NUTRITIONAL AND *ROTI* QUALITY OF SORGHUM GENOTYPES

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ABSTRACT

Sorghum grains are mostly used for the *roti* preparation. The M 35-1 (*Maldhandi*) a sorghum cultivar is known for its good quality of *roti* due to having pearly white grain color, its flour having higher water holding capacity, and good organoleptic taste. However, this cultivar is low yielder. To evolve sorghum high yielding genotype coupled with this good *roti* qualities, systematic breeding program was planned and executed to overcome this problem. Twenty local land races, 92 genotypes, and seven improved cultivars of sorghum along with check M 35-1 were studied for various nutritional quality parameters, with special reference to the *roti* quality. Considering nutritional quality and organoleptic evaluation parameters studied for *roti* quality, the local land races viz., RSLG 428-1, RSLG 1238, RSLG 1275 and the genotypes viz., RSV 290, RSV 292, RSV 858, RSV 859, RSV 861, RSV 868, RSV 894, RSV 985, RSV 992, RSV 995, RSV 999 were found to be promising for protein, sugar, water absorption, and soluble protein content. Therefore, they can be used for further improvement in nutritional quality through breeding program. Among the improved cultivars, Phule Vasudha (RSV 423), CSV 22, and Phule Chitra (SPV 1546) were found to be most promising for *roti* quality. The maximum score for overall acceptability was found for Phule Vasudha followed by Phule Anuradha (RSV 458), Phule Yeshoda (RSLG 262), and Phule Maulee (CSV 216).

[***Keywords***: Sorghum, *roti*, genetic improvement, nutritional quality]

INTRODUCTION

Grain sorghum [*Sorghum bicolor* (L.) Moench] is an important food crop particularly in arid and semi-arid tropics. It is a dual-purpose crop providing staple food for human consumption (35%) and rest of as a fodder for livestock, alcohol production, as well as preparation of industrial products (Awika and Rooney 2004). Many millions of people in Africa and Asia depend on sorghum as the stuff of life. Being a drought-tolerant crop, it can give dependable and stable yields in both rainy and post-rainy seasons. It thrives with less rainfall than is needed for rice and maize and can be grown where no other major cereal can be cultivated. Altogether, sorghum is one of several really indispensable crops required for the survival of man.

In India, sorghum is mainly consumed in the form of unleavened pancake (*bhakri/roti*). However, several indigenous processed foods such as *bhatwadi*, *papadi*, and *roti* are prepared and consumed in the semi-arid tropics. Besides, sorghum has large potential for its use in the fermentation industry, puffed products, and in weaning foods for the children of developing countries. According to an FAO (2005) report, sorghum was grown globally on an area of about 46 million ha with a production of about 60 million tons. However in India, sorghum is cultivated on an area of about 9.10 million ha with a production of 7.65 million tons (Anonymous 2006a, 2006b). Sorghum grains are important source of dietary proteins, carbohydrates, minerals, and B group vitamins particularly to the vegetarian diets in India (Salunkhe *et al*. 1984).

There is a considerable variation in sorghum for levels of proteins, lysine, lipids, carbohydrates, fiber, calcium (Ca), phosphorus (P), iron (Fe), thiamine, and niacin. All these parameters impart sorghum grain quality (Hulse *et al*. 1980). Post-rainy season sorghum is known for its quality due to which is mostly preferred for human consumption by the masses and are characterized by lustrous, pearly white, attractive grains. Developing genotypes with high yield potential coupled with nutritionally superior quality grains is the prime objective of the breeding program. This paper deals with the details of nutritional quality of grain sorghum (post-rainy season) genotypes developed through a systematic breeding program and compared with traditional ones.

MATERIALS AND METHODS

Sorghum materials were used for physical characteristics of grains, chemical and nutritional constituents, and food quality.

Genotypes

Twenty land races from the traditional sorghum growing areas of the State of Maharashtra were collected on the basis of apparent grain qualities (shape, size and color) and designated as Rahuri Sorghum Local Germplasm (RSLG). Ninety two derivatives (F7) were obtained from the crossing program involving the potential sources for grain quality viz., Barshi types, RSLG 871, 971, 1090, 1072, 1104, 1105 etc. as parents (Table 1). The segregating material (F2-F6) was handled through pedigree selection. The promising advanced genotypes comprising 92 selections were designated as Rahuri Sorghum Variety (RSV) numbering RSV 858 to RSV 1001.

Seven cultivars released for commercial cultivation by the University and commonly grown by the farmers and traditionally grown popular cultivar 'M 35-1' fetching maximum price in market were used as checks for comparison. All these 120 genotypes constituted the genetic materials for the present study (Table 1).

Table 1. Genetic background of the local land races, genotypes, and cultivars of sorghum studied.

Genotype	Pedigree	Remarks	DMRT Rank
Local land races			
RSLG 426-1-2, RSLG 888-1, RSLG 1008-2, RSLG 1398, RSLG 1190-1, RSLG 1217-1, RSLG 1156, RSLG 829, RSLG 1192, RSLG 1275, RSLG 971, RSLG 1012, RSLG 294, RSLG 295, RSLG 428, RSLG 861, RSLG 1034, RSLG 1238, RSLG 112-1-8 and M 35-1 (Selection from local Maldandi population)			
Genotypes (advanced generation F7)		Selection (s)	1
RSV 858	RSLG 871 x RN-256-6-1-1-1-1	1	1
RSV 859	RSLG 971 X RN-256-8-1-8-1-1	1	2
RSV 860	RSLG 971 X SPV 1359-5-1-1-1-1	2	1
RSV 862	RSLG 971 X RSV 143-9-1-1-1-1	1	2
RSV 863	RSLG 1090 X RSV 143-6-1-1-1-1	2	3
RSV 865	RSLG 1090 X RSV 256-2-1-1-1-1	6	2
RSV 871	RSLG 1072 X SPV 1359-2-1-1-1-1	4	2
RSV 875	RSLG 1104 X SPV 1359-1-2-1-1-1	4	2
RSV 879	RSLG 1105 X SPV 1359-5-1-1-1-1	2	3
RSV 881	RSLG 1112 X SPV 1359-3-1-1-1-1	4	2
RSV 885	RSLG 1156 X RSV 143-1-1-1-1-1	3	2
RSV 888	RSLG 1156 X SPV 1359-3-1-1-1-1	1	3
RSV 889	RSLG 1197 X SPV 256-1-1-1-1	8	2
RSV 897	RSLG 1197 X SPV 1359-4-1-1-1	5	2
RSV 902	Barshi Type-I X SPV 1411-4-1-1-1-1	5	3
RSV 907	Barshi Type X SPV 1359-1-1-1-1-1	8	2
RSV 915	Barshi Type II X SPV 1165-5-1-1-1-1	4	2
RSV 919	Barshi Type II X SPV 1380-3-1-1-1-1	5	2
RSV 924	SPV 1491 X SPV 1413-2-1-1-1-1	2	1
RSV 926	SPV 1491 X SPV 1505-7-1-1-1-1	2	2
RSV 928	SPV 1491 X SPV 1413-1-1-1-1	2	2
RSV 984	RSLG 1090 X SPV 1359-3-1-1-1-1	12	2
RSV 996	RSLG 1156 X RSV 256-2-1-1-1-1	5	2
RSV 1001	RSE 90-7-11 X SPV 1359-26-1-1-1-1	1	2
Cultivars			
Phule Vasudha	RSLG 206 X SPV 1247		1
Phule Anuradha	RSLG 539 X RSLG 1175		2
CSV 22	SPV 1359 X RSV -2		7
Phule Maulee	Local land races Mangalwedha region		4
Phule Chitra	SPV 655 X RSLG 112		6
Sel. 3	Local selection		8
Phule Yashoda	RSLG 112-1-8		3
M 35-1 (check)	Selection from local Maldandi population		5

Physical Characteristics

Shape, color, and overall appearance of the grains were evaluated by five semi-trained judges (AACC 1975). Scale of 1 (best) to 4 (fair) was used where 1 = round, creamy color, attractive appearance, lustrous; 2 = round, white color, dull appearance; 3 = oval, white color, small grain size, dull appearance; 4 = oval round, dull color, dull dusty appearance, non-lustrous (Amerine *et al*. 1980).

Chemical Analysis

Nutritional quality parameters of sorghum flour were analyzed using the following standard methods. Proteins, fiber and water uptake were analyzed by using AOAC (1990), total sugars following Dubois *et al*. (1956), and total phenolics as described by Bray and Thorpe (1954). Starch content was analyzed according to McCready *et al*. (1956), protein classes by using Osborne as described by Lund and Sandstrom (1943), and *in vitro* protein digestibility (IVPD) following Saunder *et al*. (1973). Ca and Mg contents were analyzed following Black *et al*. (1965), P, Fe, and K according to Chapman and Pratt (1961), and trace elements (Na, Mg, Cu, Zn, and Mn) using atomic absorbance spectrophotometer (AOAC 1990). The data were analyzed according to Panse and Sukhatme (1967).

Roti Quality Characteristics

Grain samples (500 g) were ground to 60 mesh using A1 stainless steel grinding mill and flour was used for chemical analysis and *roti* quality evaluation. Six cultivars with two checks were used for the *roti* quality evaluation. Approximately 50 g flour was mixed with sufficient quantity of warm water in increments and kneaded by hand on a smooth wooden board into dough (Subramanian and Jambunathan 1980). As the dough attains proper consistency, it is made into a 6 cm diameter disc and pressed by hand into the form of circular disc. This disc was placed on wooden board and flattened by fast and deft hand stokes into a thin circle. Small quantities of dry flour were used as dusting flour to eliminate stickiness during handling.

Roti size was 20 cm diameter and 3 mm thickness. This *roti* was placed on a hot concave iron pan. Small quantity of water was sprinkled on top of the *roti* when the underside is cooked (40 seconds) then *roti* was turned over. The *roti* was removed from the pan after a minute and placed near the fire, with the unmoistened side exposed to limited heat from the fire that completely puffs the *roti*.

For organoleptic quality test of the sorghum *roti*, initially, 20 traditional sorghum consumers were selected for tasting *roti* quality and triangular test trials were conducted with their help following the method suggested by Amerine *et al*. (1980). Each panelist was given three *roties*, two from the same grain sample and third from different sample. The panelists were asked to identify the odd sample. Ten panelists who identified the odd sample consistently were trained further and used to evaluate the test material. A good *roti* should be smooth, soft, and slightly sweet with characteristic sorghum aroma. The trained panelists were asked to evaluate taste, texture, aroma, and overall acceptability of *roties*. Finally an average of score obtained from them was considered for the evaluation of each test entry. Test was replicated over three weeks. Ten points hedonic scales were used for the various organoleptic characteristics (Amerine *et al*. 1980) as the following: 10 = like extremely, 9 = like very much, 8 = like moderately, 7 = like slightly, 6 = neither like nor dislike, 5 = dislikes lightly, 4 = dislike moderately, 3 = dislike very much, 2 = dislike extremely, and 1 = not acceptable at all.

RESULTS AND DISCUSSION

Identification of Genotypes with Superior Nutritional Quality

The new genotypes Phule Vasudha (RSV 423; 3.3 t ha^{-1}), CSV 22 (2.6 t ha^{-1}), and Phule Chitra (SPV 1546; 2.3 t ha^{-1}) are 20-30% higher yielder than M 35-1 (17 t ha^{-1}; Table 3). Phule Anuradha (RSV 458; 1.0 t ha^{-1}) and Sel-3 (0.6 t ha^{-1}) are the sorghum cultivars released for cultivation on shallow to light soil types so they are low yielder.

Twenty land races, ninety two derivatives (F7), and seven improved cultivars including check M 35-1 were studied for various nutritional parameters, which are mostly responsible for the *roti* quality (Table 2). It was observed that there was great variation in hectoliter weight, water absorption, protein, total sugars, soluble proteins, starch, and phenolics. The hectoliter weight was varied from 68.59 to 79.42 kg hl^{-1}. The water absorption varied from 115 to 188% and the protein was found to be 7.10-12.11%. Total sugars, soluble proteins, starch, and phenolics were varied

Table 2. Nutritional composition of promising sorghum local land races and genotypes.

Sample	Hectoliter weight (kg hl^{-1})	Water absorption (%)	Crude protein (%)	Total sugar (%)	Soluble protein (%)	Starch (%)	Phenolic (%)
RSV-290	76.83	182	10.71	1.71	1.14	68.12	0.20
RSV-292	77.54	187	10.65	1.47	0.85	68.73	0.23
RSLG-1275	75.40	142	11.28	1.19	1.07	67.11	0.16
RSLG-428-1	76.25	140	11.90	0.80	0.85	68.41	0.15
RSLG-1238	76.40	150	11.69	1.46	0.90	68.30	0.31
RSV-858	72.83	118	12.11	0.97	1.30	65.03	0.19
RSV-859	72.79	123	12.00	1.01	1.10	64.91	0.15
RSV-861	74.39	126	11.27	0.88	1.17	65.01	0.19
RSV-868	72.57	121	11.90	0.86	1.13	60.23	0.17
RSV-894	75.34	143	11.22	1.03	0.86	69.81	0.14
RSV-985	76.79	145	11.74	1.17	1.23	69.13	0.22
RSV-992	75.62	154	11.36	1.12	1.61	67.53	0.15
RSV-995	77.20	143	11.36	1.61	1.42	67.90	0.22
RSV-999	79.06	133	11.49	1.41	0.99	69.87	0.26
Statistical analysis for 110 samples							
Range	68.59-79.42	115-188	7.10-12.11	0.64-1.95	0.76-1.61	58.13-73.08	0.10-0.52
Mean	74.51	137	9.33	1.12	1.10	69.39	0.19
SE +	1.51	8	1.14	0.18	0.14	1.71	0.04
CD at 5%	4.56	25	3.45	0.56	0.45	5.14	0.14

from 0.64 to 1.95%, 0.76 to 1.61%, 58.13 to 73.08%, and 0.10 to 0.52% respectively.

The genotype RSV 999 was higher in hectoliter weight (79.06 kg ha^{-1}) in comparison to land races, derivatives, and released varieties. With regards to the water absorption, the derivatives RSV 292 (187%) and RSV 290 (182%) exhibited significantly highest. The RSV 290 is a selection from RSLG 1190 and RSV 292 from RSLG 1217 from land races. The derivative RSV 858 had higher protein (12.11%) than the rest of genotypes. The genotype RSV 290 recorded higher total sugars (1.71%) among the materials studied. As regards soluble proteins, the genotype RSV 992 exhibited higher (1.61%) in comparison to materials under study. The genotype RSV 999 had higher starch content (69.87%) among the local land races, derivatives, and released cultivars. As regards phenols, RSV 894 showed lower phenolics (0.14%) among the materials studied. RSLG 428-1 had 11.90% crude protein and 68.41% starch, while less amount of antinutritional factor phenolics (0.15%).

The derivative RSLG 1238 also gave 11.69% crude protein and 68.30% starch. The RSLG 1275 showed higher amount of crude protein (11.28%) and lower amount of phenolics (0.16%). The RSV 859 had higher crude protein (12.00%) but lower in starch content (64.91%). The derivative RSV 861 exhibited average values for nutritional quality parameters studied. The genotype RSV 868 showed 11.90% crude protein, and 1.13% soluble proteins. The derivative RSV 985 gave 145% water absorption capacity, 11.74% crude protein, and 69.13% starch content. The genotype RSV 995 contained higher crude protein (11.36%), soluble proteins (1.42%), and total sugars (1.61%).

Nutritional Constituents Responsible for *Roti* Quality

Seven improved cultivars along with check M 35-1 were studied for nutritional constituents responsible for *roti* quality (Table 3). It was observed that there is great variation in the appearance, color, shape, and lustrousness. On the basis of ranking, the improved cultivars of Phule Vasudha, Phule Anuradha, and CSV 22 showed superiority for physical appearance of the grain (score 1.0). Hectoliter weight, water absorption, crude protein, total sugars, soluble proteins, and crude fiber were ranged from 78.86 to 82.41 kg hl^{-1}, 105 to 188%, 7.51 to 9.65%, 2.29 to 2.73%, 0.97 to 1.35% and 1.10 to 1.45% respectively. The Phule Maulee variety recorded highest hectoliter weight (82.41 kg hl^{-1}) among the cultivars studied. The Phule Vasudha exhibited higher water absorption (188%), crude protein (9.65%), and total sugars (2.73%) among the cultivars studied. Phule Vasudha also had higher soluble proteins (1.35%) and crude fiber (1.45%) among the cultivars studied. Considering the overall nutritional constituents, Phule Vasudha, CSV

22, and Phule Chitra were found to be promising for *roti* quality.

The relationship between the physicochemical characters and *roti* quality indicated that quantity of water-soluble proteins, soluble sugars, and soluble amylase jointly influence the *roti* quality, as has been reported by Kadam *et al*. (1977) and Subramanian and Jambunathan (1982). More water absorption is mostly responsible for the smoothness of the *roti* for longer time. Polyhydroxy sugars and water-soluble proteins as well as soluble amylose are mostly responsible for forming cohesiveness among them while preparing the *roti*. These parameters also gave very good organoleptic properties of the *roti* due to the formation of good flavor compounds during roasting/baking on the flame. Biochemical interactions that occur during baking of *roti* are mostly responsible for increasing the acceptability of the *roti* and increasing their taste and appearance (Nagy *et al*. 1941). Statistically, all genotypes showed significant differences in all nutritional constituents studied.

Organoleptic Quality of *Roti*

Organoleptic quality parameters of *roti* viz., color, flavor, texture, taste, and overall acceptability were used for organoleptic evaluation. The results revealed that the Phule Vasudha showed superiority for organoleptic parameters (Table 4). Chandrasekhar and Desikachar (1982) reported importance of same quality parameters for processing and culinary properties as

Table 3. Nutritional constituents responsible for *roti* quality of improved cultivars of post-rainy sorghum.

Genotype	Physical appearance of grains (rank)	Hectoliter weight (kg/hl)	Water absorption (%)	Crude protein (%)	Total sugar (%)	Soluble protein (%)	Crude fiber (%)	Grain yield (t/ha)
Phule Vasudha	1	79.83	188	9.65	2.73	1.35	1.45	3.3
Phule Anuradha	1	79.33	174	8.75	2.48	1.21	1.30	1.0
CSV 22	1	79.48	164	9.04	2.45	1.05	1.40	2.6
Phule Maulee	4	82.41	105	7.51	2.29	0.97	1.10	1.7
Phule Chitra	2	79.64	169	9.35	2.49	1.29	1.10	2.3
Sel-3	3	79.42	168	8.45	2.47	1.13	1.15	0.6
Phule Yashoda	3	78.86	186	8.27	2.46	1.03	1.40	2.3
M 35-1 (check)	4	79.89	185	8.89	2.51	1.16	1.38	1.7
Range	-	78.86-82.41	105-188	7.51-9.65	2.29-2.73	0.97-1.35	1.10-1.45	0.6-3.3
Mean	-	79.86	167	8.75	2.50	1.14	1.29	1.94
SE+	-	1.01	25	0.56	0.11	0.11	0.13	0.8
CD at 5%	-	3.03	75	1.68	0.34	0.36	0.41	2.5

Table 4. Organoleptic quality of *roti* prepared from improved cultivars of post-rainy sorghum.

Genotype	Water required for dough preparation (ml 100 g^{-1})	Dough condition/ rolling property	Organoleptic quality characteristics[1]					Rank by DMRT
			Color	Flavor	Texture	Taste	Overall acceptability	
Phule Vasudha	135	Easy rolling	8.7	8.1	8.5	8.5	8.45	1
Phule Anuradha	108	Easy rolling	7.7	7.5	7.6	7.6	7.60	2
CSV 22	110	Easy rolling	7.5	6.3	6.0	7.5	6.83	7
Phule Maulee	105	Easy rolling	7.5	6.8	7.2	7.3	7.20	4
Phule Chitra	113	Easy rolling	7.1	6.8	6.6	7.2	6.93	6
Sel-3	115	Easy rolling	5.7	5.6	5.8	6.0	5.78	8
Phule Yashoda	110	Easy rolling	7.6	7.2	7.3	7.3	7.35	3
M 35-1 (check)	130	Easy rolling	7.3	6.9	7.2	6.5	6.98	5
Range	105-135	-	5.7-8.7	5.6-8.1	5.8-8.5	6.0-8.5	5.78-8.45	-
Mean	102	-	7.4	6.9	7.0	7.2	7.14	-
SE+	10	-	0.7	0.7	0.8	0.7	0.70	-
CD at 5 %	30	-	2.3	2.4	2.6	2.1	2.12	-

[1]Sensory score: 10 = like extremely, 9 = like very much, 8 = like moderately, 7 = like slightly, 6 = neither like nor dislike, 5 = dislikes lightly, 4 = dislike moderately, 3 = dislike very much, 2 = dislike extremely, 1 = not acceptable at all.

well as nutritional and processing quality of sorghum. Sorghum genotypes were ranked for organoleptic characters by using Duncan Multiple Range Test (DMRT) (Amerine *et al.* 1980). Statistically, all genotypes showed significant differences in organoleptic quality parameters studied.

Correlation Analysis

Correlation coefficients between grain, dough, and *roti* quality attributes were estimated using 8 pints (cultivars) with three replications. Some of them were statistically significant. However, some of the characters were correlated strongly with overall acceptability of *roti* to be used for indirect assessment. The study revealed that water absorption showed significant positive association with crude protein and total sugars. Crude protein showed highly significant positive correlation with soluble proteins (Table 5). Usually seed number/earhead and seed size negatively correlated with nutritional quality parameters including protein content.

Diallel selective mating system is the powerful tool for breaking such undesirable linkage blocks (Jensen 1970). This system essentially dealt with the F1s as parents and contrived to get increased parental input into populations by diallel crossing of the F1s. Thereafter F1s and mass selected F2s. Recurrent selections occurred through the repeated (over-generations) use of reserve F1s.

The correlation between various organoleptic quality traits of *roti* revealed that grain color showed highly significantly positive correlation with flavor, texture, taste, and overall acceptability (Table 6). The texture showed highly significant correlation with taste and overall acceptability. The taste showed high significant positive association with overall acceptability.

Table 6. Correlation between various organoleptic qualities of *roti*.

Organoleptic quality	Color	Flavor	Texture	Taste	Overall acceptability
Color	-	+0.939**	+0.861**	+0.960**	+0.979**
Flavour		-	+0.967**	+0.890**	+0.983**
Texture			-	+0.801**	+0.937**
Taste				-	+0.930**
Overall acceptability					-

*, ** = significant at 5% and 1% of probability levels respectively.

In Vitro Protein Digestibility (IVPD) of Grain

The consumption of enough protein does not give a guarantee of fulfilling the requirements of the amino acids of an individual. In this context, protein digestibility is one of the important factors, which is responsible for amino acid availability. It has been reported that compared to other cereals, the digestibility of sorghum proteins is low (Naik 1968). Seven improved cultivars along with M 35-1 were studied for IVPD of grain. It was observed that there was a great variation in IVPD, ranging from 72.95% (Phule Yashoda) to 81.23% (Phule Vasudha) (Table 7). Chavan and Duggal (1978) reported that the IVPD of commonly grown hybrids and varieties of sorghum ranged between 66% and 82%.

Total Nitrogen and Protein Fractions

In the present study, the protein fractions from seven cultivars along with M 35-1 were separated and their concentration was measured (Table 8). Greater variation was observed for total nitrogen and protein fractions viz., albumin, globulin, prolamin, and glutelin. The total nitrogen, albumin, globulin, prolamin, and

Table 5. Correlation between various parameters responsible for *roti* quality.

Nutritional constituent	Hectoliter weight	Water absorption	Crude protein	Total sugar	Soluble protein	Crude fiber	Water for dough	Overall acceptability
Hectoliter weight	-	-0.583	-0.388	-0.087	-0.186	-0.772	-0.038	+0.408
Water absorption		-	+0.706*	+0.664*	+0.488	+0.398	+0.543	+0.158
Crude proteins			-	+0.598	+0.805**	+0.291	+0.624	+0.255
Total sugars				-	+0.363	+0.064	+0.512	+0.577
Soluble proteins					-	+0.052	+0.634	+0.108
Crude fiber						-	+0.250	-0.086
Water for dough							-	+0.478
Overall acceptability								-

*, ** = significant at 5% and 1% of probability levels respectively.

glutelin were varied from 1.20 to 1.54%, 5.03 to 6.28%, 9.27 to 17.31%, 29.61 to 38.12%, and 29.61 to 33.73%, respectively. The Phule Vasudha cultivar (1.54%), CSV (6.28%), M 35-1 (17.31%), Phule Vasudha (38.12%), and M 35-1 (33.73%) had significantly higher total nitrogen, albumin, globulin, prolamin, and glutelin respectively. The new genotypes were prominent in prolamin and glutelin proteins. Naik (1968) reported that prolamin and glutelin are the major proteins of the sorghum grain.

Table 7. *In vitro* protein digestibility (IVPD) of sorghum cultivars.

Genotype	IVPD (%)
Phule Vasudha	81.23
Phule Anuradha	75.80
CSV 22	74.13
Phule Maulee	73.67
Phule Chitra	74.36
Sel-3	73.61
Phule Yashoda	72.95
M 35-1 (check)	78.13
Range	72.95-81.23
Mean	75.49
SE+	2.65
CD at 5%	7.97

Mineral Composition

Seven improved cultivars along with M 35-1 were studied for different minerals (Table 9). The results revealed that there was great variations in the different minerals. The Phule Anuradha cultivar recorded highest Ca (40 mg 100 g^{-1}) and P (583 mg 100 g^{-1}) among the cultivars studied. The Phule Vasudha cultivar (563 mg 100 g^{-1}), Phule Anuradha (215 mg 100 g^{-1}), and CSV 22 (5.98 mg 100 g^{-1}) had highest K, Mg and Na contents, respectively, while Phule Anuradha (41 mg 100 g^{-1}), M 35-1 (1.08 mg 100 g^{-1}), and Phule Chitra (1.93 mg 100 g^{-1}) exhibited highest Cu, Zn, and Mn contents respectively. P, K, and Mg were found

Table 8. Distribution of nitrogen in different protein fractions of sorghum cultivars.

Genotypes	Total N (%)	Albumin (%)	Globulin (%)	Prolamin (%)	Glutelin (%)	Residue (%)
Phule Vasudha	1.54	6.19	15.65	38.12	31.10	4.31
Phule Anuradha	1.40	5.11	14.23	36.30	32.63	5.67
CSV 22	1.45	6.28	13.28	33.13	31.63	10.12
Phule Maulee	1.20	5.03	9.27	32.11	29.88	12.15
Phule Chitra	1.50	5.93	11.38	35.18	29.67	11.61
Sel-3	1.35	5.99	10.23	32.83	29.61	12.87
Phule Yashoda	1.32	5.63	12.15	34.67	30.92	9.17
M 35-1 (check)	1.42	5.93	17.31	29.61	33.73	5.53
Range	1.20-1.54	5.03-6.28	9.27-17.31	29.61-38.12	29.61-33.73	4.31-12.87
Mean	1.40	5.77	12.94	33.99	31.15	8.93
SE+	0.09	0.44	2.55	2.48	1.38	3.13
CD at 5%	0.27	1.32	7.66	7.43	4.15	9.37

Table 9. Mineral and trace elements content in sorghum cultivars.

Genotype	Mineral content (mg 100 g^{-1})								
	Ca	P	K	Mg	Fe	Na	Cu	Zn	Mn
Phule Vasudha	38	530	563	213	4.13	36	1.03	1.50	1.63
Phule Anuradha	40	583	523	215	4.28	41	1.07	1.53	1.58
CSV 22	28	533	507	168	5.98	40	0.83	1.76	1.46
Phule Maulee	25	498	413	187	4.93	29	0.72	1.33	1.89
Phule Chitra	35	519	485	203	5.84	31	0.89	1.93	1.86
Sel-3	28	423	393	173	4.75	26	0.73	1.62	1.09
Phule Yashoda	24	473	467	181	5.78	28	0.53	1.64	1.78
M 35-1 (check)	36	511	539	218	5.48	42	1.08	1.55	1.60
Range	24-40	423-583	393-563	168-218	4.13-5.98	26-42	0.53-1.08	1.33-1.93	1.09-1.89
Mean	31.8	509	487	195	5.15	34	0.86	1.61	1.61
SE+	5.40	43	49	18	0.67	5	0.18	0.16	0.24
CD at 5%	16.22	132	150	54	2.03	16	0.55	0.49	0.72

in appreciable amounts in the sorghum grain. The wide range in mineral and trace element composition indicated that sorghum is a good source of minerals. Deosthale and Belavady (1978) presented similar results on mineral content in sorghum grain.

CONCLUSION

Sorghum *roti* quality was influenced by grain, flour, and dough properties. Genetic variation existing among pearly white grain types for *roti* quality could be explained through this breeding program. Plant breeder can select for pearly white grain in early generation from F3 and F4 as it in significant positively associated with overall acceptability of *roti* attributing flavor, texture, and taste. The land races or derivatives or varieties/cultivars having higher hectoliter weight exhibited higher recovery of flour. The nutritional constituents viz., crude protein, total soluble sugars, soluble proteins, and soluble amylose content were mostly responsible for the good quality *roti*. Organoleptic quality traits viz., color, flavor, texture, and taste were associated with better quality of *roti* in sorghum.

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