International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 4, No. 1, p. 47-57, 2014

INNSPUB

RESEARCH PAPER

OPEN ACCESS

# Determining the optimization seeding rate for improved productivity of wheat under Southern Egypt conditions

**Essam A. Abd El-Lattief**

*Agronomy Department, Faculty of Agriculture, South Valley University, Qena, Egypt*

**Article published on January 20, 2014**

**Key words:** durum wheat, seeding rate, grain yield, protein, regression, correlation.

## Abstract

Field experiments were conducted in two year to find out the optimum seeding rate (100, 200, 300 and 400 seeds m$^{-2}$) for both bread wheat Giza 168 (*Triticum aestivum* L.) and durum wheat Sohag 3 (*Triticum turgidum* L. ssp. *durum*) cultivars grown on a sandy loam-soil at Qena in Upper Egypt. The experiment was laid out Randomized Complete Block Design (RCBD) with split plot arrangement keeping cultivars (C) in main plots and seeding rate (SR) in sub plots having three replications. Grain yield and its components and grain protein concentration were measured. Grain yield and its components exhibited a significant response to seeding rate and cultivar differences. Significant interaction effects between seeding rate and cultivar were detected in both seasons on yield, selected yield components, and harvest index. But, weight of kernels per spike was not affected by seeding rate or the seeding rate x cultivar interaction. The highest grain and straw yields as well as harvest index were recorded for C1SR3 (Giza 168 cv and seeding 300 seeds m$^{-2}$), while the lowest values were found for C2SR1 (Sohag 3 cv and seeding 100 seeds m$^{-2}$). There was no significant response to seeding rate in grain protein concentration. Grains of Sohag 3 (durum wheat) were significantly higher in their protein concentration than grains of Giza 168 (bread wheat). Crop production functions with respect to seeding rates, determined for grain yield and yield components enable the results of this study to be extrapolated to other agro-climatic conditions similar to those in Qena.

* **Corresponding Author:** Essam A ✉ essamelhady2@gmail.com

## Introduction

Wheat is one of the most important cereal crops in the world and it has the widest distribution among cereal crops. The crop is primarily grown for its grain, which is consumed as human food. Wheat is also the most important cereal crop of Egypt and accounts for about 40.2 % of the total cereal production with acreage of 1.26 million hectares. Durum wheat account for about 7.86 % of the wheat cultivated area in Egypt (Anonymous, 2010).

Seeding rate strongly influences the capacity of wheat to utilize environmental resources because it influences the relative importance of intraplant and interplant competition for light, water and nutrients during crop development (Tompkins *et al.*, 1991a,b). Low seed rates decrease interplant competition, especially during vegetative growth, but increase intraplant competition during grain filling because plants tend to produce more spike-bearing tillers (Marshall and Ohm, 1987). Thus, low seed rates generally increase the weight of single spikes, but decrease the number of spikes per unit area, whereas the opposite occurs under high seed rates (Tompkins *et al.*, 1991a, b). Whaley *et al.* (2000) found that the number of kernels per wheat spike increased by 50% when the crop density decreased from 338 to 19 plants $m^{-2}$, but Ozturk *et al.* (2006) reported less than 10% increases when seed rate was decreased from 625 to 325 seeds $m^{-2}$. Optimum seeding rates vary from region to region. Usually, the occurrence of lodging and diseases increases at higher densities and leads to grain yield reduction. Beuerlein and Lafever (1989) found that as the seeding rate of winter wheat increased from 117 to 468 seeds $m^{-2}$, yields declined at an average of 8 %. Tompkins *et al.*, (1991) found that increasing seeding rates from 35 to 140 kg $ha^{-1}$ increased grain yield. Radwan, (1997) recorded the greatest plant growth and yield of wheat with a seed rate of 120 kg $ha^{-1}$. Geleta *et al.* (2002) reported the optimum seed rate on the basis of a response curve, that seeding rate of about 118 kg $ha^{-1}$ for grain yield, 97.5 kg for grain volume weight and 64 kg for 1000-kernel weight. Tomar (2004) compared seed rates of 100, 125, 150 kg $ha^{-1}$ and found that yield was maximum at the highest seeding rate of 150 kg $ha^{-1}$. Mennan and Zandstra (2005) reported that wheat grain yield increased with increasing seed rate and decreased with decreasing seed rate from 250 to 200 or 150 kg $ha^{-1}$. Ali *et al.* (2010) compared seed rates of 125, 150, 175, 200 kg $ha^{-1}$ and found that number of grains spike $^{-1}$, 1000-grain weight, grain yield and harvest index were highest under seeding rate of 150 kg $ha^{-1}$. Kiliç and Gürsoy (2010) compared seed rates of 50, 150, 250, 350, 450 and 550 seed per $m^2$ and found that seeding rate affected grain yield and yield components except protein content. The results revealed that 253 seed per $m^2$ was predicted to be an optimum seed rate for producing the highest average grain yield (5162 kg $ha^{-1}$) over years. Significant differences among varieties were also found for yield and yield parameters.

The protein content of wheat grains is of high value for defining the end-use quality of both *Triticum aestivum* and *T. durum* grain (Gooding *et al.*, 2003). In *T. aestivum*, Bavec *et al.* (2002) and Geleta *et al.* (2002) reported that grain protein concentration declined as seeding rate increased, probably because of a higher competition among plants for nitrogen. On the other hand, Tompkins *et al.* (1991a, b) found that grain protein concentration was slightly higher when 470 than with 115 seeds were sown per $m^2$. However, McLeod *et al.* (1996), Carr *et al.* (2003b) and Ozturk *et al.* (2006) found that seeding rate did not affect grain protein concentration.

Significant interactions between cultivars and seeding rates for grain yield have been reported by Briggs and Aytenfisu (1979) and Wiersma (2002). Briggs and Aytenfisu (1979) and Faris and De Pauw (1981) suggested that new wheat cultivars, particularly if they differed genetically from existing cultivars, should be tested at a wide range of seeding rates to determine their optimum seeding rate.

Hamed (1998) observed positive and highly significant correlation coefficients between grain yield and plant height, spike number $m^{-2}$, spike length, 1000-grain weight, biological and straw yields with increased seed rate.

Yield potential of wheat can be improved by optimizing the seeding rate. The objective of the present work was to determine the seeding rate to which maximizes grain yield of bread and durum wheat under high the temperatures prevalent in Qena, southern Egypt.

## Materials and methods

*Experimental site description*

The investigation was carried out at the experimental farm of the Faculty of Agriculture, South Valley University at Qena Governorate, Egypt, during two seasons (2010-11 and 2011-12). The farm is located at an altitude of 79 m above mean sea level and is intersected by 26°10′ N latitude and 32°43′ E longitude. The soil of the experimental site is sandy-loam throughout its profile (73.8 % sand, 16.6 % silt and 9.6 % clay), with a pH value of 7.79, 1.92 EC ($dSm^{-1}$), 0.46% organic matter content, 0.32% total N, 8.22, 191 ppm available P and K, respectively.

*Experimental treatments and design*

The treatments consisted two cultivars (C) i.e. $C_1$; Giza 168 (*Triticum aestivum* L.) and $C_2$; Sohag 2 (*Triticum turgidum* L. *ssp*. *Durum*) and four seeding rates (SR) i.e. $SR_1$ (100 seeds $m^{-2}$), $SR_2$ (200 seeds $m^{-2}$), $SR_3$ (300 seeds $m^{-2}$), $SR_4$ (400 seeds $m^{-2}$). The experiment was laid out Randomized Complete Block Design (RCBD) with split plot arrangement keeping cultivars in main plots and seeding rate in sub plots having three replications. Individual sub-plots were 3.0 m wide and 4 m long.

*Cultural practices*

Seeds of wheat cultivars "Giza 168 and Sohag 2" were hand sown on 15 and 17 November in the first and second seasons, respectively using the usual dry method of sowing (Broadcasting). The preceding summer crop was sorghum in both seasons. N, $P_2O_5$ and $K_2O$ fertilizes were applied at the rates of 230, 55 and 60 kg $ha^{-1}$, respectively. The phosphorus and potassium fertilizers were applied at the time of sowing. N fertilizer was applied in three equal doses; the first, during soil preparation, and the second and third after 21 and 42 days from sowing, respectively. Other agronomic practices were applied normal and were uniform for all treatments.

*Measured traits*

At harvest time, ten fertile stems were taken at random from each sub-plot for measuring plant height, number of kernels per spike and weight of kernels per spike. Number of spikes, was recorded on one square meter for each plot. Grain and straw yields were determined at harvest on plot basis. Grain protein content on dry matter basis was determined by the Kjeldahl method according to AOAC, (1995).

*Statistical analysis*

All measurements were subjected analysis of variance appropriate for the randomized complete block, split plot design, with cultivars as the main plots and seeding rates as split plots. Treatment means were separated using the Duncan's multiple range test (Steel and Torrie, 1980). Probability levels lower than 0.05 were categorized as significant. All data analyses were accomplished using the COSTAT system for windows, version 6.311 (CoHort software, Berkeley, CA, USA).

## Results and discussion

The results in the following section are based on the order of statistical significance, which ranges from the highest level interaction to the main effects of treatments. If there was a statistically significant interaction, then the main effects of the treatments and their interactions are presented.

*Yield components*

Data in Table 1 indicated that plant height was significantly affected by different seeding rates ($P < 0.01$), cultivars ($P < 0.05$) and seeding rate x cultivar interaction ($P < 0.05$). Giza 168 ($C_1$) and seed rate of 300 seeds $m^{-2}$ ($SR_3$) produced the tallest plants; 113.3 and 125.0 in 2010-11 and 2011-12, respectively. Conversely, the shortest plants of 80.0 and 78.3 cm in 2010-11 and 2011-12, respectively were obtained from the Sohag 3 cultivar ($C_2$) sown at the rate of 100 seeds $m^{-2}$ ($SR_1$, Table 2). The difference in plant height of the varieties was attributed to difference in their genetic make up. These findings were in line Khaliq *et al.*, (1999). The significance of the analyzed polynomial and its fitting to the determination coefficient ($R^2$) are shown (Table 3). The regression analysis revealed that plant height of Sohag 3 increased linearly ($R^2$ = 0.91) with seeding rate, while regression equation was not significant in Giza 168.

**Table 1.** Mean of squares from analysis of variance of some traits of wheat in 2010-11 and 2011-12 seasons

| *Source of variance* | *d.f* | *Plant height* | *Spike per m²* | *Kernels per spike* | *Kernel weight* | *Grain yield* | *Straw yield* | *Harvest index %* | *Protein %* |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 2010-11 | | | | | |
| Replication | 2 | 54.17 | 63.54 | 9.766 | 0.002 | 0.029 | 0.0256 | 1.785 | 0.127 |
| Cultivar (C) | 1 | 876.0 * | 17931** | 143.6* | 2.400** | 13.61** | 5.081** | 183.4* | 14.06* |
| Error a | 2 | 29.17 | 166.8 | 7.275 | 0.014 | 0.0295 | 0.040 | 3.564 | 0.293 |
| Seeding rate (SR) | 3 | 334.4** | 3096 ** | 98.61** | 0.0315 | 1.586** | 0.985** | 15.39** | 0.002 |
| SR x C | 3 | 195.5 * | 1350 ** | 32.25 * | 0.030 | 0.790** | 0.482** | 3.987 | 0.035 |
| Error b | 12 | 38.89 | 220.2 | 7.590 | 0.0190 | 0.041 | 0.055 | 2.447 | 0.273 |
| | | | | 2011-12 | | | | | |
| Replication | 2 | 27.38 | 52.67 | 11.22 | 0.034 | 0.022 | 0.029 | 1.910 | 0.755 |
| Cultivar (C) | 1 | 1320 * | 14652** | 99.63 * | 2.369** | 7.986** | 2.930** | 84.79* | 14.31* |
| Error a | 2 | 51.54 | 71.17 | 3.151 | 0.0163 | 0.034 | 0.024 | 2.323 | 0.258 |
| Seeding rate (SR) | 3 | 641.4** | 1072** | 96.48** | 0.035 | 2.379** | 0.435** | 67.42** | 0.145 |
| SR x C | 3 | 355.6** | 302.4* | 53.29** | 0.009 | 0.433** | 0.507** | 1.736 | 0.160 |
| Error b | 12 | 48.40 | 68.92 | 6.138 | 0.026 | 0.0582 | 0.045 | 2.758 | 0.137 |

* and ** Denotes significance at 0.05 and 0.01 probability levels, respectively.

Table 1 reveals that seeding rate, cultivar and their interaction significantly ($P < 0.01$) affected the number of spikes per square meter. More spikes per square meter were obtained as the seeding rate was increased (Table 2). Sowing 400 seeds $m^{-2}$ ($SR_4$) produced the maximum number of spikes per square meter (292 and 291), and the lowest (241 and 254) in 2010-11 and 2011-12, respectively obtained from sowing 100 seeds $m^{-2}$ ($SR_1$). Meanwhile, $SR_3$ and $SR_4$ not differ significant between them for spikes per square meter in both seasons. Giza 168 produced the highest number of spikes per square meter. The highest number of spikes per square meter for Giza 168 was due to increased number of tillers as compared to the other variety. Darwinkel *et al.,* (1977) and Spaner *et al.,* (2000) found that spike density generally increased as the seeding was increased. Regression analysis revealed that spikes per square meter in Giza 168 and Sohag 3 exhibited quadratic relation ($R^2$ = 0.88 and 0.90, respectively) to seed rate (Table 3).

The results in Table 1 reveal that differences among cultivars, seeding rates and the seeding rate x cultivar interaction significantly affected the kernels per spike in both 2010-11 and 2011-12. There was a consistent decrease in kernels per spike with increasing seed rate. Seeding 100 seeds $m^{-2}$ ($SR_1$) produced the highest kernels per spike followed by 200 seeds $m^{-2}$ ($SR_2$) without significant difference between them during both seasons (Table 2). The higher grain number obtained from the lowest seed rate can be attributed to more light penetration through the plant canopy. These results are in line with Ali *et al.*, (1996), Chaudhary *et al.,* (2000) and Rafique *et al.*, (1997), who reported that lower seeding rates significantly increased the number of grains. By increasing the seed rate, the number of grains per spike is reduced (Khan *et al.*, 2002, and Mehrvar & Ansari, 2006). Carr *et al.,* (2003a) reported an inverse relationship between seeding rate and kernel number per spike occurred. $C_1SR_2$ (Giza 168 cv and seeding 200 seeds $m^{-2}$), and $C_1SR_1$ (Sohag 3 cv and seeding 100 seeds $m^{-2}$), produced higher kernels per spike in 2010-11 and 2011-12, respectively. These results are in line with those of Hussain *et al.*, (2001). Regression analysis revealed that the number of kernels per spike decreased linearly ($R^2$ = 0.86, 0.70) with seed rate for Giza 168 and Sohag 3 (Table 3).

**Table 2.** Effect of different seeding rates on selected yield components of bread wheat (Giza 168) and durum wheat (Sohag 3) cultivars in 2010-11 and 2011-12 seasons.

| *Seeding rate (SR) (Seed m⁻²)* | *2010-11* | | | *2011-12* | | |
|---|---|---|---|---|---|---|
| | Cultivar (C) | | | | | |
| | Giza 168 ($C_1$) | Sohag 3 ($C_2$) | Mean | Giza 168 ($C_1$) | Sohag 3 ($C_2$) | Mean |
| Plant height (cm) | | | | | | |
| 100 ($SR_1$) | 108.3 ab** | 80.0 e | 94.2 B* | 103.0 bc | 78.3 d | 90.7 B |
| 200 ($SR_2$) | 96.7 cd | 93.3 d | 95.0 B | 100.0 bc | 91.7 c | 95.8 B |
| 300 ($SR_3$) | 113.3 a | 101.7 bcd | 107.5 A | 125.0 a | 95.0 c | 110.0 A |
| 400 ($SR_4$) | 110.0 ab | 105.0 abc | 107.5 A | 109.7 b | 113.3 a | 111.5 A |
| Mean | 107.1 A | 95.0 B* | | 109.4 A | 94.6 B | |
| Number of Spikes $m^{-2}$ | | | | | | |
| 100 ($SR_1$) | 264 c | 217 d | 241 C | 270 c | 238 e | 254 C |
| 200 ($SR_2$) | 292 b | 229 d | 261 B | 298 b | 242 e | 270 B |
| 300 ($SR_3$) | 325 a | 235 d | 280 A | 315 a | 250 de | 283 A |
| 400 ($SR_4$) | 302 ab | 283 bc | 292 A | 303 ab | 278 c | 291 A |
| Mean | 296 A | 241 B | | 297 A | 253 B | |
| Number of kernels $spike^{-1}$ | | | | | | |
| 100 ($SR_1$) | 51.83 ab | 52.47 ab | 52.15 A | 54.43 a | 43.27 cd | 48.85 A |
| 200 ($SR_2$) | 55.73 a | 46.07 cd | 50.90 A | 46.07 bc | 48.60 b | 47.33 A |
| 300 ($SR_3$) | 50.67 bc | 43.07 d | 46.87 B | 46.40 bc | 40.07d | 43.23 B |
| 400 ($SR_4$) | 44.70 d | 41.77 d | 43.23 C | 40.67 d | 39.34 d | 40.01 C |
| Mean | 50.73 A | 45.84 B | | 46.89 A | 42.82 B | |
| Kernels weight $spike^{-1}$ (g) | | | | | | |
| 100 ($SR_1$) | 3.500 | 2.800 | 3.150 | 3.317 | 2.777 | 3.047 |
| 200 ($SR_2$) | 3.470 | 2.677 | 3.073 | 3.323 | 2.737 | 3.030 |
| 300 ($SR_3$) | 3.270 | 2.710 | 2.990 | 3.343 | 2.647 | 2.995 |
| 400 ($SR_4$) | 3.247 | 2.770 | 3.008 | 3.223 | 2.533 | 2.878 |
| Mean | 3.372 A | 2.739 B | | 3.302 A | 2.673 B | |

*Means within columns or rows with the same letters are not significantly different at 5% level.

**Means within rows and columns with the same letters are not significantly different at 5% level.

**Table 3.** Regression equation for response of grain yield and yield components (Y) for seeding rate (X) of bread wheat (Giza 168) and durum wheat (Sohag 3) cultivars (over 2010-11 and 2011-12 seasons)

| *Variables* | *Cultivar* | *Regression equation* | *$R^2$* |
|---|---|---|---|
| Pant height | Giza 168 | Y = 99.92 | $0.21^{ns}$ |
| | Sohag 3 | Y = 70.83 + 0.096 X | $0.91^{**}$ |
| Spikes per $m^2$ | Giza 168 | $Y = 205.8 + 0.704 X - 0.0011 X^2$ | $0.88^{**}$ |
| | Sohag 3 | $Y = 242.5 - 0.210 X + 0.00075 X^2$ | $0.90^{**}$ |
| Kernels per spike | Giza 168 | Y = 57.24 - 0.0337 X | $0.86^{**}$ |
| | Sohag 3 | Y = 51.26 - 0.0277 X | $0.70^{**}$ |
| Kernels weight per spike | Giza 168 | Y = 3.489 - 0.00061 X | $0.45^{*}$ |
| | Sohag 3 | Y = 2.816 | $0.21^{ns}$ |
| Grain yield | Giza 168 | $Y = 1.285 + 0.027 X + 0.000045 X^2$ | $0.92^{**}$ |
| | Sohag 3 | Y = 2.513 + 0.0036 X | $0.94^{**}$ |
| Straw yield | Giza 168 | $Y = 4.261 + 0.0211 X - 0.000037 X^2$ | $0.97^{**}$ |
| | Sohag 3 | Y = 5.592 + 0.0016 X | $0.46^{*}$ |
| Harvest index % | Giza 168 | $Y = 30.80 + 0.075 X - 0.000116 X^2$ | $0.74^{**}$ |
| | Sohag 3 | Y = 31.43 + 0.0188 X | $0.94^{**}$ |
| Grain protein content % | Giza 168 | Y = 11.93 | $0.003^{ns}$ |
| | Sohag 3 | Y = 13.63 | $0.19^{ns}$ |

* and **: Significant at 0.05 and 0.01 probability levels, respectively. ns: indicates not significant.

The difference among cultivars in kernel weight per spike was significant (P < 0.01) while differences duo to seeding rates or seeding rate x cultivar interaction were non-significant (Table 1). Weight of kernels per spike was highest in Giza 168 (3.372 and 3.302 g in first and second seasons, respectively, Table 2). The difference in kernels weight per spike among cultivars was attributed to their inherent potential. According to regression analysis, kernels weight per spike decreased linearly ($R^2$ = 0.45) with increase in seed rate in Giza 168, while the regression was not significant in Sohag 3 (Table 3).

*Grain and straw yields*

Analysis of variance in Table 1 showed that the effect of seeding rate on grain and straw yields were highly significant (P < 0.01 in 2010-11 and 2011-12). Maximum grain and straw yields were 4.357 and 6.582 t $ha^{-1}$ in 2010-11, respectively and 4.605 and 6.654 t $ha^{-1}$ in 2011-12, respectively for the seeding rate of 300 seeds $m^{-2}$ ($SR_3$). However, the $SR_1$ (seeding 100 seeds $m^{-2}$) treatment resulted in significant grain and straw yields reduction of 26.0 % and 13.6 % in 2010-11 and 30.9 % and 9.0 % in 2011-12, respectively, compared with the $SR_3$ treatment (Table 4). These results are in harmony with Mennan and Zandstra, (2005), Soomro *et al.*, (2009) and Ali *et al.*, (2010). Similarly, Geleta *et al.,* (2002) found 33 % more grain yield from wheat seeded at 65 and 130 kg $ha^{-1}$ compared with the 16 kg $ha^{-1}$ seeding rate. The higher grain and straw yields in the higher seeding rates were associated with higher spike number per square meter. Spike number $m^{-2}$ was, therefore, judged to be the most important component in determining grain and straw yields. Grain and straw yields were also significantly affected by cultivars (P < 0.01 in 2010-11 and 2011-12). Table 4 also shows that Giza 168 produced significantly higher grain and straw yields $ha^{-1}$ than Sohag 3 by 32.1 and 14.2% in the first season and 24.1 and 9.8 % in the second season, respectively. This could be due to differences in the genetic make-up of the two studied cultivars. These results are in line with those of Miyan and Anderson, (2008) who found that grain yield of durum wheat cultivars yielded 4.3% less than the bread wheat cultivars. In the present study, there was a significant interaction between seeding rate and cultivar for grain and straw yields (Table 1). In most cases, the highest grain and straw yields were obtained from seeding 300 seeds $m^{-2}$ ($SR_3$) for Giza 168 ($C_1$) and 400 seeds $m^{-2}$ ($SR_4$) for Sohag 3 ($C_2$). The highest values of grain yield (5.644 and 5.572 t $ha^{-1}$ in the first and second seasons, respectively) and straw yield (7.077 and 7.472 t $ha^{-1}$) were obtained for $C_1SR_3$ (Giza 168 and seeding 300 seeds $m^{-2}$), whereas, the lowest grain yield (2.870 and 2.973 t $ha^{-1}$) and straw yield (5.373 and 6.182 t $ha^{-1}$) were obtained from $C_2SR_1$ in the first and second seasons, respectively (Table 4). Regression analysis revealed that grain yield ($R^2$ = 0.92) and straw yield ($R^2$ = 0.97) show a quadratic relation with seed rate in Giza 168, while a linear relationship was obtained between the seeding rate and grain yield ($R^2$ = 0.94) and straw yield ($R^2$ = 0.46) for Sohag 3 (Table 3).

**Table 4.** Effect of different seeding rates on grain and straw yields, harvest index and grain protein content of bread wheat (Giza 168) and durum wheat (Sohag 3) cultivars in 2010-11 and 2011-12 seasons

| *Seeding rate (SR) (Seed $m^{-2}$)* | *2010-11* | | | *2011-12* | | |
|---|---|---|---|---|---|---|
| | Cultivar (C) | | | | | |
| | Giza 168 ($C_1$) | Sohag 3 ($C_2$) | Mean | Giza 168 ($C_1$) | Sohag 3 ($C_2$) | Mean |
| Grain yield (t $ha^{-1}$) | | | | | | |
| 100 ($SR_1$) | 3.652 c* | 2.870 d | 3.261 C | 3.597 de | 2.973 f | 3.285 C |
| 200 ($SR_2$) | 4.635 b | 3.040 d | 3.837 B | 4.894 b | 3.293 ef | 4.094 B |
| 300 ($SR_3$) | 5.644 a | 3.169 d | 4.407 A | 5.572 a | 3.940 cd | 4.756 A |
| 400 ($SR_4$) | 4.849 b | 3.675 c | 4.262 A | 5.052 b | 4.293 c | 4.673 A |
| Mean | 4.695 A | 3.188 B | | 4.779 A | 3.625 B | |
| Straw yield (t $ha^{-1}$) | | | | | | |
| 100 ($SR_1$) | 5.570 cd | 5.373 d | 5.472 A | 6.409 cd | 6.182 d | 6.296 A |
| 200 ($SR_2$) | 6.674 b | 5.435 d | 6.055 A | 7.430 a | 6.387 cd | 6.909 A |
| 300 ($SR_3$) | 7.077 a | 5.588 cd | 6.332 A | 7.472 a | 6.371 cd | 6.921 A |
| 400 ($SR_4$) | 6.708 a | 5.944 c | 6.326 B | 7.041 b | 6.619 c | 6.830 B |
| Mean | 6.507 A | 5.585 B | | 7.088 A | 6.390 B | |
| Harvest index (%) | | | | | | |
| 100 ($SR_1$) | 39.59 bc | 34.80 e | 37.20 B | 35.21 d | 31.78 e | 33.50 C |
| 200 ($SR_2$) | 41.02 b | 35.11 e | 38.07 B | 39.49 bc | 34.90 d | 37.20 B |
| 300 ($SR_3$) | 44.38 a | 36.77 de | 40.57 A | 42.86 a | 38.22 c | 40.54 A |
| 400 ($SR_4$) | 41.95 ab | 38.14 cd | 40.05 A | 41.71 a | 39.32 c | 40.52 A |
| Mean | 41.73 A | 36.21 B | | 39.82 A | 36.06 B | |
| Grains protein content (%) | | | | | | |
| 100 ($SR_1$) | 11.90 | 13.55 | 12.73 | 12.30 | 13.60 | 12.95 |
| 200 ($SR_2$) | 11.88 | 13.55 | 12.72 | 11.56 | 13.58 | 12.57 |
| 300 ($SR_3$) | 12.04 | 13.48 | 12.76 | 12.07 | 13.47 | 12.77 |
| 400 ($SR_4$) | 12.06 | 13.42 | 12.74 | 12.06 | 13.50 | 12.78 |
| Mean | 11.97 B | 13.50 A | | 12.00 B | 13.54 A | |

*Means within columns or rows with the same letters are not significantly different at 5% level.

**Means within rows and columns with the same letters are not significantly different at 5% level.

*Harvest index*

Seed rate ($P < 0.01$) as well as cultivar ($P < 0.05$) had significant effects on harvest index in both 2010-11 and 2011-12. On the other hand, the interaction between the two factors was non-significant for both years (Table 1). Giza 168 produced significantly higher harvest index than Sohag 3. Seeding 300 and 400 seeds m$^{-2}$ produced the maximum harvest index in both seasons without significant difference between them (Table 4). However, Mollah *et al.,* (2009) reported that seed rate did not have a significant effect on harvest index of wheat in bed planting condition. Giza 168 showed a quadratic trend ($R^2$ = 0.74) for harvest index for the different seeding rates. Meanwhile, Sohage 3 showed a positive linear trend ($R^2$ = 0.94) for harvest index (Table 3).

*Grain-protein concentration*

Grain-protein concentration was not affected by seeding rate or seeding rate x cultivar interaction (Tables 1, 4). These results are supported by the findings of others (Khaliq *et al.*,1999, Hussain *et al.*, 2001, Patrick *et al.*, 2003, Carr *et al.*, 2003b, Ozturk *et al.*, 2006 and Nakano & Morita, 2009) who found that wheat grain protein concentration was unaffected by seeding rate. On the other hand, Bavec *et al.,* (2002) and Geleta *et al.,* (2002) reported that grain protein concentration declined as seeding rate increased. Seeds of Sohag 3 were significantly higher in protein content than those of Giza 168 in both seasons (Table 4). According to regression analyses, there was neither linear nor quadratic relationship between protein concentration and seed rate for both cultivars (Table 3).

*Correlation coefficients*

Simple correlation coefficients calculated over treatments in 2010-11 and 2011-12 are given in Table 5. Grain yield was positively and significantly correlated with plant height (r = 0.626 and 0.750), number of spike per square meter (r = 0.906 and 0.901), kernels weight per spike (r = 0.618 and 0.518), straw yield (r = 0.948 and 0.835) and harvest index (r = 0.934 and 0.921) in 2010-11 and 2011-12, respectively. This indicated that increasing these attributes, invariably resulted increased in grain yield. In most of the previous studies, similar results have been reported by Khan *et al.*, (1999), Dokuyucu and Akkaya, (1999), Mondal and Khadjura, (2001). Meanwhile, grain yield was not significantly correlated with number of kernels per spike (r = 0.203 and -0.196, in 2010-11 and 2011-12, respectively). Conversely, grain yield was negatively and significantly correlated with grain protein content (r = -0.688 and -0.643) in 2010-11 and 2011-12, respectively.

**Table 5.** Simple correlation coefficients of grain yield ha$^{-1}$ as affected by yield components (2010-11 and 2011-12 seasons)

| ***Variables*** | ***2010-11*** | ***2011-12*** |
|---|---|---|
| **Y: Grain yield ha$^{-1}$** | | |
| 1-Pant height | 0.626 ** | 0.750 ** |
| 2-Spikes per m$^2$ | 0.906 ** | 0.901 ** |
| 3-Kernels per spike | 0.203 $^{ns}$ | -0.196 $^{ns}$ |
| 4-Kernels weight per spike | 0.618 ** | 0.518 ** |
| 5-Straw yield ha$^{-1}$ | 0.948 ** | 0.853 ** |
| 7-Harvest index % | 0.934 ** | 0.921 ** |
| 8-Grain protein content % | -0.688 ** | -0.643 ** |

* and **: Significant at 0.05 and 0.01 probability levels, respectively.     ns: indicates not significant.

**Conclusions**

There were significant differences between cultivars in all studied traits in both years. In addition, significant differences due to seeding rates on all traits except weight of kernels per spike and grain protein concentration in the first and second seasons were found. The interaction between cultivar and seeding rate was significant for all studied traits except weight of kernels per spike, harvest index and grain protein concentration. The highest grain and straw yields were obtained from seeding 300 seeds $m^{-2}$ or 400 seeds $m^{-2}$ when planting Giza 168 or Sohag 3 cultivars, respectively. Based on these results, it is recommended to sow 300 seeds $m^{-2}$ (150 kg $ha^{-1}$) for planting bread wheat (Giza 164), or 400 seeds $m^{-2}$ (180 kg $ha^{-1}$) for planting durum wheat (Sohage 3) to obtain the highest grain and straw yields.

**References**

**Anonymous.** 2010. Statistics of agricultural production. Economic Affairs Sector, Ministry of Agriculture and Land Reclamation, Egypt.

**AOAC.** 1995. Official Methods of Analysis. 12th ed. Association of Official Analysis Chemists, Washington, DC. U.S.A.

**Ali M, Ali L, Sattar M, Ali MA.** 2010. Improvement in wheat (*Triticum aestivum* L.) yield by manipulating seed rate and row spacing in Vehai zone. Journal of Animal and Plant Sciences **20,** 225-230.

**Ali MA, Rehman R, Siddique M, Rashid M.**1996. Effect of seed rate and row spacing on wheat yield. Journal of Agricultural Research **34,** 351-357.

**Ansari MA, Meman HR, Tunio SD, Keerio SA.** 2006. Effect of planting pattern on growth and yield of wheat. Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences **22,** 6-11.

**Bavec M, Bavec F, Varga B, Kovacevic V.** 2002. Relationships among yield, its quality and yield components, in winter wheat (*Triticum aestivum* L.) cultivars affected by seeding rates. Bodenkultur **53,** 143-151.

**Beuerlein JE, Lafever HN.** 1989. Row spacing and seeding rate effects on soft red winter wheat yield, its components and agronomic characteristics. Applied of Agricultural Research **4,** 106-110.

**Briggs KG, Aytenfisu A.** 1979. The effects of seeding rate, seeding date and location on grain yield, maturity, protein percentage and protein yield of some spring wheats in central Alberta. Canadian Journal of Plant Sciences **59,** 1139-1145.

**Carr PM, Horsley RD, Poland WW.** 2003a. Tillage and seeding rate effects on wheat cultivars: II. Yield components. Crop Sciences **43**, 210-218.

**Carr PM, Horsley RD, Poland WW.** 2003b. Tillage and seeding rate effects on wheat cultivars. I. Grain production. Crop Sciences **43,** 202-209.

**Chaudhary MA, Ali A, Siddique MA, Sohail R.** 2000. Growth and yield response of wheat to different seed rates and wild oat (*Avena fatua*) competition durations. Pakistan Journal of Agricultural Sciences **37,** 152-154.

**Darwinkel A, Hag BA, Kuizenga J.** 1977. Effect of sowing date and seed rate on crop development and grain production of winter wheat. Netherlands Journal of Agricultural Science **5,** 83-94.

**Dokuyucu T, Akaya A.** 1999. Path coefficient analysis of correlation of grain yield and yield components of wheat (*Triticum aestivum* L.) genotypes. Rachis **18**, 17-20.

**Faris DG, De Pauw RM.** 1981. Effect of seeding rate on growth and yield of three spring wheat cultivars. Field Crops Research **3,** 289-301.

**Geleta B, Atak M, Baenziger PS, Welson LA, Baltenesperger DD, Eskridge KM, Shipnian**

**MJ, Sheton DR.** 2002. Seeding rate and genotype effect on agronomic performance and end use quality of winter wheat. Crop Sciences **42,** 827-832.

**Gooding MJ, Ellis RH, Shewry PR, Schofield JD.** 2003. Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter wheat. Journal of Cereal Sciences **37,** 295–309.

**Hamed MF.** 1998. Performance of wheat under nitrogen level, ethrel and seeding rate. Annals of Agricultural Sciences, Moshtohor **36,** 21-30.

**Hussain S, Sajjad A, Hussain MI, Saleem M.** 2001. Growth and yield response of three wheat varieties to different seeding densities. International Journal of Agricultural and Biology **3,** 228-229.

**Khaliq A, Iqbal M, Basra SMA.** 1999. Optimisation of seeding densities and nitrogen application in wheat cv. Inqalab-91 under Faisalabad conditions. International Journal of Agricultural and Biology **1**, 241-243.

**Khan AZ, Khan H, Khan R, Adel Ghoneim, Ebid A.** 2002. Effect of sowing dates and seed rates on yield and yield components of wheat. Trends in Applied Sciences Research **2,** 529-534.

**Khan HA, Shaik M, Mohammad S.** 1999. Character association and path coefficient analysis of grain yield and yield components in wheat. Crop Research, Hisar **17,** 229-233.

**Kiliç H, Gürsoy S.** 2010. Effect of seeding rate on yield and yield components of durum wheat cultivars in cotton-wheat cropping system. Scientific Research and Essays **5**, 2078-2084.

**Kirkland KJ, Holm FA, Stevenson FC.** 2000. Appropriate crop seeding rate when herbicide rate is reduced. Weed Technology **14,** 692-698.

**Marshall GC, Ohm HW.** 1987. Yield responses of 16 winter wheat cultivars to row spacing and seeding rate. Agronomy Journal **79,** 1027-1030.

**McLeod JG, Campbell CA, Gan Y, Dyck FB, Vera CL.** 1996. Seeding depth, rate and row spacing for winter wheat grown on stubble and chemical fallow in the semiarid prairies. Canadian Journal of Plant Sciences **76,** 207-214.

**Mennan H, Zandstra BH.** 2005. Influence of wheat seeding rate and cultivars on competitive ability of bifra (*Bifora radians*). Weed Technology **19,** 128-136.

**Miyan S, Anderson W.** 2008. Responses of bread and durum wheat to agronomic practices in Western Australia. Proceedings of 14th Agronomy Conference, 21-25 September 2008, Adelaide, South Australia.

**Mollah MIU, Bhuiya MSU, Kabir MH.** 2009. Bed Planting-A New Crop Establishment Method for Wheat in Rice-Wheat Cropping System. Journal of Agricultural and Rural Development **7,** 23-31.

**Mondal SK, Khajuria MR.** 2001**.** Correlation and path analysis in bread wheat (*Triticum aestivum* L.) under rainfed condition. Environment and Ecology **18,** 405-408.

**Ozturk A, Caglar O, Bulut S.** 2006. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. Journal of Agronomy and Crop Sciences **192,** 10-16.

**Radwan FI.** 1997. Effect of seeding date ad seeding rate on growth and yield of wheat (*Triticum aestivum* L.). Annals of Agricultural Sciences, Moshtohor **35,** 1079-1097.

**Rafique M, Ahmad A, Muhammad N, Siddique M, Kamran M.** 1997. Effect of seeding densities and planting techniques on late sown wheat (*Triticum* *aestivum* L.) yield. Journal of Agricultural Research **35,** 147-153.

**Soomro UA, Rahman MU, Odhano EA, Gul S, Tareen AQ.** 2009. Effects of sowing method and seed rate on growth and yield of wheat (*Triticum aestivum* L.). World Journal of Agricultural Sciences **5,** 159-162.

**Spaner D. Todd AG, McKenzie DB.** 2000. The effect of seeding date, seeding rate and N fertilization on winter wheat yield and yield components in eastern Newfoundland. Canadian Journal of Plant Sciences **80,** 703-711.

**Steel RGD, Torrie JH.** 1980. Principles and Procedures of Statistics, 2nd ed. McGraw-Hill, New York.

**Tomar SK.** 2004. Response of rainfed wheat to sowing methods and seed rate under Diara land condition. Madras Agricultural Journal **91,** 47-51.

**Tompkins DK, Fowler DB, Wright AT.** 1991a. Water use by no-till winter wheat. Influence of seed rate and row spacing. Agronomy Journal **83,** 766-769.

**Tompkins DK, Hultgreen GE, Wright AT, Fowler DB.** 1991b. Seed rate and row spacing of no-till winter wheat. Agronomy Journal **83,** 684-689.

**Whaley JM, Sparkes DL, Foulkes MJ, Spink JH, Semere T, Scott RK.** 2000. The physiological response of winter wheat to reductions in plant density. Annals of Applied Biology **137,** 165-177.

**Wiersma JJ.** 2002. Determining an optimum seeding rate for spring wheat in northwest Minnesota. Online. Crop Management doi:10.1094/CM-2002-0510-01-RS.