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STUDY ON VARIABILITY AND ASSOCIATIONS INVOLVING PROTEIN CONTENT, AMINO ACIDS AND GRAIN YIELD IN SORGHUM

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ABSTRACT

Quantitative estimations of total protein and five amino acids in 50 varieties of grain sorghum revealed significant variability for protein content (5.1–11.4%) and amino acids: lysine (0.30–2.75%), histidine (0.82–2.95%), arginine (1.70–7.61%), phenylalanine (1.88–6.14%), and isoleucine (4.43–11.85%). Five high protein (> 10.0%) lines were selected, but all were poor yielders. Correlation analysis revealed significant negative relationship of protein content with grain yield and the levels of four amino acids in their proteins. However, absence of significant negative relationship between protein content and lysine suggests the possibility of combining high protein and high lysine traits in sorghum grain. Amino acid content in the whole grain (flour), on the other hand, correlated positively with grain protein percent.

Key words: Grain sorghum, protein content, amino acids, variability, grain yield.

Protein quality of sorghum, a staple food in several parts of India, is poor, leading to malnutrition and pellagra disease among the populations using sorghum as a major food item. Therefore, identification and mass cultivation of nutritionally superior varieties of sorghum would be a logical approach to the prevention of malnutrition. Conscious screening for better nutritional value has been started only recently and the available genetic diversity for protein content and quality has not been evaluated properly [1]. The present paper deals with the estimation of total grain proteins and five essential amino acids, viz. lysine, histidine, arginine, phenylalanine and isoleucine, in 50 varieties of grain sorghum for identifying high protein lines.

MATERIALS AND METHODS

Seeds of 50 varieties of grain sorghum (*Sorghum bicolor* (L.) Moench) obtained from the Department of Plant Breeding and Genetics, Rajasthan College of Agriculture, Udaipur, were used. These varieties were selected on the basis of their diverse ecogeographic

distribution and differences in plant height, flowering and maturity durations, seed colour and grain yield, etc. For each variety, a representative sample of 50 g seed was utilised.

Protein content was estimated according to the conventional Micro-Kjeldahl method [2]. Quantitative estimation of the individual amino acids was done by paper chromatography. Each sample was analysed in two replications. Analysis of variance was carried out for all the characters. Tukey's confidence interval was calculated for the comparison of mean values as per [3]. The relationship of protein content with yield, plant height, and the five individual amino acids was determined by using [4].

RESULTS AND DISCUSSION

Total protein and individual amino acid contents among the 50 varieties of grain sorghum analysed showed significant variation (Tables 1, 2). Protein content ranged from as low as 5.1% (SPV 221) to 11.4% (SU 393), indicating a large scope for selection of high protein lines in sorghum. This finding lends support to earlier reports [5–9].

Table 1. Total seed protein content and amino acid profile of sorghum varieties

Variety	Protein content (%)	Lysine		Histidine		Arginine		Phenylalanine		Isoleucine	
		% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain
SU 1	8.3	2.10	0.17	0.90	0.07	4.83	0.40	4.60	0.38	9.86	0.82
SU 351	10.9	0.30	0.03	1.11	0.12	2.05	0.22	4.09	0.45	4.77	0.52
SU 386	7.5	0.75	0.06	1.76	0.13	4.14	0.31	2.15	0.16	4.84	0.36
SU 393	11.4	1.30	0.15	1.27	0.14	2.98	0.34	4.78	0.54	4.81	0.55
SU 396	8.6	1.43	0.12	1.93	0.17	5.13	0.44	2.13	0.18	6.05	0.52
SU 405	10.8	1.55	0.17	2.16	0.23	3.79	0.41	1.99	0.21	6.94	0.75
SU 412	9.6	2.13	0.20	1.93	0.19	2.91	0.28	4.04	0.39	4.85	0.47
SPV 101	5.6	0.96	0.05	2.11	0.12	4.95	0.28	6.14	0.34	10.15	0.57
SPV 138	5.4	2.75	0.15	2.66	0.14	2.93	0.16	4.02	0.22	9.02	0.49
SPV 221	5.1	0.94	0.05	2.63	0.13	6.73	0.34	2.39	0.12	9.20	0.47
SPV 223	6.3	0.98	0.06	1.70	0.11	3.20	0.20	2.65	0.17	8.15	0.51
SPV 224	6.1	1.19	0.07	2.90	0.18	5.05	0.31	6.12	0.37	9.09	0.55
SPV 225	6.1	2.48	0.15	2.49	0.15	6.76	0.41	3.87	0.24	9.66	0.59
SPV 241	5.2	1.20	0.06	2.04	0.11	3.69	0.19	6.00	0.31	7.56	0.39
SPV 289	7.1	2.14	0.15	1.77	0.13	3.93	0.28	3.87	0.27	6.11	0.43

(Contd.)

Table 1. (contd.)

Variety	Protein content (%)	Lysine		Histidine		Arginine		Phenylalanine		Isoleucine	
		% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain
SPV 301	5.2	1.21	0.06	2.95	0.15	5.00	0.26	3.50	0.18	9.56	0.50
SPV 316	7.1	1.67	0.12	2.27	0.16	5.13	0.36	4.64	0.33	8.67	0.62
SPV 350	6.1	1.36	0.08	2.95	0.18	4.74	0.29	6.09	0.37	8.77	0.53
SPV 352	6.1	0.94	0.06	2.20	0.13	7.25	0.44	4.06	0.25	6.56	0.40
SPV 462	6.6	2.46	0.16	1.95	0.13	3.17	0.21	5.86	0.39	6.75	0.45
SPV 472	8.9	1.56	0.14	2.20	0.20	3.64	0.32	1.88	0.17	4.78	0.43
SPV 475	7.4	2.05	0.15	2.00	0.15	1.70	0.13	2.23	0.17	8.61	0.64
SPV 669	7.4	2.06	0.15	1.97	0.15	3.00	0.22	4.01	0.30	6.01	0.44
SPV 678	6.7	2.14	0.14	2.45	0.16	4.03	0.27	3.92	0.26	7.98	0.53
SPV 710	6.7	1.47	0.10	0.82	0.05	4.80	0.32	4.19	0.28	9.26	0.62
SPV 742	6.5	2.58	0.17	2.91	0.19	7.11	0.46	4.16	0.27	7.42	0.48
SPV 750	6.5	1.47	0.10	2.27	0.15	2.64	0.17	3.47	0.23	7.04	0.46
SPV 756	7.4	2.33	0.17	2.91	0.22	3.76	0.28	4.90	0.36	9.33	0.69
SPV 772	11.2	0.87	0.10	1.67	0.19	4.96	0.56	2.85	0.32	11.85	1.33
SPV 775	8.5	1.11	0.09	1.88	0.16	4.04	0.34	4.82	0.41	8.50	0.72
SPV 803	8.7	1.20	0.10	0.99	0.09	2.70	0.23	2.98	0.26	4.63	0.40
SPV 813	8.5	1.99	0.17	2.02	0.17	5.13	0.44	4.73	0.40	8.60	0.73
SPV 819	6.2	2.55	0.16	1.97	0.12	2.81	0.17	5.40	0.33	7.96	0.49
SPV 923	7.3	1.05	0.08	1.12	0.08	5.13	0.37	2.07	0.15	6.72	0.49
SPV 937	8.3	1.50	0.12	1.97	0.16	2.73	0.23	3.60	0.30	5.92	0.49
SPV 946	8.3	2.05	0.17	1.75	0.15	3.95	0.33	4.89	0.41	6.81	0.57
SPV 948	8.4	2.27	0.19	2.17	0.18	5.12	0.43	3.05	0.42	9.13	0.77
SPV 950	8.8	1.70	0.15	2.01	0.18	2.12	0.19	4.16	0.37	4.43	0.39
SPV 952	10.2	2.46	0.25	2.50	0.26	5.69	0.58	2.41	0.25	9.83	1.00
SPV 954	7.4	1.26	0.09	1.49	0.11	2.73	0.20	3.37	0.25	5.02	0.37
SPV 961	6.2	1.94	0.12	1.54	0.10	7.61	0.47	5.90	0.37	8.81	0.55
SPV 962	7.3	2.04	0.15	2.11	0.15	3.09	0.23	4.83	0.35	4.86	0.35
SPV 964	7.3	0.85	0.06	1.32	0.10	3.97	0.29	3.12	0.23	9.81	0.72
SPV 965	7.2	2.40	0.17	1.63	0.12	5.23	0.38	1.97	0.14	6.89	0.50

(Contd.)

Table 1. (contd.)

Variety	Protein content (%)	Lysine		Histidine		Arginine		Phenylalanine		Isoleucine	
		% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain	% of protein	% of grain
SPV 966	6.3	2.48	0.16	1.51	0.10	4.90	0.31	5.35	0.34	10.05	0..63
SPV 967	7.2	0.81	0.06	2.05	0.15	5.19	0.37	3.15	0.23	4.87	0.35
SPV 970	8.1	1.06	0.09	2.04	0.17	5.20	0.42	2.11	0.17	5.58	0.45
SPV 971	6.2	2.15	0.13	1.39	0.09	4.13	0.26	3.95	0.24	6.75	0.42
SPV 973	5.8	1.21	0.07	2.88	0.17	7.27	0.42	2.88	0.17	8.27	0.48
SPV 11 (SPV 351)	6.9	1.97	0.14	2.75	0.19	2.67	0.18	2.15	0.15	10.13	0.70

Based on protein content, the 50 varieties investigated are classified into three groups as high (>10.0%), medium (7–10%), and low (<7.0%) protein lines (Table 3). Only five varieties belong to the high protein category, and all of them had medium or low yield levels. On the other hand, high yielding varieties like SPV 138, SPV 669, SPV 678, SPV 221 and SPV 224 had very low protein content (5.1–7.4%) in their seeds. This resulted into significant negative correlation (r = – 0.30) between protein content and seed yield (Table 4). These results are in agreement with the reported negative correlations between grain yield and protein in rice [10] and other cereals [11]. According to Frey [11] the observed negative correlation is a phenotypic reality and not necessarily of genetic origin. This relationship between yield and protein percentage is influenced by the amount of nitrogen available and removed from the soil. Since N, after water, is frequently the most limiting environmental factor influencing the yield of crop plants, the negative relationship between yield and grain protein concentration is a reality in production systems. Nevertheless, this does not imply that higher grain protein can not be obtained at high yield levels [12].

Table 2. ANOVA (mean squares) for total protein and amino acid content in sorghum

Character	Replications (d.f. = 1)	Varieties (d.f. = 49)	Error (d.f. = 49)
Total protein	0.0300	4.974**	0.036
Lysine	0.0044	0.739**	0.045
Histidine	0.0100	0.622**	0.013
Arginine	0.0004	4.241**	0.004
Phenylalanine	0.0102	3.239**	0.008
Isoleucine	0.0081	7.398**	0.011

**P = 0.01.

Individual amounts of the five amino acids estimated also reveal a marked difference amongst the 50 varieties. Wide variation recorded in the levels of lysine (0.30–2.75%),

histidine (0.82–2.95%), arginine (1.70–7.61%), phenylalanine (1.88–6.14%) and isoleucine (4.43–11.85%) in seed proteins suggests the possibility of developing better nutritive types in sorghum. Inverse relationship was recorded between protein content and the levels of amino acids (as % of protein) (Table 3). Correlation analysis confirmed these negative relationships (r = – 0.29 to – 0.37) in all cases except between protein and lysine percent (r = – 0.14) (Table 4). Although, lysine content (as % protein) was generally low in the high protein lines and high in low protein lines, the inverse relationship between the two was not significant. This is a very useful and significant observation and is in contrast to the established notion of a significant inverse correlation between grain protein and lysine

Table 3. Group averages for protein and amino acid content in three protein groups of sorghum varieties

Character	Character means in different protein groups		
	high (>10.0%)	medium (7–10%)	low (<7.0%)
No. of varieties	5	24	21
Protein content (%)	10.89 (10.15–11.37)	7.94 (7.06–9.60)	6.09 (5.12–6.93)
Lysine (% of protein)	1.30 (0.30–2.46)	1.65 (0.75–2.40)	1.73 (0.94–2.75)
Lysine (% of flour)	0.14 (0.03–0.25)	0.13 (0.06–0.20)	0.11 (0.05–0.17)
Histidine (% of protein)	1.74 (1.11–2.50)	1.84 (0.90–2.91)	2.24 (0.82–2.95)
Histidine (% of flour)	0.19 (0.12–0.26)	0.15 (0.07–0.22)	0.14 (0.05–0.19)
Arginine (% of protein)	3.89 (2.05–5.69)	3.94 (1.70–5.23)	4.83 (2.64–7.61)
Arginine (% of flour)	0.42 (0.22–0.58)	0.31 (0.13–0.44)	0.29 (0.17–0.47)
Phenylalanine (% of protein)	3.22 (1.99–4.78)	3.47 (1.88–4.90)	4.38 (2.15–6.14)
Phenylalanine (% of flour)	0.35 (0.21–0.54)	0.28 (0.14–0.42)	0.27 (0.12–0.39)
Isoleucine (% of protein)	7.64 (4.77–11.85)	6.70 (4.43–9.86)	8.48 (6.56–10.15)
Isoleucine (% of flour)	1.18 (0.52–1.33)	0.53 (0.35–0.77)	0.51 (0.39–0.70)

*Figures in parentheses indicate range.

content of the protein. Our results support the optimism of Pickett [13] on the possibility of combining high protein and high lysine characters in sorghum. The amount of lysine and other amino acids in the whole grain (flour), on the other hand, were significantly and positively correlated with grain protein percent (Table 4). Thus, an increase in total grain protein will result in proportional increase in the levels (as % flour) of essential amino acids also.

Table 4. Correlation coefficients of protein content with the levels of amino acids (as % of protein and whole grain), plant height and grain yield of sorghum

Character	Correlation coefficient (r)	
	protein basis	whole grain (flour) basis
Lysine	- 0.14	0.36**
Histidine	- 0.37**	0.33*
Arginine	- 0.31*	0.32*
Phenylalanine	- 0.29*	0.38**
Isoleucine	- 0.30*	0.44**
Plant height	0.14	
Grain yield	- 0.30*	

*P = 0.05; **P = 0.01.

None of the varieties studied here have both high protein content and high yielding capacity. All the five varieties selected for high protein content (SU 393, SPV 772, SU 351, SU 405 and SPV 952) were low yielders. Under these circumstances, there is urgent need to evolve varieties for high protein and high yield separately and then try to combine these two attributes by attempting crosses between them. For this purpose, varieties SU 393 and SPV 952 (high protein lines) can be utilized in crosses with SPV 669 and SPV 678 (high yielders). Pedigree breeding procedure may be used in handling progenies from these crosses, as was followed in crosses of the induced, opaque mutant, P 721 with high yielding lines in sorghum [14]. It is not as simple as it sounds, but it is possible to breed for high grain protein concentration while at the same time maintaining acceptable grain yields. There were several examples of high yield potential of nutritionally superior cereals [12]. In wheat, two genetic sources of high grain protein—Atlas 66 and Nap Hal (both produce grain with higher protein percent but are inferior agronomically)—have been used widely in breeding programmes of spring and winter wheats. Their derivatives show a distinct advantage in grain protein percent. A hard winter wheat cv. Lancota having higher grain protein content (1-2%) without reduction in grain yield, was developed at the University of Nebraska and released for cultivation [15, 16]. Other high protein, high yielding lines having significant advantage over Lancota have been developed subsequently. In rice, high protein cultivars when crossed to the high yielding cv. IR 8 gave genotypes having protein concentration higher than IR 8, but the yield levels were only two thirds of the IR 8 yield potential. However, several lines with 2% higher protein and good yield potential have been identified at the International Rice Research Institute [10]. All these suggest that it is possible to obtain higher grain protein at high yield levels in sorghum also.

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