Seed Pelleting Effects on Seed Quality Parameters in Tef [*Eragrostis tef* (Zucc.) Trotter]

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Abstract

Seed of tef is very tiny in size, making the sowing of the crop more challenging. Seed pelleting increases and homogenizes seed size, important for proper seed handling, uniform planting as well as suitable for mechanical planters. An experiment was conducted in a seed quality laboratory of Debre Zeit Agricultural Research Center, which consisted of a factorial combination of three levels of pelleting [small size or 12 times the naked seed (2-2.4mm), medium size or 20 times the naked seed (2.4-3mm) and large size or 40 times the naked seed (3mm and above)] along with un-pelleted (naked) seed and three tef varieties (Dagim, Boset and Felagot) arranged in CRD with four replications. The results revealed that pelleting size showed highly significant ($P \leq 0.01$) effect for all the traits except for shoot and root length and similarly effect of varieties were highly significant ($P \leq 0.01$) for most of the traits. But the interaction effect showed significant effect on vigour index I, speed of germination and seedling shoot length. In generally enhanced germination and early vigour were recorded from medium sized pellets (2.4-3mm) and variety Dagim was relatively better than the other varieties in terms of seed quality parameters. However the study was carried out on limited pelleting material and varieties targeting to increase only seed size. Thus supplementing of pelleting material with growth promoter, pesticide and nutrition were need to be investigated in the future.

Key words: *Eragrostis tef*, Germination, Mechanized planting, Seed pelleting, Seed quality.

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] which belongs to Poaceae or Grass Family is one of the most important cereal crops in Ethiopia for both the human food and the livestock feed. Moreover, tef is becoming popular globally because of its nutritional and health benefits (Hopman *et al*., 2008; Bergamo *et al*., 2011). Tef is the major staple cereal crop in Ethiopia, and grows extensively under various climatic and soil conditions (Neela and Solomon, 2018). In Ethiopia, tef is annually cultivated on 3.1 million ha land and produce 5.3 million tons grain, where the national average yield as only 1.94 tons ha^{-1} (CSA, 2022).

Extremely low productivity of tef is mainly due to lodging (the permanent displacement of the stalk from the upright position), drought and small seed size. Since the seed of tef is very tiny (only 0.4 mg per 1000 kernel), recommended seed rate cannot be achieved. Although research recommendation is 10 kg ha^{-1}, farmers sow tef 3-4 fold more than the recommended rate.

The small size of tef seed poses problems during sowing, and indirectly during weeding and threshing. At sowing, the very small seed size makes it difficult to control population density, distribution and makes it difficult to use mechanical planters. The uneven plant stand after germination has an impact on nutrient use efficiency of the crop, and subsequently, yield. Owing to the scattered plant stand, farmers find it difficult to use mechanical weeding implements and are forced to either hand-weed or use chemical herbicides (Ketema, 1997). Increasing the size of tef seed is, therefore, important since uniform sowing and recommended rate can be applied.

Seed pelleting, is the process of enclosing a seed with small quantities of inert material just large enough to produce globular unit of standard size to facilitate precision planting. The inert material also creates natural water holding media and provides a small amount of nutrients to young seedlings (Krishnasamy, 2003). In addition its role in mechanization, seed pelleting improves the physical properties of seeds, such as improving the strength, shape and provide more precise and better seedling conditions for irregular seeds of small grain size (Wang and Jiang, 2021). In crops like onion and carrot, the seed rate can considerably be reduced and thinning and gap-filling operations can be eliminated using seed pelleting (Hill, 1999). Pelleting is mostly practiced in small and irregular shaped seeds for easy handling and helps in mechanized sowing (Halmer, 2003, Rajeswari and Renganayaki 2020). Seed pelleting would be useful in tef husbandry as it would enable easy implementation of row planting of the tiny seeds. Preliminary tef pelleting study was done using inert material which only enables to increase the seed size for proper handling and sowing (Cannarozzi *et al*., 2018). However, future formulation may also contain compounds which improve the soil fertility and/or protect the seeds from seed /soil borne pests and diseases. The impact of pelleting technology and pelleting sizes on the seed physiological quality has not been studies on tef. The objective of current study was, therefore, to evaluate the effects of seed pelleting technology and pelleting sizes on seed quality of selected tef varieties

Materials and Methods

The Laboratory experiment was carried out at Debre Zeit Agricultural Researcher Center (DZARC) which included twelve treatments in factorial combinations involving three pelleting sizes and three tef varieties with control treatments for each variety. A laboratory experiment was carried out from September to October 2020. The treatment was arranged in Completely Randomized Design (CRD) with four replications.

The pelleting materials used in this study were Pansil 400, Danalim, Mowilith LDM 1881 B, Gypsum, and pure water. Pelleting was performed using 100 g of tef seed at a time. Before seed pelleting, the binding solution was prepared by the proportion of 90% and 10% of water and Mowilith LDM 1881 B, respectively. The proportion of 900g gypsum, 50g Pansil 400 and 50g Danalim were used to prepare the bulking or coating material. The binder and bulking materials were added alternatively with proper amount to avoid seed agglomeration, too wet condition, and the formation of empty pellets during the pelleting process. At the end of the process, pelleted seeds were dried at 80^{o} C for 30 minutes in the drying machine. After drying, the pelleted seeds were sorted through different sieve sizes starting from 2mm to 3mm. Accordingly, the size of pelleted seed range from 2-2.4mm for small size or 12 times the naked seed, 2.4-3mm for medium size or 20 times the naked seed and above 3mm for large seed size or 40 times the naked seed were used in this experiment.

The experiment was carried out at room temperature in the seed quality testing laboratory. Tef seed were planted on germination paper in the petri dish. Germination papers are made up of pure cellulose fibres, and are designed to avoid any substances which could influence the growth of the seedlings. The paper has high absorbent capacity and comes in standard specification of 5-7 pH range with good bursting strength. Before seed planting germination paper was soaked in water. One day after planting 5 ml of water was daily applied for 3-4 days. For each treatment, 50/100 seeds were sown where 3 replications were applied for each treatment.

Data collection

Standard germination

Standard germination: refers to the proportion of normally germinated seedlings on Day 4/5 to the total number of seeds sown. The number of normal, and abnormal seedlings, and un-germinated seed were recorded. The results were expressed as mean percentage of normal seedlings. Therefore, standard germination was taken as the average number of seeds that germinated as normal over the final day’s period, and it was calculated as follows:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedling}}{\text{Total number of seeds sown}} \times 100$$

Seedlings shoot and root length

The seedlings shoot length and root length was measured after the final count in the standard germination test by randomly taking ten normal seedlings from each replication. The shoot and root length was measured from the point of attachment to the cotyledon up to the tip of the shoot and root of the seedlings, respectively. The average seedling shoot and root length was determined following ISTA (2004) rules.

Seedling dry weight

The seedlings dry weight was measured after the final count in the standard germination test. Ten seedlings were randomly selected from each replication and cut free from their cotyledons weighed, and dried in an oven at 80°C for 24 h (ISTA, 2004). The dry weight was also measured.

Vigor index I: refers to the product of percent standard germination and sum of shoot length and root length.

Vigor index II: refers to the product of the percent standard germination and average seedling dry weight.

Speed of germination

The normal seedlings were counted daily from Day 4 to Day 8. Finally, speed of germination (SPG) was calculated following the procedure described by (Maguire, 1962)

$$\text{SPG} = \frac{\text{Number ofnormal seedling}}{\text{Day of first count}} + \ldots + \ldots \frac{\text{Number of normal seedling}}{\text{Day of final count}}$$

Method of data analysis

Data were subjected to analysis of variance (ANOVA) using SAS Software (Version 9.2). The mean comparison was done using least significant difference (LSD) test at 5% level of significance. Pearson correlation coefficient analysis was performed to determine the degree of association of seed quality parameters. Mean value of treatment were used for correlation analysis using SAS analysis.

Results and Discussion

ANOVA

Pelleting size showed highly significant ($P \leq 0.01$) effect for all the traits except for shoot length and seedling dry weight and similarly effect of varieties were highly significant ($P \leq 0.01$) for standard germination, shoot length, root length, vigor index I, vigor index II and speed of germination and significant ($P < 0.01$) effect on seedling dry weight (Table 1). On the other hand the interaction effect of pelleting size and varieties were highly significant ($P \leq 0.01$) for vigor index I and speed of germination and significant ($P < 0.01$) effect on shoot length (Table 1). Analysis of variance indicated that the main effect of pellet size, variety and interaction effect of pellet size x variety had highly significantly ($P \leq 0.01$) affected the speed of germination (Table 1).

Table 1. ANOVA of the effect of pelleting and tef varieties on seed quality parameters

Source of Variation	DF	SDG	SHL	RL	SDW	VI	VII	SPG
Pelleting size	3	835.47**	0.22**	0.29ns	0.00009ns	37593.44**	11.80**	36.64**
variety	2	478.40**	1.05**	1.88**	0.0008*	77845.52**	15.93**	17.78**
Pelleting x variety	6	66.51ns	0.17*	0.21ns	0.001ns	11356.38**	1.54ns	1.56**
Error	33	1376.35	1.82	0.12	0.0002	3057.53	1.42	0.17
Total	47							
CV (%)	7.54	7.62	11.20	11.97	10.37	11.58	10.12	
LSD 0.05)	4.65	0.17	0.25	0.01	39.77	0.86	0.30	

** = Significant at P < 0.01, * = significant at P < 0.05, DF= degree of freedom, SDG= Germination; SHL= Shoot length; RL=Root length, SDW= Seedling dry weight, VI= Vigor Index one, VII= Vigor Index two, SPG= Speed of germination.

Main effect of varieties and pelleting size on mean performance and seed quality traits

Standard germination

The naked or un-pelleted seeds gave the highest germination of 92.7% although the difference was not significant from the medium sized pelleting (89.5%) (Table 2). On the other hand, large size pelleted seeds had significantly low germination (73.7%). This indicates that the germination of tef seeds is negatively affected when the pelleting size is exceeding certain size. Considering standard germination, the pellet sizes of small and medium seem appropriate. Similar to our result, either delayed or lower rate germination were reported for pelleted sweet corn (Somrat *et al*., 2018) and sugar beet (Arshadi and Asgharipour 2011). On the contrary, improved germination of pelleted seeds, compared to naked seeds was reported for lettuce (*Lactuca sativa*) and guayule (*Parthenium argentatum*) (Sanchez *et al*., 2014). Regarding the performance of the varieties for standard germination, Dagim (90.75 %) and Felagot (86.3 %) showed significantly higher germination percentage than Boset (79.88 %). It is important to note that the germination percentage obtained from Dagim and Felagot fulfil the standard set by the Quality and Standards Authority of Ethiopia (QSAE, 2012).

Shoot and root length of the seedling

Highest seedling shoot length was recorded for naked seed followed by small pelleted size (3.08 cm), large pelleted size (3.05 cm) and least was from the medium pelleted size (2.94 cm). Longest seedling shoot length was obtained from Dagim (3.37 cm) while the shortest was from Boset (2.28 cm) variety. In the interaction of pellet size x variety, seed sample from Dagim variety with small pellet size (3.35cm) produced longer shoot while the Boset variety with large pellet size (2.65cm) was the least (Table 2).

The highest seedling root length (3.39cm) was obtained from Dagim variety while the lowest (2.74 cm) was from Felagot (Table 2). It is assumed that seedlings with well-developed shoot and root systems originated from quality seed and would likely withstand any adverse conditions and provide better seedling emergence and seedling establishment in the field (Bishaw, 2004)

Seedling dry weight

The highest mean value of seedling dry weight was obtained from Dagim (0.13) while the lowest was recorded from the Felagot (0.11) (Table 2). Seedling dry weight depends on seedling performance, as high seedling dry weight result for high seedling vigor index. Seedling dry weight was considered to assess the vigor of tef seed harvested from different treatment combinations.

Seedling Vigor Index I

The highest vigor index I was recorded from medium pellet size (541.50) followed by the small pellet size (519.90). Larger pellet size (468.60) was the least in vigor index I (Table 2). Similarly, the highest seedling vigor index-I was obtained from Dagim (613.95) followed by Felagot (495.23). The least seedling vigor index-I was observed for Boset tef variety (491.15) (Table 2).

Seedling Vigor Index II

Highest vigor index-II was recorded from small pellet size (10.7) followed by medium pelleted size (10.42) and the least were observed from large pellet size (8.87) (Table 2). Similarly, the highest seedling vigor index-II was obtained from Dagim (11.4) followed by Boset (9.76). The least seedling vigor index-II was observed in Felagot (9.66) (Table 2).

Speed of germination

The fastest in germination speed was recorded from medium size (3.70 days). It was followed by small size (3.57days). Seed with large pellet size resulted in delayed (2.58) germination days (Table 2). Among the tested tef varieties the highest speed of germination was recorded from Dagim (5.04) variety, followed by Felagot (4.34 days). Boset variety was delayed (2.97) in days to germination (Table 2). Toumey and Korstian (1942) emphasized rapid germination as an important component of the seed vigor, and it usually corresponds to more rapid seedling emergence in the field.

Table 2. Effect of pelleting size on seed quality parameters

Pelleting Size	SDG	SHL	RL	SDW	VI	VII	SPG
Un-pelleted seed	92.67a	3.27a	3.23a	0.12ns	603.77a	11.16a	6.63a
Small Size	86.75b	3.05b	2.93b	0.12ns	519.90b	10.7a	3.57b
Medium Size	89.50ab	2.94b	3.08ab	0.12ns	541.50b	10.42a	3.70b
Large Size	73.67c	3.08ab	3.28a	0.12ns	468.60c	8.87b	2.58c
Mean	85.65	3.08	3.13	0.12	533.44	10.29	4.12
LSD (0.05)	5.36	0.20	0.29	0.012	45.93	0.99	0.35
Varieties							
Dagim	90.75a	3.37a	3.39a	0.13a	613.95a	11.44a	5.04a
Boset	79.88b	2.88b	3.26a	0.12ab	491.15b	9.76b	2.97c
Felagot	86.31a	3.01b	2.74b	0.11b	495.23b	9.66b	4.34b
LSD 0.05)	4.65	0.17	0.25	0.01	39.77	0.86	0.30
CV (%)	7.54	7.62	11.20	11.97	10.37	11.58	10.12

SDG= Standard germination; SHL= Shoot length; RL=Root length, SDW= Seedling dry weight, VI= Vigor Index one, VII= Vigor Index two, SPG= Speed of germination, Means followed by the same letter along column are not significantly different from each other at 5% probability level.

Interaction effects (variety and pelleting size) on mean performance of quality traits

In the interaction of pellet size x variety, seed sample from Dagim variety with small pellet size (3.35cm) produced longer shoot while the Boset variety with large pellet size (2.65cm) was the least. On other hand higher vigour index was recorded from Dagim variety pelleted with medium size while lower vigour index was from Boset variety pelleted with large pelleting size (Table 3).

Table 3. Interaction effect of tef variety and pelleting size on seed quality parameters

Varieties	Pelleting Size	SHL	VI	SPG
Dagim	Naked	3.58a	707.60a	7.87a
	Small	3.35ab	607.70b	4.65cd
	Medium	3.28abc	620.70b	4.84c
	Large	3.28abc	519.80cde	2.82f
Boset	Naked	3.23bcd	592.80bc	4.94c
	Small	2.98cdef	511.50bce	2.39fg
	Medium	2.68f	438.10fg	2.12g
	Large	2.65f	422.20g	2.44fg
Filagot	Naked	3.00cde	510.90bce	7.08b
	small	2.83ef	440.50efg	3.68e
	medium	2.90def	565.70bcd	4.13de
	large	3.30abc	463.80efg	2.47fg
Mean		3.08	533.44	4.12
LSD(0.05)		0.34	79.55	0.60

SDG= Standard germination; SHL= Shoot length; RL=Root length, SDW= Seedling dry weight, VI= Vigor Index one, VII= Vigor Index two, SPG= Speed of germination, Means followed by the same letter along the column are not significantly different from each other at $P < 0.05$.

Association of seed physiological quality parameters

The simple correlation coefficient result revealed that standard germination had highly significant and positive correlation with vigor index-I (rg=0.79**), vigor index-II (rg=0.67**) and speed of germination (rg=0.72**) and it was significantly positively correlated with shoot length (rg=0.32*) (Table 4). Shoot length was highly significantly and positively correlated with root length (rg=0.44**), vigor index-I (rg=0.72**), vigor index- II (rg=0.40**) and speed of germination (rg=0.42**). Root length was positively and highly significantly correlated with vigor-I (rg=0.56**) and, positively and significantly correlated with seedling dry weight (rg=0.33*). Seedling dry weight was positively and highly significantly correlated with vigor index-II (rg=0.62*). Vigor index-I was positively and highly significantly correlated with vigor index-II (rg=0.69**) and speed of germination (rg=0.0.67**). Vigor index- II was positively and highly significantly correlated with speed germination (rg=0.54**). Previous study by Bishaw (2004) on association of seed physiological quality parameters also depicted similar findings. Contrary to this finding, Latha (2014) reported that standard germination was negatively correlated with seed dry weight and seedling vigor II.

Table 4. Pearson's simple combined correlation coefficients of seed quality

	SDG	SHL	RL	SDW	VI	VII	SPG
SDG	**1.00**	0.35*	-0.001ns	-0.16ns	0.79**	0.67**	0.72**
SHL		**1.00**	0.44**	0.20ns	0.72**	0.40**	0.42**
RL			**1.00**	0.33*	0.56**	0.25ns	0.10ns
SDW				**1.00**	0.09ns	0.62**	-0.04ns
VI					**1.00**	0.69**	0.67**
VII						**1.00**	0.54**
SG							**1.00**

** = Significantly correlated at P < 0.01, * = significantly correlated at P < 0.05, SDG= Germination; SHL= Shoot length; RL=Root length, SDW= Seedling dry weight, VI= Vigor Index one, VII= Vigor Index two, SPG= Speed of germination.

Conclusion

Overall, the results of the study showed that for better and speedy germination, uniform and good crop establishment pelleting of tef seed at medium pellet size is best suited. As the pellet size increased from small to large, the values of standard germination, vigor index-I, vigor index-II, seedling shoot and root length, speed of germination were declined for all varieties. Dagim variety was better in terms of seed quality with all pellet sizes. Highest values for seed quality parameters were obtained from the control treatments, because the pelleting materials were inert which only used to increase the size of seed for proper handling. The pelleting material used in this experiment does not provide any additional nutrient to seedling establishment. Therefore, from this experiment it is possible to conclude that, pelleting of tef at the medium pellet size (2.4-3mm) helps to increase the size of tef seed to facilitate proper planting manually or using mechanical planters.

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References

Arshadi J, Asgharipour MR. 2011. The effects of seed size on germination and early seedling growth of pelleted seeds. *Journal of Applied Science Research* 7:1257–1260.

Bergamo P, Maurano F, Mazzarella G, Iaquinto G, Vocca I, Rivelli AR, Enrica Falco D, Gianfrani C and Rossi M. 2011. Immunological evaluation of the alcohol-soluble protein Fraction from gluten-free grains in relation to celiac disease. *Molecular Nutrition and Food Research* 55:1266-1270.

Bishaw Z. 2004. Wheat and barley seed system in Ethiopia and Syria. PhD. Dissertation, Wageningen University, Netherlands.

Cannarozzi G, Chanyalew S, Assefa K, Bekele A, Blösch R, Weichert A, Klauser D, Plaza-Wüthrich S, Esfeld K, Jöst M, Rindisbacher A, Jifar H, Johnson-Chadwick V, Abate E, Wang W, Kamies R, Husein N, Kebede W, Tolosa K, Genet Y, Gebremeskel K, Ferede B, Mekbib F, Martinelli F, Pedersen HS, Rafudeen S, Hussein S, Tamiru M, Nakayama N, Robinson M, Barker I, Zeeman S, Tadele Z. 2018. Technology generation to dissemination: lessons learned from the tef improvement project. Euphytica 214(2):31

CSA. 2022. Agricultural sample survey 2021/2022. Volume I. Report on area and production of major crops. Statistical Bulletin 578 Addis Ababa, Ethiopia.

Halmer P. Enhancing seed performance for better yield and quality. Asian Seed 2003;10(2):4-7.

Hill HJ. 1999. Recent developments in seed technology. Journal of New seeds 1:105-112.

Hopman, E., Dekking, L., Blokland, M.L., Wuisman, M., Zuijderduin, W., Koning, F. and Schweizer, J. 2008. Tef in the diet of celiac patients in The Netherlands. Scandinavian journal of Gastroenterology 43(3):277-282.

ISTA. 2004. International Rules for Seed Testing. Published by the International Seed Testing Association.

Ketema S. 1997. Tef, (Eragrostis Tef (Zucc.) Trotter: Promoting the Conservation and Use of Underutilized and Neglected Crops (12). International Plant Genetic Resources Institute, Rome.

Krishnasamy V, Vakeswaran V. Technology for Synthetic Seed Development in Aswagandha (Withania somnifera Dunal). Seed Technology 2003, 206-7.

Latha, C.N., 2014. Evaluation of seed characters and their relationships with seed quality in chickpea (*Cicer arietinum* L.) genotypes. Department of Seed Science and Technology, University of Agricultural Sciences, Bangalore (Doctoral dissertation, M. Sc. Thesis).

Maguire JD. 1962. Speed of germination, an aid in selection and evaluation for seedling emergence and vigor. *Crop Science* 2:176- 177.

Neela, S. and Solomon, W.F, 2018. Review on structural, nutritional and anti-nutritional composition of tef (Eragrostis tef) in comparison with quinoa (Chenopodium quinoa Willd.). *Cogent Food & Agriculture*, *4*.

QSAE. 2012. Quality and Standards Authority of Ethiopia. Ethiopian standard wheat seed specification. First edition, ES 414 p.

Rajeswari M and Renganayaki PR. Standardization of Pellet size for Mechanized Sowing in Foxtail Millet (*Setaria italica*). Madras Agricultural Journal 2020, 107

Sanchez PL., Chen M., Pessarakli M., Hill HJ., Gore MA., Jenks MA. 2014. Effects of temperature and salinity on germination of non-pelleted and pelleted guayule (*Parthenium argentatum A.* Gray) seeds. *India Crops Production.* 55:90–96.

Somrat N., Sawadeemit C., Vearasilp S., Thanapornpoonpong SN., Gorinstein S. 2018. Effects of different binder types and concentrations on physical and antioxidant properties of pelleted sweet corn seeds. *European Food Research and Technology 244*(3):547-554.

Toumey JW and Korstian CF. 1942. Seeding and planting in the forestry practice. Ed.3. John Wiley and Sons Inc., New York.

Wang, J. and Jiang, C, 2021, April. Automatic Control System of Seed Pelletizing Coating Machine. In *International Conference on Application of Intelligent Systems in Multi-modal Information Analytics* (pp. 58-63). Springer, Cham.