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Babita Bhatt

Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, Uttarakhand, India

PK Pandey

Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, Uttarakhand, India

Tripti Tripathi

Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, Uttarakhand, India

Nidhi

Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, Uttarakhand, India

Corresponding Author: Babita Bhatt

Department of Genetics and Plant Breeding, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, 263145, Uttarakhand, India

Evaluation and identification of superior sorghum recombinant inbred lines for agronomic, shoot fly resistance, quality and fodder yield traits

Babita Bhatt¹, PK Pandey², Tripti Tripathi³, Nidhi⁴

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ABSTRACT

This study assessed genetic variability and mean performance for agronomic, shoot fly resistance, and quality traits in 210 recombinant inbred lines (RILs) of sorghum (*Sorghum bicolor* L. Moench) derived from a cross between shoot fly-susceptible parent 27B and resistant parent IS 2122. The experimental material, comprising 210 RILs and six checks, was evaluated during kharif 2018–19 at the Instructional Dairy Farm, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Data were recorded for 18 phenological, morphological, shoot fly resistance, biochemical and yield traits. Analysis of variance revealed significant variation among RILs for seedling height, days to 50 per cent flowering, plant height, stem diameter, number of nodes, leaf length, leaf width, thousand-grain weight, dry fodder yield and green fodder yield. Significant differences were also observed in oviposition and dead heart percentage at 21 days after emergence. Considerable phenotypic variation was observed, with green fodder yield ranging from 56.28 to 561.52 g plant⁻¹ and dry fodder yield from 22.01 to 172.55 g plant⁻¹. Several RILs showed superior performance for individual traits including earliness, stem diameter, number of nodes, leaf dimensions, total soluble solids, thousand-grain weight and fodder yield. The observed variability and trait-wise superior genotypes provide useful breeding material for further improvement of sorghum for fodder productivity and shoot fly resistance.

Keywords: *Sorghum*, Recombinant inbred lines, Genetic variability, Analysis of variance, Mean performance, Shoot fly resistance

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is an important cereal and fodder crop cultivated across environments where biotic stresses frequently constrain productivity. Shoot fly (*Atherigona soccata*) is an important sorghum pest, making the identification of resistant and productive genetic resources a key component of breeding programmes. Recombinant inbred lines provide stable genetic material for assessing variation and identifying promising genotypes. Evaluating a segregating population across agronomic, resistance, quality, and fodder-yield traits allows breeders to identify lines with desirable performance for specific breeding objectives.

This investigation aimed to characterize variation among sorghum RILs, compare mean performance for 18 traits, assess the significance of variation through analysis of variance, and identify RILs superior to the superior check for individual desirable traits.

Sorghum improvement depends on identifying and using variability for agronomic and fodder-yield traits. Recent evaluations of sorghum germplasm and forage materials have reported substantial variation for plant height, leaf traits, green and dry fodder yield, and related yield components, highlighting the scope for identifying superior genotypes through systematic phenotypic evaluation (Gebregergs *et al.*, 2020; Santosh *et al.*, 2024) [1, 2]. This variability is particularly relevant in breeding populations, where selecting lines with desirable agronomic and productivity traits can provide useful material for further breeding.

Shoot fly (*Atherigona soccata* Rondani) is a major constraint on sorghum production, particularly during the seedling stage, and can substantially reduce crop productivity. Recent research has documented considerable differences among sorghum genotypes for shoot fly infestation and associated resistance traits. Seedling morphophysiological and biochemical characteristics influence shoot fly preference and damage, and recent reviews emphasize the importance of host-plant resistance in reducing shoot fly-associated yield losses (Kumari *et al.*, 2021; Arora *et al.*, 2025) [3, 4]. Evaluation of segregating populations for oviposition and dead-heart incidence therefore remains important for identifying lines with improved resistance.

Fodder productivity is an important breeding objective in sorghum because of its value as livestock feed. Studies have identified green fodder yield, dry fodder yield, plant height and leaf-related traits as important components of forage performance (Santosh *et al.*, 2024; Kumari *et al.*, 2024) [2, 5]. Accordingly, simultane

ous evaluation of agronomic traits, shoot fly resistance, and fodder yield can help identify promising RILs with desirable trait combinations for subsequent breeding and validation.

Materials and Methods

Experimental material and site

The experiment was conducted at the Instructional Dairy Farm, Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand, India, during the *kharif* season of 2018. The experimental material comprised 210 recombinant inbred lines (RILs) obtained from the Indian Institute of Millet Research (IIMR), Hyderabad, developed from a cross between the shoot fly-susceptible parent 27B and the shoot fly-resistant parent IS 2122. The RIL population was evaluated along with six checks, viz., SPV 1616, SSG-59-3, Pant Chari-5, Pant Chari-6, IS 18851 (resistant check), and Swarna (susceptible check). The experiment followed an augmented block design with three replications. Pantnagar is located at approximately 29°N latitude and 79.3–79.5°E longitude, at an elevation of about 243.8 m above mean sea level, and lies in the Tarai region at the foothills of the Himalayas. The region has a humid/subtropical climate with substantial monsoon rainfall during the *kharif* season.

Experimental design and crop management

The 210 RILs and six checks were evaluated in an augmented block design with three replications during the *kharif* season of 2018. The RILs were distributed among the blocks, while the six checks were repeated across replications. The experiment followed standard recommended crop-management practices for sorghum. Observations were recorded for 18 traits, comprising days to emergence, seedling height, egg-laying percentage, oviposition, dead-heart incidence at 14, 21 and 28 days after emergence (DAE), days to 50% flowering, plant height, stem diameter, number of nodes, leaf length, leaf width, HCN content, total soluble solids (TSS), thousand-grain weight, dry fodder yield and green fodder yield.

Trait measurement

Data were recorded for 18 agronomic, shoot fly resistance and quality traits. Days to emergence and days to 50% flowering were recorded on a plot basis. At the same time, seedling height, plant height, stem diameter, number of nodes, leaf length and leaf width were measured from representative plants following standard sorghum descriptors. Shoot fly infestation was assessed during the seedling stage by recording egg incidence/egg-laying percentage, oviposition and dead-heart incidence. Egg incidence was expressed as the percentage of plants bearing shoot fly eggs, while oviposition was recorded as the number of eggs observed on the sampled plants. Dead-heart incidence was calculated at 14, 21 and 28 days after emergence (DAE) as the percentage of plants showing dead-heart symptoms among the total plants examined. We used similar procedures to phenotype sorghum shoot fly resistance.

At harvest, green fodder yield (GFY) was recorded as the fresh weight of fodder obtained from the sampled plants/plot and expressed on a per-plant basis, while dry fodder yield (DFY) was determined after drying the harvested fodder to a constant weight. Thousand-grain weight (TGW) was recorded from a representative grain sample and expressed in grams. Hydrocyanic acid potential (HCN) was estimated in ppm following the method of Hogg and Ahlagreen (1942), based on enzymatic release of HCN from cyanogenic plant tissue. Total soluble solids (TSS) were measured using a hand refractometer and expressed as a percentage.

Statistical analysis

Analysis of variance was performed for the augmented design following (Federer) [6]. Mean performance, range, standard error, and critical difference (CD) at the 5% level were used to characterize variation and identify RILs superior to the superior check.

Results

Mean performance and range of variation

The 210 RILs displayed substantial variation across phenological, morphological, biochemical, shoot fly resistance and fodder-yield traits. Days to emergence ranged from 2 to 12 days, seedling height from 3.29 to 17.25 cm, days to 50 per cent flowering from 46 to 97 days, thousand-grain weight from 4.33 to 40.86 g, dry fodder yield from 22.01 to 172.55 g plant⁻¹ and green fodder yield from 56.28 to 561.52 g plant⁻¹.

Superior RILs for individual traits

SFRIL380 showed lower egg percentage. SFRIL346, SFRIL16, SFRIL43, SFRIL258 and SFRIL12 were identified as superior for earliness. SFRIL126, SFRIL302, SFRIL143, SFRIL20 and SFRIL332 showed higher stem diameter, while SFRIL15, SFRIL185, SFRIL281, SFRIL19 and SFRIL45 showed higher number of nodes. SFRIL273, SFRIL253, SFRIL330, SFRIL261 and SFRIL220 were superior for leaf length; SFRIL129, SFRIL188, SFRIL315, SFRIL261 and SFRIL205 for leaf width; SFRIL18, SFRIL82, SFRIL200, SFRIL314 and SFRIL374 for TSS; and SFRIL245, SFRIL257, SFRIL144, SFRIL129 and SFRIL359 for thousand-grain weight.

For fodder yield, SFRIL20, SFRIL4, SFRIL97, SFRIL15 and SFRIL21 were identified for higher dry fodder yield, whereas SFRIL20, SFRIL21, SFRIL22, SFRIL4 and SFRIL329 were identified for higher green fodder yield.

Analysis of variance

Analysis of variance showed highly significant differences among RILs for seedling height, days to 50 per cent flowering, plant height, stem diameter, number of nodes, leaf length, leaf width, thousand-grain weight, dry fodder yield and green fodder yield. Significant differences were observed for oviposition and dead heart percentage at 21 days after emergence.

Table 1. Mean performance, range, and superior RILs for the evaluated traits

SI. No.	Trait	Mean	Range	No. of RILs superior over superior check	Superior RILs over check
1	Days to emergence (days)	5.25	2-12	0	No superior RILs found for early emergence
2	Seedling height (cm)	10.26	3.29-17.25	0	No superior RILs found for higher seedling height

(continued on next page)

Sl. No.	Trait	Mean	Range	No. of RILs superior over superior check	Superior RILs over check
3	Egg percentage/ number of plants with egg (for less egg percentage)	35.33	5.33-57.77	1	SFRIL380 found to be the superior RIL for less egg percentage
4	Oviposition / No of eggs per plant	3.09	0.66-7.59	0	No superior RILs found for low oviposition number
5	Dead heart % @ 14 DAE	15.44	1.71-40.54	0	No superior RILs found for low dead heart percentage
6	Dead heart % @ 21 DAE	34.45	11.11-65.52	0	No superior RILs found for low dead heart percentage
7	Dead heart% @ 28 DAE	45.28	22.33-64.22	0	No superior RILs for low dead heart percentage
8	Days to 50% flowering (days)	79.0	46 -97	8	SFRIL346, SFRIL16, SFRIL43, SFRIL258 and SFRIL12 found to be superior for earliness
9	Plant height (cm)	201.03	110.31-288.48	0	No superior RILs found for larger plant height
10	Stem diameter (cm)	1.30	0.67-2.24	18	SFRIL126, SFRIL302, SFRIL143, SFRIL20 and SFRIL332 found to be superior for larger stem diameter.
11	No of nodes/ leaves per plant	11.52	6-16	35	SFRIL15, SFRIL185, SFRIL281, SFRIL19 and SFRIL45 found to be superior for higher number of nodes
12	Leaf length (cm)	59.01	37.88-80.74	9	SFRIL273, SFRIL253, SFRIL330, SFRIL261 and SFRIL220 found to be superior for larger leaf length (cm)
13	Leaf width (cm)	12.86	3.10-23.86	185	SFRIL129,SFRIL188,SFRIL315,SFRIL261 and SFRIL205 found to be superior for more leaf width
14	HCN (ppm)	62.56	23.30-160.57	0	No superior RILs found to have low HCN content
15	TSS (%)	12.61	3.10-21.37	63	SFRIL18, SFRIL82, SFRIL200, SFRIL314 and SFRIL374 found to be superior over for high TSS%
16	1000 grain weight (g)	20.17	4.33-40.86	10	SFRIL245,SFRIL257,SFRIL144,SFRIL129 and SFRIL359 found to be superior for more grain weight
17	Dry fodder yield (g/plant)	84.91	22.01-172.55	9	SFRIL20, SFRIL4, SFRIL97, SFRIL15and SFRIL21found to be superior for higher dry fodder yield
18	Green fodder yield (g/plant)	217.86	56.28-561.52	5	SFRIL20,SFRIL21,SFRIL22,SFRIL4,SFRIL4 and SFRIL329 found to be superior for higher green fodder yield

DTE- Days to emergence, SH- Seedling Height, E %-Egg percentage/ number of plants with eggs in per cent

O- Oviposition number /Number of eggs per plant, DH%- Deadheart per cent , DTF-Days to 50 % flowering, PH-Plant height, SD-stem diameter, NN-Number of nodes, LL-Leaf Length, LW-Leaf Width, HCN –Hydrocyanic acid potential (ppm), T.S.S %-Total soluble solids in per cent, TGW-Thousand grain weight, DFY-Dry fodder yield, GFY-Green fodder yield

Discussion

The RIL population exhibited considerable variation for several agronomic traits, as reflected by significant differences in the analysis of variance. Variation in days to 50% flowering provides an opportunity to identify lines with different phenological adaptations. At the same time, differences in plant height, stem diameter, number of nodes, leaf

length, and leaf width indicate variation in plant architecture. Such variation is important for sorghum improvement because plant stature and leaf development influence biomass production and canopy development. Similar variation in plant architectural traits has been reported in recombinant inbred populations of cereals (Pan *et al.*, 2017) [7].

Variation in flowering time is particularly relevant for selecting lines suited to specific production environments. Early flowering may be advantageous where shorter crop duration is desired, whereas relatively later flowering may favour greater vegetative biomass accumulation. The observed variation in plant height, stem diameter and leaf dimensions therefore provides opportunities to select plant types according to specific breeding objectives. Quantitative variation for flowering and architectural traits has also been reported in segregating populations (Buckler *et al.*, 2009; Worede *et al.*, 2020) [8, 9].

Table 2. Analysis of variance for 18 traits in sorghum RILs

Source of variation	df	DTE (days)	SH (cm)	E%	O	DI% @ 14 DAE	DI% @ 21 DAE	DI% @ 28 DAE	DTF (days)	PH (cm)	SD (cm)	NN	LL (cm)	LW (cm)	HCN (ppm)	TSS (%)	TGW (g)	DFY (g/plant)	GFY (g/plant)
Blocks	6	29.1653**	10.6320**	269.937**	10.2058**	137.5430**	354.1150**	292.7520**	194.3520**	5060.0700**	0.6000**	24.4480**	598.1050**	8.9230**	726.6080	21.8490**	65.1960**	3774.7922**	72392.0020**
Entries	215	5.2485	6.3150**	77.2797	1.3871	53.0060	114.3520*	84.1900**	99.7470**	1785.0870**	0.0870**	2.8560**	87.7420**	1.7420**	701.2420*	23.2080**	29.3950**	616.9089	5360.1520*
Checks	5	18.8952**	18.5670**	18.4718	0.8170	76.9800	95.1610	107.6150**	135.8670**	18296.4140**	0.1960**	3.8670**	351.2030**	2.7110**	4244.5400*	4.2850**	88.7470**	4755.1918**	20400.8100**
Varieties	209	5.3451	5.0390**	77.1710	1.5567*	54.4610	115.4470*	80.2690	67.8040**	1230.6010**	0.0870**	2.6530**	68.1010**	1.6070**	612.4020	23.4120**	26.8650**	576.8506**	6672.7320**
Checks vs variety	1	-83.1794	211.7520**	394.0347**	-31.1983	-370.8970	-18.5930	786.5470**	6595.3050**	35115.9450**	-0.5680	40.2470**	2875.4030**	25.0600**	1552.3700	75.1510**	261.3440**	-11702.3312	-344172.4350
Error	30	3.8101	1.4940	51.9950	0.9202	34.0510	62.4920	35.4040	8.6810	139.6050	0.0130	0.2920	2.3920	0.0750	388.7790	0.6590	2.2390	118.4345	2670.3610

*significant at 5 %; ** significant at 1%

The significant variation observed for oviposition and dead-heart incidence indicates differences among RILs in their response to shoot fly infestation. Shoot fly resistance is a complex trait involving differences in ovipositional preference and subsequent damage development. Previous studies in sorghum RIL populations have reported associations among oviposition, dead-heart formation and other resistance-related traits. At the same time, genotype $\times$ environment interaction has also been shown to influence the expression of shoot fly resistance (Ehab *et al.*, 2020; Aruna *et al.*, 2011) [10, 11]. Identifying lines that combine favourable shoot fly resistance with desirable agronomic characteristics can therefore provide useful material for further breeding and evaluation.

We also observed considerable variation in quality- and yield-related traits, including HCN, TSS, thousand-grain weight, dry fodder yield, and green fodder yield. Variation in TSS and HCN is relevant to forage quality, whereas differences in dry and green fodder yield indicate opportunities for improving biomass productivity. Previous evaluations of sorghum populations have shown variation in morphological traits associated with fodder production and resistance to insect pests (Rohila *et al.*, 2020) [12]. The present findings therefore support identifying RILs that combine desirable fodder productivity with favourable agronomic and shoot fly-resistance characteristics.

Overall, the significant variation detected among the RILs and the identification of lines superior to the checks for individual traits demonstrate the usefulness of this population for selection. Lines showing desirable combinations of **fodder yield, plant architecture, phenology and shoot fly resistance** may provide promising material for subsequent evaluation and breeding.

Conclusion

The evaluation of 210 sorghum RILs demonstrated substantial variation for agronomic, shoot fly resistance, quality and fodder-yield traits. Analysis of variance confirmed significant differences for several important traits, and several RILs exhibited superior performance for individual breeding objectives. These lines represent useful genetic resources for further evaluation and utilization in sorghum improvement programmes.

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