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Bread Wheat (*Triticum aestivum* L.) Productivity and Profitability as Affected by Method of Sowing and Seeding Rate Under Qena Environment

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ABSTRACT

Sowing methods and seeding rate play an important role in the placement of seed at proper depth and stand establishment of the growing crop which ultimately affects crop growth and productivity. This study was conducted for 2 seasons to establish optimal sowing method and seeding rate for bread wheat (*Triticum aestivum* L.) in sandy-loam soil. The study aimed at achieving high yield and profit. A field experiment was conducted using a randomized complete block in split plot design with three planting techniques (hilling in ridges, drilling in rows and broadcasting) and four seeding rates (100, 125, 150 and 175 kg ha^{-1}) as the main plot and split plot, respectively. Results revealed that all yield and yield parameters were significantly affected by the sowing method and seed rate, while grain protein content was non-significant by these factors. The interaction of sowing method and seed rate significantly affected the number of effective tillers m^{-2}, weight of grains $spike^{-1}$, grain and straw yields ha^{-1} and harvest index. Wheat sown by drilling method at the seed rate 150 kg ha^{-1} gave the highest values of grain and straw yields ha^{-1} and harvest index and this treatment was found to be most economical. Based on these results, it is recommended to sow 150 kg ha^{-1} seeds by using drill method for planting bread wheat Giza 168 cv under similar soil and climatic conditions. Correlation coefficients analyses revealed positive significant relationships between grain yield and plant height, effective tillers m^{-2}, grain number $spike^{-1}$, straw yield and harvest index.

Key words: Bread wheat, grain yield, protein, profit, correlation

INTRODUCTION

Wheat is the world's most important and most widely grown cereal crop. Its importance is derived from many properties and uses of its grains which makes it a staple food for more than one third of world's population (Poehlman, 1987). Moreover, its straw is used as animal feed and also in manufacturing paper. The selection of suitable sowing method plays an important role in the placement of seed at proper depth which ensures better emergence and good subsequent crop growth. Wheat is planted with different sowing methods depending upon the available soil water, time of planting, amount of preceding crop residues in the field and availability of planting machinery (Sikander *et al.*, 2003). In Egypt, wheat is planted through broadcasting in a large area after rice, maize and cotton. Broadcasting not only requires higher seed rate but also results in lower plant population, whereas drill sowing method is recommended because of uniform seed distribution and sowing at desired depth which results in higher germination and uniform stand. Due to differences in crop stand establishment, wheat grain yield was significantly affected by different sowing methods including broadcast and line sowing (Singh and Singh, 1992; Galichenko, 1994; Singh *et al.*, 1994; Jan *et al.*, 2001).

Seeding rate is one of the important production factors. Higher wheat grain yield with better quality requires appropriate seeding rate for various varieties. Therefore, the response of wheat yield to seeding rates were discussed by several workers (Radwan, 1997; Geleta *et al.*, 2002; Tomar, 2004; Mennan and Zandstra, 2005; Soomro *et al.*, 2009; Ali *et al.*, 2010). Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Sajjad *et al.*, 2010). Some researchers reported that wheat grain yield positively associated with plant height, productive tillers, spike length, grains spike^{-1}, seed index and harvest index (Hamed, 1998; Burio *et al.*, 2004; Kotal *et al.*, 2010).

In view the importance of sowing method and seed rate, the present study was designed to determine the best sowing method and seed rate for bread wheat productivity and profitability under the conditions of this study.

MATERIALS AND METHODS

A field experiment was conducted during the winter season of 2009-2010 and 2010-2011 at the Experimental Farm of the Faculty of Agriculture, South Valley University (latitude 26°10' N, longitude 32°43' E, Altitude 79 m above sea level) at Qena Governorate, Upper Egypt. The soil of the experimental area was sandy loam having pH 7.9, organic matter content 0.11%; total N 0.54%; available P and K (ppm) were 8.20 and 152%, respectively.

The treatments comprised three sowing methods i.e., hilling in ridges (50 cm apart of ridges, on the two sides with 10 cm between hills), drilling in rows (15 cm apart of rows) and broadcasting designed as M_1, M_2 and M_3, respectively and four seed rates i.e., 100 (S_1), 125 (S_2), 150 (S_3) and 175 (S_4) kg seeds ha^{-1}. A randomized complete block split plot design with four replicates was used in each season. Sowing methods were randomly assigned to the main plots and seed rates were assigned to the split plots. Individual sub plots measured 3.0 m in width and 5 m in length.

Grains of bread wheat cv. Giza 168 were sown on mid November in both seasons. NPK fertilizer at the rate of 230:55:60 kg ha^{-1} was applied at the time of sowing for PK and four equal doses of N; during soil preparation 21, 42 and 63 days from sowing. The preceding summer crop was sunflower in both seasons. All other agronomic practices were kept uniform for both experiments.

At harvest time, ten fertile stems were taken at random from each sub-plot for measuring plant height, number and weight of grains spike^{-1}. Number of effective tillers, was recorded on one square meter plot^{-1}. Also, 1000-grain weight was estimated for each sub-plot. Meanwhile, grain and straw yields were estimated at sub-plot basis. Grain protein content on dry matter basis was determined, according to AOAC (1975).

Data of each season were subjected to variance analysis (ANOVA) using statistical analysis system followed by Least Significant Difference (LSD) test. The results were considered significant at $p \leq 0.05$ by MSTAT-C software.

RESULTS AND DISCUSSION

Yield components: The yield components; plant height, number of effective tillers m^{-2}, number of grains spike^{-1}, weight of grains spike^{-1}, 1000-grain weight are presented in Table 1. Both the sowing method and seeding rate significantly affected all yield components. In both seasons, drill method (M_2) demonstrated highest values for all yield components and the lowest by broadcasting

Table 1: Effect of sowing method and seeding rate on selected yield components in 2009-2010 and 2010-2011 seasons

	Sowing methods (M)							
	2009-10				2010-11			
Seeding rate kg ha^{-1} (S)	Hilling in ridges (M_1)	Drill (M_2)	Broadcast (M_3)	Mean	Hilling in ridges (M_1)	Drill (M_2)	Broadcast (M_3)	Mean
Plant height (cm)								
100 (S_1)	96.7	104.0	90.0	96.9	88.7	101.0	82.0	90.6
125 (S_2)	100.0	95.0	100.0	98.3	92.0	92.0	92.0	92.0
150 (S_3)	111.7	112.3	96.7	106.9	108.0	114.3	93.7	105.3
175 (S_4)	116.3	117.7	105.0	113.0	106.3	115.7	97.0	106.3
Mean	106.2	107.3	97.9		98.8	105.8	91.2	
LSD (0.05)	M: 6.5	S: 4.6	M×S: ns		M: 6.4	S: 4.7	M×S: ns	
Effective tillers (m^2)								
100 (S_1)	305.0	303.3	213.3	273.9	295.0	295.3	202.3	264.2
125 (S_2)	277.7	306.0	286.7	290.1	267.7	298.0	275.7	280.4
150 (S_3)	303.7	316.7	292.7	304.3	293.7	308.7	281.7	294.7
175 (S_4)	293.7	348.7	289.3	310.6	284.3	339.7	278.3	300.8
Mean	295.0	318.7	270.5		285.2	310.4	259.5	
LSD (0.05)	M: 21.7	S: 12.8	M×S: 22.2		M: 22.0	S: 12.8	M×S: 22.3	
Grains per spike								
100 (S_1)	47.0	48.6	37.7	44.4	44.0	44.9	34.2	41.0
125 (S_2)	47.9	54.0	43.2	48.4	44.9	50.0	40.7	45.2
150 (S_3)	48.8	58.3	49.6	52.2	45.8	54.3	47.1	49.0
175 (S_4)	56.9	60.1	48.9	55.3	53.9	56.1	46.4	52.1
Mean	50.1	55.3	44.8		47.1	51.3	42.1	
LSD (0.05)	M: 3.91	S: 3.04	M×S: ns		M: 3.59	S: 3.12	M×S: ns	
Grain weight per spike (g)								
100 (S_1)	2.667	3.030	2.368	2.688	2.646	3.425	3.012	3.027
125 (S_2)	2.804	3.017	2.241	2.687	2.768	3.410	2.367	2.848
150 (S_3)	2.324	2.277	2.790	2.464	2.441	3.230	2.304	2.658
175 (S_4)	2.632	2.632	2.236	2.503	3.190	2.657	2.024	2.624
Mean	2.607	2.739	2.409		2.761	3.181	2.427	
LSD (0.05)	M: 0.134	S: 0.147	M×S: 0.254		M: 0.137	S: 0.149	M×S:0.257	
1000-Grain weight (g)								
100 (S_1)	42.70	46.33	40.00	43.01	44.70	48.53	37.80	43.68
125 (S_2)	40.23	42.72	35.33	39.43	42.23	44.92	33.13	40.10
150 (S_3)	36.90	42.07	32.94	37.30	38.90	44.27	30.74	37.97
175 (S_4)	33.87	41.13	26.75	33.91	35.20	43.33	28.95	35.83
Mean	38.43	43.06	33.76		40.26	45.26	32.66	
LSD (0.05)	M: 3.90	S: 2.15	M×S: ns		M: 3.85	S: 2.04	M×S: ns	

M: Sowing method, S: Seed rate M×S: Sowing method and seed rate interaction, ns: Not significant at 5% level of significance. LSD: Least Significant Difference

(M_3). These findings are in close conformity with Tomar (2004), who found that lowest number of effective shoots m^{-2}, grain spike^{-1} and test weight were recorded with broadcasting method. Increasing the seed rate up to 175 kg ha^{-1} produced the highest values for all yield components and lower 1000-grain weight (Table 1). The lowest values of grains weights spike^{-1} were obtained from seed rate of 150 and 175 kg ha^{-1} in the first and second seasons, respectively (Table 1). Seeding wheat at 100 kg ha^{-1} resulted in lower values for yield components, while highest values for weights of grains $spike^{-1}$ (2.688 and 3.027 g) and 1000-grain weight (43.01 and 43.68 g, in the first and second seasons, respectively) were recorded (Table 1). These findings are in agreement with Arif *et al.* (2001), who showed that increasing seed rate from 100 to 175 kg ha^{-1} significantly decreased 1000-grain weight. Meanwhile, Hameed *et al.* (2003) found that higher seed rate (100 or 125 kg ha^{-1}) had more tillers m^{-2}.

The combined effect of sowing methods and seeding rate had a significant effect on number of effective tillers m^{-2} and weight of grains $spike^{-1}$ (Table 1). The highest values for effective tillers m^{-2} (348.7 and 339.7 in the first and second seasons, respectively) and weight of grains $spike^{-1}$ (3.030 and 3.425 g) were obtained form M_2S_4 and M_2S_1, respectively. The lowest values for above mentioned traits were obtained form M_3S_1 (213.3 and 202.3) and M_3S_4 (2.236 and 2.024 g), respectively (Table 1).

Wheat productivity and harvest index: Grain and straw yields and harvest index were significantly affected by sowing method (Table 2). In both seasons, seed broadcasting consistently resulted in lower grain and straw yields and harvest index compared to other treatments (hilling in ridges and drill). The highest values of grain (4152 and 4044 kg ha^{-1}) and straw (7048 and 6847 kg ha^{-1}) yields and harvest index (0.371 and 0.371) were obtained from drilling planting method in the first and second seasons, respectively (Table 2). These findings are in conformity with Soomro *et al.* (2009), who reported that wheat sown by drilling significantly increased the plant vigor and yield. Broadcast sowing was also considered inferior than other methods (Collins and Fowler, 1992; Tanveer *et al.*, 2003). Sikander *et al.* (2003) also found that broadcasting method of sowing decreased harvest index compared with drill sowing. El-Kholy and Gaballah (2005) found that drilling cultivation method surpassed ridges and hills. Higher yield in drill sowing was ascribed to more effective tillers m^{-2}, more grains per spike, heaviest grains and 1000-grain weight and better harvest index.

Grain and straw yields and harvest index were also significantly influenced by seeding rates. Seed rates of 175 or 150 kg ha^{-1} were optimum under the conditions of this study (Table 2). Seed rate of 100 kg ha^{-1} showed significant decreases of grain (3086 and 2941 kg ha^{-1}) and straw (5609 and 5591 kg ha^{-1}) yields and harvest index (0.353 and 0.345) in the first and second seasons, respectively (Table 2). These results are in harmony with Mennan and Zandstra (2005), Soomro *et al.* (2009) and Ali *et al.* (2010).

The interaction between sowing method and seeding rate had a significant effect on grain and straw yields and harvest index in both 2009-2010 and 2010-2011 seasons (Table 2). The highest values of grain (4830 and 4840 kg ha^{-1} in the first and second seasons, respectively) and straw (8483 and 8377 kg ha^{-1}) yields were obtained for M_2S_3 (drill method at seed rate of 150 kg ha^{-1}). The lowest values of grain (2547 and 2523 kg ha^{-1} in the first and second seasons, respectively) and straw (5000 and 5240 kg ha^{-1}) yields were obtained from M_3S_1 (broadcasting method at seed rate of 100 kg ha^{-1}). For harvest index, the highest values were obtained for M_1S_3 (0.383) and M_2S_4 (0.393), in the first and second seasons, respectively and the lowest for M_3S_2 (0.334) and M_3S_1 (0.325) for 2009-10 and 2010-11, respectively (Table 2). Therefore, the combination of a drill method with a seed rate of 150 kg ha^{-1} is recommended as the treatment that maximizes grain and straw yields of wheat under this study. These findings are in conformity with Soomro *et al.* (2009), who found that wheat sown by drilling method at the seed rate of 150 kg ha^{-1} significantly

Table 2: Effect of sowing method and seeding rate on grain and straw yields, harvest index and grain protein content in 2009-2010 and 2010-2011 seasons

	Sowing methods (M)							
	2009-10				2010-11			
Seeding rate kg ha^{-1} (S)	Hilling in ridges (M_1)	Drill (M_2)	Broadcast (M_3)	Mean	Hilling in ridges (M_1)	Drill (M_2)	Broadcast (M_3)	Mean
Grain yield (kg ha^{-1})								
100 (S1)	2760	3950	2547	3086	3157	3143	2523	2941
125 (S2)	3717	3983	3013	3571	3207	3993	3047	3416
150 (S3)	3917	4830	3283	4010	3413	4840	3317	3857
175 (S4)	4607	3843	3680	4043	4683	4200	3517	4133
Mean	3750	4152	3131		3615	4044	3101	
LSD (0.05)	M: 370	S: 320	M×S: 555		M: 360	S: 310	M×S: 537	
Straw yield (kg ha^{-1})								
100 (S1)	5177	6650	5000	5609	5357	6177	5240	5591
125 (S2)	6393	6767	6003	6388	5773	6357	6123	6084
150 (S3)	6303	8483	6430	7027	6233	8377	5897	6836
175 (S4)	8060	6293	6727	7072	7943	6477	6883	7101
Mean	6483	7048	6040		6327	6847	6036	
LSD (0.05)	M: 440	S: 435	M×S: 754		M: 262	S: 342	M×S: 593	
Harvest index								
100 (S1)	0.348	0.373	0.337	0.353	0.371	0.337	0.325	0.345
125 (S2)	0.368	0.371	0.334	0.357	0.357	0.386	0.332	0.360
150 (S3)	0.383	0.363	0.338	0.361	0.354	0.366	0.360	0.361
175 (S4)	0.364	0.379	0.354	0.365	0.371	0.393	0.338	0.367
Mean	0.365	0.371	0.341		0.363	0.371	0.339	
LSD (0.05)	M: 0.012	S: 0.010	M×S: 0.018		M: 0.015	S: 0.013	M×S: 0.020	
Grain protein content (%)								
100 (S1)	11.56	12.00	11.77	11.78	11.76	12.00	11.64	11.80
125 (S2)	11.54	11.26	12.02	11.60	11.74	11.16	11.87	11.59
150 (S3)	11.70	11.77	11.82	11.76	11.90	11.67	11.67	11.74
175 (S4)	11.72	11.76	11.60	11.69	11.92	11.66	11.15	11.68
Mean	11.63	11.70	11.80		11.83	11.62	11.66	
LSD (0.05)	M: ns	S: ns	M×S: ns		M: ns	S: ns	M×S: ns	

M: Sowing method, S: Seed rate M×S: Sowing method and seed rate interaction. ns: Not significant at 5% level of significance. LSD: Least Significant Difference

increased the plant vigor and yield. The results indicate that applying the proper seed rate and sowing method increased plant vitality and yield. It encourages nutrient availability, proper light penetration for photosynthesis (Chang *et al*., 1991), good soil environment for soil nutrients uptake and water use efficiency (Hossain and Maniruzzaman, 1992), which enhances crop vigor and yield.

Grain protein content: Table 2 indicates that protein content of grains was non-significantly affected by both the sowing methods and the seeding rates. Similarly, the interaction between the two factors was also non-significant. These results are supported by the findings of Khaliq *et al.* (1999), Hussain *et al.* (2001), Patrick *et al.* (2003) and Nakano and Morita (2009).

Table 3: Agro-economic productivity of wheat as affected by planting method and seed rates (data over both seasons)

Sowing method	Seeding rate kg ha^{-1}	Total costs* (L.E.)	Income (L.E.) Grain	Straw	Total	Net profit (L.E.)	Income-cost ratio
Hilling in ridges	100	5585	7396	1843	9239	3654	1.65
	125	5660	8655	2129	10784	5124	1.91
	150	5735	9163	2194	11357	5622	1.98
	175	5810	11613	2801	14414	8604	2.48
Drill	100	5600	8866	2245	11111	5511	1.98
	125	5675	9970	2297	12267	6592	2.16
	150	5750	12088	2951	15039	9289	2.62
	175	5825	10054	2235	12289	6464	2.11
Broadcast	100	5450	6338	1792	8130	2680	1.49
	125	5525	7575	2122	9697	4172	1.76
	150	5600	8250	2157	10407	4807	1.86
	175	5675	8996	2382	11378	5703	2.00

*Including seeding, land preparation, fertilizers, irrigation, harvesting, land rent, etc., Local market price: wheat grain = 2.50 L.E. kg^{-1} and wheat straw = 0.35 L.E. kg^{-1} and L.E.: Egyptian pound

Economic evaluation: A simple economic analysis such as total cost, total income, net profit and income-cost ratio for wheat for different methods of planting and seeding rate are shown in Table 3. Average results of both study seasons shows that drill sowing method with seed rate of 150 kg ha^{-1} gave the highest income (15039 L.E ha^{-1}), net profit (9289 L.E ha^{-1}) and income-cost ratio (2.62), followed by hilling in ridges sowing method with seed rate of 175 kg ha^{-1} of 14414, 8604 L.E ha^{-1} and 2.48, respectively. The minimum returns of above measures (8130, 2680 L.E ha^{-1} and 1.49, respectively), were obtained from broadcast sowing and seed rate of 100 kg ha^{-1}. The lower return in broadcast sowing and 100 kg ha^{-1} seed rate was ascribed to lowest grain and straw yield ha^{-1} in this treatment (M_3S_1) (Table 3). These results are in agreement with those reported by Tomar (2004), who compared four sowing methods (broadcasting, line sowing (20 cm), narrow sowing (15 cm) and cross sowing (20×20 cm) and three seed rates (100, 125 and 150 kg ha^{-1}) and found that broadcast sowing and seed rate of 100 kg ha^{-1} recorded the lowest value of net return compared with other treatments. Meanwhile, Mehrvar and Asadi (2006) found that rolling method and seeding rate of 110 kg ha^{-1} had the highest net income and lowest cost comparing other treatments.

Correlation coefficients: Simple correlation coefficients calculated over seasons and treatments are given in Table 4. Grain yield was positively and significantly correlated with plant height (r = 0.617). Khan and Shaik (1997) also reported positive and significant correlations between grain yield and plant height. Simple coefficient showed that there was positive correlation (r = 0.513) between number of effective tillers m^{-2} and grain yield. Previous authors had reported similar results between grain yield and spike number (Dokuyucu and Akkaya, 1999; Mondal and Khajuria, 2001). Simple correlation coefficient was a strong positive and significant between grain yield and grain number $spike^{-1}$ (r = 0.726). In most of the previous studies, similar results have been reported between grain yield and grain number $spike^{-1}$ (Khan and Shaik, 1997; Mondal and Khajuria, 2001; Shahid *et al*., 2002; Burio *et al*., 2004). In the study highly positive correlation of straw yield and grain yield was observed (r = 0.877, Table 4). Harvest index showed significant positive association with grain yield (r = 0.312, Table 4). This result is agreement with those of Burio *et al*. (2004) and Kotal *et al*. (2010). This indicated that by increasing these attributes, could

Table 4: Simple correlation coefficients of grain yield ha^{-1} as affected by yield attributes (data over both seasons and treatments)

Variables	1	2	3	4	5	6	7	8
Y: Grain yield ha^{-1}	0.617**	0.513**	0.726**	0.190ns	0.067ns	0.877**	0.312**	-0.079ns
1- Pant height	-	0.592**	0.634**	-0.076ns	0.017ns	0.579**	0.119ns	0.182ns
2- No. of effective tillers m^{-2}	-	-	0.716**	0.058ns	0.194ns	0.363**	0.330**	0.012ns
3- No.of grains $spik^{-1}$	-	-	-	0.120ns	0.147ns	0.667**	0.175ns	-0.038ns
4- Weight of grains $spike^{-1}$	-	-	-	-	0.583**	0.119ns	0.116ns	-0.059ns
5- 1000-grain weight	-	-	-	-	-	-0.064ns	0.272*	-0.032ns
6- Straw yield ha^{-1}	-	-	-	-	-	-	-0.178ns	0.008ns
7- Harvest index	-	-	-	-	-	-	-	-0.161ns
8- Grain protein content	-	-	-	-	-	-	-	-

* and ** denotes significance at 0.05 and 0.01 probability levels, respectively. ns: Not significant

invariably increase grain yield. Meanwhile, grain yield was positively and non-significantly correlated with weight of grains $spike^{-1}$ (r = 0.190) and 1000-grain weight (r = 0.067). This result is in conformity with those of Akram *et al.* (2008), who found that 1000-grain weight was positively and non-significantly correlated with grain yield. Protein content was not significantly correlated with plant height (r = 0.182), effective tillers m^{-2} (r = 0.012), grains $spike^{-1}$ (r = -0.038), weight of grains $spike^{-1}$ (r = -0.059), 1000-grain weight (r = -0.032), straw yield (r = 0.008), grain yield (r =-0.079) and harvest index (r = -0.161). These results are in harmony with Tayyar (2010), who showed that wheat grain yield was no correlation with grain protein content.

CONCLUSIONS

All studied traits in both seasons except grain protein concentration were significantly affected by sowing method and seeding rate. The interaction between sowing method and seeding rate was significant for all studied traits except plant height, number of grains per spike, 1000-grain weight and grains protein concentration. Wheat sown by drilling method at the seed rate 150 kg ha^{-1} gave the highest values of grain and straw yields ha^{-1} and this treatment was found to be most economical. Based on these results, it is recommended to sow 150 kg ha^{-1} seeds by using drill method for planting bread wheat Giza 168 cv under similar soil and climatic conditions.

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