M. Feldman

ΦΥΤΟΝ

25 de Mayo 347, of. 445, 1002 Buenos Aires, Argentina

36(1): 41-51, IV-1978

Effect of seed size and seeding rate on yield and other characteristics of durum wheat *

Y. P. Puri & C. O. Qualset **

ABSTRACT. — *** A study was conducted in an irrigated semi-arid environment at relatively high elevation (1,230 m) to examine the effects of seed size and seeding rate on the performance of durum wheat (*Triticum turgidum* L., durum group). Seeds of five tall cultivars with spring growth habit were sized by screening into three classes--large, medium, and small-with mean weights of -46, 26, and 19 mk/kernel, respectively. The seeding rates were 50, 100, 200, and 300 seeds/3 m in rows spaced 30 cm apart. A complete factorial experiment was conducted for 3 years. All cultivars responded similarly to variation in seeding rates and seed sizes. Planting large seeds gave significantly higher grain yields than planting medium and small seeds. Large seeds produced better stands than the other two seed sizes. Increased seeding rate improved stand establishment, grain yield, and decreased seed weight of the resulting crop. Seed size × seeding rate interaction was significant for the number of seedlings established, but this interaction was not significant for grain yield, probably because of compensating effects of yield components, mainly tillering ability. Large seeds of durum wheat should provide considerable economic gain in improved yields and less restrictive management practices. Large seed size and higher percentange of large seed should be included as a selection criterion in breeding programs.

* Contribution from the Department of Agronomy and Range Science, Univ. of Calif., Davis, CA 95616, U.S.A. ** Specialist, in Agronomy and Superintendent, Tulelake Field Station, University of California, Tulelake, CA 96134, U.S.A.; and Profesor, Dept. of Agronomy and Range Science, Univ. of Calif., Davis, CA 95616, U.S.A.
*** Additional index words: *Triticum turgidum* L., *Triticum durum* Desf., yield components. • Received 21 April 1977; accepted 18 May 1977.

Seed size plays an important role in stand establishment, seedling vigor, and yield. Many workers have reported a positive relation between seed size and seed yield in both grasses and legumes. Haskins & Gorz (3) reported that planting large seeds gave improved emergence and dry-matter production of sweet-clover (*Melilotus officinalis* (L.) Lam.). Smith & Camper (9) concluded that seed yields of soybeans (*Glycine max* (L.) Merr.) were higher from planting large seeds than from planting small seeds. Several workers have reported the beneficial effect of large seeds on yields of cereal crops but information is limited on seed size effects in durum wheat (*Triticum turgidum* L., durum group). Christian & Gray (1) and Randhawa et al (7) reported that wheat plants grown from large seeds had a yield advantage over plants grown from small seed of same cultivar. Kaufmann & McFadden (4, 5) had similar results with barley (*Hordeum vulgare* L.). Demirlicakmak et al (2) reported that seed size did not influence barley emergence but that tillering and yield were highest for large seed and lowest for small seed. The differences in yields between large- and smallseeded planting stock decreased slightly as seeding rate increased, but seed-rate × seed-size interaction was not significant. The lowest seeding rate produced the heaviest seeds, and the highest rate produced the lightest seeds. Parodi et al (6) and Randhawa et al (8) found that wheat coleoptiles were significantly longer from large seeds than from small seeds and the seedlings weighed significantly more. Widner & Lebsock (10) observed that several individual F_1 and F_2 large-seeded durum wheat plots yielded more than 40 g above their small-seeded counterparts.

This study was conducted in an irrigated semiarid environment to determine how the seed size of durum wheat affected yield and other agronomic characterististics related to durum wheat performance.

MATERIALS & METHODS.— Experiments with seed size, seeding rate, and genotype variables were conducted from 1968 to 1970 on a clay loam with 12 % organic matter at the Tulelake Field Station, Tulelake, California. Tulelake is located at 41° 58'N and 121° 28'W at 1,230 m elevation. The plots received a preplant flood irrigation, and about 90 kg N/ha were incorporated in the soil before planting. The seeds were planted 5 cm deep in the third week of April, and an additional flood irrigation was provided at the preboot stage. Weed control was done with 2,4-D and Carbyne.

Selected for the experiments were tall, advanced experimental lines: LD-392, LD-408, Sel. 1235, Sel. 1229, (henceforth will be designated as cultivars) and the cultivar Sentry. All these cultivars originated in the durum breeding program of the North Dakota Agricultural Experimental Station. The germ plasm pool sampled was not of diverse origin. The experimental design was a factorial arrangment of treatments, namely seed sizes, seeding rates and cultivars. Three seed sizes, large (>0.24 × 1.91 cm), medium (>0.22 × 1.91 cm), and small <0.22 × 1.91 cm), were obtained from each cultivar by sieve separation (slotted perforations). The four seeding rates were 50, 100, 200, and 300 seeds per 3-m row. A randomized complete block design with 4 replicates was used in tests in 1969 and 1970. The plot consisted of four 3-m rows spaced 30.5 cm apart. Data were collected from 2.4 m of each of the center two rows of each plot. Seedlings were counted after full emergence had been attained in 122 cm length of row. Tillers with seed-bearing spikes were counted in 122 cm of linear row in each plot. Plant height was measured on mature plants as the mean distance from the soil surface to the tip of the spike, not including the awns. In 1968 the same cultivars were used with two seed-size classes (large and medium) and three seeding rates (100, 200, and 300 seeds per 3-m row) with three replicates with the same plot size.

Mean seed weights of each size class for the five cultivars in each years is shown in Table 1. LD-408 had somewhat lighter seeds than LD-392, Sel. 1235, Sel. 1229 and Sentry. Seeding rate of large size seed when converted to kg/ha, at four seeding levels was 26, 49, 100 and 149 (Table 2) and the highest seeding rate for medium and small seed sizes was 85 and 67 kg/ha, respectively. The usual seeding rate for durum wheat in the Tulelake region is 100 to 130 kg/ha. Average proportion of the large seed size distribution in bulk harvested seed of LD-392, LD-408, Sel. 1235, Sel. 1229 and Sentry was 85, 80, 93, 94 and 90 percent, respectively, while the percentage of medium sized seeds were 10, 13, 3, 4 and 5 percent, respectively, for these cultivars.

Results and Discussion. — Seed germination and seedling emergence were normal for all years under irrigated conditions. Cultivars differed significantly in yield, height, and kernel weight of the resulting crop (Table 3). However, cultivar interactions with kernel size and seeding rate were not significant except for cultivar × seeding rate for yield and seedling number in 1969 and seed weight in 1970. Cultivar × seed size interaction was highly significant for seedling number in 1969 and in the combined analysis over years. Cultivar × seeding rate interaction was significant only for kernel weight of the subsequent crop in 1970 and in the combined analysis.

Differences between years were highly significant (Table 3) in 2-year analyses for yield, height, kernel weight, and seedling number and in 3-year analyses, differences were significant for yield, height and kernel weight. Cultivar × year interactions were not significant for yield and seedling number but were highly significant for height and kernel weight. Year × seed size interaction was significant for seedling number, yield, and kernel weight but not significant for height. Year × seeding rate interaction was highly significant for seedling number, yield, and kernel weight. Year × seed size × seeding rate interaction was not significant for any character. The absence of interaction could not be related to specific climate or soil condition during these years and such interactions could be expected because

Table 1. Mean weights of three seed-size classes of five durum wheat cultivars used for planting in 3 years.

Cultivar	Year	Size class*		
		Large	Medium	Small
		mg/seed		
LD-392	1968	49.6	25.0	--
	1969	41.5	25.2	20.2
	1970	47.0	27.0	18.1
	Mean	46.0	25.7	19.2
LD-408	1968	42.1	22.7	--
	1969	39.4	24.8	17.0
	1970	39.4	24.7	15.8
	Mean	40.3	24.1	16.4
Sel. 1235	1968	52.8	26.6	--
	1969	46.5	26.0	20.6
	1970	47.2	26.9	19.1
	Mean	48.8	26.5	19.8
Sel. 1229	1968	51.6	26.0	--
	1969	45.5	27.1	21.2
	1970	46.6	26.9	20.2
	Mean	47.9	26.9	20.2
Sentry	1968	45.2	25.4	--
	1969	48.0	28.2	22.0
	1970	50.5	27.8	21.1
	Mean	47.9	27.1	21.6
Mean (1969-70)		45.0	26.5	19.5

* Each figure represents the mean of 12 to 16 determinations.

Table 2. Conversion of seeding rates and size classes to seeding rates in kilograms/hectare averaged over the five cultivars and three years.

Seeding rate	Size class		
	Large	Medium	Small*
seeds/3 m	kg/ha		
50*	26	15	11
100	49	28	21
200	100	57	42
300	149	85	67

* Not included in 1968.

Table 3. Significance of mean squares for 6 characters from 1-2, and 3-year analyses of variance for cultivars, seed sizes, and seeding rates.

Source of variation	Yield	Ht.	Kernel wt.	% seed size distribution		Seedling no.	Tiller no.
				Large	Medium		
Years (Y)							
1969-70	**	**	**	--	--	**	--
1968-70	*	*	**	--	--	--	--
Cultivars (C)							
1968	**	**	**	**	**	--	--
1969	**	**	**	--	--	NS+	--
1970	**	**	**	--	--	NS	NS
1969-70	**	**	**	--	--	NS	--
1968-70	**	**	**	--	--	--	--
C x Y							
1969-70	NS	**	**	--	--	NS	--
1968-70	NS	**	**	--	--	--	--
Seed Sizes (S)							
1968	NS	NS	**	NS	NS	--	--
1969	**	*	*	--	--	**	--
1970	**	NS	NS	--	--	**	*
1969-70	**	*	NS	--	--	**	--
1968-70	NS	NS	*	--	--	--	--
Y x S							
1969-70	**	NS	**	--	--	*	--
1968-70	NS	*	*	--	--	--	--

Table 3 (continued)

Source of variation	Yield	Ht.	Kernel wt.	% seed size distribution: Large	% seed size distribution: Medium	Seedling no.	Tiller no.
C x S							
1968	NS	NS	NS	NS	NS	--	--
1969	NS	NS	NS	--	--	**	--
1970	NS	NS	NS	--	--	NS	NS
1969-70	NS	NS	NS	--	--	*	--
1968-70	NS	NS	NS	--	--	--	--
Y x C x S							
1969-70	**	NS	NS	--	--	**	--
1968-70	NS	*	NS	--	--	--	--
Seed Rate (R)							
1968	**	NS	**	**	**	--	--
1969	**	**	NS	--	--	**	--
1970	**	*	**	--	--	**	**
1969-70	**	NS	**	--	--	**	--
1968-70	**	NS	**	--	--	--	--
Y x R							
1969-70	**	**	**	--	--	**	--
1968-70	**	NS	**	--	--	--	--
C x R							
1968	NS	NS	NS	NS	NS	--	--
1969	*	NS	NS	--	--	*	--
1970	NS	NS	**	--	--	NS	*
1969-70	NS	NS	*	--	--	NS	--
1968-70	NS	NS	NS	--	--	--	--

Table 3 (continued)

Source of variation	Yield	Ht.	Kernel wt.	% seed size distribution Large	Medium	Seedling no.	Tiller no.
Y x C x R							
1969-70	NS	NS	NS	--	--	NS	--
1968-70	NS	NS	NS	--	--	--	--
S x R							
1968	*	NS	NS	NS	NS	--	--
1969	NS	NS	NS	--	--	*	--
1970	NS	NS	NS	--	--	**	NS
1969-70	NS	NS	NS	--	--	**	--
1968-70	NS	NS	NS	--	--	--	--
Y x S x R							
1969-70	NS	NS	NS	--	--	NS	--
1968-70	NS	NS	NS	--	--	NS	--
C x S x R							
1968	NS	NS	NS	NS	NS	--	--
1969	**	NS	NS	--	--	**	NS
1970	NS	NS	NS	--	--	NS	NS
1969-70	NS	NS	NS	--	--	NS	--
1968-70	NS	NS	**	--	--	--	--
Y x C x S x R							
1969-70	NS	**	NS	--	--	**	--
1968-70	NS	NS	NS	--	--	--	--

+ NS, nonsignificant, $P > 0.05$.
* $0.01 < P < 0.05$.
** $P < 0.01$.

of fluctuations in temperature, moisture, and other factors that do not occur at the same stage of plant development each year.

The various interactions involving cultivars were not often significant, especially those involving seeding rate and seed size. Thus it is appropriate to consider the results taken over the five cultivars. Seed size influenced grain yields in 2 out of 3 years (Tables 3 and 4). Large seeds produced significantly higher yields than medium and small seeds over a two-year period. The yield increased linearly with seed size in 1969, whereas in 1970 yields were equal for the small and medium seeds (both lower than for the large seed class). Christian & Gray (1) and Randhawa et al. (7) obtained similar results with common wheats.

The size of seed planted apparently influenced the weight of kernels of the resulting crop, although the effect was rather small (Table 4). In 1969 large seed produced significantly heavier kernels than did medium and small seed classes. In 1970 the medium seed size was better than large and small sizes. This effect, if real, could be related to the significant size × rate interaction for seedling number (Table 3). Large seeds produced more seedlings per unit area (Table 4) than small seeds. Tillering of plants from small seeds was enhanced because of low plant density (mean number of tillers/plant: 4.5, 4.6, and 5.2 from large, medium, and small seeds). Since tillers

Table 4. Effect of seed size on grain yield, seed weight, and seedling number in 1969 and 1970 (means over cultivars and seeding rates).

Year	Seed size	Yield	Kernel wt.	Seedlings/ 122 cm of row
		kg/ha	mg	no.
1969	Large	5620	43.8	64
	Medium	5050	43.0	63
	Small	4300	43.0	52
1970	Large	6750	45.2	42
	Medium	6290	46.0	40
	Small	6300	45.4	34
Mean, 2 years				
	Large	6180	44.5	53
	Medium	5670	44.5	51
	Small	5300	44.2	43
L.S.D. (0.05)	1 year	254	0.7	2.8
	2 years	180	0.5	2.0

may produce smaller seeds than main culms, this could lead to an average kernel weight that would be lower for the crop produced by plants from small seeds than from large seeds. The lack of significant interaction of rates × sizes for tiller number also support this idea.

Seeding rate influenced stand count, grain yield, and seed weight (Table 5). In 1969 the yield increased significantly with seeding rate, and in 1970 the two highest seeding rates equal in yield and significantly higher than the two lowest seeding rates. Average of two years indicated that yield increased with each increment of seeding rate. Seedling number and yield increased with seeding rate over both years (Table 5). Crop kernel weight (two years average) was significantly lower at the two highest seeding rates compared to the lower rates in 1969 and 1970. Similar yield responses to seeding rates were reported by Demirlicakmak et al. (2) and Randhawa et al. (7). In 1968 the differences in percent seed size distribution produced by the cultivars were highly significant. The large seed size distribution (average over seeding rate and size) of harvested grain of LD-392, LD-408, Sel. 1235, Sel. 1229 and Sentry was 83, 79, 90, 91 and 92 percent, respectively. Seeding rate lowered the large seed size distribution significantly (Table 3). The seeding rate of 100, 200 and 300 seeds per row produced 90, 86 and 85 percent large seed size grain, respectively (Average over size and cultivars).

Table 5. Effect of seeding rate on grain yield, seed weight, and seedling number in 1969 and 1970 (means over cultivars and seed sizes).

Year	Seeding rate	Yield	Kernel wt.	Seedlings/122 cm of row
	seeds/3.0 m	kg/ha	mg	no.
1969	50	3310	43.5	20
	100	4450	43.6	41
	200	5820	43.2	75
	300	6390	42.7	102
1970	50	5320	46.7	13
	100	6500	46.6	25
	200	6980	45.1	49
	300	6980	43.8	68
Mean, 2 years				
	50	4320	45.1	17
	100	5470	45.1	33
	200	6400	44.2	62
	300	6690	43.2	85
L.S.D. (0.05)	1 year	394	0.8	3.2
	2 years	208	0.6	2.3

The interactions, while significant in certain cases in this study, were attributable to changes in the magnitude of the differences involved rather than the direction of response. Therefore the major emphasis is placed on the main effects. The ability of the large seed class to produce better stands, higher yields, and heavier seeds of the resultant crop is an important factor in improving economic gains. In addition, to obtain optimum crop stand, the large seeds can be planted at greater depths if soil moisture is limiting at planting time. This study demonstrates the beneficial effect of large seed size on the resulting durum wheat crop.

The seeding rate in the Tulelake area is 100 to 130 kg/ha. In this study, seeding rate was determined by the number of seeds per row and not by weight of seed per row (Table 2). The commercial seeding rates were attained only in the large size and other seed sizes fell below the commercial rate. This indicates that further work is needed, but these results do suggest that if a grower had a seed lot with highly variable seed sizes there could be a benefit from the planting of only large seeds. Since the large or medium sized seeds produce a greater percentage of plants than the small sized seeds, they should produce a more consistent and uniform stand establishment. This should result in a lower seeding rate (seeds/unit area) than now being used. The average cleaning losses would only be about 12 % for cultivars used in this study, if only the large seed class was retained for planting. If seed lots were more variable in seed size there would of course be greater cleaning losses, but the advantages of size classification on the subsequent crop are expected to be greater.

Recent emphasis on developing short-statured wheats has often result in wheats with small seeds as well as short coleoptiles. There are obvious advantages in durum wheat management and seed production to have large seeds and this character should be included as a selection criterion in breeding programs. Little information is available on the heritability of this trait. In a survey of the U. S. Department of Agriculture world collection of durum wheats we identified an entry, PI 306665, with large seeds when grown under Tulelake conditions. We are now studying the heritability of kernel size and large-seeded germ plasm is being developed for selection and cultivar improvement.

References

1. Christian, C. S., & Gray, S. G., *J. Council Sci. Ind. Research* (Australia) 8 (1935) 1
2. Demirlicakmak, A., Kaufmann, M. L. & Johnson, L. P. V., *J. Plant Sci.* 43 (1963) 330
3. Haskins, F. A., & Gorz, H. J., *Agron. J.* 67 (1975) 652
4. Kaufmann, M. L., & McFadden, A. D., *Can J. Plant Sci.* 40 (1960) 623

5. Kaufmann, M. L., & McFadden, A. D., *Can J. Plant Sci.* 43 (1963) 51 ,
6. Parodi, P. C., Patterson, F. L. & Nyquist, W. E., *Crop Sci.* 10 (1970) 587
7. Randhawa, A. S., Anand, S. C. & Jolly, R. S., *J. Res. Punjab Agric. Univ.* 11 (1974) 9
8. Randhawa, G. S. Bains, D. S., & Gill, G. S., *J. Res. Punjab Agric. Univ.* 10 (1973) 291
9. Smith, T. J., & Camper, H. M. Jr., *Agron. J.* 67 (1975) 681
10. Widner, J. N., & Lebsock, K. L., *Crop Sci.* 13 (1973) 164