International Scholars Journals

Global Journal of Food and Agribusiness Management Vol. 2 (4), pp. 001-004, April, 2018. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Seed size effect on grain weight and agronomic performance of tef [*Eragrostis tef* (Zucc.) Trotter]

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Accepted 27 August, 2017

Tef [*Eragrostis tef* (Zucc.) Trotter], the indigenous Ethiopian cereal, has a very minute seed size, yet it has a strong bearing both on the preferences of farmers for planting material and consumers as quality measure. The objectives of this study were to determine the effects of sieve-graded seeds on the grain weight of tef, and to investigate whether large seed size offers yield and agronomic advantages over using un-graded planting seed materials. Seeds of two tef varieties, DZ-01-974 and DZ-Cr-37 (early type) were sieve-graded in to five seed size treatments, and were field grown at Debre Zeit and Akaki experiment stations, in 2005 and 2006, along with the un-graded seed (Mix) as a control. A split-plot design replicated three times in randomized complete block arrangements was used; varieties were used as main plots while seed sizes were kept as sub-plots. Grain yield, days- to-panicle emergence (DPE), plant height, biomass yield and panicle length were considered. There was clear increase of 100-seed weight when seed size increased. However, seed size effects were statistically significant, but not agronomically meaningful, only for DPE. Generally, there were trends of increased grain yield (up to 7%) due to large seeds, but the advantages for the other traits were nil. Relative growth rates (RGR) were similar for the seed-size groups, and therefore, were unable to explain the lack of significant effects. In conclusion, under optimum production conditions, the added advantages of large seed size do not justify tef-seed grading. On the other hand, farmers may consider the use of smaller size seeds for planting and sell large size seeds for consumption purpose.

Key words: *Eragrostis tef*, seed size, tef, tef agronomy.

INTRODUCTION

Tef [*Eragrostis tef* (Zucc.) Trotter] is the major indigenous cereal of Ethiopia; annually it accounts for 29% of the total acreage and 20% of the gross grain production of all the major cereals cultivated in the country (Central Statistical Agency, 2006). The tef grain is mainly used to prepare the traditional pancake-like Ethiopian bread, "injera". For Ethiopian farmers, tef straw is no lesser important than the grain since it is the most preferred animal feed source, particularly during the long, dry seasons of the year when other livestock feed sources are scanty. Tef is also gaining popularity as health food (Spaenij-Dekking et al., 2005) in the Western world menus and serious attempts are underway to expand its cultivation in Europe, notably the Netherlands, and the United States of America (Evert et al., 2009).

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Seeds of the tef plant are very minute in size (hundred-kernel mass = 0.18 - 0.38 mg), perhaps the smallest among cereals, and the existence of genotype differences is equivocal (Assefa et al., 2001). The great majority of tef consumers in Ethiopia traditionally prefer to buy the tef grain rather than the flour. That means both farmers (planting seeds) and consumers prefer to buy relatively large grain-sized tef (Belay et al., 2005). However, from farmers' perspectives, the advantage of large seed size over the smaller ones has not been studied before mainly because of the minute nature of the seeds, and consequently, lack of efficient grading system.

The effects of large seed size in the production of small cereals has been investigated in relation to seed germination (Lafond and Baker, 1985; Roy et al., 1996), speed of emergence (Chastain et al., 1995), seedling vigor (Mian and Nafziger, 1994), weed competition ability (Willenborg et al., 2005), and field performances as measured through developmental traits, biomass production, growth rates and grain yield (Royo et al., 2006). However,

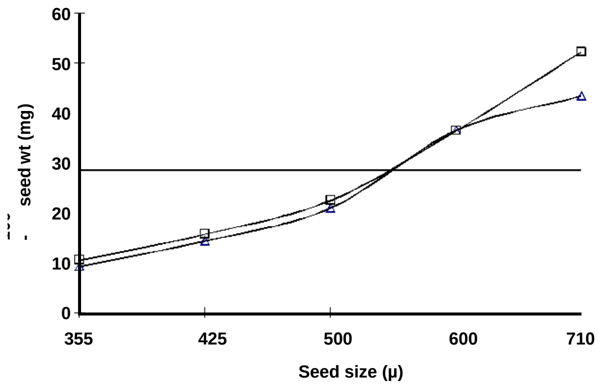

Figure 1. Relationships between sieve graded seed size and 100-seed weight of two tef varieties (DZ- 01-974; DZ-Cr-37) and mean of the ungraded. Controls (-).

Table 1. Average proportion (%) of five tef seed-size groups in 1-kg seed lot for two varieties (DZ-01-974 and DZ-Cr-37) in different sieve sizes.

	Proportion (%)		
Sieve size (μ)	**DZ-01-974**	**DZ-Cr-37**	**Mean**
355	1.18	1.22	1.20
425	4.93	4.66	4.79
500	28.63	23.49	26.06
600	65.03	70.40	67.71
710	0.23	0.24	0.24
Total	100	100	100

discernible practical advantages of large size cereal seeds over their small-sized counterparts on field performances appear inconsistent. The positive findings of the available research results are further influenced by tillage practices (Chastain et al., 1995) and moisture availability (Lafond and Baker, 1985; Mian and Nafziger, 1994).

The objectives of this study were to determine the effects of sieve-graded seed-sizes on the grain weight of tef, and to investigate whether large seed size of tef offers yield and agronomic advantages over using un-graded planting seed material.

MATERIALS AND METHODS

Two released tef varieties, DZ-01-974 and DZ-Cr- 37, representing optimum and early-maturity groups for the central highlands, were used in the present study. DZ-Cr-37 is also a relatively drought-tolerant cultivar (Teferra et al., 2000). Seed lots harvested from the previous season were size-graded in to five groups (Table 1) using Octagon Digital, Laboratory Test Sieve, Endecotts Ltd., London, England. The un- graded seed (Mix) was used as control. Proportions of each seed-size group in 1-kg seed lot and hundred-seed weight were recoded before planting. The five seed- size treatments of the two varieties were field grown at Debre zelt and Akaki experiment stations, in 2005 and 2006, using a split-plot design replicated three times and arranged in randomized complete blocks. Varieties were used as main plots while seed size groups were kept as sub-plots. Debre Zeit and Akaki represent two of the major tef production areas in Ethiopia characterized by sufficient rainfall, optimum temperature and soil type of black-clay vertisols.

Each treatment was planted in an experimental plot of 2 x 2 m with inter- and intra- block distances of 1 and 1.5m, respectively. Agronomic practices followed were essentially similar to the ones practiced by farmers in the study areas: planting was hand-broadcast, fertilizer application was 100 kg each of Diamonium Phosphate at planting and Urea top dressed at tillering, and weeding was manual. Data were recorded on plot basis for grain yield, days-to-panicle emergence (DPE), plant height, shoot-biomass yield and panicle length.

Analyses of variance (ANOVA) were used to analyze the data. Homogeneity of error variances were checked before running combined ANOVA for each trait. All statistical analyses were carried out using the Agrobase software package (AGROBASE^{TM} , 2004).

In 2006, a separate experiment (for destructive data collection) was planted at Debre Zeit in order to estimate the relative growth rates (RGR) of the seed-size groups. The treatments were laid out in the same fashion as the performance tests, but in a plot size of 1 m × 1m. In order to determine dry matter accumulation, plots were sampled at two-week intervals starting from 20 days after sowing through to maturity; 10 randomly taken plants and cut at ground level were dried in an oven at 70^0C overnight and weighed on sensitive balance. Growing degree days (GDD) with base temperature of 10^0C, instead of calendar days, were used in computing RGR, because of seasonal variations and differences in maturity between the varieties used in this study. RGR is defined as the rate of dry matter accumulation per unit of existing dry matter and was computed according to the equations given in Karimi and Siddique (1991).

RESULTS AND DISCUSSION

The disaggregated average proportions from one-kilogram seed lot of the five sieve-size grades are given in Table 1. The highest proportions (>90%) of the seeds were retained in the sieve-sizes of between 500 and 600 μ. The proportion of tef seeds that reached the 710 μ was extremely small (<1%), followed by those retained by the smallest 355 μ sieve size. The trend for the test varieties was strikingly similar. The seeds used for this study were harvests of researcher multiplied seeds; however, we would not expect different results if farmer-multiplied seeds were used. This is because our prior observations have asserted that, with centuries-old knowledge of its difficult and meticulous culture and growing it as a cash crop, farmers in the study areas produce no lesser quality tef seeds than research stations (Belay et al., 2005).

There was a clear increase of 100-seed weight when seed size increased (Figure 1); the average for the varieties ranged between 10.01 mg for the smallest sieve-size grade (355 μ) and 47.9 mg for the largest sieve size grade (710 μ). The un-graded controls had an overall average seed weight of 28.46 mg. These results translate into the following observations:

1) Only seed weights in the 500, 600 μ and the ungraded mixture lay within the range values for tef 100-seed weight

Table 2. Mean squares from the combined ANOVA of seed size effects for two tef varieties grown at Debre Zeit and Akaki, 2005 and 2006.

Source	Df	DPE	Shoot biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Plant height (cm)	Panicle length (cm)
Locations (L)	1	9312.25***	667361111***	13110434***	16107.84***	4624.00***
Years (Y)	1	2401.00***	19876736*	5541316**	2.01ns	156.25*
Varieties (V)	1	1236.69***	41710069**	3006178**	1856.17**	318.02**
Error (a)	8	1.77	3250868	163405	45.13	19.12
Seed Size (S)	5	9.71**	458333ns	185302ns	33.62ns	6.26ns
Error (b)	40	2.34	1003559	115862	28.79	9.12
Total	143					

*, **, *** indicate p < 0.05, p < 0.01 and p < 0.001, respectively. Ns = non-significant.

Table 3. Mean values of grain yield and other traits for five seed-size groups of two tef varieties grown at Debre Zeit and Akaki, 2005 and 2006.

Seed size (μ)	Days to panicle emergence			Shoot biomass (kg/ha)			Grain yield (kg/ha)			Plant height (cm)			Panicle length (cm)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
355	48.3	43.0	45.6	8958	7563	8260	1865	1715	1790	86.0	75.6	80.8	34.9	30.6	32.8
425	49.5	43.0	46.3	8479	7750	8115	1915	1549	1732	82.8	76.9	79.8	35.4	32.3	33.8
500	48.4	42.3	45.4	8917	7833	8375	1990	1753	1872	83.8	78.3	81.0	34.8	31.4	33.1
600	47.5	42.2	44.8	9333	7646	8490	2156	1765	1960	86.0	77.9	81.9	35.1	32.3	33.7
710	47.3	41.7	44.5	8688	7708	8198	2056	1823	1939	86.0	80.7	83.3	34.9	32.3	33.6
Mix	48.8	42.4	45.6	8479	7876	8188	2006	1650	1828	85.3	77.4	81.3	33.5	31.8	32.7
Grand Mean	48.3	42.4	45.4	8809	7733	8270	1998	1709	1854	85.0	77.8	81.4	34.8	31.8	33.3

V1 = DZ-01-974, V2 = DZ-Cr-37.

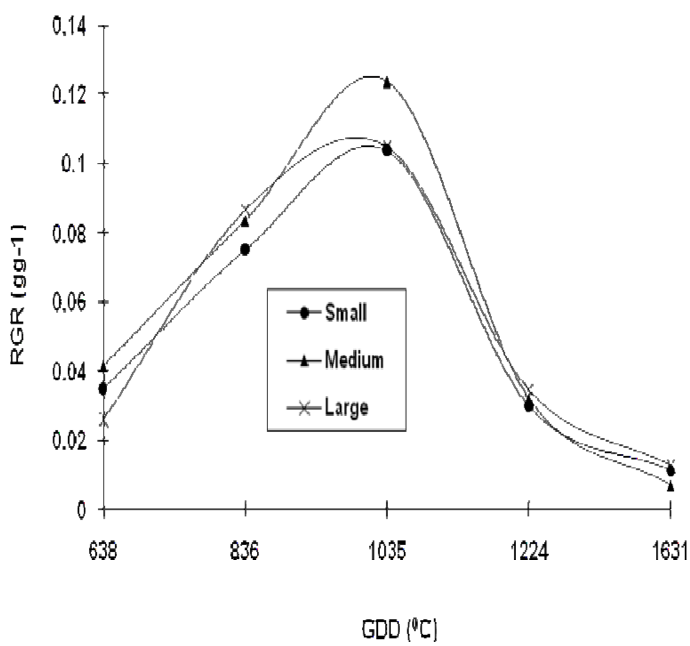

Figure 2. Mean relative growth rates (RGR) of tef plants grown from small, medium and large seeds. (Note: small = 355 μ; medium = 425 and 500 μ.

(0.18 - 0.38 mg) complied from several studies by Assefa et al. (2001).

2.) The lower sieve-size grades are 47 - 65% lower in seed weight than the un-graded control. On the other hand, the large sieve size grades (600 and 710 μ) showed 29 - 69% higher seed weight than the control.

Seed size effects were not significant (p > 0.05) for all traits considered except days-to-panicle emergence; almost all of the first and second-order interactions of the factors, including seed-size x variety, were also not significant, and therefore, only selected mean squares are presented (Table 2). Rather significant were the main effects of locations, years and varieties. Generally, when compared to the un-graded control, there were trends of increased grain yield (up to 7%) due to large seeds, but the advantages for the other traits were not discernible (Table 3). Lodging was visually assessed and no advantages were observed. We observed a transient advantage of early seedling vigor, but that was lost in a short period well before panicle emergence. The, relatively late maturing variety, DZ-01-974, produced higher biomass and grain yields, and was taller than DZ-Cr-37 (Table 3).

From the results of the second trial, seed size did not influence relative growth rate (RGR) (Figure 2). That means the absence of seed size effects on grain and biomass yields cannot be explained by growth compensation factors from plants grown initially from small seed size. The trends in RGR are similar with the results reported for tef (Teferra et al., 2000) and wheat (Karimi and Siddique, 1991).

The results of the present study on tef did not show significant effects of large seed size on the final yield and biomass production so as to justify seed grading. In cereals, influences of large seed size on germination were either negligible (Chastain et al. 1995) or smaller seeds germinated faster (Lafond and Baker, 1985; Roy et al., 1996). Several studies have reported an early advantage of seedling emergence and vigor (Mian and Nafziger, 1994; Larsen and Andreasen, 2004) from large seed sizes, but few have shown that translated into final yield (Royo et al., 2006). Grain yield advantages of 4.2% in bread wheat (Chastain et al., 1995) and 16% in durum wheat (Royo et al., 2006) have been reported from large seeds over small sized ones. Royo et al. (2006) also found that larger seeds resulted in high biomass, green area index, number of spikes per m^2 and heavier kernels. According to Manga and Yadav (1995), seed size was found to be significantly influencing early vigor, tiller number, plant height, and dry-matter production.

The advantages of large seeds may be better expressed in moisture-stress environments, where planting depths also play a role (Graven and Carter, 1990; Mian and Nafziger, 1994; Manga and Yadav, 1995). The fact that the un-graded tef seed-lots contained significant proportion of large size seed group, coupled with the optimum moisture regime of the test locations, and the broadcast sowing method used might have diminished the advantages of large-size tef seeds. However, the effects of seed size could be further tested in conjunction with sowing depth and in less-favorable environments. Considering the fact that tef suffers from severe lodging, such knowledge may be worthwhile since deeper sowing increases the depth and length of the root crown and thereby strengthening anchorage of the plants (Pinthus, 1973). Tef seeds are known to germinate from up to 1.5 cm depth (Debelo, 1992; Evert et al., 2009).

Conclusion

Under the current tef production conditions in the relatively optimum growing areas of Ethiopia, the added advantages of large-seed size do not rise to the level of justifying seed grading. On the other hand, farmers may use smaller size seeds for planting purposes and sell the large size seeds for consumption purpose since the large ones attract premium price in the market. Nevertheless, the advantages of large seed size in moisture-stress areas and in combination with sowing depth could be further investigated.

ACKNOWLEDGEMENTS

The McKnight Foundation's Collaborative Crop Research Program financed the study through the project "Breeding and genetic basis of tef improvement in Ethiopia" (Grant No. 02 - 451). We thank the technical staff of the National Tef Research Project, Debre Zeit Agricultural Research Center, particularly Amsale G.W. Senbet, for their assistance in data collection.

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