PRELIMINARY STUDIES ON PHYSICAL AND NUTRITIONAL QUALITIES OF SOME INDIGENOUS AND IMPORTANT RICE CULTIVARS OF NORTH-EASTERN HILL REGION OF INDIA

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ABSTRACT

The northeastern hills of India are endowed with rich source of rice germplasm, which may be safely estimated about 9,000 accessions, excluding the redundancies. Even though much of the germplasm have been collected, studies on nutritional aspects of these local cultivars are still lacking. Fifteen important indigenous rice genotypes collected from different rice growing ecosystem of this region were studied for physical and nutritional qualities. Kernel color of the genotypes varied from white to dark purple. All the genotypes except Manipuri were of bold-grain type. Most of the genotypes studied have fat contents more than 2.0%. The protein content was found higher in Chahou angouba and Naga special. Five cultivars were identified as high-protein cultivars of rice, with 10–12.07% protein content. Amylose content varied from 2.27 to 24.5%. Most of long-grained genotypes recorded lesser amylose than short grained. Chahou varieties were found aromatic and glutinous, which demand higher market prices in local market.

PRACTICAL APPLICATION

The north-eastern hills of India are endowed with rich source of rice germplasm, and much of the germplasm have been collected, but studies on basic and advanced nutritional aspects of these local cultivars are still lacking. This part of India has valuable rice genotypes of strong aroma, glutinous characters and slender grains with high amount of protein, fat and fiber.

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Having not known to the rest of the world and even to indigenous end users, some of such cultivars have already been lost, and some more are at the verge of extinction. Quality evaluation done in the present study provided useful information on their commercial exploitation and utilization in breeding programs of nutritional enhancement of rice to fight malnutrition among rice-consuming population, which is largest in the world.

INTRODUCTION

The northeastern region of India, comprising the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, lies in between 21°57′ to 29°28′ N latitude and 89°40′ to 97°25′ E longitude, covering an area of 2.55×10^5 km^2, and is inhabited by 67 major ethnic group of people (Fig. 1). The region being a secondary center of origin

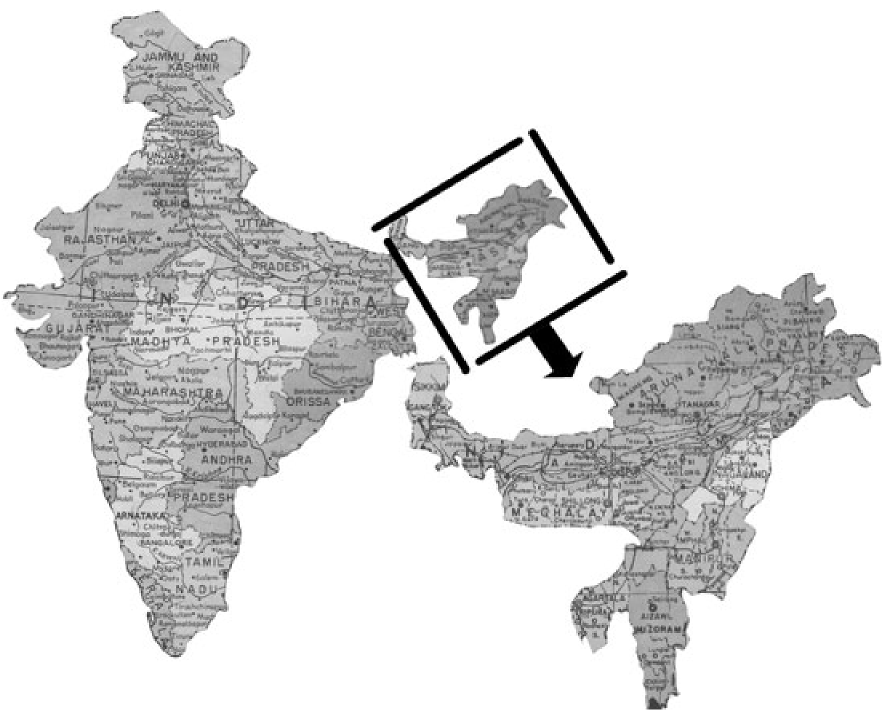

FIG. 1. MAP OF INDIA SHOWING THE EXPANDED VIEW OF THE NORTH-EASTERN HILL STATES ON THE RIGHT SIDE

for rice is endowed with about 9,000 indigenous rice cultivars. Rice, the principal food crop of the region, is grown in 72% of the total cultivable area in three major ecosystems, viz., upland, including *Jhum* lands (shifting cultivation plots), lowlands and deep-water conditions. The region is rich in variability of rice germplasm with distinguishable qualities, such as scentedness, glutinous or waxiness, ability to grow in deep-water conditions, etc.

Scented or aromatic rice occupies a special place in the international market due to its pleasant and fragrant smell (Tava and Bocchi 1999). This type of rice is highly valued in Asia and is becoming popular in Europe (Berner and Hoff 1986) and the U.S.A. (Brooks 1989). Basmati rice of India and Pakistan and jasmine rice of Thailand are major aromatic varieties of rice in the international market (Reinke *et al.* 1991). The Chahou cultivars, including Chahou amubi, which have deep, purple-colored kernel, are example of such kind of which were lying unknown to the international consumers and those in mainland India due to the difficult geographical location of this part of the country.

Being a staple food of the majority of people in the world, indigenous cultivars and improved varieties of rice had been subjected to quality analyses. Rice grains contain starch as the principal component and protein as the second highest component (Ahamed *et al.* 1998). Milled rice has been shown to contain about 78% carbohydrate (Gopalan *et al.* 1989). Many reports on variability in protein content in rice are available. A range of 6.7 to 11.0% protein in brown rice was observed in 74 varieties from the Indian mainland (Guha and Mitra 1963). Some varieties from the Gujarat state of India were reported to have 6.5 to 12.5% protein (Patel and Rajani 1967). Waxy type of rice had more amount of protein than nonwaxy types (Sampath *et al.* 1968). They hypothesized that waxy endosperm is more favorable to the accumulation of protein than the nonwaxy endosperm. Govindaswami *et al.* (1969) reported 6 to 12.6% protein content in 300 improved rice varieties of India (Govindaswami *et al.* 1969). Even a range of 6.56 to 12.86% protein content was reported in 40 rice varieties grown in Kashmir (Baba 1971). In another study on protein content of indigenous and exotic varieties, a range of 5.5 to 14% was obtained (Govindaswami and Ghosh 1973). A culture from the Institute of Radiation Breeding, Japan, had shown to contain 16.3% protein (Mahadevappa and Shankare Gowda 1973). Protein content and other constituents such as amylose, starch, crude fibre, ash and total fat can be present in different amounts in different rice varieties (Coffman and Juliano 1987; Juliano 1993). Available reports indicate that amylose content in rice varied from 0 to about 37% (Govindaswami 1985; Nakagahara *et al.* 1986). Higher amylose contents (about 20 to 30%) are associated with many South Asian varieties. Lower amylose levels (10 to 20%) are more common in East Asia, where a more cohesive cooked grain is often preferred (Olsen and Purugganan

2002). Glutinous or waxy rice has no or very little amylose. Unlike other parts of India, the people in north-eastern hill region of India prefer glutinous varieties of rice. The fat content of milled rice has been reported to have about 0.2 to 2.0% (Zhuo *et al.* 2002). The japonica types (low amylose) of rice showed higher fat contents, up to 3.58% (Tahira and Chang 1986). Low-protein milled rice was shown to have 0.36% and a high-protein rice to have 0.55% crude ash (Resurrection *et al.* 1979). Crude fiber content ranged from 0.6 to 1.1% in milled rice of low- and high-protein types (Resurrection *et al.* 1979). Selecting high-protein and low amylose types of rice is important for future rice improvement programs because of prevalence of protein calorie malnutrition and preference of glutinous rice by the people of this part of the world.

The combined forces of natural and human selection, diverse climates, seasons and soil, and varied cultural practices led to the tremendous diversity. Introduction of high-yielding varieties and natural calamities, such as landslides, earthquake, floods, which are regular phenomenon in this part of India, has led to genetic erosion. Large numbers among the genotypes are at the verge of extinction, including high-valued aromatic rice cultivars (Singh and Devi 2004), and hence conservation of valuable genetic resources is in the hour of need. Even though efforts were made to collect, characterize and evaluate these germplasm for morphological and agronomical traits, little has been done to study the quality parameters of the collected rice germplasm. A total of 2,639 accessions of rice germplasm have been collected during 1985 to 2002 and maintained in national gene bank of National Bureau of Plant Genetic Resources, New Delhi (Hore 2005). Quality evaluation, especially on nutritional aspects of these germplasm, is very meager except for a few grown in Assam. These will provide useful information on their commercial potential and utilization in further rice quality improvement programs. Due to lack of such efforts, we may lose many valuable genetic resources. Moreover, towards attaining the evergreen revolution, quality enhancement of rice is thrust area of research. Hence, the present study aims at analyzing the basic nutritional quality and grain characteristics of some indigenous and important rice cultivars of this region.

MATERIALS AND METHODS

Materials

Materials taken for the present study include 15 rice cultivars, viz., Ngoba (A), Nagaland wonder rice (B), Take (C), Makrule (D), Dehudega (E), Makrutane (F), Melourei (G), Nagaspecial (H) collected from Nagaland;

Chahou angouba (I), Chahou amubi (J), Chahou poireton (K), Chahou angangbi (L), Toathabi (M) from Manipur and Manipuri (N) from Meghalaya and Bali (O) from Arunachal Pradesh representing the different ecosystem of rice cultivation. Cultivars A, C, D, E, F, G and H are favorites of the people of Nagaland. The cultivar A is blast (important disease caused by fungus *Pyricularia oryzae* affecting the leaf, neck and panicle of the rice plant leading to 40 to 100% yield lost) tolerant and can be used as source of dwarfism. The cultivar B, which was a tall plant type (255 cm) with semi-woody texture, 175 tillers and 510 grains per panicle, was discovered by Pasteur Mr. Melhite Kenye (Anonymous 2001). This plant is included in the Guinness Book of World Record (Anonymous 1998) as tallest paddy species in the world. The cultivars I, J, K and L are highly aromatic and glutinous. Cultivars J and K are colorful with deep purple color even after cooking. These cultivars are also used for medicinal purpose and rituals in Manipur. Cultivar K is usually given to expecting mothers at the last stage of pregnancy. Lactating mothers used to take cultivar J to increase lactation. The cultivar M is a deep-water nonglutinous rice. While the cultivar N is very popular in Meghalaya, the cultivar O is common and indigenous to Arunachal Pradesh.

Physical Properties

The rice seed sample of 15 cultivar grown during the rainy season of 2002 at Indian Council of Agricultural Research (ICAR) research complex for Northeast Hill (NEH) region, Barapani, Meghalaya, India were taken for the study. The samples were 3 months old at the time of analysis. Samples were cleaned and dried to reach a moisture content of 13–14%. They were dehusked in a Satake rubber roll laboratory sheller (Staki, Hiroshima, Japan). Kernel length, kernel breadth and thickness were recorded using a dial thickness gauge (Mitudaya, Japan) and classified according (Table 1) to Ramaih Committee, 1969, instituted by Government of India with FAO recommendations (Govindaswami 1985). The grain color was studied by visual perception. The

TABLE 1.
SYSTEMATIC CLASSIFICATION OF RICE GRAIN (RAMAIAH COMMITTEE 1969)

Sl. No.	Grain length	Grain L/B ratio	Grain type
1	6.00 mm and above	3.00 and above	Long slender (LS)
2	Less than 6.00 mm	3.00 and above	Short slender (SS)
3	Less than 6.00 mm	2.50 to 3.00	Medium slender (MS)
4	6.00 mm and above	Less than 3.00	Long bold (LB)
5	Less than 6.00 mm	Less than 3.00	Short bold (SB)

L/B, length and breadth; S1. No., serial number.

presence and intensity of aroma was determined by the method of Sood and Siddiq (1978), with slight modifications. Five grams of finely ground samples were kept in Petri dish to which 20 mL of 1.7% potassium hydroxide was added, covered and shaken well for uniform distribution. The whole content was incubated for 10 min at room temperature. After the stipulated time, each Petri dish was opened and smelled immediately by the panel of experts. If the aroma is present, its intensity was graded into light, medium and strong. The waxiness (glutinous) character was determined by the method of Olsen and Purugganan (2002) using half-broken rice kernels. The broken halves of kernels were put in 1% iodine solution in a Petri dish and incubated for 30 s at room temperature. The kernels were destained with water and observed under a dissecting microscope. If the broken kernel turned blue, then it is classified as nonwaxy, and if red, then the kernel is classified as waxy.

Proximal Composition and Amylose Content

The rice kernels were polished to 5% with a Satake rice polisher and ground into fine powder. The powered samples were sieved through 100-mesh sieve for analyzing proximal composition and amylose content. Total crude protein content was determined by micro-Kjeldahl method using Elite EX, Kelpuls automatic nitrogen analyzer of Pelican Equipments, Chennai, India. Hundred milligram sample was mixed with catalyst mixture (copper sulfate : potassium sulfate : Selelium :: 10:50:1) and digested with 10 mL concentrated sulfuric acid. The digest was distilled and ammonia released was captured in 4% boric acid solution. Then it was titrated with 0.1 N HCl. The resulting N content was multiplied by a factor (5.95) to convert into total crude protein content. Official method of analysis of the Association of Official Analytical Chemists (AOAC 1980) was used to study the total fat, ash and crude fiber, taking 5 g each. The total carbohydrate was estimated by the anthrone method of Sadashivam and Manickam (1996). Fifty milligram of finely powdered sample was digested with 1 N HCL overnight at 25C and neutralized with solid sodium carbonate. Then the resulting neutral extract was diluted in 100 mL of distilled water and filtered through Whatman No. 1 filter paper. The filtrate was reacted with anthrone reagent for 8 min in boiling water bath and absorbance was recorded with Systronics 119 spectrophotometer at 630 nm, taking D-glucose as standard. The amylose content (AMC) was determined by the method of B.O. Juliano (1971).

Statistical Analyses

Three hundred seeds each of the rice cultivars collected from farmers' field were raised in three replications during the rainy season of 2002 at the lowland rice farm of ICAR Research Complex for NEH Region, Umiam, Meghalaya, India, located in 25°30′ N latitude and 91°15′ E longitude. Off-types and other variety plants in the particular cultivar were removed in order to purify them. Five sets each, comprising of five uniform-looking plants, from each replication for each cultivar were harvested to get the sample for analysis. The mean values arrived at for each replication were subjected to analysis of variance following randomized block design (RBD). The genetic parameters, viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) as per Burton (1952), heritability in broad sense (h^2) and genetic advance as percentage of mean (GA) as suggested by Johnson *et al.* (1955a), were estimated. Correlation coefficients among the proximate components were estimated as per Johnson *et al.* (1955b). All the above analyses were carried out using computer software program from INDOSTAT Services, Hyderabad, India.

RESULTS AND DISCUSSION

Physical Parameters

Physical parameters of the rice cultivars studied are presented in Table 2 and depicted in Fig. 2. The grain color of the cultivars varied from white to dark purple. White was found to be the dominant kernel color (A, B, C, E, G, H, I and O) among the cultivars studied, followed by red (F, L, M and N) and dark purple (J). The genotype K has kernel with half-red and half-dark purple color, which has not been documented any where in the world. This distinct cultivar having unusual kernel color also recorded 6.98 ± 0.09 mm of kernel length, being the longest in the group. The shortest grains were of O, with 5.20 ± 0.25 mm. With respect to grain breadth, E was the broadest and H was the slenderest. There were 10 long bold, three medium bold, one short bold and one long slender grain types. The scent or natural fragrance in the kernel is a much valued quality factor. Because of this, in trade and commerce, the scented varieties are given premium price irrespective of the variation in the size of the kernels. Among the cultivars studied there were four glutinous and four aromatic rice varieties. Such types of grains having glutinous characters with high intensity of aroma are very rare in world market. Other elite aromatic cultivars such as Basmati are mostly nonglutinous. This special property makes these four cultivars a choice of the people of this region for making special preparations like *Kheer* (a rice dessert), *chempak* (rice flakes) and others. These cultivars could also be used for preparation of other food items like candy, baked and snack foods.

Proximal Composition and Amylose Content

From the analysis of variance, it is inferred that there is significant level of variation among the cultivars for all the proximal traits. The quantity of

TABLE 2.
PHYSICAL AND SPECIAL PROPERTIES OF IMPORTANT RICE CULTIVARS

Cultivar (designation)	Grain color	Grain length (mm)	Grain breadth (mm)	Length/breadth ratio	Grain type	Waxiness	Aroma
Ngoba (A)	White	6.46 ± 0.18	2.25 ± 0.18	2.87	LB	Nonwaxy	Absent
Nagaland wonder rice (B)	White	5.88 ± 0.25	2.93 ± 0.09	2.01	MS	Nonwaxy	Absent
Take (C)	White	5.32 ± 0.22	2.88 ± 0.09	1.85	MS	Nonwaxy	Absent
Makrule (D)	Red	6.75 ± 0.08	3.5 ± 0.17	1.93	LB	Nonwaxy	Absent
Dehudega(E)	White	6.20 ± 0.40	3.95 ± 0.16	1.57	LB	Nonwaxy	Absent
Makrutane (F)	Red	5.6 ± 0.31	3.7 ± 0.11	1.51	SB	Nonwaxy	Absent
Melourei (G)	White	5.8 ± 0.11	3.25 ± 0.08	1.78	LB	Nonwaxy	Absent
Nagaspecial (H)	White	6.25 ± 0.08	2.00 ± 0.07	3.13	LB	Nonwaxy	Absent
Chahou angouba (I)	White	6.80 ± 0.18	2.78 ± 0.16	2.45	LB	Waxy	Present (strong)
Chahou amubi (J)	Dark purple	6.28 ± 0.16	2.26 ± 0.25	2.78	LB	Waxy	Present (strong)
Chahou poireiton (K)	Half-red and half-purple	6.98 ± 0.09	2.8 ± 0.16	2.49	LB	Waxy	Present (strong)
Chahou angangbi (L)	Red	6.16 ± 0.15	2.72 ± 0.16	2.26	LB	Waxy	Present (strong)
Taothabi (M)	Red	6.36 ± 0.29	2.82 ± 0.16	2.26	LB	Nonwaxy	Absent
Manipuri (N)	Red	6.52 ± 0.29	2.20 ± 0.03	2.96	LS	Nonwaxy	Absent
Bali (O)	White	5.20 ± 0.25	2.96 ± 0.05	1.76	MS	Nonwaxy	Absent

LB, long bold; SB, short bold; MS, medium slender.

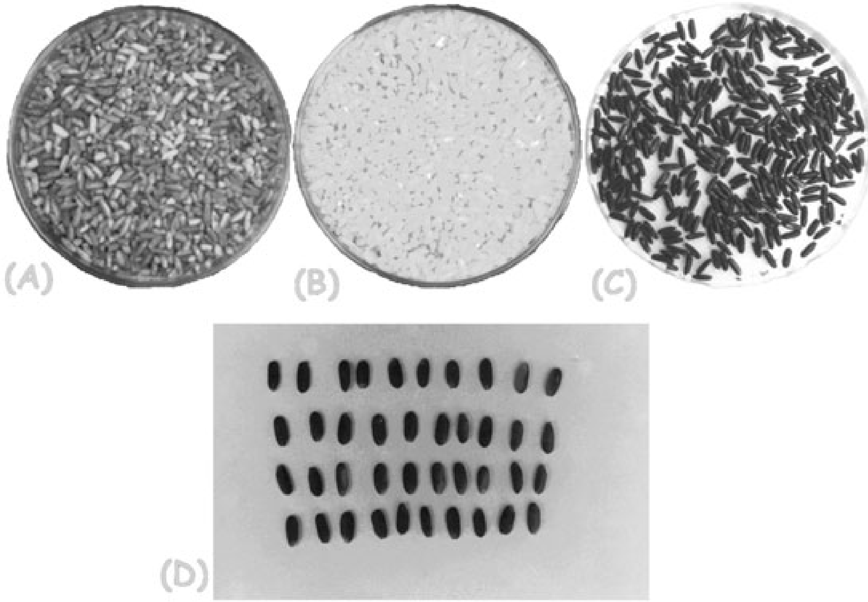

FIG. 2. KERNEL COLOR VARIATION IN THE INDIGENOUS RICE CULTIVARS OF NORTH-EASTERN HILL STATES OF INDIA: TAOTHABI RED (A); NGOBA, WHITE (B); CHAHOU AMBUI, DARK PURPLE (C); CAHOU POIREITON, HALF-RED AND HALF-PURPLE (D)

different proximal nutritional proportionate present in the rice cultivars studied is presented in Table 3. The nutritional quality of rice depends on the total quantity and quality of protein, and the quality of protein in turn depends on the amino acids composition and its mode of distribution. In the present study, we studied only the protein quantity. The crude protein content ranged from 6.14% (F) to 12.07% (H), with a mean value of 9.16%. According to protein content, the cultivars were found to have seven categories. Similarly Ahamed *et al.* (1998) reported 9.17 to 11.77% of protein in rice collections from Assam. Three cultivars, viz., H, I and N, registered significantly higher amount of total crude protein. Five cultivars, viz., A, B, H, I and N, could be identified as high-protein cultivars of rice, with 10% or more total crude protein following the classification of Resurrection *et al.* (1979). All the glutinous and aromatic cultivars taken for the present study contained good amount of protein ranging from 8.09 to 11.37%. However, Saikia and Bains (1990) and Singh *et al.* (1998) reported low protein content (around 6 to 7%) in both brown and milled rice in rice collections of Assam and Himachal Pradesh (an Indian state of similar altitude), respectively. The

TABLE 3.
PROXIMAL COMPOSITION AND AMYLOSE CONTENTS OF RICE CULTIVARS

Cultivar	Total crude protein (%)	Total carbohydrate (%)	Amylose content (%)	Total fat content (%)	Total ash content (%)	Crude fiber content (%)
Ngoba (A)	11.09^{cd}	80.67^{bc}	24.50^{l}	1.20^{a}	0.85^{a}	0.36^{ab}
Nagaland wonder rice (B)	10.00^{cd}	80.00^{bc}	14.07^{f}	1.80^{ab}	1.53^{ab}	0.39^{ab}
Take (C)	7.33^{ab}	85.59^{d}	22.93^{k}	2.20^{ab}	1.21^{ab}	0.52^{ab}
Makrule (D)	6.16^{a}	81.20^{bcd}	21.78^{j}	2.10^{ab}	0.93^{ab}	0.49^{ab}
Dehudega(E)	8.93^{b}	79.50^{bc}	9.86^{d}	1.77^{a}	0.84^{a}	0.58^{ab}
Makrutane (F)	6.14^{a}	73.77^{a}	21.76^{j}	1.43^{a}	0.95^{ab}	0.66^{ab}
Melourei (G)	7.93^{ab}	77.57^{b}	18.61^{gh}	2.07^{ab}	1.05^{ab}	0.68^{ab}
Nagaspecial (H)	11.37^{d}	82.33^{bcd}	18.00^{g}	3.20^{bc}	1.47^{ab}	0.63^{ab}
Chahou angouba (I)	12.07^{d}	84.57^{cd}	4.25^{b}	1.73^{a}	0.85^{a}	0.60^{ab}
Chahou amubi (J)	9.32^{bc}	80.33^{bc}	6.70^{c}	2.60^{ab}	1.20^{ab}	0.37^{ab}
Chahou poireiton (K)	8.09^{b}	85.33^{cd}	2.27^{a}	4.20^{bc}	1.23^{ab}	0.30^{a}
Chahou angangbi (L)	9.63^{c}	83.00^{cd}	2.28^{a}	3.60^{bc}	1.3^{ab}	0.51^{ab}
Taothabi (M)	9.58^{bc}	82.42^{bcd}	20.13^{i}	2.80^{ab}	1.63^{ab}	0.45^{ab}
Manipuri (N)	11.66^{d}	80.29^{bc}	11.20^{e}	3.20^{bc}	1.80^{ab}	0.84^{b}
Bali (O)	9.16^{bc}	79.32^{bc}	18.90^{gh}	3.40^{bc}	1.18^{ab}	0.42^{ab}
Mean	9.23	81.06	14.48	2.49	1.20	0.52
CD 5%	1.2315	3.0087	0.7212	1.0531	0.5799	0.1926
CV (%)	7.9764	2.2193	2.9773	25.3216	28.8555	22.1398

CD, critical difference; CV, coefficient of variation.
Same superscript indicates no significant difference whereas different superscripts indicate significant differences.

cultivar C recorded high amount of total carbohydrate content (85.59%) and F the lowest (73.77%). Six groups were observed in these cultivars with respect to carbohydrate content. Only two cultivars C and H were found to have significantly higher total carbohydrate content over the general mean. The amylose content ranged from 2.27% (K) to 24.50% (A) with 11 categories. However, Singh *et al.* (1998) reported narrow range of amylose content in the Himachal Pradesh rice collection (19.5 to 22.00% in brown rice and 22.0 to 25.0% in milled rice). The range of total fat content was 3.00 (from 1.20 to 4.20%), with a mean value of 2.49%. However, only three groups were found for this proximal parameter. In contrary to this, Saikia and Bains (1990) and Singh *et al.* (1998), respectively, reported narrow range of 0.31 and 1.06%. However, in the present case, five cultivars were found to have more than 3%. Among the five cultivars, H, N and O were of intermediate amylose type, and K and L are of low amylose type. Among these five cultivars, those having more amylose had less fat content. Tahira and Chang (1986) reported the influence of glutinous and nonglutinous character on lipid contents of rice. Further, they found that indica type of rice (high amylose) had low lipid content than japonica type (low amylose). Tahira and Chang (1986) reported 3.58% fat content in low amylose rice. In the present study, the cultivar K, which had lowest amylose content, recorded the highest value of total fat. Two cultivars, viz., M and N, registered significantly higher ash content than the general mean of the population. All the cultivars had very low crude fiber content, falling within the range of 0.30 to 0.84%. With respect to total ash and crude fiber contents, only two categories were observed, indicating less variability among these cultivars for these constituents.

Genetic Parameters of Variation and Association among the Nutritional Traits

The study of genetic parameters of variation is important to know the amount of variability present in the genetic material, which is in turn necessary for further improvement. The different genetic components, viz., GCV, PCV, h^2 and GA for the nutritional properties of the cultivars studied, are given in Table 4. A close agreement GCV and PCV was observed for total protein, total carbohydrate and amylose content, indicating that environmental factors showed less effect on these constituents in the grains. The other qualities such total fat, total ash and crude fiber contents were found much influenced by the environmental factors in which the grain develop and are stored. High heritability coupled with high genetic advance was found in amylose. High to moderate level of h^2 with high GA manifested by total crude protein, total fat and crude fiber content might be assigned to additive gene action

TABLE 4.
GENETIC PARAMETERS OF VARIATION FOR NUTRITIONAL QUALITIES IN RICE

Characters	GCV	PCV	h^2 (%)	GA as % mean
Total crude protein	19.63	21.20	0.86	37.48
Total carbohydrate	3.56	4.19	0.72	6.22
Amylose	53.93	54.01	0.99	110.93
Total fat	32.28	41.02	0.62	52.31
Total ash	18.69	34.38	0.30	20.93
Crude fiber	25.14	33.50	0.56	38.86

GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; h^2, heritability; GA, genetic advance.

TABLE 5.
INTERRELATIONSHIP AMONG NUTRITIONAL QUALITIES IN RICE

Characters	Total carbohydrate	Amylose	Total fat	Total ash	Crude fiber
Total crude protein	0.354	–0.290	0.080	0.547*	0.086
Total carbohydrate		–0.294	0.471	0.147	–0.370
Amylose			–0.755†	–0.456	0.060
Total fat				0.931†	–0.287
Total ash					0.286

* Significant at 5%.
† Significant at 1% level.

controlling the expression of these traits. Swain and Nagaraju (2004) also reported preponderance of additive gene action for amylose content in rice. Hence, phenotypic selection for their improvement can be effected by simple methods, like pure line selection, mass selection, bulk method, single-seed descent method, etc., following hybridization and selection in early generation. Low heritability coupled with moderate genetic gain was observed for ash content. High heritability and low genetic gain were obtained for total carbohydrate. Low heritability was due to comparatively high influence of environmental effect, and for this character, simple phenotypic selection will not bring its genetic improvement. Rather, selection based on progeny test should be followed. In spite of high heritability, low genetic gain for total carbohydrate was observed due to presence of low genetic variability (low GCV), and so for its genetic enhancement, increase of genetic variability either through collection of new genetic resources or through creation by hybridization or mutation is needed. The genotypic correlation coefficients among the nutritional traits are given in Table 5. Association of protein content with amylose content, though negative, was not significant. As reported by Govindaswami and Ghosh (1973), purple and waxy cultivars recorded higher protein content. They suggested that the purple pericarp and waxy endosperm may be used as marker in breeding program of protein amelioration. This observation is well agreeable with our results. Highly significant positive association was found between total fat and total ash, and also between total ash and total crude protein. Correlation between amylose content and total fat content was negatively significant. Among other traits, no significant level of association was observed.

From the present preliminary study, we can conclude that cultivars A, B, H, I and N could be useful as the source of high-protein trait for breeding programs intended for nutritional quality enhancement. These cultivars also can be given to protein-malnourished children, expecting and lactating mothers of this underdeveloped corner of the world, where protein malnutrition is a main cause of infant mortality and birth-related problems. Aromatic and colorful cultivars should be exposed to international and national consumers. Further glutinous cultivars could be utilized as source of waxiness and for preparation of various food products. Those cultivars which have been used traditionally as medicinal purposes should be studied thoroughly for bioactive compounds. However, detailed analysis on processing and other nutritional parameters, like vitamins, minerals, etc., should be continued with these important cultivars for further utilization.

Thus, the north-eastern hill region of India has valuable rice cultivars of strong aroma, are waxy, high-protein and colorful. These valuable cultivars can be used for commercial exploitations or breeding purposes. Moreover, those cultivars having quality traits that are at the verge of extinction should be conserved.

REFERENCES

AHAMED, S.A., BARUA, I. and DAS, D. 1998. Chemical composition of scented rice. Oryza *35*(2), 167–169.

ANONYMOUS. 1998. *Guinness Book of World Records*. Guinness World Record Ltd., London, UK.

ANONYMOUS. 2001. Research highlights. ICAR Research Complex for North Eastern Hill Region, India. Agri Complex Newsletter *24*(1), January–March, 1.

AOAC. 1980. *The Official Methods of Analysis of Association of Official Analytical Chemist*, Washington, D.C.

BABA, G.H. 1971. Note on protein content of rice (*Oryza sativa* L.) varieties of Kashmir. Indian J. Agric. Sci. *41*(10), 893–894.

BERNER, D.K. and HOFF, B.J. 1986. Inheritance of scent in American long grain rice. J. Crop Sci. *26*, 876–878.

BROOKS, D. 1989. Policy and prosperity in Thailand's rice sector. In *Rice Situation and Outlook Report* (USDA-ERS RS-56), pp. 11–17, U.S. GPO, Washington, DC.

BURTON, G.W. 1952. Quantitative inheritance in grain. *Proc. 6th Internal. Grassland Cong. 1*, pp. 277–283, Pennsylvania State College, Pennsylvania, USA.

COFFMAN, W.R. and JULIANO, B.O. 1987. Rice. In *Nutritional Quality of Cereal Grains, Genetics and Agronomic Improvement*, (R.A. Olsen and K.J. Frey, eds.) pp. 101–131, American Society of Agronomy, Madison, WI.

GOPALAN, C., RAMA SASTRI, B.V. and BALASUBRAMANIAN, S.C. 1989. *Nutritive Value of Indian Foods*. National Institute of Nutrition, Hyderabad, India.

GOVINDASWAMI, S. 1985. Post harvest technology, quality features of rice. In *Rice Research in India*, (P.L. Jaiswal, ed.) pp. 627–641, Indian Council of Agricultural Research (ICAR), New Delhi, India.

GOVINDASWAMI, S. and GHOSH, A.K. 1973. Breeding for high protein content in rice. Indian J. Gent. (Special issue of SABRAO, Second General Congress 1972).

GOVINDASWAMI, S., GHOSH, A.K. and NANDA, B.B. 1969. Varietal differences in hulling and cooking qualities. Annual Report CRRI, Cuttack, India.

GUHA, B.C. and MITRA, N.R. 1963. Studies on the consistency of thiamine and protein contents of pure-bred strains of rice. Ann. Biochem. Exp. Med. *23*(2), 69–72.

HORE, D.K. 2005. Rice diversity collection, conservation and management in north eastern India. Genet Resour. Crop Evol. *52*, 1129–1140.

JOHNSON, H.W., ROBINSON, H.F. and COMSTOCK, R.E. 1955a. Estimates of genetic and environmental variability. Agron. J. *47*, 314–318.

JOHNSON, H.W., ROBINSON, H.F. and. COMSTOCK, R.E. 1955b. Genotypic and phenotypic correlations in soybean and their implication in selection. Agron. J. *47*, 477–483.

JULIANO, B.O. 1971. A simplified assay for milled rice amylose. Cereal Sci. Today *16*(10), 334–339.

JULIANO, B.O. 1993. Rice in human nutrition. FAO, Rome. http://www.Fao.org/inpho/contents/vlibrary/t0567e/t057e.htm (accessed January 14, 2004).

MAHADEVAPPA, M. and SHANKARE GOWDA, B.T. 1973. Some important technical consideration in rice breeding. Madras Agric. J. *60*(6), 408–411.

NAKAGAHARA, M., NAGAMINE, T. and OKUNO, K. 1986. Spontaneous occurrence of low amylose genes and geographical distribution of amylose content in Asian rice. Rice Genet. Newsl. *3*, 46–48.

OLSEN, K.M. and PURUGGANAN, M.D. 2002. Molecular evidence on the origin and evolution of glutinous rice. Genetics *162*, 941–950.

PATEL, M.M. and RAJANI, H.J. 1967. Nutritive value and cooking quality of Gujarat rice varieties. Indian Farm. (New Ser) *17*(3), 34–35.

REINKE, R.F., WELSH, L.A., REECE, J.E., LEWIN, L.G. and BLAKENEY, A.B. 1991. Procedures for quality selection of aromatic rice varieties. IRRN *16*(5), 10–11.

RESURRECTION, A.P., JUALIANO, B.O. and TANAKA, Y. 1979. Nutritional content and distribution in milling fractions of rice grains. J. Sci. Food Agric. *30*, 475–481.

SADASHIVAM, S. and MANICKAM, A. 1996. *Biochemical Methods*, New Age International Publishers, New Delhi, India.

SAIKIA, L. and BAINS, G.S. 1990. Studies of some Assam rice varieties for processing and nutritional qualities. J. Food. Sci. Technol. *27*(5), 345–346.

SAMPATH, S., PATNAIK, S. and MITRA, G.N. 1968. The breeding of high protein rices. Curr. Sci. *37*, 248–249.

SINGH, M.S. and DEVI, Y.P. 2004. Aromatic rices of Manipur at the verge of extinction. Indian Farm. *54*(8) (November), 46–47.

SINGH, S., DHALIWAL, Y.S., NAGI, H.P.S. and KALIA, M. 1998. Quality characteristics of six rice varieties of Himachal Pradesh. J. Food Sci. Technol. *27*(5), 345–348.

SOOD, B.C. and SIDDIQ, A. 1978. A rapid technique for scent determination in rice. Ind. J. Genet. *38*(2), 268–271.

SWAIN and NAGARAJU, M. 2004. Diallel analysis for amylose content in rice. Oryza *41*(3&4), 125–127.

TAHIRA, H. and CHANG, W. 1986. Lipid content and fatty acid composition of Indica and Japonica of nonglutinous brown rice. J. Agric. Food Chem. *34*, 542–545.

TAVA, A. and BOCCHI, S. 1999. Aroma of cooked rice (Oryza sativa): Comparison between commercial Basmati and Italian line B5-3. Cereal Chem. *76*(4), 526–529.

ZHUO, Z., ROBARDS, K., HELLIWELL, S. and BLANCHARD, C. 2002. Composition and functional properties of rice. Int. J. Food Sci. Technol. *37*, 849–868.