).** On another hand, Giza 171 recorded the lowest values for the number of spikes per square meter. It excelled in the other components, yielding the highest number of kernels per spike and the heaviest kernels and did not differ significantly from either of the two durum cultivars Bani Suef 5 and 7 in both growing seasons.

Grain yield is the paramount trait for evaluating wheat cultivars, as it integrates the complex interplay of genetics, environment, and management. The results clearly identified the wheat cultivar (Misr 2) as the top-performing cultivar, achieving the highest grain yields (24.29 and 25.04 ardab fed^{-1}) in the first and second seasons, respectively. This superior performance can be directly attributed to its high tillering capacity, which resulted in the greatest number of spikes m^{-2}. Interestingly, in significant difference in yield was observed between the bread wheat cultivar (Misr 2) and the durum cultivar (Bani Suef 7) in the first season, suggesting a comparable yield potential under those specific conditions.

In general, the wheat cultivars Sakha 95 and Misr 4 formed an intermediate performance group, showing in significant differences in grain yield between them in either growing season.

In contrast, a second group of cultivars, including the bread wheat cultivar - Giza 171 - and durum wheat - Bani Suef 5- were consistently among the lowest-yielding cultivars. These substantial yield differences documented among the genotypes. Therefore, grain yield remains the final and most decisive arbiter for identifying and recommending superior genotypes for specific agro-ecological zones like the New Valley.

Table 4. Mean performance of number of spikes per square meter(NSM^{-2}), number of kernels spike^{-1} (k S^{-1}) 1000-kernel weight (1000-kw), and grain yield (GY) as affected by bread wheat cultivars, seeding rates and their interaction in 2022/23 and 2023/24 growing seasons.

Wheat cultivar	NSM^{-2}		K/S		1000-kw (g)		GY (Ardab fed^{-1}.)	
(C)	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
Sakha 95	382.20	402.13	47.43	46.54	47.18	45.70	22.55	22.40
Misr 4	393.67	406.07	44.55	47.52	47.85	47.63	22.32	22.20
Misr 2	450.93	464.47	42.77	47.33	41.31	40.85	24.29	25.04
Giza 171	341.33	364.60	49.20	53.48	51.61	52.18	22.48	20.45
Bani Suef 5	348.67	377.53	46.10	51.06	51.00	50.24	20.29	21.68
Bani Suef 7	378.60	392.20	46.69	50.25	51.56	48.58	24.57	21.35
F-Test	**	**	**	**	**	*	**	**
LSD 0.05	27.02	45.12	3.73	4.64	5.36	3.14	1.67	1.92
Seeding Rates (SR) (grain m^{-2})								
250	269.00	293.33	51.69	54.17	52.68	53.13	19.77	18.27
325	336.00	366.06	48.55	51.91	50.44	49.72	21.78	21.99
400	397.22	420.39	45.64	50.20	48.88	48.44	24.59	24.49
475	439.00	447.94	43.37	46.46	47.25	44.18	24.63	23.99
550	471.61	478.11	41.37	44.06	42.83	42.18	22.98	22.19
F-Test	**	**	**	**	**	**	**	**
LSD 0.05	28.15	26.47	2.56	2.01	2.75	2.62	1.90	1.67
C X SR	NS	NS	NS	NS	NS	NS	**	*
CV	10.98	9.84	8.29	6.07	8.48	8.21	12.45	11.20

3.2. Effect of seeding rates

In wheat grain, yield is mainly determined by number of spikes m^{-2} ,1000- kernel weight and number of kernels per spike. Seeding rate significantly influenced all yield components (Table 4). Firstly, a strong positive correlation was found between seeding rate and some yield components. The number of spikes m^{-2} progressively increased with higher seeding rates, culminating in the maximum values (471.61 and 478.11) at the highest rate of 550 seeds m^{-2}. Conversely, the lowest seeding rate (250 seeds m^{-2}) resulted in the minimum values for number of spikes per square matter. However, an inverse trend was observed for the other two components. The lowest seeding rate (250 seeds m^{-2}) maximized both the 1000-kernel weight (52.68 and 53.13 g) and the number of kernels per spike (51.69 and 54.17). In contrast, these components were minimized at the highest seeding rate. **Gab Alla (2019)** reported that, increasing seeding rate increased steadily number of spikes and decreases 1000-kernel weight and number of kernels spike^{-1} . On the other hand, the high value of seeding rate (550 grain m^{-2}) recorded the lowest values for1000- kernel weight and number of kernels per spike. **EL Hag (2019),** added that, the decreases in 1000-kernel weight and number of kernels spike^{-1} were due to the competition among wheat plants on nutrients, moisture, air and light.

4. Effect of interactions

The analysis of variance revealed a significant interaction effect ($P \leq 0.05$) between wheat cultivars and seeding rates for days to heading, days to maturity (in the first season only) and for grain yield (Table 5). This finding is critical, as it indicates that the cultivars' response to seeding rate is not constant; rather, the optimal seeding rate is highly dependent on the specific cultivar and prevailing environmental conditions.

The results from the first season indicated that Sakha 95 was the earliest cultivar, reaching heading and maturity in 76.33 and 139.00 days, respectively, when sown at the highest rate of 550 seeds m^{-2}. Conversely, Misr 2 was the latest cultivar, recording 88.67 days to heading and 147.00 days to maturity at the lowest seeding rate of 250 seeds m^{-2}. Grain yield, the ultimate product of all yield components, showed a clear and significant interaction. The optimal seeding rate for maximizing yield was not the highest or the lowest, but rather an intermediate range. In the first (warmer) season, Bani Suef 7 and Giza 171 achieved their highest yields at a rate of 475 grains m^{-2}. In contrast, under the more favorable conditions of the second season, Misr 2 and Sakha 95 excelled, with 'Misr 2 recording the study's peak yield (28.45 ardab fed^{-1}) at 400 grains m^{-2}. This demonstrates that cultivars possess different yield potentials and optimal plant density requirements that are further modulated by environmental conditions. These results align with previous findings that highlight the importance of matching cultivar choice with appropriate seeding rates to maximize productivity **(Baqir and Al-Naqeeb, 2018; Khan *et al.,* 2019).**

Table 5. The interaction effect of wheat cultivars and seeding rates (SR) on days to heading (DH), days to maturity(DM) in the first season(2022-2023) and grain yield (GY) in both seasons.

Cultivar	SR	DH (day) 2022-2023	DM (day) 2022-2023	GY ard fed^{-1} 2022-2023	GY ard fed^{-1} 2023-2024
Sakha 95	250	82.33	143.33	20.32	17.98
	325	81.33	142.33	22.18	23.58
	400	80.00	141.67	24.82	24.85
	475	79.67	140.33	23.30	23.02
	550	76.33	139.00	22.15	22.55
Misr 4	250	85.67	145.33	19.63	18.42
	325	83.67	144.33	21.39	23.15
	400	83.00	143.33	24.50	24.67
	475	82.33	142.67	24.18	22.95
	550	81.00	141.33	21.90	21.82
Misr 2	250	88.67	147.00	21.57	21.59
	325	86.00	144.67	24.50	24.72
	400	84.33	143.67	26.72	28.45
	475	83.00	142.33	24.70	25.87
	550	82.00	141.67	23.97	24.55
Giza171	250	80.00	143.33	19.25	16.01
	325	79.33	142.0	20.87	18.72
	400	78.67	141.33	23.26	22.19
	475	77.67	140.67	25.26	23.47
	550	77.33	139.67	23.77	21.84
Bani Suef 5	250	84.33	146.00	16.55	17.82
	325	83.33	143.33	18.37	20.27
	400	81.67	142.00	21.47	23.84
	475	81.00	141.67	23.15	24.18
	550	79.67	140.67	21.90	22.28
Bani Suef 7	250	84.33	144.00	21.30	17.76
	325	82.33	142.0	23.38	21.50
	400	82.00	141.33	26.79	22.97
	475	81.33	141.33	27.17	24.44
	550	80.33	140.33	24.22	20.08
LSD 0.05		1.8	2	4.41	4.1

5. Analysis of seeding rate response curve

The grain yield data for the investigated wheat cultivars over both growing seasons were fitted using linear, quadratic, and exponential models. Four criteria coefficient of determination (R^2), adjustment coefficient of determination (R^2 adj) F value, and model significance were taken into consideration when comparing the three models in Table 6 as obtained by **Lindsey *et al.*, (2020).** The best model fitted to the yield data was the significant model with the highest R^2 a goodness-of-fit model is shown when the R^2 adj value is close to the R^2 value.

As detailed in Tables 6 and 7, the quadratic model for all six cultivars across both seasons consistently yielded the highest R^2 and R^2 adj values, coupled with the lowest SE. The proximity of R^2 to R^2 adj further affirmed the model's robustness. This indicates a curvilinear relationship where grain yield increases with seeding rate up to an optimal point, beyond which it begins to decline due to factors like intra-plant competition. Consequently, the quadratic regression equations were selected as the most accurate predictive tool for determining both the agronomic and economic optimum seeding rates in present study. This approach aligns with findings by **Mehring *et al.*, (2020),** who also reported the superiority of polynomial models in optimizing crop inputs.

Table (6). Coefficient of determination (R^2), and significant value for linear, quadratic and exponential models for grain yield of wheat cultivars in both seasons.

	Goodness of Fit				
genotype	**Equation**	**R^2**	**Adjusted R^2**	**F**	**Sig.**
	First season (2022/2023)				
Sakha 95	**Linear**	**0.21**	**0.11**	**2.10**	**0.185**
	Quadratic	**0.88**	**0.85**	**26.12**	**0.001**
	Exponential	**0.23**	**0.13**	**2.34**	**0.164**
Misr 4	**Linear**	**0.33**	**0.24**	**3.87**	**0.085**
	Quadratic	**0.90**	**0.87**	**31.38**	**0.000**
	Exponential	**0.35**	**0.26**	**4.23**	**0.074**
Misr 2	**Linear**	**0.18**	**0.08**	**1.80**	**0.217**
	Quadratic	**0.88**	**0.85**	**26.80**	**0.001**
	Exponential	**0.20**	**0.10**	**2.03**	**0.192**
Giza171	**Linear**	**0.78**	**0.76**	**28.91**	**0.001**
	Quadratic	**0.92**	**0.90**	**39.62**	**0.000**
	Exponential	**0.79**	**0.77**	**30.62**	**0.001**
BS 5	**Linear**	**0.80**	**0.78**	**32.61**	**0.000**
	Quadratic	**0.94**	**0.92**	**54.77**	**0.000**
	Exponential	**0.81**	**0.78**	**33.68**	**0.000**
BS 7	**Linear**	**0.39**	**0.31**	**5.07**	**0.054**
	Quadratic	**0.90**	**0.87**	**31.52**	**0.000**
	Exponential	**0.41**	**0.34**	**5.52**	**0.047**
	Second season (2023/2024)				
Sakha 95	**Linear**	**0.27**	**0.18**	**2.95**	**0.124**
	Quadratic	**0.88**	**0.84**	**24.75**	**0.001**
	Exponential	**0.30**	**0.21**	**3.35**	**0.105**
Misr 4	**Linear**	**0.20**	**0.10**	**1.98**	**0.198**
	Quadratic	**0.93**	**0.90**	**42.97**	**0.000**
	Exponential	**0.22**	**0.13**	**2.29**	**0.169**
Misr 2	**Linear**	**0.20**	**0.10**	**2.04**	**0.191**
	Quadratic	**0.88**	**0.84**	**24.79**	**0.001**
	Exponential	**0.23**	**0.13**	**2.39**	**0.161**
Giza 171	**Linear**	**0.73**	**0.70**	**21.85**	**0.002**
	Quadratic	**0.96**	**0.95**	**87.30**	**0.000**
	Exponential	**0.74**	**0.71**	**22.56**	**0.001**
BS 5	**Linear**	**0.58**	**0.53**	**11.25**	**0.010**
	Quadratic	**0.95**	**0.93**	**60.66**	**0.000**
	Exponential	**0.60**	**0.55**	**12.13**	**0.008**
BS 7	**Linear**	**0.22**	**0.12**	**2.19**	**0.177**
	Quadratic	**0.92**	**0.89**	**38.88**	**0.000**
	Exponential	**0.23**	**0.13**	**2.37**	**0.162**

Dependent Variable: Grain Yield ard fed^{-1} / The independent variable is Seed Rate

Table (7). Equation of regression according to the quadratic model under five sowing rates for six wheat cultivars in two growing seasons.

Regression equations (quadratic model)			
first season (2022/2023)		second season (2023/2024)	
The regression equation is			
Sahka 95	Y = 0.784 + 0.1098 SR - 0.000129 SR^2	Sakha95	Y= - 10.94 + 0.1661 SR - 0.000193 SR^2
Misr 4	Y= - 3.321 + 0.1267 SR - 0.000146 SR^2	Misr4	Y = - 9.565 + 0.1607 SR - 0.000190 SR^2
Misr 2	Y= - 0.204 + 0.1241 SR - 0.000147 SR^2	Misr2	Y = - 7.474 + 0.1640 SR - 0.000193 SR^2
Giza 171	Y= 2.840 + 0.08502 SR - 0.000084 SR^2	Giza 171	Y = - 8.812 + 0.1322 SR - 0.000138 SR^2
Bani Suef 5	Y= - 2.250 + 0.09746 SR - 0.000096 SR^2	Bani Suef 5	Y = - 7.712 + 0.1384 SR - 0.000152 SR^2
Bani Suef 7	Y = - 5.291 + 0.1459 SR - 0.000166 SR^2	Bani Suef 7	Y = - 13.26 + 0.1745 SR - 0.000206 SR^2
	Regression equations (seed rate kg)		
Sahka 95	Y = 0.785 + 0.5538 SR - 0.003291 SR ^	Sahka95	Y = - 10.97 + 0.8662 SR - 0.005253 SR^2
Misr 4	Y = - 3.322 + 0.6338 SR - 0.003659 SR ^2	Misr4	Y = - 9.576 + 0.8037 SR - 0.004747 SR^2
Misr 2	Y = - 0.214 + 0.7155 SR - 0.004879 SR ^2	Misr2	Y = - 7.465 + 0.9546 SR - 0.006549 SR^2
Giza 171	Y = 2.839 + 0.3922 SR - 0.001786 SR ^2	Giza171	Y = - 8.838+ 0.6037 SR - 0.002874 SR^2
Bani Suef 5	Y = - 2.256 + 0.4507 SR - 0.002054 SR ^2	Bani Suef 5	Y = - 7.699 + 0.6554 SR - 0.003402 SR^2
Bani Suef 7	Y = - 5.316 + 0.6742 SR - 0.003550 SR ^2	Bani Suef 7	Y = - 13.29 + 0.8561 SR - 0.004941 SR^2

6. Economic analysis

The results of the economic analysis for the first and second seasons of seeding rates are presented in Table (8), the maximum, recommended and optimum sowing rate estimated by the quadratic equation. The maximum seeding rate were obtained in first season (84.14, 86.16, 73.32, 109.80, 109.71 and 94.96 kg fed^{-1}) whereas in the second season the maximum sowing rates were 82.45,84.65,72.88,105.95, 96.33 and 86.63 kg fed^{-1}) for the six cultivars (Sakha 95, Misr 4, Misr2, Giza 171, Bani Suef 5and Bani Suef 7), respectively.Table (8) presented grain yield at maximum seeding rates for the studied cultivars i.e. Sakha 95, Misr 4, Misr 2, Giza 171, Bani Suef 5and Bani Suef 7 were produced (24.08, 24.12, 26.02, 24.37, 22.47 and 26.69 ard fed^{-1} respectively) in first season. Whereas in the second season the maximum grain yield is (24.74, 24.44, 27.32, 23.14, 23.87 and 23.79 ard fed^{-1}).

The results also, detected the cultivars Bani Suef 7, and Misr 2 surprised the other cultivars in maximum grain yield at first season being (26.69 and 26.02 ardab fed^{-1}), On the same side, the cultivar Bani Suef 7 and Misr 2 achieved out yielded and a high profit of (56344.06 and 55410.89 LE / fed. While at maximum seeding rates of (109.80 , 109.71 kg fed^{-1}) scored by Giza171 and cultivar Bani Suef 5 in first season. On the contrary Misr 2 and Sakha 95 out yielded the other cultivars in second season being (27.32 and 24.74ardab fed^{-1}) with return height profit (58284.76 and 52363.02 LE,) respectively. In addition to maximum seeding rates of (105.95 and 96.33 kgfed^{-1}) with sowing Giza171 and cultivar Bani Suef 5 in second season . The results regarding to that the cultivar Bani Suef 5 at the highest seeding rate of (109.71 kg fed^{-1}) gave a lower yield (22.47 ardab fed^{-1}) with minimum return profit (46691.18 LE) in first season. While Giza171 recorded low yield (23.14 ardab fed^{-1}) at the highest seeding rate of (105.95 kg fed^{-1}) with little return profit (48265.52 LE) in second season.

At the recommended seeding rate (70 kg fed^{-1}), the two cultivars Bani Suef 7 and Misr 2 recorded the highest yield (26.36 and 24.33 ardab fed^{-1}) with highly profit (55988.37 and 51918.38LE fed^{-1}) in first season, on the same side in second season Misr 2 and Sakha 95 gain the highest yield (25.03 and 23.82 ard fed^{-1}) with highly profit (53459.45 and 50572.52 LE /fed). The optimum rate for each cultivar was greater than recommended seeding rate (70 kg fed^{-1}), These results has been also found by **Gab Alla *et al.,* (2019) and Abdel-Latif, *et al*., (2023).**

The optimum economic seeding rate introduced from Figs (1-6) it can be seen that optimum seeding rate and highest grain yield for six cultivar. The two cultivars Misr 2 and Bani Suef 7 at the optimum economic seeding rate achieved seed rate (72.16 to 93.36 kgfed^{-1}) and highest grain yield ranged (26.02, 26.71 ard fed^{-1}) with net profit ranged from (55442.66 to 565428.43 LE fed) in first seasons. Misr 2 and Sakha 95 in second season recorded optimum economic seeding rate (72.01 and 81.37 kg fed^{-1}) achieved grain yield (27.31 and 24.76 ardabfed^{-1}) with maximum profit ranged from (58275.81, 52442.54

LE fed^{-1}). These results has also found by **Ashmawy and Abo- Warda (2002), Abd El-Mohsen *etal.*, 2014 and Abdel-Latif, *et al*., (2023).**

Table (8). The economic analysis of wheat grain yield under five seeding rates (SR) for six wheat cultivars in 2022/2023 and 2023/2024 seasons

First season 2022/2023						
	Maximum seeding rate (Kg fed.$^{-1}$)					
	Sahka95	**Misr 4**	**Misr 2**	**Giza171**	**BS 5**	**BS 7**
N Seed m^2	**425.58**	**433.9**	**422.11**	**506.07**	**507.6**	**439.46**
SRmax (kg/fed)	**84.14**	**86.61**	**73.32**	**109.80**	**109.71**	**94.96**
Y_{max} (ard/fed)	**24.08**	**24.12**	**26.02**	**24.37**	**22.47**	**26.69**
Profit	**50872.54**	**50898.79**	**55410.89**	**50869.04**	**46691.18**	**56344.06**
Recommended seeding rate 70 (Kg fed.$^{-1}$)						
Y_{Rec} (ard/fed)	**23.55**	**23.41**	**24.33**	**23.32**	**21.22**	**26.36**
Profit Rec	**49971.22**	**49644.08**	**51918.38**	**49291.09**	**44691.46**	**55988.37**
Optimum economic seeding rate (Kgfed.$^{-1}$)						
N Seed m^2	**382.52**	**395.85**	**384.32**	**439.93**	**449.73**	**405.99**
SRobm(kg/fed)	**82.41**	**85.06**	**72.16**	**106.62**	**106.95**	**93.36**
Y_{obm}(ard/fed)	**24.07**	**24.12**	**26.02**	**24.35**	**22.46**	**26.71**
Profit	**50898.44**	**50929.62**	**55442.66**	**50912.05**	**46734.05**	**56428.43**
Second season 2023/2024						
N Seed m^2	**430.31**	**422.89**	**424.87**	**478.99**	**455.26**	**423.54**
SRmax (kg/fed)	**82.45**	**84.65**	**72.88**	**105.95**	**96.33**	**86.63**
Y_{max} (ard/fed)	**24.74**	**24.44**	**27.32**	**23.14**	**23.87**	**23.79**
Profit	**52363.02**	**51656.05**	**58284.76**	**48265.52**	**50099.10**	**50178.66**
Recommended seeding rate 70 (kg fed.)						
Y_{Rec} (ard/fed)	**23.82**	**23.76**	**25.03**	**21.87**	**23.26**	**23.59**
Profit Rec	**50572.52**	**50429.02**	**53459.45**	**46099.41**	**49172.18**	**49900.17**
Optimum economic seeding rate (Ard fed.)						
N Seed m^2	**401.53**	**393.65**	**396.09**	**438.73**	**418.71**	**396.57**
SRobm(kg/fed)	**81.37**	**83.46**	**72.01**	**103.96**	**94.66**	**85.48**
Y_{obm}(ard/fed)	**24.76**	**24.45**	**27.31**	**23.16**	**23.84**	**23.82**
Profit	**52442.54**	**51695.21**	**58275.81**	**48347.65**	**50091.38**	**50259.03**
Average optimum seeding rate (kg/fed) in both growing season						
SR obt	**83.29**	**85.63**	**73.10**	**107.87**	**103.02**	**90.80**
Y obt	**24.42**	**24.28**	**26.66**	**23.76**	**23.15**	**25.26**
Profit	**51670.49**	**51312.42**	**56859.23**	**49629.85**	**48412.71**	**53343.73**

Maximum Seeding rate = $b_q/2c_q$, : SR_{opt}: optimum sowing rate = (CP - b)/2c, SR_{Max}, sowing rate price 25 £ kg^{-1}, the yield product price= 2200 £ ard^{-}1 and Cp= 0.011364

Accurate comparisons between the six cultivars are not achievable since the estimations of profitability yield were calculated from the response to seeding rates parameters. For example, these optimal values were computed without taking into consideration data on the relationship between seeding rate and other variables. Therefore, effort should be taken when interpreting these findings. At least they shed some light on the six wheat cultivars that were studied in terms of their respective economic performance. To confirm these findings, a more thorough economic study would be necessary. In fact, by comparing the highest rate of seeding rate with the recommended rate and compare those with the optimum rate found the optimal rate was found to use the lowest level of seeds and the yield was close to the recommended rate. It is worth mentioning that the optimum rate gave the highest yield. However, this increase is not economic since results obtained a similar return using the optimal seeding rate of seeds and the lowest rate of seeds. This from the economic point of view is the economic rate is to get the highest return at the lowest cost. The cultivars Misr 2, recorded the highest return with the highest grain yields and the lowest level of seeding rates.

Season 2022-2023 **Season 2023-2024**

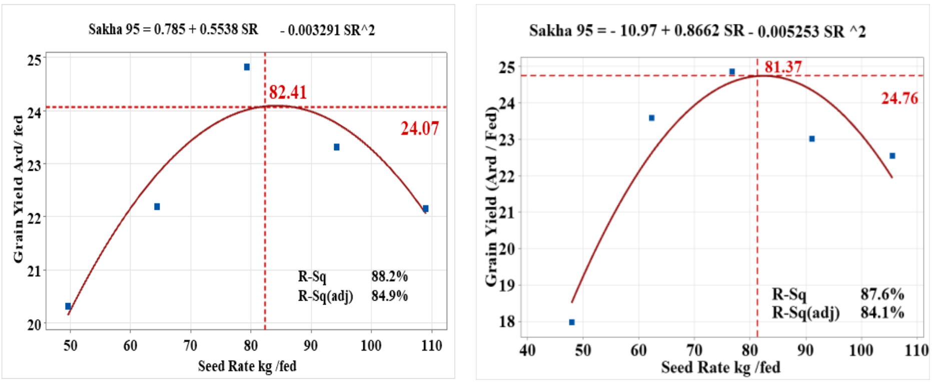

Fig (1): Reopens of grain yield of wheat cultivar Sakha 95 to seeding rate in first and second season.

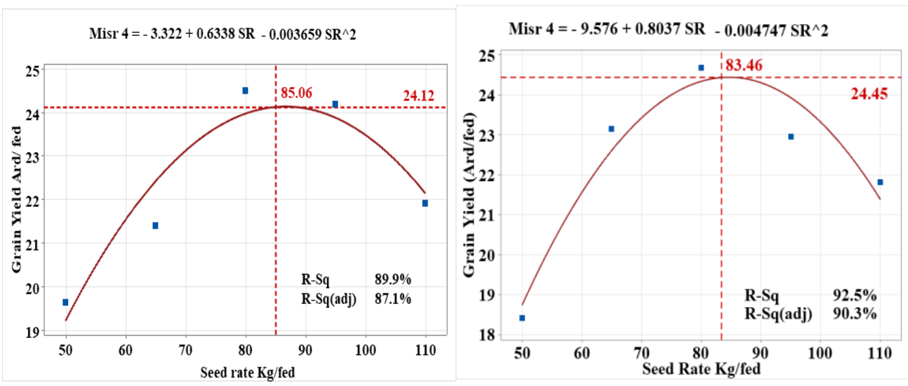

Fig (2): Reopens of grain yield of wheat cultivar Misr 4 to seeding rate in first and second season.

Season 2022-2023 **Season 2023-2024**

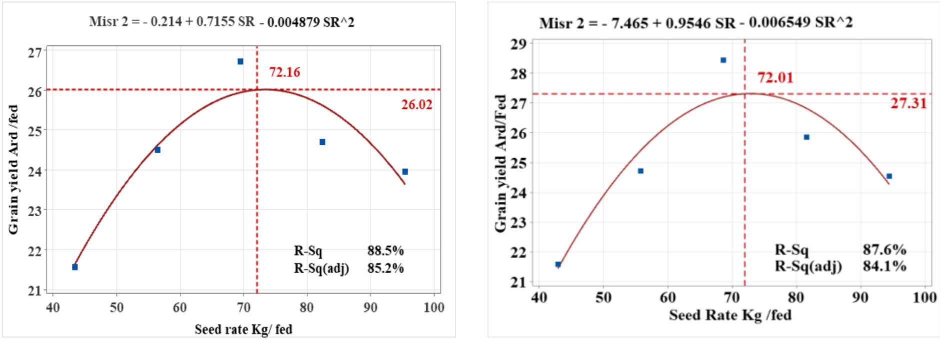

Fig (3): Reopens of grain yield of wheat cultivar Misr 2 to seeding rate in first and second season.

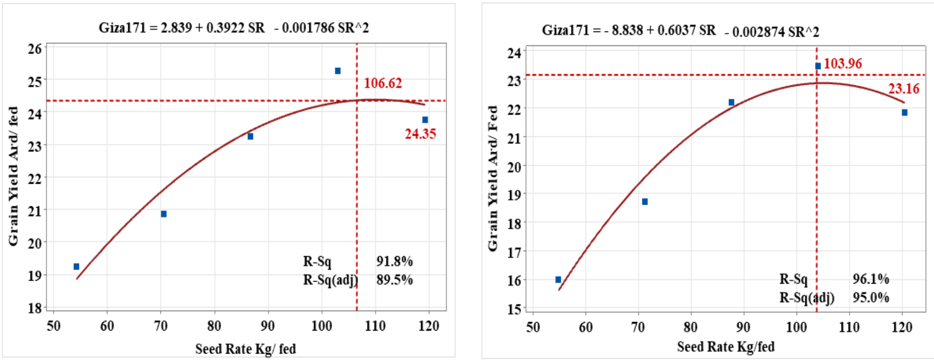

Fig (4): Reopens of grain yield of wheat cultivar Giza 171 to seeding rate in first and second season.

Season 2022-2023 **Season 2023-2024**

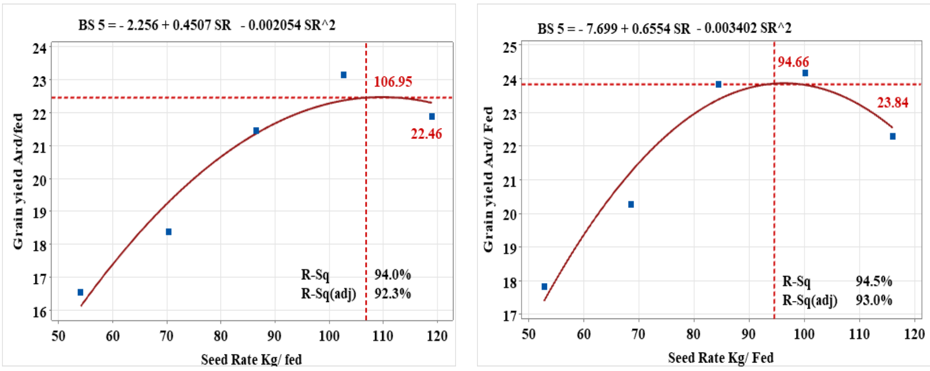

Fig (5): Reopens of grain yield of wheat cultivar Bani Suef 5 to seeding rate in first and second season.

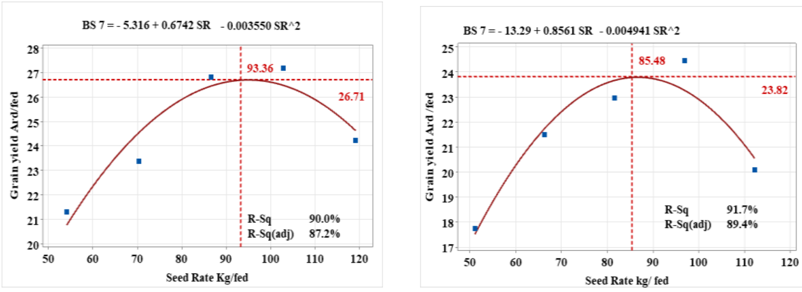

Fig (6): Reopens of grain yield of wheat cultivar Bani Suef 5 to seeding rate in first and second season.

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تحديد معدل التقاوي الامثل لبعض أصناف القمح في محافظة الوادى الجديد

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1- قسم بحوث القمح – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية.

2- المعمل المركزي لبحوث التصميم والتحليل الإحصائي- مركز البحوث الزراعية.

يعد تحسين معدلات التقاوي بما يتناسب مع كل صنف من أصناف القمح أمرًا بالغ الأهمية لتعظيم إنتاجية الحبوب والربحية، لا سيما في الأراضي الزراعية الجديدة. أُجريت تجربة حقلية خلال موسمي الزراعة 2023/2022 و2024/2023 في منطقة الفرافرة- بمحافظة الوادي الجديد – مصر، لتقييم أداء ستة أصناف من القمح: أربعة أصناف من قمح الخبز (سخا 95، مصر 4، مصر 2، جيزة 171) وصنفان من قمح المكرونة (بني سويف 5، بني سويف 7) تختلف في حجم ووزن الحبوب، تحت تأثير خمسة معدلات من التقاوي (250، 325، 400، 475، و550 حبة/م²). وقد نُفذت التجربة باستخدام تصميم القطع المنشقة بثلاث مكررات، حيث تم توزيع الأصناف على القطع الرئيسية ومعدلات التقاوي على القطع الثانوية. تم استخدام منحنى الاستجابة لتحليل اتجاهات الإنتاجية وتحديد المعدلات الاقتصادية المثلى للتقاوي. اوضحت النتائج عن وجود اختلافات عالية المعنوية بين الاصناف ومعدلات التقاوي والتفاعل بينهما على صفات التبكير، وطول النبات، ومحصول الحبوب، ومكوناته. سجل الصنف مصر 2 لقمح الخبز أعلى إنتاجية للحبوب (26.1 أردب/فدان) كمتوسط خلال الموسمين، متساويا مع قمح الديورم بني سويف 7 في الموسم الأول. بينما سجل كل من مصر 4 وسخا 95 أداءً متوسطًا، وكان اقل الاصناف في المحصول صنف جيزة 171 وبني سويف 5. أظهرت الزيادة في معدلات التقاوي عمومًا انخفاضًا في عدد الأيام حتى طرد السنابل والنضج الفسيولوجي، وعدد حبوب السنبلة، ووزن الألف حبة، بينما أدت إلى زيادة في ارتفاع النبات وعدد السنابل في المتر المربع. تم تحقيق أعلى إنتاجية لمحصول الحبوب عند استخدام معدل تقاوي 475 حبة/م² في الموسم الأول، و400 حبة/م² في الموسم الثاني. أما معدلات التقاوي المثلى (كجم/فدان) لكافة الأصناف عبر الموسمين فكانت كالتالي: مصر 2 (73.10)، سخا 95 (83.29)، مصر 4 (85.63)، بني سويف 7 (90.80)، بني سويف 5 (103.02)، وجيزة 171 (107.87كجم /فدان). وأشارت التحليلات الاقتصادية باستخدام نموذج منحني الاستجابة التربيعي إلى أن المعدل الأكثر ربحية للتقاوي كان حوالي 73 كجم/فدان، محققًا إنتاجية قصوى بلغت 26.6 أردب/فدان، وصافي ربح تجاوز 56,859.23 جنيهًا/فدان للصنف مصر 2. تؤكد النتائج ضرورة الأخذ في الاعتبار وزن الألف حبة عند تحديد معدلات التقاوي المثلى، حيث تتفاوت الأصناف في حجم الحبوب وثقلها مما يتطلب عادة معدلات أعلى من التقاوي لتحقيق أقصى إنتاجية ممكنة.