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Genetic Variability and Interrelationships among Phenological, Quality and Yield Parameters in Yellow Grain Quality Protein Maize (QPM) (*Zea mays* L.)*

P Shanthi, G Suresh Babu, J Suresh, E Satyanarayana and R Sai Kumar
Department of Genetics and Plant Breeding, Sam Higginbottom Institute of Agriculture, Technology & Sciences, Deemed University, Naini, Allahabad - 211007

ABSTRACT

The data on a total of 26 different phenological, quality and yield attributes of yellow grain quality protein maize (*Zea* mays L.) were recorded on ten parents and their 45 direct single crosses developed through diallel mating along with two standard checks *viz.,* DHM-105 and Shaktiman-2 during *Kharif* 2003 and *Kharif* 2004 at two locations (Hyderabad and Allahabad). In this study, out of 26 characters studied, grain yield and its component characters *viz.,* total anthers dehescence period, total period of silk appearance, active pollination period, number of seeds per cob, cob weight, protein yield and oil yield had expressed high estimates of GCV and PCV and high heritability (more than 85 per cent) coupled with high genetic advance with highly positive and significant phenotypic and genotypic correlations with grain yield, indicates that the genetic variances for these traits are probably owing to their high additive gene effects and hence, it is inferred that, there is a better scope for improvement of these traits through direct selection.

Key words : Genotypic correlations, Heritability, Quality Protein Maize, Phenotypic correlations.

Maize (*Zea mays* L.) is an important crop of global importance holds a unique position in world agriculture as a food, feed and industrial raw material. In India also it is the third most important cereal crop after rice and wheat. It is a good source of carbohydrates, fats, proteins and some of the important vitamins, minerals and good quality oil. However, in spite of several important uses, maize has an inbuilt drawback of being deficient in two essential amino acids, lysine and tryptophan. This makes the normal maize as nutritionally poor with a biological value (BV) of 40 to 57% (Bressani, 1992). To overcome this problem, the maize breeders have developed quality protein maize (QPM) by incorporating á – zeins regulatory gene opaque – 2. This leads to increase lysine and tryptophan content about 60 to 100% in the endosperm with a higher BV (80% as compared with milk protein casein) (Mertz *et al*., 1964; Asche *et al*., 1985; National Research Council, 1988; Burgoon *et al*., 1992). QPM looks and taste like normal maize with same or higher yield potential, but it contains nearly twice the quality of essential amino acids, lysine and tryptophan, which makes it rich in quality proteins.

The QPM research was initiated long back during 1970's, but gained momentum during 1990's with continuous breeding efforts on development of high yielding hard endosperm modified opaque-2 maize germplasm by International Centre for Maize and Wheat Improvement (CIMMYT) (Vasal, 2001). In India, the germplasm accessions received from CIMMYT, Mexico were tested at different centres of All India Coordinated Research Project on Maize (AICRPM). Through acclimatization and repeated selection, hard endosperm modified opaque-2 maize inbred lines and their crosses have been identified for better protein quality and higher yield potential. The Directorate of Maize Research (DMR), New Delhi developed first QPM composite variety, Shakti-1 with 0.63% tryptophan in the year 1997, which was released and recommended for general cultivation by Indian farmers in 1998. The QPM research gained further momentum by launch of National Agricultural Technology Project (NATP) on QPM in 1998 by the Indian Council of Agricultural Research (ICAR). In this project, a multi – disciplinary teams of multi – institutes are involved and Agricultural Research Station, Amberpet, ANGRAU, Hyderabad was one of the centre, where in the QPM germplasm received from CIMMYT was acclimatized to suit the local agro-climatic conditions in India. Further, introgression of exotic germplasm in to locally adopted maize inbreds has been widely done at this centre, as a method to expand the genetic diversity in the available germplasm and to derive many improved and elite QPM inbred lines. These lines were evaluated further for their productivity and deployed in combination breeding which led to the development and identification of the best QPM inbred lines and their cross combinations. In this direction, the present investigation was carried out to estimate genetic variability parameters and to study the association of all the characters with that of grain yield by estimating phenotypic and genotypic correlation coefficients.

MATERIAL AND METHODS:

Germplasm and Environments: -

Ten elite QPM inbred lines with yellow grain developed from Agricultural Research Station, Amberpet, ANGRAU, Hyderabad were used in this study. Among these inbred lines five are dent grain type and another five are flint grain type. The ten lines were crossed in to 45 crosses in a diallel in 2002-03 post rainy season. The experimental material including 45 single cross hybrids, ten parents and two standard checks were planted in Agricultural Research Station, Amberpet, Hyderabad (tropical and low altitude area) and also in College Farm, AAI-DU, Naini, Allahabad (subtropical and low altitude area) in two seasons, 2003 and 2004 Rainy seasons (Four environments). The standard checks used were DHM 105 (normal maize hybrid) and Shaktiman – 2 (QPM hybrid) which were public bred and released for commercial cultivation in India.

The experimental design was a randomized complete block design with three replications for each environment. The plot was one 5.0 m row spaced 0.75 cm apart with 0.20 m between hills. The field was uniformly fertilized with recommended dose of 120 kg Nitrogen, 60kg P_2O_5 and 40kg K_2O per hectare in two locations and in two seasons. Nitrogen was applied in three split doses (1/3 basal + 1/3 at knee height stage + 1/3at tasseling stage) and other two in total quantity were applied in basal application. Standard cultural and agronomic practices generally used at all locations were applied. Data were recorded for all the entries in experiment on 26 parameters which includes agronomic, quality and yield parameters *viz.,* Germination percentage, Number of days has taken for germination, Seedling vigour index, Total vegetative growth period, Days to 50 per cent tasseling, Total anthers dehiscence period, Days to 50 per cent silking, Total period of silk appearance, Days to 50 per cent silk drying, Active pollination period, Total grain filling period, Total reproductive growth period, Ratio of vegetative growth period to reproductive growth period, Plant height at maturity (cm), Ear height at maturity (cm), Ear length (cm), Ear girth (cm), Number of seeds per cob, Cob weight (g), 100-Seed weight (g), Protein content (%), Protein yield (kg / ha), Oil content (%), Oil yield (kg / ha), Tryptophan content (g / 16 g N), Grain yield per plot (kg). Five competitive plants were selected at random in each plot excluding boarder plants for recording data except for days to 50% tasseling and silking, vegetative growth period, reproductive growth period and grain yield which were recorded on whole plot basis. The coefficients of variation (phenotypic and genotypic coefficients of variation) were worked out using the formulae given by Burton (1952). The heritability (h^2) in broad sense and the expectations of genetic advance (GA) as percent of mean for different traits under selection were estimated according to Johnson *et al.* (1955). Simple correlation coefficients (phenotypic and genotypic) for grain yield and its components of the hybrids and parents were calculated by using the method given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

In the present investigation, analysis of variance revealed significant differences among the genotypes for all the traits studied at two locations and two seasons indicating the existence of sufficient variation in the material studied (Table 1). The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) in broad sense and genetic advance as per cent of mean were estimated for all the 26 characters studied and are presented in Table 2 and Table 3 respectively whereas the

Table 1. Analysis of variance for grain yield per plant and campats in yield [pooled for two locations (Hyderabad & Allahabad) and two seasons (*kharif* 2003 & *kharif* 2004)] in QPM genotypes.

S.No.	Character	Treatment Sum of Squares	CV	Mean
1.	Germination (%)	1.064**	0.45	98.26
2.	No. of days taken for germination	4.834**	3.94	6.89
3.	Seedling vigour index	246245.870**	0.38	5531.92
4.	Total vegetative growth period	21.632**	2.69	48.57
5.	Days to 50% tasseling	30.234**	2.32	55.45
6.	Total anthers dehescence period	6.0301**	8.69	4.82
7.	Days to 50% silking	30.305**	2.98	57.23
8.	Total period of silk appearance	4.697**	6.12	4.22
9.	Days to 50% silk drying	15.240**	2.41	62.81
10.	Active pollination period	3.877**	4.58	4.07
11.	Total grain filling period	129.272**	3.41	37.70
12.	Total reproductive growth period	0.448**	3.48	42.47
13.	Ratio of veg. and rep. growth period	3.938**	4.34	1.20
14.	Plant height at maturity (cm)	0.377**	3.94	137.30
15.	Ear height at maturity (cm)	2.690**	3.50	70.52
16.	Ear length (cm)	2.322**	5.40	17.24
17.	Ear girth (cm)	8.687**	5.88	14.96
18.	No. of seeds per cob	2.979**	6.83	439.94
19.	Cob weight (g)	6.118**	10.48	129.59
20.	100-seed weight (g)	2.405**	6.31	27.82
21.	Protein content (%)	1.747**	4.44	11.10
22.	Protein yield (Kg / ha)	263026.468**	4.55	870.05
23.	Oil content (%)	1.062**	4.54	7.17
24.	Oil yield (Kg / ha)	115399.234**	4.65	561.48
25.	Tryptophan content (g / 16g N)	0.0225**	3.39	0.76
26.	Grain yield per plot (Kg)	3.0367**	1.39	2.96

** Significant at P = 0.01 level

estimates of phenotypic and genotypic correlation coefficients were represented in Table 4.

Genotypic and Phenotypic co-efficient of variation

The overall range of GCV was found between 0.39 (for germination per centage) and 37.64 (for cob weight) while the over all range of PCV was from 0.83 (for germination per centage) to 38.88 (for cob weight). The highest estimates of GCV and PCV were observed for cob weight (37.64 and 38.88) followed by oil yield, grain yield, protein yield, total anthers dehescence period, total period of silk appearance, active pollination period, number of seeds per cob indicating that the genetic variances for these traits are probably owing to their high additive gene effects (Johnson *et al.* 1955).

Heritability (h^2) in broad sense (%) and Genetic advance as percent over mean (%)

The heritability estimates ranged from 27.88 per cent (for germination per centage) to 98.54 per cent (for seedling vigour index). The estimates of genetic advance as per cent over mean were found to vary from 0.44 (for germination per centage) to 75.07 (for cob weight).

In the present study heritability and genetic advance was low for the character germination

Table 2. Estimates of genotypic (GCV) and phenotypic (PCV) coefficient of variance for all the characters expressed at two locations and in two seasons studied.

S.No.	Character	Genotypic coefficient of variance (GCV)					Phenotypic coefficient of variance (PCV)				
		Kharif 2003		*Kharif* 2004		Mean	*Kharif* 2003		*Kharif* 2004		Mean
		Hyd	Alld	Hyd	Alld		Hyd	Alld	Hyd	Alld	
1	Germination (%)	0.254	0.413	0.543	0.349	0.390	0.983	0.771	0.704	0.856	0.829
2	No. of days taken for germination	1.147	17.662	18.673	16.706	13.547	15.332	17.802	19.084	16.848	17.267
3	Seedling vigour index	11.633	11.638	11.647	11.532	11.613	11.636	11.641	11.653	11.873	11.701
4	Total vegetative growth period	5.632	4.721	5.345	4.791	5.122	6.268	5.605	5.984	5.461	5.830
5	Days to 50% tasseling	5.799	5.448	5.615	5.397	5.565	6.273	6.072	6.076	5.883	6.076
6	Total anthers dehiscence period	30.672	28.251	29.495	27.437	28.964	31.724	29.288	30.747	28.559	30.080
7	Days to 50% silking	5.418	5.241	5.312	5.219	5.298	6.423	5.980	6.090	5.937	6.108
8	Total period of silk appearance	31.165	28.582	29.914	27.916	29.394	31.810	29.212	30.534	28.503	30.015
9	Days to 50% silk drying	3.320	3.103	3.342	3.105	3.218	4.021	4.035	4.117	4.046	4.055
10	Active pollination period	28.653	27.141	28.513	26.513	27.705	29.560	27.492	28.878	26.834	28.191
11	Total grain filling period	18.143	16.905	17.652	16.634	17.334	18.479	17.268	17.979	17.155	17.720
12	Total reproductive growth period	19.227	18.407	18.750	18.213	18.649	19.555	18.772	19.070	18.514	18.978
13	Ratio of veg. and rep. growth period	24.715	22.959	23.813	22.870	23.589	25.504	23.628	24.205	23.172	24.127
14	Plant height at maturity	20.326	19.628	19.999	19.445	19.850	20.802	19.951	20.383	19.706	20.211
15	Ear height at maturity	20.771	19.451	20.012	19.561	19.949	21.022	19.761	20.316	20.093	20.298
16	Ear length	17.973	16.048	17.430	15.569	16.755	18.814	16.944	18.246	16.413	17.604
17	Ear girth	15.394	13.605	13.981	13.527	14.127	16.287	14.704	15.167	14.598	15.189
18	No. of seeds per cob	28.183	27.512	27.589	27.368	27.663	29.408	28.195	28.421	28.047	28.518
19	Cob weight	38.537	37.509	37.407	37.107	37.640	39.880	38.649	38.846	38.146	38.880
20	100 - seed weight	15.961	15.965	15.910	15.841	15.919	17.053	17.160	17.114	16.946	17.068
21	Protein content	6.489	6.264	6.354	6.426	6.383	7.487	8.135	7.751	7.909	7.821
22	Protein yield	34.411	33.406	34.094	33.235	33.787	34.730	33.839	34.396	33.588	34.138
23	Oil content	7.867	7.701	7.847	7.661	7.769	8.616	9.617	9.063	9.835	9.283
24	Oil yield	35.169	34.627	35.010	34.423	34.807	35.447	35.137	35.317	35.028	35.232
25	Tryptophan content	10.900	11.244	11.119	8.825	10.522	11.207	12.261	11.624	14.887	12.495
26	Grain yield per plot	34.582	33.908	34.335	33.678	34.126	34.706	33.932	34.364	33.698	34.175

Table 3. Estimates of heritability (h^2) and genetic advance as per cent of mean for all the characters expressed at two locations and in two seasons studied.

S.No.	Character	Heritability (h^2)					Genetic advance as % of mean				
		Kharif 2003		*Kharif* 2004		Mean	*Kharif* 2003		*Kharif* 2004		Mean
		Hyd	Alld	Hyd	Alld		Hyd	Alld	Hyd	Alld	
1	Germination (%)	6.67	28.80	59.40	16.65	27.88	0.135	0.457	0.862	0.294	0.437
2	No. of days taken for germination	85.14	98.43	95.74	98.32	94.41	26.892	36.097	37.638	34.123	33.688
3	Seedling vigour index	99.95	99.95	99.90	94.34	98.54	23.957	23.970	23.980	23.074	23.745
4	Total vegetative growth period	80.74	70.93	79.79	76.94	77.10	10.425	8.190	9.837	8.656	9.277
5	Days to 50% tasseling	85.45	80.52	85.40	84.17	83.89	11.042	10.071	10.690	10.200	10.501
6	Total anthers dehiscence period	93.48	93.04	92.02	92.30	92.71	61.089	56.136	58.284	54.299	57.452
7	Days to 50% silking	71.16	76.80	76.08	77.27	75.33	9.416	9.461	9.544	9.450	9.468
8	Total period of silk appearance	95.99	95.73	95.99	95.92	95.91	62.898	57.610	60.374	56.323	59.301
9	Days to 50% silk drying	68.18	59.12	65.88	58.88	63.02	5.648	4.915	5.587	4.908	5.265
10	Active pollination period	93.96	97.46	97.49	97.62	96.63	57.214	55.197	57.993	53.963	56.092
11	Total grain filling period	96.40	95.84	96.40	94.02	95.67	36.695	34.093	35.702	33.227	34.929
12	Total reproductive growth period	96.68	96.15	96.67	96.78	96.57	38.945	37.181	37.978	36.909	37.753
13	Ratio of veg. and rep. growth period	93.91	94.42	96.79	97.41	95.63	49.338	45.957	48.261	46.496	47.513
14	Plant height at maturity	95.47	96.79	96.27	97.37	96.48	40.913	39.779	40.422	39.527	40.160
15	Ear height at maturity	97.63	96.88	97.04	94.77	96.58	42.279	39.438	40.610	39.229	40.389
16	Ear length	91.26	89.71	91.26	89.97	90.55	35.370	31.312	34.300	30.421	32.851
17	Ear girth	88.18	85.61	84.97	85.86	86.16	29.584	25.932	26.549	25.819	26.971
18	No. of seeds per cob	91.84	95.21	94.23	95.22	94.13	55.640	55.297	55.171	55.014	55.281
19	Cob weight	93.38	94.19	92.73	94.63	93.73	76.714	74.990	74.203	74.358	75.066
20	100 - seed weight	87.60	86.56	86.43	87.38	86.99	30.772	30.597	30.470	30.503	30.586
21	Protein content	75.12	59.30	67.21	66.01	66.91	11.585	9.937	10.732	10.755	10.752
22	Protein yield	98.17	97.46	98.25	97.91	97.95	70.235	67.935	69.618	67.743	68.883
23	Oil content	83.37	64.12	74.96	60.68	70.78	14.798	12.703	13.995	12.294	13.448
24	Oil yield	98.44	97.12	98.27	96.63	97.62	71.879	70.294	71.493	69.727	70.848
25	Tryptophan content	94.60	84.10	91.50	95.14	91.34	21.840	21.241	21.910	10.777	18.942
26	Grain yield per plot	99.29	99.86	99.84	99.88	99.72	70.986	69.802	70.673	69.333	70.199

Table 4. Phenotypic and genotypic correlations for 26 characters studied at Hyderabad and Allahabad during *Kharif 2003 and Kharif 2004*.

S.No.	Character		Correlation coefficients of characters on Grain yield per plot				Mean
			Kharif 2003		*Kharif* 2004		
			Hyderabad	Allahabad	Hyderabad	Allahabad	
1	Germination (%)	P	-0.0067	-0.0187	-0.1109	-0.0596	-0.0490
		G	0.0306	-0.0429	-0.1420	-0.1496	-0.0760
2	No. of days taken for germination	P	-0.4892**	-0.4748**	-0.4480**	-0.4518**	-0.4660**
		G	-0.5289**	-0.4784**	-0.4582**	-0.4559**	-0.4804**
3	Seedling vigour index	P	0.2414	0.2057	0.2153	0.1839	0.2116
		G	0.2422	0.2059	0.2157	0.1907	0.2136
4	Total vegetative growth period	P	-0.0912	-0.0277	-0.0310	-0.0560	-0.0515
		G	-0.0998	-0.0320	-0.0358	-0.0595	-0.0568
5	Days to 50% tasseling	P	-0.2358	-0.1940	-0.1994	-0.2026	-0.2080
		G	-0.2548	-0.2156	-0.2169	-0.2190	-0.2266
6	Total anthers dehiscence period	P	0.8815**	0.8834**	0.8759**	0.8802**	0.8803**
		G	0.9182**	0.9165**	0.9135**	0.9179**	0.9165**
7	Days to 50% silking	P	-0.2113	-0.1850	-0.1909	-0.1910	-0.1946
		G	-0.2493	-0.2124	-0.2227	-0.2158	-0.2251
8	Total period of silk appearance	P	0.9199**	0.9258**	0.9268**	0.9274**	0.9250**
		G	0.9460**	0.9469**	0.9479**	0.9472**	0.9470**
9	Days to 50% silk drying	P	-0.3032*	-0.2495	-0.3031*	-0.2642	-0.2800*
		G	-0.3679**	-0.3249*	-0.3700**	-0.3443*	-0.3518*
10	Active pollination period	P	0.9321**	0.9601**	0.9602**	0.9603**	0.9532**
		G	0.9673**	0.9730**	0.9735**	0.9726**	0.9716**
11	Total grain filling period	P	0.8939**	0.8728**	0.8819**	0.8655**	0.8785**
		G	0.9132**	0.8924**	0.8992**	0.8941**	0.8997**
12	Total reproductive growth period	P	0.9218**	0.9090**	0.9137**	0.9103**	0.9137**
		G	0.9411**	0.9274**	0.9300**	0.9269**	0.9314**
13	Ratio of veg. and rep. growth period	P	-0.8234**	-0.8016**	-0.8103**	-0.8117**	-0.8118**
		G	-0.8531**	-0.8261**	-0.8247**	-0.8228**	-0.8317**
14	Plant height at maturity	P	0.7330**	0.7237**	0.7278**	0.7195**	0.7260**
		G	0.7548**	0.7360**	0.7421**	0.7286**	0.7404**
15	Ear height at maturity	P	0.7072**	0.6953**	0.6973**	0.6874**	0.6968**
		G	0.7196**	0.7068**	0.7096**	0.7052**	0.7103**
16	Ear length	P	0.8006**	0.7794**	0.7857**	0.7759**	0.7854**
		G	0.8370**	0.8241**	0.8226**	0.8195**	0.8258**
17	Ear girth	P	0.8530**	0.8336**	0.8310**	0.8290**	0.8367**
		G	0.9068**	0.9016**	0.9033**	0.8936**	0.9013**
18	No. of seeds per cob	P	0.7692**	0.7604**	0.7571**	0.7574**	0.7610**
		G	0.8047**	0.7792**	0.7796**	0.7762**	0.7849**
19	Cob weight	P	0.9063**	0.9020**	0.8996**	0.9023**	0.9026**
		G	0.9376**	0.9290**	0.9329**	0.9281**	0.9319**
20	100 - seed weight	P	0.6446**	0.6809**	0.6679**	0.6840**	0.6694**
		G	0.6922**	0.7312**	0.7192**	0.7324**	0.7188**
21	Protein content	P	-0.1874	-0.2146	-0.1860	-0.2145	-0.2006
		G	-0.2071	-0.2737*	-0.2270	-0.2670*	-0.2437*
22	Protein yield	P	0.9785**	0.9728**	0.9777**	0.9743**	0.9758**
		G	0.9865**	0.9866**	0.9859**	0.9852**	0.9861**
23	Oil content	P	-0.1966	-0.1764	-0.1843	-0.1682	-0.1814
		G	-0.2102	-0.2166	-0.2137	-0.2153	-0.2140
24	Oil yield	P	0.9697**	0.9610**	0.9675**	0.9592**	0.9644**
		G	0.9761**	0.9766**	0.9752**	0.9765**	0.9761**
25	Tryptophan content	P	-0.4105**	-0.3921**	-0.4034**	-0.2639	-0.3675**
		G	-0.4253**	-0.4271**	-0.4227**	-0.4456**	-0.4302**
26	Grain yield per plot	P	1.0000	1.0000	1.0000	1.0000	1.0000
		G	1.0000	1.0000	1.0000	1.0000	1.0000

percentage while moderate heritability and low genetic advance was exhibited by total vegetative growth period, days to 50 per cent tasseling, days to 50 per cent silking, days to 50 per cent silk drying, protein content and oil content indicating the predominant role of non additive gene action and environment plays major role in governing these characters, improvement of these characters is complicated and it might be possible through heterosis breeding.

High heritability (more than 85 per cent) along with moderate genetic advance as per cent of mean for the characters *viz.,* number of days taken for germination, seedling vigour index, total grain filling period, total reproductive growth period, ratio of vegetative growth period to reproductive growth period, plant height, ear height, ear length, ear girth, 100-seed weight and tryptophan content, suggests that the careful and restricted selection will be effective for the improvement of these characters.

Grain yield and its component characters *viz.,* total anthers dehescence period, total period of silk appearance, active pollination period, number of seeds per cob, cob weight, protein yield and oil yield had expressed high heritability (more than 85 per cent) coupled with high genetic advance. This situation indicates that the genetic variances for these traits are probably owing to their high additive gene effects (Johnson *et al.* 1955) and thus there is better scope for improvement of these traits through direct selection. These findings are in consonance with the reports of earlier workers; Jha *et al.* (1997); Krishnam Raju (2001); Satyanarayana *et al.* (2003); Suresh (2004).

Correlation coefficients

In the present investigation, phenotypic and genotypic correlations were studied. Grain yield is complex character, was significantly and positively associated with total anthers dehescence period, total period of silk appearance, active pollination period, total grain filling period, total reproductive growth period, plant height, ear height, ear length, ear girth, number of seeds per cob, cob weight, 100-seed weight, protein yield and oil yield at two locations and in two seasons both at phenotypic and genotypic levels.

The maturity parameter days to 50 per cent tasseling showed significant and negative correlation with yield and its contributing characters at two locations and in two seasons.

The quality parameters protein content, oil content and tryptophan content showed negative association with grain yield at two locations and in two seasons. These results were in conformity with findings of Lakshmi *et al.* (2001); Krishnam Raju (2001); Satyanarayana *et al.* (2003) and Suresh (2004).

In conclusion, it could be inferred that, while breeding for the improvement both in terms of quantity and quality (high grain yield, protein and oil yield and tryptophan content) in QPM genotypes studied, selection of high yielding hybrids coupled with moderate protein, oil and tryptophan content would be more desirable.

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