CHEMURGIC STUDIES ON SOME DIPLOID AND TETRAPLOID GRAIN AMARANTHS

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ABSTRACT

Analytical data on four important species of grain amaranths show that polyploidy, apart from increasing significantly the grain size and weight without much loss of fertility, has generally maintained the nutritive value found at the diploid level. Lysine content is enhanced in polyploid *A. edulis* and *A. caudatus* so also the threonine content in the former.

INTRODUCTION

GRAIN amaranths (*Amaranthus* species) are among the most ancient crops of the world (Agogino, 1957). Although considerably overshadowed by cereals, they are still cultivated in several countries of Asia, Africa and the Americas. In some places in the sub-Himalayan regions they are grown as a regular food crop substantially supplementary to wheat; but, by and large, grain amaranths are used as a subsidiary food throughout India.

Ordinarily the grain is very small, about 1,300 seeds weighing a gram. It has higher caloric value than the common cereals and is comparatively richer in the minerals particularly calcium and phosphorus. The carbohydrate, though somewhat lower, is easily digestible. The protein content of the grain is reported to vary from 4·4% to 16%. Such variation perhaps reflects varietal and specific differences within the genus. The protein efficiency of the grain is considered comparable to casein (Smith *et al.*, 1959; Singh, 1961). The genetic investigation has been undertaken to improve the yield potential, the size and the weight of the grain, and analysis has been carried out to evaluate the grain samples for interspecific differences if any, for protein, their component amino-acids, fat and sugar contents in the colchiploids which in some cases have registered a 250% increase in individual seed weight (Pal and Khoshoo, 1968). The analytical data are given in Table I.

TABLE I

Species	Ploidy	Protein % (N×6·25)	Fat % (Iodine value)	Reducing sugar %	No s
A. hypochondriacus	2x	13·2	5·13 (–)	1·66	
	4x	13·1	3·75 (109·2)	1·19	
A. edulis	2x	13·6	4·0 (110·0)	0·82	
	4x	12·4	3·0 (107·0)	0·74	
A. caudatus	2x	8·9	3·2 (107·0)	2·19	
	4x	14·9	3·5 (–)	3·35	
A. cruentus	2x	15·6	3·4 (–)	Traces	
A. hybridus	2x	13·4	3·0 (109·0)	Traces	

MATERIALS AND METHODS

Seed samples of domesticates like *A. hypochondriacus* Linn., *A* Spegazzini, *A. caudatus* Linn., *A. cruentus* Linn. and one related v *hybridus* Linn. were used in the present studies. Their taxonomica fication was confirmed at the Royal Botanic Gardens, Kew, Engla these are diploids and the polyploids of the first three species we by application of 0·25% aqueous solution of colchicine at seedlir (Pal and Khoshoo, 1968). The ensuing tetraploids have remained c cally stable for the last 5 years. All plants were cultivated und conditions.

Fat was extracted using *n*-hexane in a soxhlet apparatus anc values determined by Wij's method ($\frac{1}{2}$ hour). Sugar and carbc estimations were carried out with hot water extracts of the macerat samples using Benedict's method. The nitrogen determination in samples (0·2–0·3 gm each) was carried out by modified Kjeldahl (Humphires, 1956). For estimation of the amino-acids, the hydrol the seed samples (1·5–3 gm each) was carried out in sealed tube 6 N hydrochloric acid at 100° for 30 hours. After removing the e hydrochloric acid from the respective hydrolysates in vacuum over sodium hydroxide, the solutions were prepared in 10% aqueous isopropanol (Block *et al.*, 1955). Bi-dimensional paper chromatography for component amino-acids of the hydrolyzates was carried out using (i) *n*-butanol, acetic acid, water (4: 1: 1, v/v), and (ii) phenol water (4: 1, v/v). The quantitative estimation of respective amino-acids was made after the method of Fischer *et al.* (1948), and the calculated data (Bennet Clark *et al.*, 1953; Leopold, 1955) are presented in Table II.

RESULTS AND DISCUSSIONS

The four cultivated species are more or less comparable in various constituents, but *A. caudatus* is relatively lower in protein and fat content. As a whole, even in their present-day genetically unimproved state the grain species compare very favourably with the common cereals, and in essential amino-acids and caloric value they may even excel them (Smith *et al.*, 1959).

Polyploidy does not cause much variation in fat and reducing sugar contents, but in the species, *A. caudatus*, protein content in the polyploid increases by more than 60% that of the diploid. The overall increase in the food value of tetraploid *A. caudatus* is rather interesting and may indicate that this species has not undergone direct or even indirect selection for food value because it is essentially cultivated as an ornamental. The other two species, *A. hypochondriacus* and *A. edulis*, are, however, exclusively used for their grains. It may be emphasised that taxonomically *A. caudatus* (*sensu lato*) often includes both ornamental (*A. caudatus sensu stricto*) and grain types (*A. edulis*). As expected, the former is relatively poorer in food value than the latter. The two taxa are treated here as distinct species which is also confirmed by our genetic studies (unpublished). Thus higher values reported by other authors for *A. caudatus* (Earle *et al.*, 1962; Jones *et al.*, 1966) may be explained on the basis of taxonomic confusion.

A perusal of the amino-acid spectrum has shown a small increase or decrease in mean values of the five species at diploid and three at tetraploid levels. Leaving alone the unidentified spots which may be those of peptides resistant to the hydrolytic conditions resorted to, there is no general correlation between the variation of the amino-acid contents and the ploidy level. However, the lysine content is significantly enhanced in polyploid *A. edulis* and *A. caudatus*, so also the threonine content in the former.

The average starch content of the three species analysed was about 20%. The starch is mostly in the form of spherical granules, 1·6 to 1·8 μ in

TABLE II

Amino-acid composition (%) of seed meal proteins

Species	Ploidy	Glycine	Alanine	Aspartic acid	Glutamic acid	Serine	Threonine	Valine Methionine	Non-leucine Leucine Iso-leucine
A. hypochondriacus	2x	7·0	6·1	7·8	8·0	5·1	5·4	8·1	10·9
	4x	6·9	6·1	6·9	8·4	6·1	5·9	8·5	12·4
A. edulis	2x	7·9	7·3	8·9	8·1	5·2	6·4	8·8	9·1
	4x	8·1	6·6	8·0	8·0	5·3	7·2	8·5	10·0
A. caudatus	2c	7·1	6·5	7·1	8 0	5·5	5·0	9·0	11·2
	4x	6·7	6·8	9·3	9·2	5·7	5·3	7·9	8·5
A. cruentus	2x	7·6	6·3	8·2	10·2	5·6	6·4	7·6	9·5
A. hybridus	2x	8·1	6·5	7·9	8·4	6·8	6·4	8·2	9·7

Species	Ploidy	Arginine	Histidine	Lysine	Proline	Tyrosine	Phenyl alanine	Cystine	Unidentified spots
A. hypochondriacus	2x	6·3	3·5	4·5	4·5	2·6	6·0	2·2	1·6 9·5
	4x	4·7	3·1	4·0	4·8	3·2	5·8	2·2	2·6 8·5
A. edulis	2x	4·0	3·4	4·8	4·2	4·5	4·6	2·1	1·5 9·1
	4x	4·8	4·4	5·7	5·0	..	4·8	1·2	1·8 10·5
A. caudatus	2x	4·9	3·0	4·7	5·8	3·8	5·2	1·8	2·4 8·9
	4x	4·6	4·2	5·5	4·2	4·2	5·5	2·4	1·7 8·4
A. cruentus	2x	4·4	3·5	4·4	4·6	3·8	4·6	1·8	2·4 8·1
A. hybridus	2x	3·5	3·7	4·3	4·2	3·9	5·7	2·0	3·1 7·5

diameter. Its fairly good solubility and swelling property suggests strong, uniform and extensive forces holding the mass together, thereby manifesting considerable adhesive property. During this investigation, it has been observed that *A. hybridus* and *A. cruentus* seeds are poorer in starch content. These species do not, however, appear to have been accepted as food because of the disagreeable black colour of the grains. Evidently, during the transformation from wild to the cultivated condition, effected in historical time, there has been a decided preference for white or pale colour of the grains.

From a comparison of food value of the five diploid species, it is apparent that the long selectional history, extending over 6,500 years, has been primarily directed towards evolution of white or pale coloured grains than in improving its food value and/or the size.

Even though grain amaranths have not received attention of the modern plant breeders, they, in their present-day genetically unimproved state, are comparable in food value with that of the improved cereals. Polyploidy, apart from increasing significantly the grain size and weight without much loss of fertility (Pal and Khoshoo, 1968), has, in general, maintained the food value found at the diploid level.

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