WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.6(2) : 234-237. 2008 www.world-food.net

The effects of seed size on emergence and yield of durum wheat

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Received 13 December 2007, accepted 21 March 2008.

Abstract

A two years study was conducted in the 2004/2005 and 2005/2006 growing seasons to determine the effect of seed size on seedling emergence, yield and quality of 'Ceylan 95' durum wheat. In the study, seeds were separated with different sieves and 4 different size groups were prepared. Seed sizes were smaller than 2.2 mm, 2.2-2.5 mm, 2.5-2.8 mm and bigger than 2.8 mm. The seed density of each group was 450 seeds m^{-2}. The trial was performed according to the completely randomized block design with three replications. Grain yield was increased with uniform large seeds in both years. The use of largest seeds resulted in a more competitive cropping system, improving grain yields by 15%. Germination and emergence rates were higher in bigger seeds. The 1000 kernel weight and test weight of smaller seeds were higher than those of bigger seeds because of poor emergence rate. The use of uniform large seeds increased seedling emergence and grain yield. Results demonstrate that commercial seeds >2.2 mm wide can be successfully used in wheat production.

Key words: Durum wheat, seed size, yield, emergence.

Introduction

The releasing of new durum wheat (*Triticum turgidum* L. var. *durum*) cultivars with high yield and quality can be used as a tool to increase the production of durum wheat. Beside of genotypic effects, favorable growing techniques must be determined to increase grain yield. Commercial wheat seed lots contain a small proportion of small-sized seeds. Wheat producers often remove small-sized seeds, attempting to increase seedling vigor and grain yield.

In wheat farming, yield and quality are controlled by genetic and environmental factors. Seed quality is important as much as yield and quality of used cultivar as a genetic factor. Seed quality associates germination percentage, seed size, and genetic and physical purity of seed. Royo *et al.* [12] determined that small-sized seeds had negative effects on the seedling growth, and big-sized seeds increased the yield as 16%. Similar results were reported by other authors [1-4, 6, 9-11, 14]. Therefore, in small cereal crops, non-genetic variations in seed size exert a significant impact on grain yield.

This study was performed to determine changes on germination, seedling emergence and yield with the usage of different sized seed in durum wheat (cv. Ceylan 95).

Materials and Methods

This study was conducted at Field Crops Research Area in Agricultural Faculty, Dicle University, Diyarbakir (37°53'21.00"N, 40°16'31.32"E), Turkey, in 2004/2005 and 2005/2006 growth seasons. Ceylan 95, durum wheat cultivar which was registered for the region of Southeastern Turkey was used as a material in the study. The southeastern area has a continental climate with lower temperatures during winter and hot in dry summers. Average seasonal precipitation in Diyarbakir is 430 mm, which is irregularly distributed and 97.5% of which is received during October–May.

Seeds from registered grade were cleaned in the selector of Agricultural Faculty, and three different sieves (2.2, 2.5 and 2.8 mm) of the machine of Retsch model were used to separate the seeds. Four various size groups were created as < 2.2 mm, 2.2-2.5 mm, 2.5-2.8 mm and >2.8 mm. The seeds at control group were not sieved. The seeding rate was adjusted for a density of 450 seeds m^{-2} for all seed size applications, according to standard practices. The trial was performed according to the randomized complete block design with three replications. The experiments were sown by seed drill in 7 December 2004 and 11 November 2005. Plot size was six rows, 4 m long, with 20 cm between rows. Fertilizer was applied as P_2O_5 60 kg ha^{-1} and N 100 kg ha^{-1}.

Germination test was conducted in a semi controlled growth room with three replications. Temperature was maintained at 24/20°C day/night, respectively. Each replication consisted of 100 seed. Seeds were germinated on a filter paper in Petri dishes with distilled water. Germinated seeds were counted with 2, 3, 4 and 8 d interval and germination percentages were determined. Seedling emergence was determined by counting the plants at 0.3 m^2 per plot, when plants were at two leaf stage. Heading time was recorded as a day number between emergence of coleoptile from soil surface and 50% emergence of the spikes from the boot. At maturity, plant height was measured from the soil surface to the top of the spikes excluding the awns. A sample of 10 tillers was harvested randomly from each plot to measure the yield components. Thousand grain weights were calculated from the weight of 400 kernels plot^{-1}. Grain yield was determined on the basis of the harvested plot in all trials. Test weight, measured in a sample of one kg per plot, is expressed as kg hl^{-1}.

Analysis of variance belonging to the evaluated traits was made by use of MSTAT-C package program according to completely randomized block design, and means were compared by the least significant difference method at P = 0.05. Germination rates were analyzed according to the completely randomized design.

Results

The weather was wetter during 2006 than 2005 (Table 1). The average temperature of both years during reproductive and grain filling period was higher than the average of past 25 years. In 2005, except germination and seedling emergence period, all growing stage was covered by dry period. Despite heat stress during 2006, drought stress did not extremely affect wheat growth.

Analysis of variance showed highly significant variation among the five different seed size application for seedling emergence, heading time, thousand grain weight, test weight and grain yield (Table 2). Also analysis of variance was significant for germination rates (data not shown). However, significant variation was not found for plant height, spike length, spikelet number, grain number per spike and grain weight per spike. Therefore, the evaluations were made on the traits having significant variations. The effects of year were significant for all investigated traits, except spike length. Interactions of year with seed sizes were of high magnitude for test weight and grain yield.

In this research, germination percentage was statistically significant on the second and third days, but non-significant on the fourth and eighth days. Germination percentage changed according to days as follow: percent of 55.0 to 83.0 (second day), 77.3 to 93.7 (third day), 90.7 to 97.0 (fourth day) and 94.0 to 97.7 (eighth day). Although big-sized seeds had the highest germination rates, small-sized seeds had the lowest germination percent (Table 3).

Seedling emergence values were realized as follow: 383.7 to 443.3 m^{-2} (first year), 280.3 to 426.7 m^{-2} (second year) and 332.0 to 435.0 m^{-2} (average of the years). Although the highest seedling emergence values for the first year, second year and average of them were observed from the biggest-sized (> 2.8 mm) seeds, the lowest values were obtained from the smallest-sized (< 2.2 mm) seeds (Table 3).

Heading time among seed size groups showed significant differences for first year (126.7 to 128.0 days), second year (172.0 to 173.0 days) and average of them (149.3 to 150.5 days). According to the years and average of the years, the longest heading periods were obtained from the smallest-sized seeds (< 2.2 mm). The other seed groups showed longer heading period (Table 4 and 5).

Statistical differences among seed groups for spike length were observed in the second year, and the lengths changed between 5.9 and 7.1 cm in the second year. According to the first year and average of the year, there were statistically non-significant differences between seed size groups; however, spike lengths ranged respectively from 6.0 to 6.3 cm and from 6.1 to 6.6 cm. The longest spikes were obtained from the smallest size group (< 2.2 mm) because of the lack of seedling emergence. Because low seedling emergence affected the plant number per unit area, spike lengths of the smallest seed size (< 2.2 mm) group were longer than the other groups (Table 4 and 5).

In this research, statistically different groups were found among seed sizes for thousand kernel weight (TKW) in the first year and as average of the years. Values of TKW ranged as follows: 34.3-38.1 g (first year), 50.9-52.9 g (second year) and 42.7-45.5 g (average of the years). According to the average of the years, plots which had 2.2 mm seed size were at the first group with highest TKW values (Table 4 and 5).

Seed sizes showed differences for test weight (TW) according to the second year and average of the years. Means of TW ranged between 80.9 to 82.4 kg hl^{-1} in the first year. The values observed in the second year and average of the years were 70.8-76.3 and 76.0-79.4 kg hl^{-1}, respectively. Seed size with 2.2 mm diameter showed the highest values for TW in both of the years and as average of the years (Table 4 and 5).

Seed size showed differences except the first year for grain yield (GY). Thus, GY means ranged as follows: 3077 to 3986 kg ha^{-1} (first year), 4583 to 5663 kg ha^{-1} (second year) and 4028 to 4825 kg ha^{-1} (average of the years). In both years and the average of the years, highest GY means were obtained from seed size with 2.8 mm diameter, but 2.2 mm showed lowest GY values (Table 4 and 5).

Table 1. Total monthly precipitation and average temperature recorded at Diyarbakır during 2005 and 2006 and 25 year averages.

Year	Precipitation (mm)								Temperature (°C)						
	Nov	Dec	Jan	Feb	Mar	Apr	May	Total	Nov	Dec	Jan	Feb	Mar	Apr	May
2005	123.1	4.7	58.7	46.8	58.4	36.8	26.5	355.0	8.2	1.4	2.3	3.0	8.4	14.1	19.6
2006	38.0	94.3	121.3	121.0	26.6	77.9	38.4	517.5	7.5	5.3	0.4	4.3	9.2	14.5	19.4
Average*	57.8	68.3	65.8	69.6	67.4	60.1	40.1	429.2	8.7	3.5	1.9	3.1	7.9	13.8	19.1

*25 years averages.

Table 2. Analysis of variance of investigated characteristics in durum wheat at different seed sizes.

	Df	Mean squares									
		Seedling emergence	Heading time	Plant height	Spike length	Spikelet number	Grain number per spike	Grain weight per spike	Thousand grain weight	Test weight	Grain yield
Year	1	275405**	15232.5**	1377.9**	0.23	12.6*	1318.7**	8.9**	1907.2**	506.7**	1733.4**
Seed size (S)	4	6453*	1.3**	12.9	0.21	0.3	18.4	0.6	7.3*	9.2**	3.6*
S x Year	4	2557	0.03	10.9	0.40	1.3	21.1	0.8*	2.92	4.0**	3.9*
CV		13.3	0.2	3.7	5.8	40.7	7.7	9.23	2.97	1.09	8.45

*,**, Significant at the 0.05 and 0.01 probability levels, respectively.

Table 3. Means of the seed germination on the 2nd, 3rd, 4th, 8th days, and seedling emergence according to different seed sizes in Ceylan 95, durum wheat cultivar.

Seed size (mm)	Germination (%)				Seedling emergence (no m^{-2})		
	2nd day	3rd day	4th day	8th day	2005	2006	Avarage
2.2<	77.7 a*	85.7 b	91.7	94.0	383.7 b	280.3 b	332.0 b
2.2-2.5	78.3 a	86.3 b	94.7	96.0	424.7 ab	418.0 a	421.3 a
2.5-2.8	76.0 a	90.0 ab	96.7	97.0	437.7 a	377.7 a	407.7 a
2.8>	83.0 a	93.7 a	97.0	97.7	443.3 a	426.7 a	435.0 a
Control	55.0 b	77.3 c	90.7	95.0	393.0 b	402.0 a	397.5 a
Mean	74.0	86.6	94.1	95.9	416.5	380.9	398.7
$LSD_{0.05}$	10.1	6.42	NS	NS	42.2	64.5	35.4

*Means within a column followed by the same letters are not significantly different at P = 0.05.

Table 4. Means for five agronomic traits for different seed sizes of durum wheat in 2005.

Seed size (mm)	Heading time (day)	Spike length (cm)	Thousand kernel weight (g)	Test weight (kg hl^{-1})	Grain yield (kg ha^{-1})
2.2	128.0 a*	6.1	38.1 a	82.4	3472
2.2-2.5	127.3 b	6.3	34.4 b	81.5	3473
2.5-2.8	127.0 b	6.0	35.4 ab	81.4	3627
2.8	126.7 b	6.2	36.7 ab	81.1	3986
Control	127.0 b	6.3	34.3 b	80.9	3077
Mean	127.2	6.2	35.8	81.5	3527
$LSD_{0.05}$	0.644	NS	2.72	NS	NS

*Means within a column followed by the same letters are not significantly different at P = 0.05.

Table 5. Means for five agronomic traits for different seed sizes of durum wheat in 2006.

Seed size (mm)	Heading time (day)	Spike length (cm)	Thousand kernel weight (g)	Test weight (kg hl^{-1})	Grain yield (kg ha^{-1})
2.2<	173.0 a*	7.1 a	52.9	76.3 a	4583 b
2.2-2.5	172.3 b	6.1 b	50.9	72.5 c	5397 a
2.5-2.8	172.0 b	6.5 ab	52.3	74.2 b	5293 a
2.8>	172.0 b	6.3 ab	50.9	70.8 d	5663 a
Control	172.0 b	5.9 b	51.7	73.1 bc	5487 a
Mean	172.3	6.4	51.7	73.4	5285
$LSD_{0.05}$	0.487	0.764	NS	1.25	619.0

*Means within a column followed by the same letters are not significantly different at P = 0.05.

Discussion

Seed size does not alter ultimate germination percentage but affects growth, development and yield. The seeds >2.8 mm had fast germination rate. This feature of big seeds can be important at heat and drought stress conditions. This high growth rate was resulted with early heading in both years. Rapid growth in early spring and earliness are important adaptive characteristics to avoid late drought and high temperatures especially in rainfed environments such as in the year 2005 of this study. Seedling emergence being important for optimum plant density varied with seed size (Table 3). Generally seed size higher than 2.2 mm resulted high seedling emergence. Cornish and Hindmarsh [5] reported that seed size also had an effect, with smaller seeds of the same cultivar having shorter coleoptiles. Therefore, high seedling emergence in both years can be attributing to longer coleoptiles of large seeds. Also germination rate was very high at seed size of >2.8 mm. The highest grain yield was obtained from the seed of >2.8 mm at both years.

Bigger seeds have several advantages when compared to smaller seeds, such as faster seedling growth, higher number of fertile tillers per plant and higher grain yield [13]. Similarly, the highest grain yield was obtained from biggest seeds in both years (Table 4 and 5). The advantage of bigger seeds is demonstrated when the crop is grown under environmental stresses, particularly in drought[10]. Contrary in the drought year (2005) of this study, the advantages of bigger seeds were slight with respect of small sizes for grain yield, test weight and spike length. However, in the year 2006 in which took sufficient precipitation for wheat growth (Table 1) the increase in the seed size resulted high grain yield. Although a severe early drought effect was observed after sowing in 2006, 2.2 mm>seed sizes had high grain yield (Table 5). Similar result pointed out the positive effect of larger seed size of wheat in the early drought conditions [10]. The larger root mass in seedlings from bigger seeds may help to maintain a better water balance under early water stress if water is available deeper in the soil profile. In the year 2005 after sowing the weather was not dry, but dry and heat conditions were observed throughout the growing season. Therefore, we conclude that the positive effect of larger seed on wheat has vital impact at the germination and leaf initiation period. This finding was supported by Hampton [7] and Kalakanavar *et al.* [8].

Test weight declined in the order 2.2 mm>2.2-2.5 mm≥2.5-2.8 mm >2.8 mm >control in both years. Similar trends were observed for thousand grain weight. The plants from <2.2 mm seeds produced highest grain weight in both years. Our quality data (test weight and grain weight) suggest that increasing seed size would decrease the quality parameters. The main reason of this decrease may be due to poor emergence and lower plant number per m^2.

Conclusions

Large-grained seeds showed higher germination and seedling emergence than small ones (with 2.2 mm diameter). Because of the low seedling emergence in small-grained seeds, plant numbers per unit area were low; thus, spike length, thousand kernel weight and test weight were higher. On the contrary, while the highest grain yield means were obtained from large-grained seeds (with 2.8 mm diameter), 2.2 mm seed size showed the lowest values. At the field conditions, commercial seeds >2.2 mm wide can be successfully used in wheat production.

Acknowledgements

This research work was supported (Project No: TOVAG 105 O 051) by the Scientific and Technical Research Council of Turkey (TUBITAK)-Agriculture, Forestry and Food Technologies Group (TOGTAG).

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