RP Current Trends In Agriculture And Environmental Sciences
Vol. 2, No. 2 (April – June 2023) pp. 10–13
e-ISSN: 2583-6293

Cite this article: V.S. Mor, S. Arya, Hemender, Puneeth Raj M.S., Harish M.S., Effect of panicle shape on the seed quality of forage sorghum (*Sorghum bicolor* (L.) Moench), *RP Cur. Tr. Agri. Env. Sci.* **2** (2023) 10–13.

Original Research Article

Effect of panicle shape on the seed quality of forage sorghum (*Sorghum bicolor* (L.) Moench)

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ARTICLE HISTORY
Received: 9 Feb. 2023
Revised: 22 May 2023
Accepted: 24 May 2023
Published online: 26 May 2023

KEYWORDS
Panicle shape; Seed quality; *Sorghum bicolor;* Field emergence.

ABSTRACT
The study was conducted to assess the effect of panicle shape on the seed quality of forage sorghum. The result revealed that among the panicle shapes, maximum test weight (27.39g), seed density (0.925g/cc), standard germination (95.33%), Seedling length (38.92cm), Seedling dry weight (0.013g), vigour index-1(3709), vigour index-II (1.250), AA test (83.33%), field emergence (88.11%), field emergence index (43.82) and lowest electrical conductivity (0.002) was observed in semi compact panicle shape followed by compact shape panicles while minimum test weight (14.61g), standard germination (82.56%), Seedling length (33.51cm), Seedling dry weight (0.006g), vigour index-1(2790), vigour index-II (0.529), AA test (59.11%), field emergence (73.56%), field emergence index (33.42) and maximum electrical conductivity (0.006) was observed in semi compact panicle shape. Maximum test weight (31.92g) was recorded in variety HC-136 while minimum (6.626g) was recorded in COFS-29 but seed density was recorded maximum (0.0994g/cc) in COFS-29 and minimum (0.825g/cc) was found in SSG (PSSG) followed by HC-136 (0.882g/cc). Maximum germination (96.67%) was recorded in variety HC-541 while minimum (75.67%) was found in COFS-29. In field parameters, maximum field emergence (88.67%) was recorded in HC 513 and minimum (66.67%) was noted in COFS-29. Field emergence index was recorded maximum (47.30) in ICSV-700 while it was found minimum (27.34) in COFS-29. It is concluded from the study that the varieties having semi compact panicle shape i.e. HC 541 and HC 513 contain better seed quality. Hence, these varieties should be utilized by the breeders for crop improvement programme of forage sorghum to assure the seed quality during multiplication.

1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the most important kharif cereal crops in the semi-arid tropics and is ranked the fifth most important cereal crop worldwide in terms of consumption after wheat, rice, maize and oats [1]. It is extensively cultivated to fulfill the dietary needs of livestock, including green and dry fodder, as well as animal feed. Additionally, sorghum can serve as an alternative food source and a raw material supplier for the bioethanol industry. Notably, sorghum is rich in nutrients, containing 339 calories and 11.3% protein per 100 grams of seeds [2]. India, with a livestock population of 536 million, primarily dominated by cattle and buffalo [3], experiences a substantial deficit of 36% in green fodder and 11% in dry fodder [4]. Seed deterioration results in reduced overall germination percentage, poor germination uniformity and poor plant growth. Such seeds are susceptible to environmental and biological stresses resulting to a large number of abnormal seedlings and poor plant development [5].

The panicle shape of forage sorghum can have an impact on seed quality, although it's just one of several factors that influence seed quality. *Bicolor sorghums* are characterized by their medium-sized open panicles with small grains, completely enveloped by large closed glumes. They are cultivated across Africa and are also prevalent in Asia. Guinea sorghums, on the other hand, feature long, loosely arranged panicles with small to medium-sized grains that are flattened, twisted, and oval in shape. They have open glumes and are primarily grown in West Africa. *Sorghums caudatum* exhibit panicles of varying shapes, along with grains that are asymmetrical – flat on one side and convex on the other. *Sorghums durra* has highly compact panicles with either erect or curved peduncles. Panicle compactness and shape play a crucial role in determining grain yield and are valuable traits for distinguishing different varieties and categorizing them.

The compactness of panicles appears to be linked to the level of humidity during the flowering and ripening stages. Extremely dry conditions tend to produce very dense panicles, especially in the case of compact durra sorghums, which stand out in this regard. On the other hand, regions with high rainfall, particularly in the hilly areas of the Eastern Ghats, tend to feature panicles that are more loose and drooping. This loose form aids in quicker panicle drying, thus preventing the formation of grain molds. Panicles that remain enclosed within the protective boot structure can harbor insects and promote disease development due to the favorable wet conditions within the boot. In general, landraces exhibit less panicle exsertion compared to improved cultivars, which tend to produce longer pendunces [6]. The panicle is the flowering structure of the sorghum plant, and its shape can vary among different varieties and cultivars of forage sorghum. Panicle shape can influence seed yield. Sorghum varieties with more open and branched panicles tend to produce more seeds compared to those with tightly compacted panicles. Twenty-five forage sorghum genotypes were categorized by assessing their panicle shape. Nine of these genotypes exhibited symmetrical panicles, seven had broader lower portions of their panicles, seven displayed pyramidal panicle shapes, and noteworthy exceptions included BMR-5 and S651, which featured broader upper portions in their panicle shape [7]. A higher seed yield can be considered a positive aspect of seed quality, as long as other quality factors are met. The arrangement of seeds within the panicle can affect seed size and uniformity. A well-structured panicle with evenly spaced seeds is likely to produce seeds that are more uniform in size and quality. This can be important for commercial seed production. Panicle shape can also influence the filling and maturation of seeds. Sorghum genotypes characterized by compact panicles have been documented as being vulnerable to head bugs and head caterpillars [8].

A panicle with good spacing between seeds allows for proper seed development, leading to seeds that are well-filled and mature. Well-filled and mature seeds are more likely to have higher germination rates and better vigor. The shape of the panicle can impact a plant's susceptibility to diseases and pests.

The arrangement of seeds in various parts of the parent plants can impact the color, size, shape, and ability to sprout of seeds in numerous plant species. Even within a solitary seedpod, the location of an individual seed might determine its capacity to germinate [9]. Some panicle shapes may provide better protection to developing seeds from environmental stressors and pests, which can indirectly influence seed quality. The ease of harvesting can be affected by panicle shape. Panicles that are more open and accessible can be harvested more efficiently, leading to less damage to the seeds during the harvest process. Minimizing seed damage is crucial for maintaining seed quality. Hence the present study was planned to assess the effect of panicle shape on the seed quality of sorghum genotypes.

2. Materials and methods

The study was planned to assess the effect of panicle shape on the seed quality of sorghum varieties/genotypes. Ten panicles from each shape *i.e.* compact shape (HC-171, IS-16511, HC-136), Semi-compact shaped (HC-513, ICSV-700, HC-541) and Loose shaped {SSG (PSSG), COFS-29 and SSG-59-3} were collected at the time of maturity from forage section, Department of Genetics & Plant Breeding, CCS Haryana Agricultural University, Hisar (Figure 1). The seed quality was evaluated on the following parameters at laboratory and field of Department of Seed Science and Technology. For estimation of Test weight (g), One thousand seeds replicated thrice from each genotype were counted, weighed and average seed weight of each variety was calculated. Seed density (g/cc) was calculated on hundred seeds of each genotypes in three replications and weighed on electrical balance. These seeds were dipped in water; density of water was 1.0 at 20°C. Volume of water displaced by the seeds was recorded and seed density of each variety was calculated by using the following formula:

$$\text{Seed density} = \frac{\text{Weight of 100 seeds (g)}}{\text{Vol. of water displaced by seeds (cm}^3\text{)}}$$

Standard Germination (%) was estimated on hundred seeds of each genotype in three replicates were placed in between sufficient moistened rolled towel papers (BP) and kept at 25^{o}C in seed germinator. Final count on 7th day and only normal seedlings were considered for percent germination according to the rules of International Seed Testing Association [10] Ten normal seedlings were selected randomly for estimation of Root length (cm) at the time of final count of standard germination and seedling length was measured in centimeters. The Ten seedlings of each lot replicated thrice were dried in a hot air oven for 24 hrs. at 80±1^{o} C. Seedling vigour indices were calculated according to the method suggested by Abdul-Baki and Anderson [11]:

Vigour index–I = Standard Germination (%) x Seedling length (cm)

Vigour index–II =Standard Germination (%) x Seedling dry weight (mg)

To measure the electrical conductivity, 50 normal and uninjured seeds in three replications were soaked in 75 ml deionized water in 100 ml beakers. Seeds were immersed completely in water and beakers were covered with foil. Thereafter, these samples were kept at 25^{o}C for 24 h. The electrical conductivity of the seed leachates was measured using a direct reading conductivity meter. The conductivity was expressed in µS/cm/seed. The number of seedlings emerged were counted on each day from 1st day to 15th day and the Field emergence index (speed of emergence) was calculated as described by Maguire [12].

$$\text{Speed of emergance index} = \frac{\text{No. of seedlings emerged}}{\text{First day of sowing}} + \ldots + \frac{\text{No. of seedlings emerged}}{\text{Day of last count (15}^{th}\text{)}}$$

The seedling establishment was determined by counting the total number of seedlings when the emergence was completed or when there was no further addition in the total emergence *i.e.* on 15th days. The data obtained was then analyzed using the online statistical tool (OPSTAT) developed by Sheoran [13].

Table 1: Effect of panicle shape on the seed quality of forage sorghum

Panicle Shape	Genotype	T.W.	S. D.	S.G.	S. L.	S.D.W.	V.I.-I	V.I.-II	E.C.	A.A.	F.E.	F. E.I.
Compact	HC-171	27.48	0.925	90.67	36.18	0.013	3280	1.178	0.005	74.67	75.00	43.59
	IS-16511	22.59	0.921	85.00	32.15	0.011	2733	0.934	0.005	66.67	71.00	40.40
	HC-136	31.92	0.882	87.33	33.43	0.012	2919	1.020	0.005	71.00	76.67	36.27
Mean		27.33	0.909	87.67	33.92	0.012	2977	1.044	0.005	70.78	74.22	40.08
Semi Compact	HC-513	26.93	0.965	95.00	37.89	0.014	3600	1.362	0.003	84.33	88.67	39.24
	ICSV-700	26.46	0.897	94.33	40.65	0.013	3834	1.226	0.001	85.00	87.67	47.30
	HC-541	28.80	0.912	96.67	38.23	0.012	3694	1.161	0.003	80.67	88.00	44.92
Mean		27.39	0.925	95.33	38.92	0.013	3709	1.250	0.002	0.002	88.11	43.82
Loose	SSG(PSSG)	21.21	0.825	80.67	36.15	0.008	2916	0.645	0.006	67.33	68.00	30.42
	COFS-29	6.26	0.994	75.67	27.20	0.004	2058	0.302	0.006	35.33	66.67	27.34
	SSG-59-3	16.36	0.930	91.33	37.18	0.007	3396	0.639	0.006	74.67	86.00	42.51
Mean		14.61	0.916	82.56	33.51	0.006	2790	0.529	0.006	59.11	73.56	33.42
C.D.@ 5%		0.161	0.008	1.852	1.62	0.002	129.1	0.182	0.001	1.560	2.483	1.234

Table 2: Correlation of field emergence with other seed quality parameters in forage sorghum

	F.E	T.W.	S.D.	S.G.	S.L.	S.D.W.	VI-I	VI-II	E.C.	A.A.	F.E.I.
F.E	1.000	0.456^{NS}	0.122^{NS}	0.929**	0.788*	0.564^{NS}	0.894**	0.657^{NS}	0.557^{NS}	0.795*	0.760*
T.W.		1.000	-0.466^{NS}	0.676*	0.604^{NS}	0.888**	0.638^{NS}	0.863**	0.830**	0.790*	0.574^{NS}
S.D.			1.000	-0.009^{NS}	-0.397^{NS}	-0.159^{NS}	-0.214^{NS}	-0.100^{NS}	-0.136^{NS}	-0.350^{NS}	-0.040^{NS}
S.G.				1.000	0.844**	0.772*	0.948**	0.838**	0.773*	0.910**	0.888**
S.L.					1.000	0.648^{NS}	0.969**	0.696*	0.625^{NS}	0.933**	0.753*
S.D.W.						1.000	0.719*	0.991**	0.960**	0.827**	0.689*
VI-I							1.000	0.781*	0.707*	0.949**	0.843**
VI-II								1.000	0.958**	0.853**	0.735*
E.C.									1.000	0.798**	0.717*
A.A.										1.000	0.809**
F.E.I.											1.000

T.W.-Test Weight (g), S.D.-Seed Density (g/c.c.), S.G.- Standard Germination (%), S.L.- Seedling Length (cm), S.D.W.- Seedling Dry Weight (g),V.I-I-Vigour index-I, V.I.-II -Vigour Index-II, E.C. -Electrical Conductivity (dS/m/seed), A.A.- Accelerated Aging (at 40$\pm$1^{o}C with 100% RH for 48h) Test (%), F.E-Field Emergence(%), F.E.I.-Field Emergence Index

3. Results and discussion

Significant variation was observed among the various seed quality parameters of different shaped panicles of forage sorghum. The results revealed that among the panicle shapes, maximum test weight (27.39g), seed density (0.925g/cc), standard germination (95.33%), Seedling length (38.92cm), Seedling dry weight (0.013g), vigour index-1(3709), vigour index-II (1.250), AA test (83.33%), field emergence (88.11%), field emergence index (43.82) and lowest electrical conductivity (0.002) was observed in semi compact panicle shape followed by compact shape panicles while minimum test weight (14.61g), standard germination (82.56%), Seedling length (33.51cm), Seedling dry weight (0.006g), vigour index-1(2790), vigour index-II (0.529), AA test (59.11%), field emergence (73.56%), field emergence index (33.42) and maximum electrical conductivity (0.006) was observed in semi compact panicle shape. Maximum test weight (31.92g) was recorded in variety HC-136 while minimum (6.626g) was recorded in COFS-29 but seed density was recorded maximum (0.0994g/cc) in COFS-29 and minimum (0.825g/cc) was found in SSG (PSSG) followed by HC-136 (0.882g/cc). Maximum germination (96.67%) was recorded in variety HC-541 while minimum (75.67%) was found in COFS-29. In field parameters, maximum field emergence (88.67%) was recorded in HC 513 and minimum (66.67%) was noted in COFS-29. Field emergence index was recorded maximum (47.30) in ICSV-700 while it was found minimum (27.34) in COFS-29 (Table 1).

The better seed quality in semi-compact and compact panicles may be due to better protection to seeds against adverse weather conditions and pathogens. The findings of this study align with the research conducted by Tian-Peng *et al.* [14], which similarly emphasized the heightened ecological importance of upper seeds in terms of sexual recruitment, regeneration, and the colonization of new environments in *L. virgaurea*. Twelve sorghum genotypes, primarily considering two characteristics: panicle compactness and panicle shape were categorized and reported that SSG-59-3 exhibited a very lax panicle structure, while MP Chari and HC 171 displayed semi-loose panicles with erect primary branches. In contrast, PC 9 and PC 121 showcased semi-loose panicles with drooping branches. Additionally, CSV 15, PC 23, PC 6, and PC 1 were characterized by compact elliptical panicle shapes, whereas HC 308 and HC 260 exhibited semi-compact elliptical panicles [15]. Field emergence was found significantly correlated with standard germination (0.929**), seedling length (0.788*), vigour index-I (0.894**), AA test (0.795*) and field emergence index (0.760**) (Table 2). Similar results were reported by Singh *et al.,* [16] in Coriander (*Coriandrum sativum* L.). It is concluded from the study that the varieties having semi compact panicle shape *i.e.* HC 541 and HC 513 contain better seed quality. Hence, these varieties should be utilized by the breeders for crop improvement programme of forage sorghum to assure the seed quality during multiplication.

Acknowledgements

The authors would like to express their gratitude to Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar for providing the necessary facilities to carry out this work successfully.

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