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RESEARCH ARTICLE

EFFECT OF SEEDING RATES ON PRODUCTIVITY, TECHNOLOGICAL AND RHEOLOGICAL CHARACTERISTICS OF BREAD WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Seeding rate is an important factor can influence on yield and quality of bread wheat (*Triticum aestivum* L.). In the present study, we investigated the effect of different seeding rates on growth, yield components, grain and dough quality characteristics of the bread wheat cultivar Gemmeiza 9 grown in the Nile Delta, Egypt during two growing seasons. Four seeding rates were studied: 250 grains / m^2, 300 grains / m^2, 350 grains / m^2 and 400 grains / m^2 with four replications. Increasing seeding rates up to 350 or 400 grains / m^2 increased grain, straw and biological yields and number of tillers and spikes per m^2 but significantly decreased grain filling rate. Moreover, the highest seeding rate (400 grains / m^2) gave the highest and best percentages of bran, protein and gluten as well as the highest dough in strength which assessed by both Farinograph and Extensograph. Water absorption percentage and dough stability time (measured by the Farinograph) and dough resistance to extension and proportional number (analyzed by the Extensograph) significantly increased while dough weakness and extensibility, respectively assessed by the Farinograph and Extensograph, decreased by increasing seeding rates from 250 to 400 grains / m^2.

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important winter crops in Egypt, so it is cultivated in about 1.2 million hectares yearly. The production of wheat cultivated area is about 8 million tons and which can covers less than 60% of national consumption (FAO, 2009). Egyptian government is going gradually to reduce the dependence on imported wheat by increasing grain yield and productivity (Kherallah et al.,1989). Highest grain yield production of bread wheat and the best quality properties of grain require the use of appropriate seeding rate (Geleta et al.,2002)

Seleiman *et al.* (2010) found that Gemmeiza 9 had the highest yield and yield components compared to the other cultivars under suitable field conditions. Gafaar (2007) studied the growth, yield and its components and quality characters of four Egyptian bread wheat varieties as affected by the sowing densities. He found that increasing sowing density from 200 up to 400 grains/ m^2 significantly increased each of plant height, number of spikes/ m^2 and yields, but significantly decreased the number of days to 50% heading, spike length, number of spikelets/ spike, number of grains/ spike, 1000-kernel weight, spike yield and protein percentage.

Ali et al. (2004) studied the productivity of some wheat cultivars grown under different plant densities (300, 400 and 500 grains/ m^2). They reported that increasing plant density from 300 to 400 or 500 grains/ m^2 significantly increased plant height, number of spikes/ m^2 and yields, but significantly decreased grain weight/ spike and 1000-grain weight.

Saleh (2002) studied the effect of three seeding rates (60, 120 and 180 kg grains/ ha) on yield and yield components of the Egyptian wheat cultivar (Gemmeiza 5) and the Mexican wheat cultivar (Mexipak 65). The results indicated that the lowest seeding rate, i.e. 60 kg grains/ ha gave longer spike with higher number of spikelets and grains/ spike as well as longer period from sowing to 50 % heading but lower number of spikes/ m^2 as compared with either the medium (120 kg grains/ ha) or the highest seeding rate (180 kg grains/ ha). However, plant height, 1000-grain weight and grain yield/ ha were not significantly affected by different seeding rate. Toaima et al.,(2000) studied the effect of three seeding rates, i.e. 40, 50 and 60 kg grains/ fed (4200 m^2) on yield and technological characters of three Egyptian wheat cultivars (Sakha 69, Gemmeiza 5 and Sids 1). They revealed that plant height, spike length, number of grains/ spike, grain

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yield/ spike and 1000-grain weight as well as ash, flour, bran percentages and farinograph property (weakness of dough) were significantly decreased, while number of spikes/ m^2, grain yield/ fed, protein, wet and dry gluten contents as well as farinograph properties (water absorption %, stability and mixing times of dough) were significantly increased by increasing seeding rates up to 60 kg grains/ fed. However, Gooding et al. (2002) reported that protein concentration decreased with increasing sowing rate as well as the effects of seeding rate on grain specific weight and 1000-grain weight were small and inconsistent. Also, in the same direction Geleta et al. (2002) revealed that lower seeding rates increased protein content and mixing tolerance but decreased grain yield, flour yield and mixing time.

The effects of seeding rates on milling, quality and rheological characteristics have been scarcely tested in bread wheat. Therefore, the present investigation was carried out to evaluate and study the effects of different seeding rates on yield and milling, technological and rheological characteristics of bread wheat.

MATERIAL AND METHODS

Experimental conditions

The experiments were conducted at the Experimental Farm of the Faculty of Agriculture, Shebin El-Kom, Egypt, during the growing seasons 2004/2005 and 2005/2006 (thereafter referred as season 1 and 2), on the bread wheat (*Triticum aestivum* L.) cultivar Gemmeiza 9. The preceding crop was maize in both seasons. Main soil characteristics are given by Table 1. Rainfall was low during the vegetative period (42 and 30 mm in seasons 1 and 2, respectively), and nothing during the reproductive period. The average of the temperature every month during grain filling was around 32.5°C.

The experiment included four seeding rates: 250 grains / m^2, 300 grains / m^2, 350 grains / m^2 and 400 grains / m^2. The four treatments were arranged in a randomized complete block design with four replications. The area of each experimental plot was 12 m^2. Calcium super phosphate (15.5% P_2O_5) was applied during soil preparation at the rate of 37 kg ha^{-1} P_2O_5. Sowing was done on 15th November in both growing seasons. Six irrigations were added during growth by flooding system. Total nitrogen fertilization was applied at a rate of 140 kg ha^{-1} N as urea (46.5%) in two equal doses, before the first and second irrigations.

Measurements

Days from sowing date to heading and physiological maturity were recorded for each plot. For estimating grain filling rate, five main spikes were collected from each plot at 14, 21, 28, 35 and 42 days after heading. 10 grains from the middle part of each of the 5 spikes were removed, oven dried at 80°C for 24h and weighed. Grain filling rate was calculated as GFR = (wt+1 – wt)/[(t+1) – t] where wt+1 and wt represent grain dry weight per spike at time t+1 and t, respectively, and was expressed in mg $spike^{-1}$ day^{-1}. Effective grain filling period was estimated according to Daynard et al.,(1971) as the ratio of the final grain weight per spike to the average grain filling rate. At harvest one square meter was taken randomly from the middle area of each plot to determine plant height (cm), number of tillers and spikes per m^2, number of spikelets and grains per spike, spike length (cm), thousand kernel weight (g) and grain yield per spike (g). Grain, straw and biological yields (t ha^{-1}) were determined from the whole plot area at harvest. Harvest index was estimated as the ratio of grain yield to biological yield and was expressed in per cent.

Milling characteristics (flour percentage and fine bran and coarse bran concentrations) were measured after grain milling according to AACC (2000). Crude protein percentage was obtained by multiplying grain nitrogen content by 5.7 according to the method described by AACC (2000). Nitrogen percentage in the grains was determined using micro Kjeldahl method as described by Peter and Young (1980). Ash and wet and dry gluten percentages were measured according to AACC (2000). Wet gluten was obtained by forming dough by adding 15 ml of water to 25g of flour. The dough was kept in a beaker for one hour, repeatedly washed manually until all starch was released, and weighed. Dry gluten was obtained after oven-drying the dough at 105°C. Total carbohydrate percentage in the grains was determined according to the method of Dubois et al. (1956).

Rheological characteristics of the dough obtained from grain of the different seeding rates were analysed at the Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. There were analyzed for each treatment by pooling flour samples from the four replications. Water absorption of the dough (%), dough development time (min), dough stability time (min) and dough weakness (in Brabender Units, BU) were estimated in both years using a farinograph (Nr 941020, type 8I0105001, Brabender GmbH and Co. KG, Duisburg, Germany). Water absorption was estimated as the percentage of water in the dough for reaching strength of 500 BU. Dough development time was the time in minutes elapsing from the first addition of water to the development of dough maximum consistency. Dough stability time was the time in minutes between the dough development time and breakdown of the curve (i.e., the time elapsing after the mixing curve intersected the 500 BU lines until it left it). Dough weakness was the drop in consistency (in BU) during the first 12 min of breakdown. In season 2, dough resistance to extension and extensibility were determined using a Brabender Extensograph apparatus (Nr. 946003 type 860001, Brabender GmbH and Co. KG, Duisburg, Germany). Dough resistance to extension (R) was obtained from the maximum height of the curve in Brabender Units (BU). Dough extensibility (E) was estimated by the total length of curve, in mm. A proportional number was calculated by divided dough resistance by dough extensibility (R/E). The experiment included four treatments, which were arranged in a randomized complete block design with four replications. Data obtained was analyzed using SPSS, version 15. Mean of values were compared at 5 % level of probability using Duncan's multiple range test.

RESULTS AND DISCUSSION

Results in Table (2) show that the number of days from sowing to 50 % heading, number of days from 50 % heading to maturity and number of days from sowing to maturity was substantially influenced by the tested seeding rates in the two growing seasons. Increasing seeding rates from 250 grains / m^2 to 400 grains / m^2

caused a significant increase in the number of days from sowing to 50 % heading, days from 50% heading to maturity and from sowing to maturity. It means that growing wheat plants in light density shortened the vegetative growth period resulting in acceleration of flowering and pushing plants towards reproductive phases after establishing good foliage and then days to maturity. On the other hand, the increase of planting density had a prominent role in vegetative growth and retarding effect on photosynthesis translocation towards storage in the sink floret and / or grains which lead to late maturity of the crop counted in terms number of days. Similar results were obtained by Salem (1999) who found that increasing seeding rate from 60 up to 120 kg grains / fed delayed the flowering and maturity.

Data in Table (3) detect significant positive response of grain filling rate and effective filling period of wheat plants to the effect of seeding rates. The lowest seeding rate (250 grains /m^2) was the most effective treatment on enhancing grain filling rate than 350 or 400 grains / m^2 but not greater compared to 300 grains / m^2. This trend was present throughout the course of grain filling rate in both growing seasons. These results suggest that the translocation or retranslocation of photoassimilate from their sources (leaves, sheath, culm and chaff) to the grain was higher than sowing by the first seeding rate (250 grains) and / or second seeding rate (300 grain / m^2) than the dense sowing, i.e. 400 grains / m^2. This situation may have occurred for two reasons (I) an increased ability to translocate assimilates to the sink or (II) an increased sink size. An increased ability to translocate could result from enhancements in efficiency of the biochemical processes of loading translocation in phloem elements. An increased sink size could have occurred through an increased source size or the combination of the two seasons. Similar result was obtained by El-Habbasha (2001) who found that grain filling rate increased by decreasing seeding rates. The results presented in the same table show that dense sowing, i.e. 400 grains / m^2 significantly increased grain filling period as compared to the other tested seeding rates in both seasons, but seeding rate of 300 grains / m^2 and 250 grains / m^2 came secondly and thirdly, respectively in this respect. However, the third seeding rate (350 grains / m^2) was considerably associated with the shortest effective grain filling period. This extension in grain filling period in dense sowing could be attributed to the lower grain filling rate at all samples under dense planting. In this respect, increasing seeding rates caused an increase in effective grain filling period (El-Habbasha, 2001; Salem, 1999).

Yield and its components as influenced by seeding rates were recorded during the two successive seasons in Table (4). Reversely to grain yield / spike, it can be noted that grain yield / ha was gradually and significantly increased as sowing density increased from 250 grains / m^2 up to 350 grains / m^2 and then the rate of increase remain constant with increasing sowing density up to 400 grains / m^2. On the average of both seasons, the increase in grain yield / ha obtained from plants grown at 350 and / or 400 grains / m^2 amounted to 10.21 and 5.83%, respectively more than that obtained from plants grown at 250 and 300 grains / m^2, respectively. The superiority of grain yield / ha in dense sowing could be attributed to the higher number of spikes per unit area which reverse the effect of the increasing in the grain yield / spike obtained as the sowing density was decreased. The highest straw yield / ha was obtained when wheat plants were grown using seeding rate of 350 grains / m^2 or 400 grains / m^2 without significant differences among them. However, light density of 250 grains / m^2 recorded the lowest straw yield. The increase in straw yield / ha obtained from plants grown in dense planting (400 grains / m^2) amounted to 4.31 and 5.64 %, respectively more than that obtained from plants grown in the light sowing (250 grains / m^2) in the first and second seasons. These results suggest that smaller amount of dry matter were accumulated in the temporary sinks (calum and other nongrain tissues) when plant were grown in the third sowing density (350 grains / m^2) and / or the fourth sowing density (400 grains / m^2). So the retranslocation of photoassimilate to the major sink (grains) was probably enhanced under 400 and / or 350 grains / m^2 sowing densities. Many researchers reported that increasing seeding rates caused an increase in grain and straw yield / ha (Salem, 1993; El-Bana, 2000; Gooding et al.,2002; Gafaar, 2007). The highest biological yield was achieved by using 350 and / or 400 grains/ m^2. In contrary, the light sowing produced the lowest biological yield. Such results were expected since both of 350 and/ or 400 grains / m^2, produced the highest grain and straw yields / ha as compared with either of 250 or 300 grains / m^2. Similar results were obtained by El-Habbasha (2001) and Ali et al. (2004) who found that biological yield was increased by increasing seeding rate. Moreover, (Gafaar, 2007) reported that the highest value of biological yield was obtained by increasing seeding rate up to 400 grains / m^2. Seeding rates (350 and 400 grains/ m^2) appeared to obtain higher values of harvest index as compared with light densities (250 and 300 grains / m^2). In this regard, Mosalem (1993) found that harvest index was increased by increasing seeding rate.

Dense sowing of 400 grains / m^2 appeared to produce the tallest plants followed by 350 grains / m^2 and 300 grains / m^2, while the lighter density of 250 grains / m^2 had the shortest plants. It seems that as the number of plants per unit area was increased, the more consumption of nutrients from soil will occur and consequently more nutrient demands. On the other hand, shadow between plants under dense sowing will expected, more endogenous regulators responsible for cell division and elongation such as auxins were expected to form and consequently more plant elongation will be obtained. Many researchers reported that the tallest plants were obtained by using seeding rate of 75 kg grains / fed (El-Bana and Basha, 1994), 90 kg grains / fed (Salem, 1993; and El-Bana, 2000**)**, 400 grains / m^2 (Gafaar, 2007) and 500 grains / m^2 (Ali et al.,2004). Increasing seeding rates from 250 to 400 grains / m^2 increased number of tillers and spikes / m^2. The seeding rate of 400 grains / m^2 had the highest number of tillers and spikes / m^2. Such increment in number of tillers and spikes / m^2 due to increasing sowing density could be attributed to increasing number of plants / m^2 rather than tillering capacity. These results are in agreement with those obtained by Johnson et al.,(1988), Geleta et al.,(2002) and Gafaar (2007) who found that number of spikes/ m^2 were increased by increasing seeding rate.

Table 1. Soil characteristics of the experimental field soil in both seasons

	Fine sand %	Coarse sand %	Silt %	Clay %	pH	Organic matter %	N ppm	P ppm	K ppm
Season 1	22.2	13.7	28.7	35.4	7.8	2.0	25.0	7.6	414.4
Season 2	25.7	06.2	36.0	32.1	7.9	1.8	30.0	6.5	351.2

Table 2. Effect of seeding rates on the duration of the vegetative and reproductive periods of wheat plants

Seeding rates	Days from sowing to heading		Days from heading to maturity		Days from sowing to maturity	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
250 grains / m^2	85.50^d	86.00^d	67.00^d	67.50^d	152.50^d	153.50^d
300 grains / m^2	87.00^c	87.50^c	68.50^c	69.00^c	155.50^c	156.50^c
350 grains / m^2	91.00^b	91.50^b	71.50^b	72.00^b	162.50^b	163.50^b
400 grains / m^2	93.00^a	94.00^a	73.50^a	74.00^a	166.50^a	168.00^a

For each season, mean values in the same column without a common letter are significantly different ($P<0.05$) according to the Duncan comparison test

Table 3. Effect of seeding rate on grain filling rate for grains and effective grain filling period of main wheat spikes

Seeding rate	Grain filling rate (mg/spike/day) Days after 50 % heading. 14-21		21-28		28-35		35-42		Average		Effective grain filling period (days)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
250 grains / m^2	43.9^a	44.8^a	72.1^a	72.9^a	101.5^a	103.1^a	90.5^a	91.3^a	77.0^a	78.0^a	40.8^c	40.5^c
300 grains / m^2	43.3^a	43.9^{ab}	71.8^a	72.2^a	97.0^b	99.0^b	88.5^a	91.4^a	75.2^a	76.6^a	41.5^b	41.0^b
350 grains / m^2	42.4^b	43.3^b	69.3^b	69.8^b	94.0^c	94.9^c	83.0^b	84.5^b	72.2^b	73.1^b	39.8^d	39.8^d
400 grains / m^2	40.0^c	40.3^c	55.3^c	55.4^c	92.8^c	92.9^c	75.8^c	76.5^c	66.0^c	66.3^c	42.6^a	42.8^a

For each season, mean values in the same column without a common letter are significantly different ($P<0.05$) according to the Duncan comparison test

Table 4. Effect of seeding rate on yield and its components of wheat crop

Seeding rate	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index	Plant height (cm)	Number of tillers m^{-2}	Number of spikes m^{-2}	Number of spikelets / spike	Number of grains / spike	Spike length (cm)	Thousand kernel weight (g)	Grain weight / spike (g)
						Season 1						
250 grains / m^2	2.63^c	4.97^c	7.59^c	0.34^b	109.1^c	301.0^d	277.2^d	23.15^a	73.9^a	12.54^a	52.67^a	3.14^a
300 grains / m^2	2.73^b	5.07^b	7.80^b	0.35^a	110.6^c	375.0^c	352.2^c	22.65^b	72.3^b	12.46^a	52.10^a	3.12^b
350 grains / m^2	2.83^a	5.15^a	7.97^a	0.35^a	116.1^b	388.0^b	364.7^b	22.50^b	72.0^b	12.32^b	51.45^b	2.90^c
400 grains / m^2	2.82^a	5.18^a	8.00^a	0.35^a	121.1^a	405.0^a	375.5^a	21.75^c	71.1^c	11.25^c	49.5^c	2.81^d
						Season 2						
250 grains / m^2	2.66^c	4.91^c	7.57^c	0.35^b	109.2^d	307.2^d	293.5^d	23.15^a	74.0^a	12.59^a	53.35^a	3.16^a
300 grains / m^2	2.78^b	5.09^b	7.86^b	0.35^b	111.5^c	$382 .0^c$	363.0^c	22.90^b	72.5^b	12.53^a	52.97^a	3.14^b
350 grains / m^2	3.00^a	5.23^a	8.23^a	0.36^a	115.4^b	421.2^b	400.7^b	22.50^b	72.2^{bc}	12.37^b	52.09^b	2.91^c
400 grains / m^2	3.01^a	5.19^a	8.20^a	0.36^a	119.9^a	438.5^a	415.0^a	21.80^c	71.2^c	11.25^c	48.98^c	2.84^d

For each season, mean values in the same column without a common letter are significantly different ($P<0.05$) according to the Duncan comparison test

Table 5. Effect of seeding rates on quality properties of wheat grain

Seeding rates	**Protein %**		**Wet gluten %**		**Dry gluten %**		**Ash %**		**Carbohydrate (%)**	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
250 grains / m^2	12.36^b	12.41^b	27.22^b	28.26^b	11.96^b	12.50^b	1.81^a	1.82^a	76.28^a	76.30^a
300 grains / m^2	12.36^b	12.47^b	27.85^b	28.76^b	12.30^b	12.89^b	1.81^a	1.81^a	74.90^b	75.20^b
350 grains / m^2	12.50^b	12.54^b	28.30^b	28.96^b	12.50^b	13.00^b	1.77^b	1.77^b	74.00^c	74.12^c
400 grains / m^2	13.28^a	13.30^a	31.20^a	30.22^a	13.06^a	13.72^a	1.76^b	1.78^b	73.63^d	73.66^d

For each season, mean values in the same column without a common letter are significantly different

It is obvious that, the light density (250 grains / m^2) gave the highest significant number of spikelets and grains/ spike followed by the second seeding rate (300 grains / m^2) and / or third seeding rate (350 grains/ m^2) without significant differences between them. Otherwise, dense planting (400 grains / m^2) had the lowest mean value of both characters. Such reduction in number of spikelets and grains/ spike resulted from dense sowing may be due to the intensive competition between individual plants and struggling for available nutrients, light and etc. in the surrounding media and consequently caused a decrease, the assimilate supply for floret growth

Table 6. Effect of seeding rates on rheological properties (Farinograph) of wheat dough

Seeding rates	Water absorption (%)		Dough development time (min)		Dough stability time (min)		Dough weakness (BU)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
250 grains / m^2	59.50	60.50	5.00	4.00	3.00	4.00	120	125
300 grains / m^2	62..50	63.00	1.50	1.50	3.50	4.00	100	100
350 grains / m^2	64.00	65.50	1.00	2.00	3.50	4.00	95	90
400 grains / m^2	68.50	69.50	2.00	2.50	7.50	10.50	60	40

Table 7. Effect of seeding rates on rheological properties (Extensograph) of wheat dough

Seeding rates	Dough resistance to extension (B.U.)	Dough extensibility (mm)	Proportional number (R/E)
250 grains/ m^2	280	115	2.43
300 grains/ m^2	330	110	3.00
350 grains/ m^2	390	92	4.50
400 grains/ m^2	550	87	6.32

and development during the duration of floret initiation which decrease the number of fertile spikelets / spike. The longest spikes were obtained from 250 and 300 grains / m^2 but without significant differences between both of them. However, the shortest spikes were recorded by using the highest seeding rate (400 grains / m^2). Such decrease in spike length might be due to the competition between greater numbers of plants for the environmental conditions. This could have been reflects in lower rates of photosynthesis and growth of those plants, which was expressed in noticeable decrease in spike length. Generally, thin density (250 grains / m^2) produced heavier individual grain, but not significantly greater than that obtained by growing wheat plants under the second seeding rate (300 grains / m^2). Otherwise, dense sowing (400 grains / m^2) gave the smallest grain size.

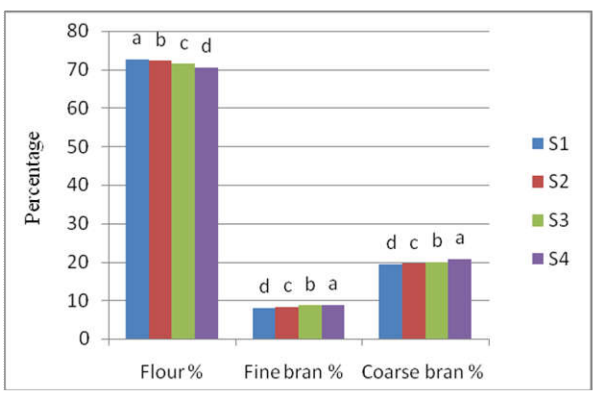

Figure 1. Effect of seeding rates on milling characters of wheat grains
S1: 250 grains / m^2; **S2**: 300 grains / m^2; **S3**: 350 grains / m^2; **S4**: 400 grains / m^2

It has been suggested that the translocation or retranslocation of photoassimilate from their sources to the grains was much higher under light sowing density, i.e. (250 grains / m^2). Such increase in 1000- grain weight might be due to the decrease in competition and less mutual shading among plants which increased the total dry matter produced and consequently seed index. In the same Table, the results reveal that grain yield / spike was significantly increased as the sowing density was decreased from 400 grains / m^2 to 250 grains / m^2.

This could be expected since the thin sowing (250 grains / m^2) produced greater number of spikelets and grains/ spike, spike length and 1000–grain weight than the dense one (400 grains / m^2). All these components tended finally to produce more grain yield/ spike. Many researchers mentioned that the highest values of grain yield / spike and the heaviest 1000-grain weight were obtained by using the lowest seeding rates per unit area (Toaima et al.,2000; Gafaar, 2007).

Data in Figure (1) show that flour percentage was significantly increased with decreasing seeding rates from 400 to 250 grains / m^2. The superiority of flour percentage obtained at low seeding rate may be due to the increase in grains weight (as shown in Table 3) as well as total carbohydrate percentage (as shown in Table 4). On the other hand, increasing seeding rates from 250 up to 400 grains / m^2 led to a significant increase in each of fine and coarse bran percentages. The superiority of bran percentage obtained at high seeding rate (400 grains / m^2) may be attributed to the decrease in the size and weight of grains which had low total carbohydrate and starch percentages and consequently high bran percentage. In this respect, Toaima et al.,(2000) found that increasing seeding rates from 40 up to 60 kg grains / fed decreased flour percentage but increased bran percentage in wheat grains. However, Dawood (1994) reported that fine and coarse bran percentages were not significantly affected by increasing row spacing from 10 up to 26 cm. On the other hand, Geleta et al.,(2002) found that flour yield deceased with the lower seeding rates.

Data presented in Table (5) show that protein percentage and its related characters, i.e. wet and dry gluten increased with increasing planting density. Higher sowing density (400 grains / m^2) produced significantly highest values of protein percentage and its related characters compared to other treatments. However, 350, 300 and 250 grains / m^2 did not differ significantly in this respect. It has been suggested that as the plants were decreased per unit area, plants were able to absorb more amounts of nitrogen and other minerals from soil, also more photosynthesis rate was occurred and consequently the assimilation of more protein were expected to be

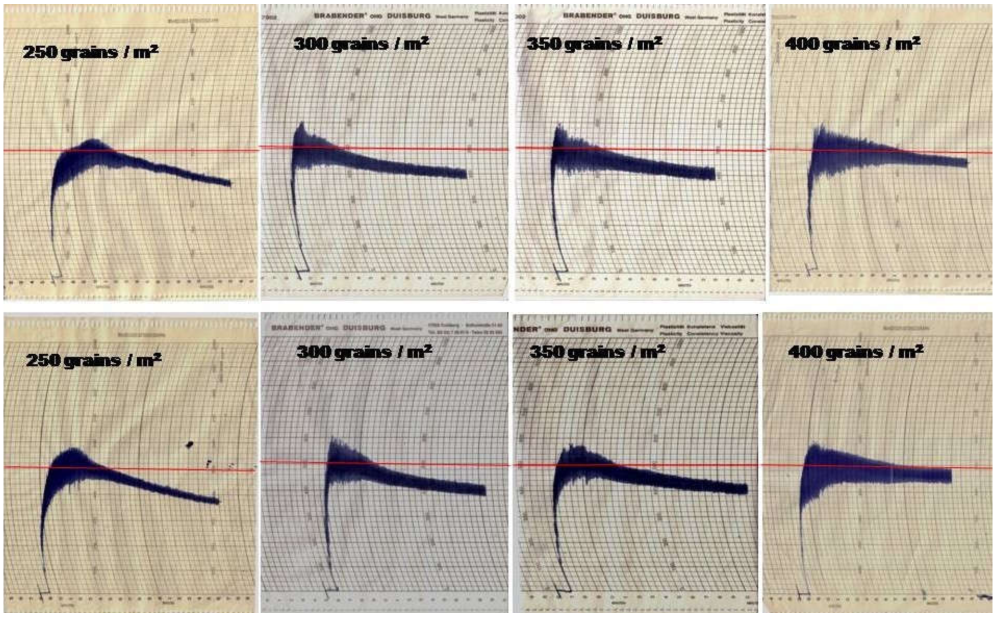

Figure 2. Effect of seeding rates on rheological properties (Farinograph) of wheat dough (above: season 1; below, season 2)

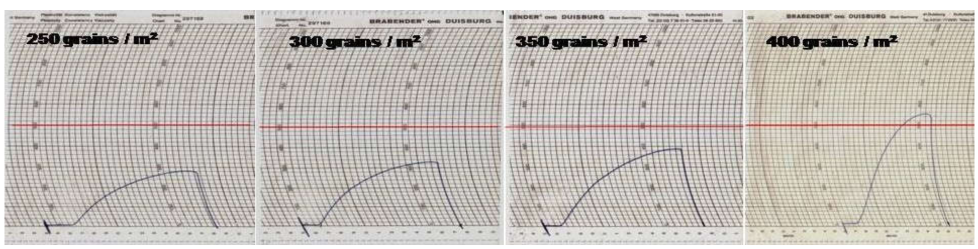

Figure 3. Effect of seeding rates on rheological properties (Extensograph) of wheat dough in season 2

formed. In dissimilarity with protein percentage, the obtained data indicated that the density which had the highest protein percentage, i.e. 400 grains / m^2 had the lowest ash and total carbohydrate percentages. However, the differences in ash percentage between 250 and 300 grains/ m^2 or between 350 and 400 grains/ m^2 did not differ significantly in both seasons. These results are in accordance with those obtained by Toaima et al.,(2000) who found that increasing seeding rate significantly increased protein, wet and dry gluten percentages but decreased ash percentage. On the other hand, Geleta et al.,(2002) and Gooding et al.,(2002) reported that protein concentration decreased with increasing sowing rate.

The effect of seeding rates on rheological properties of wheat dough are shown in Table (6) and illustrated in figure (2). The results indicated that increasing seeding rates from 250 up to 400 grains / m^2 increased the water absorption percentage and dough stability time. However, dough development time and dough weakness were decreased by increasing plant density from 250 up to 400 grains / m^2. From these results, it can be concluded that the dough quality of wheat flour were improved by increasing seeding rates. The improvement in the dough quality herein may be due to the increase in the protein and dry gluten percentages, and the decrease in the total carbohydrate percentage by increasing seeding rates as shown in Table (5). In this respect, Toaima et al.,(2000) and Geleta et al.,(2002) found that farinograph properties (water absorption percentage, stability and mixing times of dough) were significantly increased, while dough weakness was significantly decreased by increasing seeding rates. Data in Table (7) and figure (3) revealed that the dough resistance to extension and proportional number were increased, but dough extensibility was decreased by increasing seeding rates from 250 to 400 grains / m^2. This means that the dense sowing caused an increase in the dough strength more than the wide sowing. This superiority in the dough strength may be mainly due to the increase in the protein and gluten percentages which obtained in the dense sowing as shown previously in Table (5).

In summary, lower seeding rates gave the highest filling grain rate and the recommended seeding rate of 350 grains / m^2 was the best and highest in grain yield / ha. However, the highest seeding rates (400 grains / m^2) produced the highest quality and strength in grains and dough.

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