heterotic hybrids from which substantial variability can be uncovered in segregating generations.

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Genetic Studies for Improvement of Quality Characters in *Rabi* Sorghum Using Landraces

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Introduction

Sorghum *(Sorghum bicolor)* is one of the important cereal crops cultivated in India during *kharif* (rainy) and *rabi* (postrainy) seasons. *Rabi* sorghum is highly valued for its excellent grain quality and also for its food use. The better grain quality fetches high market price often at par or higher than wheat *{Triticum aestivum)* (Nerkar 1998). However, there are certain major constraints in *rabi* sorghum improvement such as narrow genetic base, low variability for yield and grain quality parameters with *rabi* season adaptation. Indian *rabi* sorghum landraces are rich repository of genetic variability and are preserved by the farmers due to local adaptability, good grain quality and for specific food products. Thus, it becomes more relevant to utilize such typical landraces in breeding programs.

Materials and Methods

Five promising *rabi* sorghum varieties (lines), SPV 1155, SPV 1380, SPV 1411, SPV 1413 and SPV 1457 (Table 1), were selected from the All India Coordinated Trial conducted at the Sorghum Research Station, Parbhani, Maharashtra, India. Six landraces (testers), *Giddi Maldandi, Dagdi Solapur, Barshi Joot, Yennigar Jola, Dood Mogara* and *Ramkhe* (Table 1) were selected from breeding material available at the Sorghum Research Station, Parbhani. Thirty hybrids with line x tester mating design were developed during 1999/2000. Hybrids were developed by following manual method of hand emasculation and pollination. The landraces were selected on the basis of their diverse ecogeographic distribution and differences in plant height, flowering and maturity duration, seed color and grain yield.

The material was evaluated in *rabi* 2000/01 in a randomized block design with three replications. Each replication consisting of 44 entries (30 hybrids and 11 parents along with 3 checks) was divided in two tires and randomized within replication. Each genotype was sown in a single row of 5 m length with 45 cm and 15 cm inter- and intra-row spacing, respectively. Recommended dose of fertilizers and carbofuran granules at 4 kg ha^{-1} was applied to the plots.

Table 1. Description of sorghum breeding material used for genetic studies.

Parents	Pedigree/source
Lines	
SPV 1155	(SPV 86 x E 36-1) x Local selection
SPV 1380	SPV 86 x E 36-1
SPV 1411	Selection from GD 31-4-2-3, a restorer from ICRISAT
SPV 1413	RSLG 112-1-54
SPV 1457	RSLG 1613
Testers	
Giddi Maldandi	Dharwad, Karnataka
Dagdi Solapur	Dharwad, Karnataka
Barshi Joot	Barshi local, Maharashtra
Yennigar Jola	Dharwad, Karnataka
Dood Mogara	Dhule, Maharashtra
Ramkhe	Dhule, Maharashtra
Checks	
M 35-1	Selection from Maldandi Bulk
CSH 15R	MS 104A x RS 585
Phule Yashoda	RSLG 112-1-8

Table 2. Sorghum parents with significant general combining ability (GCA) effect for protein content and other important chemical constituents and grain yield.

Parents	Protein (%)	Starch (%)	Soluble/free sugars (%)	Grain yield (%)
Barshi Joot	1.166**[1]	-0.099**	0.045	2.090**
Dagdi Solapur	1.132**	-1.591**	0.095**	-6.870**
Yennigar Jala	0.482**	-0.493**	-0.079**	5.810**
Ramkhe	0.446**	-0.059	0.278**	3.753**
SPV 1457	0.279**	0.377**	0.113**	-0.880**

1. ** = Significant at 1% level.

The quality characters including physical and chemical parameters were evaluated using bulked grain of five selected plants. The proximate composition analysis was carried out as per AOAC (1990) using whole meal flour samples. The genetic analysis was done by adopting line x tester method as suggested by Kempthorne(1957).

Results and Discussion

Grain quality studies in *rabi* sorghum are limited. The results revealed that the majority of the landraces used in this study exhibited higher protein content than improved and popular varieties under cultivation. Protein content was highest (12.42%) in *Dood Mogara* followed by *Yennigar Jola* (11.55%) and SPV 1155 (11.37%). ICRISAT (1980) also reported higher protein range in landraces. The starch in parents ranged from 74.41% *{Barshi Joot)* to 75.95% (SPV 1457) and soluble/free sugars, which impart sweetness to sorghum, ranged from 1% *{Barshi Joot)* to 2.5% *{Giddi Maldandi).* These results were comparable with Ismail (1998).

Genetic studies revealed that the landraces were good general combiners for higher protein content, low starch and high soluble/free sugars content (Table 2). Rao et al. (1982) also observed that positive general combining ability (GCA) effect for protein content was accompanied by negative GCA effect for starch content. The main features of crosses with standard heterosis (%) over M 35-1 for protein content and grain yield are presented in Table 3.

The hybrids had acceptable grain quality as well as grain yield compared to the check M 35-1. The majority of the crosses had semi-compact elliptical panicles with medium to bold and yellow to chalky white grains. The highest heterosis for grain yield was observed for SPV 1155 x *Barshi Joot* while highest heterosis for protein content was observed for SPV 1413 x *Barshi Joot.* Nayeem and Bapat (1984) reported that when wide genetic diversity is present in the parental material

Table 3. Main features of sorghum hybrids with higher standard heterosis for grain/fodder yield and protein.

Cross	Grain yield (g plant^{-1})	Standard heterosis (%)			Panicle shape[1]	Glume coverage (% grain covered)	Grain size	Grain shape	Grain color (visual score)
		Grain yield (g plant^{-1})	Protein (%)	Fodder yield (g plant^{-1})					
SPV 1155 × *Barshi Joot*	80.0	98.8	23.5	56.6	Sce	50	Bold	Sublenticular	Creamy
SPV 1155 × *Yennigar Jola*	79.6	82.1	28.1	75.0	Sce	25	Medium	Oval	Creamy
SPV 1380 × *Ramkhe*	73.2	67.3	14.6	34.1	Sce	25	Medium	Round	Yellow
SPV 1413 × *Ramkhe*	63.8	45.8	23.3	14.9	Ce	50	Medium	Flat	Creamy
SPV 1413 × *Dood Mogara*	62.5	42.8	15.0	23.3	Sce	25	Medium	Sublenticular	Chalky white
SPV 1413 × *Barshi Joot*	57.8	32.1	31.1	13.3	Co	25	Medium	Sublenticular	Creamy
SPV 1411 × *Barshi Joot*	57.3	31.0	21.6	16.6	Sce	25	Bold	Spherical	Yellow
SPV 1411 × *Ramkhe*	55.6	26.0	16.0	27.0	Sce	50	Medium	Globular	Creamy
SPV 1457 × *Giddi Maldandi*	53.2	21.7	7.7	1.1	Sce	50	Small	Sublenticular	Yellow
M 35-1 (check) (Mean values)	43.7		11.3	42.7	Sce	50	Medium	Globular	Creamy

1. Ce = compact elliptical; Co = compact; Sce = semi-compact elliptical.

(improved lines and landraces), it is possible to evolve hybrids/varieties with high grain yield along with acceptable agronomic and grain parameters.

Correlation studies indicated that for protein content improvement in terms of quantity, the starch content must decrease or compensate at biochemical level in the grain, during grain development stage. Shinde et al. (1986) reported superiority of improved line x landrace crosses for heterosis over improved line x improved line crosses due to genetic diversity in the parents. Considering the narrow genetic base and other adaptability features of *rabi* sorghum, such improved line x landrace cresses that are involved in this study are useful for *rabi* sorghum improvement.

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Importance of Economically Significant Constraints for *Kharif* Sorghum in Different Regions of India

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The All India Coordinated Sorghum Improvement Project centers and randomly selected private sector seed companies were asked to score for economic importance of constraints on quality/marketability for *kharif*(rainy) season sorghum *(Sorghum hicolor)* (grain and dual purpose) production in different regions of India on a 1 to 9 scale (1 = most important; 9 = least important). The objective of this study was to identify constraints within each zone, I, II and III, which were classified on the basis of end user needs. Responses obtained are summarized in Tables 1-3. Table 1 summarizes the importance given by 18 public sector sorghum groups while Table 2 summarizes views of 3 private companies. Finally, Table 3 summarizes the relative importance of different traits based on scoring by both sectors.

Scoring for Importance of Stress Factors in Sorghum Production

Insect pests. In almost all the states (Table 1), shoot fly was identified by the public sector as the most important constraint (score 1.0 to 3.0). The other important pest was stem borer (average score 2.9; range 1.0 to 5.0). Stem borer is an important constraint in the states of Uttaranchal, Uttar Pradesh, Rajasthan and Haryana. Head bug is a major constraint of Kovilpatti (Tamil Nadu), followed by Palem (Andhra Pradesh) and Parbhani (Maharashtra). Private companies also identified shoot fly (score = 2) and stem borer (score = 4.1) to be major pests in their areas of operation (Table 2).

Diseases. Grain mold was rated by the public sector as a top priority disease in the states of Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra and Gujarat. It was least important in Rajasthan, Haryana and Gujarat. Ergot was identified as a problem in Dhule and Jalgaon in Maharashtra, Palem in Andhra Pradesh and Surat in Gujarat. Private companies also identified the above two diseases as the most important constraints (score 2 for grain mold and score 3.6 for ergot). All other diseases were given lesser importance both by the public sector