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RESEARCH NOTES

Quality Indices, Preferences and Quality Rating Method for Sorghum Grain as Derived from their Relationship to Grain Market Price

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I

INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is an important foodgrain crop grown in India over an area of 9.1 million hectares with an annual production of 6.7 million tonnes of grain. It is grown for food and fodder purposes, both during the rainy (*rabi*) and post-rainy seasons (*kharif*) in India. About 30 per cent of the total grain that is produced is sold in the market (Marsland and Rao, 1999).

Many quality characteristics like moisture, protein, fat, fiber, ash, carbohydrate contents of grain, grain hardness, 100 seed weight are used to compare the quality of sorghum grain in research (Cagampang and Kirleis, 1984; Jambunathan *et al*., 1992; Buffo *et* al., 1998). Also many quality characteristics of sorghum grain like normal grains, molded grains, insect eaten grains, hardness, colour, uniformity, moisture content are mentioned in the Agricultural Produce Act, 1937 which form the basis of the pricing of grain in the Indian market. But information is scant on the relative importance of these characteristics in determining the price of the grain as well as the specific relationships of these characteristic values with price values. Determining the relative importance of the quality characteristics as well as their relationship with price would be helpful in developing a suitable quality indexing system for use in research programmes. Such quality indexing would help in identifying suitable production practices, genotypes, parents, progenies for the production of market acceptable grains. The objectives of the present study are therefore (1) to determine the levels of grain size, grain hardness, percentage of normal grains, damaged grains (molded grains), insect eaten grains, 100 seed weight, proportion of grains of different weight categories and components of the proximate principles in sorghum grain samples of different market prices of both the rainy season (*kharif*) and post-

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rainy season (*rabi*) sorghum grain samples, (2) to identify the relatively important quality parameters determining the market prices of the samples and (3) to develop an objective quality indexing system for sorghum grain samples based on the relationship between the gradation or the levels of quality characteristics and market prices of the sorghum grain samples.

II

MATERIAL AND METHODS

One kg each of forty-two sorghum grain samples were collected in duplicate. These consisted of 21 samples (in duplicate) collected in October 2006, from 21 different genotypes grown during the rainy season (*kharif*) 2006 at the farm of the Directorate of Sorghum Research, Rajendranagar, Hyderabad. Another set of 6 samples (in duplicate) were collected during February 2007 from six different genotypes grown during the post-rainy season (*rabi*) 2006-07 at the farm of the Directorate of Sorghum Research, Rajendranagar, Hyderabad. A third set of 15 grain samples (in duplicate) covering maximum variation in price/kg found in the market were collected during April 2007 from nine retailer shops of sorghum grain located in two main agricultural marketing areas of Hyderabad, viz., Osmangunj and Malakpet. As and when the samples were collected from the farm harvest or from the market, they were kept in paper packets for one month at ambient temperature in the lab. Thereafter, the samples were stored at 4^{o}C prior to physical and proximate characteristic determinations.

All the 42 sorghum grain samples, in duplicate, were assessed at the same time for market prices from two different traders, one in Osmanganj and one in Malakpet and the mean values were reported. The two traders' assessment (r=0.81 and r=0.83) were correlated with the retail prices of the fifteen samples purchased from the Hyderabad market. The price of all 42 sorghum grain samples were based on the traders' assessment.

Moisture was determined in whole grain as well as in the air dried, powdered samples, which had passed through a 1 mm sieve. Moisture and the proximate composition of grain were determined according to methods mentioned by Horwitz (1965). The proximate composition was reported on a moisture free basis. In randomly collected small samples totalling 15 g each, taken in duplicates from each main sample, the normal grains, molded grains and insect damaged grains were separated, weighed and the percentages by weight of these types of grains in the samples was calculated. Normal grains were white or yellowish, of uniform colour and shape, with less than 10 per cent of the area of grain covered with molds or other colourations and without any hole in the grain. Molded grains represented that proportion of grains in the sample which had a black mold colouration or spots on >10 per cent of area of each gain. Insect damaged grains were the grains having visible holes or damage on the surface due to insect attack. For determining 100 seed

weight, one hundred randomly collected seeds, in duplicate, were taken from each sample and weighed. Insect damaged grains were excluded. For determining the percentage of grains with 10 ± 5 mg, 20 ± 5 mg, 30 ± 5 mg, 40 ± 5 mg and 50 ± 5 mg weights, fifty randomly collected seeds, in duplicate, taken from each sample, were individually weighed to the nearest milligram and the percentage of each weight category was calculated. Insect damaged grains were excluded. Grain hardness was determined in 10 randomly taken seeds, in duplicate, taken from each sample. The moisture content of whole grain of the rainy season samples ranged from 8.0 – 10.7 per cent and those of post-rainy season samples ranged from 3.7 – 9.7 per cent. In these air dry grain samples, grain hardness was determined using a manually operated kiya hardness tester (No. 174886, Kiya Seisakusho Ltd., Tokyo, Japan) without bringing them to a uniform moisture content. The force in kilogram used to crack each grain was measured. The length, breadth and thickness were measured in 10 randomly taken seeds, in duplicate, from each sample using a plastic scale. The values of all quality characteristics and price/kg reported in this paper for each sample are the mean of the four determinations.

Relatively important characteristics were identified by the step-down regression analysis, and path analysis carried out using the quality characteristic values obtained from the 42 sorghum grain samples. By the step-down regression analysis, the group of characters which had the highest R^2 values were considered to be the most important characteristic related to market value of grain. By path analysis, the characteristics which had larger direct path coefficients than any indirect path coefficient, were considered to be relatively more important characters related to the market value of the grain.

Preferred Levels of Quality Characteristics and Quality Rating System

The preferred levels of each quality characteristic was estimated from the simple correlation relationship between the market values and the particular quality characteristic values for the 42 sorghum grain samples. A positive correlation of the characteristic was taken to indicate that high levels of the characteristics represented the preferred levels. A negative correlation of the characteristic indicated that low levels of the characteristics represented the preferred levels.

Another method followed for identifying the preferred levels was by examining the distribution of market prices across a range of particular characteristic values. For this purpose, first, the values obtained for each characteristic were sorted and arranged in descending order of magnitude. Then the market price obtained for each sample was placed opposite to the quality characteristic value for the particular sample. After arranging the market price of the sample opposite the quality characteristic value obtained for the sample, they were examined for regions of high, medium and low market prices. Then the mean of prices corresponding to successive sets of two, three, four, and five values of the characteristics taken at a time were

calculated, starting from the highest value of the characteristic towards the lowest value. Each of means of these sets were examined for the amount of variability within each set and then the regions of high, medium and low market values were finally decided. After examining all these sets, the regions or range of levels of the characteristics corresponding to high, medium and low market values were finally selected in the main data. All the market values corresponding to each of the selected range of levels of the characteristic were averaged to get the mean market values corresponding to a particular range. These mean market values so determined represented the quality rating or score for that particular range of level of the characteristic. The range with the highest market value was taken to represent the preferred level for that particular characteristic.

As an illustration of the frequency distribution method, the values of normal grains (per cent) and market price obtained for the 42 samples are presented in Table 1. Here the regions of high, medium and low market price of the samples could be identified after examining the mean of prices corresponding to successive sets of two, three, four, and five values of the characteristics taken at a time starting from the highest value of the characteristic towards the lowest value. After careful examination of all the sets of values, three zones or ranges corresponding to high, medium and low market prices could be demarcated based on minimum variability within any one set and also based on difference in value from that of other zone or ranges that were selected finally.

Correlation, regression and path analysis were done using Genstat (Payne, 2002). A uniform sample size of 42 sorghum grain samples was used in all the statistical analysis.

III

RESULTS AND DISCUSSION

The statistical relationship between price/kg and the physicochemical characteristics of sorghum grain samples are presented in Table 2. Price/kg significantly and positively correlated with carbohydrate, grain hardness, 100 seed weight, grain length, breadth, thickness and proportions of grains with 40 $\pm$ 5 mg and 50 $\pm$ 5 mg weight. The results indicate that the high levels of these characteristics were preferred by consumers as they were associated with higher market priced samples. The preference of higher carbohydrate content agrees with the purpose for which cereals are consumed, i.e, as a major and economical source of energy. The positive relation of harder grains with price/kg conforms with the Agricultural Produce Act (1937), which mentions that sorghum grain should be hard. The 100 seed weight, grain length, breadth, thickness and proportion of grain having 40 $\pm$ 5 mg and 50 $\pm$ 5 mg weight are different components or measures of size and mass of grain. Our results indicate that the larger sized and heavier seeds are preferred by consumers which support, confirm and clarify the general usage of grain size,

TABLE 1. FREQUENCY DISTRIBUTION BASED SELECTION OF LEVELS OF NORMAL GRAINS ASSOCIATED WITH HIGH, MEDIUM AND LOW PRICED SAMPLES

Sl. No. (1)	Normal grains (per cent) in descending order of values (2)	Corresponding price of sample (Rs./ kg) (3)	Mean price of successive set of 2 samples (4)	3 samples (5)	4 samples (6)	5 samples (7)	Final selected range (8)	Mean price of selected range (9)
1.	100	5.45	5.41	5.33	5.28	5.19		
2.	100	5.36					S. Nos. 1 to 15[@]	5.61
3.	100	5.18	5.16					
4.	100	5.13		4.65				
5.	100	4.83	4.41		5.65			
6.	100	3.99				5.87		
7.	99.2	7.23	6.90	6.82				
8.	99.2	6.56						
9.	98.8	6.68	5.78		5.95			
10.	98.8	4.88		5.70				
11.	98.4	6.08	6.12			5.89		
12.	98.3	6.15						
13.	98.3	5.55	5.73	5.74	5.52			
14.	97.7	5.90						
15.	97.7	5.76	5.31					
16.	96.4	4.85		4.37		4.70		
17.	96.0	4.00	4.13		4.66		S. Nos. 16 to 34	4.52
18.	96.0	4.25						
19.	93.1	7.00	5.20	5.13				
20.	93.0	3.40						
21.	92.4	5.00	5.08		4.66	4.65		
22.	91.5	5.15		4.54				
23.	89.3	4.47	4.24					
24.	88.4	4.00						
25.	87.2	4.65	5.20	5.00	4.89			
26.	86.9	5.75				4.57		
27.	86.8	4.60	4.58					
28.	86.1	4.55		4.17				
29.	86.1	3.60	3.98		3.83			
30.	85.9	4.35						
31.	85.4	3.10	3.68	3.98		4.11		
32.	84.8	4.25						
33.	83.2	4.60	4.74		4.22			
34.	80.2	4.87		4.09				
35.	78.6	3.75	3.70					
36.	74.2	3.64				3.71	S. Nos. 35 to 42	3.71
37.	65.6	3.95	3.53	3.38	3.73			
38.	63.1	3.10						
39.	62.2	3.10	3.93					
40.	60.9	4.75		4.12				
41.	58.8	4.50	3.80					
42.	54.5	3.10						

@The variability is within a small range (between 5.0 and 5.9) when 5 successive values are averaged and hence this range from S. No. 1 to 15 is selected as the high market priced range. Using similar criteria the intermediate (S. No. 16 to 34) and low market priced ranges (S. Nos. 35 to 42) have been selected. The mean prices for the three ranges are different.

particularly 100 seed weight as a quality parameter of sorghum grain by several workers Buffo *et al.,* 1998; Jambunathan *et al.* 1992; Menkir *et al.*,1996. Von Oppen and Rao (1982) have also reported a significant and positive correlation of 100 seed weight with price/kg (r=0.30 to 0.54) in different sets of sorghum grain samples.

Price/kg correlated significantly and negatively with moisture, crude protein, crude fiber, proportion of grain having 10 $\pm$ 5 mg and 20 $\pm$ 5 mg weights and molded grains. Evidently low levels of these constituents were preferred based on their association with higher market priced samples. The preference of lesser moisture is as per the Agricultural Produce Act (1937) where a level of less than 12 per cent is acceptable. Our results indicate that lesser crude protein content in sorghum grain is preferred, but von Oppen and Rao (1982) found no significant correlation between the protein content of grain and price/kg of sorghum grain samples collected from the Hyderabad market. The different correlation of the protein content of grain with the market value of sorghum grain samples as found in the present study, as compared to that of von Oppen and Rao (1982) might possibly be due to differences in the samples that were used in these two studies.

The characteristics which were significantly correlated with price/kg were subjected to stepdown linear multiple regression analysis to identify the relatively important quality parameters. The analysis indicated that normal grains, 100 seed weight and crude fiber were relatively more important, as these three characters together explained 56 per cent of the total variation in price as compared to 66 per cent, when all the characters were taken together (Table 2). The results agree with those of von Oppen and Rao (1982) who have reported that the percentage of molded grains and 100 seed weight, very significantly explained the price of sorghum grain samples in a multiple regression analysis. In the present study, normal grain instead of molded grain was identified to be important and crude fiber was also identified to be important.

Path analysis was done to identify the important characteristics among groups of interrelated or similar characteristics. The results were presented in Table 2. Among the characteristics of the Agricultural Produce Act (1937), normal grains was identified to be more important as it had a greater direct effect on its market value than any other characteristic. Similarly, among the parameters measuring size and heaviness of the seeds, 100 seed weight and grains having 10 $\pm$ 5 mg, 20 $\pm$ 5 mg weights were found to be relatively more important. Among the grain size measurement parameters, grain breadth was more important. Among the proximate composition characteristics, crude fiber and ash were found to be more important. Another important characteristic was grain hardness. While all the characteristics identified in path analysis correlate significantly with price/kg, ash does not. The implication of ash content with price/kg of sample may possibly be the role ash content has on sorghum roti flavour and texture as identified in the stepwise regression analysis by Subramanian and Jambunathan (1981). Path analysis also

TABLE 2. STATISTICAL RELATIONSHIPS BETWEEN QUALITY CHARACTERISTICS OF SORGHUM GRAIN AND PRICE

Character (1)	Simple correlation coefficient (2)	Direct path coefficient (3)	Largest indirect path coefficient through (4)	Total indirect path coefficient (5)	Multiple linear regression coefficients for important characters: Fifteen characters (R)** (6)	Eight characters (R)** (7)	Three characters (R)** (8)
					Intercept = -2.7491	Intercept = 2.8161	Intercept = 2.309*
Normal grains (per cent by wt.)	0.5312**	0.5454	-	-0.0143	0.0194	0.0189*	0.0163*
Damaged (molded) grains (per cent by wt.)	-0.4862**	0.1843	-0.5288 normal grains	-0.6705	-0.00092		
Insect eaten grains (per cent by wt.)	-0.1883	-	-	-	-	-	-
100 seed weight (g)	0.6734**	0.6429	-	0.0304	1.0804	1.0934**	0.691**
Grains having 10 ±5 mg weight (per cent by wt.)	-0.3419*	0.6047	-	-0.9467	0.0519	0.0372*	
Grains having 20 ±5 mg weight (per cent % by wt.)	-0.4899**	0.6429	-	-1.1328	0.0176	0.00028	
Grains having 30 ±5 mg weight (per cent by wt.)	-0.1015	-	-	-	-	-	-
Grains having 40 ±5 mg weight (per cent by wt.)	0.6094**	0.3669	-0.5546 grains with 20 mg weight	0.2425	0.0146	-	-
Grains having 50 ±5 mg weight (per cent by wt.)	0.4587**	-	-	-	-0.0108	-	-
Grain length (mm)	0.4635**	0.3585	-0.568 grain breadth	0.1049	0.5572	-	-
Grain breadth (mm)	0.4705**	-0.5680	-	1.0387	-1.3648	-0.6528	-
Grain thickness (mm)	0.4202**	0.3742	-0.5136 grain with 20 mg weight	0.0461	1.1929	-	-
Grain hardness (kg)	0.3021*	0.2125	-	0.0896	0.1397	0.0999	-
Moisture (per cent)	-0.3432*	0.1914	-0.2918 crude fiber	-0.5347	0.0567	-	-
Crude protein (per cent) †	-0.388*	-0.029	-0.244 100 seed weight	-0.359	-0.0226	-	-
Fat (per cent) †	0.2122	-	-	-	-	-	-
Crude fiber (per cent) †	-0.5144**	-0.5042	-	-0.0104	-0.5537	-0.3894*	-0.360*
Ash (per cent) †	-0.2579	-0.1668	-	-0.0911	-	-0.4412	-
Carbohydrate (per cent) †	0.5039**	0.00	0.3846 crude fiber	0.5039	0.0106	-	-
					$R^2 = 0.66$ Adj. R^2=0.47	$R^2 = 0.64$ Adj. R^2=0.55	$R^2 = 0.56$ Adj. R^2=0.52

† Moisture free dry basis.

* Significant at P = 0.05. ** Significant at P = 0.01.

indicated that all other characteristics were affecting price/ kg through the characteristics that were having direct effects (Table 2). Hence the increase in molded grains was lowering market value by decreasing normal grains (r = -0.97), increase in grains with 40 $\pm$ 5 mg weight was increasing market value by the associated decrease in grains with 20 $\pm$ 5 mg weight (r = -0.87), increase in grain length was increasing market value by the associated increase in grain breadth (r = 0.95), increase in grain thickness was increasing market value by the associated decrease in grains with 20 $\pm$ 5 mg weight (r = -0.77), increase in moisture content was lowering market value through its association with higher crude fiber content (r = 0.58), increase in protein content was lowering market value through the associated decrease in 100 seed weight (r = -0.38), increase in carbohydrate content was increasing market value through the associated decrease in crude fiber content (r = -0.76). The relative importance of quality characteristics as found in this study indicate that normal grains, 100 seed weight and crude fiber are priority characteristics to be considered in grain quality improvement breeding studies. Next to this are those identified by path analysis to have a direct effect and thereafter the remaining other characteristics which are significantly correlated with market value.

An objective of this study was to develop a quality indexing system based on the important characteristics determining the price of sorghum grain for use in research studies. To identify the specific range of levels of each characteristic associated with high, medium and low market valued samples, the frequency distribution examination of the market values across the entire range of values of each characteristic was done. The ranges of levels of each characteristic and the mean prices corresponding to these ranges were identified. The ranges of levels of each characteristic, which had the highest mean prices represented the consumer-preferred levels for the particular characteristic (Figures 1 and 2). It was found that the relationship between the market values and the range of levels of characteristics were not strictly linear in case of grain length, grain breadth, grains having 10 $\pm$ 5 mg weights, grain hardness, moisture, protein and carbohydrates. Two preferred levels for these characteristics were observed. These were 4.06-4.65 mm and 3.36 to 3.65 mm for grain length, 3.49-4.20 mm and 2.96-3.21 mm for grain breadth, 9.31 – 10 per cent and 3.7 –6.2 per cent for moisture, 9.6 –10.4 per cent and 4.9 – 7.3 per cent for protein and 75.2 – 76.1 per cent and 79.1 – 83.54 per cent for carbohydrates. The preferred ranges of normal, molded and insect eaten grains derived from market value, in the present study, agrees well with the Agricultural Produce Act (1937). These results validate the method of determining preferred levels of grain characteristics. These preferred levels of physicochemical characteristics can be used in quality evaluation studies.

` For calculating the overall quality rating using many characteristics, the quality rating values given in Figures 1 and 2 can be taken. Based on the levels of physicochemical characteristics present in the sorghum grain samples under study, the quality rating/score of individual characteristics so obtained from Figures 1 and 2

			Ranges	Preferred ranges (in dark black)	Grain character
		54 - 9.9	80 - 96.9	97 - 100	Normal grains (%)
		3.71	4.52	5.61	Mean price (Rs.) / Quality rating
		44 - 8	7.9 - 1.6	1.5 - 0	Molded grains (%)
		4.01	4.97	5.44	Mean price (Rs.) / Quality rating
		25.88-1.47	1.46– 0.41	0.40 - 0	Insect eaten grains (%)
		4.18	4.74	5.36	Mean price (Rs.) / Quality rating
		1.2 - 2.7	2.8 - 3.1	3.2 - 4.1	100 seed weight (g)
		4.07	4.77	5.81	Mean price (Rs.) / Quality rating
3.13 -3.35	3.36 -3.65	3.66 -3.79	3.80- 4.05	4.06-4.60	Grain length (mm)
3.63	4.68	4.07	5.08	5.68	Mean price (Rs.)/ Quality rating
2.73 - 2.95	2.96 - 3.21	3.22- 3.33	3.34 -3.48	3.49 -4.20	Grain breadth (mm)
3.87	4.80	3.86	4.68	5.56	Mean price (Rs.) / Quality rating
	2.10 – 2.35	2.36 -2.69	2.70 -2.95	2.96 -3.40	Grain thickness (mm)
	3.43	4.01	4.89	5.73	Mean price (Rs.) / Quality rating
	5.8 – 51.3	51.2 - 6.1	6.0 -0.32	0.31 - 0	Grains with 10 ± 5 mg weight (%)
	3.6	4.68	5.54	4.78	Mean price (Rs.) / Quality rating
		66 - 36.1	36.0 - 5.6	5.5 - 2.7	Grains with 20 ± 5 mg weight (%)
		3.98	4.83	6.01	Mean price (Rs.) / Quality rating
		0.21- 1.95	1.96- 5.60	5.61 -7.56	Grains with 30 ± 5 mg weight (%)
		3.32	5.07	4.31	Mean price (Rs.) / Quality rating
		0 - 14.0	14.1- 38.9	39.0 -45.3	Grains with 40 ± 5 mg weight (%)
		4.05	4.89	5.96	Mean price (Rs.) / Quality rating
			0 - 7.9	8.0 - 42.4	Grains with 50 ± 5 mg weight (%)
			4.48	5.82	Mean price (Rs.) / Quality rating
		8 - 9.8	9.9 - 11.2	11.3 - 3.3	Grains hardness (kiya force in kg)
		3.9	5.41	4.7	Mean price (Rs.) / Quality rating

Figure 1. Market Price Derived Quality Rating System and Quality Indices for Levels of Physical Characteristics of Sorghum Grain

Ranges				Preferred ranges (in dark black)	Grain character (dry weight basis)
10.3- 10.1	10 - 9.31	9.3 - 8.3	8.2 - 6.3	6.2 - 3.7	Moisture (%)
3.10	5.04	3.94	4.98	5.27	Mean price (Rs.) / Quality rating
12.7-11.3	11.2-0.5	10.4 - 9.5	9.4 - 8.8	8.7 - 7.4	7.3 - 4.9	Protein (%)
3.63	4.98	5.50	4.43	4.87	5.77	Mean price (Rs.) / Quality rating
		5.16- 3.71	3.70 -2.31	2.30- 1.00	Crude fiber (%)
		3.20	4.52	5.38	Mean price (Rs.) / Quality rating
			1.43 -2.95	2.96- 3.97	Fat (%)
			4.43	5.52	Mean price (Rs.) / Quality rating
			2.79 -1.51	1.50 -1.12	Ash (%)
			4.40	5.30	Mean price (Rs.) / Quality rating
67.5-71.3	71.4-.1	75.2- 76.1	76.2- 77.4	77.5- 79.0	79.1-83.5	Carbohydrate (%)
3.10	4.50	5.08	4.43	5.24	5.62	Mean price (Rs.) / Quality rating

Figure 2. Market Price Derived Quality Rating System and Quality Indices for Levels of Proximate Composition of Sorghum Grain

are added up to get the overall rating/score of the sample and then dividing the total score by the number of characteristics used to rate the quality. Another method followed, for getting the quality rating based on many characteristics, was by using the multiple regression equation coefficients given in Table 2. Both these methods of quality rating were then compared. When quality rating was determined with three important characteristics using the frequency distribution method, the correlation with prices of 42 samples of this study was found to be 0.75, whereas by the multiple regression method (Table 2), it was found to be 0.70. Similarly when eight relatively important characteristics were used (Table 2), the correlation of quality ratings with prices were 0.80 and 0.85 by these two methods respectively. When 15 important characteristics were used, the correlation were 0.83 and 0.81 by the two methods respectively. Hence, use of the three most important characteristics and the frequency distribution method was found to be the suitable method for quality evaluation for the most practical purposes. For further resolution the eight important characteristics can be used in the frequency distribution method. But beyond the use of eight important characteristics, there is no large advantage in including other characteristics as indicated by the adjusted R^2 values, which was maximum for the 8 characteristics group than for the other two multiple regression equations that were compared (Table 2). This indicated that the prediction value of the particular 8 characteristics group was maximum rather than any other group of characteristics' combination.

IV

CONCLUSION

The frequency distribution based quality rating system is advantageous, apart from its better correlation with actual prices, due to the clarity and understanding it gives about the quality and rating of the sorghum sample, which is not evident when the multiple regression equation is used. Better prediction by the frequency distribution method is, because it closely approximates the actual relationship between the characteristics and market value, which may or may not be strictly linear in nature. In the multiple regression equation method, the relationship between the characteristic values and market values are assumed to follow a strictly linear trend, which is not found to be the case with respect to certain characteristics in the present study, as already indicated. One of the limitations of this study was a separate study could not be carried out for *kharif* and *rabi* sorghum and should be attempted in future since the utilisation patterns for the crop grown in the two seasons vary. The quality requirements of the product for which the grain is utilised has also not been included in the study. If the use of grain is for making roti, then dough quality characteristics and roti quality characteristics including organoleptic scoring should also be included to make the relationship between grain characteristics, use and price of the grain more comprehensive. Even though the quality characteristics included in the quality index determination explain 56 per cent of the variation of market price, there is still a possibility that inclusion of quality characteristics relevant for the product usage of the grain could further improve the quality indexing.

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