GRAIN QUALITY EVALUATION, CHALKINESS FORMATION AND MOLECULAR GENETIC DIVERSITY STUDIES OF RICE VARIETIES OF GOA

A Thesis submitted to Goa University for the Award of the Degree of
DOCTOR OF PHILOSOPHY
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Botany

By
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Certified that no corrections were suggested by the examiners in this thesis.

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STATEMENT

As required by the University Ordinance OB 9.9 (iv), I state that the present thesis "**Grain Quality Evaluation, Chalkiness Formation and Molecular Genetic Diversity Studies of Rice Varieties of Goa**", is my original contribution and the same has not been submitted on any occasion for any other degree or diploma of this University or any other University/Institute. To the best of my knowledge, the present study is the first comprehensive work of its kind from the area mentioned. The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

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CERTIFICATE

As required by the University Ordinance O.B. 9.9 (vi), this is to certify that the thesis entitled "**Grain Quality Evaluation, Chalkiness Formation and Molecular Genetic Diversity Studies of Rice Varieties of Goa**", submitted by **Ms. Shilpa J. Bhonsle** for the award of the degree of Doctor of Philosophy in Botany, is based on her original and independent work carried out by her during the period of study, under my supervision.

The thesis or any part thereof has not been previously submitted for any other degree or diploma in any University or Institute.

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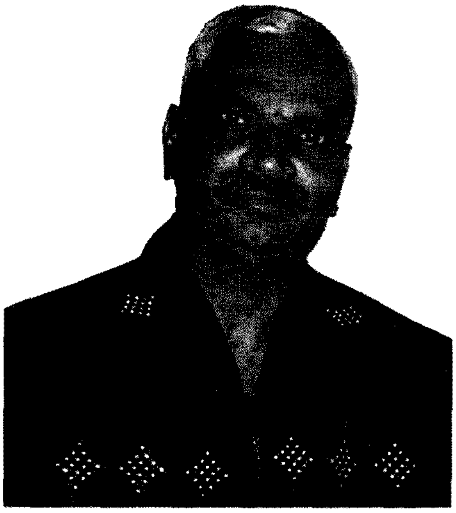

Dedicated to the Memories of My Beloved Father Shri. Jagannath S. Bhonsle

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ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
AC	Amylose Content
ASV	Alkali Spreading value
bp	Base pair
BR	Brown Rice
Ca	Calcium
cm	Centimeter
DAF	Day after Fertilization
°C	Degree Centigrade
°E	Degree East
°N	Degree North
EDTA	Ethylenediaminetetraacetic Acid
Fig.	Figure
g	Grams
>	Greater Than
GC	Gel Consistency
GT	Gelatinization Temperature
h	Hours
HCl	Hydrochloric Acid
$HCLO_4$	Perchloric Acid
%	Percent
HF	Hydrogen Fluoride
HNO_3	Nitric Acid
HRR	Head Rice Recovery

ICAR	Indian Council of Agricultural Research
ISSR	Inter Simple Sequence Repeat
ISSR	Inter Simple Sequence Repeat
K	Potassium
kb	Kilo base pair
Kg	Kilogram
KLAC	Kernel Length After Cooking
Km	Kilometer
L	Litre
L/B	Length/Breadth
<	Less than
LB	Long Bold
LS	Long Slender
μl	Microlitre
μM	Micro mole
M	Molar
m	Meter
Mg	Magnesium
mg	Milligram
min	Minutes
ml	Millilitre
mM	Millimolar
mm	Millimeter
MS	Mild Scented
N	Normal

NaOH	Sodium Hydroxide
ng	Nanogram
nm	Nanometer
NS	Non-Scented
OD	Optical Density
PCA	Principal Component Analysis
PGWC	Percentage of Grains with Chalkiness
±	Plus or minus
ppm	Part per million
psi	Pounds per square inch
rpm	Revolutions per minute
RT	Room Temperature
SB	Short Bold
sec	Seconds
Sq. Km	Square Kilometer
SS	Short Slender
SS	Strongly Scented
UPGMA	Unweighted pair group method with arithmetic mean
UV	Ultra Violet
v/v	Volume by volume
WASP	Web Agri Stat Package

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INTRODUCTION

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the principal cereal crop for more than half of the world's population. About 90% of the total world's rice is grown and consumed in Asia (Tyagi *et al.*, 2004). In India, approximately 70% of people consume rice as staple food and the area under cultivation is around 42 million hectares (ha) with an annual production of about 100 million tonnes (Hindu Survey of Agriculture, 2010) and rice is cultivated throughout the year in varied ecological conditions and second highest production in the world.

Asia accounts for over 90% of the world's production of rice, with China, India and Indonesia. About 85% of the rice that produced in the world is used for human consumption. In India, the production of rice is almost tripled from 30.4 million tonnes during the last three decades to 91.79 to 99.18 million tonnes from the year 2006-2010 respectively (Hindu Survey of Agriculture, 2010). The rice yield has been increased due to the cultivation of improved rice varieties with appropriate inputs of fertilizers, plant protection measures and judicious use of irrigation.

1.1. Rice Cultivation in the State of Goa

The available area for cultivation in Goa is 3,61,113 ha, of which total cropped area is 1,68,634 ha. Out of the total cropped area, 72,650 ha (43.08%) is under the food grain crops, 92,310 ha (53.73%) is under horticulture crops and 4,985 ha (2.95%) under crops like sugarcane and groundnut. Among the total cultivated area in the State, rice occupies about 52,191 ha and of which 34,261 ha are grown during *kharif* and remaining 17,930 ha are grown during *rabi* season. About 90% of *kharif* and entire area of *rabi* seasons are covered under high yielding rice varieties. The area under rice cultivation, average yield and the total rice production during the year 2008-11 is provided in Table 1. The area under rice cultivation in each taluka for the year 2011-2012 is given in Table 2.

Table 1. Area under rice cultivation, yield and production in the State of Goa.

Rice	2008-2009			2009-2010			2010-1011		
	Kharif	**Rabi**	**Total**	**Kharif**	**Rabi**	**Total**	**Kharif**	**Rabi**	**Total**
Area (ha)	34278	15688	49966	31166	15938	47104	30632	15980	46612
Average yield (Kg/ha)	3507	3625	3566	2853	3890	3371	3537	4041	3789
Total production (t)	120206	56875	177081	88913	62006	150919	108333	64156	172489

(Directorate of Agriculture Goa, 2012)

Table 2. Area under rice cultivation in different taluka of Goa for the year 2011-2012.

State/district/taluka	Area of rice cultivation in ha		
	Kharif	**Rabi**	**Total**
Goa state	31247	15990	47237
North Goa	**18019**	**8450**	**26469**
Tiswadi	4914	620	5534
Bardez	5550	1580	7130
Pernem	2698	1235	3933
Bicholim	1660	1705	3365
Sattari	480	665	1145
Ponda	2717	2645	5362
South Goa	**13228**	**7540**	**20768**
Sanguem	860	2280	3140
Canacona	2518	780	3298
Quepem	3238	2290	5528
Salcete	6192	1745	7945
Marmugao	420	445	865

(Directorate of Agriculture Goa, 2012)

Goan farmers cultivate rice under three distinct ecological conditions such as in *Morod*, *Kher* and *Khazan* lands during *kharif* or ‘sord’ season and it is mainly rain-fed. The irrigated crops are grown in *rabi* season and called as ‘vaingon’.

The rice varieties like Kendal, Khochro, Damgo, Korgut, Muno and Assgo are traditionally cultivated by farmers are decreasing due to the introduction of hybrid and breeded varieties. Korgut, Assgo, Muno are grown in *khazan* lands and known to be salt tolerant. However, in 1966 high yielding rice varieties programme was launched. This programme was adopted by many farmers, every year more and more areas of high yielding rice have been cultivated. During 1970's IR-8, Jaya and Annapurna were very popular (Manjunath *et al.*, 2009). Today high yielding varieties predominantly grown in Goa are Jaya, Jyoti and Karjat.

Morod lands: The upland commonly called as *morod* crop and is mainly rain-fed, short duration; rice varieties of early maturity groups are grown. The preferred rice varieties are Novan, Kendal, Jiresal, Sal and Kotimirsal.

Kherlands: The midlands generally called as kherlands are mostly sandy loam soils, irrigated lands and require enough water to grow. Long and medium duration rice varieties such as Khochro and Barik Kudi are grown.

***Khazan* lands:** The *khazan* lands are saline floodplains along Goa's tidal estuaries and are ecologically, economically and socially very important in agriculture. The local farming community traditionally practices rice cultivation by growing salt tolerant rice varieties during monsoon season in conjunction with shrimp aquaculture during off seasons. *Khazan* lands cover an area of about 17,200 ha and it is only one crop in the monsoon season. Though the *khazans* are saline lands, farmers get an average yield of about 2.9 t/ha. The increasing labor costs and scarcity of labor is the main problem in rice cultivation in coastal areas and hence, rice cultivation under *khazan* lands is decreasing. The major salt tolerant varieties grown in *khazan* lands are Korgut, Assgo, Karo Mungo, Khochro and Damgo.

1.2. Rice in Goan Culture

Rice is sanctified and used in all sacred religious ceremony and temples. Hindus relate rice with Lakshmi devi, the goddess of wealth. After the monsoon season, in the month of August-September (*Bhadra-Pada*), first *kharif* crop is harvested with prayers conducted in the paddy fields and offered to lord Ganesh, whereas, Christians celebrate *Festa de Espiga* or *Novidade* in each village, the first offering is made to the church and the paddy is specially blessed. Rice also plays important role in marriage ceremonies and mainly the sign of fertility and prosperity. Rice products from Goa are mainly puffed rice (*Chirmulyo, Chanburo*), popped rice (*lahyo*), flattened rice (*Fov/avel*), rice flour (*Tandlache pit*), rice broken (*kanyo*) and rice husk (*kundo*). Other rice products like Rice bran oil, rice bran and rice bran wax (Bhonsle and Krishnan, 2012).

1.3. Basmati Rice in Goa

In Goa, the cultivation of traditional rice varieties by farmers is becoming rare due to less yield and increase labor costs. As the cultivation area is small and in patches, the cost for cultivation is high and less profit owning to framers. As basmati rice are mostly preferred by consumers for pulao and biryani as long grains with scent and have price in both international and domestic markets. Some local farmers grow basmati rice for which seeds are supplied by ICAR Research Complex, Goa. Mostly the basmati rice cultivation is carried out in *kharif* season as the required climatic conditions are available during the rainy season. Therefore, the sowing of the Basmati seed starts during late May so that the seedlings are ready for transplanting by the third week of June. For the prosperous cultivation of basmati, the prevailing range of maximum day temperatures during the months of August-September has to be exploited to the maximum advantage. To get the maximum aroma in the grain, the critical period of 30 d between the flowering stage and the grain hardening stage should coincide with the maximum day temperature (below 29°C) which normally prevails in Goa between August and early November (Manjunath *et al.*, 2009).

Aromatic rice varieties are more susceptible to storage pests. Improper storage leads in both qualitative and quantitative loss of Basmati rice. Before storage the moisture content of un-milled, stored paddy should be 12-14%. For high-quality yield the farmer should follow the recommended management practices and can get the yield between 3.5 to 3.7 t/ha from high yielding basmati varieties. Recently the economics of basmati grown in Goa gave a positive response but much of the farmers are not cultivating basmati rice, as lack of knowledge. Several aromatic rice varieties like Pusa Basmati-1, Pusa Sugandh-2 and Kasturi are grown and consumed. The traditional tall Basmati cultivars are very poor in yield. Selection of the rice variety is critical for the success of Basmati rice cultivation.

1.4. Hybrid Rice

Hybrid rice is the commercial rice crop from F1 seeds of cross between two genetically dissimilar parents. High-quality rice hybrids have potential yielding of 15-20% more than the best inbred variety grown under similar conditions. For the cultivation of hybrid rice, farmers will have to buy fresh seeds every cropping season. We need to go for hybrid rice because yield levels of semi-dwarf varieties of the green revolution era have to produce more on less land and with fewer inputs. Hybrids have ability to perform better under adverse conditions of drought and salinity (Tint and Joveno, 2008).

For developing commercial rice hybrids, use of a male sterility is essential. Male sterility by genetic or non-genetic means makes the pollen unviable and such rice spikelets are incapable of setting seeds through selfing. Thus, a male sterile line can be used as female parent of a hybrid. A male sterile line, when grown side with a pollen parent in an isolated plot, can produce a bulk quantity of hybrid seed due to cross pollination with the adjoining fertile pollen parent. The seed set on male sterile plant is the hybrid seed which is used for growing the commercial hybrid crop.

Biotechnology play an important role in the development of hybrid rice, as it helps in improving the rice yield and tolerances. This is carried out by transfer of economically important traits across the genus and species into the rice gene pool. This technique increases the efficiency of selection and shortening the breeding cycle. The three major applications of rice biotechnology that are expected to contribute both directly and indirectly towards rice improvement are DNA marker technology, genetic engineering and application of genomic tools (Chandrasekaran *et al.*, 2008).

Rice has two cultivated species and about 20 wild species. The cultivated species are *Oryza sativa* L. and *Oryza glaberrima* Steud. *Oryza sativa* is grown all over the world, while *Oryza glaberrima* is cultivated only in Africa for last ~3500 years. Rice is grown in semi-aquatic habitat and an annual herbaceous grass. *O. sativa* the Asian rice species have spread in most parts of the world and is more diverse than *O. glaberrima*. *O. sativa* is broadly divided into *indica* and *japonica* subspecies. The genus *Oryza* is believed to have originated in Gondwanaland (Chang, 1976). The genus *Oryza* is a member of the family Poaceae (Gramineae), sub family Oryzoideae and the tribe Oryzeae (Gould and Shaw, 1983).

1.5. Origin, Antiquity of Rice Cultivation and Species Complexes of Rice

Though the place of origin of cultivated rice (*O. sativa*) has not been fully settled, it is certain that it originated in South and or Southeast Asia where India forms a major part of this region. Based on hitherto published information and evidences, Chang (1976) reported that *O. sativa* could have evolved in a broad area extending over "the foot hills of Himalayas in South Asia and its associated mountain ranges in main land, Southeast Asia and Southwest China". Chang (1976) proposed that *O. sativa* evolved from *O. rufipogon* and *O. nivara*. The Asian cultivated rice has distinctly evolved into three eco-geographic races namely *indica*, *japonica* and *javanica*. In each race three distinct cultural types are found: upland, lowland and deep water rice. Further, based on local selection according to ethnic, agronomic and taste preferences, several diverse groups have been evolved which hold evolutionary climaxes and distinctive properties. *O. glaberrima* has not evolved into races like *O. sativa* and it has never spread beyond tropical Africa.

Agricultural practices began in the Neolithic age about 10,000 to 15,000 years ago. Neolithic settlements like Ali Kosh in Iran (9500 years before present) (B.P.), Jericho in Jordan (9500 B.P.) and ecologically similar localities of other places reveal the first attempts of agriculture (Randhawa, 1980). *O. sativa* was first domesticated in the foot hills on both flanks of the Himalayan range (Chang, 1988). The centre of origin of cultivated rice are probably the Gangetic plains and the eastern foot hills of the Himalayas from Assam through Burma, Northern Thailand, Laos and North Vietnam to Southwest and South China (Roschevicz, 1931; Chatterjee, 1951; Chang, 1964; Kumar, 1988). Initially rice grains were collected from the wild by prehistoric people of these regions (Whyte, 1972; Chang, 1976; Grist, 1982).

In China, rice remains of *indica* and *japonica* types were obtained from Ho-mu-tu and Lou-jia-jiao dated about 7,000 B.P. In Thailand the Ban Chiang site rice remains are dated about 5,500 B.P. Rice excavated in Solana in the Philippines is dated to 3,400 B.P. In Indonesia, grain and glume fragments from Ulu Leang are dated to 6,000 B.P. (Porteres, 1976).

Rice cultivation in India probably began before the Aryan invasion (Vishnu-mittre, 1961). Radiocarbon dating of archaeological remains from Koldhiwa site in Belan valley in Uttar Pradesh indicates the use of rice 8,520 B.P. Other dates of early use of rice in India are about 4,300 B.P. in Lothal and 4000 B.P. in Rangpur, both in Gujarat (Kumar, 1988). The earliest evidence of rice cultivation in South India is from Hallur in Karnataka, dated about 3,100 B.P.

Hence, the first domesticated rice of Asia was claimed to be originated in the South or South East Asia in which India is the major region (Singh *et al.*, 2001). The wild progenitors of cultivated rice are very rich in diversity and this genetic diversity provides an insurance against crop failure (Subba Rao *et al.,* 2001). The traditional cultivars and wild species have enormous valuable genes which can be used in the breeding programmes which can improve the yield potential and quality (Saxena *et al.,* 1988). Collection, documentation and characterization of the germplasm are vital in present era for defending the unique rice and utilizing the appropriate attribute based donors in breeding programmes (Plucknett *et al.,* 1987; Vaughan, 1989; Nakagahra *et al.,* 1997; Bhonsle and Krishnan, 2011).

1.6. Rice Grain Quality

Rice varieties are evaluated for the various grain qualities like physical, chemical and cooking characters. Grain quality is a very wide subject encompassing diverse characters that are directly or indirectly related to exhibit one quality type (Siddiqui *et al.*, 2007). The kernel appearance, size, shape, aroma, nutritional value and cooking characteristics are important for judging the quality and preference of rice from one group of consumer to another (Dela Cruz and Khush, 2000; Sellappan *et al.*, 2009). Kernel shape and L/B ratio are important features for grain quality assessment (Rita and Sarawgi, 2008). Aroma, hardness and roughness are depends on temperature and variety specific which affects the sensory properties of cooked rice (Yau and Huang, 1996). Individual preferences varied, most of the consumer's preferred imported rice but differed in their preferences for the local rice (Tomlins *et al.*, 2005). Aroma in scented rice depends on the levels of 2-acetyl-1-pyrroline content and it varies with genetic and environmental conditions (Nadaf *et al.*, 2006). The consumers demand has increased markedly to pay a premium price for fragrant rice (Louis *et al.*, 2005).

Different cultivars showed significant variations in their morphological, physico-chemical and cooking properties (Yadav *et al.*, 2007). The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are the three major rice traits that are directly related to cooking and eating quality (Little *et al.* 1958). On the other hand Lisle *et al.*, 2000, found that the varying contents of amylose content, amylopectin structure and protein composition explained the variation in cooking quality of rice.

Post harvest losses are one of the major problems in rice production and other cereals. Losses in food crops occurring during harvesting, threshing, drying, storage, transportation and processing by industries etc. have been estimated between 30 and 40 percent of all food crops in developing countries. If post harvest losses are reduced, the world supply can be increased by 30-40 per cent without cultivating additional hectares of land or increasing any additional expenditure on seed, fertilizer, irrigation and plant protection measures to grow the crop and deterioration of food quality have areas of major concern in developing countries of the world.

Several grain qualities are affected by physiological disorders. Chalkiness is a major concern in rice breeding as it is one of the key factors in determining rice quality and price. If part of the milled rice grain is opaque rather than translucent, it is characterized as chalky. Percentage of grains with chalkiness (PGWC) is one of the important traits assessing rice grain appearance (Yosuke *et al.*, 2007). Chalkiness affects the appearance and quality of milled rice. Chalky grains tend to be broken easily during processing, which results in low head rice rate (Xu *et al.,* 1995; Liao *et al.,* 1999). Chalk, an opaque area in the grain, affects the visual appearance of white rice. Chalk mainly occurs at the center of the grain and can occupy >50% of the area of the grain. High air temperatures have unfavorable effects on rice grain-filling process which take an account of the accumulation of storage materials such as starch, protein and causing yield loss (Peng *et al.*, 2004). A storage of starch deposition results in loosely packed starch granules, creating air spaces that reflect light (Tashiro and Wardlaw, 1991; Zakaria *et al.*, 2002).

1.7. Molecular Genetic Diversity Studies

The molecular marker is a useful tool for assessing genetic variations and resolving cultivar identities (Rabbani *et al.*, 2008). Molecular markers provides information that help to define the distinctiveness of germplasm and their ranking according to the number of close relatives and their phylogenetic position (Kibria *et al.*, 2009). In rice, molecular markers have been used to identify accessions (Virk *et al.*, 1995; Olufowote *et al.*, 1997), to determine the genetic structure and pattern of diversity for cultivars of interest (Zhang *et al.*, 1992; Yang *et al.*, 1994; Mackill, 1995; Akagi *et al.*, 1997), and to optimize the assembly of core collections (Schoen and Brown, 1995). Compared to morphological analysis, molecular markers can reveal differences among accessions at the DNA level and thus provide a more direct, reliable and efficient tool for germplasm conservation and management. Molecular marker technologies can assist conventional breeding efforts and are valuable tools for the analysis of genetic relatedness and the identification and selection of desirable genotypes for crosses as well as for germplasm conservation in gene banks (Alvarez *et al.*, 2007).

The genetic diversity of rice germplasm has examined globally on large scale using molecular markers but few studies have taken an in-depth view of a large number of rice landraces on a local scale (Yu *et al.*, 2003; Garris *et al.*, 2005; Caicedo *et al.*, 2007). Consequently, the global studies will present an excellent overview of the population structure of cultivated rice however they cannot provide an in-depth view of rice germplasm on a local scale. This is because small area will represent a few rice varieties. Increasingly, studies have begun to characterize subsets of rice germplasm at the country/state level to understand genetic diversity of rice in particular area (Jain *et al.*, 2004; Gao *et al.*, 2005; Pessoa-Filho *et al.*, 2007; Thomson *et al.*, 2007).

OBJECTIVES OF THE PRESENT INVESTIGATION

Considering the above and no previous studies available in the State, the present study aimed for the collection, documentation and evaluation of rice grain quality characteristics of traditional, high yielding and hybrid rice varieties from Goa. Second part of study includes the physicochemical characteristics of collected rice varieties which are significant indicators of grain quality and mainly takes an account of the physical, chemical and cooking characteristics. The chalkiness in rice grain is the major problem not only for the hybrid rice, but also the traditionally cultivated rice varieties which reduce the rice grain quality. The molecular markers can assist conventional breeding efforts and will be valuable tools for the analysis of genetic relatedness, identification and selection of desirable genotypes for breeding programmes and germplasm conservation. Hence, the present work was undertaken with the following specific objectives:

1. Collection and documentation of traditionally cultivated, introduced and hybrid rice varieties from the state of Goa and adjoining regions.
2. Evaluation of the grain quality characteristics of traditionally cultivated, introduced and hybrid rice varieties.
3. Characterization and tracing the origin of chalkiness in rice grain from anthesis to maturation.
4. Molecular genetic diversity studies among the rice varieties of Goa and adjacent regions using molecular markers.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1. Collection and Documentation of Rice Germplasm

Vavilov (1951) was the first person to recognize the importance of genetic diversity for crop improvement and organized extensive germplasm collections of various crops from their 'centers of origin' and distribution for conservation. The collection, documentation and evaluation of rice germplasm are one of the very important achievements of consumers demand. The diversity of rice helps in expansion of agriculture, production and economic growth. The breeders prefer rice with high content of protein, minerals and vitamins. The conservation of the existing rice diversity will facilitate against unidentified further demands in farming systems at local to global levels (Singh *et al.,* 2000). The quality of rice is considered with the varied types of shape, size and length breadth ratio of milled and cooked rice (Dela Cruz and Khush, 2000). Germplasm, gene pool of species consisting of accepted cultivars, advanced breeding lines, landraces of wild and weedy associates are main materials for crop improvement. With different edaphic and climatic conditions, socioeconomic variation between regions and diversity of cropping systems also contributes to variation and differentiation among landraces (Paterniani, 1990).

Rice germplasm materials are the building blocks for the construction of improved rice varieties. However, as farmers turns to high yielding rice varieties, the present rice varieties are undergoing a narrowing of the diversity. Therefore, a great need of conserving the biodiversity of traditionally cultivated rice varieties. Farmers have turned to modern varieties, extant of the germplasm experience a narrowing of diversity. The safe storage system for the germplasm is the *ex-situ* conservation in gene bank which has the systematic classification. Just collection and documentation is not enough for selection, more information of morpho-agronomic traits, pests, diseases and quality are required, as broad selection helps in varietal improvement. The existing diversity in the germplasm also provides an assurance. In crop improvement program, genetic variability for agronomic traits as well as quality traits in almost all the crops is important, since this component is transmitted to the next generation (Singh, 1996). Collection, conservation and investigation of rice genotypes are critical to develop a gene-pool for breeding purposes of high yielding varieties (Pervaiz *et al.*, 2009).

Compared with other crops, the genetic diversity in rice germplasm is large as the three subspecies the *indica*, *japonica* and *javanica*, compose a large reservoir of rice germplasm including the traditional rice and cultivars (Khush, 1997; Lu *et al.*, 2005; Garris *et al.*, 2005). Even though rice is rich in genetic resources (wild relatives), only few of the world rice germplasm have been used as potentially valuable resources for the improvement of cultivated rice (Ren *et al.*, 2003). Hore (2005) studied the germplasm collection which has extended the occurrence of large number of rice landraces in northeastern region of India. During 1985 to 2002, 2639 accessions of rice germplasm with wild relatives were collected and conserved in National Gene Bank.

During the period of 1977-1978, ICAR research complex for Goa, surveyed and collected traditionally grown rice varieties like Damgo, Babri, Patni, Bello, Nermar, Khochri, Kendal, Assgo and Korgut and their yielding potential were also observed. Among them Damgo, Babri and Nermar were found to be high yielding (4.75 t/ha), where as Khochri and Bello were with the yield of over 3 t/ha. Korgut, Tamdi recorded to have low yield (2.7 t/ha) and varieties like Assgo Patni and Kendal were recorded less than 2 t/ha, but the grain quality was found to be very good in Patni, Assgo and Kendal (Manjunath *et al.*, 2009).

2.2. Rice Grain Quality - Physical Characteristics

Rice varieties with higher yield potential, increased tolerance to biotic and abiotic stresses and superior grain quality need to be continuously developed (Sarla *et al.*, 2003). Vanaja and Babu (2003) studied the correlation between physicochemical and cooking qualities of 56 high yielding rice varieties from different geographical environment (Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines and Sri Lanka), the results revealed that the longer grain had more milling recovery than wider grain. Rice varieties with high amylose absorb more amount of water with low gelatinization temperature, produce more cooked material and high amylose increases the cooking time.

Rachmata *et al.* (2006) observed that the consumers are very selective for the rice with good quality due to the higher incomes and improved life style. Customers are prepared to pay higher price for specific quality. Grain quality involves physical, chemical and cooking characteristics. They have analyzed relationship between price and grades of rice and consumer preference, the rice color is the important parameter determining consumer's preference and consequently determining price difference. Otegbayo *et al.* (2001) studied that the parboiling of the rice help in milling and cooking qualities and advantageous for the consumers demand and acceptability.

Poehlman and Borthakur (1969) reported that the plant breeders need to see the milling properties of the varieties and strains of rice they produced. In the early stages of testing, only a small quantity of seed is required and quality can be determined easily. An estimate of total milled rice may be obtained by hulling 100 g sample of rough rice and this determines the percentage of hull removed. The brown rice samples obtained are than milled and polished in a test tube miller. The milled rice obtained may be examined for grain size, shape and chalkiness and for cooking characteristics.

The alkali spreading value (ASV) gives the estimate of gelatinization temperature and it varies from 3.0 (Uday) to 7.0 (Indira) indicating very wide variability. The quality and quantity of starch and gelatinization temperature strongly influence the cooking quality. The gelatinization temperature affects the water uptake, volume expansion ratio and linear kernel elongation (Vanaja and Babu, 2003). Alkali spreading value gives an idea for gelatinization temperature.

Physicochemical properties need to be maintained after the introduction of foreign genes except for improved appearance and milling quality (lower chalkiness and higher head rice yield) and slight difference in texture i.e. lower springiness and chewiness (Li *et al.*, 2008). Xu *et al.* (2002) reported that for breeding purposes, the grain size plays an important role in determining the weight of the grain. The grain size is positively correlated with several characters including grain length, width and thickness. Vanaja and Babu (2006) reported that the high heritability of alkali spreading value, L/B ratio of grain, milling percentage, amylose content, volume expansion ratio and water uptake implying the potential of these parameters to be used in breeding programmes.

Dipti *et al.* (2002) studied the physical and cooking characteristics in six rice varieties. The milling percentage was 64-70% with the head rice recovery (HRR) ranged from 61-82%. Grain length was 3.6-6.5 mm and breadth was calculated as 1.7-3.7 mm. Amylose content in the varieties ranged from 18.6-28.0% and the highest protein was recorded as 8.6%. The maximum cooking time was about 25 min. and minimum of 14.5 min.

Among the exporters of basmati rice, India is one of the leading countries in the world (Husaini *et al.*, 2009). As consumers judge the quality of rice, they are keen to pay a premium price for scented rice (Bradbury *et al.*, 2005). Level of 2-acetyl-1-pyrroline content plays an important role in scented rice varieties and differs with environmental condition and genetic composition (Nadaf *et al.*, 2006). Kernel appearance, size, shape, aroma, nutritional value and cooking characteristics are important quality and the preference of rice varieties varies from one group of consumer to another (Dela Cruz and Khush, 2000; Sellappan *et al.*, 2009). The shape and L/B ratio of the grain are essential features for grain quality estimation (Rita and Sarawgi, 2008). Aroma, hardness and roughness of rice are depends on temperature and variety specific which affects the sensory properties of cooked rice (Yau and Huang, 1996). Tomlins *et al.* (2005) reported that the consumer preferences varies from person to person, as some preferred imported rice, but differed in their preferences for the local rice.

Koutroubas *et al.* (2004) investigated relationships with physiological traits of 318 rice lines of five European countries. Variation was noted in milling, cooking, processing and nutritional qualities. Grain length (GL) of brown rice ranged 4.3-8.5 mm, grain width (GW) 1.9-3.6 mm and length width (L/W) ratio from 1.3-4.0. GL was negatively correlated with GW, indicating that selection for long grains would result in a negative response of GW. Both milling and yield parameters were higher for early maturing lines than for late maturing lines. AC ranged from 12.8-27.6%, while grain protein content ranged from 4.8-11.9%. Protein content was greater in tall and late maturing lines than in short and early maturing ones. Gelatinization temperature ranged from 50.1 to 77.5°C with a mean value of 61.56°C. The variation among lines found in this study offers opportunities to breed for grain quality in either direction in order to meet the specific requirements of each country. By the material examined, 25 lines met all the requirements of *indica* type rice. These lines could be used as parental for introducing desired traits to current *indica* cultivars grown in Europe. Additionally, the interrelations among grain quality traits found in this study may be useful to understand the relationship among grain quality components and to optimize the selection criteria.

Vidal *et al.* (2007) studied grain characteristics, morphological, chemical composition and starch properties of 27 rice varieties, by cell walls characterization with arabinoxylan and beta-glucan contents. A rapid method for determining optimum rice cooking time was developed based on the swelling ratio. Optimum cooking time appears positively correlated with kernel thickness and thousand kernel weight (TKW) but also with ash content. Laser Confocal and scanning electron microscope observation of uncooked rice grains revealed different structural features (cell size) and fracture behavior for some cultivars, the fracture showed ruptured cells, whereas for others most cells were intact. These structural differences, which may be linked to pectin content, partly explain the behavior of cooked rice.

Yadav *et al.* (2007) studied the physicochemical characteristics of non-basmati and basmati varieties. Length was calculated as 5.85 to 8.25 mm, breadth varied from 1.65 to 2.93 mm. Basmati varieties had higher elongation ratio and water uptake. Water uptake was observed to be correlated positively with L/B ratio and hardness. Correlation coefficient for elongation ratio and water uptake was significant and positive correlation with amylose content. Elongation ratio of cooked kernels had high significant and positive correlation with L/B ratio.

2.3. Rice Grain Quality - Chemical Characteristics

Mohapatra *et al.* (2002) observed that high amylose content (AC) in rice was found to have lesser cooking time than the low amylose variety. Thicker grains tend to have higher degree of milling, lower amylase content and higher cooking time than their slender counterparts as water diffusion was influenced by the thickness of grain and bran layer. Low milled rice was characterized by high optimum cooking time, hardness and low adhesiveness, cohesiveness, length expansion ratio, volume expansion ratio and water uptake. Whereas, highly milled rice was characterized by high cohesiveness, adhesiveness, length expansion ratio, volume expansion ratio, water uptake and low hardness and optimum cooking time. The cooking and textural properties were largely dependent on the chemical composition of the cultivars rather than their physical characteristics.

Zhong *et al.* (2005) evaluated the deterioration of eating and cooking quality caused by high temperature on four cultivars with 22°C and high (32°C) temperature regimes. High temperature decrease or kept stable gel consistency values for cultivars with higher amylose content and increased gel consistency values for those with lower amylose content. High temperature significantly increased the gelatinization temperature of all cultivars. It was proposed that the high temperature during grain-filling affect the structure of starch and result in decline of eating and cooking quality.

Lii *et al.* (1996) suggested that waxy rice starch with very low amylose content, the crystalline structure was easily destroyed. The starch granule also absorbed much water, exhibiting high swelling power. It was assumed that the rigidity of starch granule was in inverse proportion to the swelling power and was dependent on the amylose content. It was concluded that the major influencing factors on the rheological property of the starch during heating were the granular structure and component, followed by the amount of leached-out amylose. The quantity of starch and protein play very crucial role in the yield and quality of rice. Duan and Sun *et al.* (2005) observed that the amylose content of starch is a determining factor in cooking quality, while the amount of essential amino acids balances the storage proteins which affect the nutritional quality of rice.

It was also reported that glutinous cultivars had intermediate and high digestibility in alkali solution, while non-glutinous rice cultivars with intermediate and high amylose contents were resistant to disintegration of starch granules in alkali solution (Prathephaa *et al.*, 2005). Waxy rice has very little amylose and cooked milled waxy rice is extremely soft and sticky. When the bran is left on, waxy rice is slightly chewy and flavorful (Bergman *et al.*, 2000).

Sanchez *et al.* (1987) reported that only the intermediate and high-amylose rice showed intermediate gelatinization temperature (GT, alkali spreading value 4-5). Gel consistency was soft (>60 mm) for waxy and low amylose rice, medium (41-60 mm) for intermediate amylose rice and mostly varied for high amylose rice. Recently, degree of polymerization is used to measure GT variations between waxy varieties observed closely related to the structural differences in the amylopectin of the starch (Patindol and Wang, 2002; Qi *et al.*, 2003).

Phenotypic and genotypic coefficients of variation (PCV and GCV) for various quality traits were largely similar. Highest PCV and GCV were noted for alkali-spreading value. Characters like water uptake, L/B ratio of grain, and volume expansion also showed relatively high GCV and PCV (Vanaja and Babu, 2006).

Hussian *et al.* (1987) reported that each quality characters are less influenced by environment, but more associated to phenotypic and breeding values. Likewise, high expected genetic advance for alkali spreading value (ASV), water uptake, kernel L/B ratio, amylose content, percentage of milling and volume expansion ratio suggest that improvement should be made by selection from segregating populations. The high heritability and high expected genetic gain coupled with moderate genotypic coefficients of variation (GCV) exhibited by these characters imply that these are under additive gene effects and could be relied upon for further selection based on phenotypic performance. It has been studied by Kudo (1968), as single gene *(alk)* mapped on chromosome 6 is related for ASV dissimilarity rice crosses of *indica* and *japonica*.

Danbaba *et al.* (2011) evaluated the cooking and eating quality of *Ofada* rice having grain elongation ratio of 1.24-1.75. The highest length/width ratio of cooked rice was from 2.49-3.68, the water uptake (174-211 ml), cooking time (17-24 min.) and amylose content ranged from 19.77-24.13%. This study showed that there was significant positive correlation between amylase content and water uptake, while significant positive association was observed between length/width ratio and AC.

Kang *et al.* (2011) estimated the physicochemical properties and palatability of rice from six elite varieties in Korea. The results suggested that 17-18 g/100g rice starch amylose content belong to low amylose group. Among the studied varieties, Hitomebore had high essential amino with low mineral content. Variety Mihyangbyeo computed the high amount of protein content 8.10 g/100 g, pasting temperature 82.7°C and cooking time 3.78 min. Potassium have negative correlations with palatability, which help gelatinization characteristics estimation of eating quality. Nadaf and Krishnan (2005) studied starch gelatinisation pattern in rice grain.

2.4. Rice Grain Quality - Cooking Characteristics

The texture of food, together with its appearance, determines its consumer acceptability. Rice texture has been usually evaluated with taste panels. However, taste panels are time consuming, require large samples and have no fixed point of reference. In recent years, a number of methods using instruments have been developed for assessing rice texture. Some of these are based to assess cooked rice hardness and stickiness. In addition to studies carried out in many world Rice Research Centers, it would be useful to evaluate the relationship between cooked rice texture and amylose content using large range of rice varieties and breeding lines. Hardness of cooked rice showed positive correlation with amylose content, but provided more alkali spreading values at intermediate and high amylose rice and less ASV in low amylose rice. Juliano *et al.* (1981) suggested that varietal differences in the texture of cooked rice of similar amylose content are probably related to differences in hardness, since the range of stickiness values is narrow, except low amylose rice. As major rice varieties grown in Spain are low amylose rice, the stickiness of cooked rice is more useful test for texture differences among varieties of similar amylose content. The cooking and eating qualities of rice have been attributed to starch as amylose and amylopectin are the two basic starches that make up the rice endosperm. This macromolecules ratio causes the main differences in starch composition that control the physicochemical and metabolic properties of rice. Amylose is fundamentally a linear molecule in which D-glucose units are linked by linear α-1,4 glucosidic bonds, while amylopectin, a branched polymer, contains both α-1,4 and α-1,6 bonds. Frei *et al.* (2003) studied differences in amylose and amylopectin macromolecules ratio in rice kernels and it varies from waxy (1-2% amylose), very low amylose content (2-12%), low amylose content (12-20%), intermediate amylose content (20-25%) and high amylose content (25-33%). Amylopectin, is made up of branched chains of glucose molecule, easily digested than amylose. Long grain rice has more amylose and is less sticky than medium and short grain rice which tends to have increasingly higher amylopectin content. Sticky or glutinous rice has very low amylose. Though, rice varieties with similar amylose content also vary in cooking quality and time (Juliano, 1998; Patindol and Wang, 2002). As we know, amylose content is considered important for cooking quality, but other component viz. protein, amylopectin and lipid also plays an important role (Hizukuri, 1986; Tester and Morrison, 1990). Bhattacharya (2009) observed that the differences in structural and composition of starch are linked with the cooking and eating characteristics which consist of amylose and amylopectin.

Low temperature storage at -20°C does not affect most of the rice properties such as milling yield, quality parameters, water absorption, cooking time and pH. It is evident from the study that low temperature technique is very useful for storage of rice (Parkash *et al.,* 2001). Otegbayo *et al.* (2001) reported that the parboiling decrease the breakage of rice kernel, fat, protein and amylose content, where as an increase in the cooking time, water uptake and thiamine contents.

Shahidullah *et al.* (2009) studied the genetic divergence in scented rice for grain quality and nutrition feature. Total of 40 genotypes, consisting of 32 local scented 5 exotic scented and 3 non-scented rice varieties. Major differences between grain length and breadth (L/B) ratio, kernel weight, milling yield, kernel length, L/B ratio of kernel, volume expansion ratio (VER), protein content, amylase content, elongation ratio and cooking time were observed. The most of the local aromatic rice were characterized by lodging susceptible plant with smaller grain size. Rice varieties like, Elai, Sarwati and Sugandha-1 are with medium plant height and good appearances and used in germplasm improvement.

Cai *et al.* (2011) studied grain formation phase to understand differences in grain quality between two non-waxy rice cultivars (Wuyujing3 and 30you917) with similar amylose content. He noted that there variation in their apparent amylose contents from 5 days after anthesis (DAA) to 15 DAA was significant but not significant in the late grain filling stage. Variety Wuyujing3 showed a slower increase in grain weight and was sticky than 30you917 from 10 to 25 DAA. This suggested that the differences in cooking and eating quality parameters of the two matured rice were determined by the differences in grain-filling and the dynamic changes in the main rice quality components such as amylose content, grain weight and differential scanning calorimetry and rapid visco analyser (RVA) properties, which will help cultivators to understand the physical basis of rice quality.

In cooking quality, the gelatinization temperature (GT) is very important parameter. During increase in temperature the starch granules irreversibly lose their crystalline order which happens during cooking (Parker and Ring, 2001). GT are calculated ultimately depending on the digestibility of milled rice kernel in alkaline solution and scored the alkali spreading value (ASV). The disintegration of rice kernels in alkaline solutions is linked with the cooking properties and the GT of milled rice (Little *et al.*, 1958; Juliano *et al.*, 1964).

Bhattacharya (2011) reported that native and local rice germplasm have been constantly used by the breeders to increase yield in rice. The physiochemical properties like increased head rice recovery, low broken rice, best cooking time, nutrient value and aroma, taste are very important. The desired characteristics are attained with breeding for specific properties like uniform flowering and short panicle length which help in reducing milling breakage. To reduce the wide grains i.e. the kernels >2.3 mm wide which induces more frequency of chalkiness (white belly) and increase grain cracking. Breeding helps in selection for crack resistance, hard kernels with shallow ridges and low husk content which in turn reduces grain breakage and increasing milling yield. Close palea and lemma interlocking help in insect resistance. Proper chemical and physical properties are necessary for puffed rice, popped rice for better end products.

2.5. Biochemical Characteristics

Kwarteng *et al.* (2003) assessed the rice grain quality of Ghana, 10 breeding lines were compared with 10 local varieties. Shape and size (L/W 3.12), good endosperm appearance and milling quality (67.2%) with high amylose content (22.87-30.78%) was found in breeding lines than local varieties. But the local varieties had low broken rice (22.50%), higher protein (6.78–10.50%), water soluble proteins (0.21–0.49%), ash (0.48–0.67%) and minerals (K and Ca) contents. It was concluded that the local varieties exhibited nutritional superiority especially potassium, calcium and protein contents and this varieties should be given attention since they form a rich resource for incorporation into rice breeding programmes.

Lu *et al.* (1997) identified the major source of carbohydrates mainly in the form of starch which constitutes 90% in milled rice. Brown rice has less starch compared to milled rice, but the physicochemical characters like pasting, rheological and thermal are related to rice starches. physicochemical properties of rice starch varies with variation in starch granule size, shape, presence of phosphate esters, relative proportion of amylose and amylopectin, their chain length distribution and occurrence and spacing of branched points in amylopectin molecule.

2.6. Minerals in Rice Grain

Jiang *et al.* (2007) studied the relationship among 274 genotypes of K, Ca, Na, Mg, Fe, Zn, Cu and Mn in milled rice with three cooking quality traits and protein and amino acid content. The study showed significant correlations among Mg, Fe and Mn contents with other mineral element, where as Cu showed significantly negative correlation with Mg and K contents. The associations among the mineral contents and cooking quality revealed that the gel consistency (GC) was significantly correlated with Cu, K and Mn contents, where as amylose content (AC) was significantly associated with K, Na, Mg, Cu and Mn contents. The alkali spreading value had positive correlations with Ca, Mg and Mn contents. These correlations may assist future selection of appropriate rice genotypes for specific nutritional needs.

Silva *et al.* (2003) developed method for calculating iron (mg) in rice plants using graphite furnace atomic absorption spectrometry (GFAAS) and the method was highly sensitive with micro-sampling capability. Four micro-methods was investigated, but direct solid sampling analysis gave better results, the slurry technique with ultrasonic treatment to samples was suspended in dilute nitric acid was accepted and tested to determine the iron in leaves and roots in two rice varieties (one variety sensitive to iron toxicity and another resistant to iron toxicity). These results suggest that the iron toxicity is directly related to uptake and accumulation of this metal by the plant where as the second cultivar is due to a smaller uptake of iron from the soil, resulting in lower iron levels in all compartments of the plant.

Crusciol *et al.* (2008) studied the milling, protein and nutrient contents in polished rice from upland rain-fed and sprinkler irrigation. Sprinkler irrigation increased both percentage of milling and head rice yield. Lower water availability promoted increased protein, N, P, Ca, Mg, Fe and Zn levels and reduced S and Cu levels in polished grains. When cropping systems was compared with upland rice polished grains, the nutrient levels was calculated in increasing order N > Ca > P > S>K > Mg > Zn > Fe > Mn > Cu for both cultivars. Minerals and quality of grain are an important parameter to determine market value which influenced by water availability and type of rice cultivars.

2.7. Chalkiness in Rice Kernels

In rice, chalkiness is a major problem which determines the physical, chemical and cooking characteristic of the grain. The chalky grain is concern in hybrid and breeding program as important feature in determining the quality and price (Xu *et al.*, 1995; Liao *et al.*, 1999) as consumers prefer rice with low chalkiness or free of opaqueness and translucence grains. The chalky grains showed the loose packing of starch granules compared to non chalky grains and are therefore more prone to breakage during milling (Del Rosario *et al.*, 1968). Chalkiness in rice is mainly of three types white belly, white back and white core (Del Rosario *et al.*, 1968; Satoh and Omura, 1981; Tan *et al.*, 2000; Li *et al.*, 2008). The cellular morphology of chalky rice endosperm depends on the genetic and environmental condition and also affects the grain-filling during the development of grain (Yamakawa *et al.*, 2007; Lisle *et al.*, 2000). Due to chalkiness, during cooking cracks develop which decrease the quality the cooked rice (Nagato and Ebata 1959; Cheng *et al.*, 2005). Chalky grains contain loosely packed starch granules in the endosperm are useful in the production of rice wine (Hoshikawa, 1989). Chalkiness formations more specifically proposed to be induced by increasing temperatures during critical development stages of rice (Cooper *et al.*, 2008; Fitzgerald and Resurreccion, 2009) and during the ripening period (Tashiro and Wardlaw, 1991). As the high temperature increase the amount of chalkiness the effects are observed during hulling and milling (processing) of rice grain result in low head rice recovery and increase the broken rice (Xu *et al.*, 1995; Liao *et al.*, 1999, Tashiro and Wardlaw, 1991).

There is no standard method to study chalkiness rather than human visual inspection. Yosuke *et al.* (2007) made an attempt to classify the chalky grains into different categories based on the effectiveness of image information processing with a digital image scanner to measure the chalkiness. This method of analysis supported the image data generated an accuracy of about 90 percent in accuracy with that of human visual inspection of chalkiness, and principal-components analysis of the image data provided new quantitative variables related to the location and degree of chalkiness with much greater. These results indicated that image processing may be a useful tool for evaluating the chalkiness of rice in scientific research and breeding programs.

Chalky rice grains are proven to crack longitudinal and transverse easily during cooking, thereby reducing the palatability of cooked rice (Nagato and Ebata, 1959). Nadaf and Krishnan (2001, 2002) studied the effect of cooking on aleurone in the caryopsis of *indica* rice and aleurone thickness and its relation to patterns of breakage of rice caryopsis during cooking. Ashida *et al.* (2009) observed the differences in the chalky rice grain, packing of amyloplasts was irregular with air spaces in the rice endosperm and thus the chalkiness formation occurs during the period of grain filling. Chalkiness occupy >50% of the area in the grain, mainly occurs from the centre and make the rice grain opaque (Lisle *et al.*, 2000). Chalkiness decreases the grain quality and reduces the market value. Chalkiness is a major problem not only in traditionally cultivated rice varieties but also in high yielding and hybrid rice varieties. The differences in percentages of chalkiness play an important role in assessing the rice grain appearance and quality. Percentage of grains with chalkiness (PGWC) is an undesirable character and concern in rice breeding as the increase amount of chalkiness decreases the market value (Yosuke *et al.*, 2007). To overcome this difficulty, rice breeders and scientists are carrying out various studies to better understand the genetic and physiological mechanisms that govern the chalkiness (He *et al.*, 1999; Tan *et al.*, 2000; Patindol and Wang, 2003; Cheng *et al.*, 2003; Lin *et al.*, 2005; Tabata *et al.*, 2005; Wan *et al.*, 2005). Chalkiness is a major concern in rice breeding because it is one of the key factors which determining quality and price. Chalkiness affects the appearance and qualities of milled rice are the main characters determining grain price. Chalky grains tend to be broken easily during processing, which results in low head rice rate (Xu *et al.*, 1995; Liao *et al.*, 1999). The chalky appearance is associated with the development of numerous air spaces between loosely packed starch granules and the resulting change in light reflection (Tashiro *et al.*, 1991; Chun *et al.*, 2009).

Chun *et al.* (2009) investigated the ultra-structure of chalky grains. The chalky grains were significantly different from that of head rice. Chalky grains had more air spaces, a disordered cellular structure and rounder amyloplasts. Absorption of water is more rapid while cooking and volume expansion was little larger and confirms the loose starch granule than the translucent grains. As amylose is 1,4 linked glucose units with a small number of branches, a linear molecule and in endosperm of rice grain it is synthesized by a granule-bound starch synthase (GBSS), a product of the waxy gene. The lesser amylose content of chalky grains have high soluble solid and more iodine index, while cooking signifying the lower eating properties when compared to translucent kernels. The shorter branch chain amylopectin structures are related with lower gelatinization temperature of chalky kernels. Chalky kernels resulted in low protein content and are less sticky with a harder texture requiring little more time for chewing than the translucent grains. Linear decrease was observed with the increasing chalky rice proportion in the sensory evaluation in the palatability of cooked rice. It was proposed that the chalky grains induce quality deterioration and it was observed that the amylography peak and final viscosities greatly decreased. The chalky grains have less amylose in turn contained more amylopectin with much more short chain amylopectin (Patindol and Wang, 2003). Gelatinization temperature and the eating properties of the grains are related to water absorption (Choi *et al.,* 1999).

Ishimaru *et al.* (2009) studied the water distribution in the developing stages of rice by magnetic resonance imaging with increasing temperature. In the milky and white cored type of chalky grains, chalkiness noted around the centre of the endosperm. This chalkiness was created during high-temperature condition. When observed in SEM, a decrease content of water around the centre of the endosperm with disorganized development of amyloplasts was seen. A transcript for α-amylase was not located during the early and middle stage. This concluded that starch degradation by α-amylase was not related with chalky grains. During middle stage, water content in the central chalky grain was high than the lateral translucent area. The amyloplasts loosely packed in chalky grain allowed pooling of water in the empty space with high water content after the middle stage. This resulted that physiological mechanism for the formation of chalkiness occurred by high-temperature stress. Studies by He and Suzuki (1989) showed that the accumulation of starch was faster around the centre of the endosperm till the middle stage during development of the caryopsis, producing large amyloplasts, whereas in the lateral part, starch accumulation proceeds at a slower rate with the formation of smaller amyloplasts.

Yun *et al.* (2010) evaluated the chalkiness formation during rice grain development on physiological basis. The formation of chalkiness was investigated by taking six mutants with 80% from T-DNA insertion mutant pool of cultivar Nipponbare with chalkiness resulted from genetic factors. During the whole grain-filling period the wild type was compared with, mutants *mu1* and *mu2* was having low activities of sucrose synthase (SS), early grain-filling stage had higher activity of adenosine diphosphoglucose pyrophosphorylase (AGPase) and in late grain-filling stage higher activities of SS I and total soluble starch synthase (SSS). White belly grains were seen in 6 mutants with no differences, compared with wild type after iodine staining. In Mutants *mu2* and *mu5* fructose, sucrose and total soluble sugar content were higher than in wild type. Mutants, *mu3* and *mu6* had less activities of SS I, total SSS, pullulanase, isoamylase during early filling stage and higher isoamylase activity at late filling stage than the wild type. When compared with wild type, during early and middle stages of grain filling, mutants *mu4* and *mu5* exhibited higher SS activity and lower activity of total SSS during the whole grain-filling period.

Zhou *et al.* (2009) used a set of chromosome segment substitution lines, made from a cross between cv. PA64s and cv. 9311 and showed inheritance of percentage of grains with chalkiness (PGWC) by designating two loci controlling PGWC as qPGWC-6 on chromosomes 6 and qPGWC-7 on chromosomes 7. Chalkiness was compared between the

C-51 (chalky endosperm) and 9311 (translucent endosperm) where the chalky endosperm contains loosely packed starch granules, and differences in amylopectin structure and degree of crystallinity was noted, but no differences in amylose content or starch viscosity. Later the F2 population (C-51 X 9311), had PGWC a semi-dominant trait which was controlled by single nuclear gene and used for fine mapping of qPGWC-7, which was located to a 44-kb DNA fragment, suggested 13 possible genes.

Chalkiness in rice kernels is an unattractive and undesirable trait which degrades the visual appearance and cooking quality of milled rice before and after cooking. The quick diffusion of water in chalky grains while cooking is due to the presence of air spaces and a disorganized cellular structure which takes less time in cooking time than the counterpart translucent grains (Lisle *et al.*, 2000; Singh *et al.*, 2003). Chalkiness decrease Head rice yield (HRY) as chalky kernels tend to prone more to breaking during milling than translucent kernels (Webb, 1991; Siebenmorgen and Qin, 2005). Bautista *et al.* (2009) suggested that the place of rice cultivation and years drastically affect the kernel chalkiness level. Rice susceptibility to chalkiness development was attributed to the cultivar's inherent genetic response to different environments during developmental stages therefore it inversely and linearly correlated to head rice yield (HRY). Some rice varieties are resistant to chalkiness and have good milling qualities (Cooper *et al.*, 2008). Yamakawa *et al.* (2007) reported that the rice grain chalkiness is influenced by cultivar genetics and environment. Standardization of cooking is required to evaluate the rice texture. While cooking end point differ as some utilize the disappearance of the chalk in excess water or others use to set cooking time or fixed rice to water ratio (Juliano *et al.,* 1981).

Horigane *et al.* (2006) studied using the three-dimensional gradient echo magnetic resonance imaging, the water penetration during soaking in the rice kernel. When the comparative study was conducted between milled and brown rice kernels, in milled endosperm water first go through the ventral side, moves to the embryo site, then migrated along the transverse fissure and later diffused to entire endosperm. In milled chalky grains water rapidly creep into the cracks on the dorsiventral line and then diffused to the lateral side, but in brown rice water penetrated very gradually and did not infiltrate directly into transverse cracks or the white core due to reserve by pericarp and seed coat. The water penetration is related with the packing of the starch granules. White-core (chalkiness in centre) and white belly (chalkiness in peripheral) chalkiness differ with location and high-temperature stress as starch is accumulated around the centre of the kernel from early to middle stages and at the periphery at the late stage (Tsukaguchi and Iida, 2008). In rice, there is a rapid grain filling rate at early grain filling stages where as when compared to late grain filling stage the grain filling is slow and this support the formation of chalky grains (Raju and Srinivas, 1991; Zhu *et al.*, 2000).

Li *et al.* (2011) studied the effect of grain quality and seed protein accumulation profiles of grain filling in *indica* rice '9311' during the night high temperature (NHT) and day high temperature (DHT). The above treatment cause the decrease of the grain weight, brown rice, milled rice, head rice, AC and GC, while increasing particularly chalkiness degree which achieved up to 6.7 fold relative to the control. NHT have less effect on rice grain characteristics and chalkiness compared with the DHT with greater effect on grain weight. The proteomic study was conducted for the dynamic accumulation variation of 61 protein spots, explained the different suppression level of accumulation of chalkiness between NHT and DHT. Therefore, the high temperature has adverse effects on rice yield and quality.

Moisture content in grain, number of immature grains, cracked grains and chalky grains differ from field to field, at any time from plant to plant, tiller to tiller, panicle to panicle. Fissures are cracks in the rice kernel. During milling, kernels with fissures tend to break, causing lower head rice in total percentages. Sun drying, endosperm tissues of rice are destroyed slightly and stress cracks were produced. Stress cracks are produced in a combination of areas between the seed capsule and endosperm of rice. Stress cracks and ruptures were not produced in the rice embryo tissue. Stress cracks on the surface of rice are not observed by light box method, but by Scanning Electron Microscope. Some stress cracks are inside the endosperm, the length and width of cracks were smaller. Stress cracks were produced in the center of the endosperm tissues and propagated along the seed capsule, the boundary of propagation was near the protein. When stress cracks were produced, only endosperm tissues on both sides of cracks were destroyed, but the tissues in other areas stayed intact. Propagating routes of stress cracks inside rice are to pass through cell walls, and then propagate along the edges of starch granules. A part of stress cracks were not only propagated along edges of starch granules, but also propagated through the interiors of starch granules and tore some starch granules (Li *et.al.*, 2007; Mahadevappa *et al.*, 1969; Bhattacharya, 2011). In general, crack formation of rice grains, which is a cause of the unfavorable conditions, cracked grains occurs when rice plants are subjected to natural weathering in the field far after the maturing stage or when rice grains dry rapidly in the drying machine. Crack formation occurred more at the top part of panicles than the middle part of panicles and the varietal differences varied more at the top part of panicles than the middle part of panicles (Tadashi, 2002).

Ripening under high temperature, results in the occurrence of grains with various degrees of chalky appearance and decreased weight. Among them, severely chalky grains contained amylopectin enriched particularly with long chains compared to slightly chalky grains, suggesting that such alterations of amylopectin structure might be involved in grain chalkiness. Further differentiation of dissecting structure of rice dorsal vascular bundle may be relative to formation of chalkiness (Yang *et al.*, 2005).

Hakata *et al.* (2012) showed that the high temperature during grain filling in rice reduce the formation of starch resulting in chalky grains. Such type of decline of grain quality is accompanied by the changed expression of related genes for starch metabolism and reported that starch hydrolyzing enzyme (α-amylase) in high temperature triggered grain chalkiness. Zhu *et al.* (2012) used the high resolution X-ray microtomography (XMT) compared with SEM to study transgenic rice with high amylose rice and its wild type rice. SEM expose 2-D microstructure with high-resolution of high amylose rice and wild type rice, while XMT is better which had full 3-D characterization. Air space distribution was not uniform in the high amylose rice kernel. XMT is used for the whole kernel without taking section or cutting and exposed air spaces were not uniformly distributed in high amylose rice. High amylose rice were opaque detected with more air spaces with smaller, elongated starch, wild type rice was translucent with little air space and polygonal starch granules.

The differences in the variety and their packing of the amylopectin structure is due to the chain length differences and they play an important role in the physicochemical properties of the starch and the developmental stages of rice endosperm and differences in the starch is present due to the degree of divergence expression of various isoforms of starch biosynthetic enzymes (Tang *et al.*, 1989; Shobha Rani *et al.*, 2006). Starch have two component, amylose and amylopectin which control rice cooking and textural quality and this is control by several enzymes of various isoforms. Various activities of different isoforms of starch-synthesizing enzymes results in various forms of starch structure based on the amylopectin chain length and average external, internal and core chain length distribution and hence results in varying physicochemical and cooking quality. Pandey *et al.* (2012) reported the effect on rice physicochemical, cooking and eating qualities and relation of various isoforms towards rice starch synthesis by mapping the gene/QTLs and provided the relationship between the physicochemical and cooking properties by transform the allelic pattern. The tissue specific organization among enzyme isoforms controlling eating and cooking properties through combining desired alleles. Kang *et al.* (2005) SEM studies revealed that these abnormal endosperm chalky grains consisted of loosely packed starch granules.

2.8. Rice Grain Structure, Development and Storage Compounds

Krishnan and Dayanandan (2003) studied the structure and development of rice grain from anthesis to maturation and grain-filling in the caryopsis of rice (*Oryza sativa*). The study revealed that the nutrients are transported to the endosperm through a single ovular vascular trace present on the ventral side of the ovary. During the early stage of development, solute enters through the chalaza into the nucellar projection and then into the endosperm. In the mature stage, transport of nutrients occurs through the nucellar epidermis, centripetally towards the endosperm. The cell walls of the nucellar epidermis are provided with rib-like thickenings. A comparison of grain-filling in C_3 and C_4 cereals suggested that rice has structural features close to wheat, however, with significant differences. Krishnan *et al.* (2009) reported the structure of rice caryopsis in relation to distribution of micronutrients in polished, unpolished *indica* and *japonica* rice varieties and transgenic rice grains.

Krishnan *et al.* (2001) localized major storage compounds such as protein, lipid and starch during various developmental stages of caryopsis and minerals like calcium, potassium and iron in matured rice grain using specific fluorescent, non-fluorescent dyes and biochemical techniques. Vasconcelos *et al.* (2003) expressed iron and zinc in the endosperm cells of rice grain through transgenics using endosperm specific promoters. During this study many transgenic lines were developed with enhanced iron and zinc level in the endosperm. Krishnan and Dayanandan (2003) localized tissue specifically the iron and β-carotene in transgenic and non-transgenic rice grains. The study revealed that iron in non-transgenic rice grain iron is restricted only in the aleurone and embryo, while in transgenic rice grain iron was localized in the entire endosperm other than in aleurone and embryo indicating the expression of iron in the endosperm of transgenic rice. Iron was also localized in transgenic Pusa Basmati rice varieties, the study revealed the deposition of high iron in the embryo and endosperm of transgenic rice grains while in non-transgenic rice showed no iron in the endosperm, less amount of iron in embryo and aleurone layer (Sivaprakash *et al.*, 2006; Krishnan *et al.*, 2009).

2.9. Molecular Genetic Diversity Studies

Quantification and characterization of genetic diversity has major goal in evolutionary biology. For the rational use of genetic resources, genetic diversity studies among the closely related varieties are essential. The analysis of genetic variation both within and among elite breeding materials is of fundamental interest to plant breeders. It contributes to monitoring the germplasm and can also be used to predict potential genetic gains (Chakravarthi and Naravaneni, 2006).

The molecular markers provide a valuable tool to improve genetic diversity and population differentiation in species with the rapid development of markers (O'Hanlon *et al.*, 2000). Recently, simple sequence repeat (SSR), inter simple sequences repeat (ISSR), microsatellites markers are frequently used as allele-specific and co-dominant markers to study the genetic diversity and evolutionary relationships in different species (Song *et al.*, 2003). More recently, SSR markers are more used as they are more informative, monolocus, co-dominant and simple to analyze (Chambers and Avoy, 2000; Gracia *et al.*, 2004).

Zietkiewicz *et al.* (1994) first published a paper describing the ISSR technique which utilizes repeat anchored primers for amplifying DNA sequences between two inverted simple sequences repeats. These have high annealing temperature with longer sequence of ISSR primers which yield reliable, reproducible bands and low cost. As a result, ISSR primers have recognized wide relevance in genetic diversity studies in a wide range of plant species. Bernardo (2008) reviewed the development in molecular markers and said that molecular markers related information is easily accessible and the benefit of low cost of this technique need to be taken as advantage and used for genotyping.

Vanniarajan *et al.* (2012) studied the genetic diversity of rice genotypes from Tamil Nadu, *indica* and *japonica* cultivars were used. The study was carried out using highly polymorphic microsatellite markers and allele discrimination index was calculated in subpopulation. It separated *indica* and *japonica* genotypes forming two distinct groups concluded that genotypes *indica* had two subpopulations within. The association analysis revealed nine marker trait associations with three agronomic traits, of which 67% were previously reported. The study concluded that testing landraces and cultivars opened a avenue for genome wide association mapping. Sun *et al.* (2001) studied the genetic diversity between Asian cultivated rice and wild rice using RFLP markers and reported that genetic diversity of wild rice was higher than that of cultivated rice, similarly, the genetic diversity of *indica* was higher than that of *japonica*.

Shylaraj and Sasidharan (2005) studied variety VTL 5 (Mahsuri mutant) in relation to salinity, acidity and submergence tolerant. This variety VTL 5 was grown in pokkali lands of Ernakulam and Alappuzha district, which is tall, medium duration, white kernel and high yielding (~3500 kg/ha) without chemical inputs. In pokkali lands, the daily tidal inflows and outflows, with large quantities of organic matter making the land fertile but pokkali farmers where gaining ~2000 kg/ha which were unprofitable. Hence four pokkali rice VTL 1 to VTL 4 were released from the Rice Research Station, Vyttila (Kerela). The pokkali system of rice cultivation in the acid saline soils of Kerala is a unique method, similarly in Goa the khazan lands are unique, salt tolerant rice varieties such as Korgut, Assgo and Muno are cultivated (Bhonsle and Krishnan, 2011).

Random amplified polymorphic DNA (RAPD), the molecular marker techniques were used effectively for genetic diversity in diverse species including rice, yet it has quite a few limitations like dominance, uncertain locus homology, sensitivity to reaction conditions and low reproducibility. These problems can overcome with inter-simple sequence repeat (ISSR) amplification to assess genetic diversity (Qian *et al.,* 2001; Ajibade *et al.*, 2000; Galvan *et al.*, 2003) and concluded that the ISSR are improved tool than RAPD for phylogenetic studies. ISSR primers have been extremely helpful in detecting genetic diversity and population study of barley (Hou *et al.*, 2005), capsicum (Ruanet *et al.*, 2005), rice (Ravi *et al.*, 2003), common bean (Marotti *et al.*, 2006) and orchids (Parab *et al.*, 2008; Parab and Krishnan, 2008).

Girmal *et al.* (2010) used inter simple sequence repeats for studying genetic diversity of three wild and three cultivated rice varieties of Ethiopia. A total of 93 reproducible bands were generated using four dinucleotides and two tetra nucleotide primers. Based on UPGMA, the dendrogram showed six clusters depending on populations of origin. Semagn *et al.* (2006) reported that the *Oryza glaberrima*, *Oryza sativa* and NERICA-3 (derived from inter-specific hybridization between *O. sativa* and *O. glaberrima* then backcrossed with their *O. sativa* parents), clustered as one group, while *Oryza barthii, Oryza longistaminata* were clustered in another group, this is due to genetic admixture.

Kladmook *et al.* (2012) reported the genetic diversity between 126 rice varieties using DNA markers. Inter-simple sequence repeats (ISSR) and simple sequence repeat (SSR) markers were used. The results categorized the rice into two groups, *indica* and *japonica*. The dendrogram constructed revealed the studied rice varieties into five clusters.

Reddy *et al.* (2002) reported that the ISSR primers are used in genetic diversity, phylogeny, genome mapping and evolutionary biology studies. ISSR markers are beneficial (simple and high reproducibility) than microsatellites (SSRs), amplified fragment length polymorphism (AFLP) and random amplified polymorphic DNA (RAPD). ISSR primer are different in length, anchor and motif are feasible which are long about 16-25 bp and amplified products are usually 200-2000 bp long. This review provides an overview of the above technique and its application.

Joshi *et al.* (2000) used thirty ISSR primers to determine genetic diversity and phylogenetic relationships in 42 genotypes and 17 wild species of rice. These genotypes were with AA, BB, CC, EE, FF, GG, BBCC, CCDD, and HHJJ genomes and *O. sativa*, *O.*

glaberrima (AA). The consensus tree constructed and ISSR analysis showed genus *Oryza* have evolved from polyphyletic pathway viz. O*ryza brachyantha* (FF) is the most divergent species in *Oryza* and *Oryza australiensis* (EE) does not fall under the *Officinalis* complex. DNA profiles based on ISSR markers have revealed potential diagnostic fingerprints for various species and genomes. ISSR markers are used in fingerprinting and understanding the evolutionary relationships.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

The present study was carried out for the Ph.D. programme in the Department of Botany, Goa University during the period from July 2008 to June 2012. Detailed methodology used for the study is presented in this chapter.

3.1. Study Area

Goa is a small state with an area of 3,702 sq. km. and having length of 105 km. and width of 60 km. It is located between 73° 38'-74° 24' E longitudes and 14° 49'-15° 52' N latitudes. Goa is a part of the coastal territory known as Konkan. Goa's main rivers are Mandovi, Zuari, Terekhol, Chapora and Sal. River Zuari and Mandovi are the lifelines of Goa, covers a distance of 61.6 km and the river Zuari meanders through 34 km in Goa with their tributaries drain 69% of states geographic area. The total navigable length of Goa's river is 253 km (Rao, 1985; Naithani *et al.*, 1997).

Goa has a hot and humid climate, since in the tropical zone and near the Arabian Sea. During the monsoon seasons the rain arrive by early June and this marks the starting of rice cultivation in *kharif* season. The annual rainfall is received through the monsoon and which last till the late September followed by the post monsoon from October to November. Goa has a short winter season between mid-December and February with moderate amounts of humidity and the summer season is from March to May (Rao, 1985).

The state is divided into two districts, North Goa and South Goa. Panjim is the headquarters of the North Goa district, while Margao is headquarters of the South Goa.

The districts are further divided into twelve talukas. Talukas of North Goa are Bardez, Bicholim, Pernem, Ponda, Sattari and Tiswadi, while the talukas of South Goa are Canacona, Mormugao, Quepem, Salcete, Sanguem and Dharbandora (Figure 1) (Official Gazette, 2011).

3.2. Collection and Documentation of Rice Varieties from Goa

During this study, periodic field survey was carried out in all parts of Goa, for the collection of rice varieties. The traditionally cultivated rice varieties were collected from local farmers from the field, dried and stored. High yielding rice varieties and hybrid rice were obtained from the Indian Council of Agricultural Research (ICAR) Complex, Ela, Old Goa, Goa. Collected rice varieties were stored at room temperature as well as in the refrigerator conditions for further study.

3.2.1. Herbarium Preparation

The rice specimens of different varieties were collected from various parts of the study area and processed using the standard protocol described by Fosberg and Sachet (1965). The herbarium specimens prepared are deposited in Botany Department Herbarium, Goa University, Goa.

3.3. Rice Grain Quality - Physical Characteristics:

Samples were pre-cleaned thoroughly using winnower manually to remove the chaffy and other foreign particles including inorganic and organic matters. The inorganic matters like sand, gravel dirt, metallic pieces, lumps of earth like clay, mud and organic matters such as shall, husk, chaff, straw, weed seeds and other inedible grains were removed.

3.3.1. Hulling Percentage [Brown Rice (BR) Yield]

Desired 100 g of paddy was weighed and de-husked in a standard de-husker or sheller. After cleaning, the de-husked kernel (brown rice) was weighed and the percentage was calculated using the following formula (Anonymous, 2004).

$$\textbf{Hulling percentage: } \frac{\textbf{Weight of the de-husked kernel}}{\textbf{Weight of paddy}} \times 100$$

3.3.2. Head Rice Recovery (HR)

Depending on the size of the grains, 100 g of de-hulled rice grains that had no visible breakage (full grains) and ¾ sized grains were considered. The whole grains were separated from the broken grains and the percentage of head rice recovery and broken grains were calculated as per the following formula (Anonymous, 2004).

$$\textbf{Head rice recovery: } \frac{\textbf{Weight of the whole polished grains}}{\textbf{Weight of paddy}} \times 100$$

$$\textbf{Broken rice percentage: } \frac{\textbf{Weight of polished broken grains}}{\textbf{Weight of paddy}} \times 100$$

3.3.3. Grain Classification

De-husked brown rice was used for computing the grain shape and size. Minimum of 10 full grains per replication were measured using graph paper. Average length and breadth were taken in millimeter and length/breadth (L/B) ratio was calculated. Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB) (Anonymous, 2004).

Table 3. Systematic classification of grain.

Long Slender (LS)	Length 6 mm and above, length/breadth ratio 3 and above
Short Slender (SS)	Length less than 6 mm, length/breadth ratio 3 and above
Medium Slender (MS)	Length less than 6 mm, length/breadth ratio 2.5-3.0
Long Bold (LB)	Length 6 mm and above, length/breadth ratio less than 3
Short Bold (SB)	Length less than 6 mm, length/breadth ratio less than 2.5

For basmati rice the minimum grain length is 6.61 mm and above to be acceptable as Basmati. On the basis of average length of kernels, brown rice was classified into following International classification (Tables 4, 5).

Table 4. International classification for grain size, shape and appearance.

Scale	Size	Length (mm)
1	Extra-long	>7.50
2	Long	6.61-7.50
3	Medium	5.51-6.60
4	Short	5.50 or less

Table 5. Grain shape estimation by length/breadth ratio of kernels.

Scale	Grain shape	Length (mm)
1	Slender	Over 3.0
2	Medium	2.1-3.0
3	Bold	1.1-2.0
4	Round	1.0 or less

3.3.4. Chalkiness of Endosperm

The degree of chalkiness was determined using milled rice by observing under stereo-zoom microscope. Based on the observation the chalkiness of the endosperm was classified into white belly, white centre and white back (Anonymous, 2004). Degree of chalkiness is provided in Table 6.

Table 6. Degree of chalkiness in rice endosperm.

Abbreviation	Degree of chalkiness	Area of chalkiness (extent)
A	Absent	None
VOC	Very occasionally present	Small (less than 10%)
OC	Occasionally present	Medium (11-20%)
P	Present	Large (more than 20%)

3.3.5. Chalk Index Determination

Ten de-husked rice grains were placed on light box and visually identified the grain with more than 50% of chalkiness, weighed and percentage of chalkiness was calculated using the following formula (Anonymous, 2004).

$$\textbf{Chalkiness percentage: } \frac{\textbf{Weight of chalky grains}}{\textbf{Weight of 10 rice grain}} \times 100$$

3.4. Rice Grain Quality - Chemical Characteristics:

3.4.1. Alkali Spreading and Clearing Test

Six milled rice were taken in Petri plates in duplicate and 10 ml of 1.7% potassium hydroxide was added to the sample. Enough space was provided between the kernels and was kept undisturbed for 23 h in an incubator at 27-30°C. A standard variety was used as a check and all samples were evaluated in three replications. The spreading and clearing of kernels were noted on a 7 point scale and expressed as average of six kernels. Scoring was done as given below (Table 7) (Perez and Juliano, 1978).

Table 7. Spreading and clearing of kernels noted on a 7 point scale.

Scale	Spreading Scale	Clearing Scale
1	Kernel not affected	Kernel chalky
2	Kernel swollen	Kernel chalky, collar powdery
3	Kernel swollen, collar incomplete and narrow	Kernel chalky, collar cottony or cloudy
4	Kernel swollen, collar complete and white	Centre cottony, collar cloudy
5	Kernel split or segmented, collar complete and wide	Centre cottony, collar clearing
6	Kernel dispersed, merging with collar	Centre cottony, collar, cleared
7	All kernels dispersed and inter mingled	Centre and collar cleared

Based on the alkali spreading value, gelatinization temperature was determined (Table 8).

Table 8. Classification on the bases of gelatinization temperature (GT).

Classification	Alkali spreading value (ASV)	Gelatinization temperature(GT)
1-2	Low	High 75-79 °C
3-5	Intermediate	Intermediate (70-74°C)
6-7	High	Low (55-69°C)

3.4.2. Gel Consistency (GC)

Milled rice was ground to a fine powder using mortar and pestle, sieved with 1 mm sieve. 100 mg of rice flour was taken in long test tube (2×19.5 cm) in three replication and added 0.2 ml of ethanol containing 0.025% thymol blue. Then 2.0 ml of 0.2N potassium hydroxide (KOH) was added and mixed well using vortex mixture, kept in boiling water bath for 8 min., cooled for 5 min., mixed and kept in ice bath for 20 min. Later the tubes were removed, laid horizontally for one hour and measurements were made using graph paper. Length of the blue coloured gel from inside bottom of the test tube to the gel front was then measured as gel consistency of the sample (Bhattacharya, 1979). Classification of gel consistency is provided in Table 9.

Table 9. Classification of gel consistency test.

26-40 mm	Hard gel consistency
41-60 mm	Medium gel consistency
61-100 mm	Soft gel consistency

3.4.3. Amylose Content (AC)

In 100 ml volumetric flask, 100 mg of rice flour was taken and added 1 ml of 95% ethanol and 9 ml of 1 N NaOH, mixed well and heated in boiling water-bath for 10 min. Samples were diluted to 100 ml with distilled water. Later, 5 ml of sample suspension was added to 50 ml of distilled water in a 100 ml of flask and 1 ml of 1N acetic acid (57.75 ml of concentrated glacial acetic acid in one litre water) was added to acidify the sample along with 1.5 ml of iodine solution (0.2% iodine in 2% potassium iodide). Distilled water was added to make the volume of 100 ml and the suspension was mixed well and kept for 20 min. As a control, NaOH solution was used for the calibration of spectrophotometer and absorbance of samples were measured at 620 nm. Samples with known values of high, medium and low AC were used to draw the standard AC curve. The AC of different varieties was calculated in comparison with standard graph and classified (Table 10) (Perez and Juliano 1978).

Table 10. Classification of amylose content.

Waxy	1-2%
Very Low	2-9%
Low	9-20%
Intermediate	20-25%
High	25-33%

3.4.4. Aroma

5 g of rice samples were taken in test tube (200 mm x 35 mm), added about 15 ml of water and soaked for 10 min. Samples were cooked in the water bath for 15 min. Transfered the cooked rice into a Petri plate. After cooling, samples were kept in the refrigerator for 20 min. Then the Petri plates were opened and the contents were smelled by a random panel: strongly scented (SS); mild scented (MS); non-scented (NS). The samples possessing the scent, as one could easily feel, produce a sharp and readily recognizable aroma (Anonymous, 2004).

3.5. Rice Grain Quality - Cooking Characteristics:

3.5.1. Volume Expansion Ratio and Elongation Ratio

15 ml of water was taken in 50 ml graduated centrifuge tubes and 5 g of rice sample was added. After adding 5 g of rice, initial increase in volume was measured (Y) and soaked for 10 min. Increase of volume before cooking was noted (Y-15). Rice samples were cooked for 20 min on a water bath and placed on a blotting paper. Ten cooked rice

kernels were selected (intact at both ends) and length of the kernels measured using graph paper for computing the kernel length after cooking (KLAC). Then all the 5 g of cooked rice were placed in 50 ml water taken in 100 ml measuring cylinder and increase in volume of cooked rice in 50 ml of water was measured (X). Later, the volume raise was recorded (X-50). Then volume expansion ratio and elongation ratio were calculated (Anonymous, 2004).

Y = Increase in volume after adding 5 g of rice

Y-15 = Increase in volume before cooking

X = Increase in volume of cooked rice in 50 ml of water

X-50 = Increase in volume after cooking

$$\textbf{Volume expansion: } \frac{\textbf{Increase in volume after cooking (X-50)}}{\textbf{Increase in volume before cooking (Y-15)}}$$

$$\textbf{Elongation ratio: } \frac{\textbf{Kernel length after cooking (mm)}}{\textbf{Kernel length before cooking (mm)}}$$

3.5.2. Water Uptake

2 g of rice samples were taken in graduated test tubes with 10 ml of water and soaked for 30 min. Boiled for 45 min at 77 to 80°C in a constant temperature water bath. 2-3 test tubes were kept with 10 ml of water as control in a water bath without rice grains. Immediately the tubes were placed in a beaker containing cold water for cooling. The supernatant were poured into graduated cylinder, after cooling and the water level was

noted. Similarly water level of control was also measured. Water uptake was calculated using the following formula (Anonymous, 2004).

Water uptake = 100 /2 g × actual water absorbed

3.5.3. Organoleptic Test

5 g rice samples were taken in a test tube then 15 ml of water added and soaked for 10 min. Rice samples were cooked in water bath for 15 min and transferred into a Petri plate and scored as per panel test performance (Anonymous, 2004).

3.5.4. Statistical Analysis

Experiments were carried out using three replicates. The data was statistically analyzed using WASP-Web Agri Stat Package 2.0 for significance and STATISTICA 6.0 (Statistica Stat Soft, Inc.) for correlation and Principle Component Analysis (PCA).

3.6. Biochemical Analysis:

3.6.1. Total Carbohydrates

In a boiling test tube 100 mg of rice samples were taken and hydrolyzed by keeping in a boiling water bath for 3 h with 5 ml of 2.5 N HCL, cooled to room temperature. Samples were neutralized with solid sodium carbonate until the effervescence ceases. Later, volume was made to 100 ml and centrifuged. Supernatant was collected and 0.5 and 1 ml aliquots were taken for the analysis. The standard was prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml from the working standard, 0 served as blank. Volume was made to 1 ml in all the test tubes including the sample tubes by adding distilled water. Then 4 ml of anthrone reagent was added and heated for eight minutes in a boiling water bath. Cooled rapidly and the green to dark green color was measured at 630 nm using spectrophotometer. A standard graph was drawn by plotting concentration of the standard on the X-axis versus absorbance in the Y-axis. Using the standard graph the amount of carbohydrate present in the samples was calculated (Yemm and Willis, 1954).

$$\textbf{Total carbohydrate:} \ \frac{\textbf{Mg of glucose}}{\textbf{Volume of sample}} \times 100$$

3.6.2. Total Proteins

Reagents

2% Sodium carbonate in 0.1N Sodium hydroxide (reagent A). 0.5% Copper sulphate ($CuSO_4.5H_2O$) in 1% potassium sodium tartrate (reagent B). Alkaline copper solution: 50 ml of A mixed to 1 ml of solution B prior to use (reagent C). Folin-Ciocalteau (reagent D).

Standard Protein Solution (Stock Solution)

50 mg of bovine serum albumin (fraction V) weighed accurately and dissolved in distilled water and made up to 50 ml in a standard flask. For working standards 10 ml of the stock solution was diluted to 50 ml with distilled water in a standard flask.

Extraction of Proteins from the Rice Sample

Extraction was carried out with buffer used for the enzyme assay. 500 mg of the samples were weighed and grinded well with a pestle and mortar in 5-10 ml of the extraction buffer, centrifuged and the supernatant was used for estimation of protein.

Preparation of Phosphate Buffer (Extraction Buffer)

(A) 0.2 M monobasic sodium phosphate (NaH_2PO_4) prepared by weighing 27.8 g of NaH_2PO_4 in the volumetric flask and adjusted the volume to 1 L with distilled water. (B) 0.2 M dibasic sodium phosphate ($Na_2HPo_47H_2O$) prepared by weighing 53.6 g of dibasic sodium phosphate in the volumetric flask and the volume adjusted to 1 L with distilled water. The extraction buffer was prepared (0.1 M, pH 7.9) by mixing 16.0 ml of (A) and 84 ml of (B) and adjusted the volume to 200 ml with distilled water.

Estimation of Protein

The standard graph was prepared by taking 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard in to test tubes. Prepared 0.1 ml and 0.2 ml of the sample extracts in test tubes and the volume made to 1 ml in all the test tubes. A tube with 1 ml of distilled water served as the blank. 5 ml of reagent C was added to each tube including the blank, mixed well and allowed to stand for 10 min. Then 0.5 ml of reagent D was added, mixed well and incubated at room temperature in the dark for 30 min. Blue colour developed. Absorbance was measured at 660 nm. Using standard graph the amount of total proteins in the samples was calculated (Lowry *et al.*, 1951).

3.7. Determination of Mineral Content by Atomic Absorption Spectrophotometer

The rice grains were grinded into fine powder with mortar and pestle for the analyses of mineral content viz. zinc, potassium and calcium using the atomic absorption spectrophotometer (AAS) (Jarvis and Jarvis, 1985). 0.2 g flour of each rice variety was digested in tri-acid mixture (7:3:1) of HF: HNO_3: $HCLO_4$ (Hydrogen fluoride: Nitric acid: Perchloric acid) on hot plate at a temperature of 180°C for about 4 h, until the residue was completely dried and carried out in a fume hood. 2 ml of concentrated hydrochloric acid (HCL) was added to the sample and then the samples were kept for complete drying on the hot plate. 10 ml of 50% nitric acid was added to the sample and kept on the hot plate for 10 min. After cooling, the samples were diluted to 50 ml with distilled water. The mineral contents such as iron (Fe), potassium (K), zinc (Zn) and calcium (Ca) in the digested samples were analyzed using atomic absorption spectrophotometer.

3.8. Histochemical Characterization of Origin and Development of Chalkiness

The origin and development of chalkiness in rice grains from anthesis to maturation (developmental stages, 1-4 stages) were carried out using histochemical techniques. The rice varieties with different chalky and non chalky grains from 1 to 4 developmental stages (1 to 4 stages) were persevered in 70% ethanol. The grains were fixed on a specimen holder in cryo-microtome (Leica CM1800, Leica Instruments, Nussloch, Germany) in a required direction by adding distilled water around the grain to form ice, so that the specimen was fixed thoroughly on the specimen holder. Then the specimen holder along with specimen was fixed in cryo-microtome at right direction and position. The cryo-microtome temperature was set -6°C and thin transverse sections of 8-10 μm were obtained. Then the sections were collected in a Petri plate containing distilled water. Intact sections were selected and stained with safranin, toluidine blue and acridine orange, washed thoroughly with distilled water, mounted in dilute glycerin (5%) and observed under bright-field and fluorescence microscope. Standard histochemical procedures were used to carry out the histochemical staining reactions (Pearse, 1972; Krishnan, 1996; Krishnan and Dayanandan, 2003; Krishnan *et al.*, 2001; Krishnan *et al.*, 2009). Fluorescent and non-fluorescent dyes used during this study were obtained from Sigma-Aldrich Chemical Company, St. Louis, USA. The detailed preparation of stains is given below.

Safranin

0.1% Safranin was prepared by dissolving 0.1 gm of safranin in 100 ml of distilled water. Thin sections were placed in safranin for 2-3 min., and excess stain was removed by placing it in distilled water. After washing, sections were mounted in dilute glycerin and observed under bright-field mode of examination under light microscope (Krishnan and Dayanandan, 2003).

Toluidine Blue

0.1% toluidine blue was prepared by dissolving 0.1 g of toluidine blue in 100 ml of distilled water. Thin sections were placed in the stain for 2-3 min., and excess stain was removed by placing it in water. After washing, sections were mounted in dilute glycerin and observed under bright-field microscope (Krishnan and Dayanandan, 2003).

Acridine Orange

Acridine orange stock was prepared by dissolving 0.1 gm of acridine orange in 100 ml of distilled water. The working solution was prepared just prior to use. 1 ml of acridine orange stock solution was diluted with 9 ml of phosphate buffer pH 6. Thin sections were selected and placed first in the phosphate buffer for 2 min, then stained with acridine orange working solution for 15 min. After staining, sections were thoroughly washed 2-3 times in buffer solution and mounted with dilute glycerin and observed immediately under fluroscent microscope with blue excitation filter.

3.9. Photography

To understand the origin and development of chalkiness in rice grain, various developmental stages of rice grains were sectioned, stained with fluorescent and non-fluorescent dyes. The prepared slides were observed and photographed using bright-field and fluorescent microscopy, depending on the staining reactions. The observation and photographs were made using *Nikon E800* Research Microscope attached with Nikon Cool Digital Camera and Nikon Image Analyzing System (NIS-Elements basic research version 3.00). Macro-photographs were taken using *Nikon D90 SLR* digital camera attached with 60 mm macro lens. The Nikon microscope, image analyzing system and camera were obtained from Nikon Corporation, Tokyo, Japan.

3.10. Scanning Electron Microscopic (SEM) Studies of Chalkiness in Rice Grain

The ultra-structural studies were carried out to understand the chalkiness in rice grains. The different stages of development (7 stages) of rice grains of chalky and non-chalky varieties were used. Thin transverse sections (TS) and longitudinal sections (LS) of chalky and non-chalky grain were taken with the help of sharp razor blade, the sections were critically dried and attached to aluminum stubs and then the cut surface was coated with gold using an ion sputtering device (JFC-1100E) under vacuum. The specimens were observed and photographed using scanning electron microscope (SEM) JSM5800LV, Jeol (Jeol, India Pvt. Ltd, New Delhi, India).

3.11. Molecular Genetic Diversity Studies of Rice Varieties

3.11.1. Plant Material

All the collected rice varieties were germinated in the laboratory condition and allowed to grow for 20 days. The young leaves of rice seedling after 20 days were collected, cleaned with distilled water, air dried and 5 g of leaf tissue was weighed and used for DNA isolation and replicates of the rice samples were stored in -80°C for further use.

3.11.2. Genomic DNA Extraction

Genomic DNA was extracted from fresh/frozen rice leaf material using the method described by Datta *et al.*, (1997). During this study, DNA was isolated using 5 g of leaf tissue. Leaf materials were cut into small pieces and grind to a fine powder using liquid nitrogen. Before thawing, the fine powder was transferred to 50 ml centrifuge tube and 25 ml of pre-warmed (37°C) extraction buffer [2% (w/v) CTAB; 2M NaCl; 100 mM Tris-HCl (pH 8.0); 20 mM EDTA pH 8.0]. Then 50 µl β-mercaptoethanol was added to the tube. The content of the centrifuge tubes were mixed by inverting three to four times and incubated at 60°C for 30 min., (every ten min. interval the tube was inverted three to four times and opened the cap to release the gas). After 30 min., equal volume of chloroform: isoamyl alcohol (24:1) was added and mixed by inverting the tube three to four times and centrifuged at 12,000 rpm for 20 min., at 4°C. Supernatant was carefully transferred to the new centrifuge tube and 0.6 volume of ice cold isopropanol was added. The tubes were incubated at -20 °C for 2 h. The DNA was pelleted down by centrifuging at 12,000 rpm for 20 min., at 4°C. After centrifugation, the supernatant was discarded and the pellet containing DNA was dissolved in 700 μl of TE buffer (10 mM Tris-HCl and 1mM EDTA, pH 8.0).

3.11.3. Purification of DNA

The various steps are involved in the purification of genomic DNA. The DNA was purified using equal volume of phenol: chloroform (1:1) independently to the tube, mixed by inverting and centrifuged at 8000 rpm for 10 min at room temperature (RT). Then the supernatant was transferred to a new Eppendorf tube and equal volume of chloroform was added. The content was mixed by inverting the tube three to four times and centrifuged at 8000 rpm for 10 min., at RT (this step was repeated two times). The supernatant was transferred to a new tube and 1/10th volume (40 μl) of 3M sodium acetate and three volumes (1 ml) of ethanol (100%) were added and then incubated at -20°C for overnight followed by centrifugation at 8000 rpm for 20 min., at RT. The supernatant was discarded and 1 ml of ethanol (70%) was added to the pellet, gently vortexed and centrifuged at 8000 rpm for 10 min at RT. The DNA pellet was air dried or incubated at 37°C for 15 min., till no water droplets present in the pellet. Then the DNA pellet was dissolved in 200 μl of TE buffer and stored at -20°C for further use.

3.11.4. Determination of Purity of DNA by Spectrophotometer

The purity of the DNA was determined by using spectrophotometric method. 15 μl of DNA sample was taken in a cuvette and 735 μl of TE buffer was added and gently mixed. Absorbance was measured at 260 nm and 280 nm by using spectrophotometer. TE buffer was used as a blank. The absorbance ratio of A_{260} nm and A_{280} nm provided an estimate of the purity of DNA. If the ratio found between1.8-2.0 which indicates that the DNA is pure without any contamination. If the ratio found below 1.8 which denotes that the DNA is contaminated with protein and or other UV absorbers in the sample. If the ratio higher than 2.0 indicates the samples may be contaminated with chloroform or phenol (CIMMYT, 2005).

3.11.5. Determination of Quality of DNA by Agarose Gel Electrophoresis

The quality of DNA was determined by using agarose gel containing ethidium bromide. 0.8 g of agarose was added in 100 ml of 1X TBE buffer and heated in a microwave melt the agarose, waited for a few min. to temperature come down. Three micro litre of ethidium bromide (stock 10 mg/ml) was added in the agarose solution, mixed well and poured in to gel-casting tray with proper comb setting, kept for 10-20 min for solidification of the gel. Agarose gel was carefully taken in to gel-running tray with 1X TBE buffer and slowly comb was removed. 1 μl of 6X gel loading dye was taken in 0.5 ml of PCR tube and placed in ice box, 10 μl of DNA sample was added and mixed well. The DNA samples were carefully loaded into the well and the samples were run at 50 volt for 5 min and then the voltage was increased to 100. When the DNA samples reached three fourth length of the gel, the electrophoresis unit was put off. Later, the gel was visualized and photographed using the gel documentation system (Alpha DigiDoc™, Alpha Innotech Corporation, California, USA).

3.11.6. Quantification of DNA

DNA yield was determined by the method described by CIMMYT, (2005). DNA concentration was measured by measuring the absorbance at 260 nm using spectrophotometer (UV-2450, Shimadzu Corporation, Kyoto, Japan). An A260 value of 1 corresponds to 50 µg DNA per ml. During the analysis, 15 µl of DNA sample was taken in a cuvette and 735 µl of TE buffer was added and gently mixed well. Absorption value was taken at 260 nm in spectrophotometer by using TE buffer as a blank. Calculations were made as follows:

Volume of DNA sample = 15 µl

Dilution = 15 µl of DNA sample + 735 µl of TE

$$\textbf{Concentration of DNA sample } (\mu g/\mu l) = \frac{A_{260} \times 50\ \mu g/ml \times \text{dilution } (50)}{1000}$$

3.11.7. Inter Simple Sequence Repeat (ISSR) Analysis

ISSR analysis of genomic DNA of traditionally cultivated and high yielding rice varieties were carried out using universal random oligonulceotide primers obtained from Metabion International AG, Martinsried, Germany and the list of primers are summarized in the Table 37.

3.11.8. Amplification Reaction

Polymerase chain reaction (PCR) amplification was carried out in final volume of 25 µl containing 30-50 ng of genomic DNA, 2.5 µl of 10X Taq assay buffer, 3 µl of 25 mM $MgCl_2$, 2.5 µl of 10 mM dNTPs mix, 15 ng of primers and 0.5 units of Taq polymerase. All PCR chemicals were obtained from Merck Specialities Pvt. Ltd., Bangalore, India.

3.11.9. Amplification Conditions

The PCR amplification was performed as described by Parab and Krishnan (2008) in a Mastercycler gradient (Eppendorf AG, Hamburg, Germany). The PCR reaction mixture contained 2 µl of 1 mM dNTPs, 2.5 µl 10X PCR buffer, 3 µl $MgCl_2$, 3 µl of 5 µM forward and reverse primers, 13 µl dd H_2O, 1 µl of 50 ng/µl template DNA and 0.5 µl Taq polymerase (~2.5 units/µl). Template DNA was initially denatured at 94°C for 5 min followed by 30 cycles of PCR amplification following: 1 min of denaturation at 94°C, 1 min of primer annealing at 53.8°C and 2 min of primer extension at 72°C. Final 10 min incubation at 72°C was allowed for complete of primer extension.

3.11.10. Loading and Visualizing the Amplified Products

Amplified products were mixed with 1 µl of bromophenol blue gel loading dye, loaded in the wells of 2% agarose gel with ethidium bromide and electrophoresis was carried out using 1X TBE buffer pH 8.0 at room temperature. Then the gel was visualized under ultraviolet light and photographed using gel documentation system (AlphaDigiDoc™, Alpha Innotech Corporation, Canada).

3.11.11. Scoring and Data Analysis

Each ISSR amplified product gel was named by primer code. The banding pattern varied from primer to primer. The experiment was repeated two times in order to obtain reproducible data. Scoring of ISSR bands was carried out in terms of a binary code (1 and

0 (1 for presence of bands and 0 for absence of bands). Each informative ISSR band was scored independently and percentage of polymorphism was calculated as the proportion of polymorphic bands over the total number of bands. Dendrogram and genetic distance were generated by clustering according to the Unweighted Paired Group Method with Arithmetic Mean (UPGMA) method using the NTSYS-pc Version-2 computer software (Rohlf, 1992).

RESULTS

CHAPTER 4

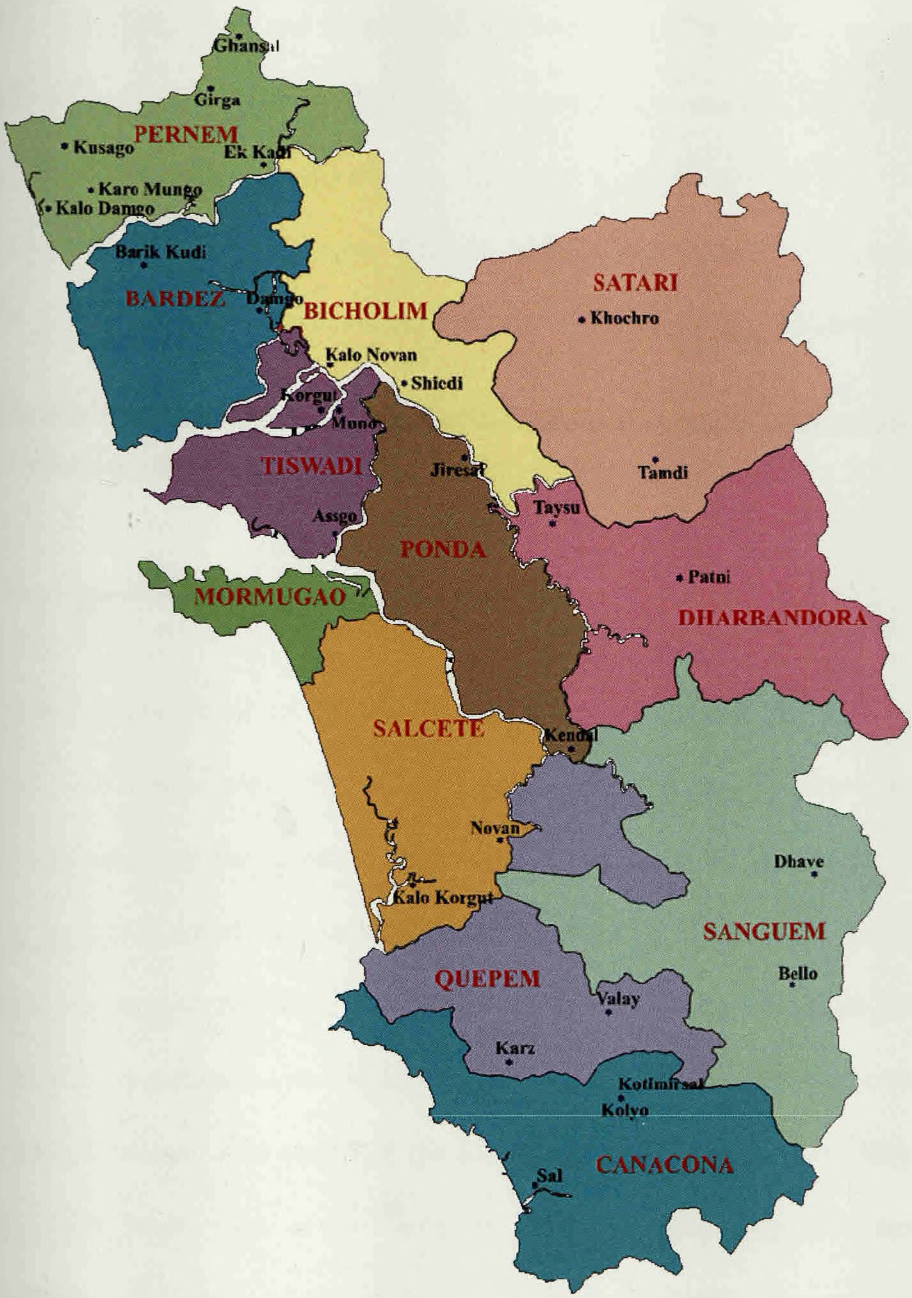
RESULTS

The results reported here are based on the survey, collection and documentation of the traditionally cultivated and the high yielding rice varieties cultivated in the State of Goa. (i) During this study, the field survey and collection trips were made to different places in Goa during the period from July 2008 to June 2012 for the collection of traditionally cultivated, introduced and hybrid rice varieties. The collected rice varieties were cleaned in the laboratory and stored for further studies. (ii) The rice varieties were evaluated for their grain quality. In rice grain quality, the physical, chemical and cooking characteristic were studied along with nutritional nutrient value (total carbohydrates, total proteins and minerals such as iron, zinc, potassium, calcium). The data was compared with the traditionally cultivated and high yielding rice varieties. (iii) Histological studies were carried out to understand the origin and development of chalkiness in rice grain from anthesis to maturation. During this study, four rice varieties (Jaya, Korgut, MO-7, KRH-2) were selected based on their percentage of chalkiness for the detailed characterization of chalkiness in various developmental stages of grain. (iv) Molecular genetic diversity studies were carried out among the traditionally cultivated, introduced and hybrid rice varieties of Goa and adjacent regions using ISSR markers to understand their relationship (genetic identities) among the varieties.

4. 1. Study Area

The entire State of Goa covering all 12 talukas namely Bardez, Bicholim, Pernem, Ponda, Sattari, Tiswadi, Canacona, Mormugao, Quepem, Salcete, Sanguem and Dharbandora were surveyed. The systematic field survey and collections trips were made

Fig. 1. Map of Goa showing collection sites of traditionally cultivated rice varieties.



throughout the kharif and rabi season covering different parts of Goa and adjoining regions for the collection of traditionally cultivated, high yielding rice varieties and hybrid rice. The map of Goa showing the collection sites of traditionally cultivated rice varieties with talukas are given in Figure 1. During the field survey, it was observed that rice is grown under three different conditions in Goa such as Morod or lateritic uplands (Plate 1a, b), Kher or midlands (Plate 1c, d) and Khazan lands (Plate 1e, f). The interaction with farmers and local people revealed that the traditionally cultivated rice varieties are grown in small patches and specific to some regions of Goa. The cultivation of some of the varieties such as Jiresal, Kalo Novan, Kalo Damgo, Kusago and Bello are becoming rare. The rice varieties like Korgut, Assgo, Muno and Kalo Korgut are traditionally cultivated in khazan lands (saline lands) and these rice varieties are found to be highly salt tolerant. The distribution of khazan lands in the State of Goa is provided in Figure 2.

4.2. Collection and Documentation of Rice Varieties

During this study, total of 50 rice varieties were collected from local farmers, villagers and ICAR Complex, Old Goa, Goa. Among them 28 rice varieties are traditionally cultivated by the farmers (local rice varieties) and 22 rice varieties are high yielding rice varieties which are introduced to the state of Goa. Each traditional rice varieties were with unique characteristics of size, shape and colour. The grain morphology of all the traditionally cultivated rice varieties is provided in Plate 2 to 6. The collected rice varieties were pre-cleaned and stored in the Department of Botany, Goa University, for further study. The details such as the names of the traditionally cultivated rice variety, place of collection and name of the taluka from which the varieties were collected are provided in Tables 11. The list of high yielding rice varieties collected from ICAR Complex Goa and from other region is given in Table 12.

Fig. 2. Map of Goa showing the distribution of khazan lands.

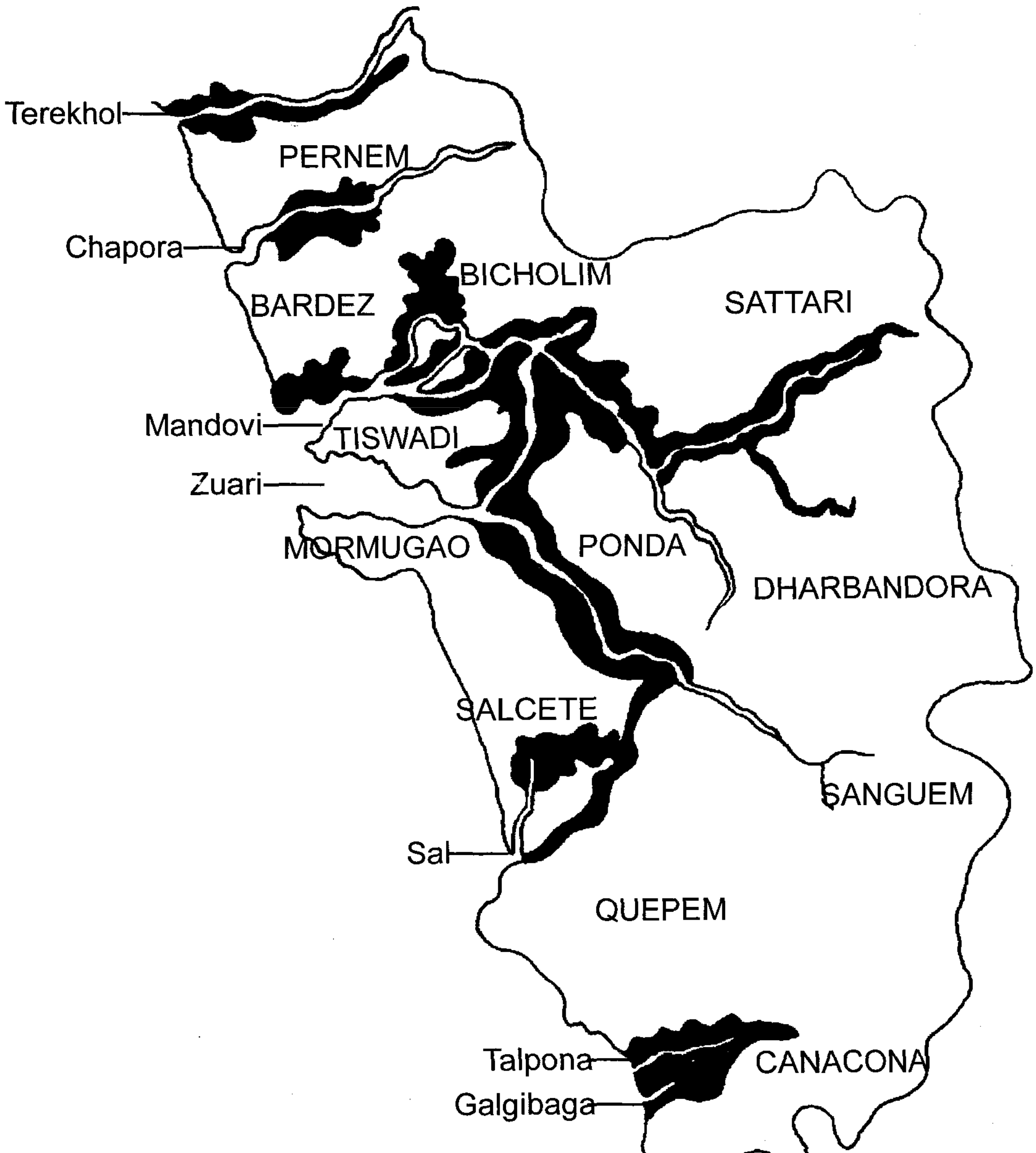


Plate 1

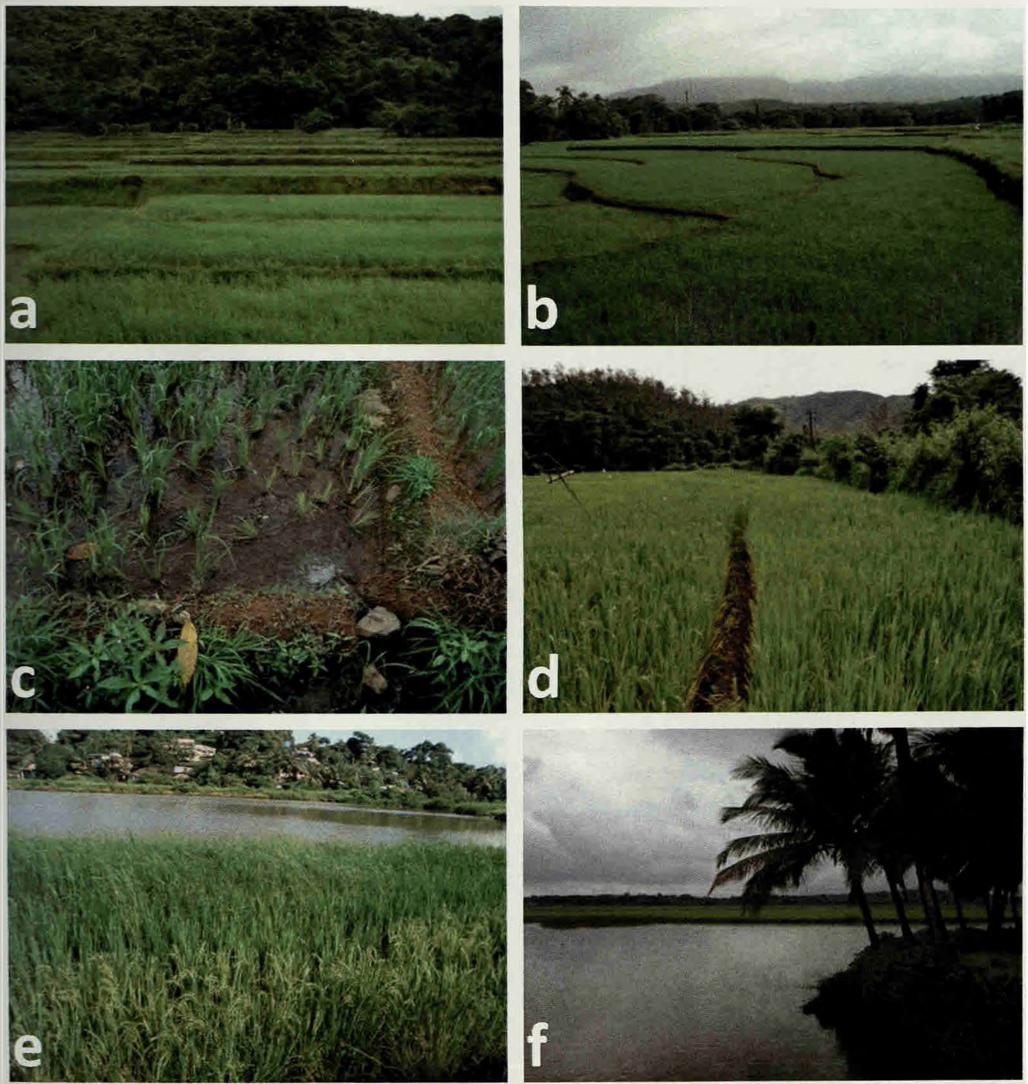


Plate 1. Rice cultivation in the State of Goa. Rice is grown in three distinct ecological conditions, morodlands or uplands (a, b), Kerlands or midlands (c, d) and Khazan lands or saline areas (e, f).

Plate 2. Traditionally cultivated local rice varieties with hull, de-hulled and after cooking. Assgo (a-c); Damgo (d-f); Dhave (g-i); Barik Kudi (j-l); Bello (m-o); Ek Kadi (p-r).

Plate 3. Traditionally cultivated rice varieties with hull, de-hulled grains and after cooking. Ghansal (a-c); Girga (d-f); Jiresal (g-i); Kalo Damgo (j-l); Kalo Korgut (m-o); Kalo Novan (p-r).

Plate 4. Traditionally cultivated rice varieties with hull, de-hulled grains and after cooking. Karo mungo (a-c); Karz (d-f); Kendal (g-i); Khochro (j-l); Kolyo(m-o); Korgut (p-r).

Plate 5. Traditionally cultivated rice varieties with hull, de-hulled grains and after cooking. Kotimirsal (a-c); Kusago (d-f); Muno (g-i); Novan (j-l); Patni (m-o); Sal (p-r).

Plate 6. Traditionally cultivated rice varieties with hull, de-hulled grains and after cooking. Shiedi (a-c); Tamdi (d-f); Taysu (g-i); Valay (j-l).

Table 11. List of traditionally cultivated rice varieties collected from Goa.

Sl. No.	Varieties	Place of collection	Taluka
1	Assgo	Neura-O-Grande	Tiswadi
2	Barik Kudi	Siolim	Bardez
3	Bello	Sigonem	Sanguem
4	Damgo	Corjuem	Bardez
5	Dhave	Bati	Sanguem
6	Ek Kadi	Ozorim	Pernem
7	Ghansal	Torxem	Pernem
8	Girga	Amberem	Pernem
9	Jiresal	Savoi-Verem	Ponda
10	Kalo Damgo	Mandrem	Pernem
11	Kalo Korgut	Assolna	Salcete
12	Kalo Novan	Naroa	Bicholim
13	Karo Mungo	Parcem	Pernem
14	Karz	Barcem	Quepem
15	Kendal	Ponchavadi	Ponda
16	Khochro	Naneli	Satari
17	Kolyo	Gaodongrem	Canacona
18	Korgut	Navelim	Tiswadi
19	Kotimirsal	Gaodongrem	Canacona
20	Muno	Cumbarjua	Tiswadi
21	Kusago	Davanvado	Pernem
22	Novan	Paroda	Salcete
23	Patni	Sancordem	Dharbandora
24	Sal	Poinguinim	Canacona
25	Shiedi	Amone	Bicholim
26	Taysu	Usgao	Dharbandora
27	Tamdi	Cotorem	Satari
28	Valay	Pirla	Quepem

Table 12. List of high yielding, scented and hybrid rice varieties collected from ICAR and other regions.

Sl. No.	Varieties	Place of collection
1	Annapurna	Mandrem (Pernem)
2	CSR-27	ICAR
3	IR-8	Tivrem (Ponda)
4	Jaya	Saligao (Bardez)
5	Jyoti	Siolim (Bardez)
6	Karjat-3	Paroda (Salcete)
7	Karjat-5	Amona (Quepem)
8	Kasturi	ICAR
9	KRH-2	ICAR
10	MO-7	ICAR
11	MO-9	ICAR
12	MO-17	ICAR
13	Mugadh Sugandh	ICAR
14	Pusa Basmati-1	ICAR
15	Pusa Sugandh-2	ICAR
16	Pusa Sugandh-3	ICAR
17	Pusa Sugandh-5	ICAR
18	R-6857	ICAR
19	Sahyadri-1	ICAR
20	Salt Tolerant AVT-1901	ICAR
21	Salt Tolerant AVT-1918	ICAR
22	Vasmati	ICAR
23	Pokkali	Kerala
24	*Oryza rufipogon* (Wild rice)	Taleigao (Tiswadi)

4.3. Rice Grain Quality - Physical Characteristics:

4.3.1. Hulling Percentage [Brown Rice (BR) Yield]

Hulling percentage was calculated for all the traditionally cultivated rice varieties (Table 13) and high yielding rice varieties (Table 14). The de-hulling of rice is one of the important post harvest processes. If the hulling percentage is high, then the recovery of rice is also increased. The hulling percentage for 28 traditionally cultivated rice varieties were compared with high yielding varieties (introduced rice). Among traditionally cultivated rice varieties, hulling percentage ranged from 65.5 to 82.46%. The highest hulling percentage (82.46%) was observed in variety Ek Kadi and lowest (65.5%) in variety Kolyo (Figure 3). In high yielding rice varieties, hulling percentage ranged from 63.18 to 81.3%. The highest hulling percentage (81.3%) was calculated in Karjat-3 and lowest (63.18%) in variety R-6857 (Figure 4). The eighty percent or more are the desirable hulling characteristics for rice.

4.3.2. Head Rice Recovery (HR)

The head rice recovery (HR) indicates that weight of complete caryopsis (not broken) obtained after industrial processing and more than 65% is desirable. HR was calculated for all the traditionally cultivated (Table 13) and high yielding rice varieties (Table 14). HR value ranged from 39-78% in all the rice varieties evaluated. Among the traditional rice varieties, Ghansal (77.6%) showed highest head rice recovery and lowest (44.5%) in variety Valay (Figure 5). In high yielding rice varieties, the highest HR (68.1%) was calculated in Jyoti and lowest (39.1%) in variety Salt Tolerant AVT-1918 (Figure 6).

Fig. 3. Hulling percentage in traditional rice varieties.

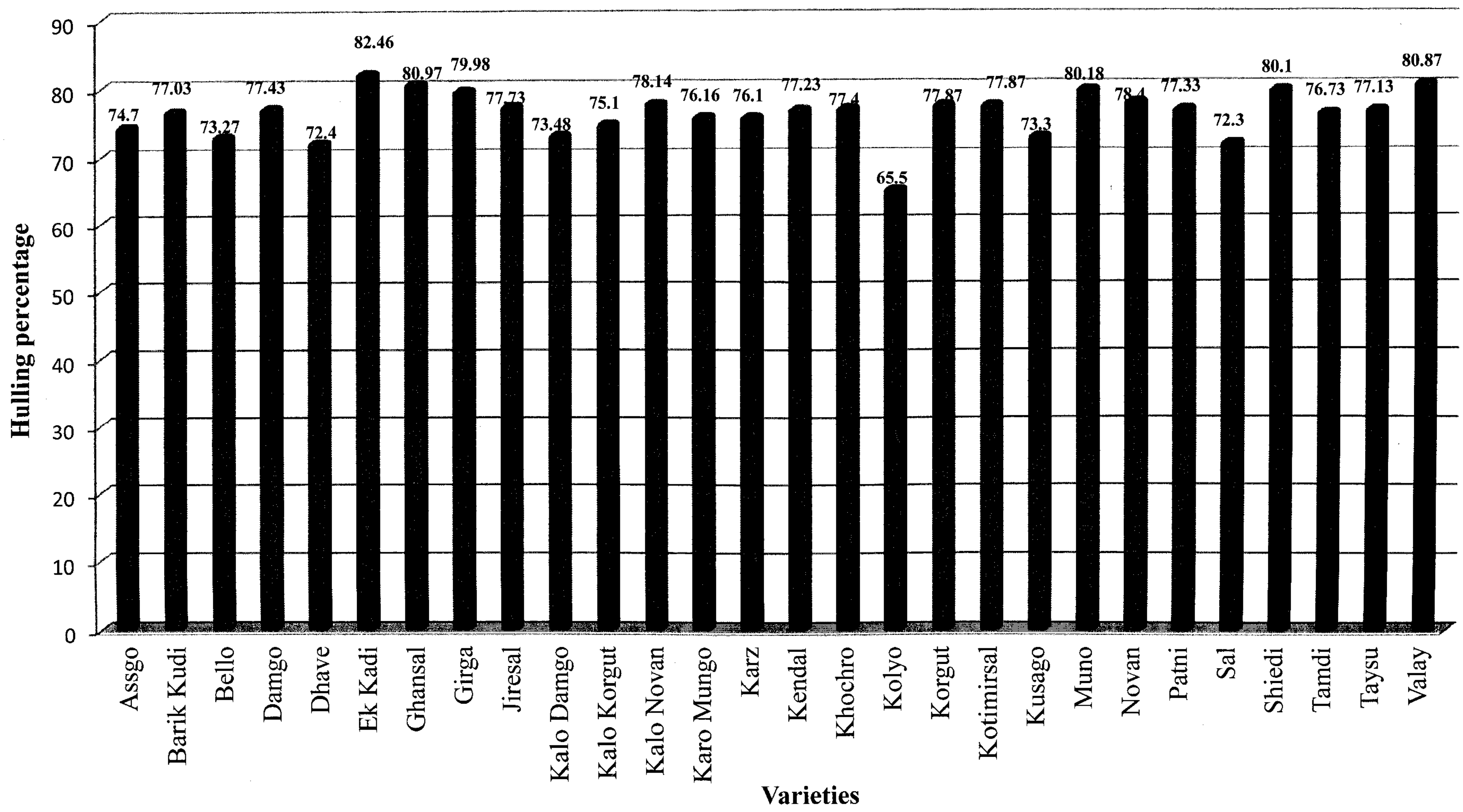


Fig. 4. Hulling percentage in high yielding rice varieties.

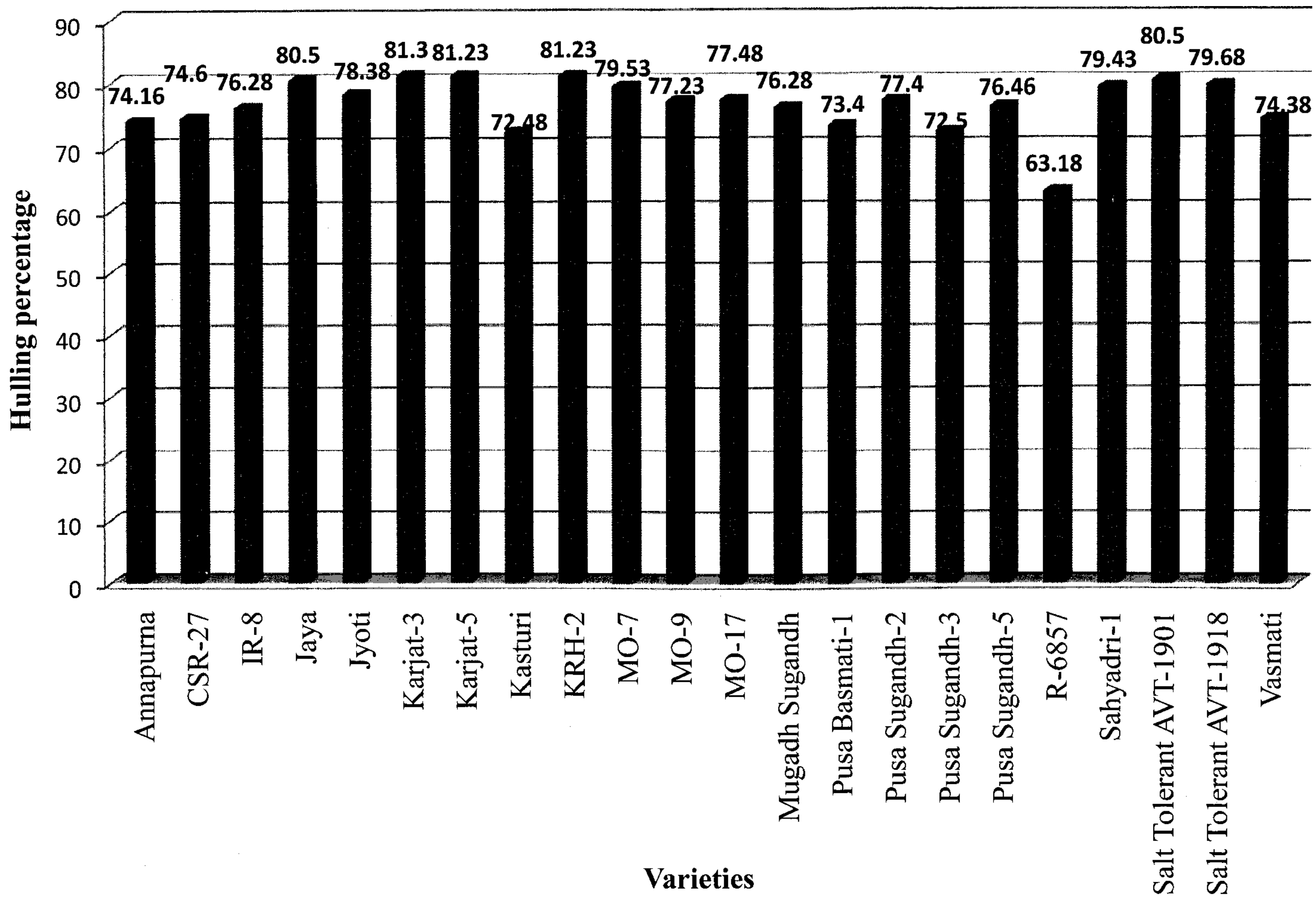


Fig. 5. Head rice recovery in traditional rice varieties.

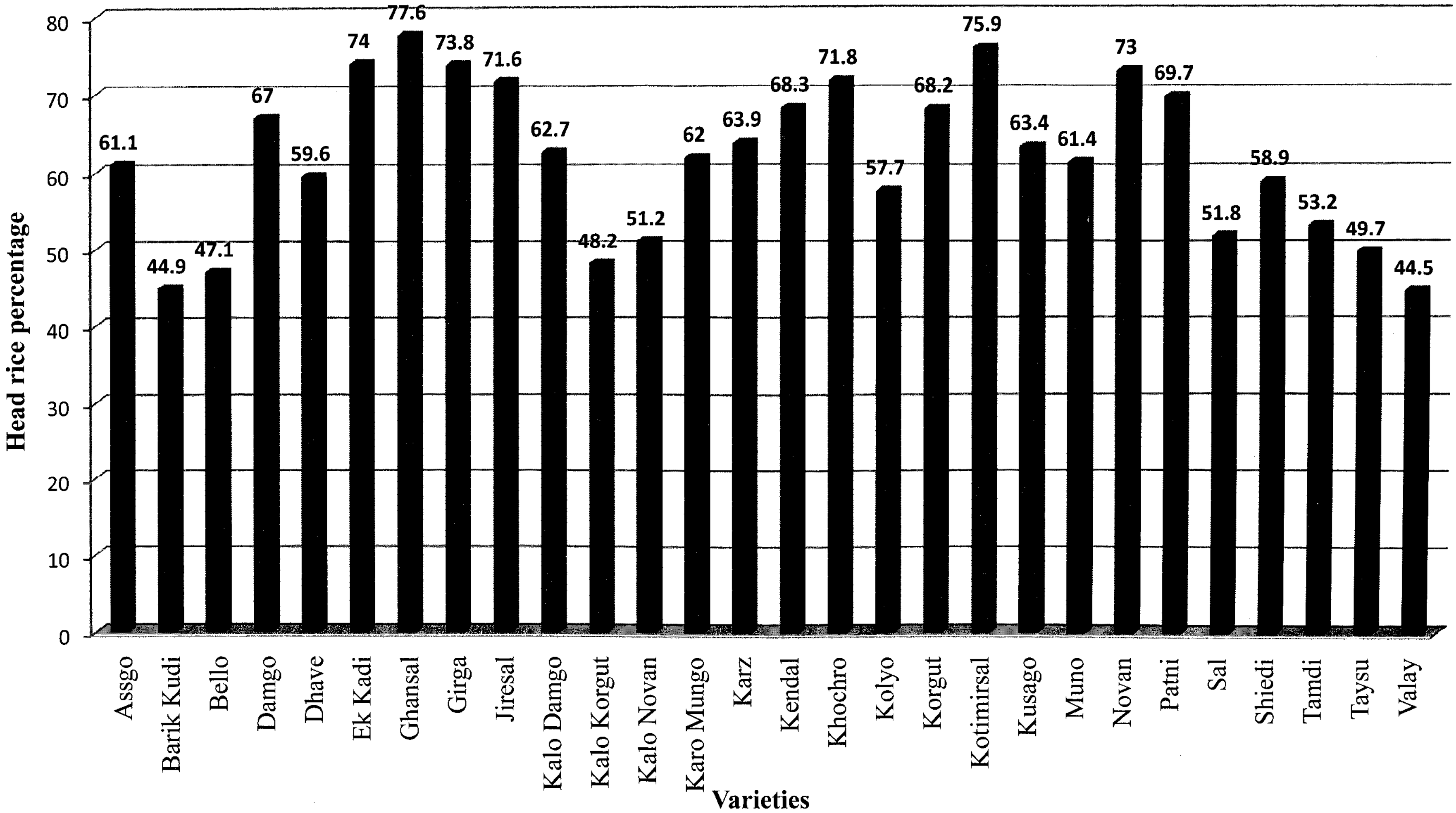


Fig. 6. Head rice recovery in high yielding rice varieties.

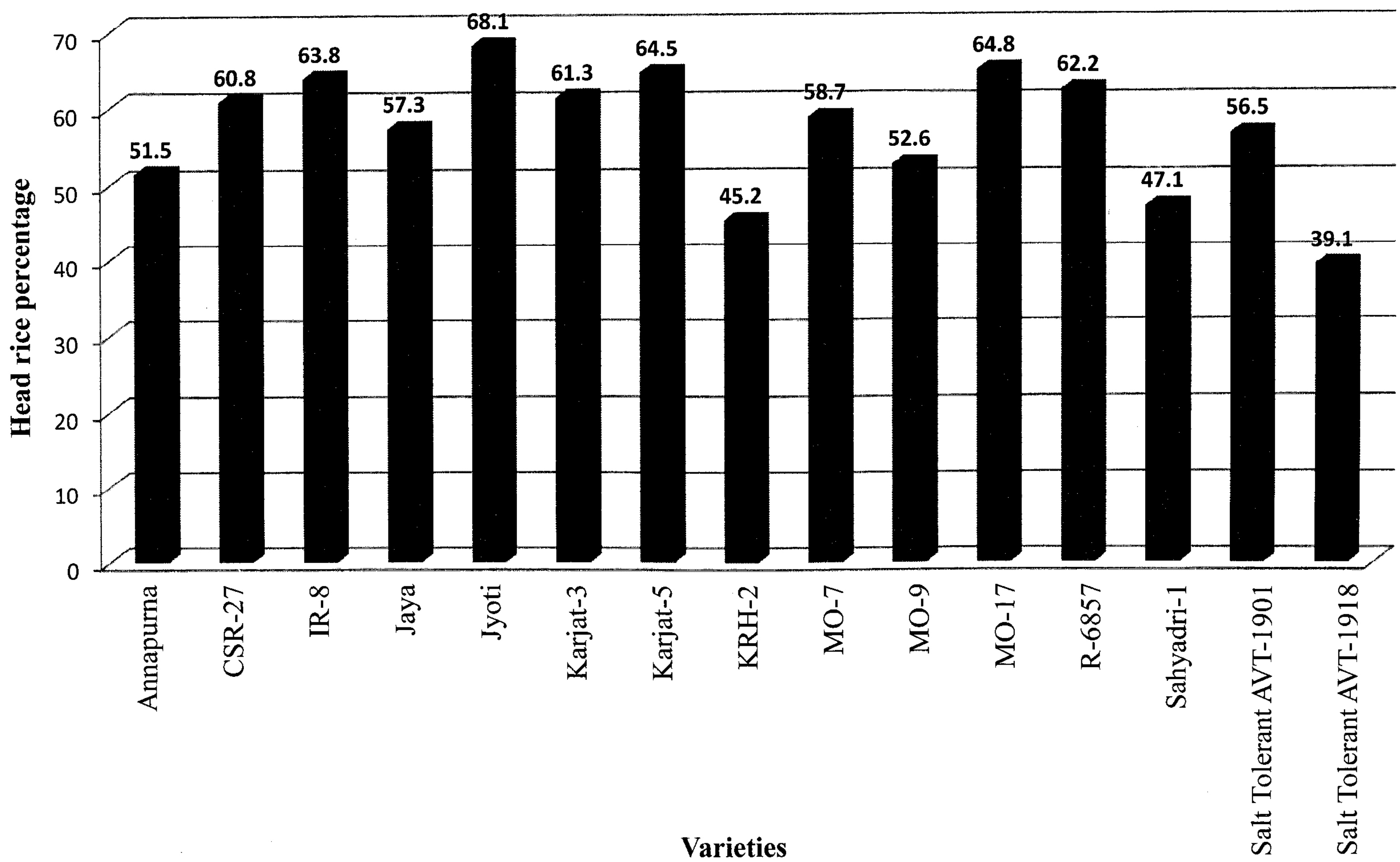


Table 13. Physical characteristics of traditionally cultivated rice varieties showing the percentage of hulling, head rice recovery and broken rice.

Sl. No.	Varieties	Hulling %	Head Rice Recovery %	Broken rice %
1	Assgo	74.70±0.43^{ij}	61.1±1.05^{kl}	13.5±1.1^{f}
2	Barik Kudi	77.03±1.26^{efg}	44.9±1.51st	32.1±0.72^{b}
3	Bello	73.27±0.96^{jk}	47.1±0.75^{rs}	26.2±0.31^{c}
4	Damgo	77.43±1.36^{efg}	67.0±0.4^{h}	10.4±1.75^{ghi}
5	Dhave	72.40±0.75^{k}	59.6±0.4^{lm}	14.8±2.39^{f}
6	Ek Kadi	82.46±1.2^{a}	74.0±4.55^{bc}	8.4±3.42^{hijk}
7	Ghansal	80.97±1.96^{ab}	77.6±2.06^{a}	3.3±3.93^{mn}
8	Girga	79.98±0.32^{bcd}	73.8±1.36^{bcd}	6.1±1.17^{kl}
9	Jiresal	77.73±2.25^{efg}	71.6±1.59^{ef}	6.1±2.1^{kl}
10	Kalo Damgo	73.48±2.25^{jk}	62.7±2.18^{ijk}	10.7±1.42^{gh}
11	Kalo Korgut	75.10±1.8^{hij}	48.2±1.1^{qr}	26.8±1.41^{c}
12	Kalo Novan	78.14±0.9^{def}	51.2±0.95^{nop}	26.9±1.62^{c}
13	Karo Mungo	76.16±1^{fghi}	62.0±1.58^{ijk}	14.1±0.76^{f}
14	Karz	76.10±1.66^{ghi}	63.9±0.62^{i}	12.2±2.01^{fg}
15	Kendal	77.23±1.25^{efg}	68.3±1^{gh}	8.9±1.18^{hij}
16	Khochro	77.40±1.01^{efg}	71.8±0.52^{def}	5.6±1.22^{lm}
17	Kolyo	65.50±0.11^{l}	57.7±0.55^{m}	7.7±1.44^{ijkl}
18	Korgut	77.87±0.58^{efg}	68.2±0.65^{gh}	9.6±0.82^{ghij}
19	Kotimirsal	77.87±2.32^{efg}	75.9±1.62^{ab}	2.6±2.32^{n}
20	Kusago	73.30±1^{jk}	63.4±0.64^{ij}	9.9±1.64^{ghij}
21	Muno	80.18±0.37^{bc}	61.4±0.78^{jkl}	18.7±1.05^{e}
22	Novan	78.40±1.08^{cde}	73.0±0.47^{cde}	5.3±1.19^{lm}
23	Patni	77.33±1.1^{efg}	69.7±0.55^{fg}	7.6±0.56^{jkl}
24	Sal	72.30±0.9^{k}	51.8±0.52^{nop}	20.5±1.04^{e}
25	Shiedi	80.10±0.7^{bcd}	58.9±0.55^{m}	21.1±0.93^{de}
26	Tamdi	76.73±0.47^{efgh}	53.2±0.95^{n}	23.5±1.14^{d}
27	Taysu	77.13±2.08^{efg}	49.7±0.38^{opq}	27.4±2.44^{c}
28	Valay	80.87±0.35^{ab}	44.5±2.14^{t}	36.3±1.79^{a}
Critical differences (CD) (5%)		1.986	2.164	2.653
Coefficient of Variation		1.640	2.135	10.893

Mean ±SD followed by different letters differ significantly at 5%

Table 14. Physical characteristics of high yielding rice varieties showing the hulling percentage, head rice recovery and broken rice.

Sl. No.	Varieties	Hulling %	Head Rice Recovery %	Broken Rice%
1	Annapurna	74.16±0.75^{gh}	51.5±0.46^{j}	22.6±1.78^{de}
2	CSR-27	74.6±0.78^{g}	60.8±1.27^{e}	13.8±1.9^{h}
3	IR-8	76.28±0.2^{f}	63.8±0.58^{c}	12.4±0.6^{hi}
4	Jaya	80.5±0.4^{a}	57.3±0.12^{g}	23.1±0.42^{d}
5	Jyoti	78.38±0.32^{c}	68.1±3.89^{a}	10.2±0.25^{j}
6	Karjat-3	81.3±1.1^{a}	61.3±0.15^{e}	19.9±1.25^{f}
7	Karjat-5	81.23±0.65^{a}	64.5±0.4^{bc}	16.7±0.91^{g}
8	Kasturi	72.48±0.45^{i}	0±0^{n}	0±0^{k}
9	KRH-2	81.23±0.25^{a}	45.2±0.3^{m}	35.4±2.05^{a}
10	MO-7	79.53±0.35^{b}	58.7±0.46^{f}	21.1±0.28^{ef}
11	MO-9	77.23±0.05^{de}	52.6±1.18^{i}	24.6±0.28^{d}
12	MO-17	77.48±0.45^{d}	64.8±0.1^{i}	13.9±1.46^{h}
13	Mugadh Sugandh	76.28±0.11^{f}	0±0^{n}	0±0k
14	Pusa Basmati-1	73.4±0.3^{h}	0±0^{n}	0±0^{k}
15	Pusa Sugandh-2	77.4±0.66^{d}	0±0^{n}	0±0^{k}
16	Pusa Sugandh-3	72.5±0.4^{i}	0±0^{n}	0±0^{k}
17	Pusa Sugandh-5	76.46±0.4^{ef}	0±0^{n}	0±0^{k}
18	R-6857	63.18±1.05^{j}	62.2±1.1^{d}	11.9±1.7^{i}
19	Sahyadri-1	79.43±0.4^{b}	47.1±0.1^{l}	33.3±1.34^{b}
20	Salt Tolerant AVT-1901	80.50±0.46^{a}	56.5±0.46^{h}	24.0±0.29^{c}
21	Salt Tolerant AVT-1918	79.68±0.41^{b}	39.1±17.3^{k}	30.5±0.47^{c}
22	Vasmati	74.38±0.47^{g}	0±0^{n}	0±0^{k}
Critical differences (CD) (5%)		0.831	0.828	1.569
Coefficient of Variation		0.657	1.280	6.675

Mean ±SD followed by different letters differ significantly at 5%

Broken rice was calculated for all the traditionally cultivated (Table 13) and high yielding rice varieties (Table 14). In traditionally cultivated rice varieties, the percentage of broken rice (BR) grains ranged from 2.6 to 36.3%. Among the traditional rice varieties, lowest breakage (2.6%) was recorded in variety Kotimirsal and highest (36.3%) in Valay (Figure 7). In high yielding rice varieties, the percentage of broken rice (BR) grains ranged from 10.2 to 35.4%, highest in KRH-2 and lowest in Jyoti (Figure 8).

4.3.3. Grain Classification

Grain classification was done for all the 50 rice varieties. Among the traditional rice varieties studied, the L/B ratio ranged from 1.59-3.69% (Table 15). The traditional rice variety Taysu recorded the highest L/B ratio and lowest in Novan (Figure 9). The L/B ratio in high yielding rice varieties ranged from (IR-8) 2.05 to (Pusa Basmati-1and Mugadh Sugandh) 4.88 (Table 16; Figure 10). Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB). The traditional rice varieties, Assgo, Ghansal, Jiresal, Kalo Damgo, Kalo Novan, Karo Mungo, Khochro, Kolyo, Korgut, Kotimirsal, Kusago, Novan, Patni and variety Sal belonged to the categories of short bold (SB); Barik Kudi, Tamdi and Taysu fall in the category of long slender (LS); Bello, Dhave, Girga, Karz, and Muno classified into medium slender (MS); Damgo, Ek Kadi, Kalo Korgut, Kendal, Shiedi and variety Valay assigned to long bold (LB) type of grains (Table 15). The high yielding rice varieties, Annapurna, IR-8 and R-6857 belonged to SB category; CSR-27, Jaya, Jyoti, KRH-2, MO-7, Sahyadri-1, Salt Tolerant AVT-1901 and Salt Tolerant AVT-1918 assigned to LS; Karjat-3 and MO-17 reached to MS category; Karjat-5 and MO-9 classified to LB and remaining all basmati varieties are categorized to extra-long slender (Table 16).

Fig.7. Broken rice percentage in traditional rice varieties.

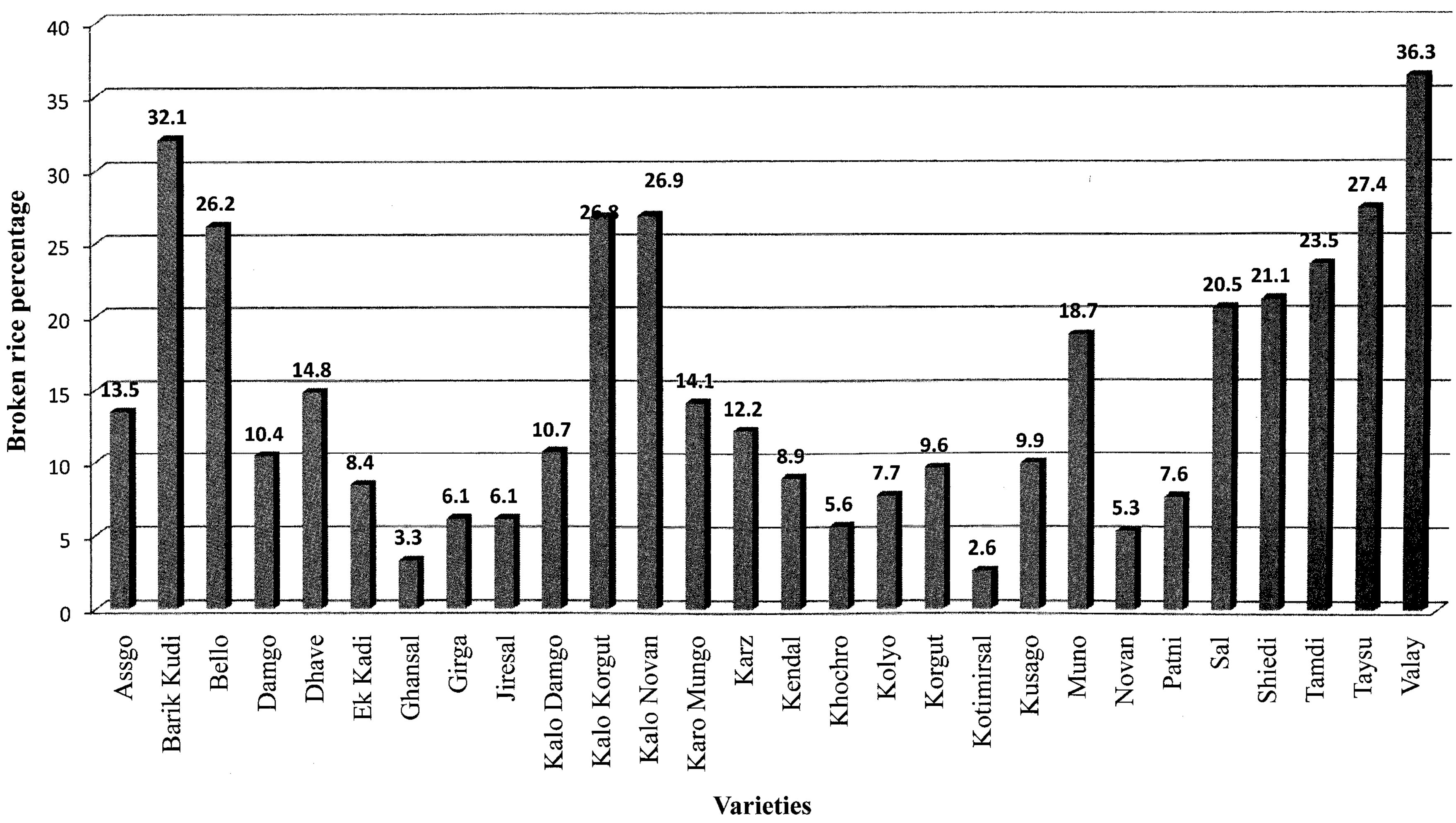


Fig. 8. Broken rice percentage in high yielding rice varieties.

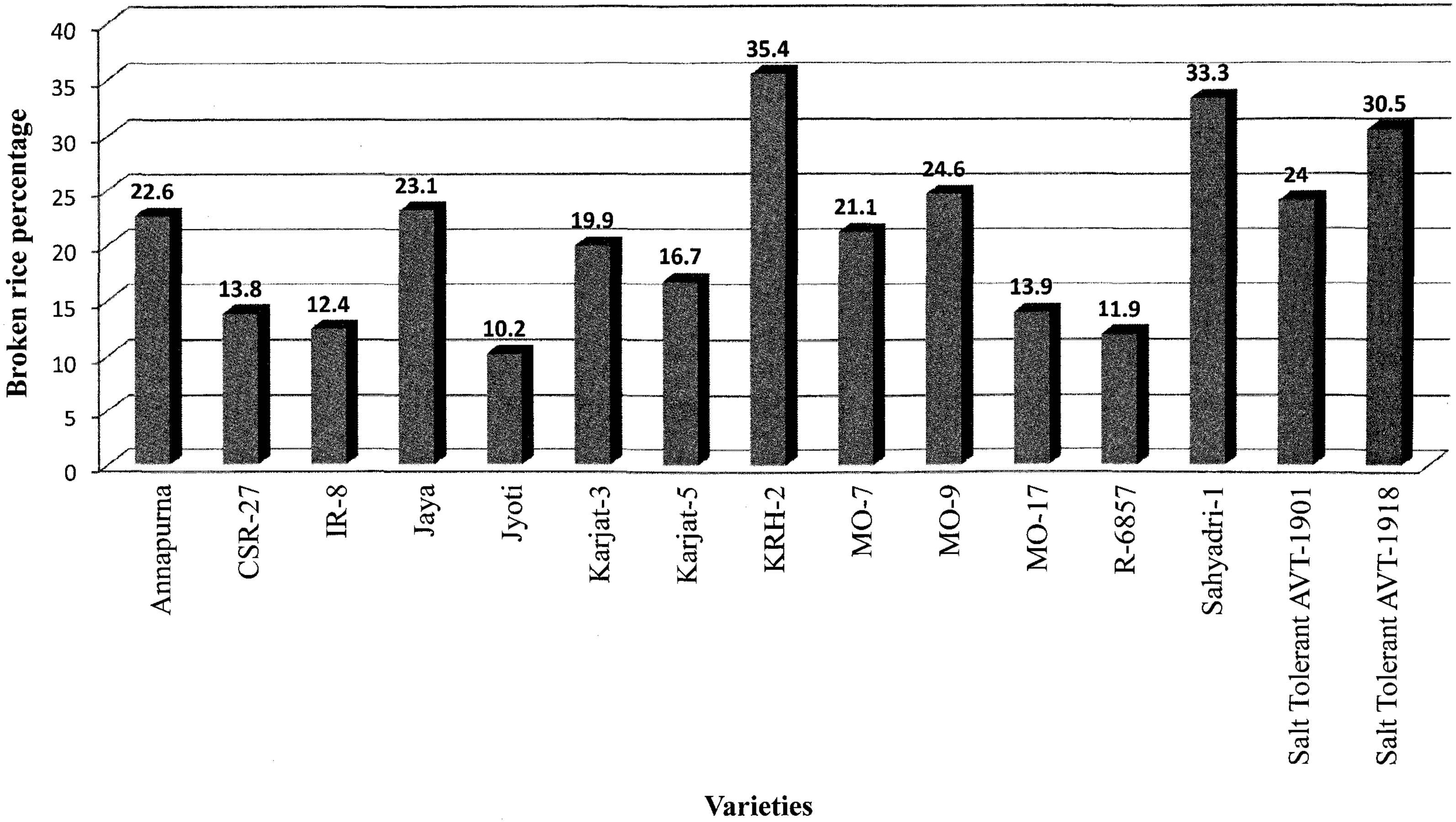


Fig. 9. L/B ratio in traditional rice varieties.

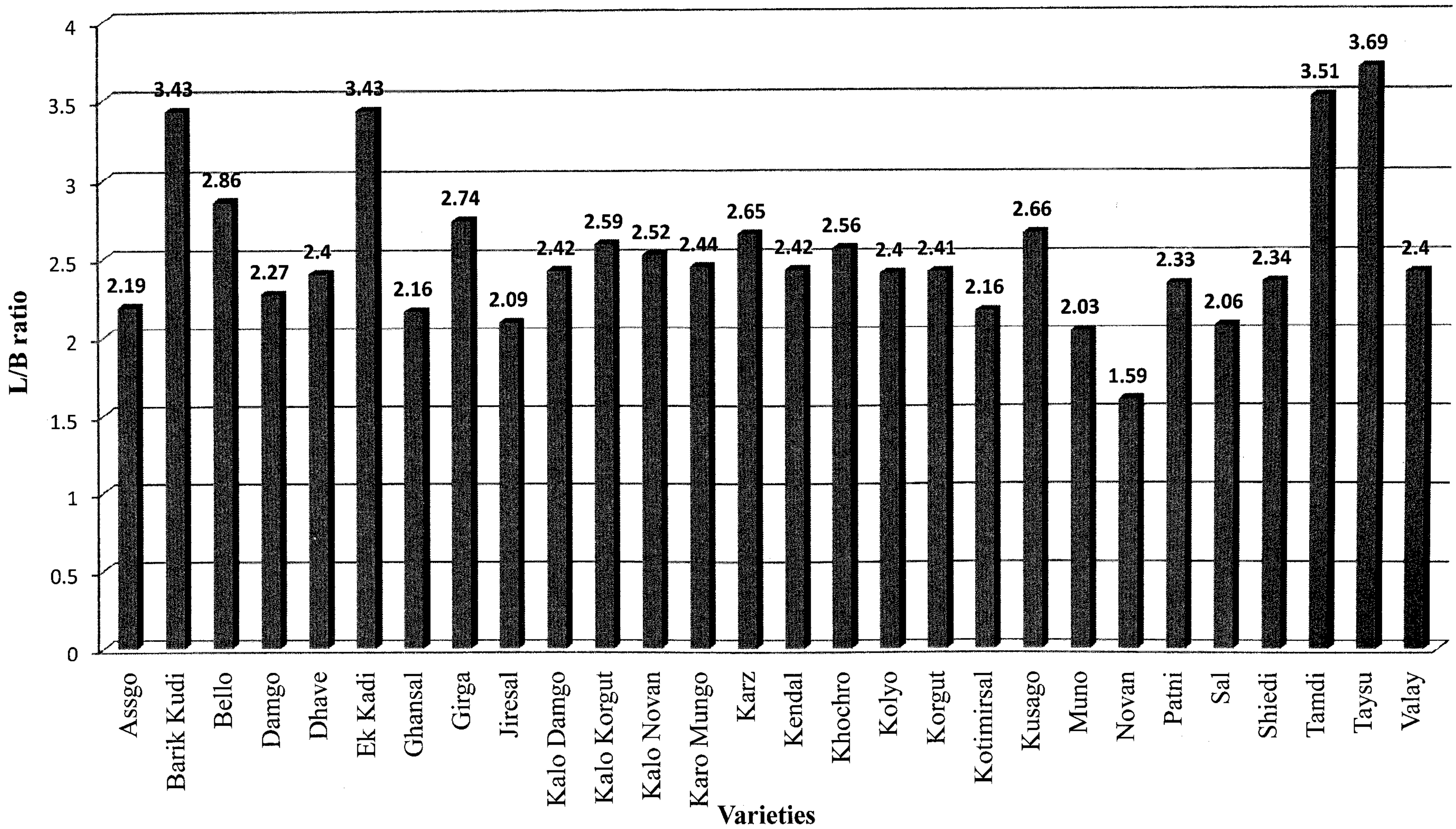


Fig. 10. L/B ratio in high yielding rice varieties.

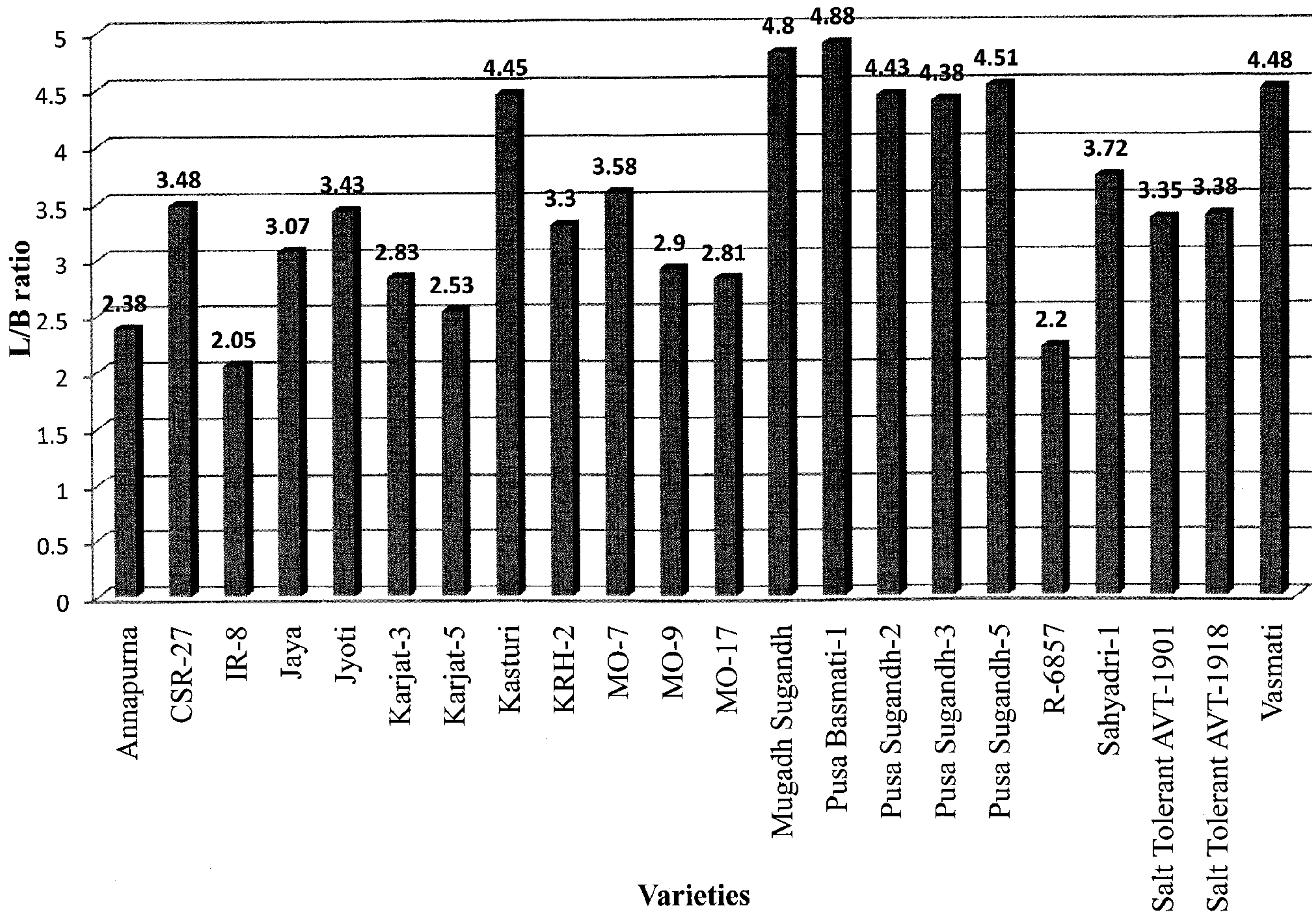


Table 15. Physical characteristics of traditionally cultivated rice varieties showing the L/B ratio and systematic grain classification.

Sl. No.	Varieties	L/B ratio	Grain Classification
1	Assgo	2.19 ± 0.02^{ijkl}	Short Bold
2	Barik Kudi	3.43 ± 0.02^{b}	Long Slender
3	Bello	2.86 ± 0.05^{c}	Medium Slender
4	Damgo	2.27 ± 0.21^{hijkl}	Long Bold
5	Dhave	2.40 ± 0.21^{efgh}	Medium Slender
6	Ek Kadi	3.43 ± 0.06^{c}	Long Bold
7	Ghansal	2.16 ± 0.01^{jkl}	Short Bold
8	Girga	2.74 ± 0.03^{cd}	Medium Slender
9	Jiresal	2.09±0.08jkl	Short Bold
10	Kalo Damgo	2.42 ± 0.06^{efghij}	Short Bold
11	Kalo Korgut	2.59 ± 0.27^{defg}	Long Bold
12	Kalo Novan	2.52 ± 0.17^{defgh}	Short Bold
13	Karo Mungo	2.44 ± 0.02^{efghi}	Short Bold
14	Karz	2.65 ± 0.18^{cdef}	Medium Slender
15	Kendal	2.42 ± 0.24^{efghij}	Long Bold
16	Khochro	2.56 ± 0.29^{defg}	Short Bold
17	Kolyo	2.40 ± 0.26^{fghij}	Short Bold
18	Korgut	2.41 ± 0.1^{efghij}	Short Bold
19	Kotimirsal	2.16 ± 0.01^{jkl}	Short Bold
20	Kusago	2.66 ± 0.25^{cde}	Short Bold
21	Muno	2.03 ± 0.02^{l}	Medium Slender
22	Novan	1.59 ± 0.19^{m}	Short Bold
23	Patni	2.33 ± 0.35^{ghijk}	Short Bold
24	Sal	2.06 ± 0.21^{cde}	Short Bold
25	Shiedi	2.34 ± 0.03^{ghijk}	Long Bold
26	Tamdi	3.51 ± 0.08^{ab}	Long Slender
27	Taysu	3.69 ± 0.18^{a}	Long Slender
28	Valay	2.40 ± 0.26^{fghji}	Long Bold
Critical differences (CD) (5%)		0.264	
Coefficient of Variation		6.379	

Mean ±SD followed by different letters differ significantly at 5%

Table 16. Physical characteristics of high yielding rice varieties showing L/B ratio and systematic grain classification.

Sl. No.	Varieties	L/B ratio	Systematic Grain Classification
1	Annapurna	2.38 ± 0^{k}	Short Bold
2	CSR-27	3.48 ± 0.02^{ef}	Long Slender
3	IR-8	2.05 ± 0.07^{m}	Short Bold
4	Jaya	3.07 ± 0.07^{h}	Long Slender
5	Jyoti	3.43 ± 0.27^{g}	Long Slender
6	Karjat-3	2.83 ± 0.02^{i}	Medium Slender
7	Karjat-5	2.53 ± 0.03^{j}	Long Bold
8	Kasturi	4.45 ± 0.07^{b}	Extra-long slender
9	KRH-2	3.30 ± 0.04^{g}	Long Slender
10	MO-7	3.58 ± 0.04^{e}	Long Slender
11	MO-9	2.90 ± 0.02^{i}	Long Bold
12	MO-17	2.81 ± 0.04^{i}	Medium Slender
13	Mugadh Sugandh	4.80 ± 0.06^{a}	Extra-long slender
14	Pusa Basmati-1	4.88 ± 0.05^{a}	Extra-long slender
15	Pusa Sugandh-2	4.43 ± 0.05^{bc}	Extra-long slender
16	Pusa Sugandh-3	4.38 ± 0.03^{c}	Extra-long slender
17	Pusa Sugandh-5	4.51 ± 0.01^{b}	Extra-long slender
18	R-6857	2.20 ± 0.05^{l}	Short Bold
19	Sahyadri-1	3.72 ± 2.62^{d}	Long Slender
20	Salt Tolerant AVT-1901	3.35 ± 0.03^{g}	Long Slender
21	Salt Tolerant AVT-1918	3.38 ± 0.02^{fg}	Long Slender
22	Vasmati	4.48 ± 0.06^{b}	Extra-long slender
Critical differences (CD) (5%)		0.117	
Coefficient of Variation		2.028	

Mean ±SD followed by different letters differ significantly at 5%

4.3.4. Chalkiness of Endosperm

Chalkiness in the endosperm of rice was classified into white belly, white centre and white back based on the position and orientation of chalkiness (Plate 7). The frequency of the chalkiness in rice grains was calculated as present (P), very occasionally present (VOP), occasionally present (O), and absent (A). The frequency of chalkiness in traditional rice varieties Assgo, Bello, Damgo, Kalo Damgo, Kalo Korgut, Kalo Novan, Karo Mungo, Karz, Kendal, Khochro, Korgut, Kusago, Muno, Novan, Patni, Shiedi, Tamdi and Valay belonged to the category of present (P); Barik Kudi, Girga and Sal assigned to very occasionally present (VOP); Ek Kadi, Dhave, Jiresal, Kolyo and Taysu segregated to occasionally present (O); and variety Ghansal and Kotimirsal reached to the category of absent (A) (Table 17). The frequency of chalkiness in high yielding rice varieties, Annapurna, CSR-27, IR-8, Jaya, Jyoti, Karjat-3, Kasturi, KRH-2, MO-7, MO-9, MO-17, Mugadh Sugandh, R-6857 and Sahyadri-1 assigned to (P); Karjat-5 and Pusa Basmati-1 belonged to (VOP); Pusa Sugandh-3, Pusa Sugandh-5, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918 and Vasmati to the category of (O) and Pusa Sugandh-2 to (A) (Table 18). Based on frequency of chalkiness the kernel area of chalkiness was determined. If the chalkiness is present the kernel area is large (more than 20%), chalkiness is occasionally present the kernel area is medium (11% to 20%), chalkiness is very occasionally present, the kernel area is small (less than 10%) and if zero chalkiness, then the chalkiness in kernel is absent (Table 17&18).

4.3.5. Chalk Index Determination

The rice varieties having minimum amount of chalkiness is consider as good quality grains in comparison with chalky ones which decrease the rice grain quality.

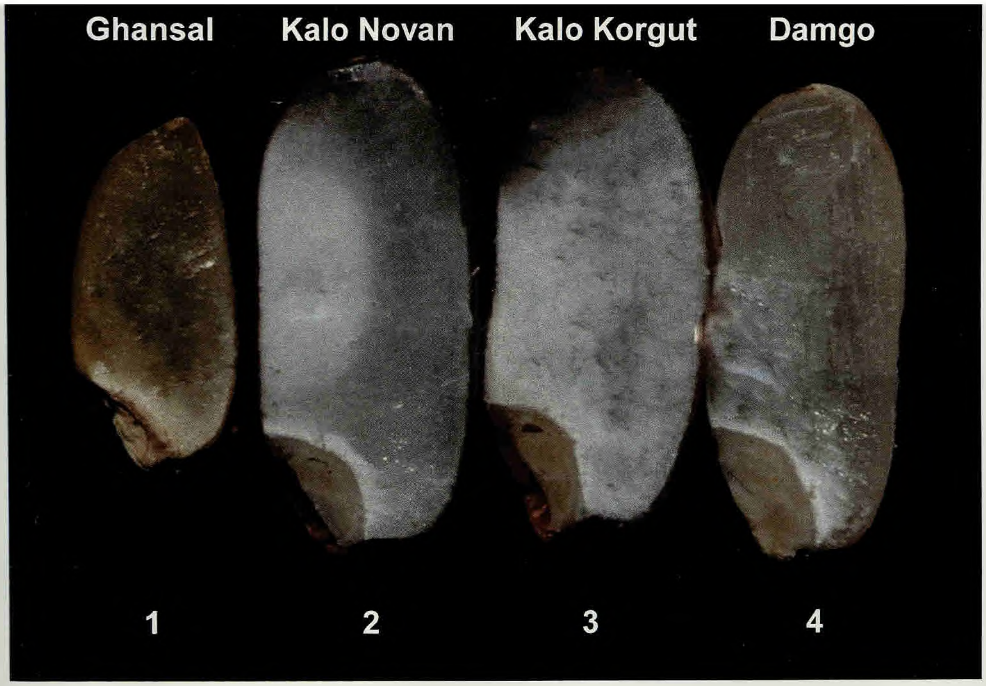


Plate 7. Chalkiness in the endosperm of rice classified on the basis position and orientation. 1. Non-chalky; 2. White centre; 3. White back; 4. White belly.

Table 17. Traditionally cultivated rice varieties showing the chalkiness frequency and kernel area of chalkiness.

Sl. No.	Varieties	Frequency of Chalkiness	Kernel area of Chalkiness
1	Assgo	Present	Large (more than 20%)
2	Barik Kudi	Very Occasionally Present	Small (less than 10%)
3	Bello	Present	Large (more than 20%)
4	Damgo	Present	Large (more than 20%)
5	Dhave	Occasionally Present	Medium (11% to 20%)
6	Ek Kadi	Occasionally Present	Medium (11% to 20%)
7	Ghansal	None	Absent
8	Girga	Very Occasionally Present	Small (less than 10%)
9	Jiresal	Occasionally Present	Medium (11% to 20%)
10	Kalo Damgo	Present	Large (more than 20%)
11	Kalo Korgut	Present	Large (more than 20%)
12	Kalo Novan	Present	Large (more than 20%)
13	Karo Mungo	Present	Large (more than 20%)
14	Karz	Present	Large (more than 20%)
15	Kendal	Present	Large (more than 20%)
16	Khochro	Present	Large (more than 20%)
17	Kolyo	Occasionally Present	Medium (11% to 20%)
18	Korgut	Present	Large (more than 20%)
19	Kotimirsal	None	Absent
20	Kusago	Present	Large (more than 20%)
21	Muno	Present	Large (more than 20%)
22	Novan	Present	Large (more than 20%)
23	Patni	Present	Large (more than 20%)
24	Sal	Very Occasionally Present	Small (less than 10%)
25	Shiedi	Present	Large (more than 20%)
26	Tamdi	Present	Large (more than 20%)
27	Taysu	Occasionally Present	Medium (11% to 20%)
28	Valay	Present	Large (more than 20%)

Table 18. High yielding rice varieties showing the frequency of chalkiness and kernel area of chalkiness.

Sl. No.	Varieties	Frequency of Chalkiness	Kernel area of Chalkiness
1	Annapurna	Present	Large (more than 20%)
2	CSR-27	Present	Large (more than 20%)
3	IR-8	Present	Large (more than 20%)
4	Jaya	Present	Large (more than 20%)
5	Jyoti	Present	Large (more than 20%)
6	Karjat-3	Present	Large (more than 20%)
7	Karjat-5	Occasionally Present	Medium (11% to 20%)
8	Kasturi	Present	Large (more than 20%)
9	KRH-2	Present	Large (more than 20%)
10	MO-7	Present	Large (more than 20%)
11	MO-9	Present	Large (more than 20%)
12	MO-17	Present	Large (more than 20%)
13	Mugadh Sugandh	Present	Large (more than 20%)
14	Pusa Basmati-1	Very Occasionally	Small (less than 10%)
15	Pusa Sugandh-2	None	Absent
16	Pusa Sugandh-3	Occasionally Present	Medium (11% to 20%)
17	Pusa Sugandh-5	Occasionally Present	Medium (11% to 20%)
18	R-6857	Present	Large (more than 20%)
19	Sahyadri-1	Present	Large (more than 20%)
20	Salt Tolerant AVT-1901	Occasionally Present	Medium (11% to 20%)
21	Salt Tolerant AVT-1918	Occasionally Present	Medium (11% to 20%)
22	Vasmati	Occasionally Present	Medium (11% to 20%)

Damgo, Kusago, Kalo Korgut, Muno, MO-7, Kendal and Khochro recorded 100% chalkiness where as no chalkiness was observed in traditional rice varieties Ghansal and Kotimirsal and in high yielding rice variety Pusa Sugandh-2. Percentage of chalkiness was calculated for all the traditionally cultivated (Table 19) and high yielding rice varieties (Table 20). It was noted that the percentage of chalkiness in traditional cultivated rice varieties ranged from 10.23-93.08, highest in variety Sal and lowest in variety Barik Kudi (Figure 11). In high yielding rice varieties the percentage of chalkiness was found to be from 14.13-85%, minimum in variety Salt Tolerant AVT-1901 and maximum (85%) in Jyoti (Figure 12).

4.4. Rice Grain Quality - Chemical Characteristics:

4.4.1. Alkali Spreading and Clearing Test

Alkali spreading value and gelatinization temperature were calculated for all the rice varieties and the results of the same are summarized in Tables 21, 22. Results indicated the following categories of alkali spreading value: low, intermediate and high. Based on the alkali spreading value gelatinization temperature was calculated. Low alkali spreading value means the gelatinization temperature is high (75-79°C). If intermediate alkali spreading value the gelatinization temperature is intermediate (70-74°C) and high alkali spreading value indicated that the gelatinization temperature is low (55-69°C).

The alkali spreading value in traditional rice varieties viz. Assgo, Barik Kudi, Damgo, Dhave, Kalo Korgut, Karo Mungo, Kendal, Khochro, Muno, Shiedi, Tamdi, Valay (low); Ek Kadi, Karz, Korgut, Bello, Ghansal, Girga, Jiresal, Kalo Damgo, Kalo Novan, Kolyo, Kotimirsal, Kusago, Patni, (intermediate) and Novan, Sal, Taysu (high) (Table 21). The alkali spreading value, in high yielding rice varieties Annapurna, CSR-27,

Fig. 11. Percentage of chalkiness in traditional rice varieties.

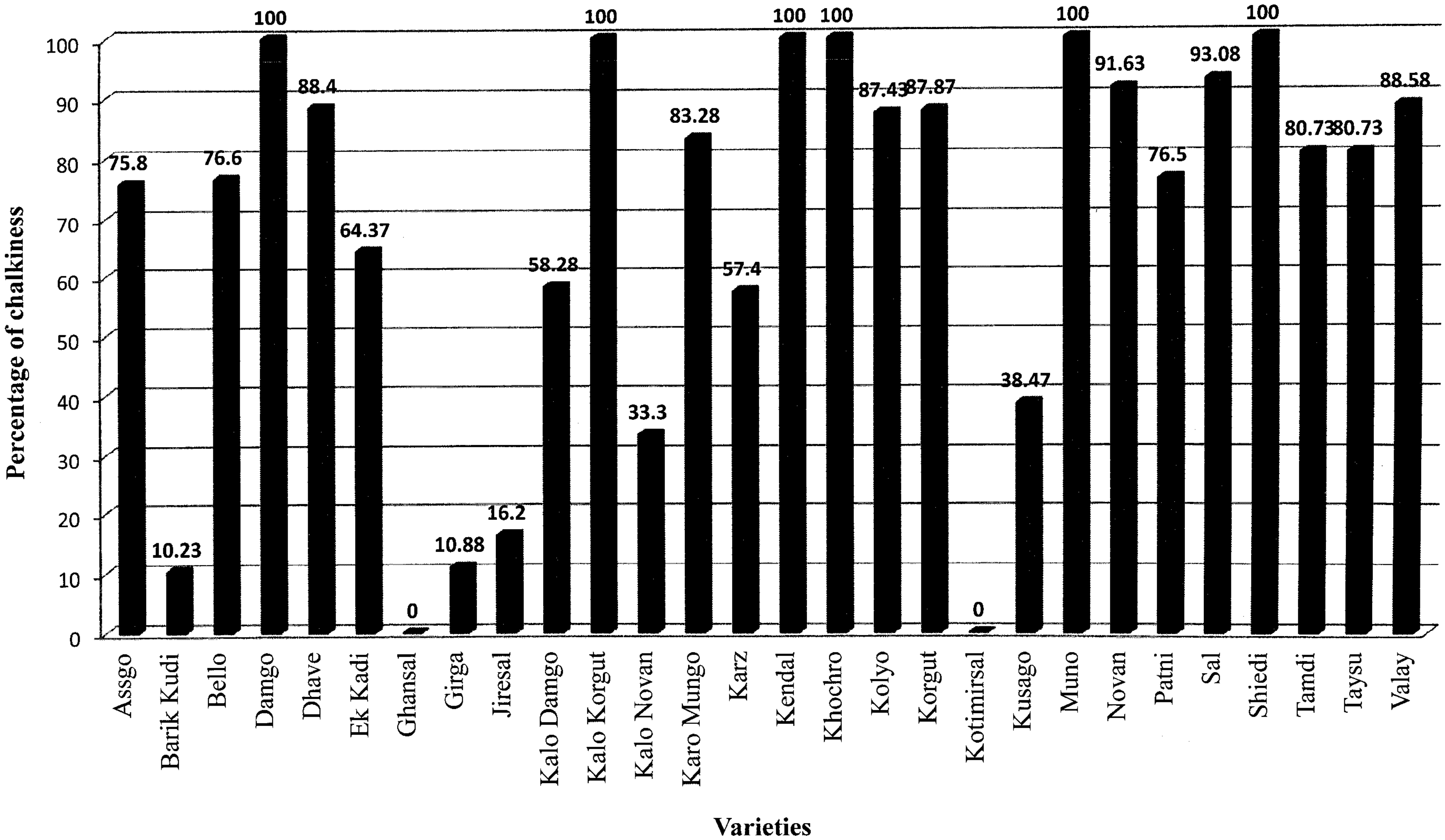


Fig. 12. Percentage of chalkiness in high yielding rice varieties.

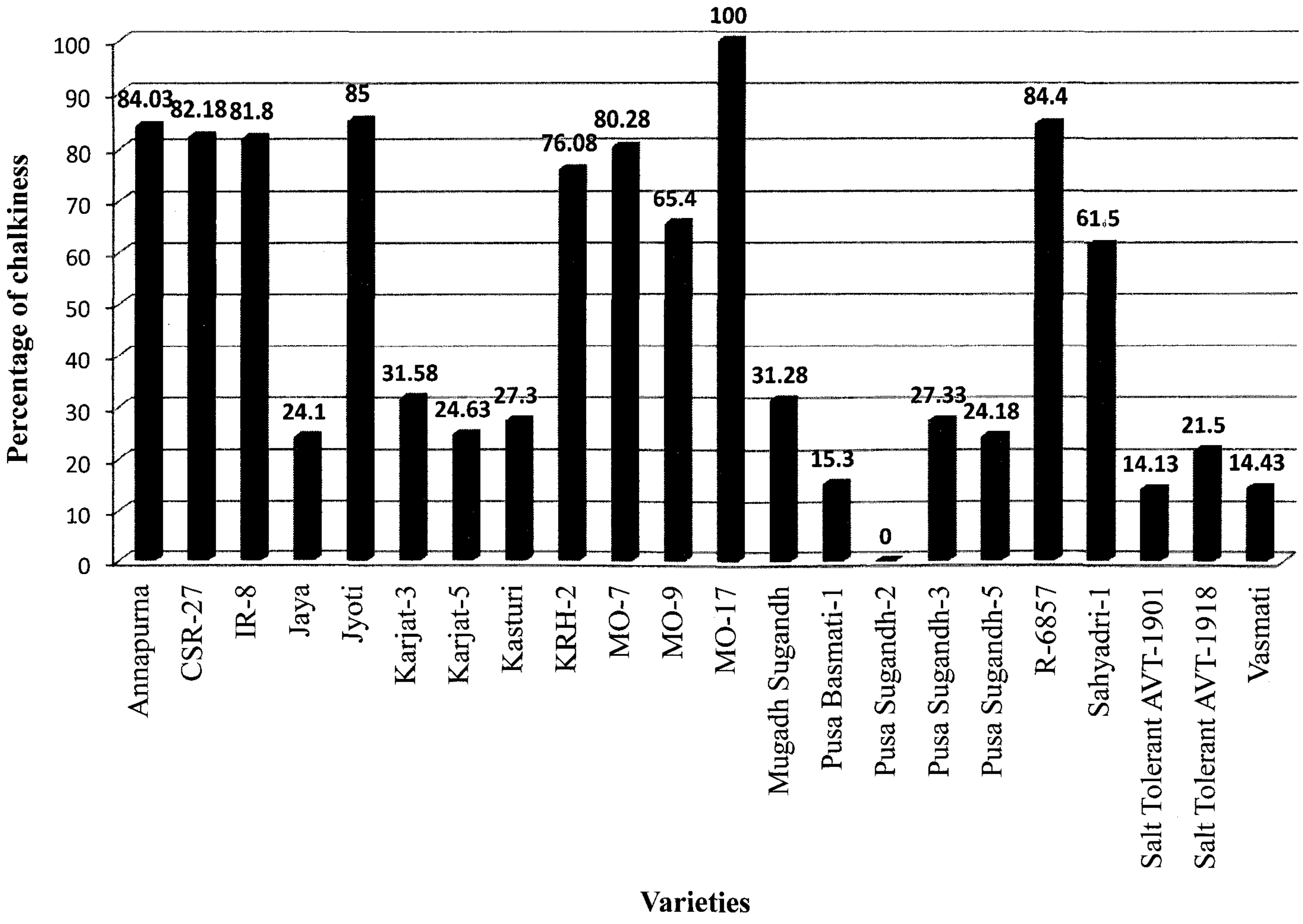


Table 19. Traditionally cultivated rice varieties showing the type of chalkiness and percentage of chalkiness.

Sl. No.	Varieties	Type of chalkiness	Chalkiness percentage
1	Assgo	White Belly	75.8 ± 2.51^{f}
2	Barik Kudi	White Centre	10.23 ± 0.87^{l}
3	Bello	White Belly	76.60 ± 1.21^{f}
4	Damgo	White Belly	100 ± 0^{a}
5	Dhave	White Belly	88.40 ± 0.98^{c}
6	Ek Kadi	White Belly	64.37 ± 2.2^{g}
7	Ghansal	None	0 ± 0^{m}
8	Girga	White Centre	10.88 ± 3.09^{l}
9	Jiresal	White Belly	16.20 ± 0.9^{k}
10	Kalo Damgo	White Belly	58.28 ± 3.35^{h}
11	Kalo Korgut	White Back	100 ± 0^{a}
12	Kalo Novan	White Centre	33.30 ± 1.04^{j}
13	Karo Mungo	White Belly	83.28 ± 0.9^{d}
14	Karz	White Belly	57.40 ± 1.31^{h}
15	Kendal	White Belly	100 ± 0.00^{a}
16	Khochro	White Belly	100 ± 0.00^{a}
17	Kolyo	White Centre	87.43 ± 1.05^{c}
18	Korgut	White Belly	87.87 ± 0.65^{c}
19	Kotimirsal	None	0 ± 0.00^{m}
20	Kusago	White Centre	38.47 ± 1.18^{i}
21	Muno	White Centre	100 ± 0.00^{a}
22	Novan	White Belly	91.63 ± 0.22^{b}
23	Patni	White Belly	76.50 ± 0.66^{f}
24	Sal	White Belly	93.08 ± 2.67^{b}
25	Shiedi	White Back	100 ± 0^{a}
26	Tamdi	White Belly	80.73 ± 0.45^{e}
27	Taysu	White Centre	80.73 ± 0.45^{e}
28	Valay	White Belly	88.58 ± 0.42^{c}
Critical differences (CD) (5%)			2.131
Coefficient of Variation			1.919

Mean ±SD followed by different letters differ significantly at 5%

Table 20. High yielding rice varieties showing type of chalkiness and percentage of chalkiness.

Sl. No.	Varieties	Type	Chalkiness percentage
1	Annapurna	White Belly	84.03 ±1.6[bc]
2	CSR-27	White Belly	82.18 ± 1.54[cd]
3	IR-8	White Centre	81.8 ± 1.15[d]
4	Jaya	White Centre	24.10 ± 1.47[j]
5	Jyoti	White Belly	85.0 ± 0.75[b]
6	Karjat-3	White Centre	31.58 ± 0.55[h]
7	Karjat-5	White Centre	24.63 ± 0.55[j]
8	Kasturi	White Belly	27.30 ± 1.15[i]
9	KRH-2	White Belly	76.08 ± 3.53[e]
10	MO-7	White Belly	80.28 ± 0.37[d]
11	MO-9	White Belly	65.40 ± 0.06[f]
12	MO-17	White Belly	100 ± 0.00[a]
13	Mugadh Sugandh	White Belly	31.28 ± 1.12[h]
14	Pusa Basmati-1	White Belly	15.30 ± 0.36[l]
15	Pusa Sugandh-2	None	0 ± 0.00[m]
16	Pusa Sugandh-3	White Centre	27.33 ± 1.08[i]
17	Pusa Sugandh-5	White Belly	24.18 ± 0.81[j]
18	R-6857	White Centre	84.40 ± 1.02[b]
19	Sahyadri-1	White Centre	61.50 ± 1.4[g]
20	Salt Tolerant AVT-1901	White Belly	14.13 ± 0.86[l]
21	Salt Tolerant AVT-1918	White Belly	21.50 ± 0.65[k]
22	Vasmati	White Belly	14.43 ± 1.18[l]
Critical differences (CD) (5%)			1.918
Coefficient of Variation			2.424

Mean ±SD followed by different letters differ significantly at 5%

Table 21. Traditionally cultivated rice varieties, showing the alkali spreading value, and gelatinization temperature.

Sl. No.	Name of the varieties	Alkali spreading value	Gelatinization temperature
1	Assgo	Low	High 75-79 °C
2	Barik Kudi	Intermediate	Intermediate (70°C-74°C)
3	Bello	Intermediate	Intermediate (70°C-74°C)
4	Damgo	Low	High 75-79 °C
5	Dhave	Intermediate	Intermediate (70°C-74°C)
6	Ek Kadi	Intermediate	Intermediate (70°C-74°C)
7	Ghansal	Intermediate	Intermediate (70°C-74°C)
8	Girga	Intermediate	Intermediate (70°C-74°C)
9	Jiresal	Intermediate	Intermediate (70°C-74°C)
10	Kalo Damgo	Intermediate	Intermediate (70°C-74°C)
11	Kalo Korgut	Low	High 75-79 °C
12	Kalo Novan	Intermediate	Intermediate (70°C-74°C)
13	Karo Mungo	Low	High 75-79 °C
14	Karz	Intermediate	Intermediate (70°C-74°C)
15	Kendal	Low	High 75-79 °C
16	Khochro	Low	High 75-79 °C
17	Kolyo	Intermediate	Intermediate (70°C-74°C)
18	Korgut	Intermediate	Intermediate (70°C-74°C)
19	Kotimirsal	Intermediate	Intermediate (70°C-74°C)
20	Kusago	Intermediate	Intermediate (70°C-74°C)
21	Muno	Low	High 75-79 °C
22	Novan	High	Low (55°C-69°C)
23	Patni	Intermediate	Intermediate (70°C-74°C)
24	Sal	High	Low (55°C-69°C)
25	Shiedi	Low	High 75-79 °C
26	Tamdi	Low	High 75-79 °C
27	Taysu	High	Low (55°C-69°C)
28	Valay	Low	High 75-79 °C

Mean ±SD followed by different letters differ significantly at 5%

Table 22. High yielding rice varieties, showing the alkali spreading value and gelatinization temperature.

Sl. No.	Varieties	Alkali spreading value	Gelatinization temperature
1	Annapurna	Low	High 75-79 °C
2	CSR-27	Low	High 75-79 °C
3	IR-8	Low	High 75-79 °C
4	Jaya	High	Low (55°C-69°C)
5	Jyoti	Low	High 75-79 °C
6	Karjat-3	Intermediate	Intermediate (70°C-74°C)
7	Karjat-5	Intermediate	Intermediate (70°C-74°C)
8	Kasturi	Intermediate	Intermediate (70°C-74°C)
9	KRH-2	Low	High 75-79 °C
10	MO-7	Low	High 75-79 °C
11	MO-9	Intermediate	Intermediate (70°C-74°C)
12	MO-17	Low	High 75-79 °C
13	Mugadh Sugandh	Low	High 75-79 °C
14	Pusa Basmati-1	High	Low (55°C-69°C)
15	Pusa Sugandh-2	Intermediate	Intermediate (70°C-74°C)
16	Pusa Sugandh-3	Intermediate	Intermediate (70°C-74°C)
17	Pusa Sugandh-5	High	Low (55°C-69°C)
18	R-6857	Intermediate	Intermediate (70°C-74°C)
19	Sahyadri-1	Low	High 75-79 °C
20	Salt Tolerant AVT-1901	Intermediate	Intermediate (70°C-74°C)
21	Salt Tolerant AVT-1918	Intermediate	Intermediate (70°C-74°C)
22	Vasmati	High	Low (55°C-69°C)

Mean ±SD followed by different letters differ significantly at 5%

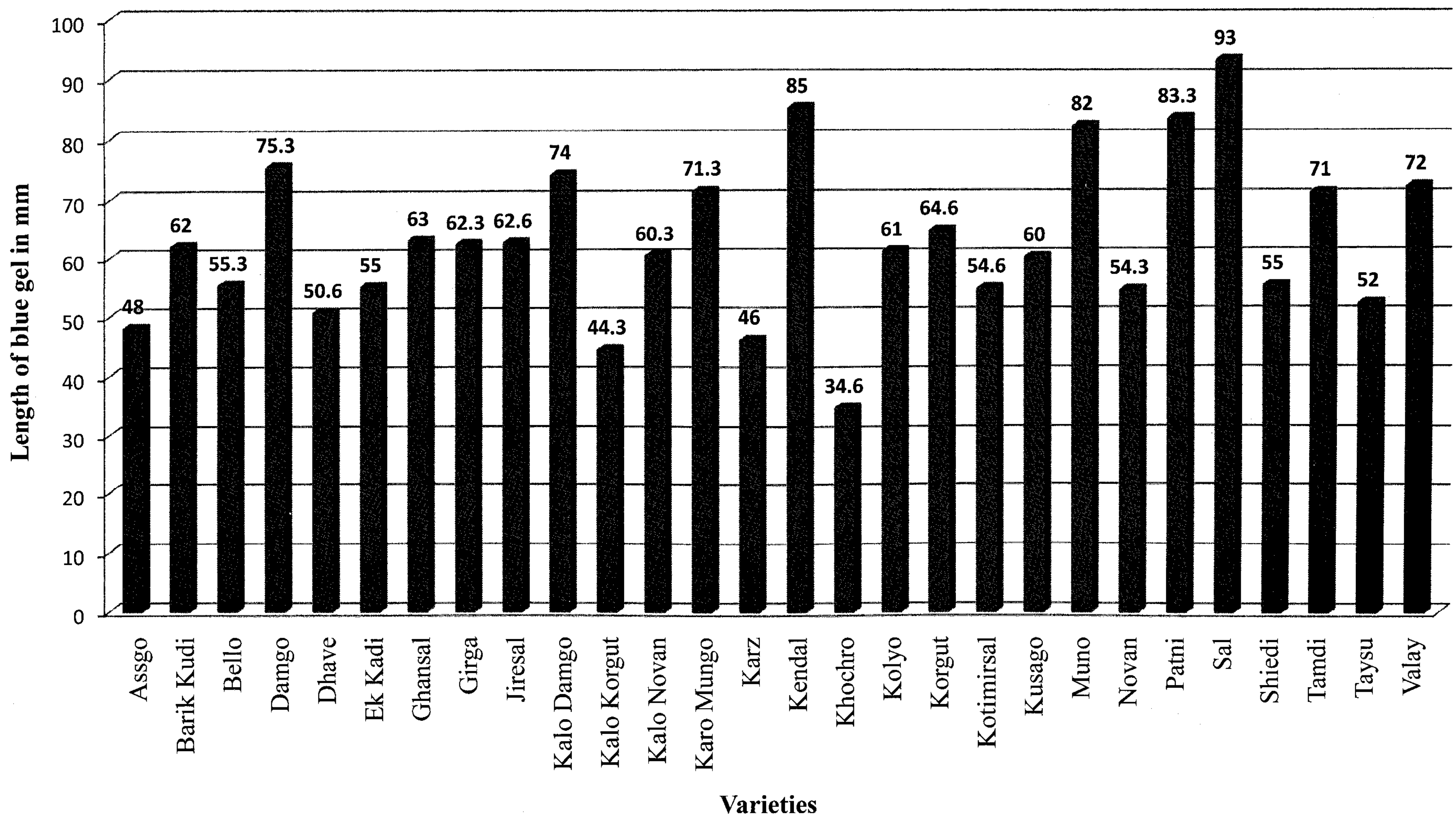
IR-8, Jyoti, KRH-2, MO-7, MO-17, Mugadh Sugandh, Sahyadri-1 (low); Salt Tolerant AVT-1901, Salt Tolerant AVT-1918, Karjat-3, Karjat-5, Kasturi, MO-9, Pusa Sugandh-3, Pusa Sugandh-2, R-6857(intermediate) and Jaya, Pusa Sugandh-5, Pusa Basmati-1, Vasmati (high) (Table 22).

4.4.2. Gel Consistency (GC)

The gel consistency (GC) is measured into soft, medium and hard. Among the traditional rice varieties, the length of the blue gel was highest in Sal (93 mm) and lowest (34.6 mm) in Khochro (Table 23; Figure 13). In high yielding rice varieties the gel consistency ranged from 28-91.3 mm (Table 24). Among the high yielding rice varieties, the length of the blue gel was highest in R-6857 (91.3 mm) and lowest (28 mm) in Pusa Basmati -1 (Figure 14).

The soft gel consistency was recorded in traditional rice varieties viz. Barik Kudi, Bello, Damgo, Girga, Jiresal, Kalo Damgo, Karo Mungo, Kendal, Kolyo, Korgut, Muno, Patni, Sal, Tamdi and Valay; the medium gel consistency was noted in varieties Assgo, Dhave, Ek Kadi, Ghansal, Kalo Korgut, Kalo Novan, Karz, Khochro, Kotimirsal, Kusago, Novan, Shiedi and Taysu (Table 23). In high yielding rice varieties, the soft gel consistency was observed in varieties Annapurna, CSR-27 and IR-8; the medium gel consistency was noted in varieties Jaya, Jyoti, Karjat-3, Karjat-5, KRH-2, MO-7, Mo-9, R-6857, Sahyadri-1, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918 and the hard gel consistency was recorded in the varieties Kasturi, MO-17, Mugadh Sugandh, Pusa Sugandh-3, Pusa Sugandh-2, Pusa Sugandh-5, Pusa Basmati-1 and Vasmati (Table 24).

Fig. 13. Length of blue gel in traditional cultivated rice varieties.



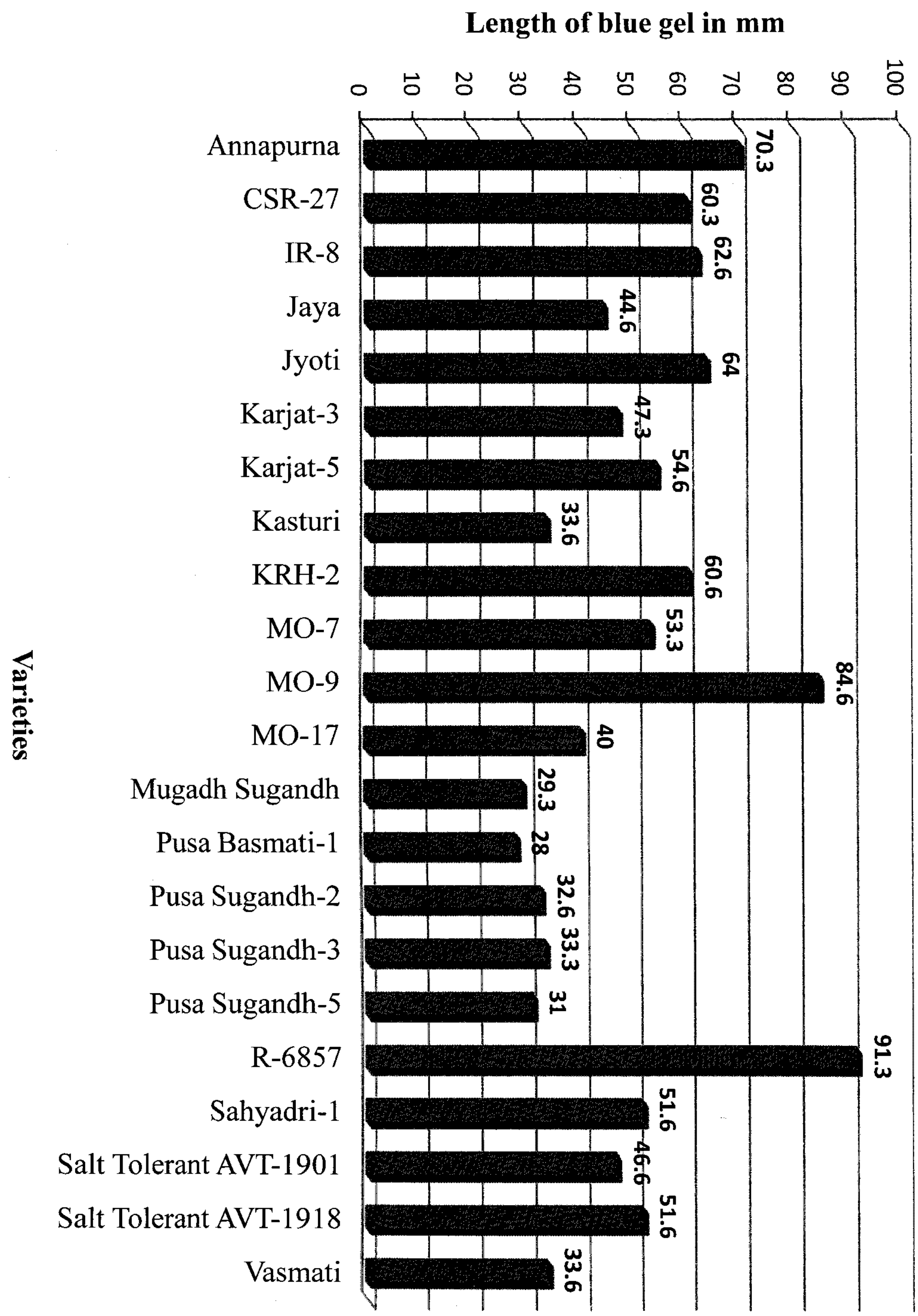


Fig. 14. Length of blue gel in high yielding rice varieties.

Table 23. Traditionally cultivated rice varieties, showing the length of blue gel, gel consistency, aroma and amylose content in percentage.

Sr. No.	Name of the varieties	Length of blue gel in mm	Gel Consistency	A	Amylose Content %
1	Assgo	48.0 ± 1^{jk}	Medium	NS	19.57 ± 0.51^{abcd}
2	Barik Kudi	62.0 ± 1^{ef}	Soft	NS	14.04 ± 0.87^{fg}
3	Bello	55.3 ± 1.53^{g}	Medium	NS	16.08 ± 1.28^{def}
4	Damgo	75.3 ± 3.51^{c}	Soft	NS	17.2 ± 0.69^{cdef}
5	Dhave	50.6 ± 1.15^{ij}	Medium	NS	17.99 ± 0.61^{abcdef}
6	Ek Kadi	55.0 ± 3^{gh}	Medium	NS	20.37 ± 0.72^{abcd}
7	Ghansal	63.0 ± 3.6^{ef}	Medium	S	18.7 ± 1.25^{abcd}
8	Girga	62.3 ± 2.52^{ef}	Soft	S	20.46 ± 0.47^{abcd}
9	Jiresal	62.6 ± 2.52^{ef}	Soft	S	18.05 ± 2.2^{abcd}
10	Kalo Damgo	74 ± 2^{cd}	Soft	NS	20.34 ± 0.83^{abc}
11	Kalo Korgut	44.3 ± 2.52^{l}	Medium	NS	21.78 ± 0.92^{a}
12	Kalo Novan	60.3 ± 0.58^{f}	Medium	NS	23.72 ± 0.76^{ab}
13	Karo Mungo	71.3 ± 1.15^{d}	Soft	NS	18.83 ± 0.52^{abcd}
14	Karz	$46\pm3.61^{k}1$	Medium	NS	20.41 ± 0.85^{abcd}
15	Kendal	85 ± 2^{b}	Soft	NS	19.91 ± 0.33^{cdef}
16	Khochro	34.6 ± 0.58^{m}	Hard	NS	14.65 ± 0.37^{efg}
17	Kolyo	61 ± 0.57^{f}	Soft	NS	16.46 ± 1.09^{cdef}
18	Korgut	64.6 ± 2.52^{e}	Soft	NS	17.55 ± 1.46^{cdef}
19	Kotimirsal	54.6 ± 2.51^{gh}	Medium	S	17.27 ± 1.05^{abcde}
20	Kusago	60.0 ± 0.58^{f}	Medium	NS	19.35 ± 1.32^{cdef}
21	Muno	82.0 ± 1^{f}	Soft	NS	17.43 ± 1.35^{cdef}
22	Novan	54.3 ± 4.04^{gh}	medium	NS	17.19 ± 0.84^{cdef}
23	Patni	83.3 ± 1.53^{b}	Soft	NS	19.07 ± 1.29^{bcdef}
24	Sal	93 ± 1^{a}	Soft	S	18.31 ± 0.36^{abcd}
25	Shiedi	55 ± 1.73^{gh}	medium	NS	21.6 ± 0.76^{abcd}
26	Tamdi	71 ± 1^{d}	Soft	NS	16.85 ± 0.58^{cdef}
27	Taysu	52 ± 1.73^{hi}	Medium	NS	17.43 ± 0.23^{cdef}
28	Valay	72 ± 2^{d}	Soft	NS	16.7 ± 0.94^{g}
Critical differences (CD)		3.082			3.926
Coefficient of Variation		3.046			13.090

Non Scented (NS); Scented (S); Aroma (A)

Mean ±SD followed by different letters differ significantly at 5%

Table 24. High yielding rice varieties, showing the length of blue gel, gel consistency, aroma and amylose content in percentage.

Sl. No.	Name of the varieties	Length of blue gel in	Gel Consistency	A	Amylose Content %
1	Annapurna	70.3 ± 1.53^{c}	Soft	NS	19.57 ± 0.62^{h}
2	CSR-27	60.3 ± 2.08^{d}	Soft	NS	22.1 ± 1.27^{ef}
3	IR-8	62.6 ± 2.51^{d}	Soft	NS	17.88 ± 0.59^{gh}
4	Jaya	44.6 ± 2.52^{f}	Medium	NS	23.33 ± 0.88^{cd}
5	Jyoti	64.0 ± 4^{d}	Soft	NS	24.75 ± 4.13^{bc}
6	Karjat-3	47.3 ± 1.53^{f}	Medium	NS	21.26 ± 0.65^{ef}
7	Karjat-5	54.6 ± 2.52^{e}	Medium	NS	17.34 ± 1.03^{gh}
8	Kasturi	33.6 ± 5.86^{e}	Hard	S	21.83 ± 0.36^{de}
9	KRH-2	60.6 ± 1.15^{d}	Medium	NS	22.14 ± 1.59^{de}
10	MO-7	53.3 ± 1.53^{e}	Medium	NS	21.16 ± 0.98^{ef}
11	MO-9	84.6 ± 2.53^{b}	Soft	NS	22.15 ± 0.49^{ef}
12	MO-17	40.0 ± 1^{g}	Hard	NS	20.46 ± 0.62^{ef}
13	Mugadh Sugandh	29.3 ± 2.08^{ij}	Hard	S	27.69 ± 1.49^{a}
14	Pusa Basmati-1	28.0 ± 1^{j}	Hard	S	26.43 ± 1.69^{ab}
15	Pusa Sugandh-2	32.6 ± 2.07^{hi}	Hard	S	25.84 ± 0.67^{ab}
16	Pusa Sugandh-3	33.3 ± 3.51^{h}	Hard	S	26.42 ± 0.41^{ab}
17	Pusa Sugandh-5	31.0 ± 1^{hij}	Hard	S	25.83 ± 0.37^{ab}
18	R-6857	91.3 ± 2.31^{a}	Medium	NS	23.6 ± 1.21^{ef}
19	Sahyadri-1	51.6 ± 0.57^{e}	Medium	NS	23.62 ± 0.74^{gh}
20	Salt Tolerant AVT-	46.6 ± 0.57^{f}	Medium	NS	18.36 ± 0.66^{gh}
21	Salt Tolerant AVT-	51.6 ± 1.53^{e}	Medium	NS	19.24 ± 0.21^{fg}
22	Vasmati	33.6 ± 1.53^{h}	Hard	S	22.34 ± 1.12^{de}
Critical differences (CD) (5%)		3.799			5.624
Coefficient of Variation		4.587			2.050

Non Scented (NS); Scented (S); Aroma (A)

Mean ±SD followed by different letters differ significantly at 5%

4.4.3. Amylose Content (AC)

The Amylose content (AC) is considered to be the single most important characteristic for predicting rice cooking and processing behaviors. AC was calculated for all 50 rice varieties. The Amylose content in traditional rice varieties ranged from 14-23.7% (Table 23). The highest AC was noted in traditional rice variety Kalo Novan and lowest in variety Barik Kudi (Figure 15). In high yielding rice varieties AC ranged from 17.34-27.69% (Table 24), least (17.34%) amylose content in variety Karjat-5 and high (27.69%) amylose content in variety Mugadh Sugandh (Figure 16).

4.4.4. Aroma

Aroma is another important trait and the aromatic rice has high demand in the market. It was observed in the present study that few native varieties were with aroma, for which these varieties are preferred for consumption by local people. Aroma was tested among all the 50 rice varieties and classified as scented and non-scented. The scented native rice varieties are Ghansal, Girga, Jiresal, Kotimirsal, Sal and non scented traditional rice varieties are Assgo, Barik Kudi, Bello, Damgo, Dhave, Ek Kadi, Kalo Damgo, Kalo Korgut, Kalo Novan, Karo Mungo, Karz, Kendal, Khochro, Kolyo, Korgut, Kusago, Muno, Novan, Patni, Shiedi, Tamdi, Taysu and Valay (Table 23). Among the high yielding varieties, scented rice varieties are Kasturi, Mugadh Sugandh, Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5and Vasmati. The non-scented rice varieties are Annapurna, CSR-27, IR-8, Jaya, Jyoti, Karjat-3, Karjat-5, KRH-2, MO-7, MO-9, MO-17, R-6857, Sahyadri-1, Salt Tolerant AVT-1918 and Salt Tolerant AVT-1901 (Table 24).

Fig. 15. Percentage of amylose content in traditional cultivated rice varieties.

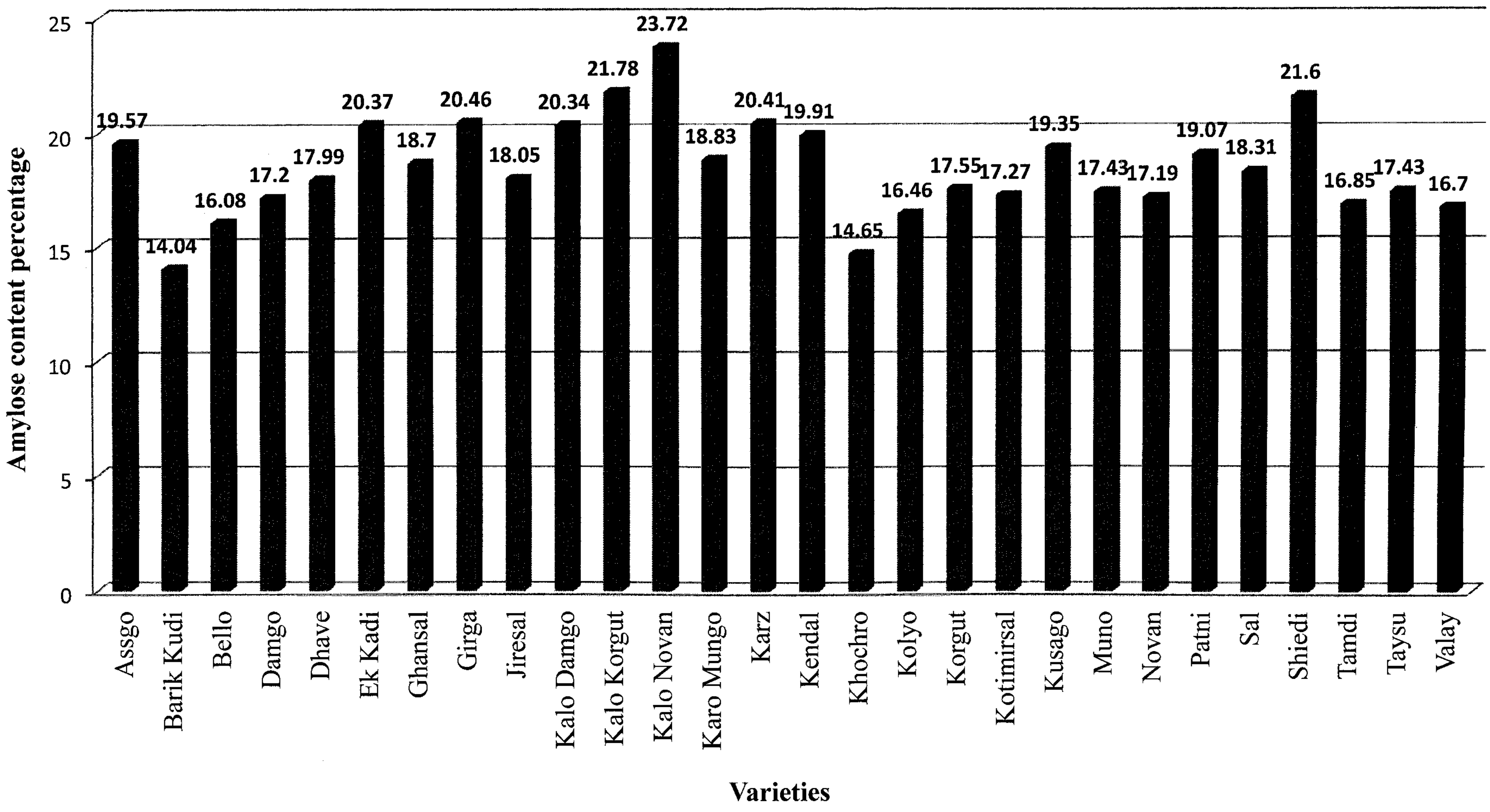
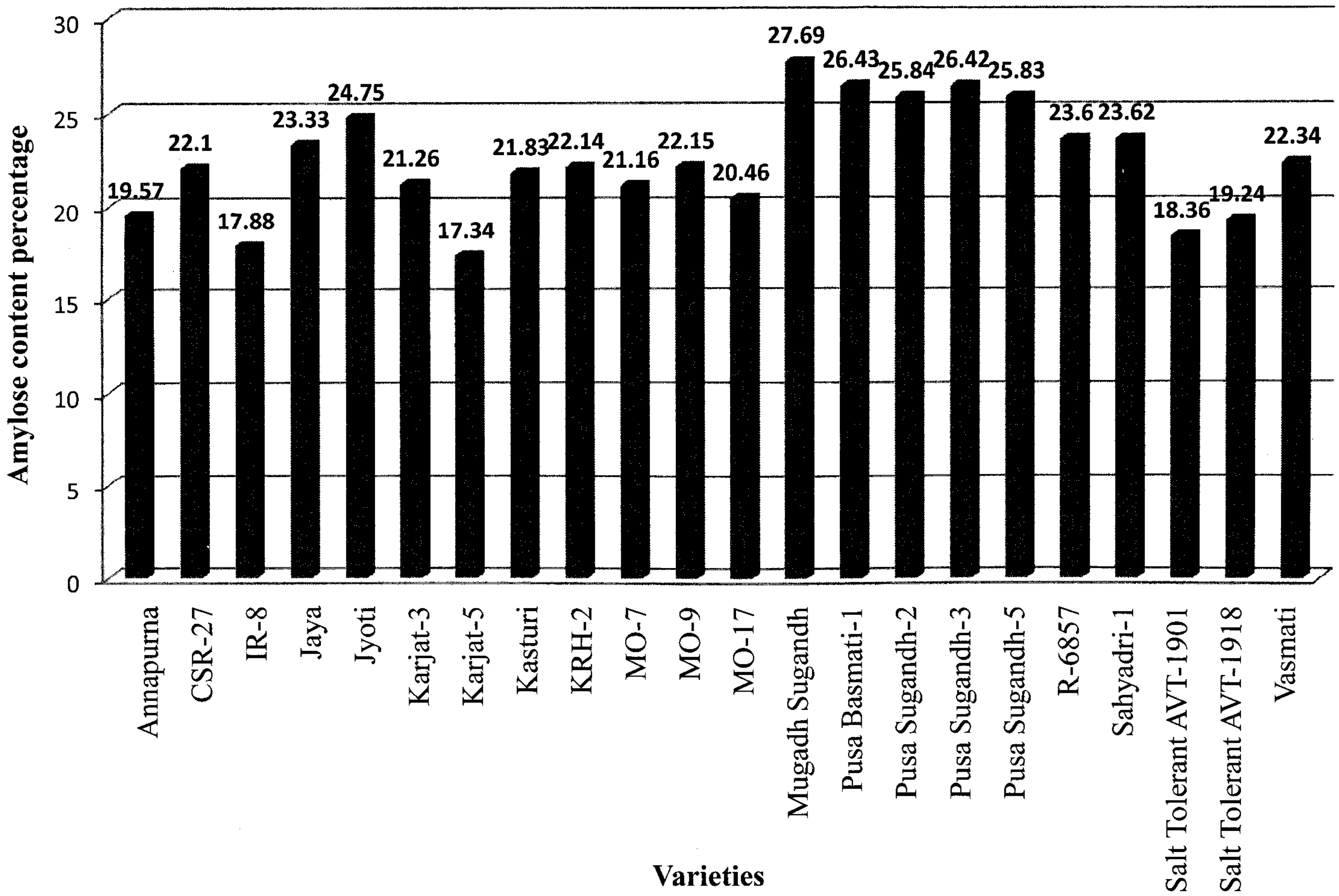


Fig. 16. Percentage of amylose content in high yielding rice varieties.



4.5. Rice Grain Quality - Cooking characteristics:

4.5.1. Volume Expansion Ratio and Elongation Ratio

Volume expansion ratio and elongation ratio were calculated for traditional rice varieties and high yielding rice varieties. Volume expansion ratio in traditional rice varieties ranged from 1.6 to 4.1 (Table 25). The maximum volume expansion was noted in variety Jiresal and minimal volume expansion ratio in variety Kalo Korgut (Figure 17). Volume expansion ratio in high yielding rice varieties ranged from 1.6 to 4.03 (Table 26). The highest volume expansion was recorded in variety KRH-2 and lowest volume expansion ratio in variety Karjat-5 (Figure 18).

Kernel elongation ratio (ER) in traditional rice varieties ranged from 1.01-1.66 (Table 25). Variety Kalo Damgo showed the lowest (1.01) ER and highest (1.66) in variety Bello (Figure 19). ER in high yielding rice varieties ranged from 1.01 to 1.52 (Table 26), maximum (1.52) in variety Karjart-5and lowest (1.01) in Jyoti (Figure 20).

Kernel length after cooking (KLAC) was calculated for all 50 rice varieties. Among the traditional rice varieties KLAC ranged from 6.64-10.8 mm (Table 27). In traditional rice varieties the highest (10.8 mm) KLAC was recorded in Barik Kudi and lowest (6.64 mm) KLAC was recorded in variety Kotimirsal (Figure 21). In high yielding rice varieties, highest (14.18) KLAC was recorded in Vasmati and minimum (8.03) in variety IR-8 (Table 28; Figure 22).

Fig. 17. Volume expansion ratio in traditional cultivated rice varieties.

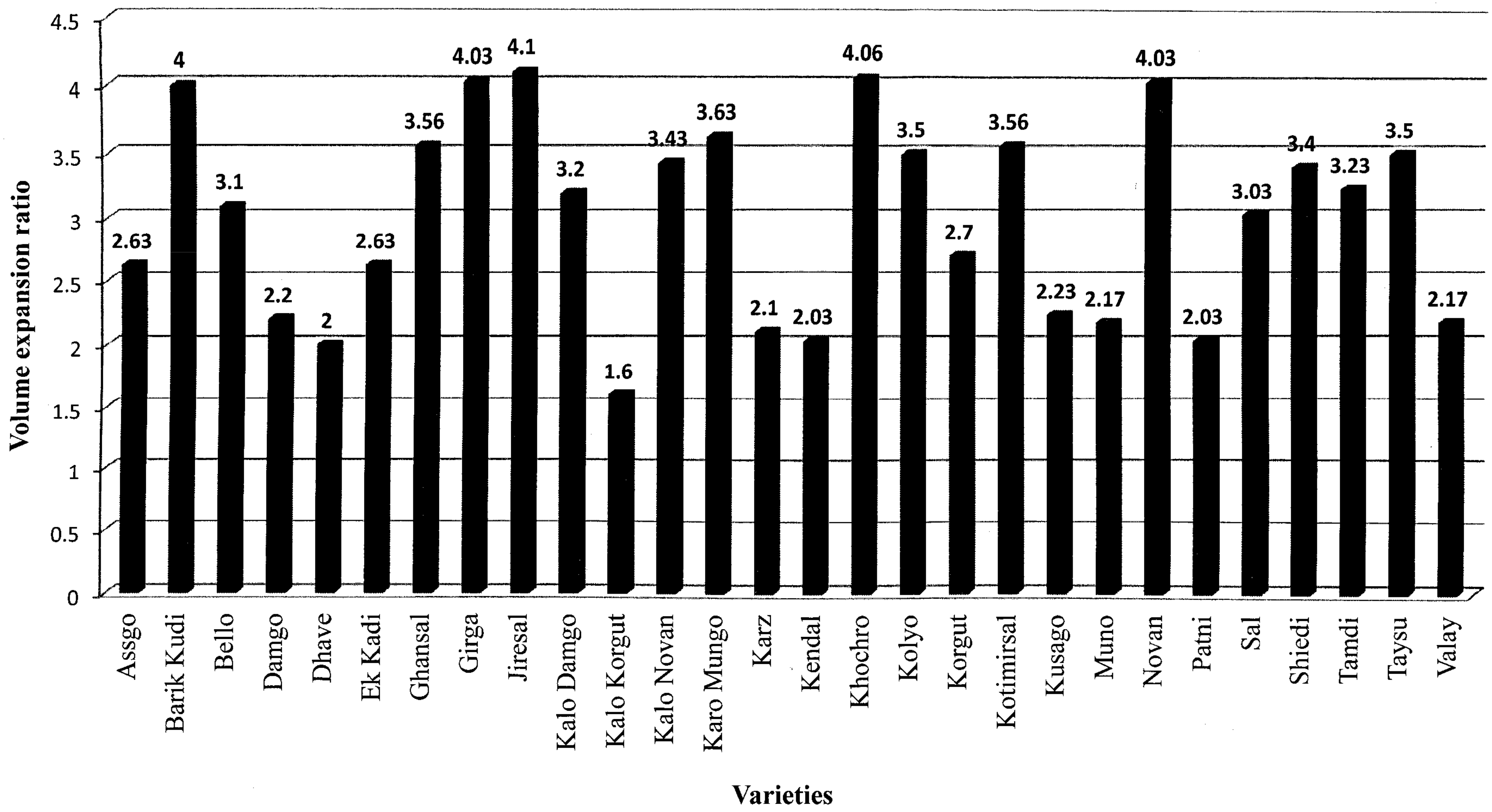


Fig. 18. Volume expansion ratio in high yielding rice varieties.

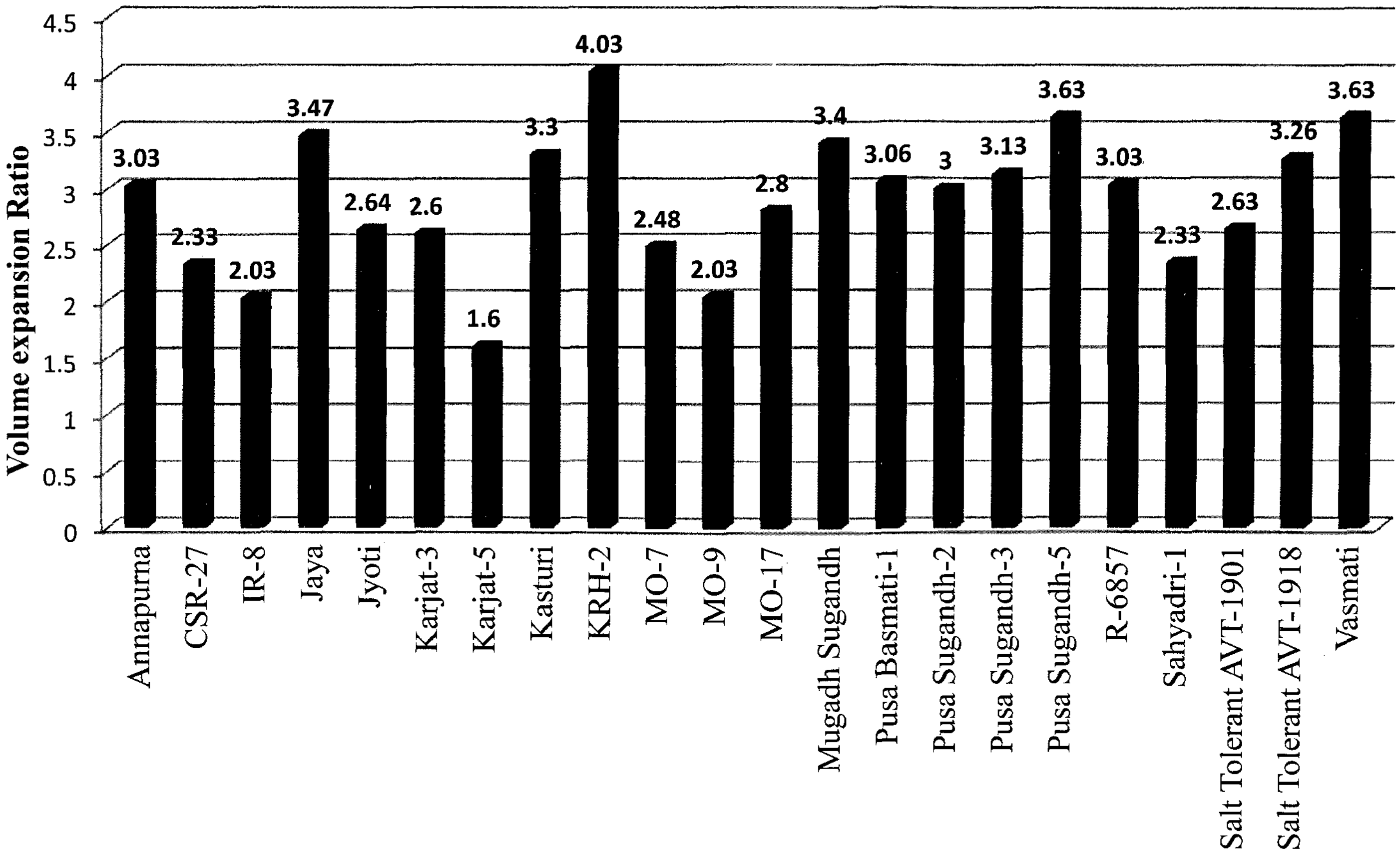


Fig. 19. Kernel elongation ratio in traditional rice varieties.

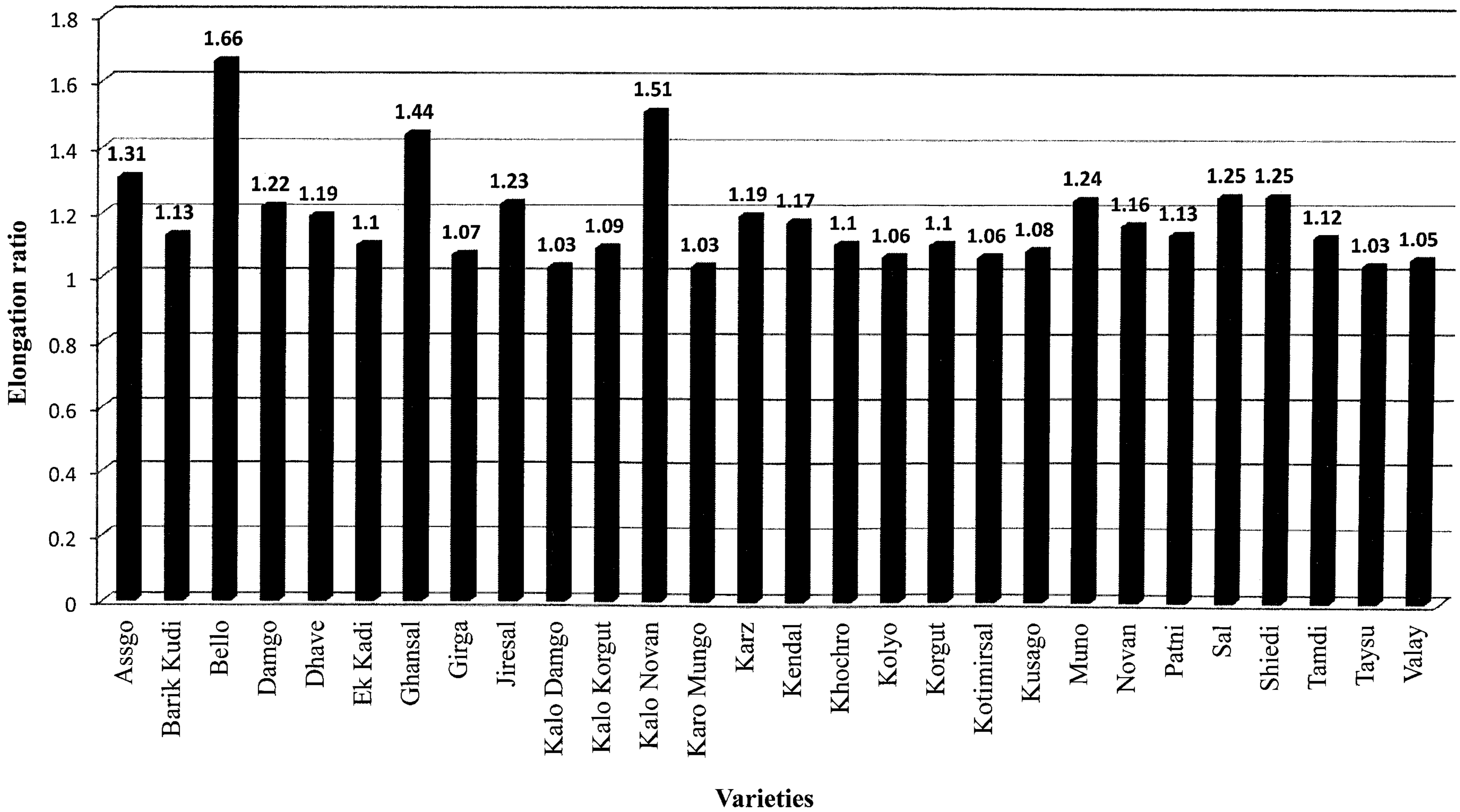


Fig. 20. Kernel elongation ratio in high yielding rice varieties.

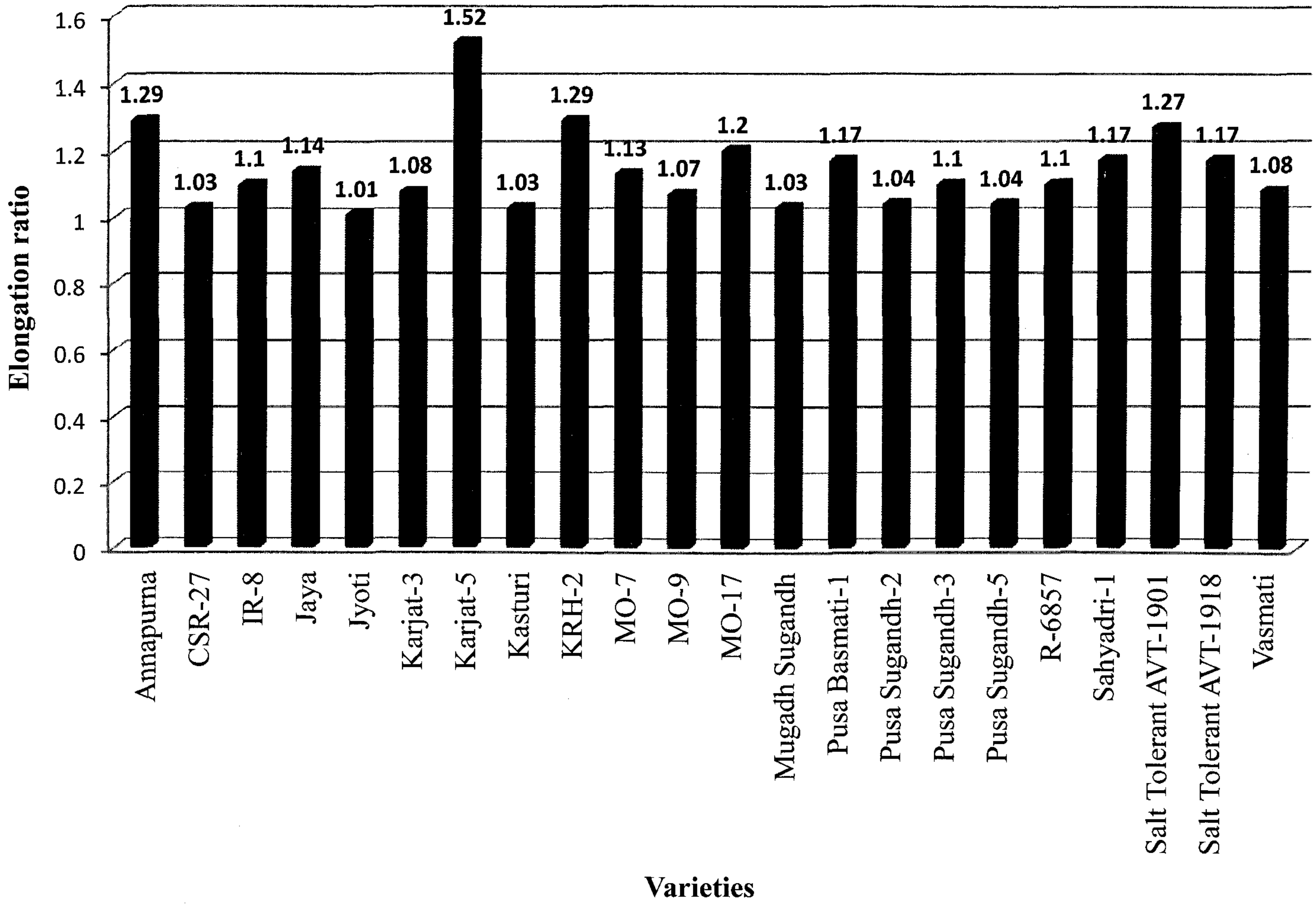


Fig. 21. Kernel length after cooking in traditional cultivated rice varieties.

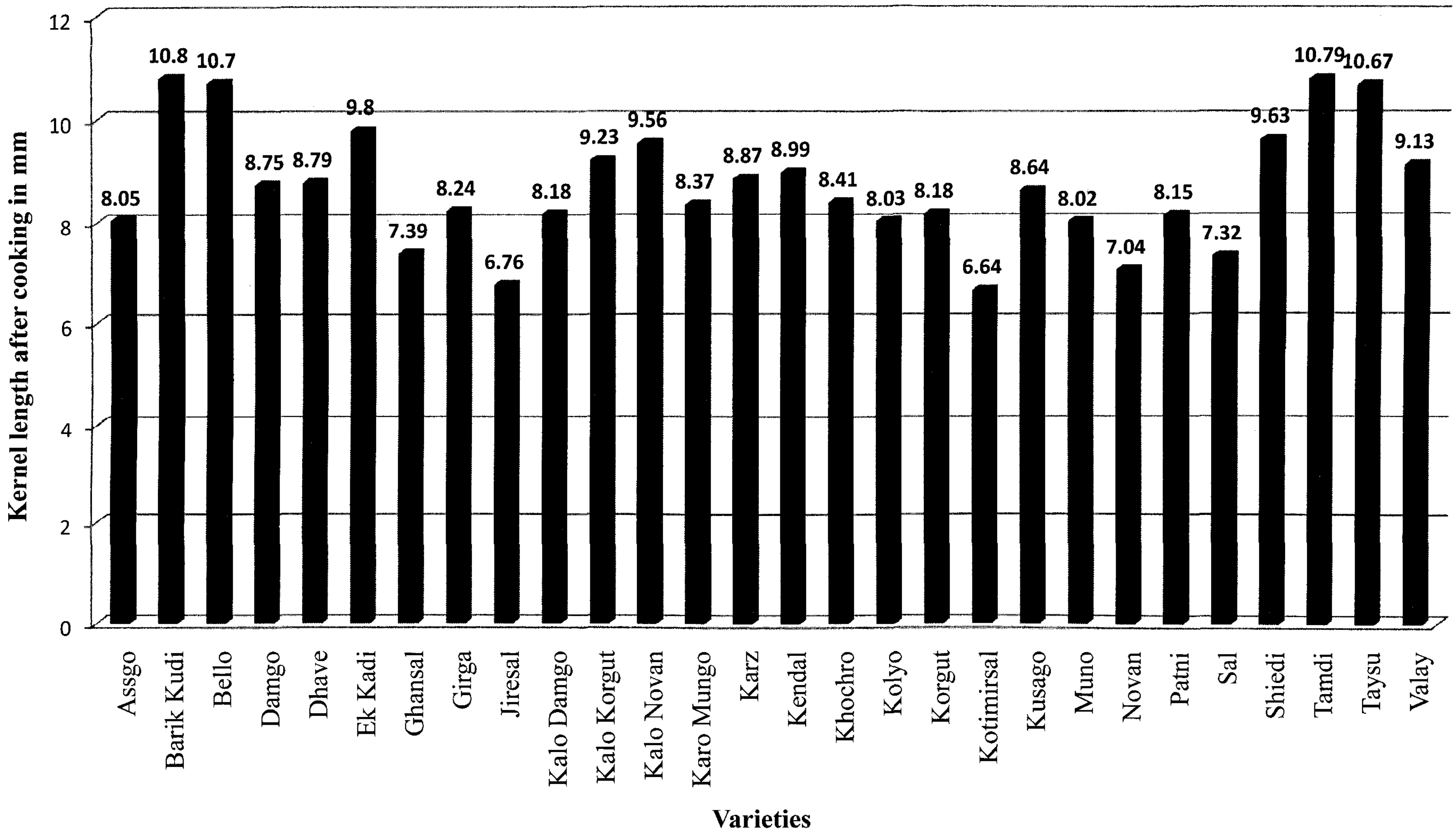


Fig. 22. Kernel length after cooking in high yielding rice varieties.

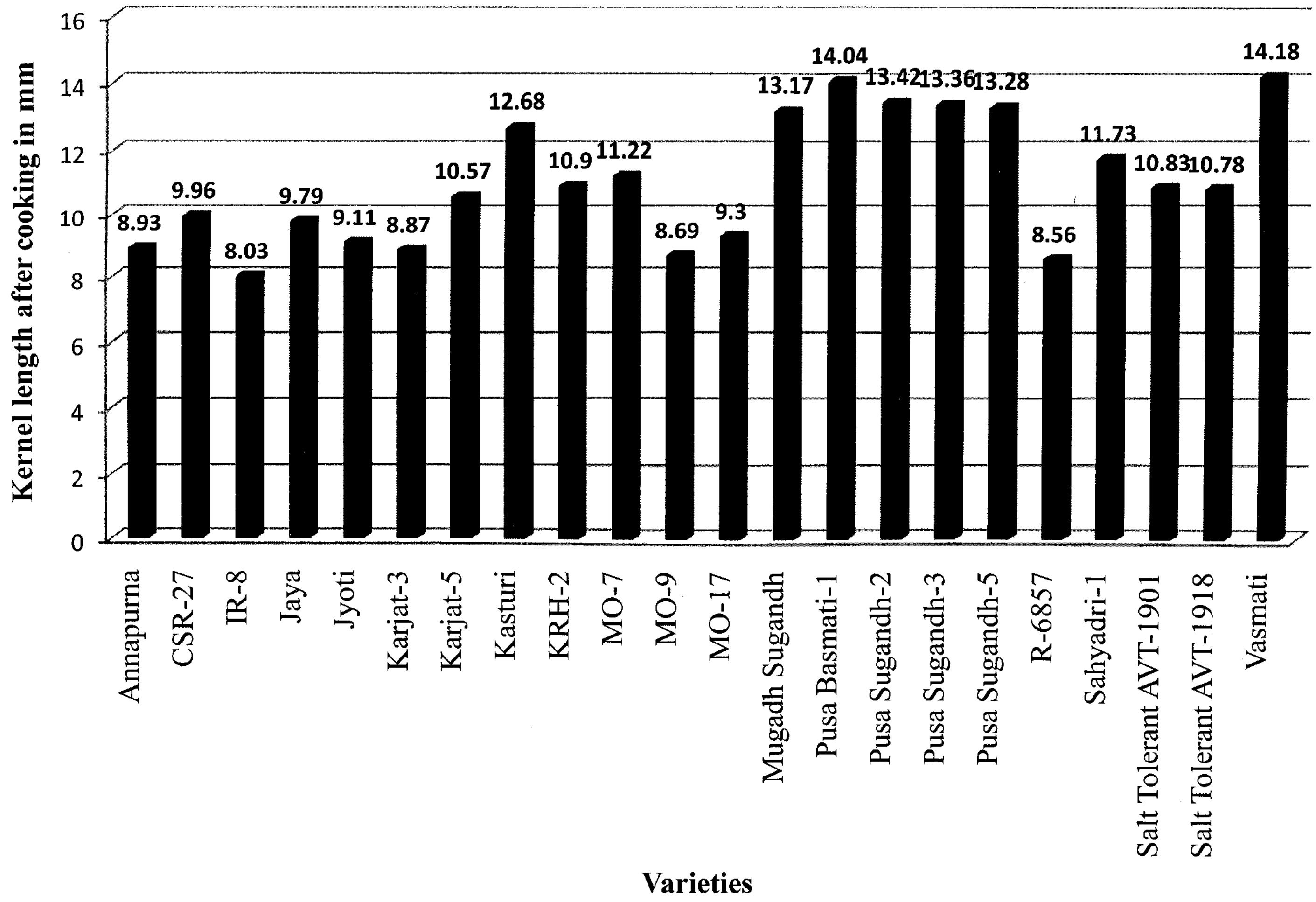


Table 25. Cooking characteristics of traditionally cultivated rice varieties, showing volume expansion and elongation ratio.

Sl. No.	varieties	Volume Expansion ratio	Elongation ratio
1	Assgo	2.63 ±0.05^{e}	1.31±0.005^{cd}
2	Barik Kudi	4.00±0^{a}	1.13±0.025^{efghijkl}
3	Bello	3.10 ±0.1^{d}	1.66±0.072^{a}
4	Damgo	2.20 ±0.1^{fgh}	1.22±0.13^{defgh}
5	Dhave	2.00 ±0^{i}	1.19±0.1^{defghij}
6	Ek Kadi	2.63 ±0.15^{f}	1.1±0.02^{ghijkl}
7	Ghansal	3.56 ±0.15^{bc}	1.44±0.03^{bc}
8	Girga	4.03 ±0.05^{a}	1.07±0.005^{jkl}
9	Jiresal	4.10 ±0.1^{a}	1.23±0.08d^{efg}
10	Kalo Damgo	3.20 ±0.1^{d}	1.03±0.01^{l}
11	Kalo Korgut	1.60 ±0.1^{j}	1.09±0.34^{ijkl}
12	Kalo Novan	3.43 ±0.28^{c}	1.51±0.06^{b}
13	Karo Mungo	3.63 ±0.06^{b}	1.03±0.02^{l}
14	Karz	2.10 ±0.1^{ghi}	1.19±0.11^{defghi}
15	Kendal	2.03 ±0.06^{hi}	1.17±0.1^{efghijk}
16	Khochro	4.06 ±0.07^{a}	1.1±0.04^{hijklm}
17	Kolyo	3.50 ±0.1^{bc}	1.06±0.06^{kl}
18	Korgut	2.70 ±0.1^{e}	1.1±0.1^{hijkl}
19	Kotimirsal	3.56 ±0.05^{bc}	1.06±0.01^{jkl}
20	Kusago	2.23 ±0.21^{fg}	1.08±0.12^{ijkl}
21	Muno	2.17 ±0.06^{ghi}	1.24±0.01^{def}
22	Novan	4.03 ±0.05^{a}	1.16±0.16^{efghijk}
23	Patni	2.03 ±0.05hi	1.13±0.06^{ghijkl}
24	Sal	3.03 ±0.06^{d}	1.25±0.11^{de}
25	Shiedi	3.40 ±0.1^{c}	1.25±0.03^{de}
26	Tamdi	3.23 ±0b^{c}	1.12±0.02^{fghijkl}
27	Taysu	3.50 ±0.05^{b}	1.03±0.02^{l}
28	Valay	2.17 ±0.29^{ghi}	1.05±0^{kl}
Critical differences (CD) (5%)		0.193	0.126
Coefficient of Variation		3.925	6.555

Mean ±SD followed by different letters differ significantly at 5%

Table 26. Cooking characteristics of high yielding rice varieties, showing volume expansion and elongation ratio.

Sl. No.	Varieties	Volume Expansion ratio	Elongation ratio
1	Annapurna	3.03±0.06^{f}	1.29±0.04^{b}
2	CSR-27	2.33±0.06^{i}	1.03±0.03^{ij}
3	IR-8	2.03±0.06^{j}	1.1±0.02^{cd}
4	Jaya	3.47±0.32^{c}	1.14±0.02^{f}
5	Jyoti	2.64±0.05^{h}	1.01±0.005^{j}
6	Karjat-3	2.60±0^{h}	1.08±0.005^{h}
7	Karjat-5	1.60±0k	1.52±0.03^{a}
8	Kasturi	3.30±0.1d	1.03±0.005^{ij}
9	KRH-2	4.03±0.06a	1.29±0.005^{b}
10	MO-7	2.48±0.06i	1.13±0.02^{fg}
11	MO-9	2.03±0.05j	1.07±0.005^{j}
12	MO-17	2.80±0g	1.2±0.03^{c}
13	Mugadh Sugandh	3.40±0.12gh	1.03±0.01^{ij}
14	Pusa Basmati-1	3.06±0.12f	1.17±0.02^{fg}
15	Pusa Sugandh-2	3.00±0f	1.04±0.01^{ij}
16	Pusa Sugandh-3	3.13±0.06ef	1.1±0.01^{gh}
17	Pusa Sugandh-5	3.63±0.06b	1.04±0.01^{i}
18	R-6857	3.03±0.05i	1.1±0.005^{ij}
19	Sahyadri-1	2.33±0.06i	1.17±0.005^{ef}
20	Salt Tolerant AVT-	2.63±0.06h	1.27±0.01^{c}
21	Salt Tolerant AVT-	3.26±0.06de	1.17±0.01^{de}
22	Vasmati	3.63±0.05b	1.08±0.01^{h}
Critical differences (CD) (5%)		3.305	0.028
Coefficient of Variation		0.153	1.491

Mean ±SD followed by different letters differ significantly at 5%

Table 27. Cooking characteristics of traditionally cultivated rice varieties, showing kernel length after cooking and water uptake.

Sl. No.	Varieties	Kernel length after cooking mm	Water uptake (ml)
1	Assgo	8.05±0.01	200±10[j]
2	Barik Kudi	10.8±0.07	390±10[a]
3	Bello	10.7±0.16	245±0[g]
4	Damgo	8.75±0.05	210±10[ij]
5	Dhave	8.79±0.08	275±0[ef]
6	Ek Kadi	9.8±0.03	350±10[b]
7	Ghansal	7.39±0.08	325±0[c]
8	Girga	8.24±0.04	250±10[g]
9	Jiresal	6.76±0.06	310±10[d]
10	Kalo Damgo	8.18±0.005	220±10[hi]
11	Kalo Korgut	9.23±0.04	250±10[g]
12	Kalo Novan	9.56±0.11	175±0[k]
13	Karo Mungo	8.37±0.01	280±10[e]
14	Karz	8.87±0.1	200±10[j]
15	Kendal	8.99±0.03	240±10[g]
16	Khochro	8.41±0.11	270±10[ef]
17	Kolyo	8.03±0.03	250±10[g]
18	Korgut	8.18±0.34	160±10[l]
19	Kotimirsal	6.64±0.05	350±10[b]
20	Kusago	8.64±0.08	250±10[g]
21	Muno	8.02±0.005	250±10[g]
22	Novan	7.04±0.03	300±10[d]
23	Patni	8.15±0.2	265±0[f]
24	Sal	7.32±0.07	300±10[d]
25	Shiedi	9.63±0.05	275±0[ef]
26	Tamdi	10.79±0.05	280±10[e]
27	Taysu	10.67±0.03	250±10[g]
28	Valay	9.13±0.05	225±0[h]
Critical differences (CD) (5%)			14.24
Coefficient of Variation			3.316

Mean ±SD followed by different letters differ significantly at 5%

Table 28. Cooking characteristics of high yielding rice varieties, kernel length after cooking and water uptake.

Sl. No.	Varieties	Kernel length after cooking mm	Water uptake (ml)
1	Annapurna	8.93±0.06	265±0[ijk]
2	CSR-27	9.96±0.2	300±10[ef]
3	IR-8	8.03±0.04	390±10[a]
4	Jaya	9.79±0.02	290±10[fg]
5	Jyoti	9.11±0.02	290±10[fg]
6	Karjat-3	8.87±0.01	290±10[fg]
7	Karjat-5	10.57±0.04	330±10[bc]
8	Kasturi	12.68±0.03	280±10[dh]
9	KRH-2	10.90±0.02	320±10[cd]
10	MO-7	11.22±0.01	255±0[k]
11	MO-9	8.69±0.15	275±0[hi]
12	MO-17	9.3±0.12	270±10[hij]
13	Mugadh Sugandh	13.17±0.05	300±10[ef]
14	Pusa Basmati-1	14.04±0.04	335±0[b]
15	Pusa Sugandh-2	13.42±0.005	310±10[de]
16	Pusa Sugandh-3	13.36±0.02	300±10[ef]
17	Pusa Sugandh-5	13.28±0.05	310±10[de]
18	R-6857	8.56±0.04	300±10[ef]
19	Sahyadri-1	11.73±0.06	260±10[jk]
20	Salt Tolerant AVT-	10.83±0.01	340±10[b]
21	Salt Tolerant AVT-	10.78±0.04	320±10[cd]
22	Vasmati	14.18±0.01	320±10[cd]
Critical differences (CD) (5%)			14.884
Coefficient of Variation			2.988

Mean ±SD followed by different letters differ significantly at 5%

4.5.2. Water Uptake

Water uptake ratio was calculated for traditional rice varieties and high yielding rice varieties. In traditional rice varieties, water uptake ranged from 160-390 ml, whereas in high yielding varieties, water uptake ranged from 255-390 ml (Table 27 & 28). Among traditional rice varieties the minimum water uptake was noted in variety Korgut and maximum in variety Barik Kudi. In the high yielding rice varieties maximum water uptake was calculated in variety IR-8 and minimum in variety MO-7 (Figure 23 & 24).

4.5.3. Organoleptic Test

The Organoleptic test were conducted for appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability for traditional cultivated and high yielding rice varieties The results of the same are summarized in Tables 29, 30. The best cooking quality (appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation) was observed in the rice varieties Tamdi, Dhave and Kendal. The present investigation revealed that the traditionally cultivated salt tolerant rice varieties *viz.* Korgut, Khochro, Muno and Shiedi showed good grain quality characteristics. Among the scented rice varieties like Jiresal, Kotimirsal (local varieties), Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5, Kasturi and Vasumati (high yielding varieties) with best cooking quality characteristics and consumer's preference. The results imply that three major characteristics such as amylose content, gelatinization temperature and grain shape are involved in grain quality especially these characteristics which influence the physicochemical properties like texture.

Fig. 23. Water uptake in traditional rice varieties.

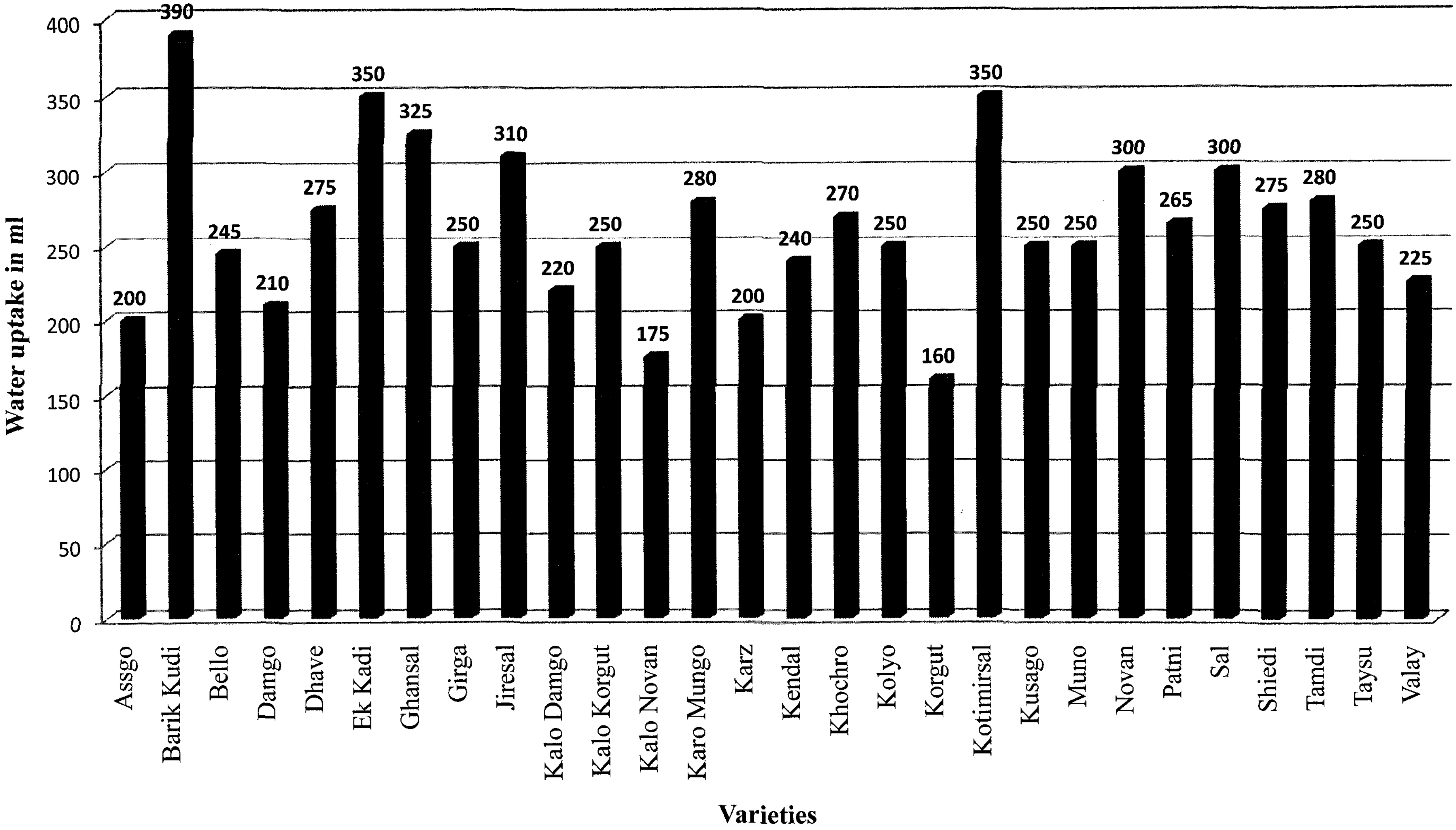


Fig. 24. Water uptake in high yielding rice varieties.

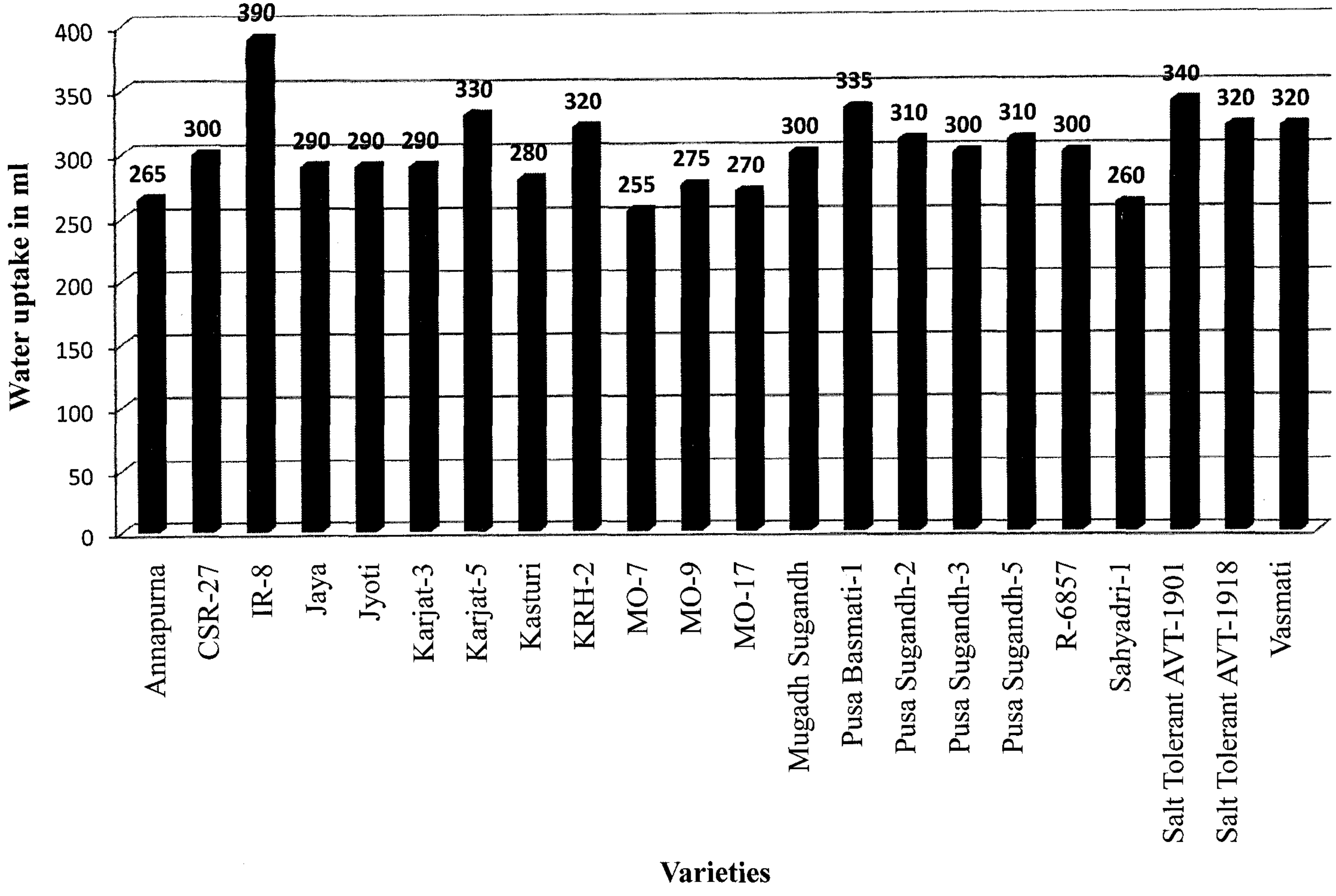


Table 29. Organoleptic characteristics in traditionally cultivated rice varieties.

Sl. No.	Characteristics	Traditional rice varieties																											
		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	1	2
A	**Appearance**																												
5	White			+																									
4	Creamishwhite/brown	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
3	Red streaks																												
2	White with brown																												
1	White with black																												
B	**Cohesiveness**																												
5	Well separated	+	+	+	+		+	+		+	+	+	+		+	+	+	+	+	+	+		+			+		+	+
4	Partially separated					+			+					+								+			+		+		
3	Slightly separated																												
2	Moderately separated																												
1	Very sticky																												
C	**Tenderness**																												
5	Soft								+																				
4	Moderately soft			+		+						+															+		
3	Moderately hard									+	+		+			+							+		+				
2	Hard	+	+		+		+	+						+	+		+	+	+	+	+	+				+		+	+
1	Very soft																												
D	**Tenderness**																												
5	Soft								+																	+	+		
4	Moderately soft					+								+						+		+			+				
3	Moderately hard			+	+					+	+	+				+					+								
2	Hard	+	+				+	+					+		+		+	+	+				+					+	+
1	Very soft																												
E	**Taste**																												
5	-																												
4	Good					+			+											+							+		
3	Desirable	+	+	+	+		+	+		+	+				+	+		+	+		+				+			+	+
2	Tasteless											+	+	+			+					+	+			+			
1	Undesirable																												
F	**Aroma**																												
5	Strong																												
4	Optimal								+																				
3	Mild						+	+										+		+					+				
2	Other than basmati	+				+								+	+		+				+	+				+	+	+	
1	No scent		+	+	+					+	+	+	+			+			+				+						+
G	**Elongation**																												
5	-																												
4	Excellent																								+				
3	Good		+	+		+		+							+			+	+		+					+	+	+	+
2	Moderate	+			+		+		+	+	+	+	+	+		+	+			+		+	+						
1	None																												
H	**Overall**																												
5	-																												
4	Excellent		+						+										+		+								
3	Good	+		+		+	+	+								+		+		+					+	+	+		
2	Acceptable				+					+	+	+	+	+	+		+					+	+					+	+
1	Undesirable																												

Rice Varieties : Assgo (a); Damgo (b); Dhave (c); Barik Kudi (d); Bello (e); Ek Kadi (f); Ghansal (g); Girga (h); Jiresal (i); Kalo Damgo (j); Kalo Korgut (k); Kalo Novan (l); Karo Mungo (m); Karz (n); Kendal (o); Khochro (p); Kolyo (q); Korgut (r); Kotimirsal (s); Kusago (t); Muno (u); Novan (v); Patni (w); Sal (x); Shiedi (y); Tamdi (z); Taysu (1); Valay (2).

Table 30. Organoleptic characteristics in high yielding rice varieties.

Sl.	Characteristics	High yielding rice varieties																					
No,		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v
A	**Appearance**																						
5	White																						+
4	Creamishwhite/	+	+	+		+					+	+	+	+		+	+		+				
3	Red streaks																						
2	White with brown				+		+	+	+	+					+			+		+	+	+	
1	White with black																						
B	**Cohesiveness**																						
5	Well separated	+				+	+	+		+			+	+	+	+	+	+	+	+	+	+	+
4	Partially separated		+	+	+				+		+	+											
3	Slightly separated																						
2	Moderately separated																						
1	Very sticky																						
C	**Tenderness**																						
5	Soft				+					+													
4	Moderately soft		+						+		+	+			+						+	+	
3	Moderately hard															+	+	+	+	+			
2	Hard	+		+		+	+	+					+	+									+
1	Very soft																						
D	**Tenderness**																						
5	Soft				+					+	+	+			+								
4	Moderately soft		+						+								+	+	+	+	+	+	
3	Moderately hard	+		+		+	+									+							+
2	Hard							+					+	+									
1	Very soft																						
E	**Taste**																						
5	-																						
4	Good								+							+	+	+					+
3	Desirable	+	+	+	+			+			+	+	+	+	+				+	+	+	+	
2	Tasteless					+	+			+													
1	undesirable																						
F	**Aroma**																						
5	Strong														+	+	+						
4	Optimal								+	+								+					+
3	Mild							+			+	+		+									
2	Other than basmati	+	+	+	+	+	+						+						+	+	+	+	
1	No scent																						
G	**Elongation**																						
5	-																						
4	Excellent								+														
3	Good					+		+		+	+	+	+	+	+	+	+	+	+	+	+	+	
2	Moderate	+	+	+	+		+																+
1	None																						
H	**Overall**																						
5	-																						
4	Excellent								+	+	+	+			+	+	+	+				+	+
3	Good	+	+		+	+							+	+					+	+	+		
2	Acceptable			+			+	+															
1	Undesirable																						

Rice Varieties : Annapurna (a); CSR-27 (b); IR-8 (c); Jaya (d); Jyoti (e); Karjat-3 (f); Karjat-5 (g); Kasturi (h); KRH-2 (i); MO-7 (j); MO-9 (k); MO-17 (l); Mugadh Sugandh (m); Pusa Basmati-1 (n); Pusa Sugandh-2 (o); Pusa Sugandh-3 (p); Pusa Sugandh-5 (q); R-6857 (r); Sahyadri-1 (s); Salt Tolerant AVT-1901 (t); Salt Tolerant AVT-1918 (u); Vasmati (v).

4.6. Biochemical Analysis:

4.6.1. Total Carbohydrates

The total carbohydrate was calculated for traditional and high yielding rice varieties. Among the traditionally cultivated rice varieties, the percentage of carbohydrates ranged from 67 to 87% (Tables 31). Highest percentage of carbohydrate (87%) was recorded in variety Kalo Damgo and lowest (67%) in variety Bello (Figure 25). In high yielding rice varieties, the percentage of carbohydrate ranged from 70-85% (Table 32), least (70%) of carbohydrates in varieties MO-9 and Mugadh Sugandh and high (85%) carbohydrate content in variety Jyoti (Figure 26).

4.6.2. Total Proteins

The total protein was calculated for traditional rice varieties and high yielding rice varieties. The percentage of protein ranged from 6.37-9.75% in traditional rice varieties (Tables 31). Highest percentage of protein was noted 9.75% in variety Kalo Damgo and lower percentage of protein (6.37%) observed in variety Bello (Figure 27). In high yielding rice varieties, percentage of protein ranged from 8.75-6.37% and results are summarized in Table 32. Lower protein content was calculated in varieties CSR-27, Jaya, Karjat-5, Mugadh Sugandh, Pusa Basmati-1, Salt tolerant-1918 and Vasmati. The high protein content was noted in varieties MO-7 and R-6857 (Figure 28).

4.7. Determination of Minerals Content by Atomic Absorption Spectrophotometer

Minerals content in all 28 traditional rice varieties were determined by using atomic absorption spectrophotometer. In high yielding rice varieties only few varieties

Fig. 25. Total carbohydrates in traditional rice varieties.

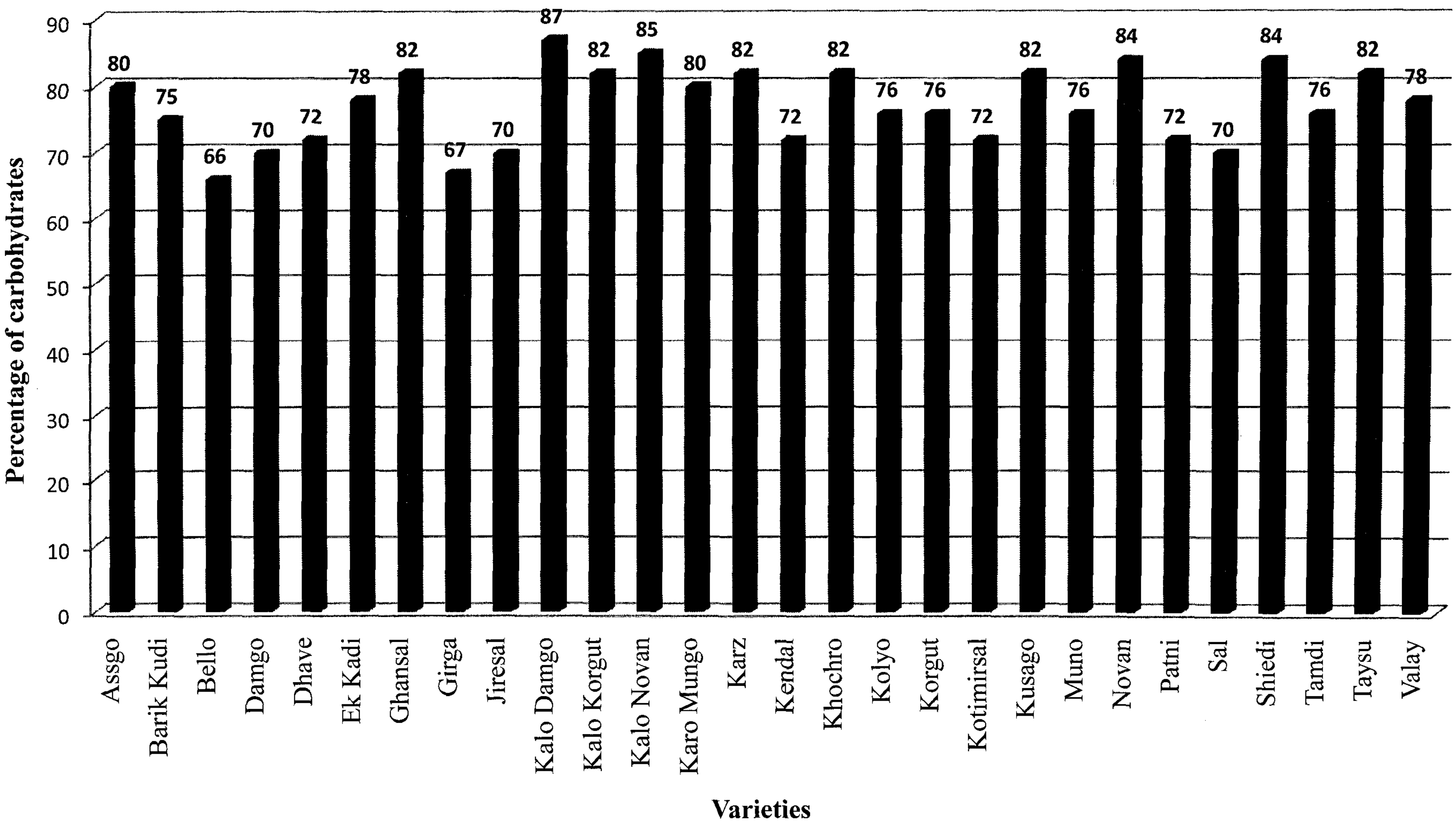


Fig. 26. Total carbohydrates in high yielding rice varieties.

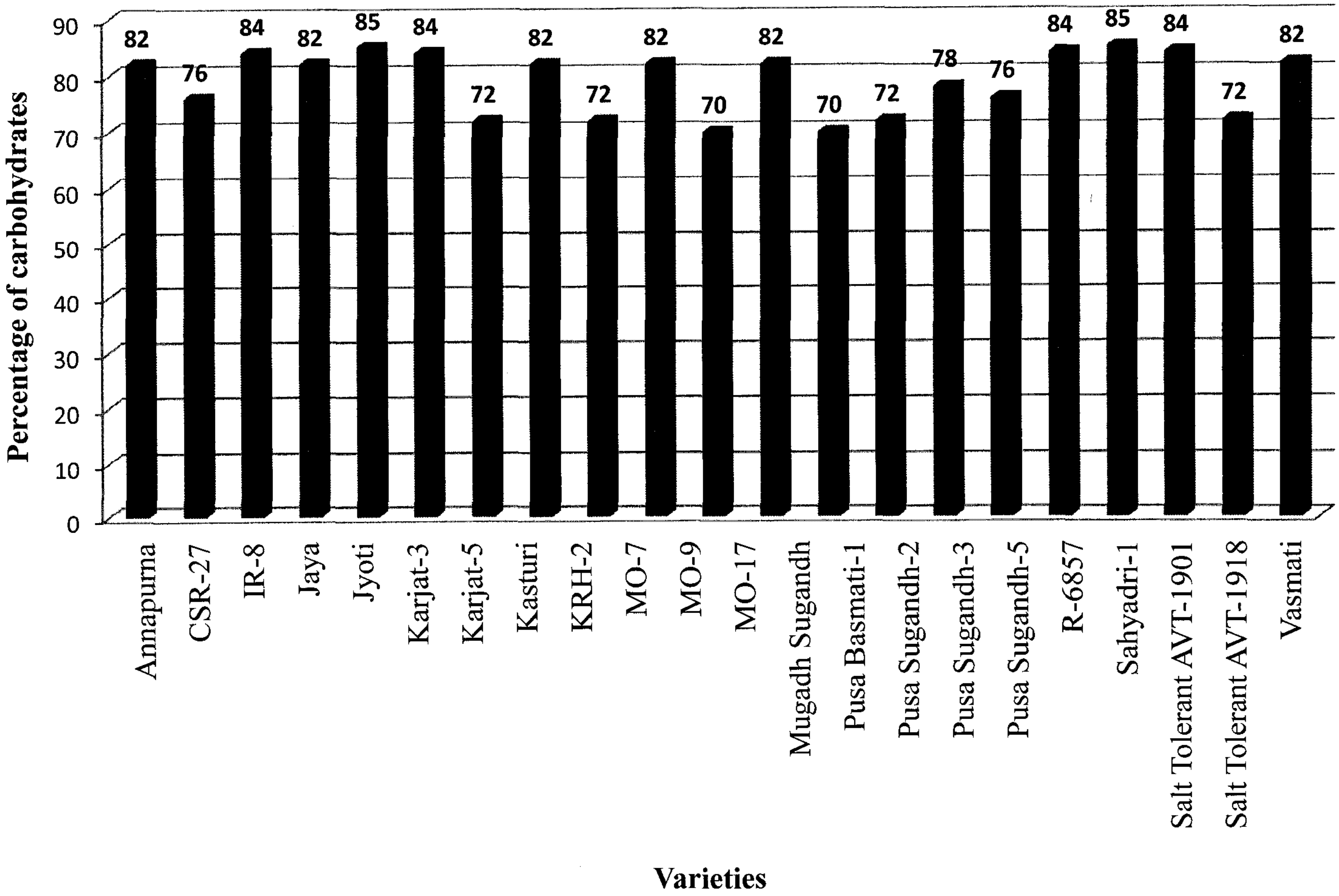


Fig. 27. Total proteins in traditional rice varieties.

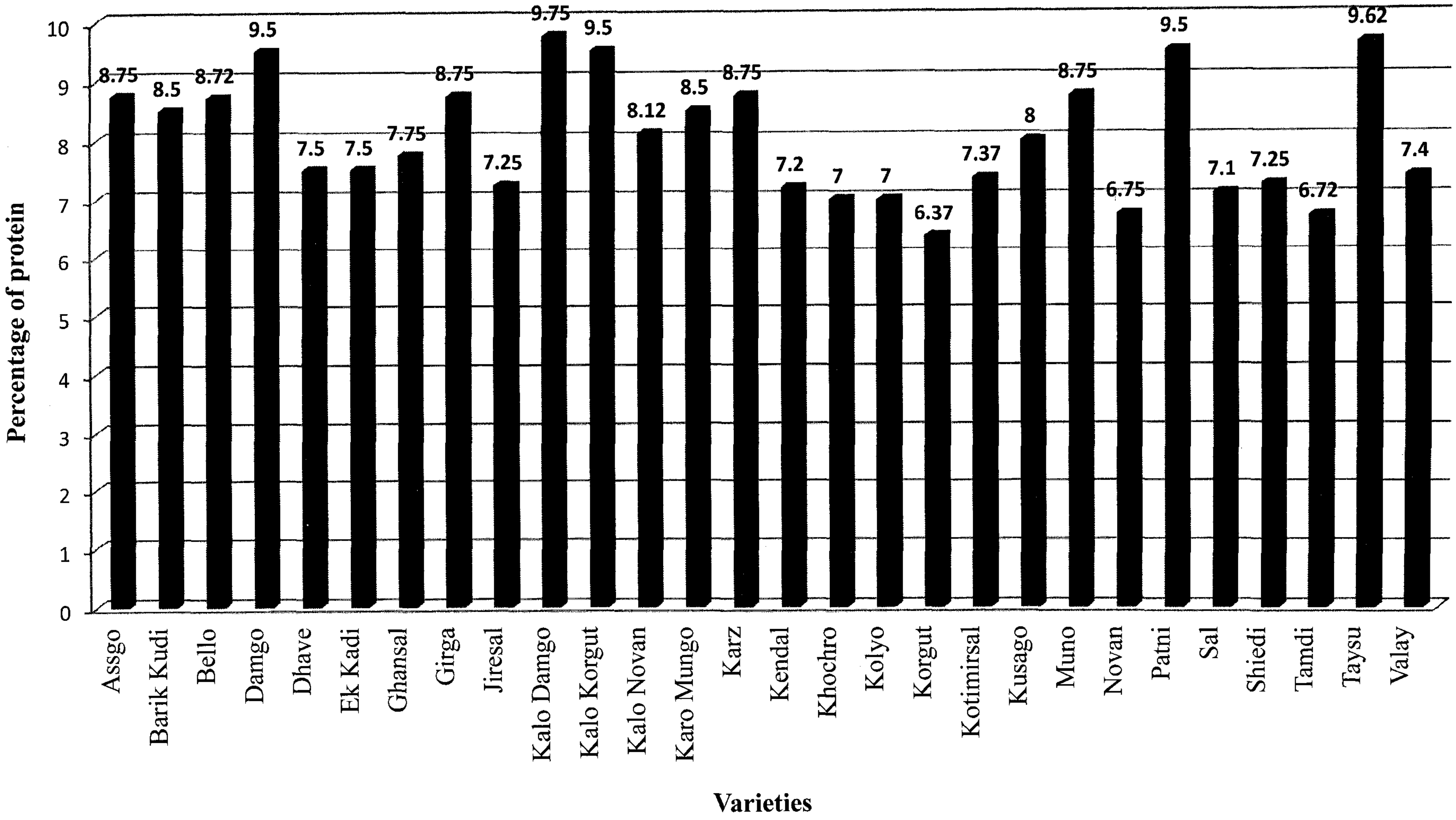


Fig. 28. Total proteins in high yielding rice varieties.

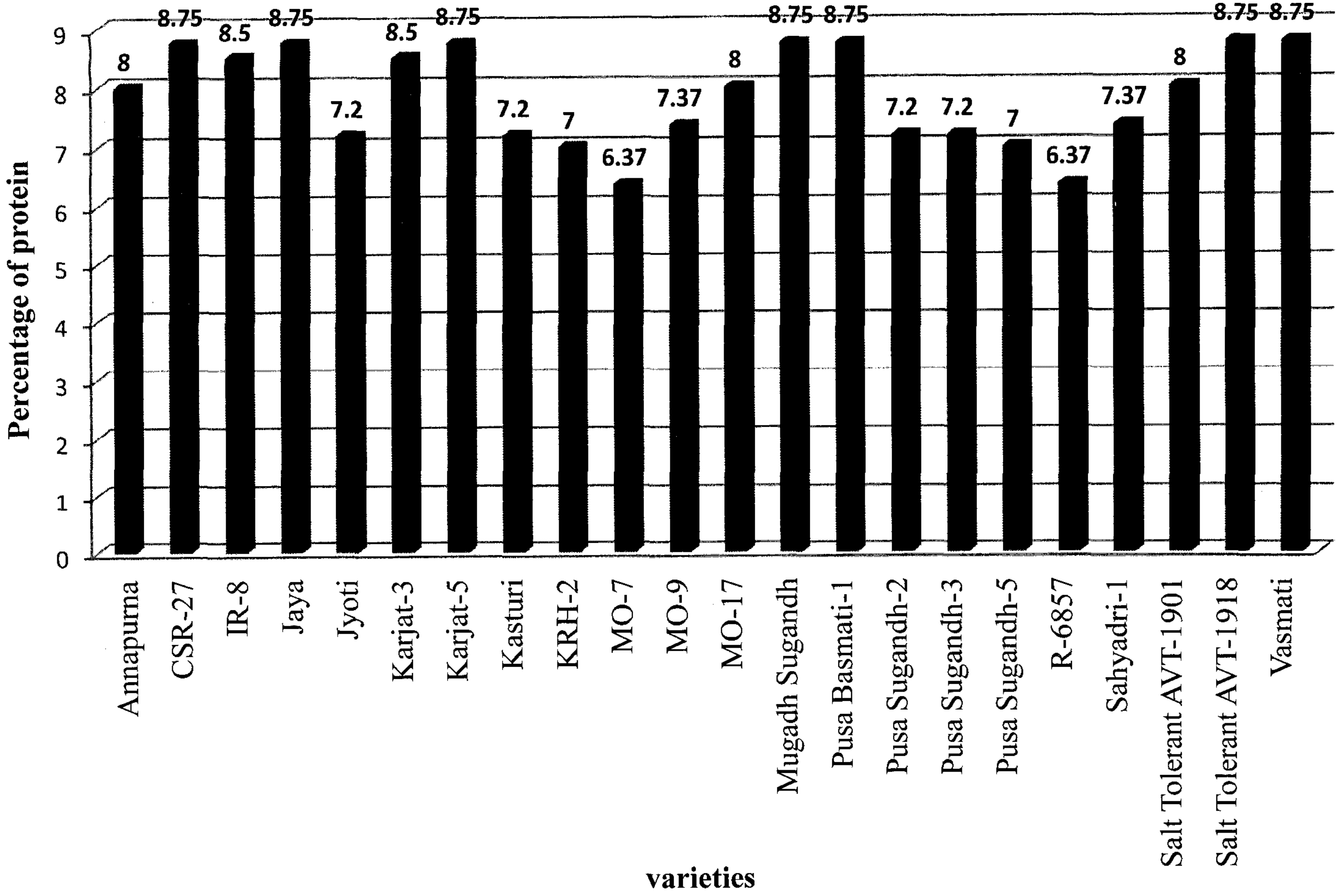


Table 31. Total carbohydrates and total protein content in traditional cultivated rice varieties.

Sl. No.	Varieties	Total carbohydrates %	Total proteins %
1	Assgo	80	8.75
2	Barik Kudi	75	8.50
3	Bello	66	8.72
4	Damgo	70	9.50
5	Dhave	72	7.50
6	Ek Kadi	78	7.50
7	Ghansal	82	7.75
8	Girga	67	8.75
9	Jiresal	70	7.25
10	Kalo Damgo	87	9.75
11	Kalo Korgut	82	9.50
12	Kalo Novan	85	8.12
13	Karo Mungo	80	8.50
14	Karz	82	8.75
15	Kendal	72	7.20
16	Khochro	82	7.0
17	Kolyo	76	7.0
18	Korgut	76	6.37
19	Kotimirsal	72	7.37
20	Kusago	82	8.0
21	Muno	76	8.75
22	Novan	84	6.75
23	Patni	72	9.50
24	Sal	70	7.10
25	Shiedi	84	7.25
26	Tamdi	76	6.72
27	Taysu	82	9.62
28	Valay	78	7.40

Table 32. Total carbohydrates and total proteins content in high yielding rice varieties.

Sl. No.	varieties	Total carbohydrates %	Total proteins %
1	Annapurna	82	8.0
2	CSR-27	76	8.75
3	IR-8	84	8.50
4	Jaya	82	8.75
5	Jyoti	85	7.20
6	Karjat-3	84	8.50
7	Karjat-5	72	8.75
8	Kasturi	82	7.20
9	KRH-2	72	7.0
10	MO-7	82	6.37
11	MO-9	70	7.37
12	MO-17	82	8.0
13	Mugadh Sugandh	70	8.75
14	Pusa Basmati-1	72	8.75
15	Pusa Sugandh-2	78	7.20
16	Pusa Sugandh-3	76	7.20
17	Pusa Sugandh-5	84	7.0
18	R-6857	85	6.37
19	Sahyadri-1	84	7.37
20	Salt Tolerant AVT-1901	72	8.0
21	Salt Tolerant AVT-1918	82	8.75
22	Vasmati	72	8.75

ere checked for the mineral content viz. Jyoti, Jaya, CSR-27, MO-17, KRH-2, Sahyadri-. R-6857, Karjat-5, Pusa Basmati-1, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918, nd IR-8. The iron, zinc, potassium and calcium content was estimated in traditional rice arieties and compared with high yielding rice varieties.

The iron content in traditional rice varieties ranged from 5.82 to 13.25 mg/Kg, the east amount of iron content was detected in variety Girga (5.82 mg/Kg), where as the high amount (13.25 mg/Kg) of iron content was calculated in variety Kendal (Table 33; Figure 29). In high yielding rice varieties the iron content ranged from 7.52 to 11.62 mg/Kg, least n was recorded in variety KRH-2 and highest in variety Pusa Basmati-1 (Table 34; Figure 29).

The zinc content in traditional rice varieties ranged from 13.63 to 41.66 mg/Kg, the minimum amount of zinc content was detected in variety Novan (13.63 mg/Kg), where as the maximum amount of zinc content was calculated in variety Kalo Korgut (41.66 mg/Kg), zinc content of all the traditional varieties are provided in Table 33; Figure 29. In high yielding rice varieties the zinc content ranged from 18.05 to 43.27 mg/Kg, minimum amount of zinc content was calculated in variety Salt Tolerant AVT-1918 and highest zinc content recorded in variety Pusa Basmati-1 (Table 34; Figure 29).

The calcium content in traditional rice varieties ranged from 0.02 to 0.09%, the minimum amount of calcium content was detected in varieties CSR-27, MO17, Sahaydri-1 (0.02%), where as the maximum calcium content was calculated in variety R6857 (0.09%), calcium content provided in Table 33; Figure 30. In high yielding rice varieties the calcium content ranged from 0.01 to 0.09%, lowest amount of calcium was found in variety Kendal and highest content in variety Ek Kadi (Table 34; Figure 30).

Fig. 29. Comparison of Iron and Zinc content in mg/kg in traditional and high yielding rice varieties.

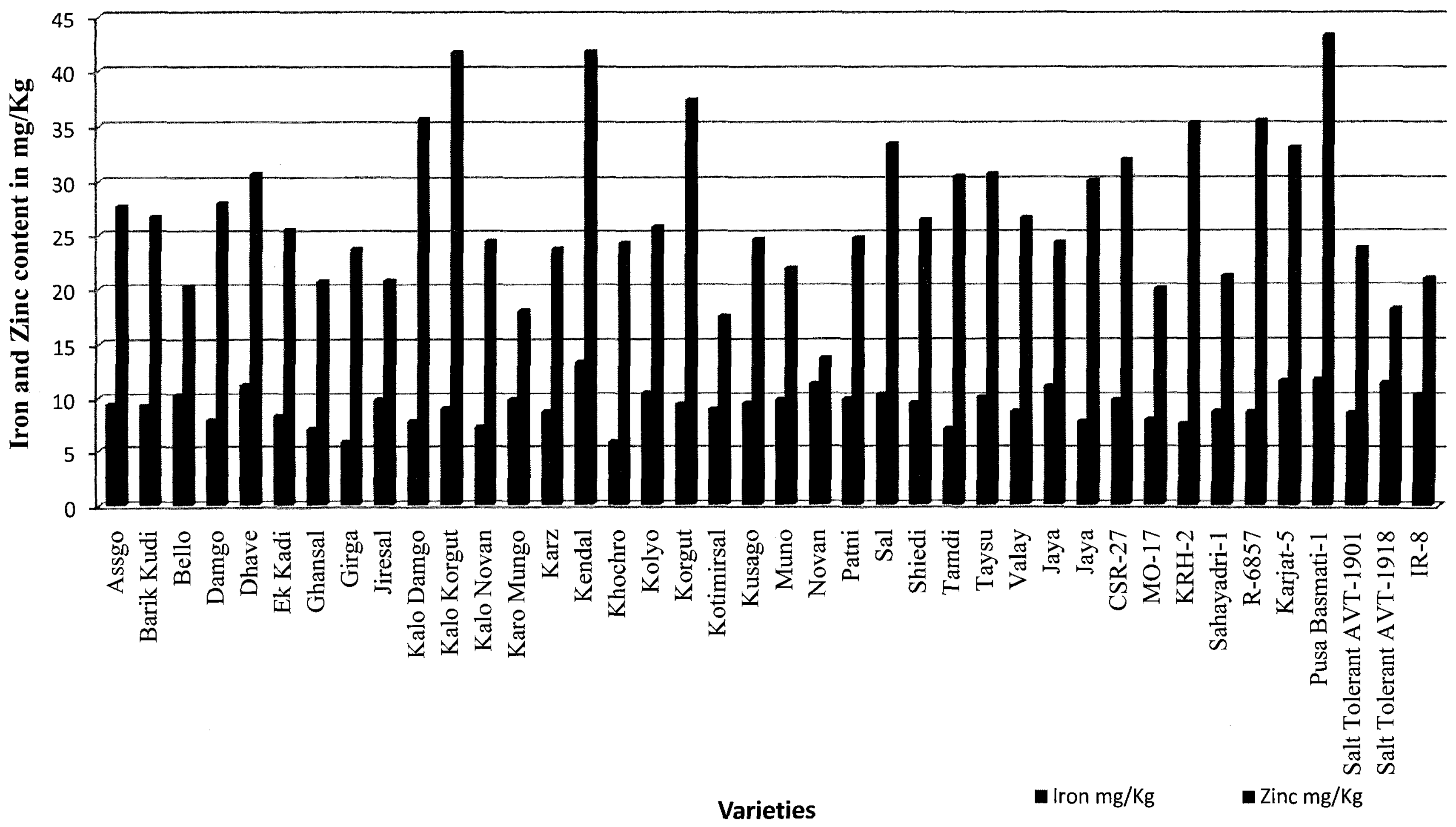


Fig. 30. Comparison of potassium and calcium content in percentage in traditional and high yielding rice varieties.

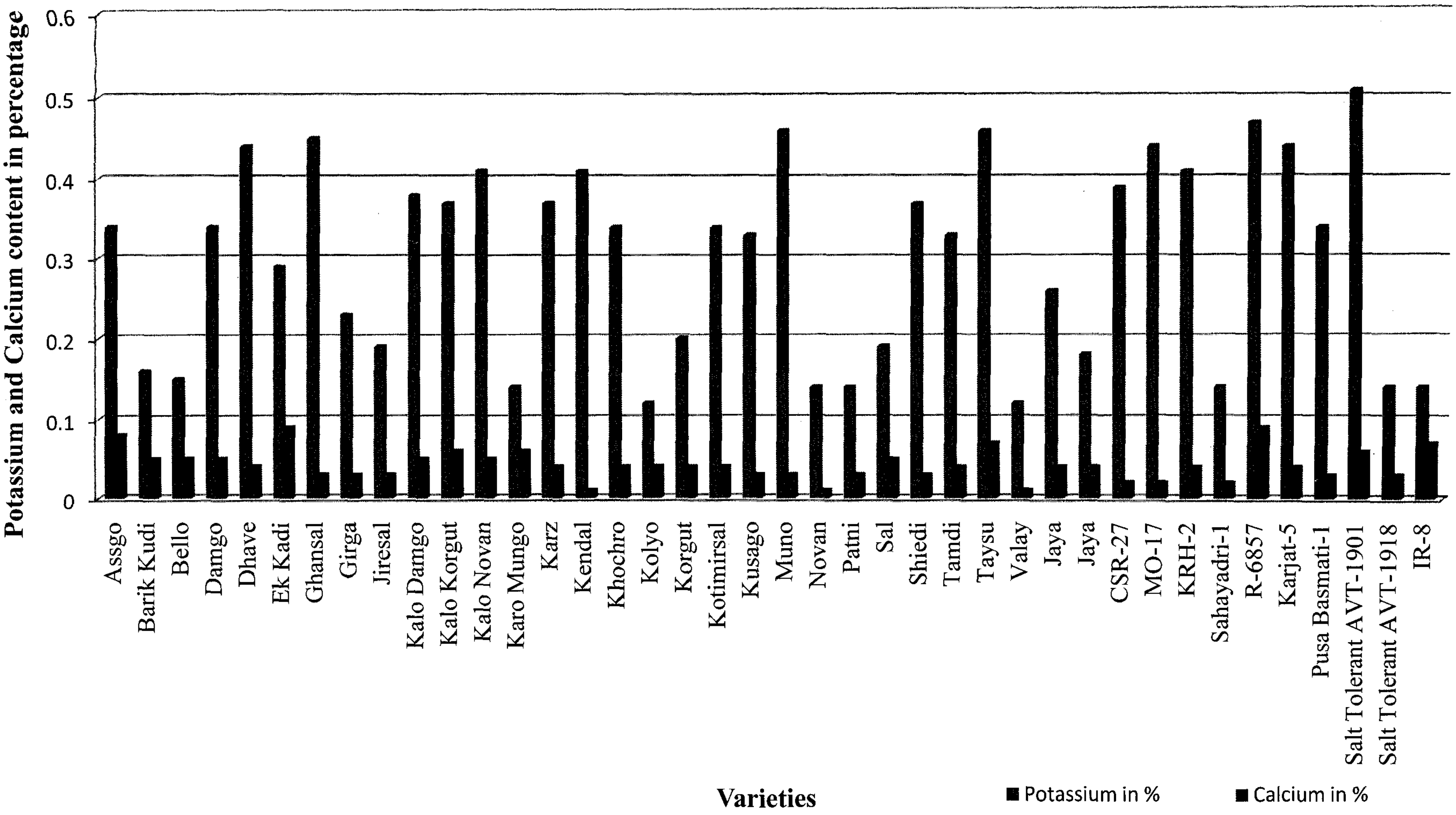


Table 33. Mineral content (iron, zinc, potassium, calcium) of traditionally cultivated rice varieties.

Sl. No.	Varieties	Iron (mg/kg)	Zinc (mg/kg)	Potassium %	Calcium %
1	Assgo	9.44	27.7	0.34	0.08
2	Barik Kudi	9.29	26.7	0.16	0.05
3	Bello	10.27	20.25	0.15	0.05
4	Damgo	7.89	27.96	0.34	0.05
5	Dhave	11.20	30.66	0.44	0.04
6	Ek Kadi	8.23	25.5	0.29	0.09
7	Ghansal	7.06	20.68	0.45	0.03
8	Girga	5.82	23.66	0.23	0.03
9	Jiresal	9.78	20.75	0.19	0.03
10	Kalo Damgo	7.79	35.73	0.38	0.05
11	Kalo Korgut	8.97	41.66	0.37	0.06
12	Kalo Novan	7.20	24.4	0.41	0.05
13	Karo Mungo	9.80	18.0	0.14	0.06
14	Karz	8.68	23.68	0.37	0.04
15	Kendal	13.25	41.8	0.41	0.01
16	Khochro	5.84	24.25	0.34	0.04
17	Kolyo	10.43	25.82	0.12	0.04
18	Korgut	9.38	37.45	0.20	0.04
19	Kotimirsal	8.89	17.55	0.34	0.04
20	Kusago	9.47	24.6	0.33	0.03
21	Muno	9.77	21.88	0.46	0.03
22	Novan	11.30	13.63	0.14	0.01
23	Patni	9.85	24.75	0.14	0.03
24	Sal	10.29	33.4	0.19	0.05
25	Shiedi	9.50	26.43	0.37	0.03
26	Tamdi	7.03	30.47	0.33	0.04
27	Taysu	9.97	30.65	0.46	0.07
28	Valay	8.70	26.62	0.12	0.01

Table 34. Mineral content (iron, zinc, potassium, calcium) of some high yielding rice varieties.

Sl. No.	Varieties	Iron mg/kg	Zinc mg/kg	Potassium %	Calcium %
1	Jyoti	10.96	24.25	0.26	0.04
2	Jaya	7.77	30.04	0.18	0.04
3	CSR-27	9.73	31.95	0.39	0.02
4	MO-17	7.90	19.95	0.44	0.02
5	KRH-2	7.53	35.30	0.41	0.04
6	Sahyadri-1	8.70	21.15	0.14	0.02
7	R-6857	8.63	35.55	0.47	0.09
8	Karjat-5	11.50	33.10	0.44	0.04
9	Pusa Basmati-1	11.62	43.27	0.34	0.03
10	Salt Tolerant AVT-1901	8.59	23.75	0.51	0.06
11	Salt Tolerant AVT-1918	11.32	18.05	0.14	0.03
12	IR-8	10.27	20.85	0.14	0.07

The potassium content in traditional rice varieties ranged from 0.12 to 0.46 %, the minimum amount of potassium content was detected in varieties Valay and Kolyo (0.12 %), where as the maximum amount of potassium content was calculated in varieties Muno and Taysu (0.46 %), potassium content in traditional rice varieties are summarized in Table 33; Figure 30. In high yielding rice varieties the potassium content ranged from 0.14 to 0.51 %, lowest amount of potassium content was calculated in variety Sahaydri-1 and highest amount of potassium in variety Salt Tolerant AVT-1901(Table 34; Figure 30).

4.8. Histochemical Characterization of Origin and Development of Chalkiness

Histochemical studies were carried out to understand the origin and development of chalkiness in rice grain from anthesis to maturation. Four different developmental stages of rice grains i.e. Stage-1 (5 DAF); Stage 2 (10 DAF); Stage 3 (20 DAF); Stage 4 (30 DAF) were selected for the study (Plate 8). For tracing the origin and development of chalkiness, four different rice varieties were selected which includes chalky and non-chalky rice varieties. The high yielding rice variety Jaya (24% chalkiness) was selected as control i.e grains with very less chalkiness. In chalky category a local rice variety Korgut (87% chalkiness), a hybrid rice variety KRH-2 (76% chalkiness) and another high yielding rice variety MO-7 (80% chalkiness) were selected to understand the origin and development of chalkiness (Plate 8a-d). Transverse sections (TS) and longitudinal section (LS) of rice grains were stained with safranin, toluidine blue and acridine orange and examined under bright-field microscope and fluorescence microscopes.

4.8.1. Chalkiness in Developmental Stage 1 (5 DAF) of rice grain

Thin transverse and longitudinal sections of rice grain of 5 days of fertilization of variety Jaya revealed the early stage of development of endosperm (Plate 9a-h). At this

Plate 8. Four different stages of development of rice caryopsis from anthesis to maturation. a. Jaya; b. Korgut; c. KRH-2; d. MO-7. Stage 1 (5 DAF), Stage 2 (10 DAF), Stage 3 (20 DAF), Stage 4 (30 DAF).

stage, the transverse sections (Plate 9a-d) of rice grain showed pericarp with many layers and ovular vascular bundle was in early stages of development. Nucellar epidermis, nucellar projection and cross cells were also noted (Plate 9 c, d). Endosperm cells not well organized, no difference was noted in the appearance of endosperm cells in the centre of the rice grain and in the peripheral region. Further, the endosperm cell development was normal with uniform deposition of the starch observed. At this stage, LS of rice grain showed the development of the embryo (Plate 9e, f) and uniform endosperm cells development (Plate 9g, h). Similarly, the transverse and longitudinal sections of variety Korgut (5 DAF) is presented in Plate 13a-h. At this stage, Korgut revealed the origin of chalkiness, especially in the longitudinal section uneven deposition of starch appeared as mild patches indicating the initiation of chalkiness (Plate 13f-h). However, no significant different in starch deposition was noted in transverse section of variety Korgut at 5 DAF (Plate 13a-d).

4.8.2. Chalkiness in Developmental Stage 2 (10 DAF) of rice grain

Thin transverse and longitudinal sections of rice grain of 10 days after fertilization of variety Jaya (Plate 10a-h) revealed the uniform endosperm cells with normal deposition of starch. At this stage, peripheral endosperm cells differentiated to form aleurone (Plate 10c). The endosperm cell development was normal with no chalkiness was detected and uniform deposition of the starch with even staining. The number of pericarp layer was reduced in comparison with Stage-1. The LS of rice grain Jaya also showed the similar endosperm characteristics without chalkiness (Plate 10e-h). The endosperm cells were well organized and showed uniform arrangement (Plate 10e). Likewise TS and LS of rice grain of variety Korgut (Plate 14a-h) were examined for the development of chalkiness. The safranin staining reaction showed significant difference with darkly stained patches in the

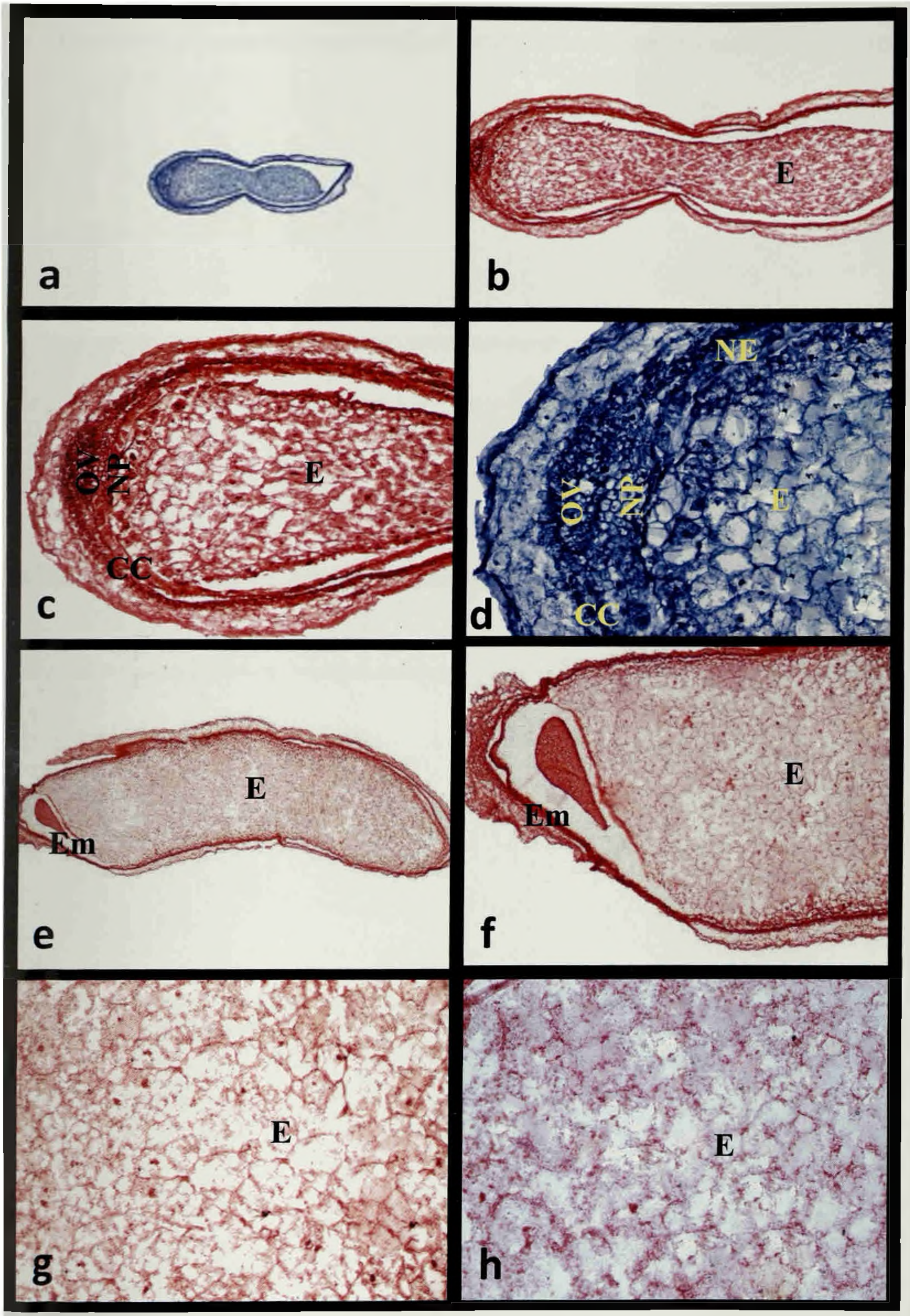


Plate 9. Anatomical characterization of rice variety Jaya, 5 days of fertilization (Stage 1). Transverse section of rice grain (a-d), stained with safranin (b, c, e-h) and toluidine blue (a, d). Longitudinal section (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. CC, cross cells; Em, embryo; E, endosperm; OV, ovular vascular bundle, NE, nucellar epidermis; NP, nucellar projection.

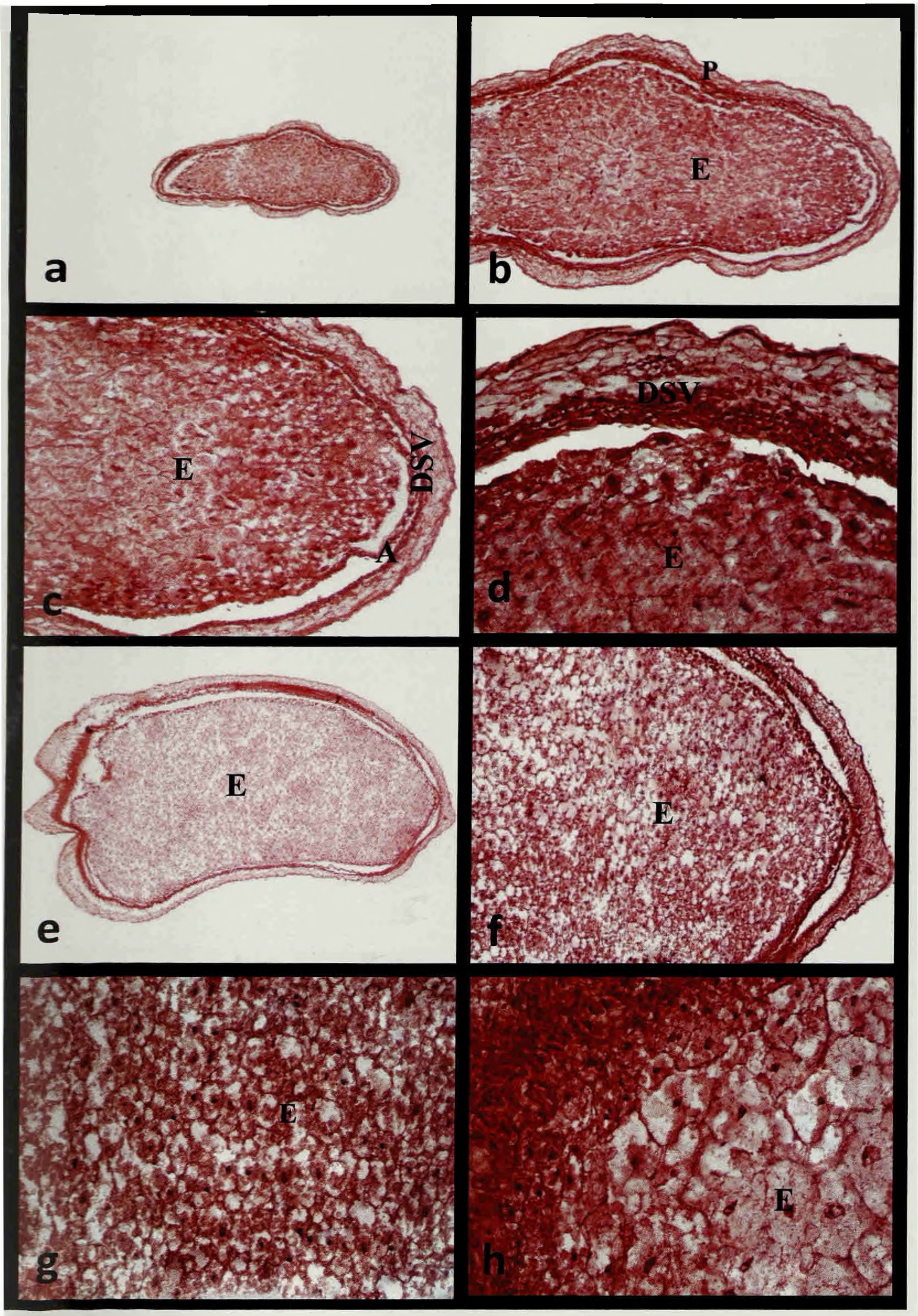


Plate 10. Anatomical characterization of rice variety Jaya, 10 days of fertilization (Stage 2). Transverse section of rice grain stained with safranin (a-h), a-d. Longitudinal section (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. E, endosperm; P, pericarp; DSV, dorsal stylar vascular bundle.

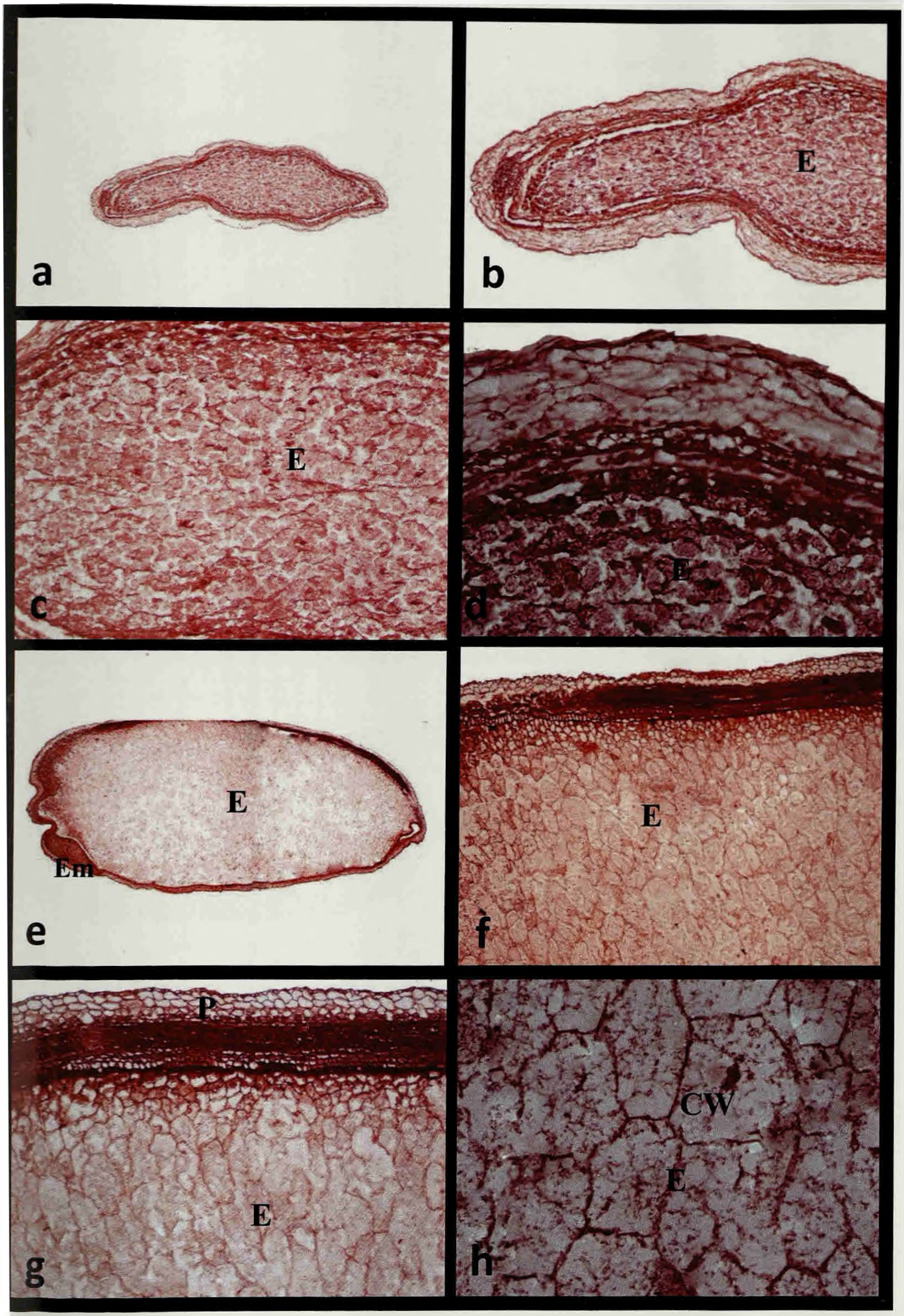


Plate 11. Anatomical characterization of rice variety Jaya, 20 days of fertilization (Stage 3). Transverse section of rice grain stained with safranin (a-h), a-d. Longitudinal section (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. E, endosperm; Em, embryo; CW, cell wall; P, pericarp.

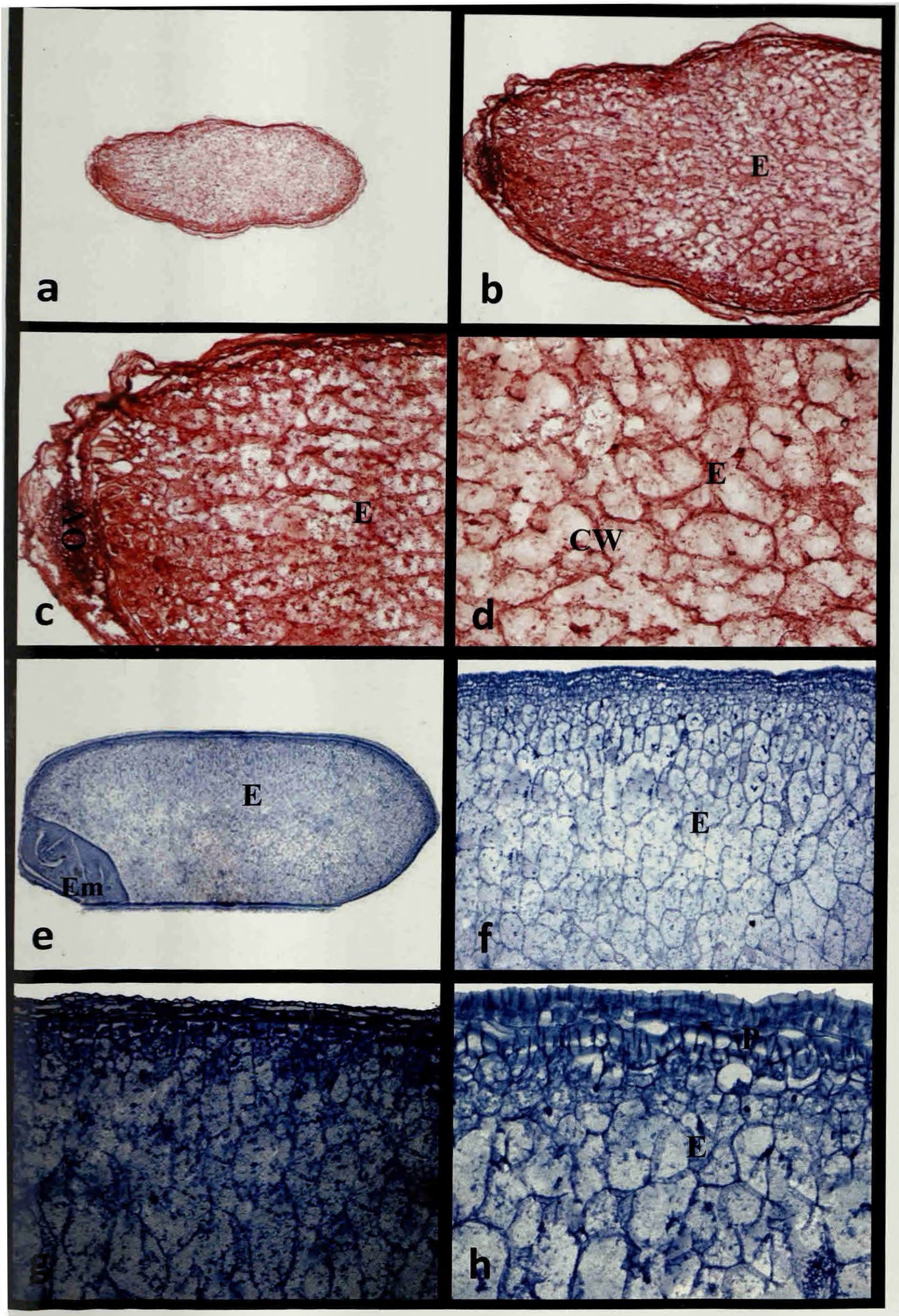


Plate 12. Anatomical characterization of rice variety Jaya, 30 days of fertilization (stage 4). Transverse section of rice grain stained with safranin (a-d) and Longitudinal section stained with toluidine blue (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. E, endosperm; Em, embryo; CW, cell wall; OV, ovular vascular .

endosperm cells especially in the longitudinal section indicating that endosperm cells are not uniform showing the chalky cell (Plate 14e-h). Further, in variety Korgut showed the endosperm cells were loosely arranged in comparison with variety Jaya at this Stage of development.

4.8.3. Chalkiness in Developmental Stage 3 (20 DAF) of rice grain

Transverse and longitudinal sections of rice grain of 20 days after fertilization of rice variety Jaya revealed the presence of uniformly packed endosperm cells with no chalkiness and normal deposition of the starch was noted (Plate 11a-h). At this stage very few layers of pericarp was seen in the TS (Plate 11a, b, d). In longitudinal section perfect endosperm cell structure was noted with uniform staining reaction of safranin and no chalkiness was detected (Plate 11e-h). At this stage, endosperm cells were uniformly arranged with tightly packed cell wall as shown in Plate 11h. In contrast to variety Jaya, the rice variety Korgut revealed with clear presence of chalkiness at this stage (Plate 15a-h). The toluidine blue staining reaction in transverse section showed patches of endosperm cells in the central region as indicated by dark staining. The chalkiness was noted from ovular vascular bundle to opposite region as shown in Plate 15a. The staining reaction also revealed the uneven deposition of starch in the endosperm cells (Plate 15b). In longitudinal section of rice grain of Korgut, when stained with safranin, the staining reaction clearly indicated the origin of chalkiness starting from embryo side and then extended to the tip of the rice grain and chalkiness found as a narrow strip in the endosperm (Plate 15e). The chalky areas of endosperm cells take more stain in comparison with adjacent endosperm cells (Plate 15f-h). It is seen that the non-chalky endosperm cells were stained normal and the arrangements of cells shown with compact and regular arrangement. In closer view chalky endosperm cells were stained dark and appear as patches (Plate 15d, j, h). It was

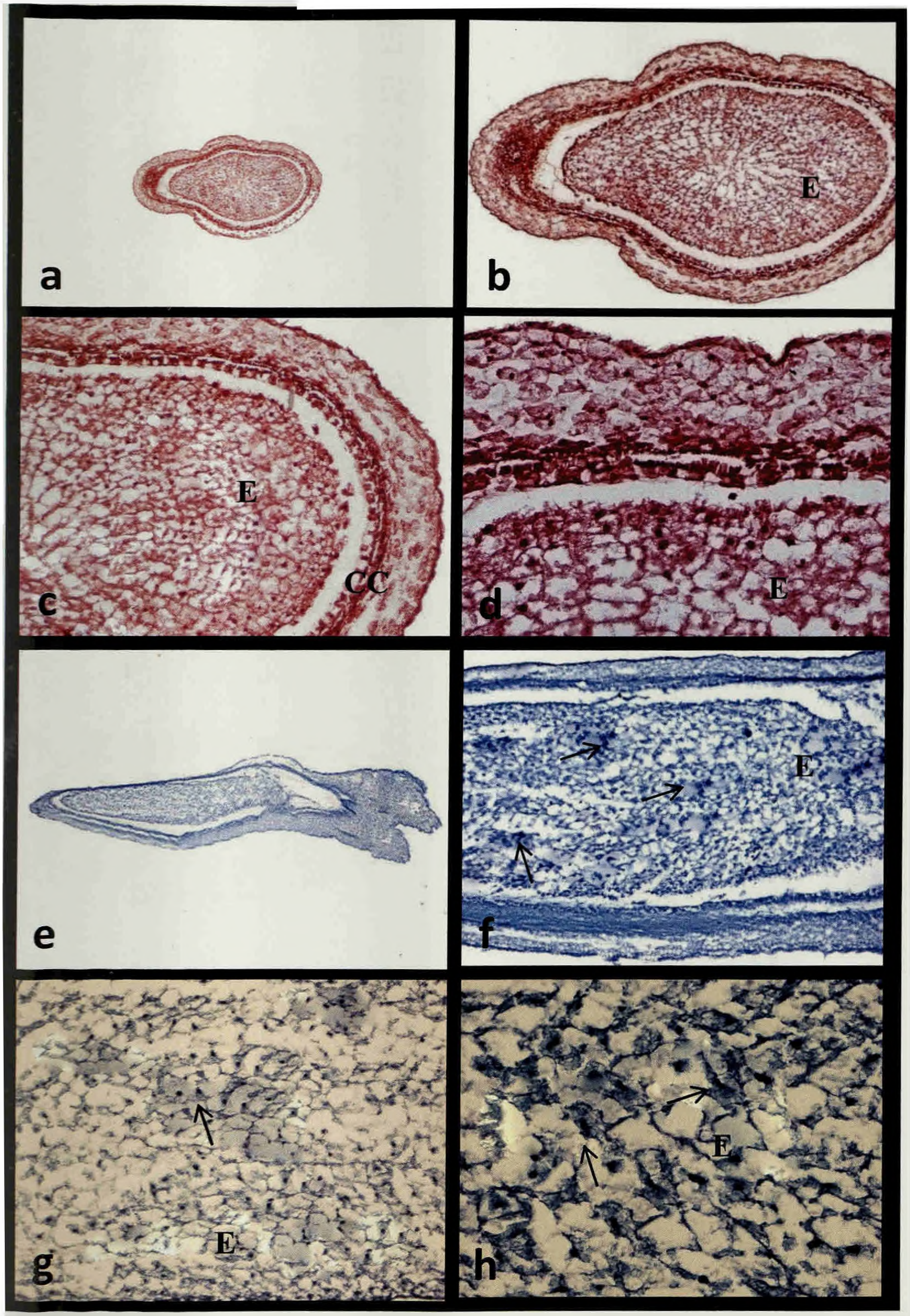


Plate 13. Anatomical characterization of rice variety Korgut, 5 days of fertilization (Stage 1). Transverse section of rice grain stained with safranin (a-d) and Longitudinal section (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. E, endosperm; Arrow shows the chalky endosperm.

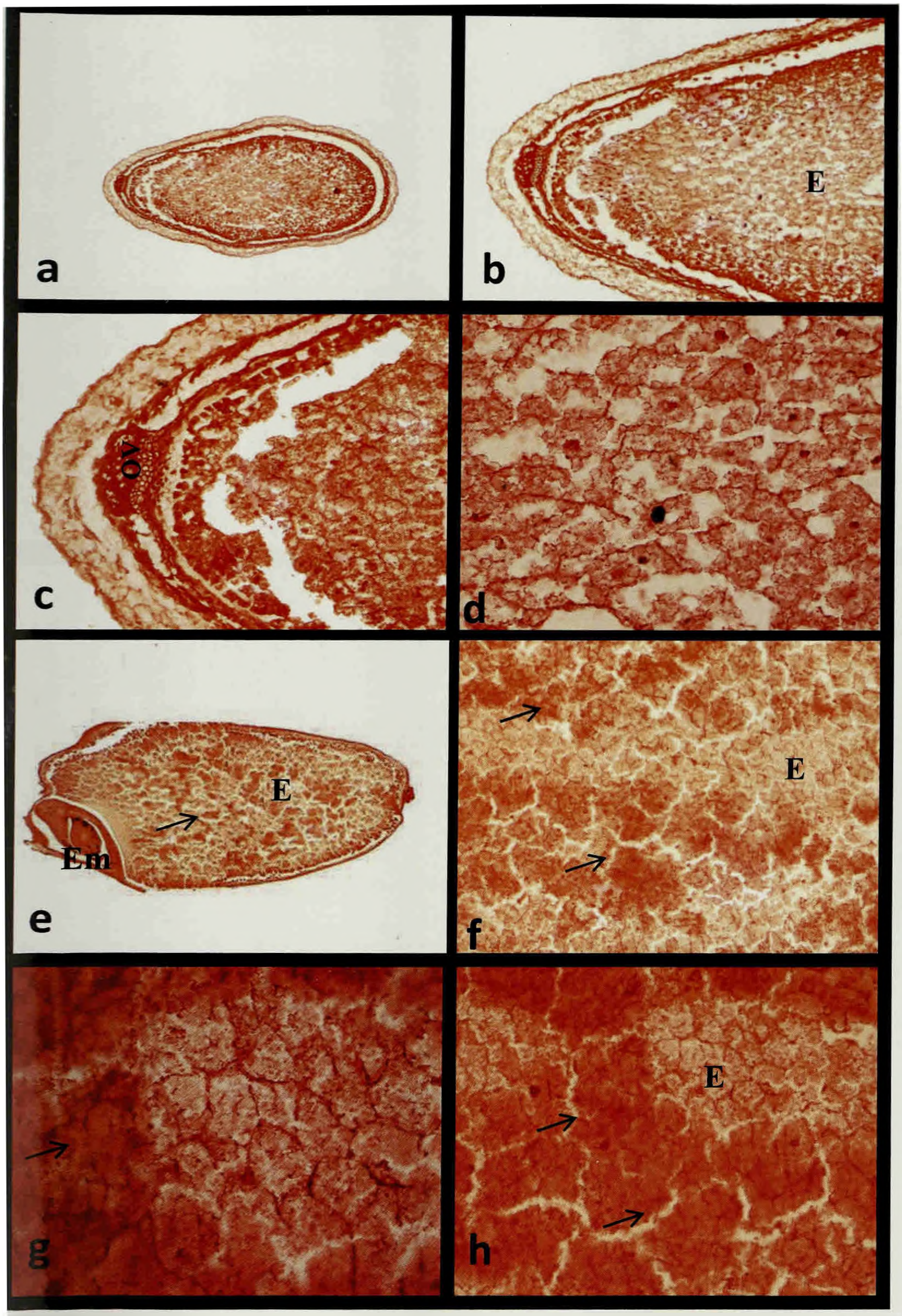


Plate 14. Anatomical characterization of rice variety Korgut, 10 days of fertilization (Stage 2). Transverse section (a-d) and Longitudinal section (e-h) of rice grain stained with safranin. a, e. X20; b, f. X50; c, g. X100 and d, h. X200. Em, embryo; E, endosperm; OV, ovular vascular bundle, Arrow shows the chalky endosperm.

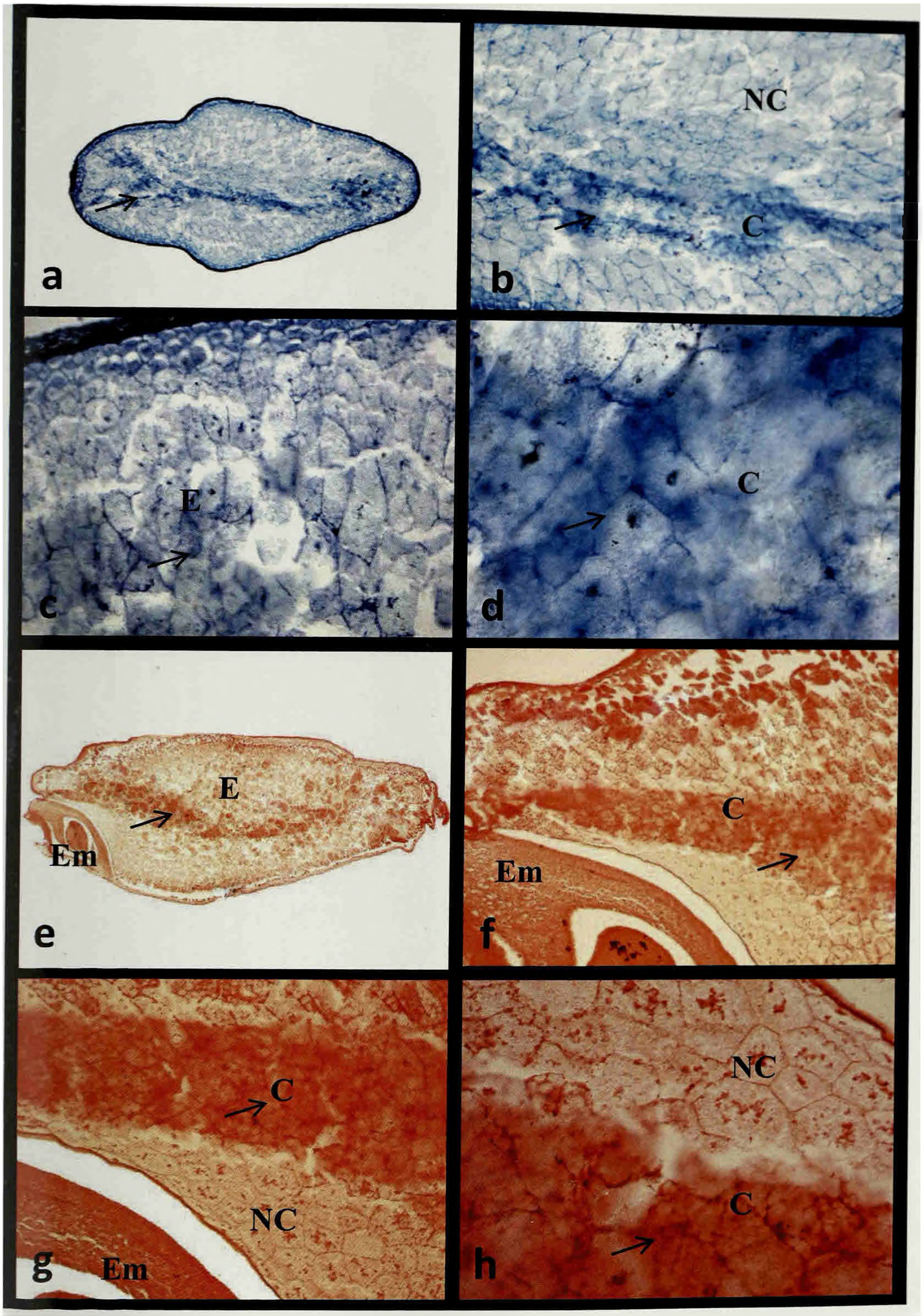


Plate 15. Anatomical characterization of rice variety Korgut, 20 days of fertilization (Stage 3). Transverse section of rice grain stained with safranin (a-d) and Longitudinal section stained with toluidine blue (e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. Em, embryo; E, endosperm; C, chalky cells; NC, non chalky cells, Arrow shows the chalky endosperm.

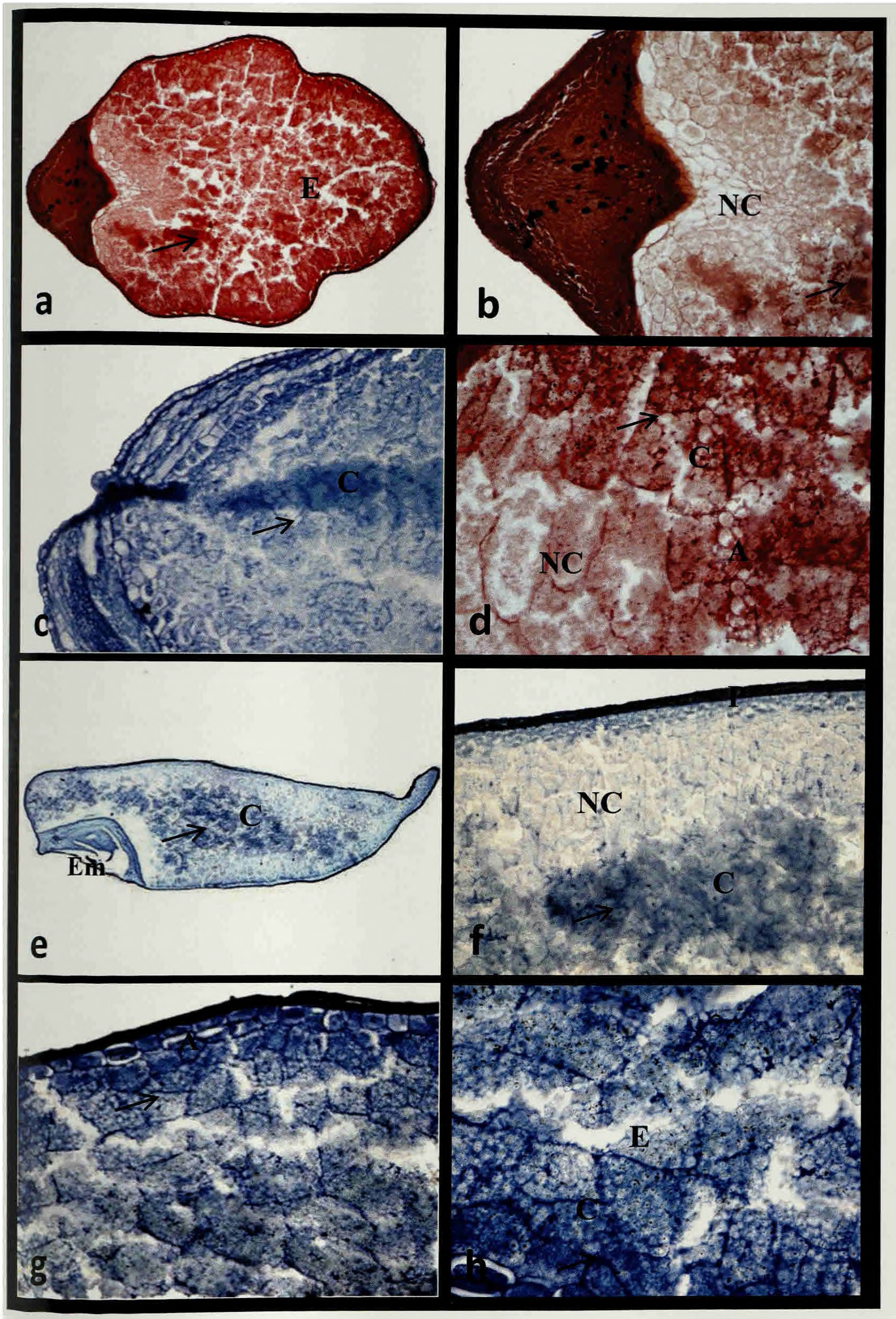


Plate 16. Anatomical characterization of rice variety Korgut, 30 days of fertilization (Stage 4). Transverse section of rice grain (a-d) stained with safranin (a, b, d) and Longitudinal section stained with toluidine blue (c, e-h). a, e. X20; b, f. X50; c, g. X100 and d, h. X200. Em, embryo; E, endosperm; C, chalky cells; NC, non chalky cells, Arrow shows the chalky endosperm.

observed that the LS of Korgut showed the proper path and initiation of the chalkiness from the embryo sides and the moving through the centre of the endosperm and then reaching the tip of the grain as shown in the Plate 15e.

4.8.4. Chalkiness in Developmental Stage 4 (30 DAF) of rice grain

Thin transverse and longitudinal sections of matured rice grain of 30 days after fertilization of variety Jaya showed with absence of chalkiness in the rice grain (Plate 12a-h). The endosperm cells arranged perfectly without any chalky cells. Both the staining reactions were uniform without any dark patches. The endosperm cell development was normal with uniform and normal deposition of the starch without any variation in deposition. The LS also revealed the similar characters as shown in TS with compact and uniform packing of starch (Plate 12e-h). In contrast, rice variety Korgut (Plate 16a-h), showed the maximum chalkiness with internal cracks and fissure as the chalkiness development observed in entire rice grain (Plate 16a). The TS showed clear difference in packaging of starch (patches in endosperm) (Plate 16c, d), while uniform and compact packing was seen in the non-chalky grains with proper endosperm cell wall. In LS, it is prominently shown that the chalkiness originates from embryo side and extends towards the tip of the grain (Plate 16e).

4.8.5. Chalkiness in variety MO-7 and KRH-2

Thin transverse and longitudinal sections of rice varieties MO-7 and KRH-2 were shown the similar results as seen in variety Korgut. The rice grain after 5 DAF of variety MO7 and KRH-2 showed mild patches of chalkiness as shown by safranin and toluidine. Then the rice grain of 10 days after fertilization (DAF) revealed that the endosperm cells are loosely arranged with patches of darkly stained regions in the centre of the endosperm

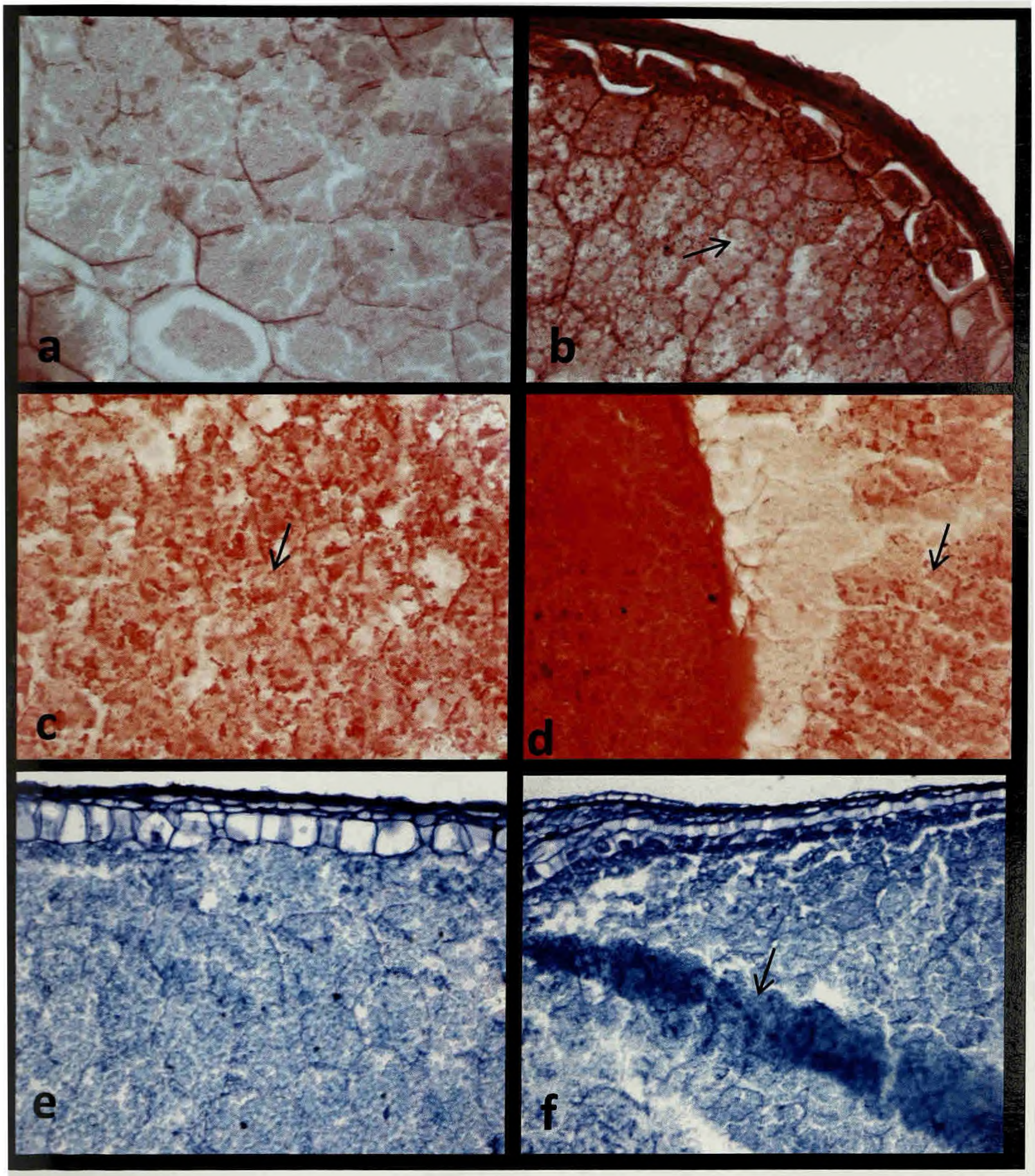


Plate 17. Anatomical characterization of rice variety MO-7 (a, b) and KRH-2 (c-f). Transverse section of rice grain 30 days after fertilization stained with safranin (a-d) and toluidine blue (e, f,). a, e. Non-chalky areas. a, b. X200; c-f. X100. Arrow shows the chalky endosperm.

and also in periphery. The later stage of development of about 20 DAF was examined in MO-7 and KRH-2 showed the prominent chalkiness starting from the embryo sides, extending towards centre and reaching up to the tip of the grain. The matured rice grains of about 30 DAF was investigated revealed the distinct differences in packing of starch in the endosperm, the chalky areas showed loosely packed starch and patches of endosperm cells (Plate 17a-f).

4.8.6. Fluorescence Microscopic Studies of Chalkiness in Rice Grain

The fluorescent dye acridine orange was used to understand the chalkiness in variety Jaya and Korgut. Thin transverse sections of matured rice grain of 5 to 30 days after fertilization of variety Jaya revealed with absence of chalkiness (Plate 18a-d). The endosperm cells arranged perfectly without any chalky cells. The staining reactions were uniform and the endosperm cell development was normal with even deposition of starch and compactly arranged endosperm cells (Plate 18a-d). In contrast, rice variety Korgut (Plate 18e-h), showed with internal cracks and fissure in the endosperm cells. The chalky areas were with unevenly packed and loosely arranged endosperm cells (Plate 18e-h).

4.8.7. Scanning Electron Microscopic (SEM) Studies of Chalkiness in Rice Grain

The Scanning Electron Microscopic studies were carried out to understand the chalkiness in rice grain. During this study, two rice varieties were selected. Rice variety Jaya was selected as control i.e. the grains without chalkiness. A local rice variety Korgut with chalky grains was selected for the study. Only matured rice grains of 20 DAF and 30 DAF were selected for the study. The SEM photographs of variety Jaya revealed with absence of chalkiness, the endosperm cells were arranged perfectly with uniform development of endosperm cells in both 20 DAF and 30 DAF (Plate 19, 20). The

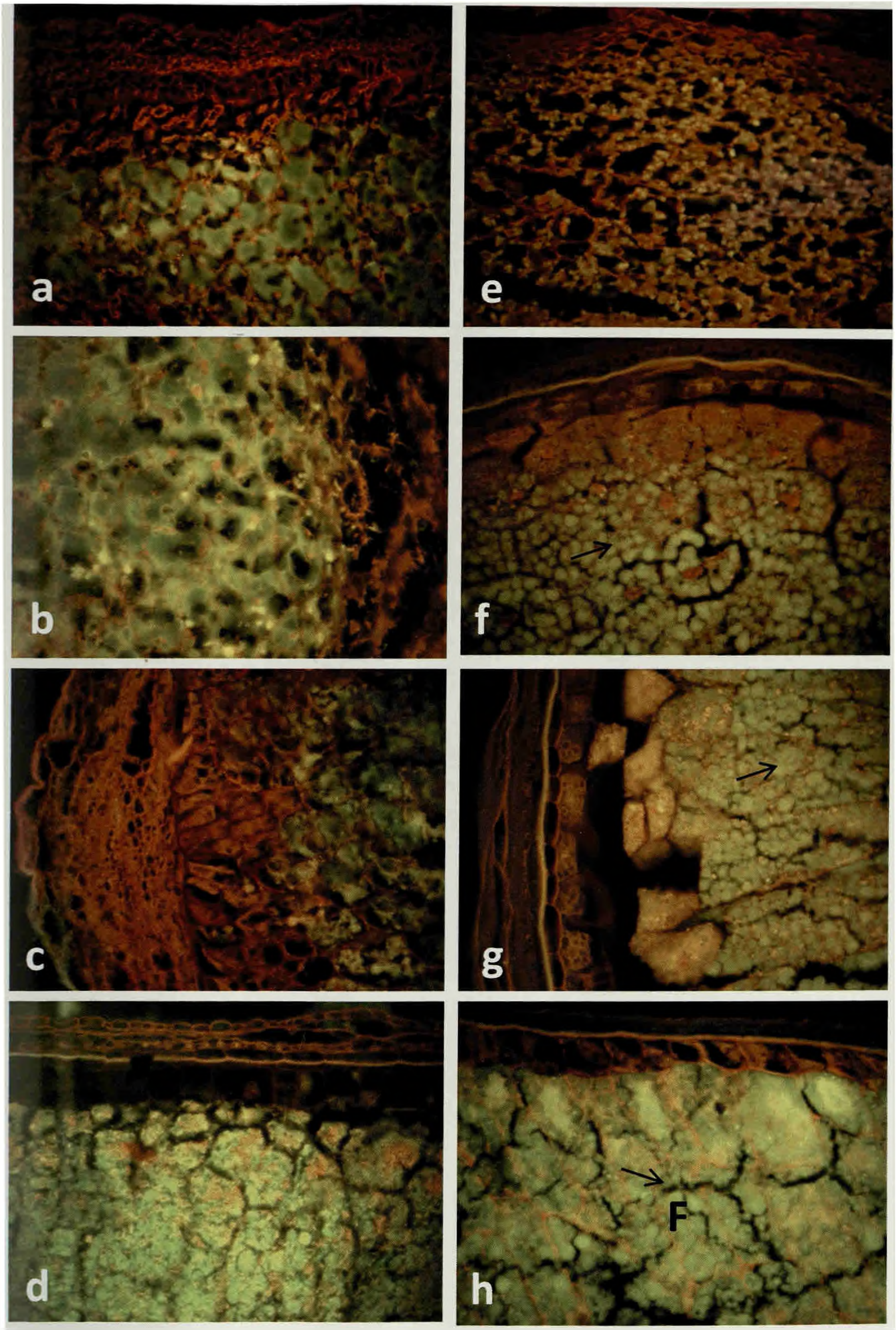


Plate 18. Anatomical characterization of rice variety Jaya (a-d; X200) and Korgut (e-g; X200). Transverse section of rice grain of (a, e; 5 DAF) stage 1, (b, f; 10 DAF) stage 2, (c, g; 20 DAF) stage 3 and (d, h; 30 DAF) stage 4 stained with acridine orange. Arrow shows the chalky endosperm. F, fissure.

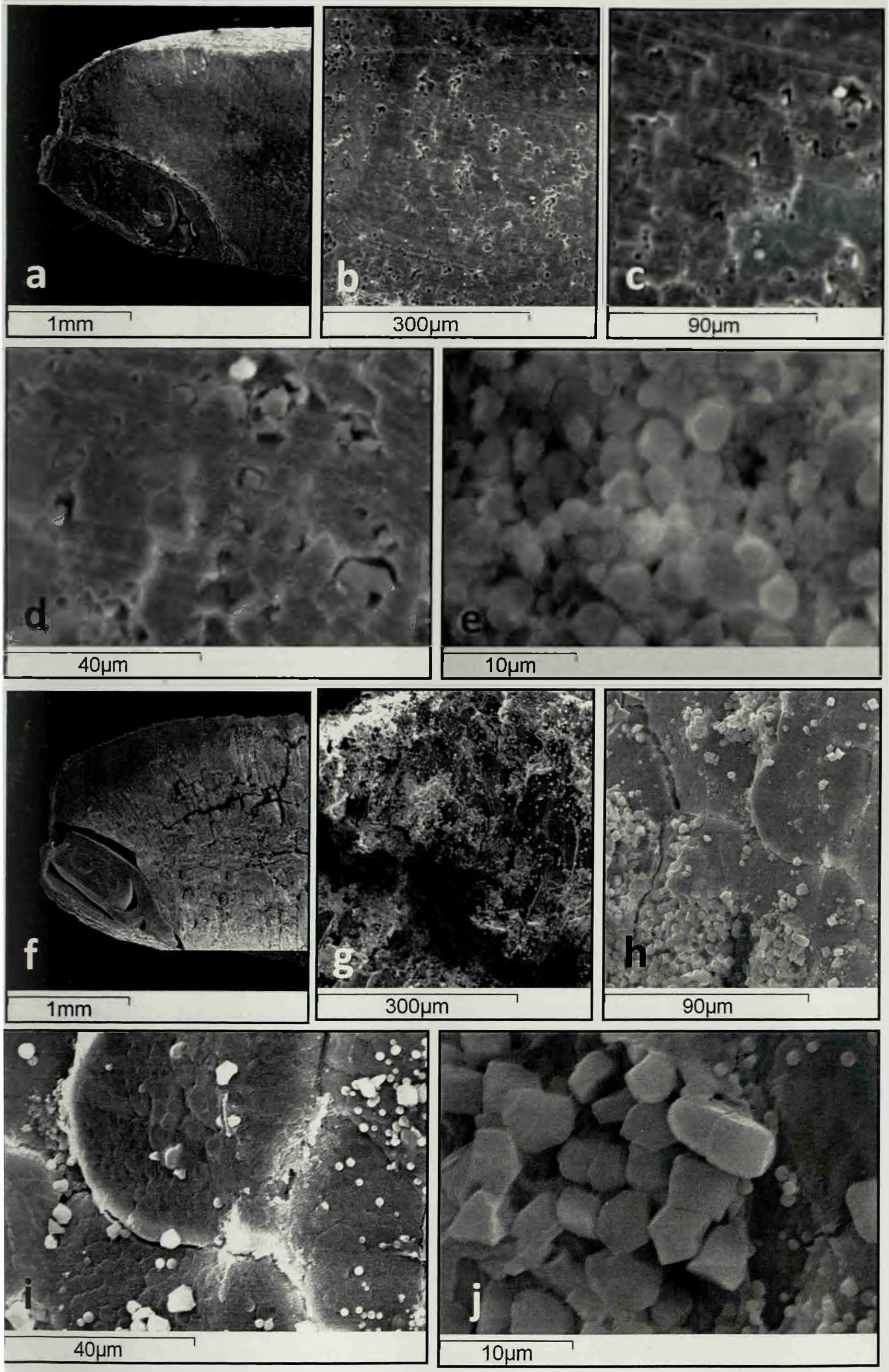


Plate 19. Scanning electron micrograph of rice variety Jaya and Korgut (25 DAF). a-e. Longitudinal section (LS) of rice grain of variety Jaya; f-j. Longitudinal section (LS) of rice grain of variety Korgut. a, f. X37; b, g. X200; c, h. X700; d, i. X1500; e, j. X4000.

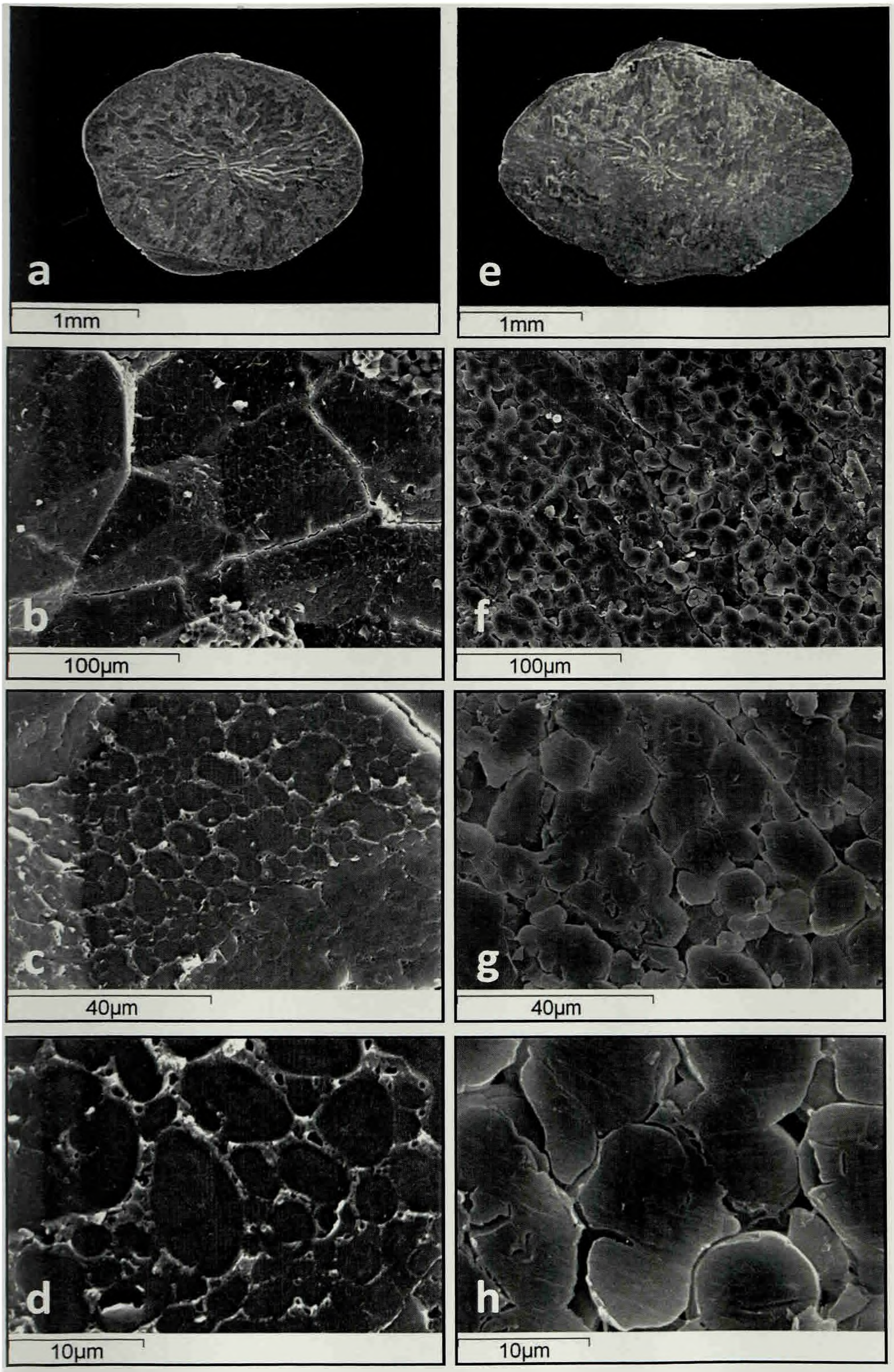


Plate 20. Scanning electron micrograph of rice variety Jaya and Korgut (30 DAF). TS of mature rice grain of variety Jaya (a-d). TS of mature rice grain of variety Korgut (e-h). a, e. X37; b, f. X500; c, g. X1500; d, h. X4000.

deposition of starch was very uniform and the wall of the endosperm cells were connected to each other and no gap between the endosperm cells and they were compactly arranged (Plate 19, 20a-e). In contrast, rice variety Korgut showed with internal cracks and fissure in the endosperm cells. The endosperm cells with unevenly packed and loosely arranged in the chalky grains of Korgut (Plate 19, 20e-j).

4.9. Molecular Genetic Diversity Studies of Rice Varieties

Genomic DNA was extracted from all the collected rice varieties including the salt tolerant rice variety Pokkali from Kerala and wild rice *Oryza rufipogon* from Goa. Quantitative and qualitative estimation of genomic DNA were carried out for all the rice varieties and the same is summarized in Table 35, 36. PCR was performed using ISSR random primers to understand the genetic variation between the 51 rice varieties in comparison with a wild rice *Oryza rufipogon.*

4.9.1. Screening of ISSR Primers

Nineteen ISSR random primers were initially screened with randomly selected two rice varieties for the reproducibility of bands. Out of 19 primers, fifteen primers showed consistent and reproducible bands (when the profiles with these primers reproduced with at least three different preparation of the genomic DNA). The details of primers and their annealing temperatures are given in Table 37. Four primers namely ISSR-809, IB-3, IB-4 and ISSR-6 did not amplify the tested DNA. Total 15 primers showed clear visible banding pattern and were used for PCR amplification of DNA of all 51 rice varieties and wild rice *Oryza rufipogon.*

Table 35. Quantitative and qualitative estimation of genomic DNA from the traditionally cultivated rice varieties.

Sl. No.	DNA extracted from rice varieties	Absorbance at 260 nm	Absorbance at 280 nm	Absorbance ratio 260/280	Quantity of DNA (µg/µl)
1	Assgo	0.527	0.280	1.88	1.35
2	Barik Kudi	1.117	0.587	1.90	2.79
3	Bello	1.855	0.989	1.87	4.64
4	Damgo	0.593	0.306	1.93	1.48
5	Dhave	2.656	0.781	1.93	6.64
6	Ek Kadi	1.515	0.781	1.93	3.78
7	Ghansal	3.191	1.643	1.94	7.97
8	Girga	1.897	0.940	2.00	4.74
9	Jiresal	1.500	0.842	1.78	3.75
10	Kalo Damgo	0.280	0.155	1.80	0.70
11	Kalo Korgut	3.869	2.121	1.82	9.47
12	Kalo Novan	1.259	0.689	1.82	3.15
13	Karo Mungo	2.421	1.269	1.90	6.05
14	Karz	0.831	0.469	1.77	2.07
15	Kendal	0.851	0.472	1.80	2.13
16	Khochro	1.969	1.063	1.85	4.92
17	Kolyo	1.858	0.998	1.86	4.64
18	Korgut	0.565	0.309	1.82	1.41
19	Kotimirsal	1.879	0.974	1.929	4.69
20	Kusago	0.257	0.135	1.903	0.64
21	Muno	1.095	0.588	1.862	2.73
22	Novan	1.153	0.615	1.874	2.88
23	Patni	0.875	0.447	1.957	2.19
24	Sal	2.018	1.010	1.998	5.05
25	Shiedi	0.499	0.277	1.800	1.25
26	Tamdi	2.916	1.428	2.040	7.29
27	Taysu	0.404	0.225	1.795	1.01
28	Valay	1.007	0.513	1.960	2.52
29	*Oryza rufipogon*	1.879	0.974	1.929	4.69

Table 36. Quantitative and qualitative estimation of genomic DNA from the high yielding rice varieties.

Sl. No.	DNA extracted from rice varieties	Absorbance at 260 nm	Absorbance at 280 nm	Absorbance ratio 260/280	Quantity of DNA (µg/µl)
1	Annapurna	2.432	1.278	1.900	6.08
2	CSR-27	1.071	0.555	1.929	2.67
3	IR-8	1.436	0.783	1.833	3.59
4	Jaya	1.348	0.695	1.930	3.37
5	Jyoti	0.397	0.215	1.846	0.99
6	Karjat-3	1.384	0.729	1.898	3.46
7	Karjat-5	0.515	0.262	1.960	1.29
8	Kasturi	0.792	0.409	1.936	1.98
9	KRH-2	0.497	0.258	1.926	1.24
10	MO-7	1.014	0.541	1.870	2.54
11	MO-9	1.005	0.547	1.830	2.51
12	MO-17	1.386	0.765	1.811	3.46
13	Mugadh Sugandh	0.889	0.488	1.82	2.22
14	Pusa Basmati-1	0.589	0.313	1.881	1.47
15	Pusa Sugandh-2	0.782	0.405	1.930	1.95
16	Pusa Sugandh-3	0.840	0.434	1.935	2.10
17	Pusa Sugandh-5	0.525	0.281	1.868	1.31
18	R-6857	1.570	0.819	1.916	3.92
19	Sahyadri-1	2.074	1.010	2.050	5.18
20	Salt Tolerant AVT-1901	0.308	0.168	1.830	0.77
21	Salt Tolerant AVT-1918	0.290	0.168	1.720	0.72
22	Vasmati	1.127	0.588	1.910	2.82
23	Pokkali	1.095	0.558	1.962	2.74

Table 37. ISSR primers used for the analysis traditionally cultivated and high yielding rice varieties with number of amplified bands.

Sl. No.	Primer name	5'-3' Sequence	AT	Amplified primer	Number of amplified bands
1	ISSR-810	GAGAGAGAGAGAGAGAT	49.4	+	8
2	1SSR-808	AGAGAGAGAGAGAGAGC	51.8	+	7
3	ISSR-809	AGAGAGAGAGAGAGAGG	51.8	-	-
4	1SSR-834	AGAGAGAGAGAGAGAGYT	51.4	+	9
5	UBC-828	TGTGTGTGTGTGTGTGA	49.4	+	8
6	UBC-811	GAGAGAGAGAGAGAGAC	51.8	+	9
7	IB-3	TCTCTCTCTCTCTCTCC	51.8	-	-
8	IB-4	ACACACACACACACACC	51.8	-	-
9	1SSR-7	GGCGGCGGCGGCGGCTA	66.2	+	10
10	ISSR-2	AAGAAGAAGAAGAAGGC	47.0	+	9
11	ISSR-3	AAGAAGAAGAAGAAGTG	44.5	+	9
12	ISSR-6	AGCAGCAGCAGCAGCCG	59.0	-	-
13	ISSR-807	AGAGAGAGAGAGAGAGT	49.4	+	7
14	ISSR-812	GAGAGAGAGAGAGAGAA	49.4	+	6
15	RM-ST1	CACGTGAGACAAAGACGGAG	58.4	+	8
16	RM-ST2	GAGAGAGAGAGAGAGAYG	53.8	+	8
17	ISSRA1	GAAGGCAAGTCTTGGCACTG	58.4	+	2
18	ISSRA2	ACTATGCAGTGGTGTCACCC	58.4	+	3
19	ISSRA3	TGGCCTGCTCTCTCTCTCTC	58.45	+	7

+ Amplified; - Not amplified; AT, annealing temperature

4.9.2. ISSR Amplification and Banding Pattern

ISSR analysis was carried for 28 traditional rice varieties and 22 high yielding rice varieties from different regions of Goa. In addition, salt tolerant rice variety collected from Kerala and a wild rice *Oryza rufipogon* collected from Goa for ISSR amplification. Fifteen primers used for amplification of genomic DNA, which showed clear and reproducible banding pattern. Amplification profiles of amplified primers are shown in Plate 21 to 35. A total of 110 ISSR bands were obtained from 15 different primers with an average of 7.33 bands per primer (Table 38). Out of 110 bands, 104 bands were polymorphic for all the rice varieties with an average of 6.93 bands per primer. The number of amplified bands ranged from 2 (ISSRA1) to 10 (1SSR-7). The percentage of polymorphism among the primers is shown in Figure 31. The percentage polymorphism across all the samples varied from 50 to 100%, with an average of 92%. Polymorphic banding pattern of 100% was obtained using primers 1SSR-808, 1SSR-834, UBC-828, UBC-811, 1SSR-7, ISSR-2, ISSR-807, ISSR-812 and ISSRA3, while, lowest polymorphism (50%) was observed in ISSRA1 primer (Table 38; Figure 32).

4.9.3. Genetic Identity and Cluster Analysis

Pair wise genetic similarities were computed from ISSR data using NTSYS-pc computer software (Rohlf, 1992). The identity values of all 51 rice varieties and a wild rice *Oryza rufipogon* are given in Table 39. The genetic identity value varied from 0.5091 to 0.9727, with the average of 0.740. Among 51 rice varieties, the Salt Tolerant AVT-1908 and Salt Tolerant AVT-1918 shared maximum genetic identity (0.9727), where as the traditionally cultivated rice varieties Ek Kadi and Dhave were shown almost similar range of genetic identities (0.9273). The traditional salt tolerant rice varieties Kalo Korgut and

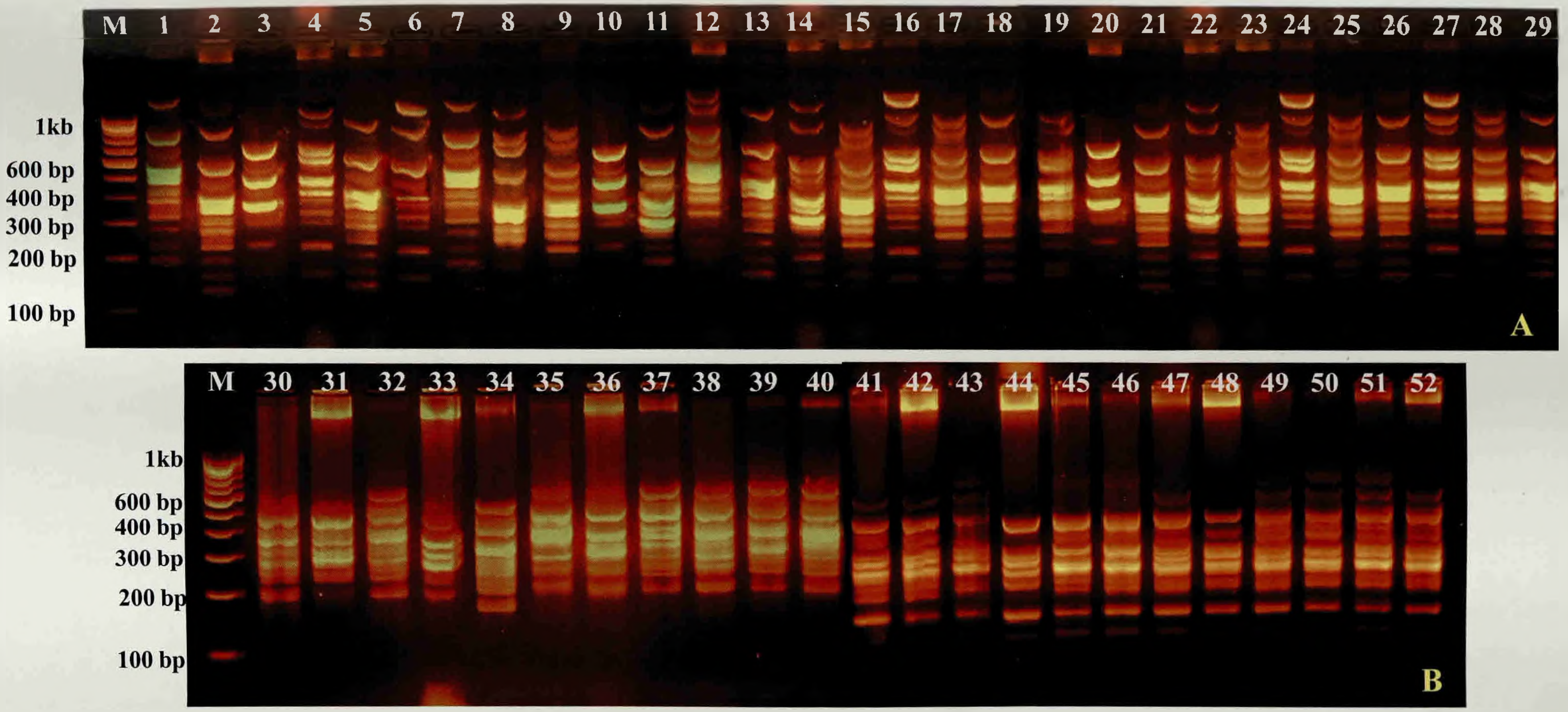


Plate 21. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-810. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

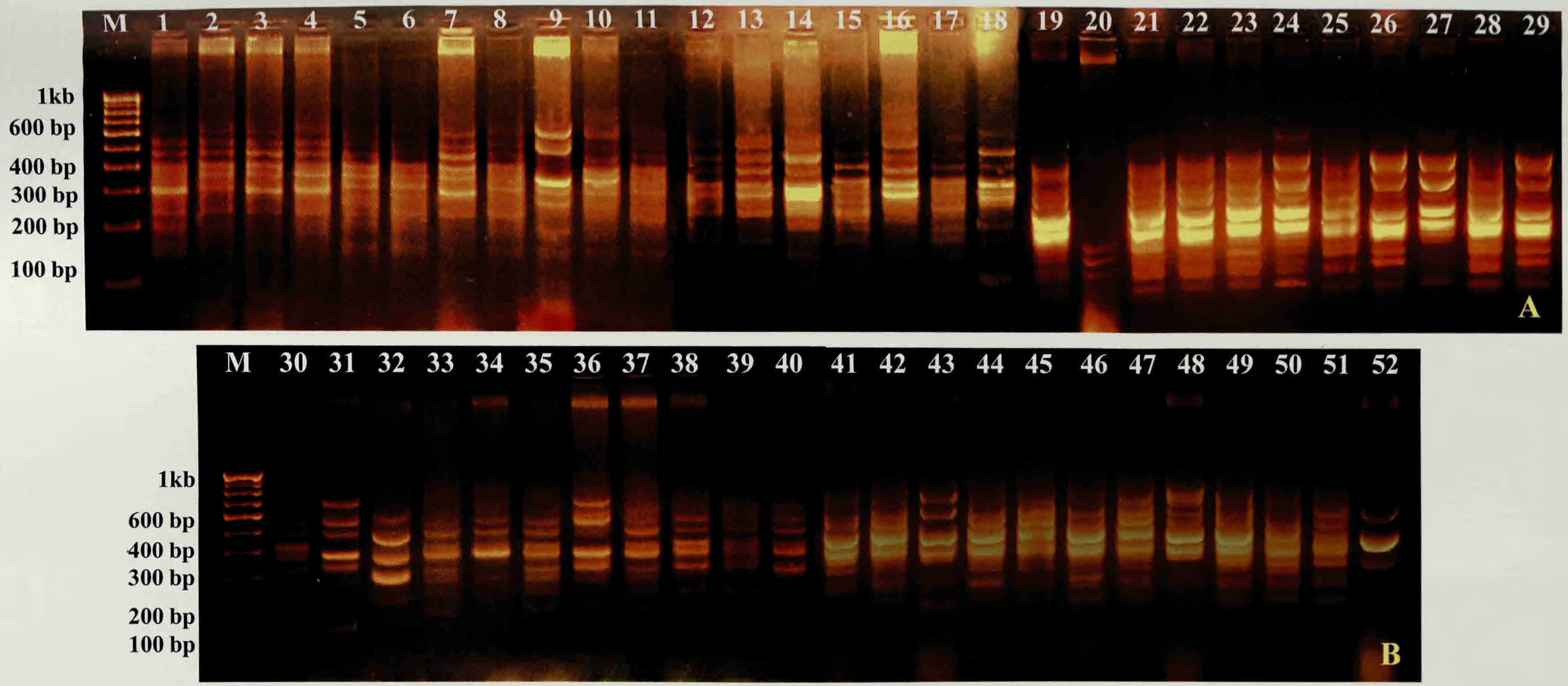


Plate 22. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-808. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati-1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

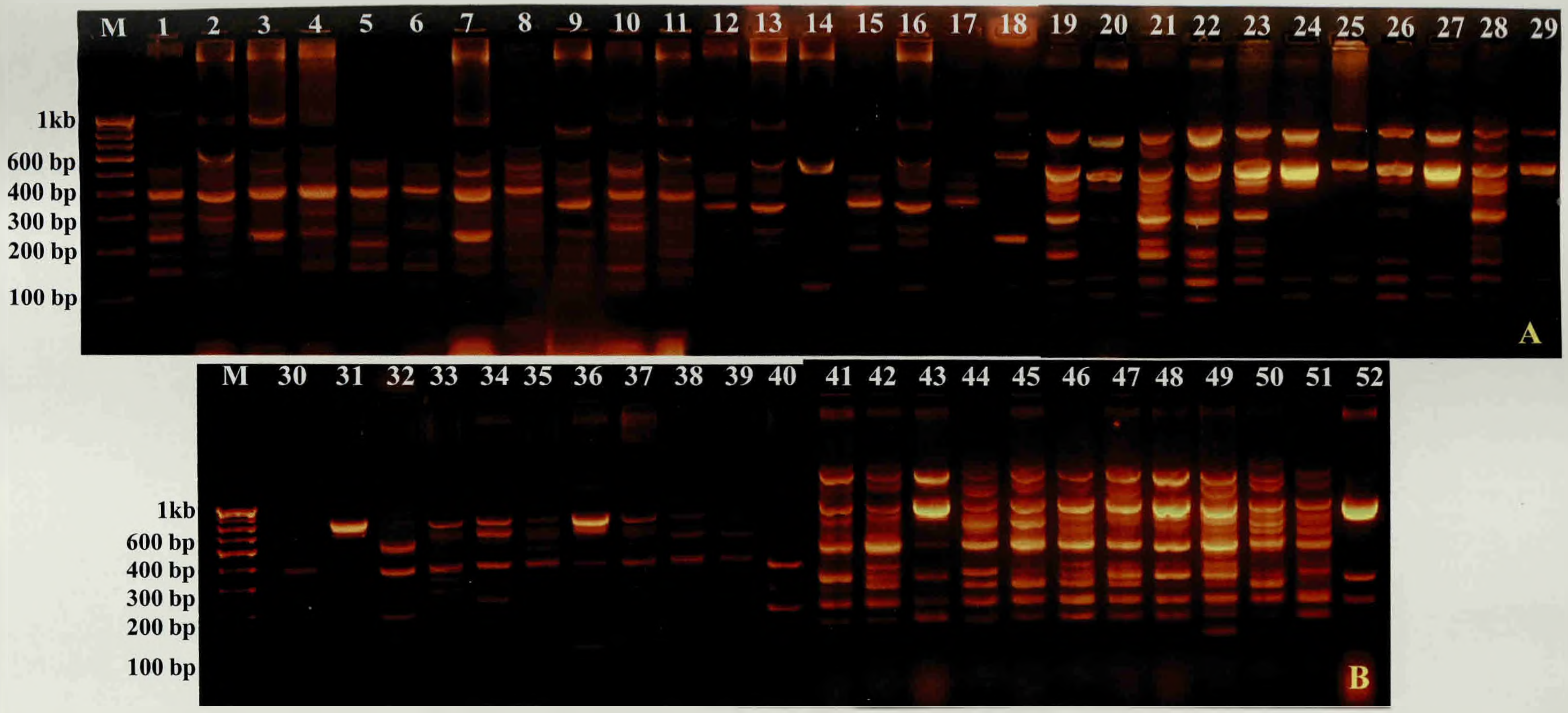


Plate 23. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-834. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati-1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

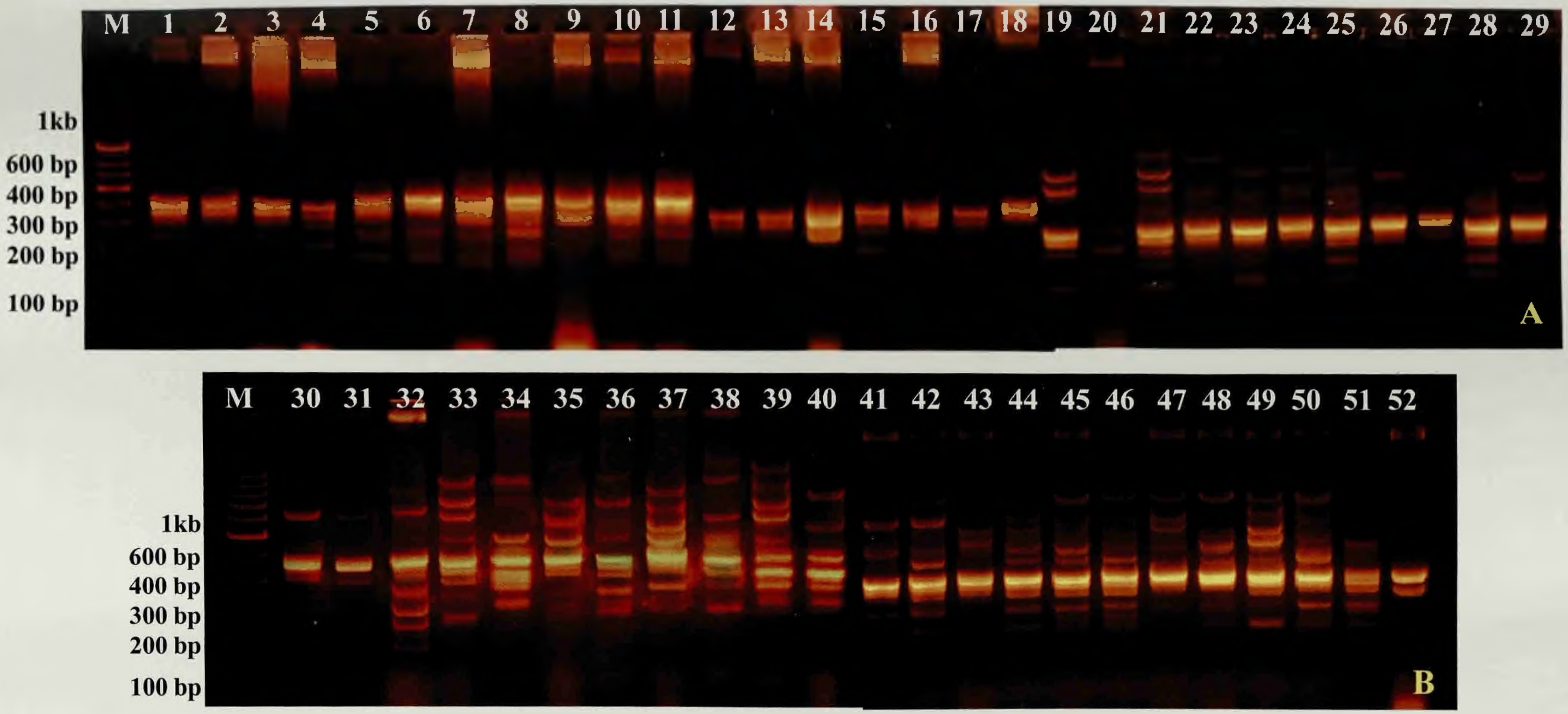


Plate 24. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer UBC-828. Lane 1. Gene ruler^{TM} 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

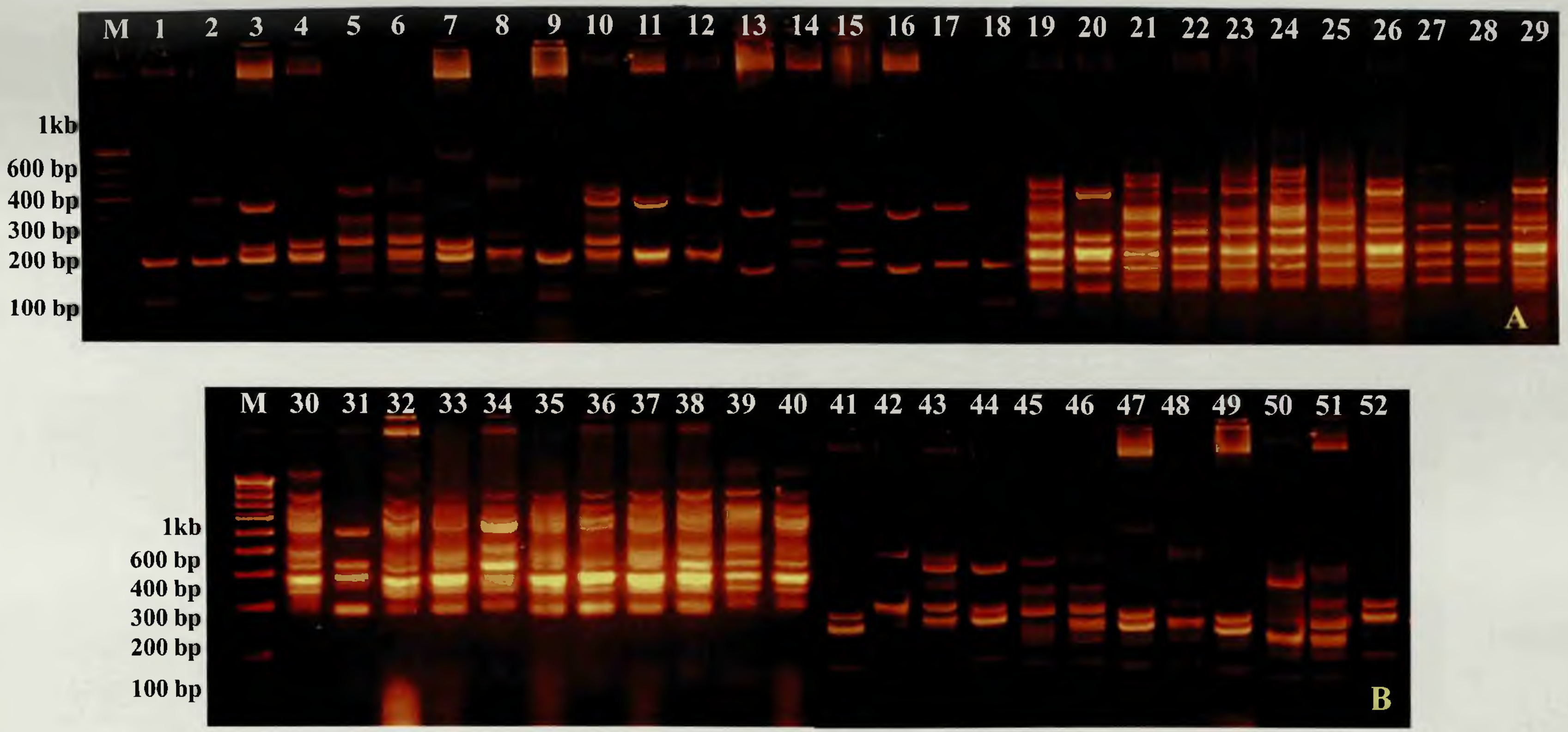


Plate 25. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer UBC-811. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

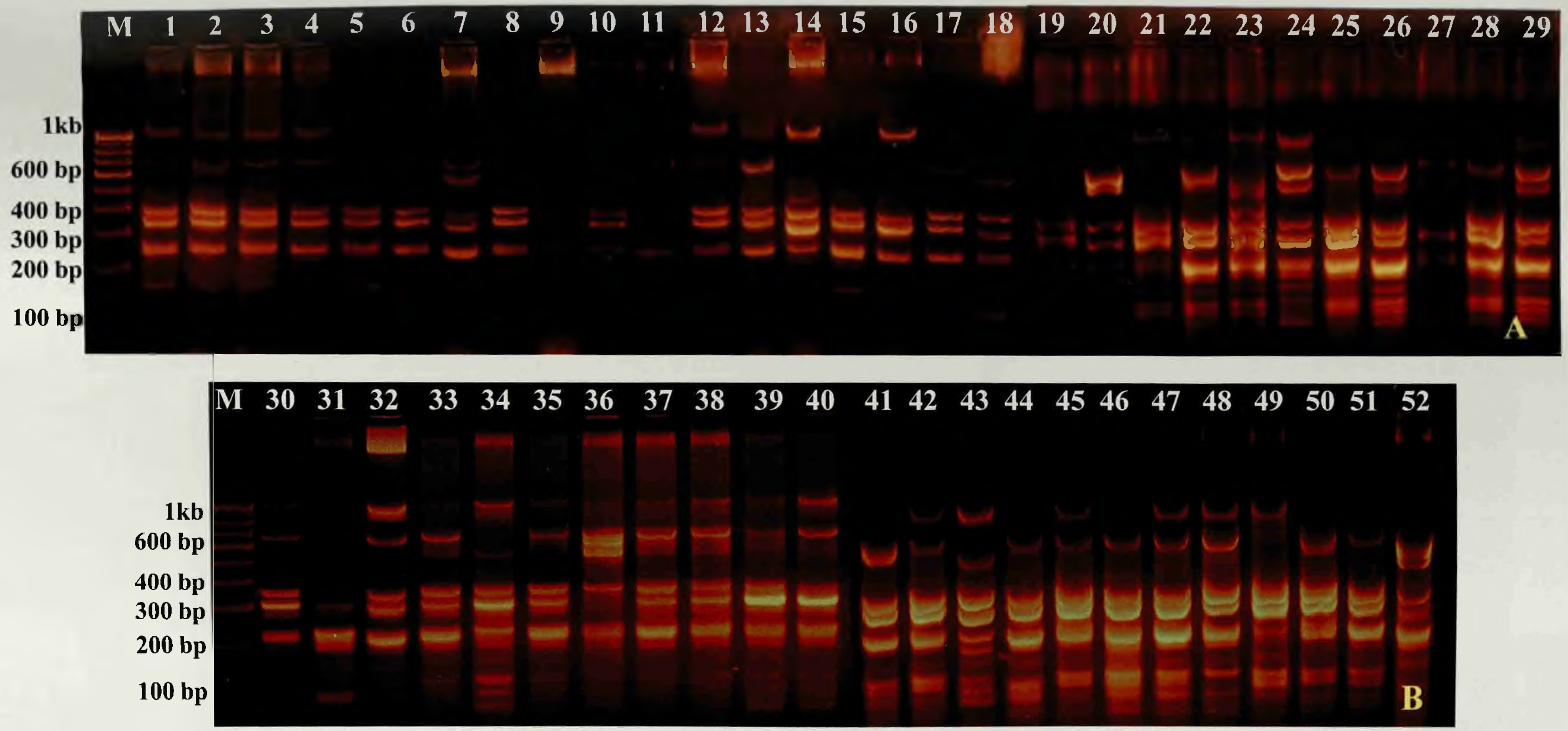


Plate 26. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-7. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

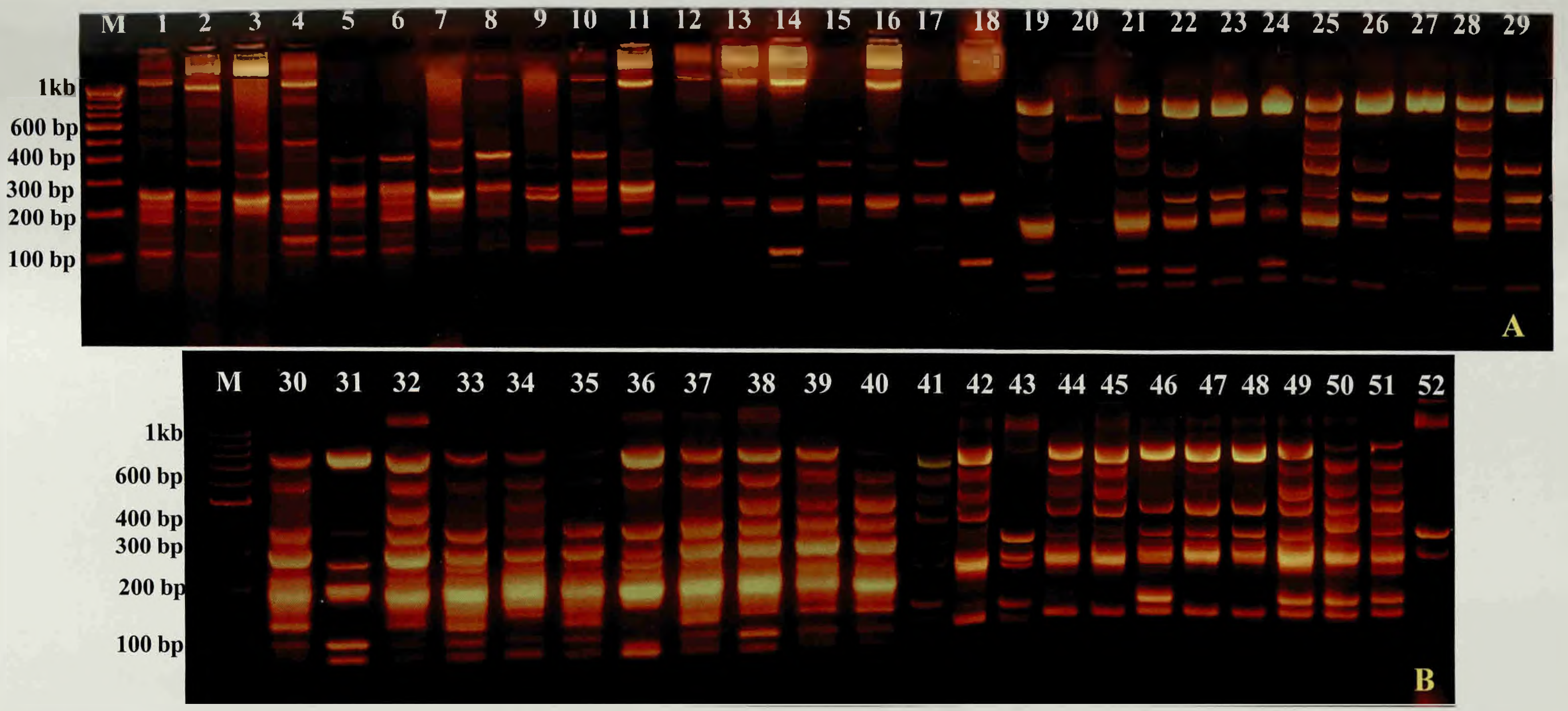


Plate 27. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-2. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

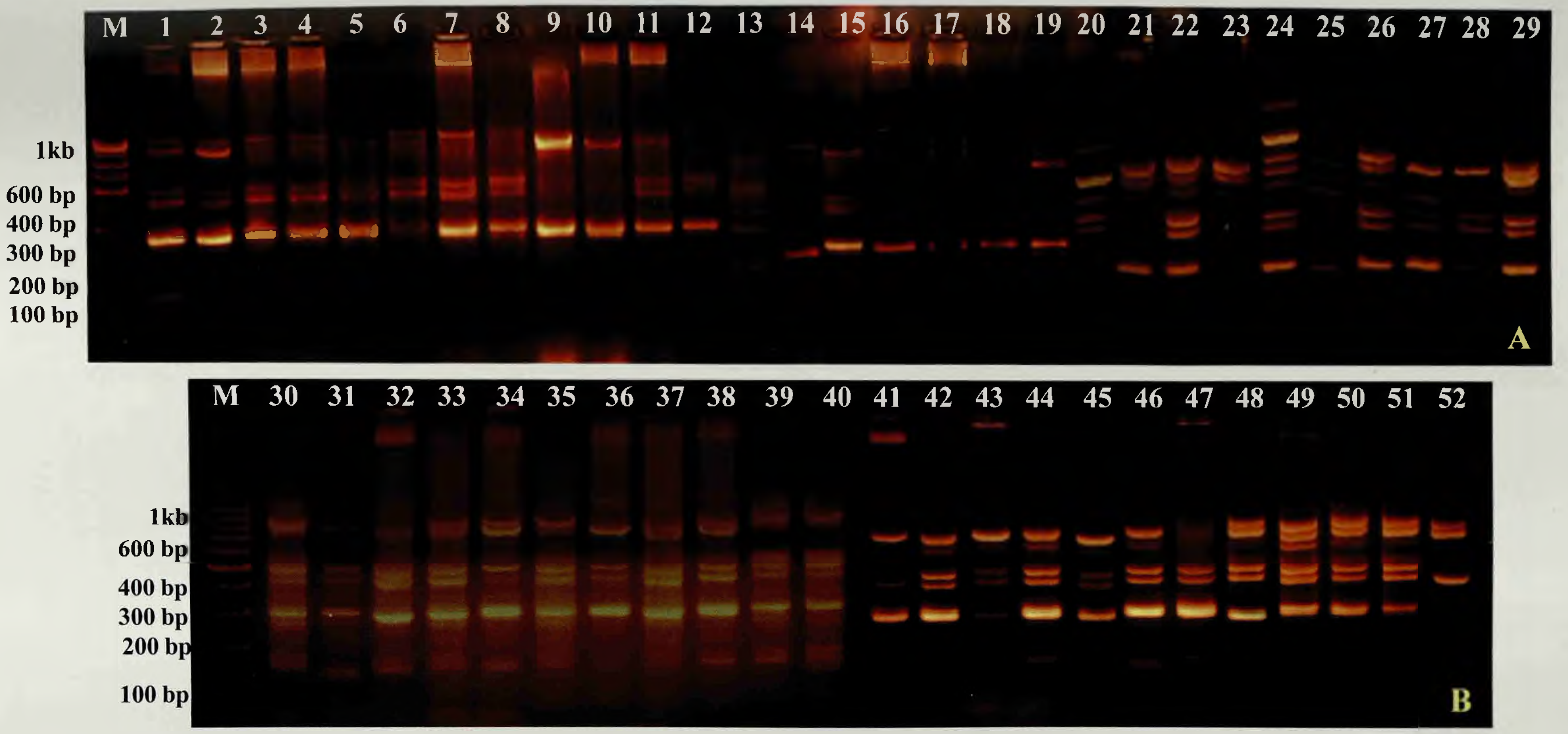


Plate 28. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-3. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

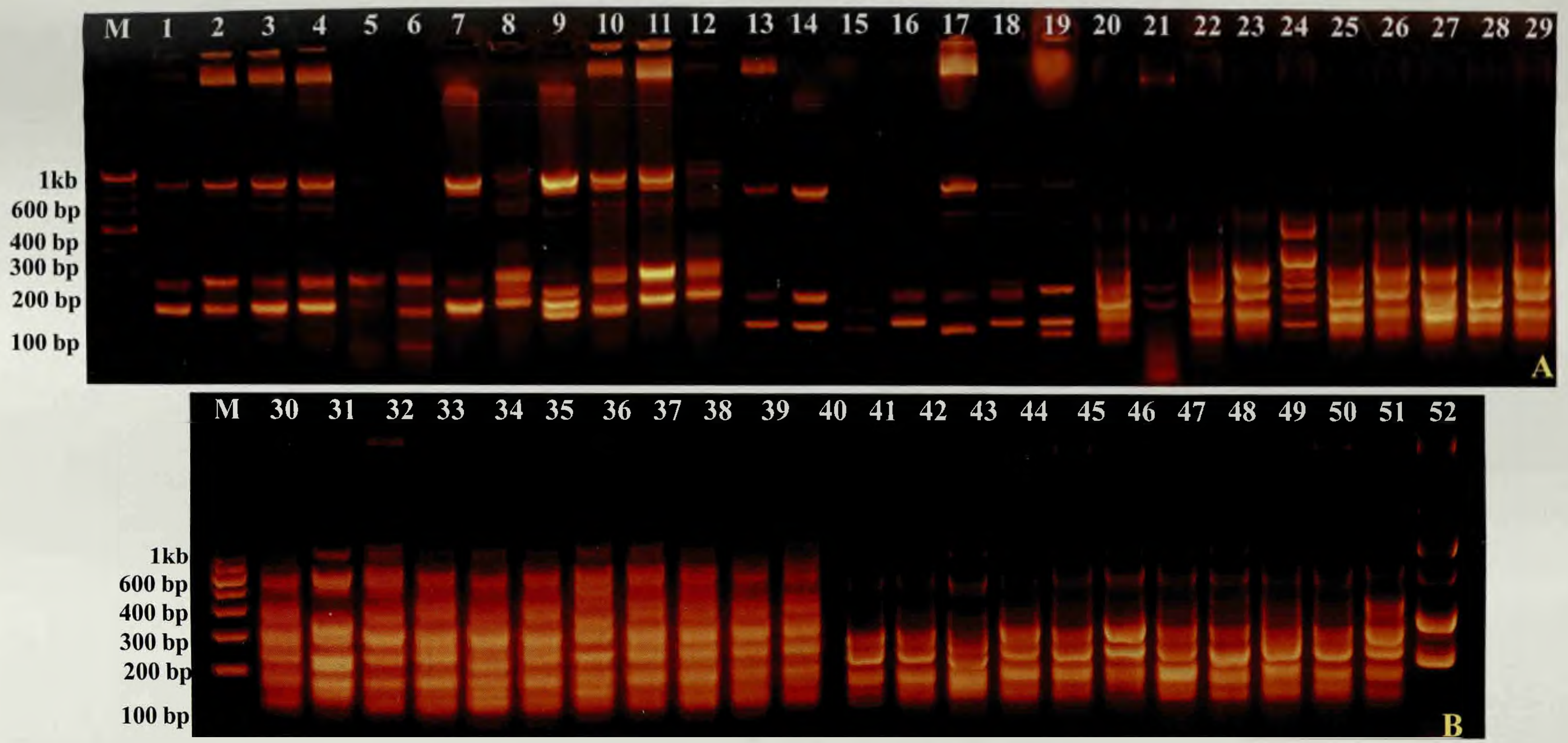


Plate 29. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-807. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

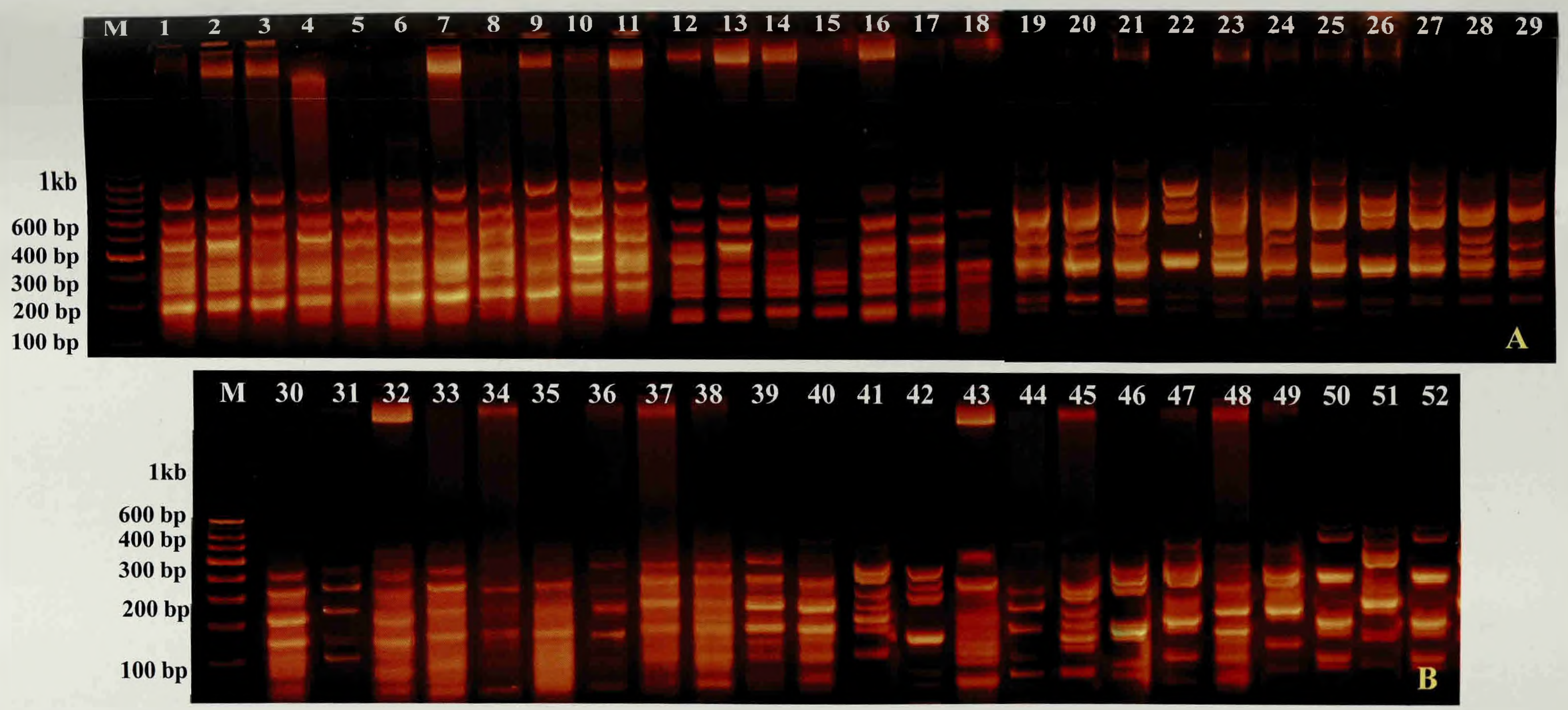


Plate 30. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-812. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

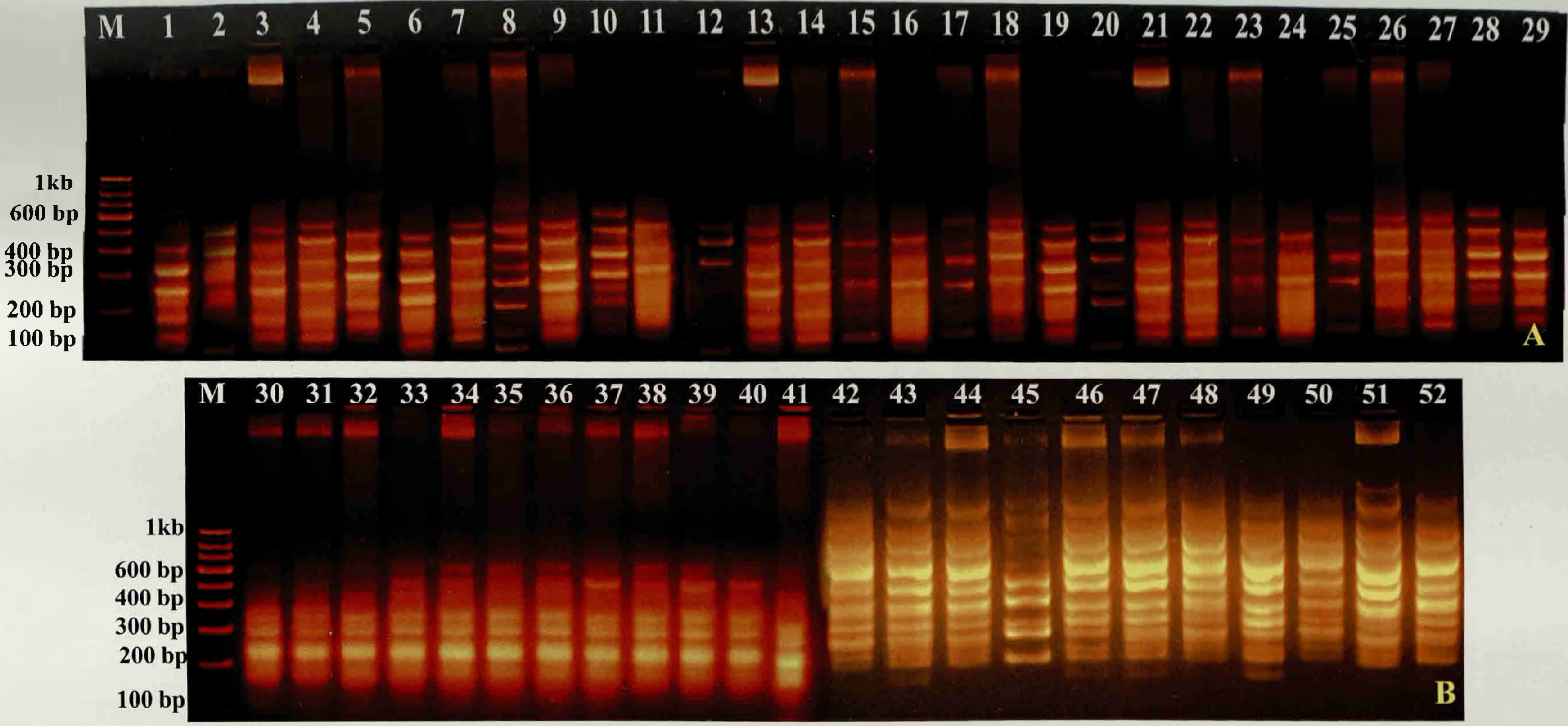


Plate 31. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer RM-ST1. Lane 1. Gene ruler^{TM} 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

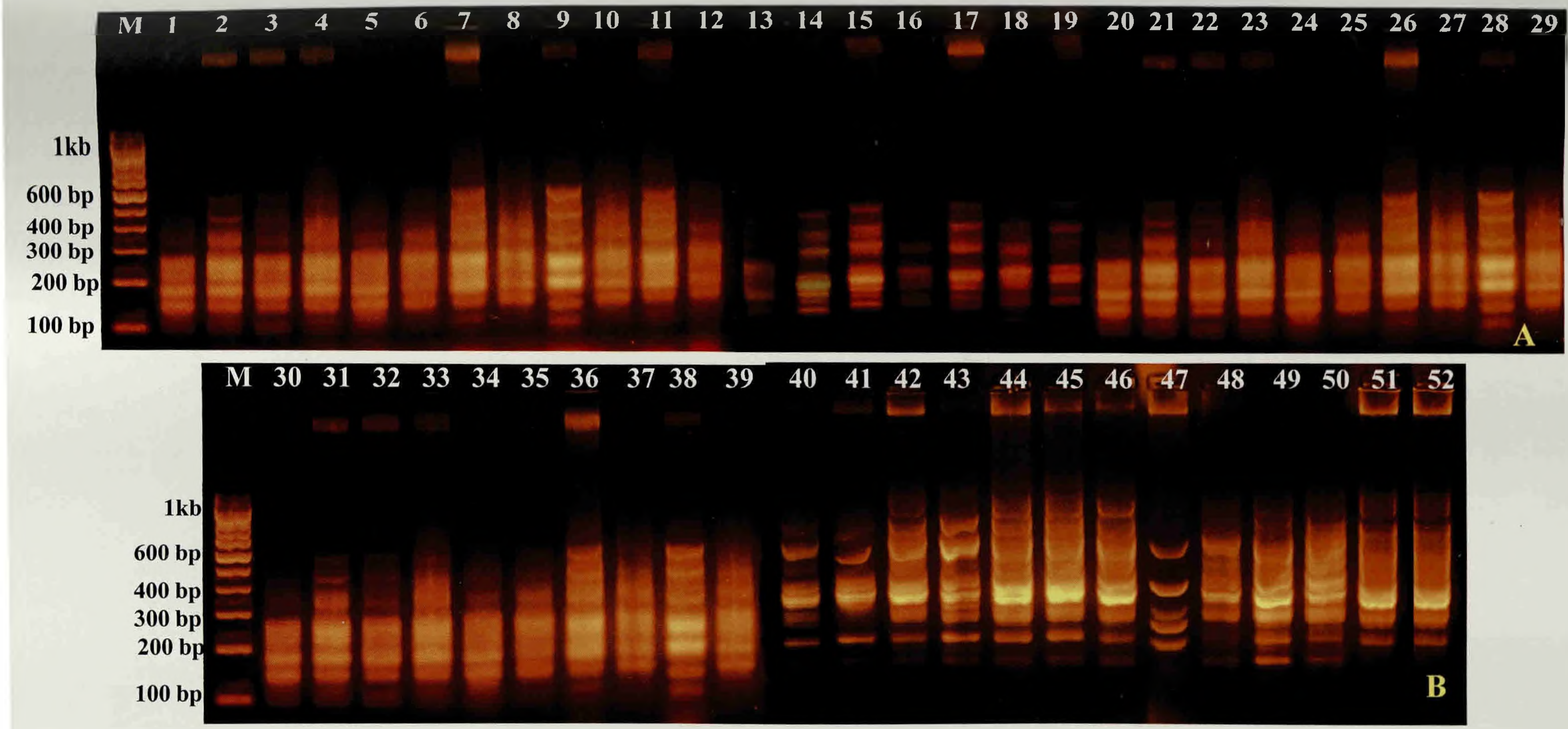


Plate 32. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSR-ST2. Lane 1. Gene ruler^{TM} 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

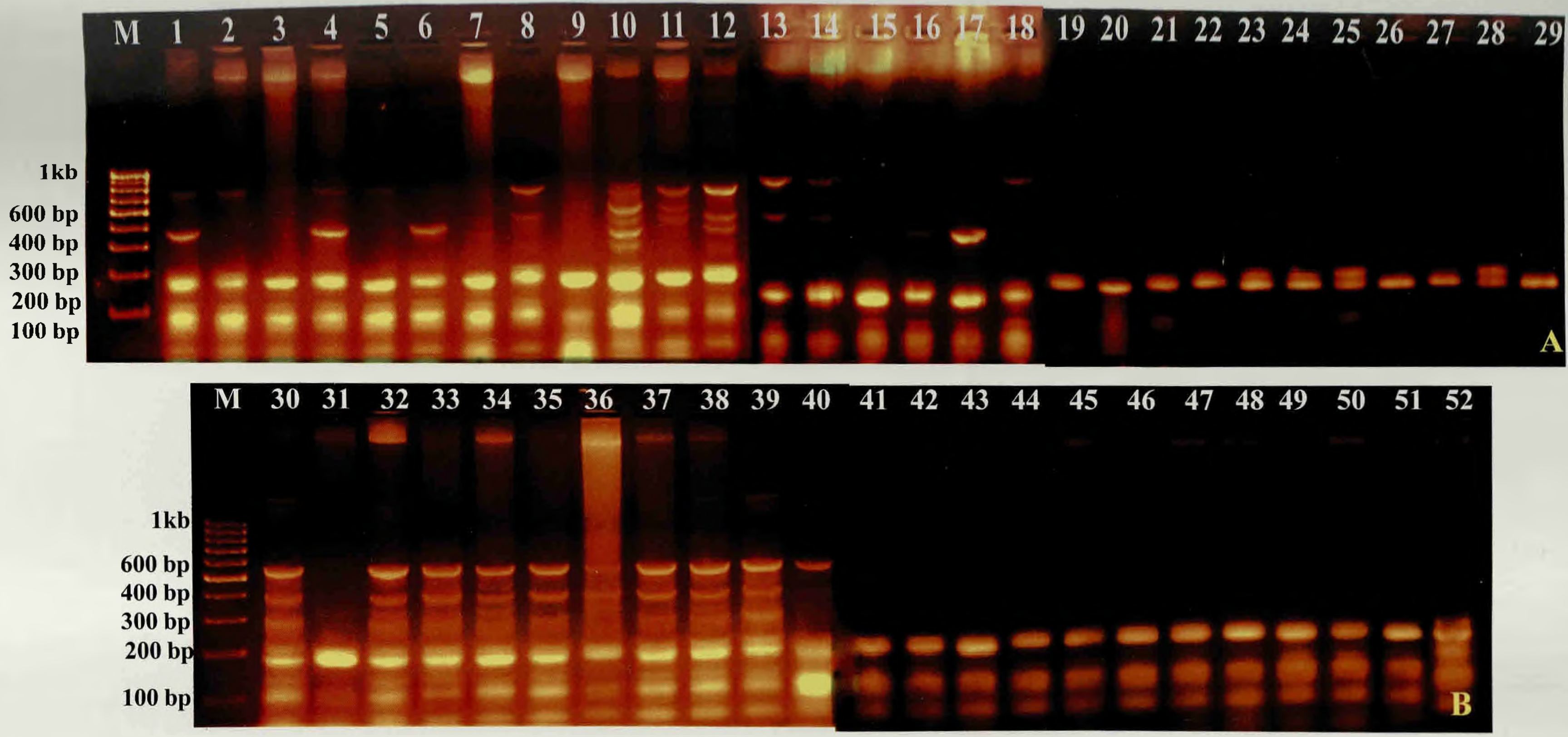


Plate 33. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer ISSRA1. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

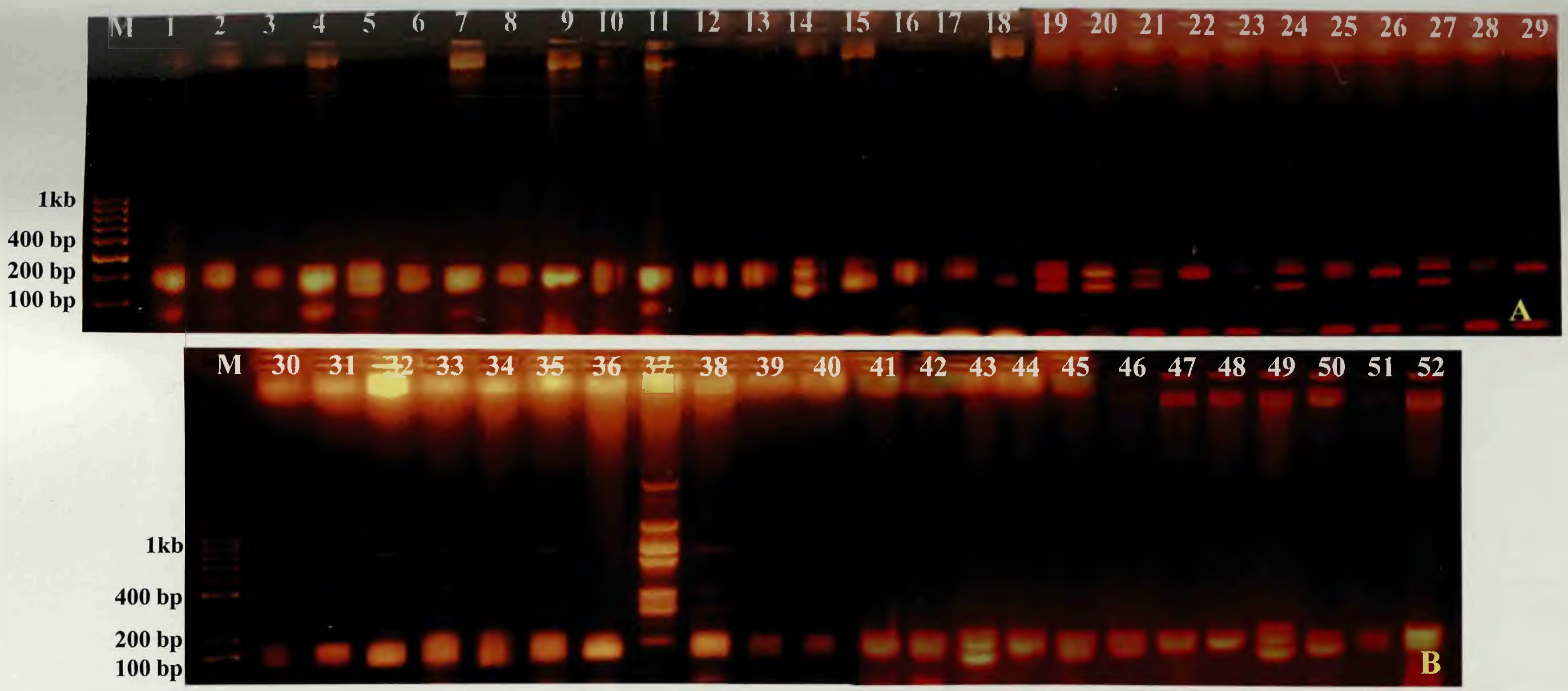


Plate 34. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer SSRA2. Lane 1. Gene ruler™ 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

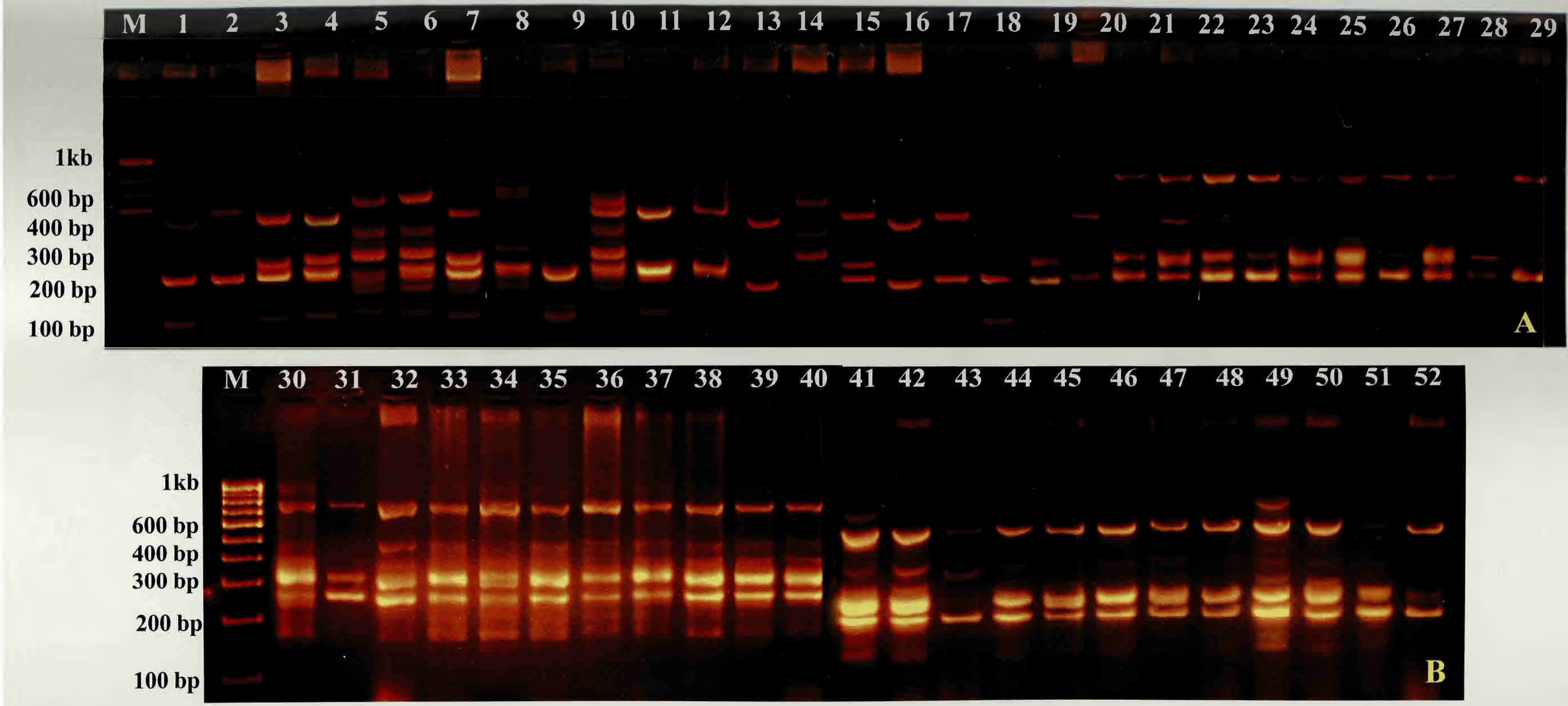


Plate 35. ISSR amplification profile of 51 rice varieties and a wild rice *Oryza rufipogon* with primer SSRA3. Lane 1. Gene ruler^{TM} 1 kb DNA ladder marker; 1. Barik Kudi; 2. Bello; 3. Dhave; 4. Ek Kadi; 5. Kalo Novan; 6. Kalo Damgo; 7. Karz; 8. Kendal; 9. Khochro; 10. Kolyo; 11. Kusago; 12. Novan; 13. Patni; 14. Sal; 15. Taysu; 16. Tamdi; 17. Valay; 18. *Oryza rufipogon;* 19. Ghansal; 20. Girga; 21. Jiresal; 22 Kotimirsal; 23. Pusa Basmati1; 24. Pusa Sugandh-2; 25. Pusa Sugandh-3; 26. Pusa Sugandh-5; 27. Kasturi; 28. Vasmati; 29. Mugadh Sugandh, 30. Assgo; 31. Damgo; 32. Kalo Korgut; 33. Karo Mungo; 34. Korgut; 35. Muno; 36. Shiedi;37. CSR-27; 38. Salt tolerant-1901; 39. Salt tolerant-1918; 40. Pokkali; 41. Annapurna; 42. IR-8; 43. Jaya; 44. Jyoti; 45. Karjat-3; 46. Karjat-5; 47. MO-7; 48. MO-9; 49. MO-17; 50. R-6857; 51. KRH-2; 52. Sahyadri-1.

Fig. 31. Amplified and polymorphic bands in ISSR primers for traditional and high yielding rice varieties.

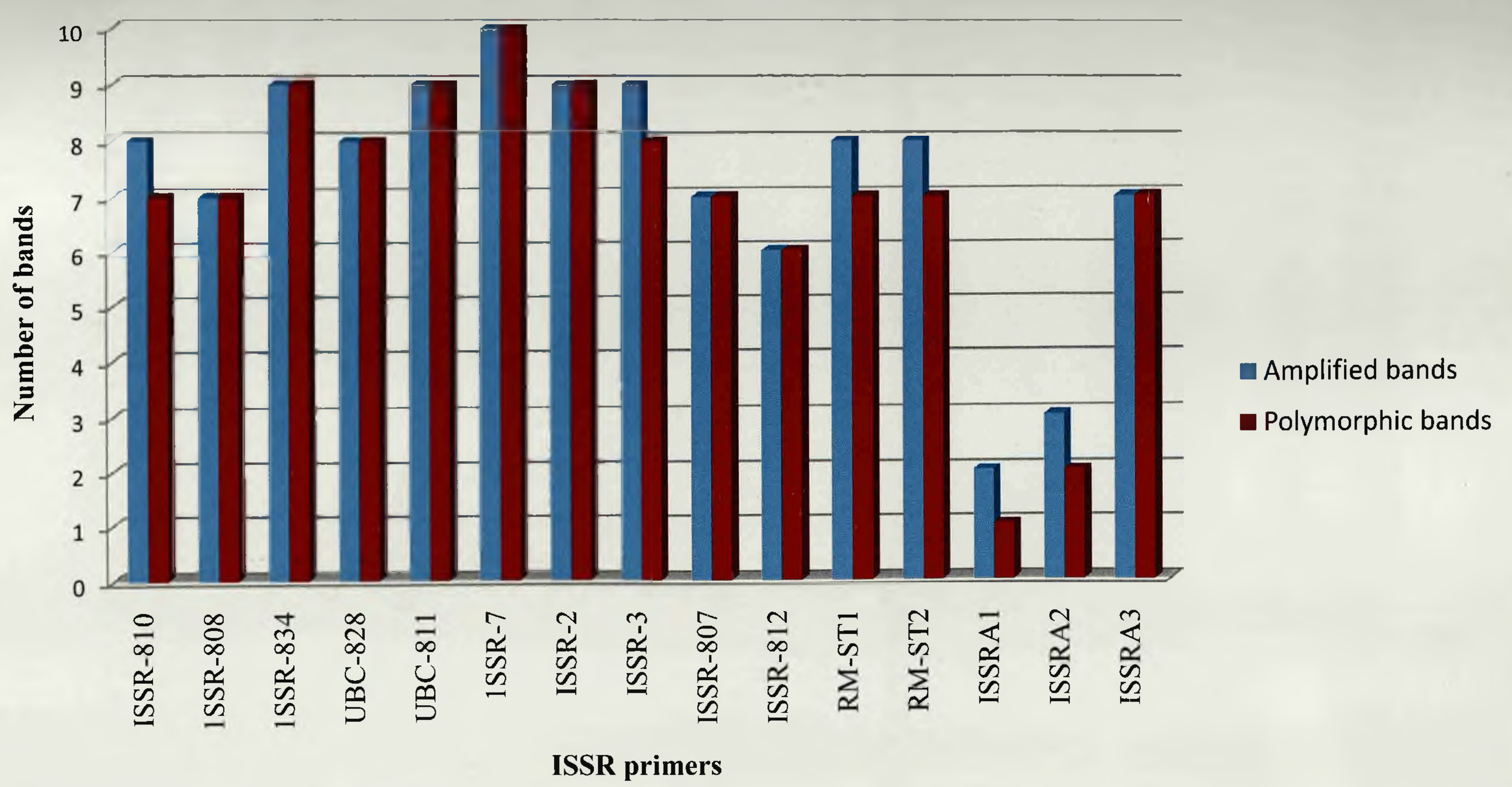


Fig. 32. Polymorphic percentage in ISSR primers for traditional and high yielding rice varieties.

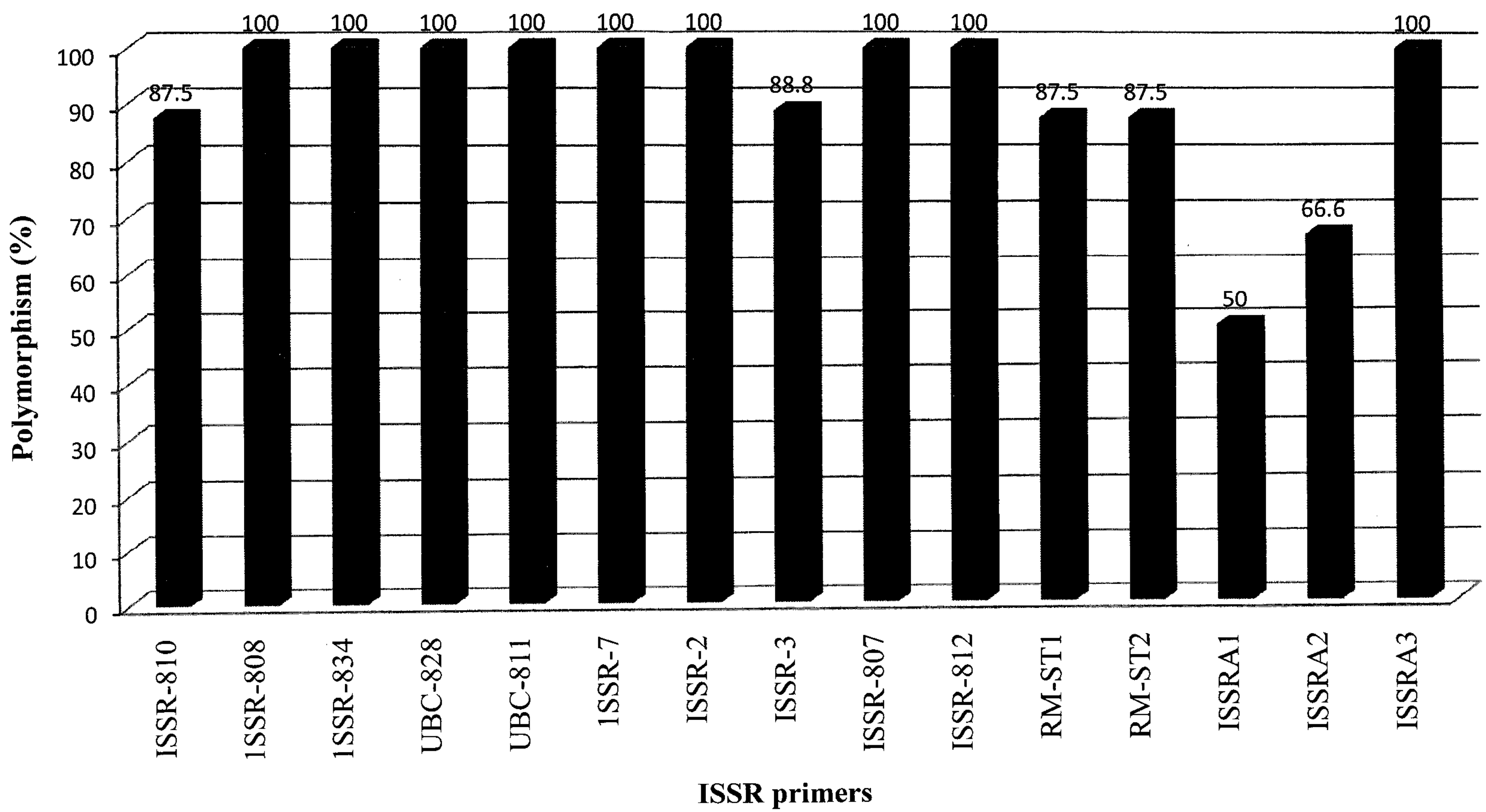


Table 38. **Number of amplified and polymorphic bands and the percentage of polymorphism of ISSR primers.**

Sl. No	Primer name	No. of amplified bands	No. of polymorphic bands	Polymorphism %
1	ISSR-810	8	7	87.5
2	1SSR-808	7	7	100
3	1SSR-834	9	9	100
4	UBC-828	8	8	100
5	UBC-811	9	9	100
6	1SSR-7	10	10	100
7	ISSR-2	9	9	100
8	ISSR-3	9	8	88.8
9	ISSR-807	7	7	100
10	ISSR-812	6	6	100
11	RM-ST1	8	7	87.5
12	RM-ST2	8	7	87.5
13	ISSRA1	2	1	50.0
14	ISSRA2	3	2	66.6
15	ISSRA3	7	7	100
Total		110	104	-
Mean		7.33	6.93	92.0

Table 39. Genetic identity values of 51 rice varieties and a wild rice *Oryza rufipogon* based on ISSR primer amplification.

pop ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	****	0.8455	0.7545	0.7545	0.8000	0.7636	0.7909	0.8182	0.8091	0.8182	0.7636	0.7091	0.6545	0.6364	0.6636	0.6273	0.6727	0.6727	0.7182	0.6545	0.6182	0.6091	0.5818	0.7545	0.6091	0.7091
2		****	0.7091	0.7818	0.7909	0.7364	0.7273	0.7727	0.7818	0.7909	0.6636	0.7182	0.6273	0.6091	0.6182	0.6182	0.6273	0.6636	0.6727	0.6636	0.6091	0.6000	0.5545	0.7455	0.5818	0.6818
3			****	0.7455	0.7909	0.7909	0.7818	0.7909	0.6727	0.7364	0.7364	0.7182	0.6273	0.6273	0.6545	0.6364	0.6818	0.6455	0.6364	0.6273	0.6455	0.6545	0.7000	0.7273	0.6182	0.7000
4				****	0.8091	0.8091	0.7636	0.7545	0.7455	0.7909	0.7364	0.6818	0.6455	0.6273	0.6727	0.6727	0.6818	0.7000	0.6727	0.6636	0.6636	0.6727	0.6455	0.6909	0.5455	0.7000
5					****	0.8727	0.8455	0.7636	0.7727	0.8182	0.7818	0.7273	0.6909	0.6182	0.6818	0.6091	0.6364	0.6909	0.6818	0.6727	0.6364	0.6455	0.6364	0.7727	0.5909	0.7091
6						****	0.8818	0.7818	0.7182	0.8182	0.7636	0.7455	0.6727	0.6727	0.7000	0.6455	0.6545	0.6727	0.7000	0.6727	0.6727	0.6818	0.6364	0.7364	0.6273	0.6909
7							****	0.8273	0.7636	0.7545	0.7182	0.7727	0.6455	0.6091	0.6545	0.6000	0.6455	0.6818	0.6545	0.6636	0.6636	0.6727	0.6818	0.7091	0.5455	0.6636
8								****	0.7545	0.7818	0.7455	0.7455	0.6000	0.6000	0.6636	0.6455	0.6909	0.6545	0.6636	0.6545	0.6364	0.6455	0.6182	0.7182	0.5545	0.7091
9									****	0.8455	0.7545	0.7545	0.5909	0.6091	0.6545	0.6364	0.7000	0.7000	0.6909	0.7000	0.6455	0.6545	0.5909	0.7091	0.5636	0.6818
10										****	0.8182	0.7455	0.6727	0.6364	0.7182	0.6818	0.6909	0.7273	0.7364	0.7273	0.7091	0.7182	0.6364	0.7000	0.6091	0.6909
11											****	0.6727	0.6545	0.6545	0.7364	0.6636	0.6909	0.6545	0.7182	0.6909	0.6727	0.6818	0.6000	0.7545	0.6636	0.7273
12												****	0.6182	0.6909	0.6273	0.6455	0.6727	0.6727	0.6273	0.6545	0.6545	0.6636	0.6909	0.6455	0.5727	0.6364
13													****	0.7273	0.8818	0.7909	0.7636	0.7818	0.7909	0.8182	0.8182	0.8455	0.7636	0.7182	0.6091	0.6727
14														****	0.7182	0.7182	0.7091	0.7091	0.7000	0.7273	0.7273	0.7364	0.6727	0.6273	0.5727	0.6182
15															****	0.8545	0.8636	0.8273	0.8727	0.8818	0.8818	0.9091	0.7727	0.7455	0.6545	0.6818
16																****	0.8818	0.8636	0.8182	0.8818	0.8636	0.8364	0.7727	0.6545	0.6545	0.6818
17																	****	0.8364	0.8091	0.8545	0.8364	0.8273	0.7455	0.7182	0.6455	0.7455
18																		****	0.8455	0.9091	0.8727	0.8636	0.8182	0.6636	0.5909	0.6909
19																			****	0.8818	0.8273	0.8364	0.7545	0.7273	0.6364	0.6636
20																				****	0.8909	0.8818	0.7818	0.7182	0.6273	0.6727
21																					****	0.9727	0.8545	0.6818	0.5909	0.6727
22																						****	0.8636	0.6727	0.5818	0.6636
23																							****	0.6273	0.5182	0.6000
24																								****	0.7273	0.8455
25																									****	0.7182
26																										****
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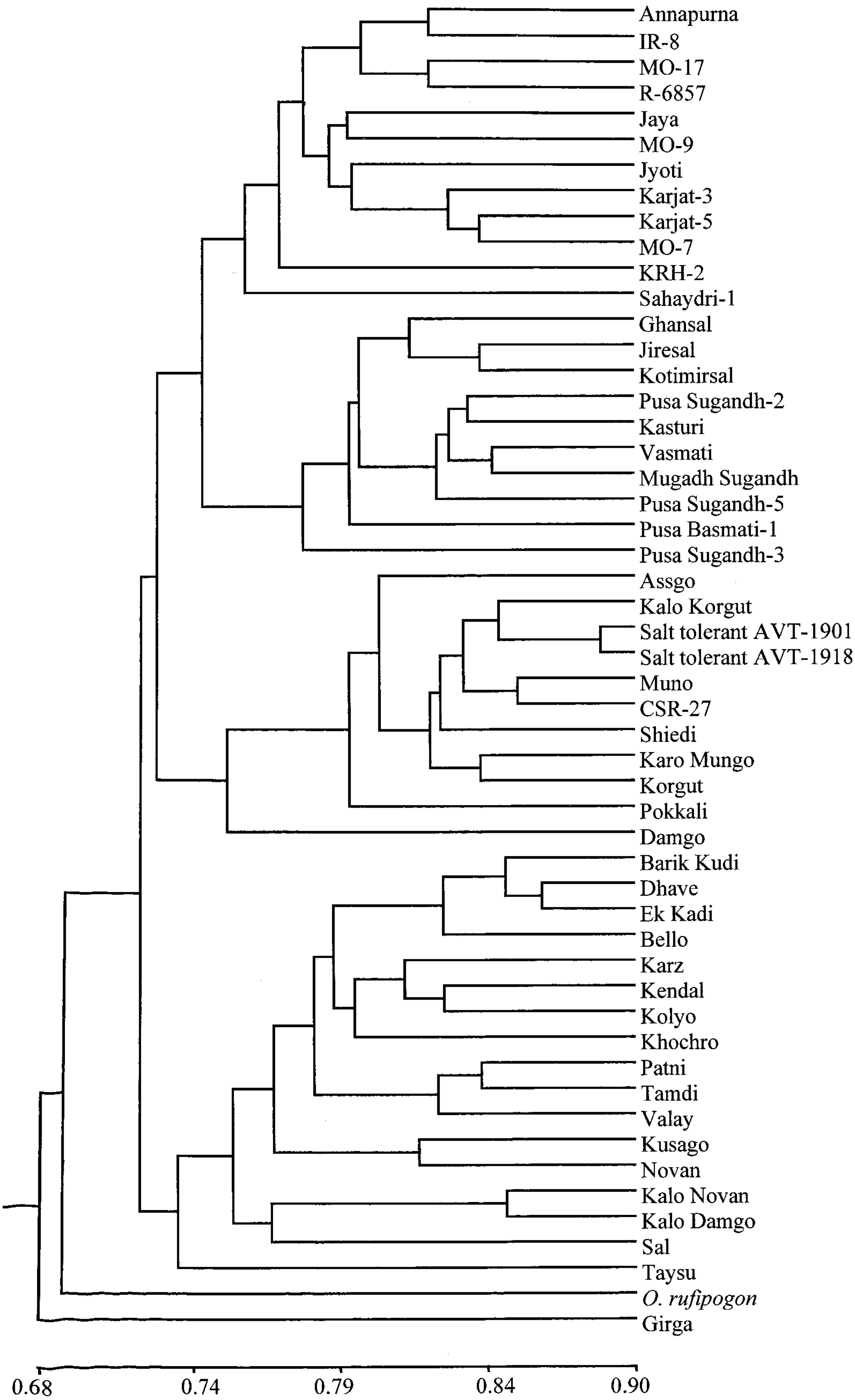
POP ID	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
1	0.7364	0.6364	0.6455	0.6545	0.7182	0.7182	0.7273	0.6727	0.7455	0.7273	0.7273	0.7636	0.7000	0.7273	0.7273	0.7182	0.6727	0.7545	0.7273	0.6727	0.6818	0.7273	0.6091	0.6909	0.7273	0.5727
2	0.7091	0.5909	0.6000	0.5909	0.6727	0.6364	0.6818	0.6636	0.7182	0.7000	0.6818	0.7182	0.6364	0.6636	0.6455	0.6545	0.6273	0.7091	0.6818	0.6273	0.6364	0.6818	0.5636	0.6636	0.6636	0.5818
3	0.7455	0.7000	0.7273	0.6818	0.7455	0.7273	0.7364	0.7364	0.7000	0.7364	0.6818	0.7000	0.6909	0.7000	0.6818	0.6909	0.5909	0.7091	0.6818	0.6273	0.6545	0.7364	0.6364	0.6455	0.6455	0.6000
4	0.7091	0.6455	0.6364	0.6455	0.6727	0.6364	0.7000	0.6636	0.6636	0.6636	0.6455	0.6818	0.6727	0.6636	0.6455	0.6545	0.5909	0.6909	0.6636	0.5909	0.6364	0.7000	0.6000	0.6636	0.6455	0.6182
5	0.7182	0.6727	0.7000	0.6909	0.7000	0.7000	0.7636	0.7091	0.7091	0.7273	0.7091	0.7091	0.7000	0.6727	0.7091	0.7364	0.6182	0.7364	0.7273	0.6727	0.7000	0.7091	0.5909	0.6727	0.6727	0.5727
6	0.7545	0.6909	0.7545	0.7455	0.7545	0.7364	0.7455	0.7455	0.6727	0.6727	0.6727	0.7091	0.6818	0.6727	0.7091	0.7364	0.6182	0.7182	0.7273	0.6182	0.6273	0.7273	0.6273	0.6545	0.6909	0.5909
7	0.7091	0.6818	0.7091	0.7000	0.7455	0.7273	0.7364	0.7182	0.7545	0.7182	0.7364	0.7727	0.6909	0.7000	0.7364	0.7273	0.6455	0.7273	0.7545	0.6636	0.6727	0.7182	0.6364	0.7000	0.6818	0.6000
8	0.7364	0.6545	0.7364	0.6909	0.7545	0.7182	0.7455	0.7091	0.6909	0.6727	0.6727	0.7091	0.6273	0.6545	0.6545	0.6818	0.5818	0.7000	0.7091	0.6000	0.6273	0.6909	0.6091	0.6364	0.6364	0.5909
9	0.6727	0.6455	0.6545	0.6455	0.6727	0.6545	0.7000	0.7182	0.7182	0.7000	0.7000	0.7545	0.6364	0.6091	0.6455	0.6182	0.6818	0.6727	0.6455	0.6273	0.6182	0.6091	0.5636	0.6455	0.6455	0.6545
10	0.7182	0.6727	0.7000	0.6727	0.7000	0.6636	0.7273	0.7091	0.7273	0.7273	0.7091	0.7455	0.6818	0.6545	0.7091	0.6818	0.6364	0.7364	0.6909	0.6364	0.6455	0.6909	0.6273	0.6545	0.6909	0.6455
11	0.7364	0.6909	0.7545	0.7455	0.7364	0.7727	0.7818	0.7091	0.7273	0.7091	0.7273	0.7636	0.6818	0.6909	0.7455	0.7182	0.7091	0.7545	0.6909	0.6182	0.6636	0.6909	0.6636	0.6727	0.7273	0.6455
12	0.6818	0.6364	0.7000	0.6909	0.6636	0.7000	0.6545	0.7091	0.6727	0.6909	0.7091	0.6909	0.6273	0.6545	0.6909	0.6818	0.6545	0.6818	0.7091	0.6364	0.6818	0.6727	0.6273	0.7091	0.6909	0.6818
13	0.6818	0.6364	0.6636	0.6364	0.6636	0.6636	0.6364	0.6364	0.6182	0.6364	0.6727	0.6545	0.6273	0.6545	0.7091	0.7182	0.6182	0.7545	0.6545	0.6364	0.7000	0.6909	0.5545	0.6182	0.6545	0.5545
14	0.6455	0.6364	0.7000	0.6182	0.6818	0.7182	0.6545	0.6909	0.6727	0.6364	0.6909	0.6727	0.5727	0.6182	0.6909	0.6273	0.6545	0.6273	0.6182	0.5455	0.6636	0.7091	0.6091	0.6545	0.6727	0.6818
15	0.7273	0.7182	0.7818	0.7364	0.7091	0.7091	0.7364	0.7182	0.6455	0.6273	0.6636	0.6818	0.5818	0.6273	0.7545	0.7273	0.6273	0.7455	0.6455	0.6455	0.6727	0.6636	0.5455	0.6273	0.6818	0.5818
16	0.7091	0.6636	0.7091	0.6818	0.6909	0.6727	0.7000	0.6818	0.6091	0.5909	0.6636	0.6636	0.6000	0.5727	0.6636	0.6364	0.6091	0.7091	0.6091	0.6091	0.6364	0.6636	0.6000	0.6091	0.6636	0.5636
17	0.7545	0.7273	0.7545	0.7273	0.7364	0.7364	0.7455	0.7455	0.6182	0.6182	0.6545	0.6727	0.6091	0.6182	0.6727	0.6455	0.6182	0.7364	0.6364	0.6545	0.6636	0.6364	0.5909	0.6182	0.6727	0.6091
18	0.6909	0.7364	0.6909	0.6818	0.6364	0.6818	0.6636	0.7273	0.6909	0.6727	0.6364	0.6909	0.6909	0.6273	0.6000	0.6909	0.6636	0.6182	0.7182	0.6182	0.6364	0.6636	0.6545	0.5182	0.6364	0.6727
19	0.6909	0.6818	0.7091	0.7000	0.6909	0.6909	0.7545	0.7182	0.6818	0.6455	0.6818	0.7000	0.5818	0.6273	0.7727	0.7636	0.7000	0.7636	0.6455	0.6091	0.6545	0.6636	0.5091	0.6636	0.6818	0.6364
20	0.7182	0.6727	0.7727	0.6909	0.7182	0.7182	0.7455	0.7455	0.6545	0.6364	0.6909	0.7091	0.6091	0.6182	0.6909	0.6636	0.5818	0.7182	0.6182	0.6182	0.6455	0.6545	0.5364	0.6000	0.6727	0.6273
21	0.7182	0.6727	0.7727	0.6909	0.7182	0.7182	0.7455	0.7455	0.6545	0.6364	0.6909	0.7091	0.6091	0.6182	0.6909	0.6636	0.5818	0.7182	0.6182	0.6182	0.6455	0.6545	0.5364	0.6000	0.6727	0.6273
22	0.7091	0.6818	0.7818	0.6818	0.7091	0.7091	0.7364	0.7364	0.6636	0.6636	0.6818	0.7000	0.6000	0.6273	0.7182	0.6909	0.6091	0.7091	0.6273	0.6273	0.6545	0.6636	0.5455	0.6091	0.6636	0.6364
23	0..6636	0.6545	0.7000	0.6364	0.7000	0.6636	0.7091	0.6727	0.6545	0.6545	0.6909	0.6727	0.6273	0.6545	0.7091	0.7000	0.6000	0.7000	0.6909	0.6909	0.7182	0.6727	0.6091	0.6545	0.6545	0.6091
24	0.8182	0.7545	0.7818	0.7364	0.8000	0.8000	0.8455	0.7909	0.6818	0.6818	0.7000	0.7182	0.6182	0.6818	0.7182	0.7455	0.6455	0.7636	0.7182	0.6273	0.6545	0.6455	0.5455	0.6636	0.6818	0.5455
25	0.7091	0.6636	0.7091	0.7000	0.6364	0.6727	0.7000	0.6818	0.5727	0.5909	0.5727	0.5727	0.5818	0.5909	0.6273	0.6182	0.6091	0.6727	0.5909	0.5182	0.5818	0.6273	0.5818	0.5909	0.6636	0.5091
26	0.8818	0.8000	0.7545	0.7091	0.7909	0.7727	0.8364	0.7818	0.6727	0.6909	0.7091	0.7091	0.6636	0.6727	0.6182	0.6818	0.6182	0.7364	0.6545	0.5636	0.6091	0.6727	0.5909	0.6364	0.6364	0.5545
27	****	0.8273	0.8000	0.7364	0.8182	0.8000	0.8273	0.7727	0.7182	0.7364	0.7545	0.7545	0.6545	0.6818	0.6636	0.7273	0.6273	0.7818	0.7182	0.6273	0.6727	0.7000	0.6364	0.6636	0.7182	0.5636
28		****	0.8091	0.7273	0.8091	0.7545	0.8182	0.7636	0.7091	0.6909	0.6909	0.7091	0.6455	0.6909	0.6727	0.7182	0.6727	0.7545	0.6909	0.6545	0.6455	0.6545	0.5909	0.6727	0.6545	0.5909
29			****	0.8091	0.8364	0.8727	0.8636	0.8636	0.7000	0.6818	0.7000	0.7182	0.6182	0.6636	0.7000	0.6909	0.6091	0.6909	0.7000	0.6273	0.6364	0.7000	0.6182	0.6273	0.6636	0.6364
30				****	0.7727	0.8091	0.8000	0.7636	0.5818	0.6000	0.6000	0.6000	0.5182	0.5818	0.6545	0.6636	0.6000	0.7000	0.6909	0.6182	0.5727	0.6000	0.5909	0.6000	0.6545	0.5909
31					****	0.8545	0.8818	0.8273	0.7000	0.6818	0.7000	0.7364	0.6182	0.6636	0.6818	0.7091	0.6273	0.7273	0.7182	0.6091	0.6364	0.6636	0.6000	0.6636	0.6818	0.6364
32						****	0.8636	0.8455	0.6818	0.6818	0.7000	0.7000	0.6364	0.7000	0.7000	0.7091	0.6455	0.7091	0.7182	0.6273	0.6545	0.6636	0.6182	0.6455	0.7000	0.6182
33							****	0.8909	0.7091	0.6909	0.7091	0.7273	0.6091	0.6545	0.7091	0.7182	0.6182	0.7364	0.7091	0.6182	0.6273	0.6727	0.5727	0.6545	0.6727	0.6273
34								****	0.6727	0.6545	0.6727	0.7091	0.6091	0.6727	0.6727	0.6818	0.6000	0.6818	0.6545	0.5636	0.5909	0.6909	0.5727	0.6364	0.6545	0.6636
35									****	0.8727	0.8909	0.9091	0.7000	0.7455	0.8182	0.7545	0.8182	0.7727	0.7455	0.7091	0.7909	0.7455	0.7000	0.8000	0.7455	0.7364
36										****	0.8727	0.8182	0.6818	0.6727	0.7455	0.7545	0.7818	0.7909	0.7455	0.7091	0.7909	0.6909	0.7000	0.7273	0.7455	0.6455
37											****	0.9273	0.7182	0.7273	0.8000	0.7545	0.7636	0.8091	0.7636	0.7273	0.8091	0.7091	0.6818	0.7455	0.7091	0.6636
38												****	0.7545	0.7818	0.8182	0.7727	0.7636	0.7727	0.7455	0.7273	0.7545	0.7455	0.6818	0.7636	0.7636	0.7000
39													****	0.9000	0.7000	0.7455	0.6818	0.7455	0.7000	0.7000	0.6909	0.7182	0.6909	0.6636	0.6636	0.6182
40														****	0.7818	0.7909	0.7091	0.7545	0.7273	0.7091	0.7182	0.7636	0.7182	0.7273	0.7091	0.6455
41															****	0.8455	0.8182	0.8091	0.7636	0.7455	0.7909	0.7636	0.6818	0.7818	0.7273	0.6818
42																****	0.7909	0.8545	0.8091	0.7727	0.7818	0.7545	0.6545	0.7727	0.8091	0.6182
43																	****	0.7727	0.7091	0.6727	0.7727	0.6545	0.6818	0.8000	0.7455	0.7182
44																		****	0.8273	0.7727	0.8000	0.7000	0.6545	0.7545	0.7545	0.6000
45																			****	0.8364	0.7364	0.6909	0.6636	0.7455	0.7273	0.5727
46																				****	0.7727	0.6545	0.6636	0.7091	0.7091	0.5545
47																					****	0.7182	0.7091	0.8818	0.8455	0.6909
48																						****	0.6636	0.7455	0.7273	0.6455
49																							****	0.6818	0.7364	0.6182
50																								****	0.8545	0.7545
51																									****	0.6818

Kalo Damgo showed the genetic identity value of 0.9000. The lowest genetic identity value (0.5091) was observed in local scented rice variety Girga and a wild rice *Oryza rufipogon.*

ISSR data of 51 rice varieties and a wild rice *Oryza rufipogon* were used to generate dendrogram by using Unweighted Paired Group Method with Arithmetic Mean (UPGMA) method through the NTSYS-pc Version-2 computer software (Rohlf, 1992). The dendrogram generated from ISSR data revealed the clustering of rice varieties and four major clusters were observed in the dendrogram (Figure 33). The four major clusters (group) include (i) high yielding rice varieties; (ii) scented rice varieties (iii) salt tolerant rice varieties; (iv) traditional rice varieties of Goa. The first cluster comprised of 12 varieties belonging to high yielding rice varieties (Annapurna, IR-8, MO-17, R6857, Jaya, MO-9, Jyoti, Karjat-3, Karjat-5, MO-7, KRH-2, Sahaydri-1). Total ten rice varieties belonging to traditional scented rice and high yielding scented rice varieties were clustered together as second group (Ghansal, Jiresal, Kotimirsal, Pusa Sugandh-2, Kasturi, Vasmati, Mugadh Sugandh, Pusa Sugandh-5, Pusa Basmati-1, Pusa Sugandh-3). The third group consisted of eleven rice varieties which belonging to traditional salt tolerant and high yielding salt tolerant rice varieties (Assgo, Kalo Korgut, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918, Muno, CSR-27, Shiedi, Karo Mungo, Korgut, Pokkali and Damgo). While, fourth cluster comprised of 17 rice varieties belonging to the traditionally cultivated rice varieties (Barik Kudi, Dhave, Ek Kadi, Bello, Karz, Kendal, Kolyo, Khochro, Patni, Tamdi, Valay, Kusago, Novan, Kalo Novan, Kalo Damgo, Sal and Taysu). Surprisingly, a scented rice variety Girga remained separate not clustered with any groups of rice varieties studied. A wild rice *Oryza rufipogon* formed a separate clade indicating its uniqueness and distance.

Fig. 33. Dendrogram of Nei's genetic distance between the traditionally cultivated, scented, salt tolerant and high yielding rice varieties based on ISSR data.



DISCUSSION

CHAPTER 5

DISCUSSION

Rice is the staple food for the people of Goa, however, the cultivation of this staple food crop is being threatened by increase in cost of production over the years. Rice cultivation in the State of Goa occupies an area of about 52,191 ha, among them 34,261 ha are grown during *kharif* and remaining 17,930 ha during *rabi* season. About 90% of *kharif* and entire area of *rabi* seasons are covered under high yielding rice varieties (Manjunath *et al.*, 2009). Due to the introduction of high yielding varieties in the State, the cultivation of local traditional varieties is being disappeared (Bhonsle and Krishnan, 2012). In the present study efforts were made to collect all the traditionally cultivated and high yielding rice varieties from the state of Goa and evaluated them for their grain quality. The study further aimed to understand the origin and development of chalkiness and genetic diversity among all the collected rice varieties. This study is very important in the point of view of improving the profitability is processing and enhancing the quality of the seeds. Estimation of quality traits of different genotypes, will aid not only in the selection of varieties for meeting the consumer preferences but also help in marketing.

5. 1. Collection and Documentation

During the present investigation 50 rice varieties were collected covering all the seasons starting from June 2008 to June 2012. Frequent field trips were made to collect, the different rice germplasm maintained by the farmers in different parts of Goa (Table 11, 12). As rice is the staple food for more than half of the world population and it is one of the most important food crops grown worldwide (Sasaki and Burr, 2000). The collection, documentations, preservation, conservation, evaluation and use of rice genetic resources have been emphasized as there is increasing threats of genetic erosion faced by Asian wild rice population and have seriously destroyed and fragmented the wild and traditional rice varieties (Akimoto *et al.*, 1999).

Out of 50 rice varieties, 28 traditional rice varieties were collected from the local farmers (Table 11) and 22 high yielding rice varieties from farmers as well as from ICAR Research Complex, Old Goa, Goa (Table 12). The predominant rice varieties grown in different parts of Goa are Jaya, Jyoti, Karjat3 and IR-8 and the best established local cultivated rice varieties are Assgo and Korgut (with awns) are still popular in khazan (saline) lands. Due to the introduction of high yielding varieties, the local germplasm and their genetic diversity of rice is being eroded. The introduced varieties like Jaya and Jyoti are better for the framers, because of their high yield and better growth. This has increased the total productivity of rice yield. However, as a consequence, the local rice varieties are disappearing. The local rice varieties like Kendal, Khochro, Muno, Shirdi, and Jiresal are now on the way of extinction. The introduced rice varieties are in different group *viz.* medium duration, short duration, hybrid varieties, salt-tolerant and scented groups. This has lead to a major shift in the cultivation, yield and market potential. The widespread acceptance of high-yielding rice varieties by farmer has led to biological scarcity of rice germplasm, as local rice varieties are neglected for modern varieties (Gao, 2003) though people still prefer to make specific food items using the traditional rice.

Traditional Goan rice varieties have incredible diversity in shape, size, colour i.e. white to red, brown and black (Plate 2-6). This diversity is a result of selection and cultivation by farmers, adaptation to various environmental conditions, breeding with wild relatives and local varieties in the evolutionary process over centuries. On the basis of continuous evaluation, rice varieties for saline environment, drought, deep water etc are being traditionally evolved. It is also important to advocate sustainable use of rice germplasm at large and efforts for this are required (Avadu, 2000). Different types of rice could be differentiated from one another on the basis of various characteristics, thus it is evident that there is tremendous scope exists to improve the rice yield by continuously improving the potential germplasm of *Oryza.* Early evolutionary selection, cultivation and domestication of rice differentiated into two major subspecies *indica* and *japonica* (Chang 1976; Oka 1988; Morishima *et al.,* 1963).

The post harvest losses are the major problems in rice and other cereals. Losses occur during harvesting, threshing, drying, storage, transportation and processing by industries. If post harvest losses are reduced, the world supply can be increased by 30-40% without cultivating additional hectares of land or increasing any additional expenditure on seed, fertilizer, irrigation and plant protection measure to grow the crop. Backhop (1980) stated that post-production losses and deterioration of food quality are areas of major concern in many developing countries of the world.

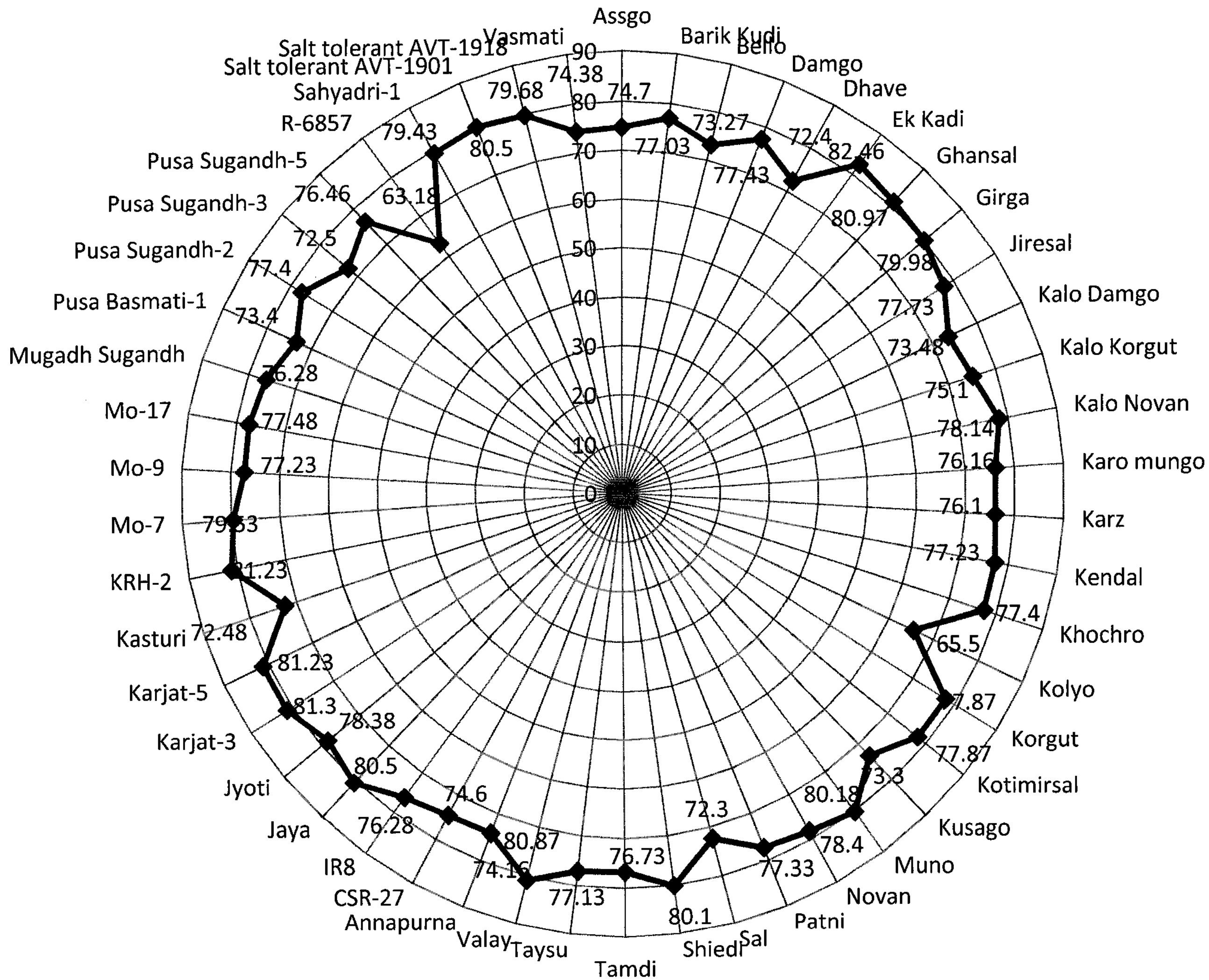
5.2. Rice Grain Quality - Physical Characteristics:

The collected rice varieties were evaluated for the various grain qualities like the physical, chemical and cooking characters. In pre cleaning, the rice varieties were cleaned to remove all organic and inorganic matter, which helped to avoid further contamination of the rice with 13% of moisture content. The moisture level is also important for the grain quality. The moisture content of 12-14% wet basis is suitable for the storage or milling of rice (Wiset *et al.,* 2001). Air temperatures used for rice drying have significant effects on head rice quality.

5.2.1. Hulling Percentage [Brown rice (BR) yield]

Hulling percentage is one of the most important characters in rice. Different rice varieties have different milling percentage. Milling yield is one of the most important criteria for rice quality. Two values of milling yield are whole-grain rice yield (head rice) and total (whole plus broken) rice yield. Broken rice is generally valued at only 30-50% of whole grain. The accurate measurement of the amounts and classes of broken grains is very important. Thus, standardized procedures are used for official grading. The hulling percentages of traditionally cultivated and high yielding rice varieties from the state of Goa are provided in Figure 34. Among the traditional rice varieties the highest hulling percentage was calculated in variety Ek Kadi (82.4%) and lowest in Kolyo (65.5%). In high yielding rice varieties, the high hulling percentage of about 81% was recorded in varieties Jaya, Karjat-5, Karjat-3, KRH-2 and Salt Tolerant AVT-1901. The eighty percent or more are the desirable hulling characteristics for rice (Shobha Rani *et al.*, 2006). If part of the milled rice grain is opaque rather than translucent, it is characterized as chalky. Chalky grains tend to be broken easily during processing, which results in low head rice rate (Liao *et al*,. 1999). Chalkiness affects the appearance quality of milled rice and is a main character determining grain price (Yoshioka *et al.*, 2007). The correlation coefficients among the physical characters are presented in Table 40. Hulling percentage showed a positive correlation with the head rice recovery and broken rice percentage. However, it had significant negative correlation with L/B ratio and percentage of chalkiness (Figure 39). Based on the physical traits, the scattered plot of principle component analysis (PCA) showed that the high yielding rice varieties viz. R-6857, KRH-2 and all Basmati varieties were grouped together showing the differences in hulling percentage and other related traits (Figure 40). Rice that breaks or powders during milling

Fig. 34. Comparison of hulling percentage in traditional and high yielding rice varieties.



due to chalkiness is called as chalk affects (Braidotti, 2008). Rita and Sarawgi (2008) reported that more than 80% of hulling percentage is preferred and if the hulling percentage increases the head rice recovery also increased.

5.2.2. Head Rice Recovery (HR)

Head rice recovery (HRR) is the percentage of whole kernels recovered after milling and removal of the broken kernels. Lisle *et al.* (2000) showed that the chalkiness reduces grain resistance to forces applied during the milling process, causing a decrease in head rice recovery. The presence of chalky kernels adversely affects consumer acceptability and usually, rice containing more than 2% chalky kernels is rejected in most world markets. In the present study, HRR value ranged from 39-78% in all rice varieties studied (Figure 35). Traditional rice varieties were compared with high yielding rice varieties showed that the highest HRR in traditional scented rice variety Ghansal (77.6%) and in high yielding rice varieties the HRR was low in variety Jyoti (68.1%). Miah *et al.*, (2002) suggested that when the raw rice is parboiled the broken rice is less compared to non-parboiled grains due to the absorption water which increases the HRR (milling) and lessen the broken rice. The correlation coefficients among the head rice recovery showed a positive correlation with the hulling percentage, broken rice recovery and percentage of chalkiness. However, it had a significant negative correlation with L/B ratio (Table 40; Figure 39). Among the traditional rice varieties, lowest breakage was in Kotimirsal (2.6%) and highest in Valay (36.3%) when compared with high yielding varieties the broken rice (BR) grains ranged from 10.2 to 35.4%, highest in KRH-2 and lowest in Jyoti shown in Figure 36. High hulling percentage resulted in higher head rice yield of 93.3% in parboiled rice with the higher process steam pressure (Igbeka *et al.*, 2008). Irregular cracks are

Fig. 35. Comparison of head rice recovery in traditional and high yielding rice varieties.

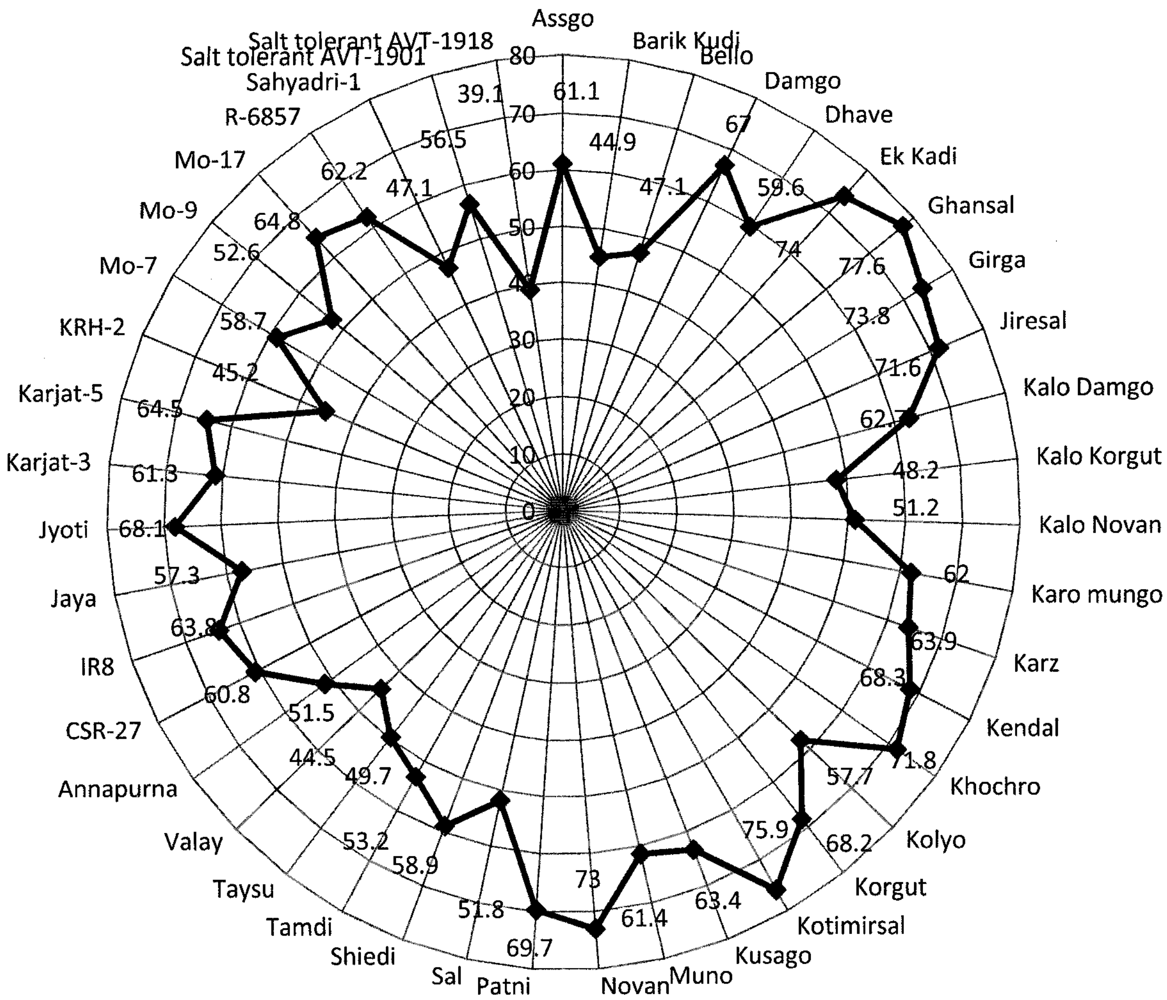
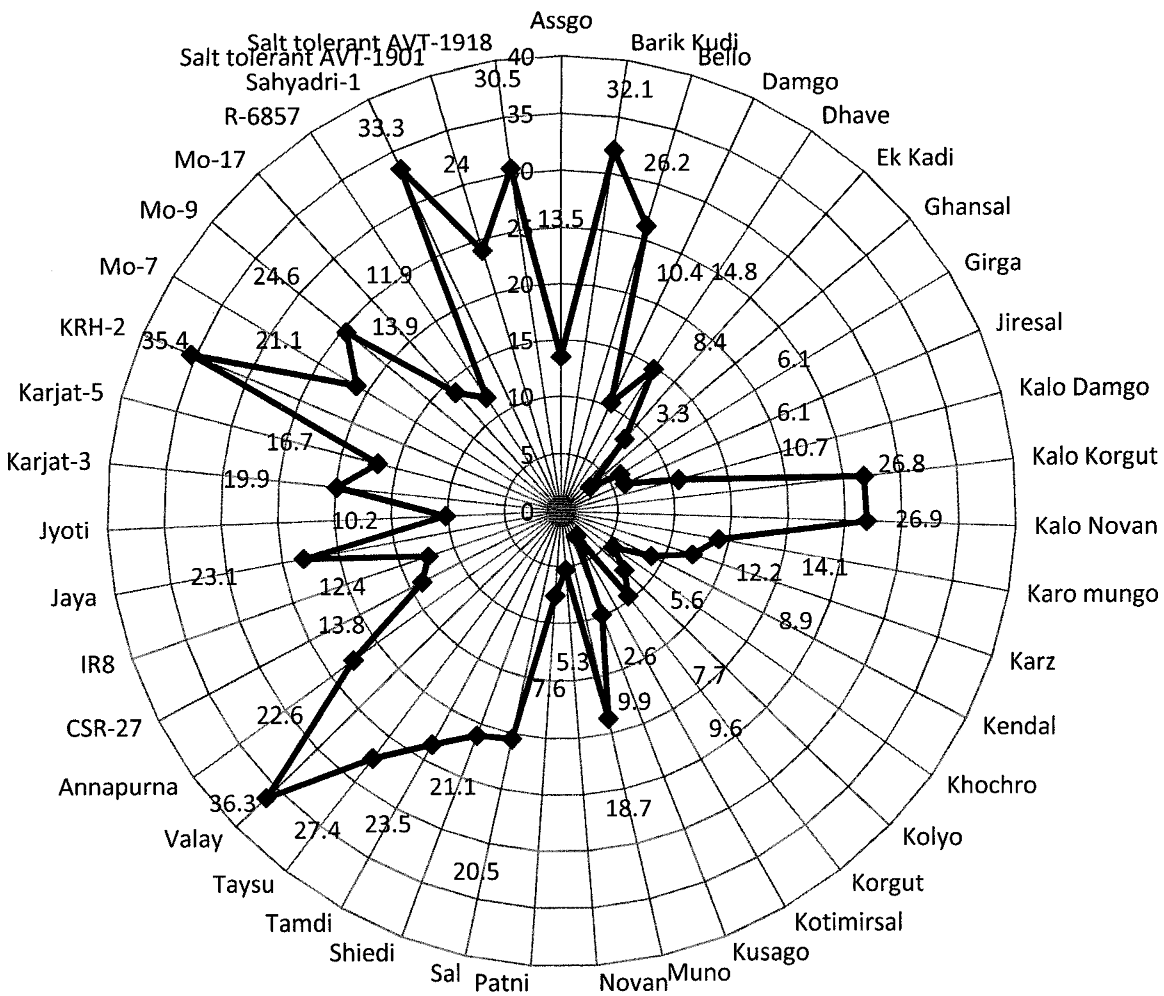


Fig. 36. Comparison of broken rice in traditional and high yielding rice varieties.



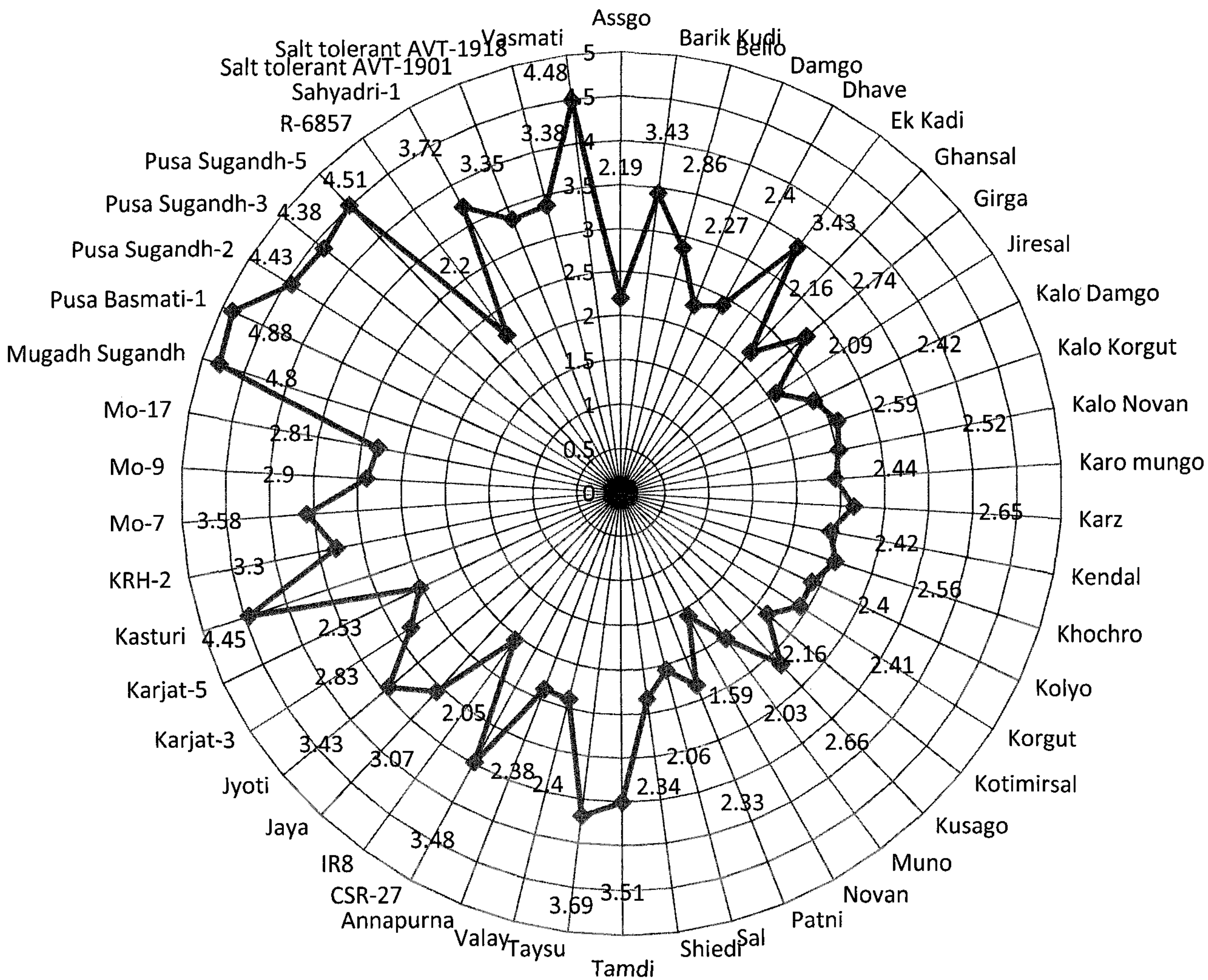
caused in rice by hot-air drying but wetting of paddy tended to get healed upon long soaking (Swamy *et al.*, 2009). The correlation coefficients in broken rice showed positive correlation with hulling percentage, head rice recovery and percentage of chalkiness and a significant negative correlation with L/B ratio (Table 40; Figure 39).

Milling of rice increases its shelf life and provides consumers with a desired physical property through polishing (whiteness). The quantity of bran remaining on the surface of the grain after milling is defined as milling degree. A high milling degree means that the milled rice is very white. Degree of milling is influenced by to grain hardness, size, shape, depth of surface ridges, bran thickness and mill efficiency (Bergman *et al.*, 2000). It was reported that high milling removes all the minerals in the aleurone layer (Krishnan *et al.*, 2001; Krishnan and Dayanandan, 2003). Milling recovery depends on grain shape and appearance, which has direct effect on the percentage of hulling, milling and head rice recovery (Shobha Rani *et al.*, 2006).

5.2.3. Grain Classification

Kernel shape and L/B ratio are important features for grain quality assessment (Rita and Sarawgi, 2008). Rice grains were classified into six different categories as short bold, short slender, long bold, long slender and medium slender for traditional (Table 15) and high yielding rice varieties (Table 16). The L/B ratio in traditional rice Taysu (3.69) recorded the highest ratio and lowest in Novan (1.59), whereas in high yielding rice varieties ranged from 2.05 (IR-8) to 4.88 in Pusa Basmati-1and Mugadh Sugandh (Figure 37). Based on the physical traits, the scattered plot of principle component analysis (PCA) showed that the varieties which are shorter in length viz. Sal, Kolyo, Girga, Kotimirsal and Jiresal were grouped together showing the differences in physical characteristic in

Fig. 37. Comparison of L/B ratio in traditional and high yielding rice varieties.



comparison with Basmati long grain varieteis (Figure 40). After cooking, it is firm and fluffy (not sticky). Medium-grain rice is generally has an amylose content of 16-18 per cent and after cooking it becomes soft, moist and sticky in texture. Conventional long grain rice has 19 to 23% of grain amylose content. In general short grain rice has cooking quality and amylose content similar to that of rice in the medium grain category (Bergman *et al.* 2000). Bhattacharjee and Kulkarni (2000) analyzed some preferred brands of basmati rice and reported that the L/B ratio ranged from 4.47-4.81.

5.2.4. Chalkiness of Endosperm

Consumers have a preference for rice that is transparent and not chalky. Chalky areas of the grain are as a result of air spaces in between the starch granules that make up the endosperm. Variation in kernel whiteness and transparency can be due to differences in rice varieties and cultivation management methods (Bergman *et al.,* 2000). Based on the presence and absence of chalkiness in the endosperm, rice grains were classified (Table 17, 18). Different types of chalkiness are white belly, white back and white core (Tan *et al.*, 2000; Li *et al.*, 2004) and the type of chalkiness is mainly under genetic control, but degree of chalkiness can be affected by the weather conditions like temperature, water uptake experienced during the grain filling period (Yamakawa *et al.*, 2007). The chalky grains reduce the palatability of cooked products, thus the presence of more than 20% chalkiness in rice kernels is not acceptable in world markets (Cheng *et al.*, 2005).

5.2.5. Chalk Index Determination

Chalkiness of the rice kernel is related to the air spaces in the endosperm (Hoseney, 1986). While broken kernels are considered detrimental to the quality of rice. Chalk kernels shows lower viscosity and lower amylose contents than in non chalky grain (Sandhya and Bhattacharya, 1989). In the present study, it was observed that the chalkiness was absent in varieties Pusa Sugandh-2, Kotimirsal, Ghansal. The quality declined in chalky rice varieties. Excessive chalkiness lowered the grades and reduced milling recovery. Chalk index determination value indicated that varieties Damgo, Kusago, Kalo Korgut, Muno, MO-7, Kendal and Khochro showed 100% chalk index (Table 19, 20; Figure 38). Chalkiness percentage showed a positive correlation with the head rice recovery and broken rice. However, it had significant negative correlation with L/B ratio and hulling percentage (Table 40; Figure 39). The cooking and textural properties of chalky and translucent kernels differed significantly. The chalky kernels from different varieties showed lower values for cooking (cooking time, water uptake, L/B ratio and elongation ratio) and textural parameters (packing of starch granules, cohesiveness, chewiness, hardness) than the translucent kernels (Narpinder *et al.*, 2003).

5.3. Rice Grain Quality - Chemical Characteristics:

5.3.1. Alkali Spreading and Clearing Test

Juliano *et al.* (1964); Shobha Rani *et al.* (2006); Tang *et al.* (1989) concluded that amylose content decides the firmness and stickiness after cooking, while rice with low GT requires low temperature, less water and time to cook than those with high or intermediate GT. When studied the GT is directly correlated to time required for cooking, therefore, most of the consumers preferred rice with intermediate GT rather than high or low-GT. These two properties have highest effect on cooked rice grain quality and thus play major role in influencing consumer's preference. Alkali spreading value and gelatinization temperature (GT) were calculated for all the rice varieties (Table 21, 22). Umemoto *et al.*

Fig. 38. Comparison of Percentage of chalkiness in traditional and high yielding rice varieties.

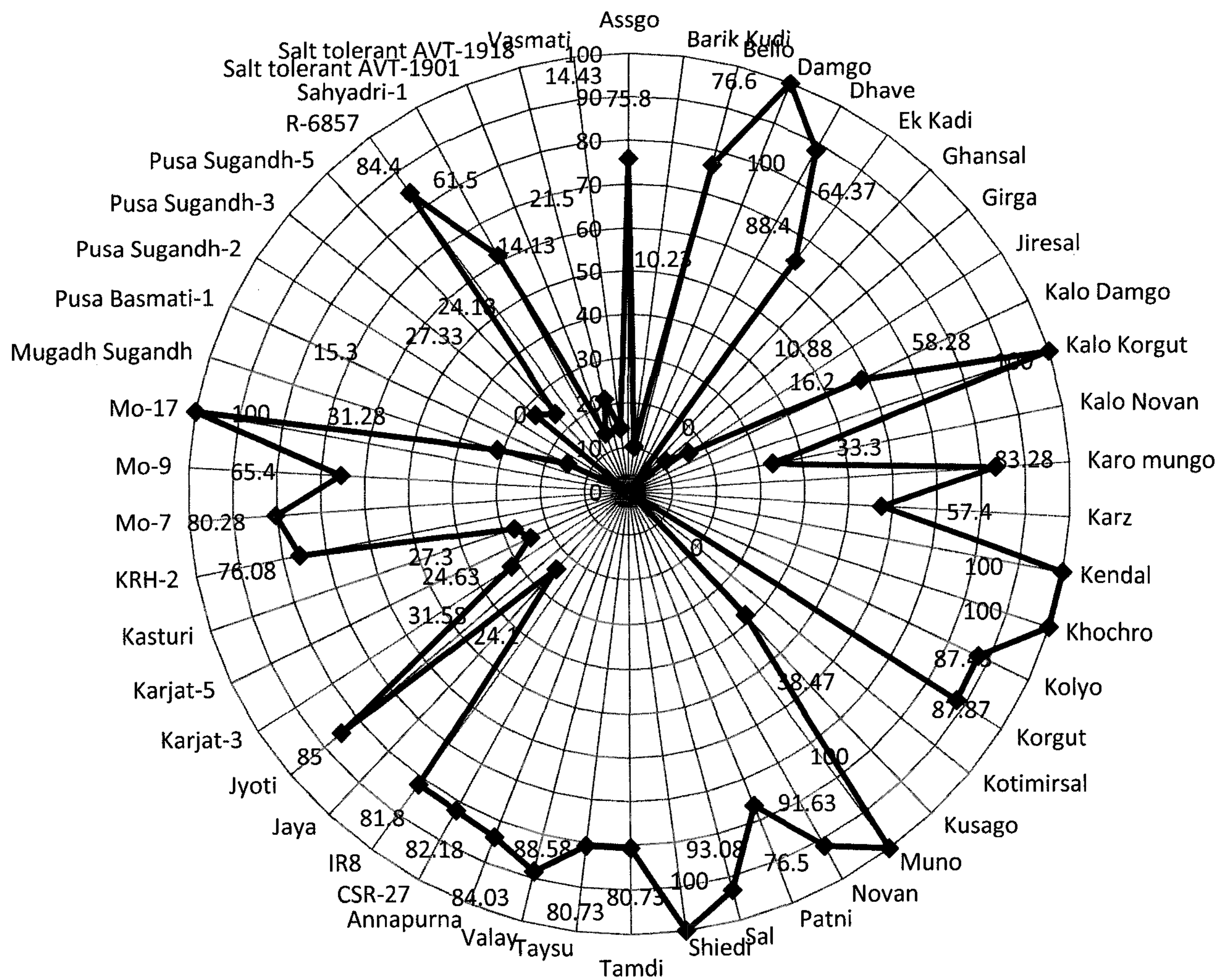


Fig. 39. Principle component analysis (PCA), correlation of physical characteristic.

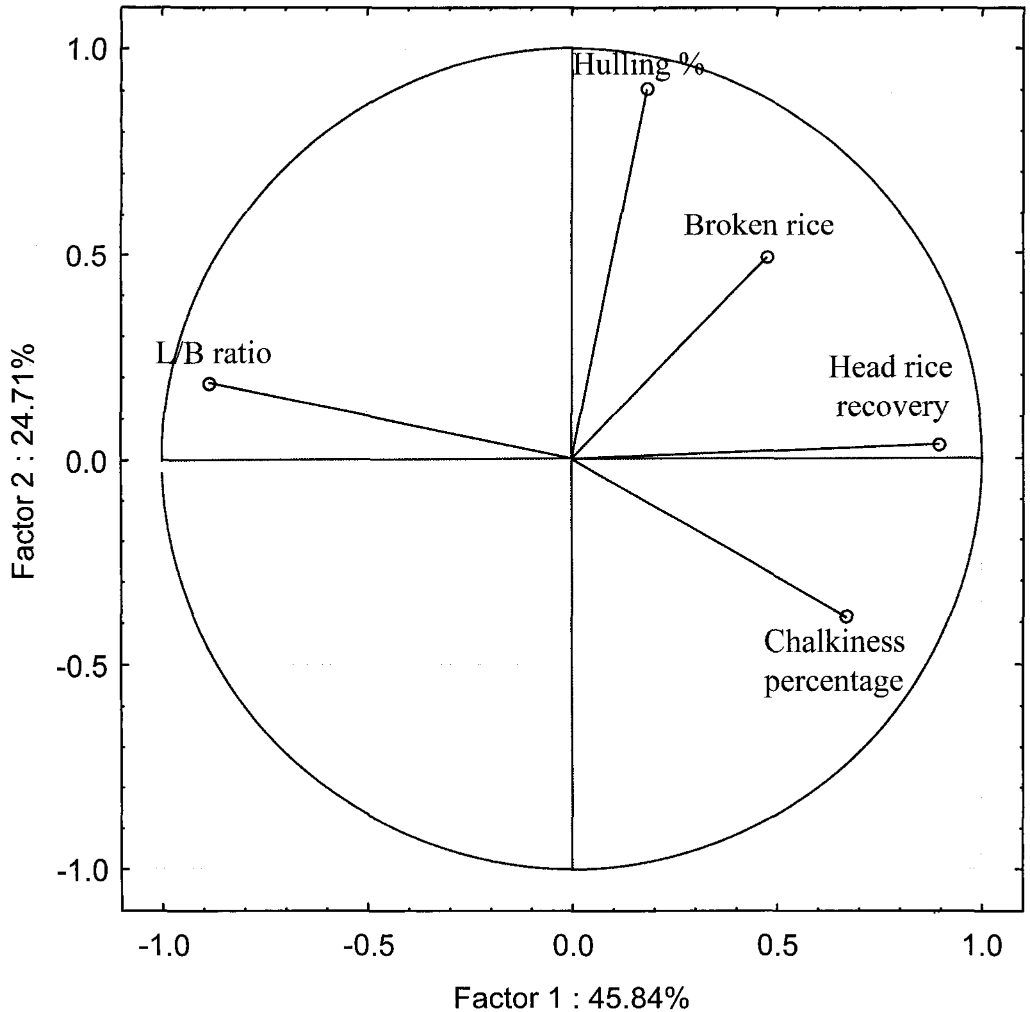
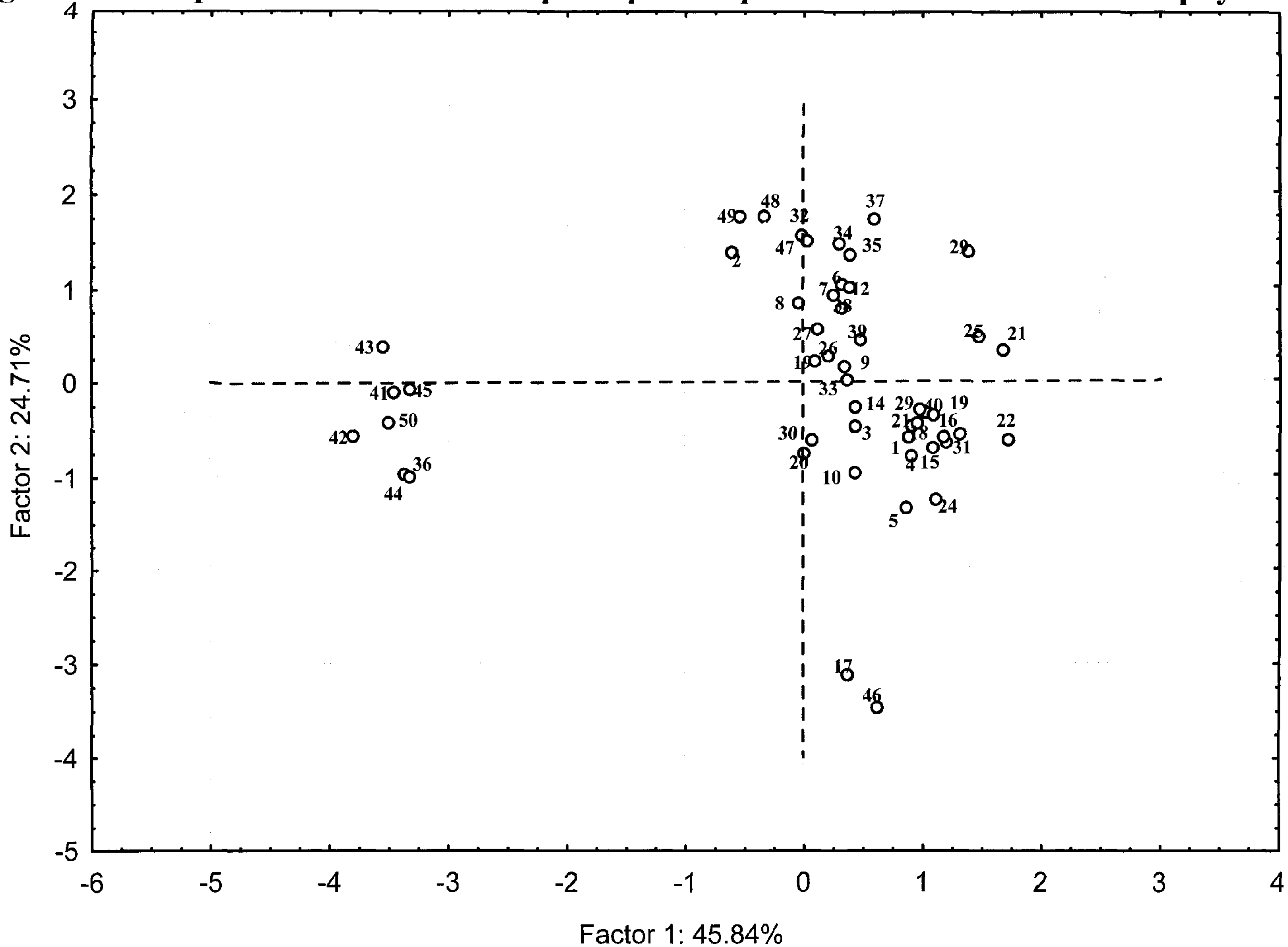


Fig. 40. Scatter plot of first and second principal component scores of rice based on physical traits.



1, Assgo; 2, Barik Kudi; 3, Bello; 4, Damgo; 5, Dhave; 6, Ek Kadi; 7, Ghansal; 8, Girga; 9, Jiresal; 10, Kalo Damgo; 11, Kalo Korgut; 12, Kalo Novan; 13, Karo Mungo; 14, Karz; 15, Kendal; 16, Khochro; 17, Kolyo; 18, Korgut; 19, Kotimirsal; 20, Muno 21, Kusago; 22, Novan ; 23, Patni; 24, Sal; 25, Shiedi; 26, Taysu; 27, Tamdi; 28, Valay; 29, Annapurna; 30, CSR-27 ; 31, IR-8; 32, Jaya; 33, Jyoti ; 34, Karjat-3; 35, Karjat-5; 36, Kasturi; 37, KRH-2; 38, MO-7; 39, MO-9; 40, MO-17; 41, Mugadh Sugandh; 42, Pusa Basmati-1; 43, Pusa Sugandh-2 ; 44, Pusa Sugandh-3; 45, Pusa Sugandh-5; 46, R-6857; 47, Sahayadri-1; 48, Salt Tolerant AVT-1901; 49, Salt Tolerant AVT-1918; 50, Vasmati

Table 40. Physical characteristic of traditional and high yielding rice varieties.

	Hulling %	Head Rice recovery	Broken rice	L/B ratio	Chalkiness %
Hulling %	1.00				
Head Rice recovery	0.23	1.00			
Broken rice	0.28	0.22	1.00		
L/B ratio	-0.01	-0.83	-0.19	1.00	
% of chalkiness	-0.18	0.40	0.28	-0.46	1.00

Correlations are significant at $p < .05000$, rice varieties 50

(2002) reported that the amylopectin chain-length profiles of disintegrated-starch granule cultivars were clearly different from those of the unaffected-starch granule cultivars. Starch granules that had amylopectin enriched in short chains were more easily disintegrated in alkali solution than starch granules with amylopectin enriched in long chains. Starch gelatinization, the disruption of the molecular order within starch granules when they are heated in the presence of water, is one of the most important rheological indicators of the cooking quality and processing characteristics of rice starch. Juliano *et al.* (2003) found a significant correlation between the disintegration of rice starch granules in alkali (KOH) solution and gelatinization temperature (GT) of milled rice (Prathephaa *et al.*, 2005). The alkali spreading value showed significant positive correlation with water uptake and elongation ratio (Nayak *et al.*, 2003). Rice with high-quality get a hold of privileged returns to the farmers as increased demand due to rising population and consumers. Therefore, it is necessary to get better AC and GT in advantageous range into conventionally bred varieties for their improved acceptance by farmers and consumers (Shobha Rani *et al.*, 2006). Cooking time of the rice depends on coarseness of the grain. The intermediate ASV indicated the medium disintegration and classified as intermediate GT which highly desirable for quality grain (Bansal *et al.*, 2006). It was reported that high amylose starch requires high temperature for gelatinization (Luallen, 1985). The gelatinization temperature of the rice samples are classified as high to intermediate which means that the temperature required for normal cooking time is 75-79°C. While the gel consistency of the rice samples was 65-70 mm and it was categories as soft, this means the tendency of cooked rice to be soft on cooling.

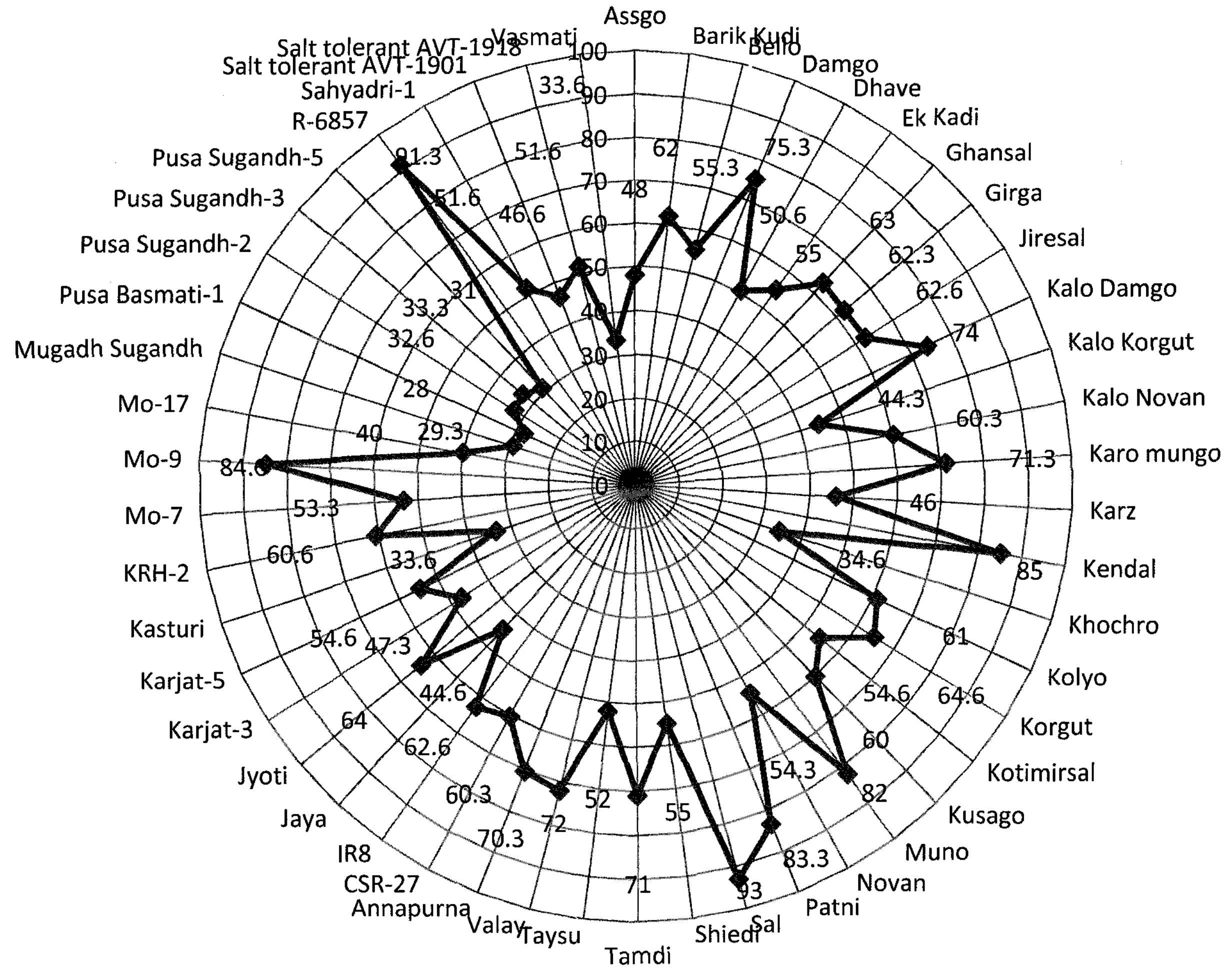
5.3.2. Gel Consistency (GC)

The gel consistency (GC) was measured into soft, medium and hard for the landraces studied (Pandey *et al.*, 2007) which is another important chemical character. During this study, the gel consistency (GC) was measured as soft, medium and hard (Table 23, 24). Soft and medium gel consistency were observed in most of the high yielding varieties, except in basmati rice varieties hard gel consistency was recorded. In traditional varieties length of the blue gel was highest in Sal (93 mm) and in high yielding variety R-6857 was 91.3 mm, when compared with the lowest length of the blue gel in Khochro (34.6 mm) and Pusa Basmati -1 (28 mm) (Figure 41). The different rates of drying affect the gel consistency (Cagampang *et al.*, 1973). Gel consistency showed positive correlation with carbohydrates content, however, the significant negative correlation with amylose content and total proteins, principle component analysis (PCA), showed clear differences (Table 41; Figure 43). Amylose content, starch, gel consistency and non-reducing sugar content decrease with elevated temperature (Pandey *et al.*, 2007).

5.3.3. Amylose Content (AC)

Amylose consists of 1, 4 linked glucose units with a small number of branches, a linear molecule, whereas the amylopectin consisting well branched linear chains of a 1, 4 linked biopolymer combined of glucose residues joined together by a 1, 6 linkages (Frei *et al.*, 2003). The physicochemical and metabolic properties of rice are caused by variation in the proportions of starch (amylose and amylopectin) (Zhou *et al.*, 2002). The main chemical character is the amylose content in rice. Amylose content was estimated for 50 rice varieties and ranged from 14 to 28%. The highest AC was noted in traditional rice variety Kalo Novan (23.7%) and lowest (14%) in variety Barik Kudi whereas in HYV rice

Fig. 41. Comparison of percentage of Length of blue gel in traditional and high yielding rice varieties.



varieties Karjat-5 had least amount 17.34% and high amount AC (27.69%) in variety Mugadh Sugandh (Figure 42). Amylose content is considered to be the single most important characteristic for predicting rice cooking and processing behaviors (Juliano, 1979; Webb, 1985). The range of amylose percentage of all rice grades ranged between 20.7 and 21.4%. Based on Juliano (2003), the amylose percentage of the rice was intermediate (containing 20-25%). Most consumers preferred rice with intermediate amylose content (Rachmat, 2006). The correlation coefficients among the chemical characteristic are presented in Table 41. Amylose content showed positive correlation with protein content and significant negative correlation with gel consistency and total carbohydrates (Figure 43). Based on the chemical traits, the scattered plot of principle component analysis (PCA) showed that most of the traditionally cultivated rice varieties like Assgo, Barik Kudi, Damgo, Valay, Taysu, Kendal and Kalo Novan were grouped together and had negative correlation with high yielding rice varieties (Figure 44).

Based on the amylose content (dry base), rice can be classified as Waxy rice, Very Low, Low, Intermediate and High amylose content varieties. The difference in brightness probably is due to the higher content of amylose since waxy rice grains with higher amylopectin and lower amylose content usually appear milky or cloudy (Wijaya *et al.*, 2007). Webb (1991) reported that amylose content is commonly used as an objective index for cooked rice texture. Low amylose levels are associated with cohesive, tender, and glossy cooked rice. Conversely, high levels of amylose cause rice to absorb more water and consequently expand more during cooking, and the grains tend to cook dry, fluffy, and separate (Juliano 1971). Amylose content showed positive significant association with elongation ratio and volume expansion. However, it had significant negative correlation with alkali spreading value and water uptake (Nayak *et al.*, 2003). The crystalline

Fig. 42. Comparison of percentage of amylose content in traditional and high yielding rice varieties.

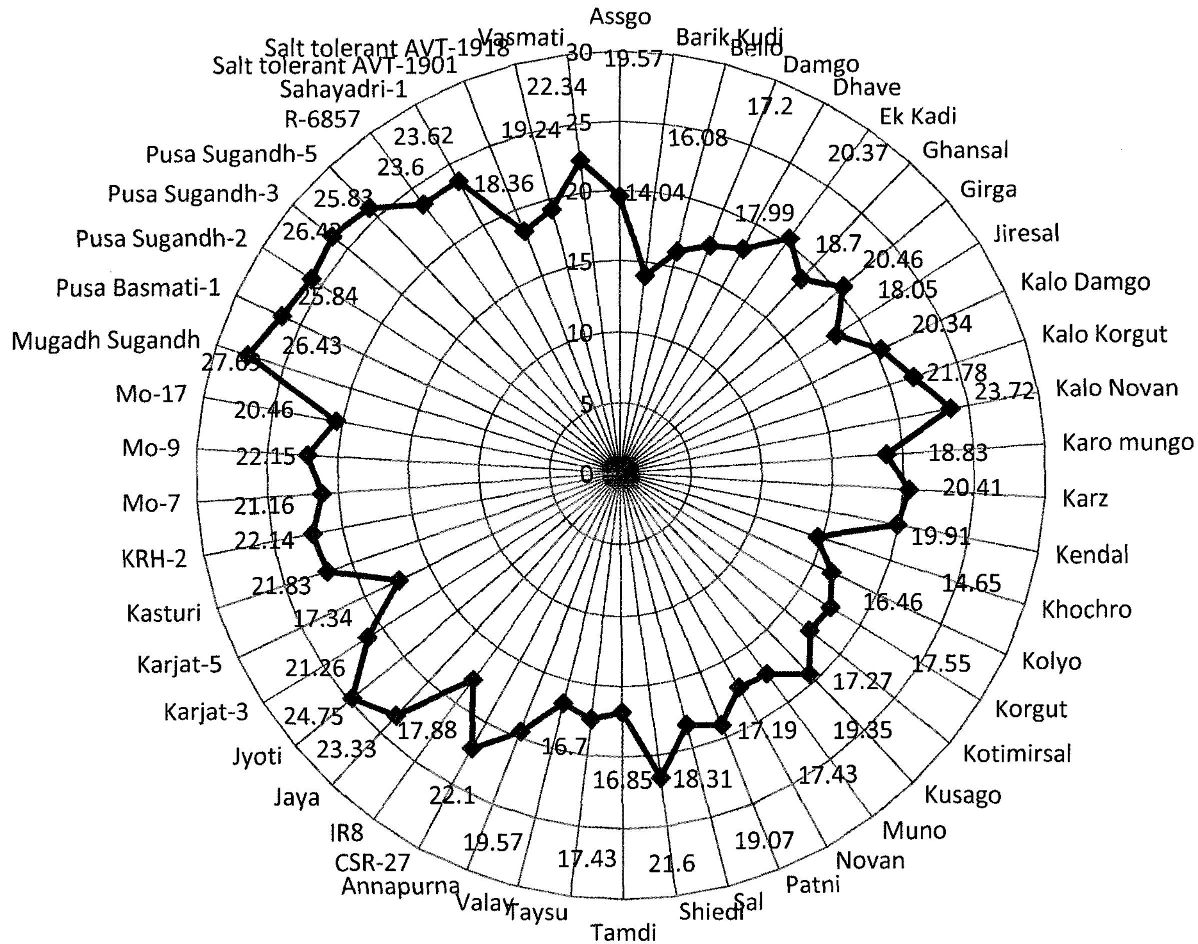


Fig. 43. Principle component analysis (PCA), correlation of chemical characteristic.

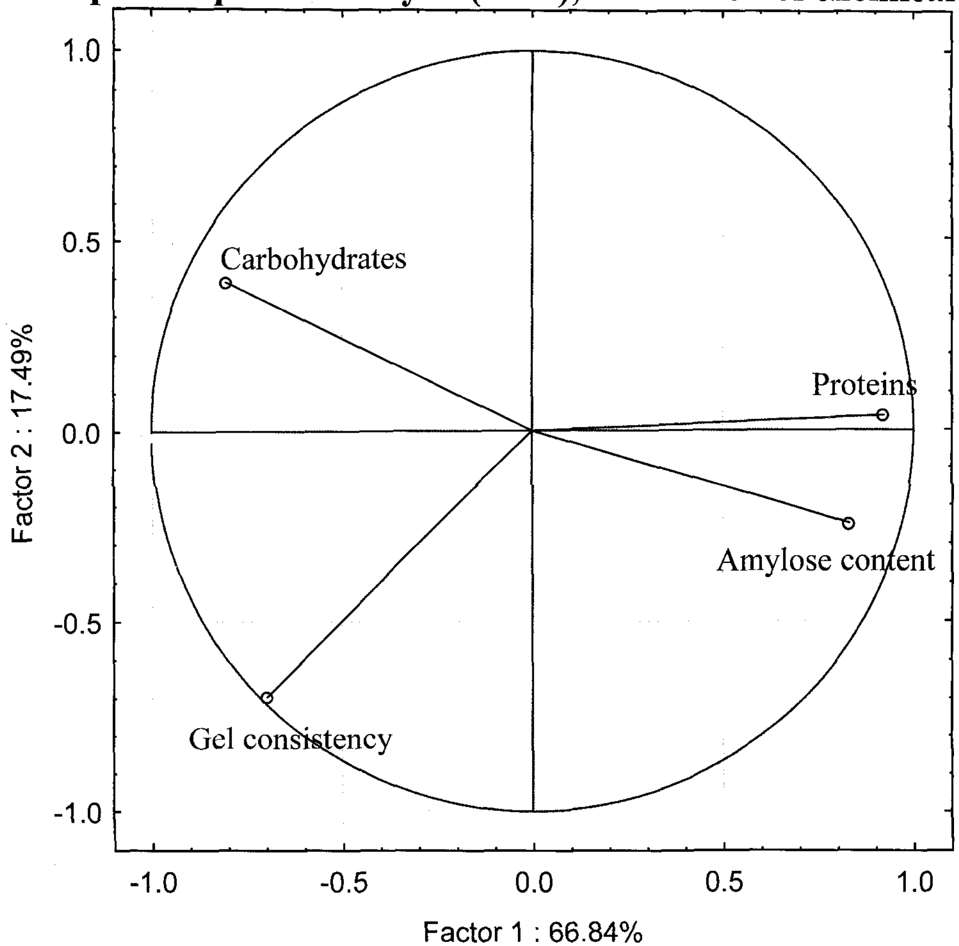
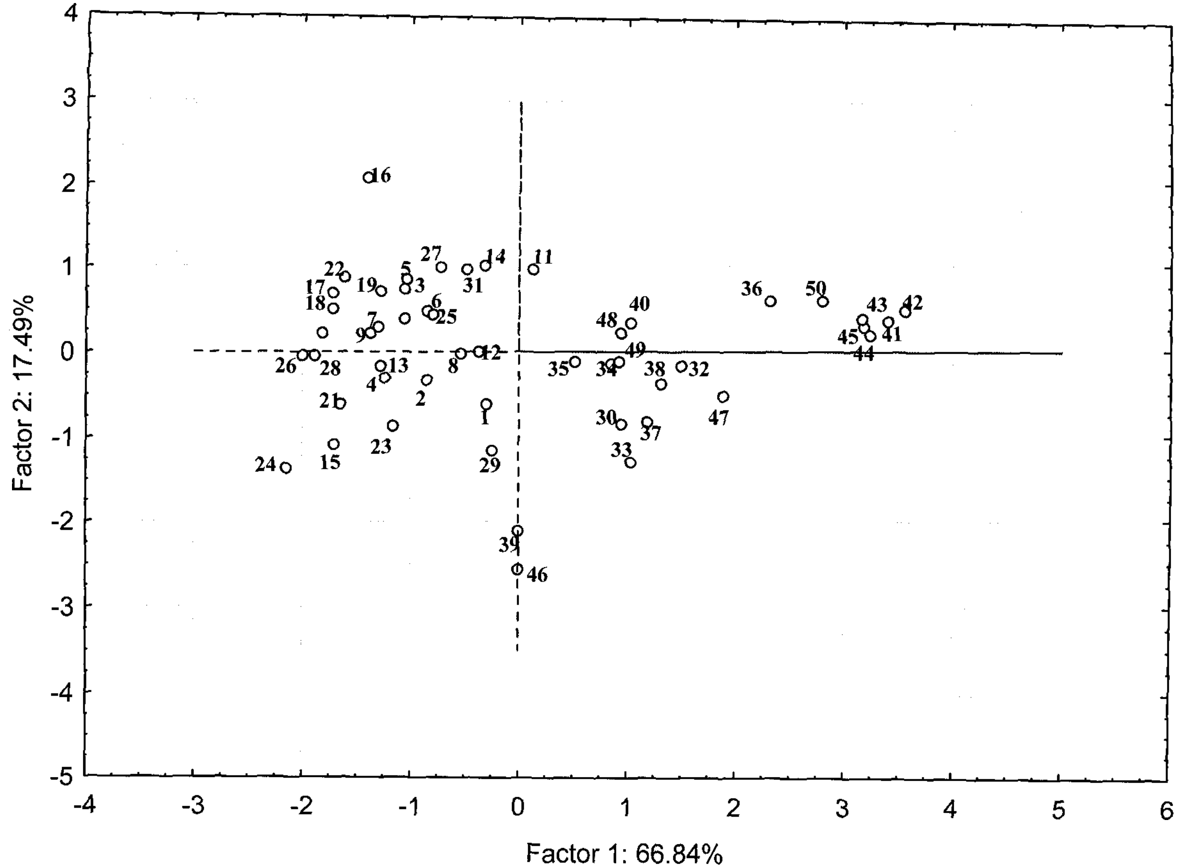


Fig. 44. Scatter plot of first and second principal component scores of rice based on chemical traits.



1, Assgo; 2, Barik Kudi; 3, Bello; 4, Damgo; 5, Dhave; 6, Ek Kadi; 7, Ghansal; 8, Girga; 9, Jiresal; 10, Kalo Damgo; 11, Kalo Korgut; 12, Kalo Novan; 13, Karo Mungo; 14, Karz; 15, Kendal; 16, Khochro; 17, Kolyo; 18, Korgut; 19, Kotimirsal; 20, Muno 21, Kusago; 22, Novan ; 23, Patni; 24, Sal; 25, Shiedi; 26, Taysu; 27, Tamdi; 28, Valay; 29, Annapurna; 30, CSR-27 ; 31, IR-8; 32, Jaya; 33, Jyoti ; 34, Karjat-3; 35, Karjat-5; 36, Kasturi; 37, KRH-2; 38, MO-7; 39, MO-9; 40, MO-17; 41, Mugadh Sugandh; 42, Pusa Basmati-1; 43, Pusa Sugandh-2 ; 44, Pusa Sugandh-3; 45, Pusa Sugandh-5; 46, R-6857; 47, Sahayadri-1; 48, Salt Tolerant AVT-1901; 49, Salt Tolerant AVT-1918; 50, Vasmati

Table 41. Chemical characteristic of traditional and high yielding rice varieties.

	Amylose content	Gel consistency	Carbohydrates %	Proteins %
Amylose content	1.00			
Gel consistency	-0.40	1.00		
Carbohydrates %	-0.59	0.34	1.00	
Proteins %	0.69	-0.61	0.68	1.00

Correlations are significant at $p < .05000$, rice varieties 50 character of starch granule and the physical properties of the starch determine the distribution of branch lengths in amylopectin (Myers *et al.*, 2000).

5.3.4. Aroma

Aroma is another important trait in rice and aromatic rice has high demand in the market. All the basmati varieties are scented (Table 23, 24). Few native varieties are having aroma, for which these varieties are preferred for consumption by local people. Most of the traditional rice varieties and some high yielding rice varieties have aroma, however, they belong to other than basmati type. It was reported that 2-acetyl-pyrroline (2-AP) is the major aroma compound responsible for the aroma in basmati rice varieties. The quantity of 2-AP varies with varieties and it is sensitive to temperature and other climatic conditions (Nadaf *et al.*, 2006). Traditionally, *Pandanus amaryllifolius* leaf has been used during cooking of non-scented rice to get the smell of basmati rice. It was found that the leaves of *Pandanus amaryllifolius* contain the similar aroma compounds and it stored in epidermal papillae of lower epidermis of leaf (Wakte *et al.*, 2007).

5.4. Rice Grain Quality - Cooking characteristics:

5.4.1. Volume Expansion Ratio and Elongation Ratio

Horigane *et al.* (2006) showed using (MRI) that water penetrates in the centre of endosperm in milled rice grain during soaking, this is due to the loose packing of amyloplasts in the central region of endosperm compared to the lateral side, even in the normal grain. Ishimaru *et al.* (2009) reported using MRI showed that water content declined first in the centre of the endosperm, then in the lateral endosperm. In the present study, among the traditional rice varieties, the volume expansion ratio (VER) was highest in variety Jiresal (4.1) and lowest in variety Kalo Korgut (1.6), whereas in high yielding rice varieties highest VER was noted in KRH-2 (4.03) and lowest in variety Karjat-5 (1.6) (Figure 45). The correlation coefficients among the cooking characteristic are presented in Table 42. Volume expansion ratio showed positive correlation with kernel length after cooking and water uptake ratio, however, a negative correlation with elongation ratio (Figure 49). Based on the cooking traits, the scattered plot of principle component analysis (PCA), showed that most of the traditionally cultivated rice varieties like Kalo Damgo, Dhave, Korgut, Valay and Kendal were grouped together and where as high yielding scented rice varieties formed another group (Figure 50). Nayak *et al.* (2003) reported that the volume expansion ratio significantly positive correlation with water uptake, but significant negative correlation with cooked kernel length and elongation ratio.

Kernel elongation ratio was lowest in variety Kalo Damgo (1.01) and highest in variety Bello (1.66) while in high yielding varieties highest in Karjart-5 (1.52) and lowest in Jyoti (1.01) (Figure 46). Kernel elongation ratio showed negative correlation with volume expansion, kernel length after cooking and water uptake (Figure 49, 50). High-amylose rice varieties absorb more water with low gelatinization temperature and produce more cooked material. When the amylose content of a variety increases, cooking time increases. Selection for improved amylose content would result in a correlated improved response in other cooking qualities (Juliano and Villareal, 1993).

Kernel length after cooking (KLAC) was compared in traditional rice varieties and high yielding rice varieties. Highest was calculated in Barik Kudi (10.8 mm) and lowest in Kotimirsal (6.64 mm) while in high yielding rice varieties highest in Vasmati (14.18) and

Fig. 45. Comparison of volume expansion in traditional and high yielding rice varieties.

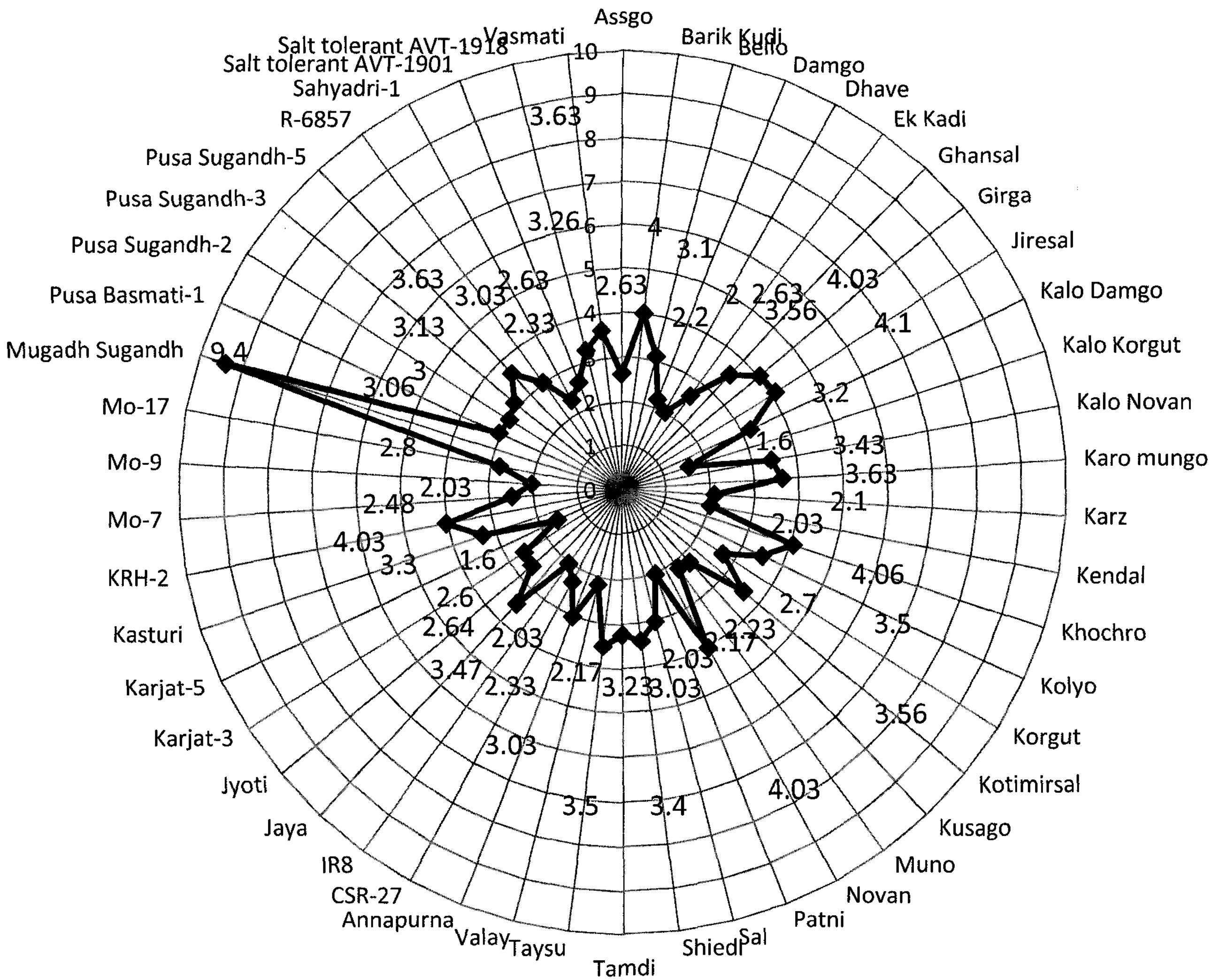
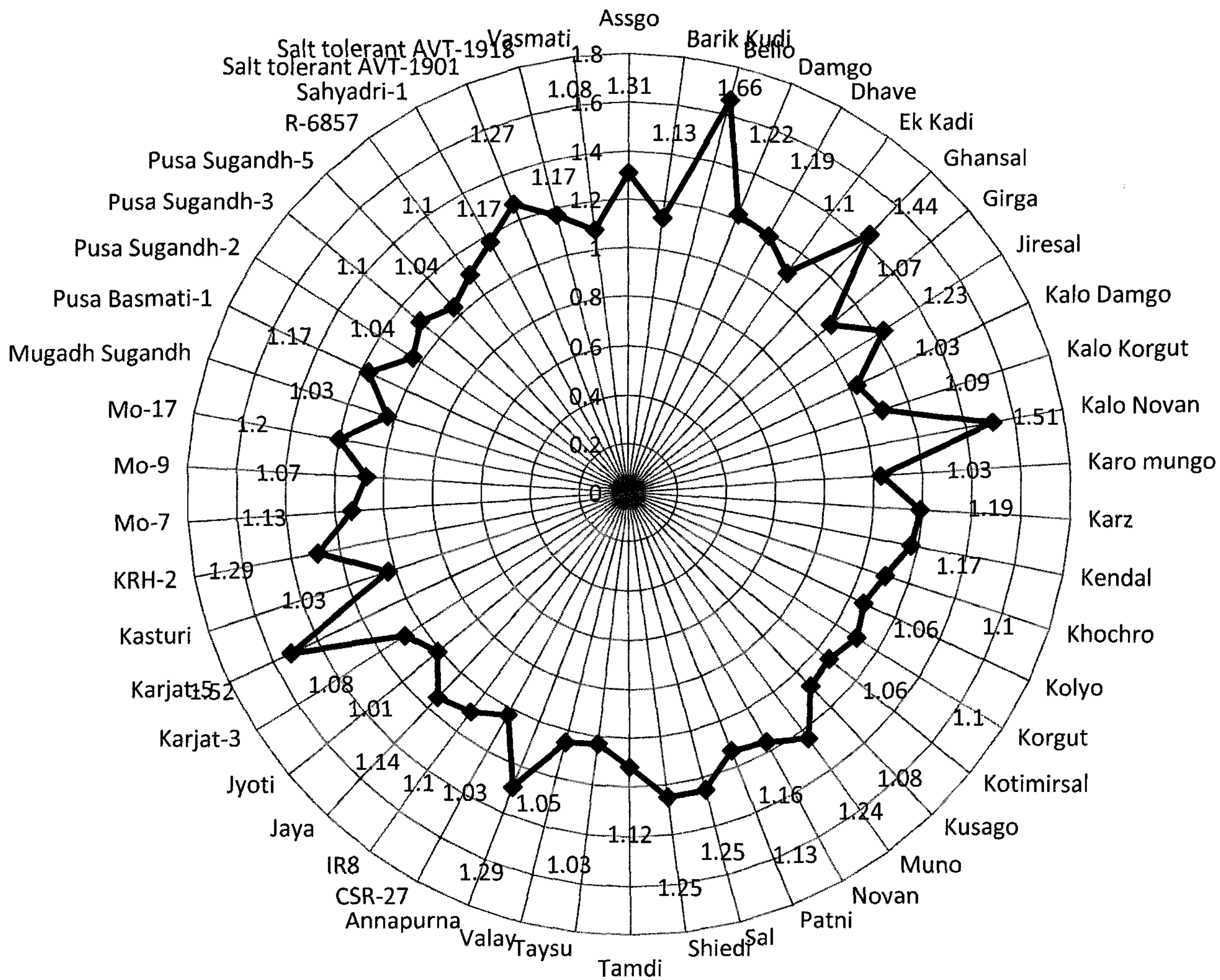


Fig. 46. Comparison of elongation ratio in traditional and high yielding rice varieties.



lowest in IR-8 (8.03) (Figure 47). Kernel length after cooking showed positive correlation with volume expansion and water uptake, however a negative correlation with elongation ratio (Figure 49, 50). Shahidullah *et al.* (2009) reported that lower VER is preferred by the consumers than higher VER, on the other hand, higher elongation ratio (ER) of the cooked rice is preferred than lower ER.

5.4.2. Water Uptake

Among the traditional rice varieties studied, the lowest water uptake was in Korgut (160 ml) and highest in variety Barik Kudi (390 ml). Whereas in HYV highest in variety IR-8 (390 ml) and lowest in variety MO-7 (255 ml) (Figure 48). The appearance in the quality of cooked rice grains is associated with the amount of water uptake during the cooking process, which may be associated with the appearance of milled rice grain, as well as overall water absorption (Tan *et al.*, 2000). The positive correlation of AC with water uptake ratio, volume expansion ratio and alkali spreading value indicates that high-amylose rice varieties will absorb more water at low gelatinization temperature and will produce a greater volume of cooked material (Hussain *et al.*, 1987). But Chauhan *et al* (1995) found a negative association between these two traits. Madan and Bhat (1984) reported a positive and significant association of amylose content with volume of cooked rice and water absorption. The data are consistent with the results reported by Sandhyd-Randi and Bhattacharya (1989), which showed that chalky kernels absorb more water than vitreous kernels in ambient temperature.

Fig. 47. Comparison of kernel length after cooking in traditional and high yielding rice varieties.

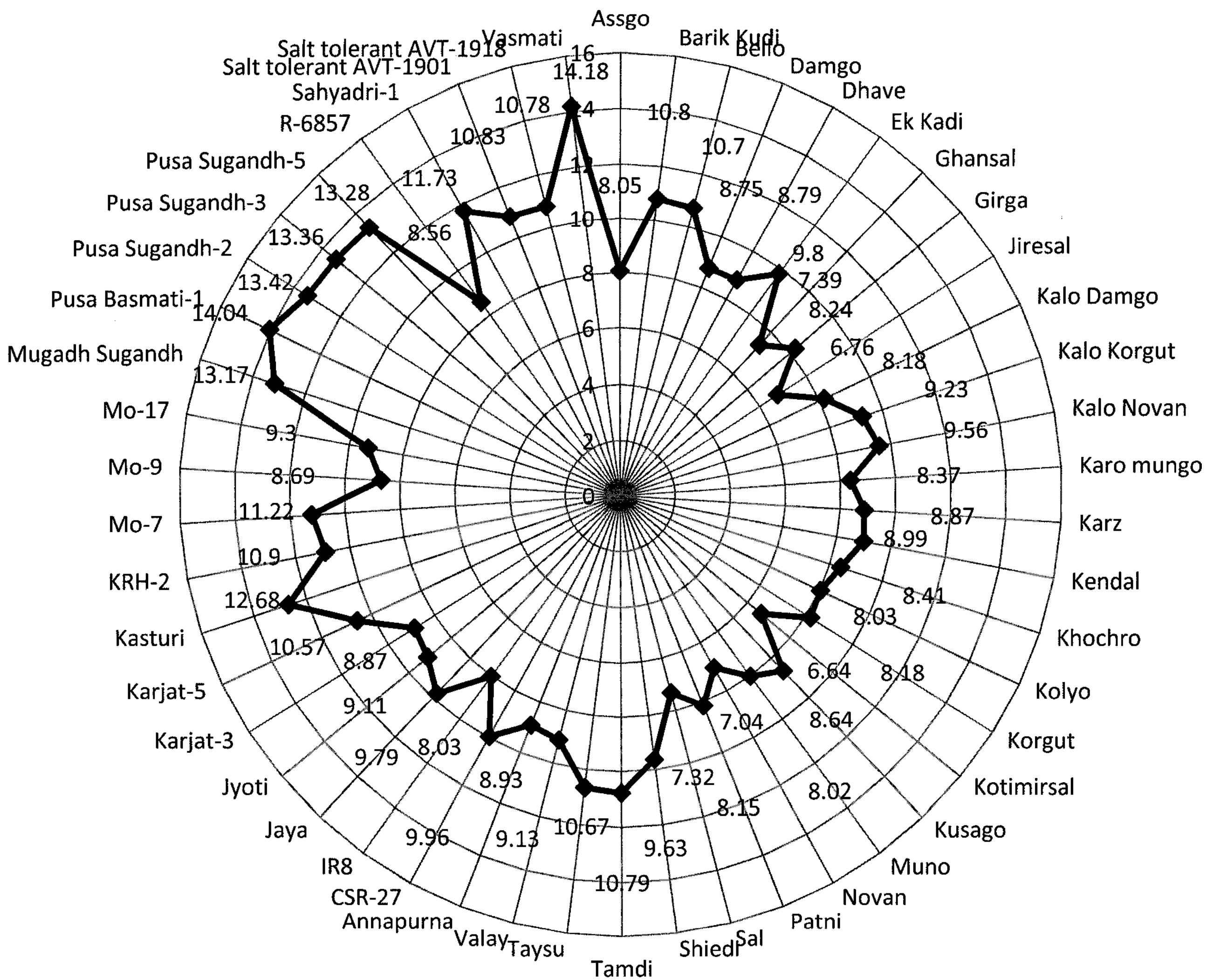


Fig. 48. **Comparison of water uptake in ml in traditional and high yielding rice varieties.**

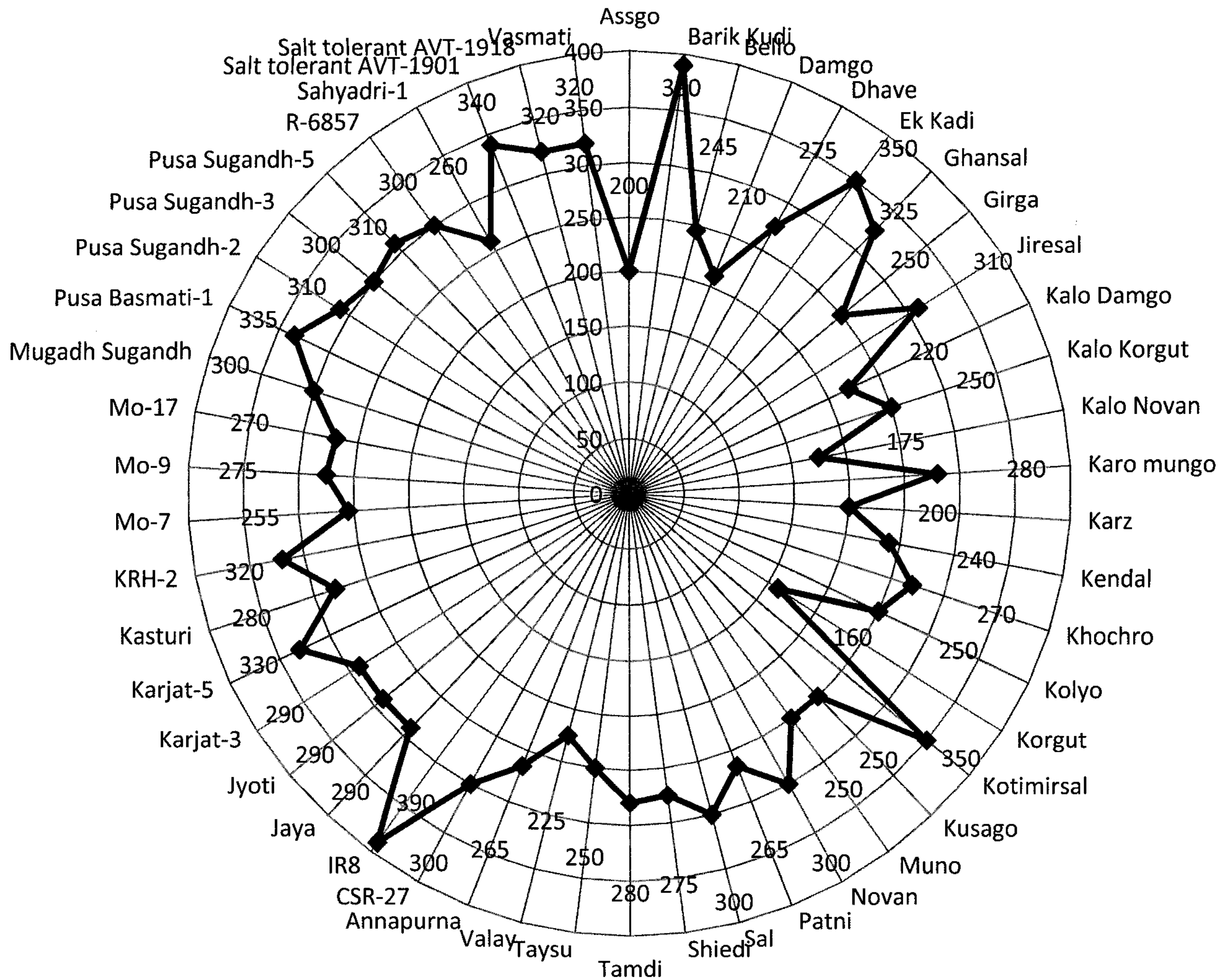


Fig. 49. Principle component analysis (PCA), correlation of cooking characteristic

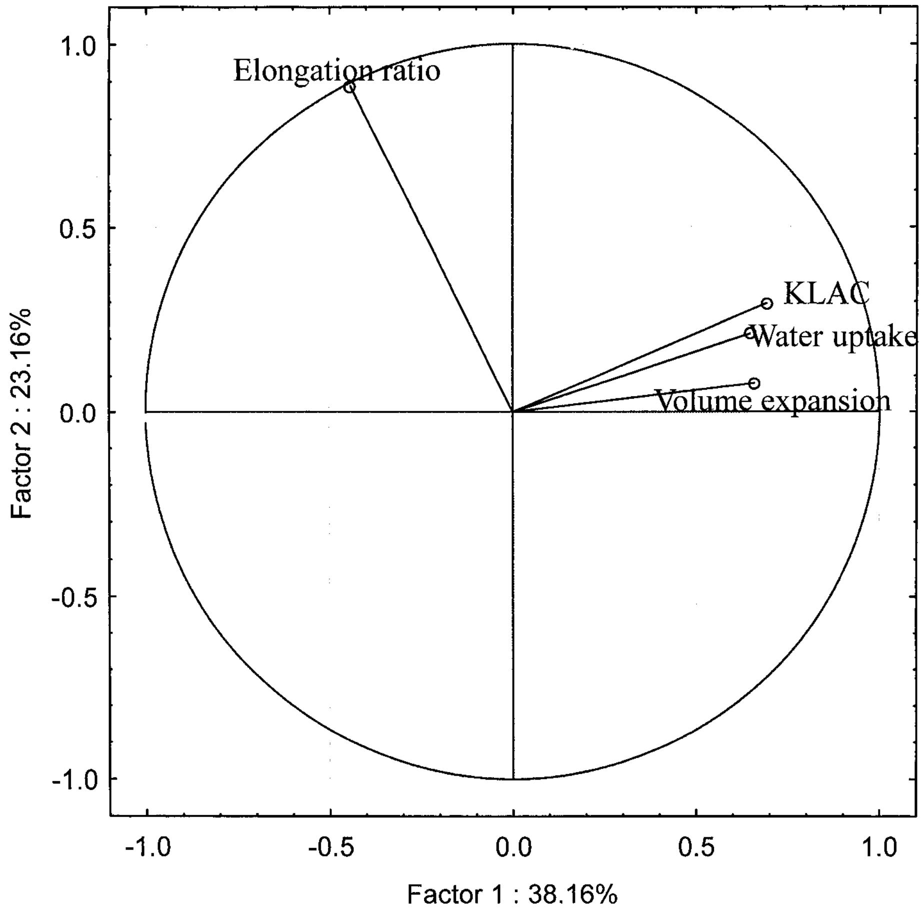
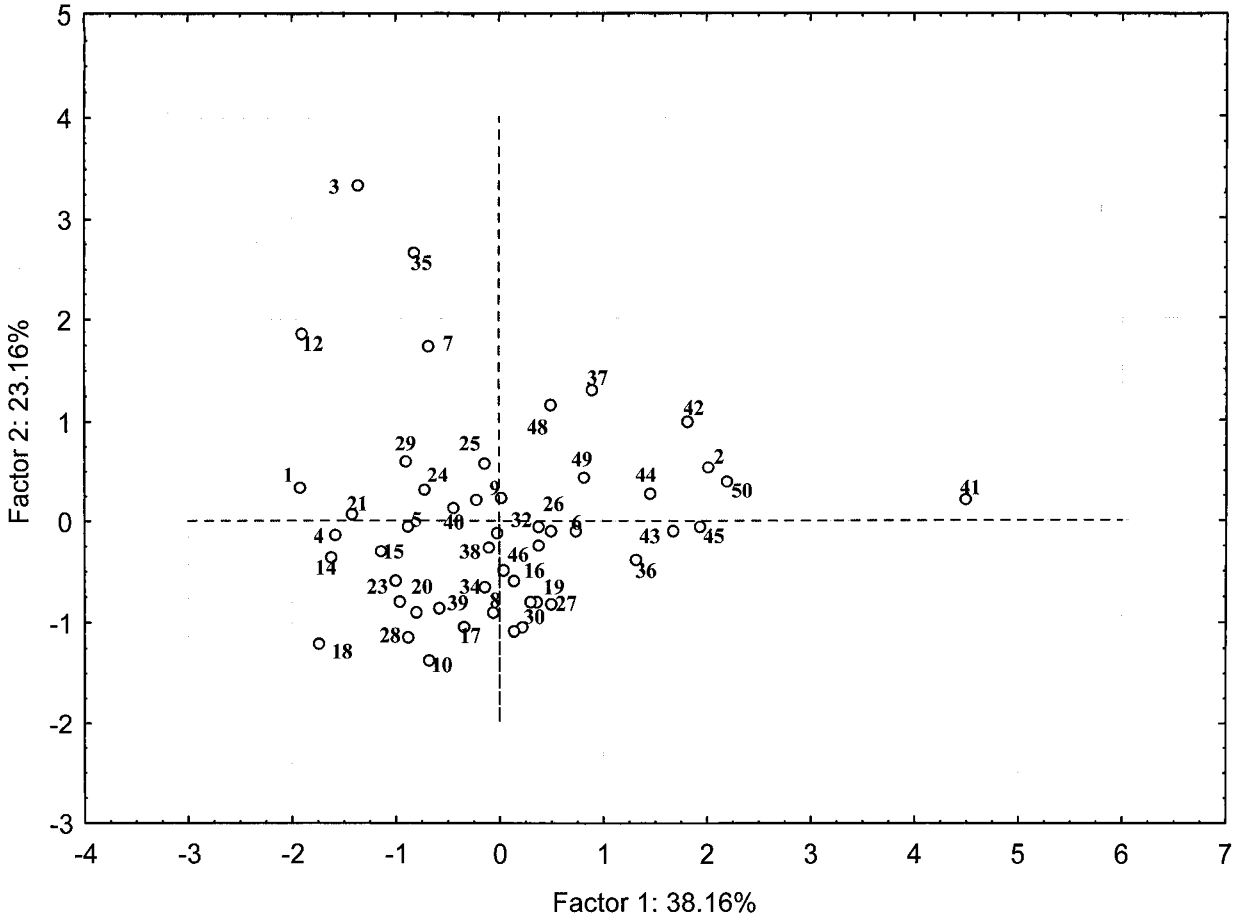


Fig. 50. Scatter plot of first and second principal component scores of rice based on cooking traits.



1, Assgo; 2, Barik Kudi; 3, Bello; 4, Damgo; 5, Dhave; 6, Ek Kadi; 7, Ghansal; 8, Girga; 9, Jiresal; 10, Kalo Damgo; 11, Kalo Korgut; 12, Kalo Novan; 13, Karo Mungo; 14, Karz; 15, Kendal; 16, Khochro; 17, Kolyo; 18, Korgut; 19, Kotimirsal; 20, Muno 21, Kusago; 22, Novan ; 23, Patni; 24, Sal; 25, Shiedi; 26, Taysu; 27, Tamdi; 28, Valay; 29, Annapurna; 30, CSR-27 ; 31, IR-8; 32, Jaya; 33, Jyoti ; 34, Karjat-3; 35, Karjat-5; 36, Kasturi; 37, KRH-2; 38, MO-7; 39, MO-9; 40, MO-17; 41, Mugadh Sugandh; 42, Pusa Basmati-1; 43, Pusa Sugandh-2 ; 44, Pusa Sugandh-3; 45, Pusa Sugandh-5; 46, R-6857; 47, Sahayadri-1; 48, Salt Tolerant AVT-1901; 49, Salt Tolerant AVT-1918; 50, Vasmati

Table 42. Cooking characteristic of traditional and high yielding rice varieties.

	Volume Expansion	KLAC mm	Elongation ratio	Water uptake ratio
Volume Expansion	1.00			
KLAC mm	0.24	1.00		
Elongation ratio	-0.13	-0.10	1.00	
Water uptake ratio	0.18	0.24	-0.11	1.00

Correlations are significant at $p < .05000$, rice varieties 50

KLAC, kernel length after cooking

5.4.3. Organoleptic Test

The Organoleptic test were conducted for appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability for traditional cultivated and high yielding rice varieties and details are given in Tables 29, 30. Grain quality in rice is difficult to define with precision as preference for quality varies from country to country and within the country from region to region and between ethnic groups (Manjunath *et al.*, 2009). During this investigation, the excellent cooking quality was recorded in the rice varieties Damgo, Muno, and Korgut. Among the rice varieties Jiresal, Kotimirsal, Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5, Kasturi and Vasumati with best cooking quality characteristics and consumer's preference. The cooking quality and taste preference of consumers varies within ethnic groups and from one country to another or within different geographical regions (Juliano *et al.*, 1964). The grains with very low quality (texture) after cooking due to the low moisture content which results in crack formation (Yanase and Ohtsubo, 1986). The results imply that three major characteristics such as amylose content, gelatinization temperature and grain shape are involved in grain quality especially these characteristics which influence the physicochemical properties like texture. The grain quality and agro-morphological characteristic studies using genetic molecular marker may also help in investigating the variability and relatedness among different rice landraces which is a positive step towards documentation of our scattered knowledge about rice germplasm available in India (Yogendra and Singh, 2006). In the context of changing agricultural scenario, there has been increase in demand for the quality rice throughout the world. Grain quality evaluation and organoleptic analysis always helps the consumers to select better rice varieties (Bhonsle and Krishnan, 2010a, b).

5.6. Biochemical Analysis:

5.6.1. Total Carbohydrates

Rice is very rich in carbohydrates, contains a moderate amount of protein, and is a source of the vitamins, thiamin, riboflavin, and niacin (Fresco, 2005). In the present study, highest percentage of carbohydrate was found in traditional cultivated varieties 87% in Kalo Damgo and lowest in Bello (67%) while in HYV least carbohydrate content (70%) in two rice varieties MO-9, Mugadh Sugandh and high (85%) in variety Jyoti (Figure 51). It is known that the physiological and biochemical metabolism in grains are managed by genetic and environmental factors which comprehensively results rice quality (Smith *et al.*, 1997; Okita 1992).

5.6.2. Total Proteins

The cooking quality of rice was determined on the basis of the variety and its physicochemical properties, mainly amylose content (Sujatha *et al.*, 2004) and cooked rice is composite food consisting of different biopolymers, including starch and proteins along with moisture (Ahmed *et al.*, 2007).The total protein content was compared in traditional and high yielding varieties and the percentage of protein varied from 6.37-9.75% (Figure 52). Highest percentage was calculated in Kalo Damgo (9.75%) and lowest in Bello (6.37%) while in HYV lower protein content was noted in varieties CSR-27, Jaya, Karjat-5, Mugadh Sugandh, Pusa Basmati-1, Salt Tolerant-1918, Vasmati (6.37%) and highest 8.75% in varieties MO-7 and R-6857 (Figure 52). According to Champagne *et al.* (2007) the increased protein content increases the chewiness and hardness of cooked rice.

Fig. 51. Comparison of total carbohydrates in traditional and high yielding rice varieties.

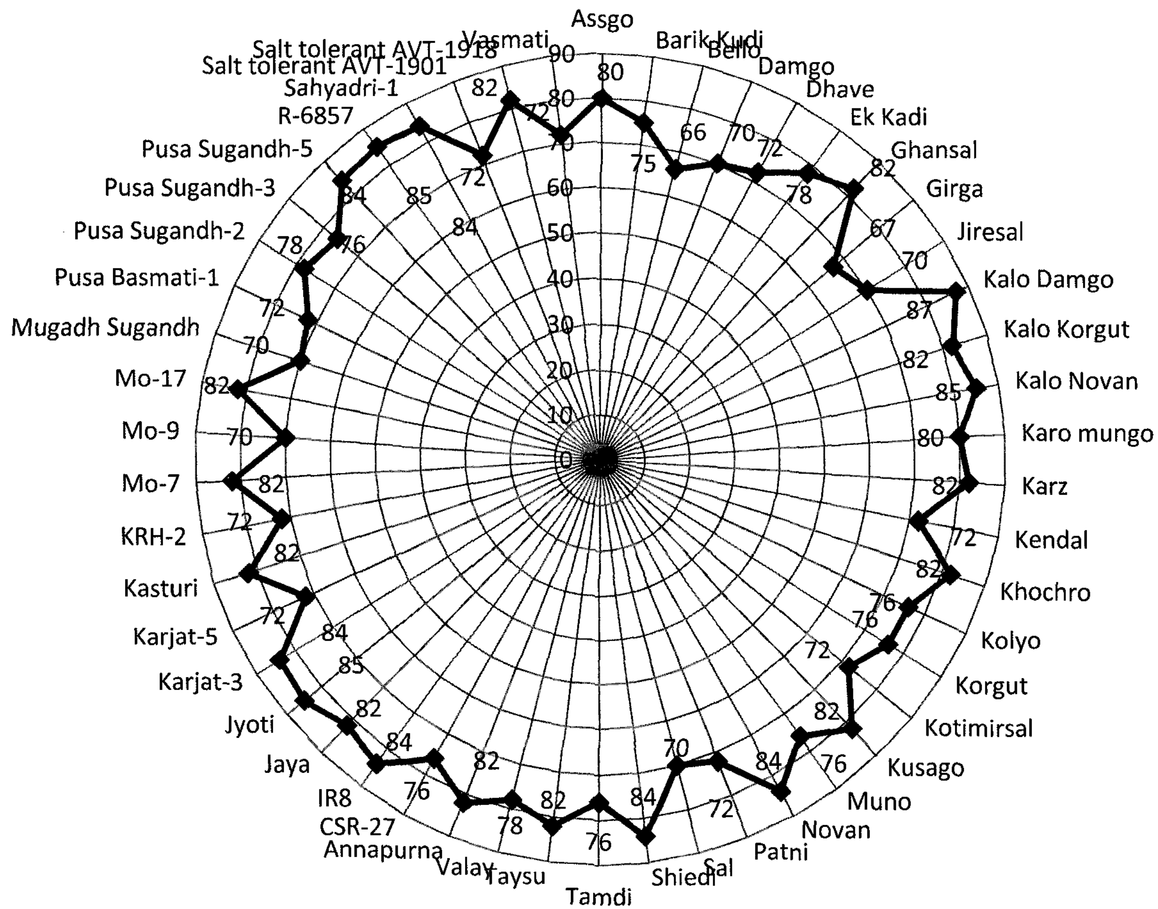
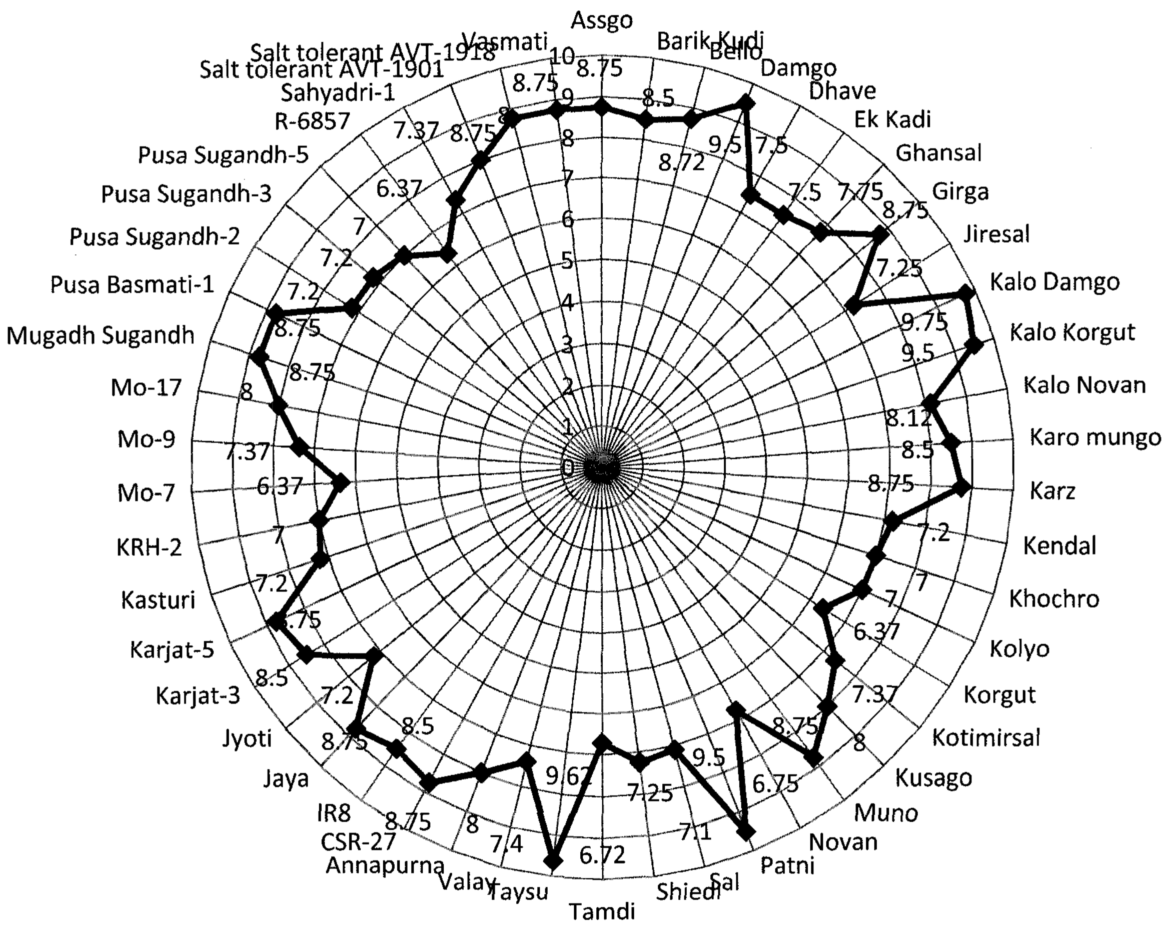


Fig. 52. Comparison of Percentage of proteins in traditional and high yielding rice varieties.



5.7. Determination of Minerals (Iron, Zinc, Calcium, Potassium) by AAS

In the present study, iron, zinc, potassium and calcium content was estimated in traditional varieties and compared with some HYV using atomic absorption spectrophotometer (AAS). The lowest iron content was recorded in Girga (5.82 mg/Kg), where as the highest in Kendal (13.25 mg/Kg) when compared with the HYV lowest iron content of 7.52 mg/Kg in KRH-2 and highest in Pusa Basmati-1 (11.62 mg/Kg) (Figure 29). Screening of rice germplasm revealed that no accession/varieties contain high iron and zinc level which could be used for conventional breeding to increase the iron, zinc and other micronutrients in rice (Tan *et al.*,2000; Ye *et al.*, 2000). The transgenic approach have been made to enhance iron and zinc content in the endosperm of rice (Vasconcelos *et al.*, 2003; Datta *et al*, 2003; Krishnan *et al.*, 2003; Sivaprakash *et al.*, 2006; Sellappan *et al.*, 2009). In the present study, the lowest zinc content was detected in Novan (13.63 mg/Kg) and while highest in Kalo Korgut (41.66 mg/Kg), in HYV zinc content was lowest 18.05 mg/Kg in Salt Tolerant AVT-1918 and highest 43.27 mg/Kg in Pusa Basmati-1 (Figure 29).

The lowest calcium content was calculated in HYV CSR-27, MO17, Sahaydri-1 (0.02%), and highest in R 6857 (0.09%), whereas in traditionally cultivated rice varieties lowest (0.01%) was in Kendal and highest in Ek Kadi (0.09). The highest potassium content was in traditional rice in varieties Valay and Kolyo (0.12%) and lowest in varieties Muno and Taysu (0.46 %). Whereas the lowest potassium content in HYV was in Sahaydri-1 (0.14%) and highest in Salt Tolerant AVT-1901 (0.51%) (Figure 30). Genetic and environmental factors are mainly responsible for the variations in the composition and cooking quality of rice (Yoon *et al.*, 2008). With the increasing demand for quality rice, appropriate food processing methods and rice breeding to be continuously carried out to develop rice cultivars to meet consumers demand (Yoon *et al.*, 2009).

5.8. Histochemical Characterization of Origin and Development of Chalkiness

5.8.1. Bright-field microscopic Studies of Chalkiness in Rice Grain

In the present study, origin and development of chalkiness in rice grains were studied in rice varieties Jaya (non chalky) and Korgut (chalky). In variety Jaya, during 5-10 DAF, the endosperm cell development was normal with uniform deposition of the starch observed (Plate 9, 10). At 20 DAF, uniformly packed endosperm cells with no chalkiness and normal deposition of the starch were noted (Plate 11). In matured rice grain (30 DAF) the endosperm cells arranged perfectly without any chalky cells. The endosperm cell development was normal with uniform and normal deposition of the starch without any variation in deposition (Plate 12). In contrast, in Korgut at 5 DAF showed mild patches of chalkiness as semi translucent cell structures. Then the rice grain of about 8 days after fertilization (DAF), the endosperm cells were loosely arranged with dark staining by safranin in the centre of the endosperm and also in periphery. The later stage of development of about 20 DAF was examined in Korgut showed the prominent chalkiness starting from the embryo sides, extending towards centre and reaching up to the tip of the grain (Plates 9-17). (Singh *et al.*, 2006) reported the large air spaces between starch granules and showed significantly different physico-chemical, morphological and cooking characteristics in chalky rice grain in comparison with those of translucent grains (Cheng *et al.*, 2005). During this study, the matured rice grain of about 30 DAF revealed the distinct differences in packing of starch in the endosperm. The compact and uniform packing of starch granules were seen in non-chalky grains while chalky grains were with uneven and loosely packed starch granules. Chalkiness is an important quality characteristic in rice and occurs most commonly when high temperatures are experienced during grain development. Bhashyam and Srinivas (1981) indicated the loose packing of starch granules and reported that the width of the rice grain increases chalkiness appears in the grain. Lisle (2000) reported that the rice grown at the higher temperature contained more chalky grains.

5.8.2. Fluorescence Microscopic Studies of Chalkiness in Rice Grain

The fluorescent dye acridine orange revealed that chalky endosperm cells were arranged perfectly with even deposition of starch and compactly arranged endosperm cells (Plate 18). The chalkiness evaluation was traditionally performed by human visual inspection and there have been no standard methods to effectively classify chalky grains (Yoshioka *et al,* 2007). Whereas in the fluorescent dye acridine orange cleared showed fissure in endosperm, unevenly packed and loosely arranged starch granules in chalky grains (Plate 18). Lisle (2000) showed that the shape, size, packing of amyloplasts in the cells of endosperm of chalky grains differed from those in translucent grains and might offer an explanation for the differences in cooking quality.

5.8.3. Scanning Electron Microscopic (SEM) Studies of Chalkiness in Rice Grain

The Scanning Electron Microscopic studies were carried for chalky and non chalky rice grain. The SEM photographs distinctly revealed the non chalky rice varieties with uniform arrangement of endosperm cells and endosperm cell walls and also the uniform deposition of starch with no gap between the endosperm cells and their compact arrangements. In contrast, the chalky rice grains showed the unevenly arranged endosperm cells with loosely packed starch granules (Plate 19, 20). The scanning electron microscope (SEM) studies by Kang *et al.* (2005); Singh *et al.* (2006); Yamakawa *et al.* (2007); Fujita *et al.* (2007) showed that chalky endosperms are filled with loosely packed, round and large compound starch granules, while translucent endosperms have tightly packed, polyhedral and small starch granules. The SEM studies of Qiao *et al.* (2011) stated that white-core starch granules are simply broken into many single granules and no protein bodies are visible. In white-belly the starch granules are intact and enclosed by globular protein bodies with air spaces, also this study suggests nitrogen suppress influence of chalky grains. Horigane *et al.* (2006) shown the water penetration route, cracking pattern, morphological structure, softness and hardness interconnected with packing of the starch granules in the rice grain.

5.9. Molecular Genetic Diversity Studies of Rice Varieties

4.9.1. ISSR Amplification and Banding Pattern

ISSR primers have been very useful in detecting genetic diversity and population structure of coffee (Tesfaye, 2006), barley (Hou *et al.*, 2005) and orchids (Parab *et al.*, 2008; Parab and Krishnan, 2008). ISSR primer analysis was carried for all 50 rice varieties from different regions of Goa with an additional salt tolerant rice variety Pokkali collected from Kerala and a wild rice *Oryza rufipogon* from Goa. Fifteen ISSR primers showed amplification of genomic DNA, with reproducible banding pattern with average of 7.33 bands per primer (Table 38). Molecular marker techniques, like Random amplification polymorphic DNA (RAPD) has been successfully employed to determine genetic diversity in different species including rice (Ge *et al.*, 1999, Qian *et al.*, 2001), but RAPD has several limitations including dominances, uncertain locus homology, sensitivity and low reproducibility. In order to solve these problems, inter-simple sequence repeat (ISSR) amplification has been used to assess genetic diversity and distance (Qian *et al.*, 2001). Moreover, ISSR was also found better than RAPD to detect genetic diversity among barley accessions (Hou *et al.*, 2005). In the present study, the total amplified bands were 110, out of which 104 bands were polymorphic for all the rice varieties with an average of 6.93 bands per primer. The number of amplified bands ranged from 2 (ISSRA1) to 10 (1SSR-7). Polymorphic banding pattern of 100% was obtained in ten primers (Table 37). It was observed in our study that AG and GA based primers were given 100% polymorphism. Joshi *et al.* (2000); Reddy *et al.* (2000) reported the similar finding of AG and GA based primers have been shown to amplify clear bands in rice.

5.9.2. Genetic Identity and Cluster Analysis

Indigenous knowledge of landraces gathered from local farmers has provided a rich background to compare with the genetic relationships of native rice varieties. However, there is still a lack of data that describe molecular diversity of rice on a local scale (Thomson *et al.*, 2009). In our study ISSR primers were used to identify the identity values of all 51 rice varieties and a wild rice *Oryza rufipogon* (Table 37). In the present study, the genetic identity values differed from 0.5091 to 0.9727, with the average of 0.740. Among 51 rice varieties, the lowest genetic identity value (0.5091) was observed in local scented rice variety Girga and a wild rice *Oryza rufipogon* (Table 39). Sharma and Shastri (1965) reported that the weed races may also contributed to the differentiation of the cultivated species. This differentiation and diversification of annual species is due to marked climatic changes over long period of time and selection by human beings according to their need in manipulated cultural environment. During this study, pairs have formed between Salt

Tolerant AVT-1908 and Salt Tolerant AVT-1918; Ek Kadi and Dhave; Kalo Korgut and Kalo Damgo having the closest genetic identity with each other (Figure 33).

ISSR data of 51 rice varieties and a wild rice *Oryza rufipogon* were used to generate dendrogram revealed the formation of four distinct clusters which distinctly separates the high yielding varieties, scented rice varieties, salt tolerant and traditionally cultivated rice varieties (Figure 33). The first cluster was formed by all 12 high yielding rice varieties, whereas the second cluster was formed by both traditional scented rice and high yielding scented rice varieties. The third group encompass salt tolerant rice varieties in which Pokkali is also included showing the uniqueness of the grouped rice varieties. As rice variety Pokkali also has acid tolerance, submergence tolerance in seedling stage and know to be salt tolerant variety (Shylaraj *et al.*, 2006). While, fourth cluster comprised of 17 rice varieties belonging to the traditionally cultivated rice varieties (Barik Kudi, Dhave, Ek Kadi, Bello, Karz, Kendal, Kolyo, Khochro, Patni, Tamdi, Valay, Kusago, Novan, Kalo Novan, Kalo Damgo, Sal and Taysu). Vanniarajan *et al.* (2011) reported that the testing landraces together with known cultivars have permitted genome wide association mapping and suggests scope to revise more rice landraces collected from different geographical region. Among the rice varieties studied, a scented variety Girga not joined with scented group and it formed a separate clade showing some uniqueness, however, it needs further study. A wild rice *Oryza rufipogon* formed a separate clade representing its distinctiveness. The genus *Oryza* consists of two cultivated species and about 20 wild species (Tateoka, 1963) and according to Sharma and Shastri (1965), the Asian cultivated rice *O. sativa L.* have been evolved following a sequence of wild perennial *O. rufipogon* Griff to wild annual *O. nivara* and then the cultivated annual *O. sativa* L.

CONCLUSIONS

CONCLUSIONS

Rice is the staple food for the people of Goa and rice cultivation occupies an area of about 52,191 ha, among them 34,261 ha is grown during *kharif* and remaining 17,930 ha during *rabi* season. About 90% of *kharif* and entire area of *rabi* seasons are covered under high yielding rice varieties. Due to the introduction of high yielding varieties, the cultivation of traditional varieties is being disappeared. During this study 50 rice varieties were collected from the State of Goa. Among them 28 rice varieties were traditionally cultivated by the farmers and 22 rice varieties were high yielding. All the traditional rice varieties were with unique characteristics of size, shape and colour. The survey revealed that some of the rice varieties are specifically grown in khazan lands and are highly salinity tolerant and these rice germplasm need to be conserved and used for breeding programme.

The physical, chemical and cooking characteristics revealed that the traditional rice varieties Jiresal, Damgo, Muno, Korgut and Kotimirsal are with excellent grain quality. The chalkiness in the major concern of rice breeders which reduces the grain quality and consumer prefers translucent rice grain without any chalkiness. The highest AC was in variety Kalo Novan (23.7%) and lowest in variety Barik Kudi (14%). Aroma is another important trait and the aromatic rice has high demand in the market. The traditional rice varieties such as Ghansal, Girga, Jiresal, Kotimirsal and Sal assigned to scented rice varieties. In addition Ghansal and Kotimirsal do not have any chalkiness and also have aroma. The highest percentage of carbohydrate and protein was recorded in variety Kalo Damgo. The maximum iron content was observed in variety Kendal where as the maximum zinc content was calculated in variety Kalo Korgut. Similarly, highest calcium content was found in variety Ek Kadi and highest potassium content was recorded in varieties Muno and Taysu. The grain quality evaluation studies revealed that the above traditional rice varieties have high potential and could be used for crop improvement and rice breeding programmes.

Histochemical studies of origin and development of chalkiness in rice grain from anthesis to maturation using bright-field, fluorescence microscopic and scanning electron microscopic studies revealed that the non- chalky rice grains are with uniform deposition of starch with no gap between the endosperm cells and they are compactly arranged. In contrast, the chalky rice grains showed the unevenly arranged endosperm cells with loosely packed starch granules. This finding will help in understanding of chalkiness behavior by breeders to overcome the chalkiness character especially while developing hybrid rice which known to have the problem of chalkiness.

ISSR primer analysis was carried for all 50 rice varieties from different regions of Goa with an additional salt tolerant rice variety Pokkali collected from Kerala and a wild rice *Oryza rufipogon* from Goa. Fifteen ISSR primers showed amplification of genomic DNA with 100% polymorphic banding pattern in ten primers. Dendrogram revealed the formation of four distinct clusters which distinctly separates the high yielding varieties, scented rice varieties, salt tolerant and traditionally cultivated rice varieties. Among the rice varieties studied, a scented variety Girga not joined with scented group and it formed a separate clade showing some uniqueness, however, it needs further study. A wild rice *Oryza rufipogon* formed a separate clade representing its distinctiveness. This study help in the understanding of close genetic identity between the landraces and cultivars and opens up a avenue for the use of traditional rice varieties for breeding, genome wide association mapping and conservation of rice germplasm.

SUMMARY

SUMMARY

Rice is the staple food for the people of Goa and occupies an area of about 52,191 ha, among them 34,261 ha is grown during *kharif* and remaining 17,930 ha during *rabi* season. About 90% of *kharif* and entire area of *rabi* seasons are covered under high yielding rice varieties. Due to the introduction of high yielding varieties in the State, the cultivation of local traditional varieties is being disappeared. In the present study efforts were made to collect all the traditionally cultivated and high yielding rice varieties from the state of Goa for the evaluation of grain quality characteristics, chalkiness and molecular genetic diversity.

During this study 50 rice varieties were collected from the State of Goa. Among them 28 rice varieties were traditionally cultivated by the farmers and 22 rice varieties were high yielding. All the traditional rice varieties were with unique characteristics of size, shape and colour.

Rice Grain Quality - Physical Characteristics:

The hulling percentage for 28 traditionally cultivated rice varieties were compared with high yielding varieties. Among traditionally cultivated rice varieties, hulling percentage ranged from 65.5 to 82.46%. The highest hulling percentage (82.46%) was observed in variety Ek Kadi and lowest (65.5%) in variety Kolyo. In high yielding rice varieties, hulling percentage ranged from 63.18 to 81.3%. The highest hulling percentage (81.3%) was calculated in Karjat-3 and lowest (63.18%) in variety R-6857.

The head rice recovery (HR) indicates that weight of complete caryopsis. HR was calculated for all the traditionally cultivated and high yielding rice varieties. Among the traditional rice varieties, Ghansal (77.6%) showed highest head rice recovery and lowest (44.5%) in variety Valay. In high yielding rice varieties, the highest HR (68.1%) was calculated in Jyoti and lowest (39.1%) in variety Salt Tolerant AVT-1918. Among the traditional rice varieties, lowest breakage (2.6%) was recorded in variety Kotimirsal and highest (36.3%) in Valay. In high yielding rice varieties, the percentage of broken rice (BR) grains ranged from 10.2 to 35.4%, highest in KRH-2 and lowest in Jyoti.

Grain classification was carried out based on the length/breadth (L/B) ratio. The traditional rice varieties, Assgo, Ghansal, Jiresal, Kalo Damgo, Kalo Novan, Karo Mungo, Khochro, Kolyo, Korgut, Kotimirsal, Kusago, Novan, Patni and variety Sal belonged to the categories of short bold (SB); Barik Kudi, Tamdi and Taysu fall in the category of long slender (LS); Bello, Dhave, Girga, Karz, and Muno classified into medium slender (MS); Damgo, Ek Kadi, Kalo Korgut, Kendal, Shiedi and variety Valay assigned to long bold (LB) type of grains. The high yielding rice varieties, Annapurna, IR-8 and R-6857 belonged to SB category; CSR-27, Jaya, Jyoti, KRH-2, MO-7, Sahyadri-1, Salt Tolerant AVT-1901 and Salt Tolerant AVT-1918 assigned to LS; Karjat-3 and MO-17 reached to MS category; Karjat-5 and MO-9 classified to LB and remaining all basmati varieties are categorized to extra-long slender.

The chalkiness frequency in traditional rice varieties Assgo, Bello, Damgo, Kalo Damgo, Kalo Korgut, Kalo Novan, Karo Mungo, Karz, Kendal, Khochro, Korgut, Kusago, Muno, Novan, Patni, Shiedi, Tamdi and Valay belonged to the category of present (P); Barik Kudi, Girga and Sal assigned to very occasionally present (VOP); Ek Kadi, Dhave, Jiresal, Kolyo and Taysu segregated to occasionally present (O); and variety Ghansal and Kotimirsal reached to the category of absent (A). The frequency of chalkiness in high yielding rice varieties, Annapurna, CSR-27, IR-8, Jaya, Jyoti, Karjat-3, Kasturi, KRH-2, MO-7, MO-9, MO-17, Mugadh Sugandh, R-6857 and Sahyadri-1 assigned to (P); Karjat-5 and Pusa Basmati-1 belonged to (VOP); Pusa Sugandh-3, Pusa Sugandh-5, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918 and Vasmati to the category of (O) and Pusa Sugandh-2 to (A).

The rice varieties having minimum amount of chalkiness is consider as good quality grains in comparison with chalky ones which decrease the rice grain quality. Damgo, Kusago, Kalo Korgut, Muno, MO-7, Kendal and Khochro recorded 100% chalkiness where as no chalkiness was observed in traditional rice varieties Ghansal and Kotimirsal and in high yielding rice variety Pusa Sugandh-2. The percentage of chalkiness in traditional cultivated rice varieties ranged from 10.23-93.08, highest in variety Sal and lowest in variety Barik Kudi. In high yielding rice varieties the percentage of chalkiness was found to be from 14.13-85%, minimum in variety Salt Tolerant AVT-1901 and maximum (85%) in Jyoti.

Rice Grain Quality - Chemical Characteristics:

The alkali spreading value in traditional rice varieties like Assgo, Barik Kudi, Damgo, Dhave, Kalo Korgut, Karo Mungo, Kendal, Khochro, Muno, Shiedi, Tamdi, Valay was found low; Ek Kadi, Karz, Korgut, Bello, Ghansal, Girga, Jiresal, Kalo Damgo, Kalo Novan, Kolyo, Kotimirsal, Kusago, Patni was intermediate and Novan, Sal, Taysu was high. The alkali spreading value, in high yielding rice varieties Annapurna, CSR-27, IR-8, Jyoti, KRH-2, MO-7, MO-17, Mugadh Sugandh, Sahyadri-1 was low, while Salt

Tolerant AVT-1901, Salt Tolerant AVT-1918, Karjat-3, Karjat-5, Kasturi, MO-9, Pusa Sugandh-3, Pusa Sugandh-2, R-6857 found intermediate and Jaya, Pusa Sugandh-5, Pusa Basmati-1, Vasmati was high. Based on the alkali spreading value gelatinization temperature was calculated. Low alkali spreading value means the gelatinization temperature is high (75-79°C). If intermediate alkali spreading value the gelatinization temperature is intermediate (70-74°C) and high alkali spreading value indicated that the gelatinization temperature is low (55-69°C).

The gel consistency (GC) was measured into soft, medium and hard. Among the traditional rice varieties, the length of the blue gel was highest in Sal (93 mm) and lowest (34.6 mm) in Khochro whereas in high yielding rice varieties, the length of the blue gel was highest in R-6857 (91.3 mm) and lowest (28 mm) in Pusa Basmati -1. The soft gel consistency was recorded in traditional rice varieties viz. Barik Kudi, Bello, Damgo, Girga, Jiresal, Kalo Damgo, Karo Mungo, Kendal, Kolyo, Korgut, Muno, Patni, Sal, Tamdi and Valay; the medium gel consistency was noted in varieties Assgo, Dhave, Ek Kadi, Ghansal, Kalo Korgut, Kalo Novan, Karz, Khochro, Kotimirsal, Kusago, Novan, Shiedi and Taysu. In high yielding rice varieties, the soft gel consistency was observed in varieties Annapurna, CSR-27 and IR-8; the medium gel consistency was noted in varieties Jaya, Jyoti, Karjat-3, Karjat-5, KRH-2, MO-7, Mo-9, R-6857, Sahyadri-1, Salt Tolerant AVT-1901, Salt Tolerant AVT-1918 and the hard gel consistency was recorded in the varieties Kasturi, MO-17, Mugadh Sugandh, Pusa Sugandh-3, Pusa Sugandh-2, Pusa Sugandh-5, Pusa Basmati-1 and Vasmati.

The Amylose content in traditional rice varieties ranged from 14-23.7%. The highest AC was noted in traditional rice variety Kalo Novan and lowest in variety Barik

Kudi. In high yielding rice varieties AC ranged from 17.34-27.69%, least (17.34%) amylose content in variety Karjat-5 and high (27.69%) amylose content in variety Mugadh Sugandh.

Aroma is another important trait and the aromatic rice has high demand in the market. The scented native rice varieties are Ghansal, Girga, Jiresal, Kotimirsal and Sal. Among the high yielding varieties, scented rice varieties are Kasturi, Mugadh Sugandh, Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5and Vasmati.

Rice Grain Quality - Cooking characteristics:

Volume expansion ratio and elongation ratio were calculated for traditional and high yielding rice varieties. Volume expansion ratio in traditional rice varieties ranged from 1.6 to 4.1. The maximum volume expansion was noted in variety Jiresal and minimal volume expansion ratio in variety Kalo Korgut. Volume expansion ratio in high yielding rice varieties ranged from 1.6 to 4.03. The highest volume expansion was recorded in variety KRH-2 and lowest volume expansion ratio in variety Karjat-5.

Kernel elongation ratio (ER) in traditional rice varieties ranged from 1.01-1.66. Variety Kalo Damgo showed the lowest (1.01) ER and highest (1.66) in variety Bello. ER in high yielding rice varieties ranged from 1.01 to 1.52, maximum (1.52) in variety Karjart-5and lowest (1.01) in Jyoti. Among the traditional rice varieties KLAC ranged from 6.64-10.8 mm. In traditional rice varieties the highest (10.8 mm) KLAC was recorded in Barik Kudi and lowest (6.64 mm) KLAC was recorded in variety Kotimirsal. In high yielding rice varieties, highest (14.18) KLAC was recorded in Vasmati and minimum (8.03) in variety IR-8.

In traditional rice varieties, water uptake ranged from 160-390 ml, whereas in high yielding varieties, water uptake ranged from 255-390 ml. Among traditional rice varieties the minimum water uptake was noted in variety Korgut and maximum in variety Barik Kudi. In the high yielding rice varieties maximum water uptake was calculated in variety IR-8 and minimum in variety MO-7.

The Organoleptic test were conducted for appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability for traditional cultivated and high yielding rice varieties. The best cooking quality was in varieties Tamdi, Dhave, Kendal, whereas Korgut, Khochro, Muno and Shiedi showed good grain quality characteristics. Among the scented rice varieties like Jiresal, Kotimirsal, Pusa Basmati-1, Pusa Sugandh-2, Pusa Sugandh-3, Pusa Sugandh-5, Kasturi and Vasumati with best cooking quality characteristics and consumer's preference. The results imply that three major characteristics such as amylose content, gelatinization temperature and grain shape are involved in grain quality especially these characteristics which influence the physicochemical properties like texture.

Biochemical Analysis:

Among the traditionally cultivated rice varieties, the percentage of carbohydrates ranged from 67 to 87%. Highest percentage of carbohydrate (87%) was recorded in variety Kalo Damgo and lowest (67%) in variety Bello. In high yielding rice varieties, the percentage of carbohydrate ranged from 70-85%, least (70%) of carbohydrates in varieties MO-9 and Mugadh Sugandh and high (85%) carbohydrate content in variety Jyoti.

The total protein content in traditional rice varieties ranged from 6.37-9.75%. Highest percentage of protein was noted 9.75% in variety Kalo Damgo and lower percentage of protein (6.37%) observed in variety Bello. In high yielding rice varieties, percentage of protein ranged from 6.37%. 8.75-Lower protein content was calculated in varieties CSR-27, Jaya, Karjat-5, Mugadh Sugandh, Pusa Basmati-1, Salt tolerant-1918 and Vasmati. The high protein content was noted in varieties MO-7 and R-6857.

Determination of Minerals Content by Atomic Absorption Spectrophotometer

The iron content in traditional rice varieties ranged from 5.82 to 13.25 mg/Kg, the least amount of iron content was detected in variety Girga (5.82 mg/Kg), where as the high amount (13.25 mg/Kg) of iron content was calculated in variety Kendal. In high yielding rice varieties the iron content ranged from 7.52 to 11.62 mg/Kg, least in was recorded in variety KRH-2 and highest in variety Pusa Basmati-1.

The zinc content in traditional rice varieties ranged from 13.63 to 41.66 mg/Kg, the minimum amount of zinc content was detected in variety Novan (13.63 mg/Kg), where as the maximum amount of zinc content was calculated in variety Kalo Korgut (41.66 mg/Kg). In high yielding rice varieties the zinc content ranged from 18.05 to 43.27 mg/Kg, minimum amount of zinc content was calculated in variety Salt Tolerant AVT-1918 and highest zinc content recorded in variety Pusa Basmati-1.

The calcium content in traditional rice varieties ranged from 0.02 to 0.09%, the minimum amount of calcium content was detected in varieties CSR-27, MO17, Sahaydri-1 (0.02%), where as the maximum calcium content was calculated in variety R6857 (0.09%).

In high yielding rice varieties the calcium content ranged from 0.01 to 0.09%, lowest amount of calcium was found in variety Kendal and highest content in variety Ek Kadi.

The potassium content in traditional rice varieties ranged from 0.12 to 0.46 %, the minimum amount of potassium content was detected in varieties Valay and Kolyo (0.12 %), where as the maximum amount of potassium content was calculated in varieties Muno and Taysu (0.46 %). In high yielding rice varieties the potassium content ranged from 0.14 to 0.51 %, lowest amount of potassium content was calculated in variety Sahaydri-1 and highest amount of potassium in variety Salt Tolerant AVT-1901.

Histochemical Characterization of Origin and Development of Chalkiness

Histochemical studies were carried out to understand the origin and development of chalkiness in rice grain from anthesis to maturation. Four different developmental stages of rice grains i.e. Stage-1 (5 DAF); Stage 2 (10 DAF); Stage 3 (20 DAF); Stage 4 (30 DAF) were selected for the study. The high yielding rice variety Jaya (24% chalkiness) was selected as control i.e grains with very less chalkiness. In chalky category a local rice variety Korgut (87% chalkiness), a hybrid rice variety KRH-2 (76% chalkiness) and another high yielding rice variety MO-7 (80% chalkiness) were selected to understand the origin and development of chalkiness using bright-field, fluorescence microscopy and scanning electron microscopy.

The origin and development of chalkiness in variety Jaya at 5-30 DAF revealed the normal uniform deposition starch and perfectly packed endosperm cells. In contrast, Korgut at 5 DAF showed mild patches of chalkiness as semi translucent cell structures. Then the rice grain of about 8 days after fertilization (DAF), the endosperm cells were loosely arranged in the centre of the endosperm and also in periphery. The later stage of development of about 20 DAF showed the prominent chalkiness starting from the embryo sides, extending towards centre and reaching up to the tip of the grain. The matured rice grain (30 DAF) revealed the distinct differences in packing of starch in the endosperm. The compact and uniform packing of starch granules were seen in non-chalky grains while chalky grains were with uneven and loosely packed starch granules. Chalkiness is an important quality characteristic in rice and occurs most commonly when high temperatures are experienced during grain development. The fluorescent microscopic and SEM studies further confirmed that the non chalky rice varieties with uniform arrangement of endosperm cells and endosperm cell walls and also the uniform deposition of starch with no gap between the endosperm cells and their compact arrangements. In contrast, the chalky rice grains showed the unevenly arranged endosperm cells with loosely packed starch granules.

Molecular Genetic Diversity Studies of Rice Varieties

ISSR primer analysis was carried for all 50 rice varieties from different regions of Goa with an additional salt tolerant rice variety Pokkali collected from Kerala and a wild rice *Oryza rufipogon* from Goa. Fifteen ISSR primers showed amplification of genomic DNA, with reproducible banding pattern with average of 7.33 bands per primer. In the present study, total amplified bands were 110, out of which 104 bands were polymorphic for all the rice varieties with an average of 6.93 bands per primer. The number of amplified bands ranged from 2 (ISSRA1) to 10 (1SSR-7). Polymorphic banding pattern of 100% was obtained in ten primers. It was observed in our study that AG and GA based primers were given 100% polymorphism.

During this study, ISSR primers were used to determine the identity values of all 51 rice varieties and a wild rice *Oryza rufipogon.* The genetic identity values differed from 0.5091 to 0.9727, with the average of 0.740. Among 51 rice varieties, the lowest genetic identity value (0.5091) was observed in local scented rice variety Girga and a wild rice *Oryza rufipogon.* Based on the genetic identity value, pairs have formed between Salt Tolerant AVT-1908 and Salt Tolerant AVT-1918; Ek Kadi and Dhave; Kalo Korgut and Kalo Damgo having the closest genetic identity with each other.

Dendrogram revealed the formation of four distinct clusters which distinctly separates the high yielding varieties, scented rice varieties, salt tolerant and traditionally cultivated rice varieties. The first cluster was formed by all 12 high yielding rice varieties, whereas the second cluster was formed by both traditional scented rice and high yielding scented rice varieties. The third group encompass salt tolerant rice varieties in which Pokkali is also included showing the uniqueness of the grouped rice varieties. As rice variety Pokkali also has acid tolerance, submergence tolerance in seedling stage and know to be salt tolerant variety. While, fourth cluster comprised of 17 rice varieties belonging to the traditionally cultivated rice varieties (Barik Kudi, Dhave, Ek Kadi, Bello, Karz, Kendal, Kolyo, Khochro, Patni, Tamdi, Valay, Kusago, Novan, Kalo Novan, Kalo Damgo, Sal and Taysu). Among the rice varieties studied, a scented variety Girga not joined with scented group and it formed a separate clade showing some uniqueness, however, it needs further study. A wild rice *Oryza rufipogon* formed a separate clade representing its distinctiveness.

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Grain Quality Evaluation and Organoleptic Analysis of Aromatic Rice Varieties of Goa, India

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Abstract

Rice grain quality characteristics such as physical (hulling, length and breadth (L/B), grain classification, chalkiness, chalk index), chemical (alkali spreading value (ASV), amylose content (AC), gel consistency (GC), aroma), cooking (volume expansion, elongation ratio (ER), water uptake) and organoleptic-tests based on consumer preferences like appearance, cohesiveness, tenderness on touching, chewing, taste, aroma, elongation and overall acceptability were studied for fourteen aromatic rice varieties. The higher hulling percentage was recorded in 'Ek-Kadi' (82.46%) and 'Ghansal' (80.96%). The Length/Breadth (L/B) ratio among the varieties ranged from 2.08-4.85. No chalkiness was recorded in 'Ghansal', 'Kotimirsal' and 'Pusa sugandh-2'. Among the varieties examined AC was ranged from 17.26-27.69%. The highest GC was recorded in 'Ghansal' and lowest in 'Pusa Basmati-1'. Kernel length after cooking (KLAC) ranged from 2.31-5.88 mm. Water uptake ratio was ranged from 250-350. Organoleptic-test revealed that the varieties 'Basmati local', 'Jiresal', 'Kotimirsal', 'Pusa Basmati-1', 'Pusa Sugandh-2', 'Pusa Sugandh-3', 'Pusa Sugandh-5', 'Kasturi' and 'Vasumati' were with excellent grain quality characteristics, preference and overall acceptability.

Keywords: Basmati rice, Quality, Physicochemical properties, Scented rice

1. Introduction

India is one of the largest exporters of basmati rice in the world (Husaini *et al.*, 2009). The consumers demand has increased markedly to pay a premium price for fragrant rice (Louis *et al.*, 2005). Aroma in scented rice depends on the levels of 2-acetyl-1-pyrroline content and it varies with genetic and environmental conditions (Nadaf *et al.*, 2006). Rice is the predominant food crop of Goa occupying an area of 39% (52 442 ha) of the total cultivated land in the state (Manjunath *et al.*, 2009). The kernel appearance, size, shape, aroma, nutritional value and cooking characteristics are important for judging the quality and preference of rice from one group of consumer to another (Dela Cruz and Khush, 2000; Sellappan *et al.*, 2009).

Kernel shape and L/B ratio are important features for grain quality assessment (Rita and Sarawgi, 2008). Aroma, hardness and roughness are depends on temperature and variety specific which affects the sensory properties of cooked rice (Yau and Huang, 1996). Individual preferences varied, most of the consumer's preferred imported rice but differed in their preferences for the local rice (Tomlins *et al.*, 2005).

Study Objectives/purpose

In this paper, we are presenting the finding of grain quality characteristics (physical, chemical, cooking) and organoleptic analysis of traditionally cultivated scented rice varieties of Goa in comparison with basmati rice.

2. Materials and methods

2.1 Plant material

The field survey was carried out in different parts of Goa and adjoining regions for the collection of scented rice varieties.

2.2 Physical traits

2.2.1 Hulling percentage

100 g of rice seeds were de-hulled using a standard de-husker and the average whole-grain yield was calculated (Anonymous 2004).

2.2.2 Grain Classification

Ten de-husked entire brown rice grains were measured using dial micrometer and based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB) (Anonymous 2004).

2.2.3 Chalkiness of endosperm

Milled rice was observed under a stereo-zoom microscope and based on the orientation of chalkiness, the rice grains were classified into white belly, white centre and white back (Anonymous 2004).

2.2.4 Chalk index determination

Ten de-husked rice grains were placed on light box and visually identified the grain with more than 50% of chalkiness, weighed and percentage of chalkiness was calculated (Anonymous 2004).

2.3 Chemical traits

2.3.1 Alkali spreading value (ASV) and Clearing test

Six milled rice grains were taken in Petri plates and 10 ml of 1.7% of KOH was added and kept in incubator at 27-30 °C for 23 hours. Then the alkali spreading value was calculated as low, low-intermediate, intermediate or high (Perez and Juliano, 1978).

2.3.2 Amylose content (AC)

To 100 mg of rice flour 1 ml of 95% ethanol and 9 ml of 1.0 N NaOH was added. This was mixed well and heated in a boiling water-bath for 10 min. Samples were diluted to 100 ml with distilled water. From this suspension, 5 ml of sample was taken and 1 ml of acetic acid (57.75 ml in one liter water) was added to acidify the sample along with 1.5 ml of iodine solution (0.2% iodine + 2% potassium iodide) and the volume was made to 100 ml with distilled water. The samples were incubated at room temperature for 20 min. The absorbance was measured at 620 nm using spectrophotometer. As a control, NaOH solution was used. The AC of different varieties was calculated in comparison with standard graph (Perez and Juliano, 1978).

2.3.3 Gel consistency (GC)

100 mg of rice flour was taken in test tube (2×19.5 cm), 0.2 ml of ethanol containing 0.25% thymol blue and 2.0 ml of 0.2 N of KOH were added and kept in boiling water-bath for 8 min, cooled, mixed well and kept in ice bath for 20 min. Later the test tubes were laid horizontally for one hour and measurements were made using graph paper. The degree of disintegration of kernel was evaluated using a 7 point scale (Bhattacharya, 1979).

2.3.4 Aroma

To 5 g of rice 15 ml of water was added, soaked for 10 min and cooked for 15 min, transferred into a Petri dish and placed in refrigerator for 20 min. Then the cooked rice was smelled by a random panel: strongly scented (SS); mild scented (MS); non scented (NS) (Anonymous, 2004).

2.4 Cooking characteristics

2.4.1 Volume expansion ratio (VER) and elongation ratio (ER)

15 ml of water was taken in 50 ml graduated centrifuge tubes and 5 g of rice sample was added. Initial volume increase was measured (Y) and soaked for 10 min. Then increase in volume before cooking was noted (Y-15). Rice samples were cooked for 20 min in a water bath. Cooked rice was placed on bloating paper. Ten cooked rice kernels were selected (intact at both ends) and length of the kernels measured using graph paper for computing the kernel length after cooking (KLAC). Then the cooked rice was placed in 50 ml water taken in 100 ml measuring cylinder and increase in volume of cooked rice in 50 ml of water was measured (X). Then the volume raise was recorded (X-50). VER and ER were calculated (Anonymous, 2004).

2.4.2 Water Uptake

2 g of samples were taken in graduated test tubes with 10 ml of water and soaked for 30 min. As a control 10 ml of water was taken in 2-3 test tubes. All the test tubes were kept in water-bath for 45 min at 77 to 80 °C. After cooling, the supernatant of the samples were poured into graduated measuring cylinder and water level was noted. Similarly control water was measured. Then water uptake was calculated as 100/2 g × actual water absorbed (Anonymous, 2004).

2.5 Organoleptic test

To 5 g of rice samples 15 ml of water were added and soaked for 10 min. Rice samples were cooked in water bath for 15 min and scored as per panel test performance (Anonymous, 2004).

2.6 Statistical analysis

All the experiments were carried out using three replicates. The data were analyzed by using a statistical software WASP-2.0.

3. Results and discussion

3.1 Physical characteristics

The hulling percentage for traditionally cultivated scented and basmati rice varieties ranged from 72-82 (Table 1). The highest hulling (82.4%) was noted in variety 'Ek-Kadi' and lowest in 'Basmati local' and 'Kasturi' (72%), whereas intermediate value was recorded in 'Pusa Sugandh-2' (77.4%). High hulling percentage resulted in higher head rice yield of 93.3% in parboiled rice with the higher (5.5 x 104 N/m2) process steam pressure (Igbeka *et al.*, 2008). Rita and Sarawgi (2008) reported that the more than 80 value of hulling percentage is preferred and if the hulling percentage increases the head rice recovery also increased. Irregular cracks are caused in rice by hot-air drying but wetting of paddy tended to get healed upon long soaking (Swamy *et al.*, 2009).

Among the varieties studied, the L/B ratio ranged from 2.0-4.8. The variety 'Pusa Basmati-1' recorded the highest L/B ratio and least was found in 'Jiresal'. The L/B ratio among basmati varieties ranged from 4.34 to 4.85, lowest in 'Pusa Sugandh-3'. Based on the L/B ratio, the collected rice varieties were classified into five different categories: 'Basmati local' (long slender), 'Ek-kadi' (long bold), 'Ghansal', 'Jiresal', 'Kotimirsal' (short bold), 'Girga', 'Masuri' (medium slender) and all the basmati rice varieties to the category of extra long slender grains (Table 2). Bhattacharjee and Kulkarni, 2000 analyzed some preferred brands of basmati rice and reported that the L/B ratio ranged from 4.47-4.81.

The chalkiness of the rice grain was classified into white belly, white centre and white back. Among the rice varieties examined, the chalkiness was absent in varieties 'Ghansal', 'Kotimirsal' and 'Pusa Sugandh-2'. The varieties such as 'Basmati local', 'Ek-Kadi' and 'Pusa Sugandh-3' and 'Pusa Sugandh-5', chalkiness were occasionally present whereas in 'Girga', 'Masuri' and 'Pusa Basmati-1' chalkiness were very occasionally present (Table 2). The chalky area more than 20% was observed in 'Mugada Sugandh' and 'Kasturi'. The percentage of chalkiness in all the varieties studied ranged from 13.8-64.36. The highest chalkiness was recorded in varieties 'Mugadh Sugandh' (31.26) and 'Ek-Kadi' (64.36). 'Basmati local', 'Ek-Kadi', 'Jiresal', 'Pusa Basmati-1', 'Pusa Sugandh-5', 'Mugadh Sugandh', 'Kasturi' and 'Vasumati' have white belly type of chalkiness. White centre was observed in 'Girga', 'Masuri' and 'Pusa Sugandh-3'. The chalky grains reduce the palatability of cooked products, thus the presence of more than 20% chalkiness in rice kernels is not acceptable in world markets (Cheng *et al.*, 2005).

3.2 Chemical characters

The alkali spreading value (ASV) and gelatinization temperature (GT) were calculated for all the rice varieties examined. The low ASV and high GT were detected in 'Basmati local' and 'Mugadh Sugandh'. The intermediate ASV and GT were noted in varieties such as 'Ghansal', 'Girga', 'Jiresal', 'Kotimirsal', 'Pusa Sugandh-2', 'Pusa Sugandh-3' and 'Kasturi'. The high ASV and low GT were recorded in high yielding varieties viz. 'Pusa Basmati-1', 'Pusa Sugandh-5' and 'Vasumati', whereas low-intermediate ASV and high-intermediate GT was observed in traditional scented rice variety 'Ek-Kadi' (Table 3). Cooking time of the rice depends on coarseness of the grain. The intermediate ASV indicated the medium disintegration and classified as intermediate GT which highly desirable for quality grain (Bansal *et al.*, 2006).

The rice varieties were examined for amylose content (AC) and classified as waxy, very low, low, intermediate and high AC. Among the varieties studied, AC ranged from 17.26-27.69%. The lowest level of AC was recorded in 'Kotimirsal', whereas highest in 'Mugadh Sugandh'. Most of the traditional aromatic varieties showed low

AC content in comparison with basmati rice varieties (Table 3). Shahidullah *et al.*, 2009 reported that the AC in all grades of rice ranged between 20.7-21.4%. Cooked rice becomes moist and sticky due to low AC. Amylose and amylopectin in kernels determine the texture of cooked rice and consumers prefer rice with intermediate AC.

The gel consistency (GC) was measured into soft, medium and hard. The GC of the rice samples ranged from 65-70 mm and categorized as soft, this means the tendency of cooked rice to be soft on cooling. The length of the blue gel was high in aromatic traditionally cultivated rice varieties 'Girga' 20.46 mm and lowest in 'Kotimirsal' 17.26 mm. In basmati rice 'Mugadh Sugandh' recorded high 27.69 mm and the lowest in 'Kasturi' 21.83 mm (Table 3). Amylose content, starch, gel consistency and non-reducing sugar content decrease with elevated temperature (Pandey *et al.*, 2007).

Aroma is an important trait, has high demand in the global market. The native varieties studied during this investigation showed the presence of aroma, for which these varieties are preferred by local people for consumption. Mild aroma was detected in varieties like 'Basmati local', 'Ek-Kadi' and 'Mugadh Sugandh'. 'Ghansal', 'Jiresal', 'Pusa Sugandh-5', 'Kasturi'and 'Vasumati' were more scented than other varieties. The strong aroma was detected in 'Pusa Basmati-1', 'Pusa Sugandh-2' and 'Pusa Sugandh-5' (Table 3). Nadaf *et al.*, 2006 reported that Basmati rice contains more aroma than the traditionally cultivated scented rice varieties.

3.3 Cooking characteristics

The volume expansion ratio (VER) in aromatic traditional rice varieties ranged from 2.36-4.10, while in basmati varieties 2.73-3.63. 'Pusa Sugandh-5' showed the VER 3.63 and 'Mugadh Sugandh' with 2.73 (Table 4). It was reported that lower VER is preferred by the consumers than higher VER, on the other hand, higher elongation ratio (ER) of the cooked rice is preferred than lower ER (Shahidullah *et al.*, 2009). Kernel length after cooking (KLAC) ranged from 2.31-3.76 mm in aromatic traditionally cultivated rice and 4.62-5.88 mm in basmati rice. Minimum KLAC was observed in 'Kotimirsal' and 'Basmati local'. Kernel elongation ratio (ER) in aromatic traditional rice ranged from 1.01-1.42 and basmati rice ranged from 1.02-1.12. Highest kernel ER was observed in 'Ghansal' and lowest in 'Masuri' (Table 4).

In basmati varieties, water uptake ratio ranged from 280-335 and in aromatic traditional rice varieties 250-350. Among the traditional rice varieties, 'Ek-Kadi' recorded the highest water uptake ratio and minimum in 'Masuri' (Fig.1). The amount of water uptake during cooking process is associated with the appearance of cooked rice (Tan *et al.*, 2000).

3.4 The Organoleptic Analysis

The organoleptic-test was conducted for the appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability of cooked rice and evaluated by trained assessors using the above descriptive analysis in a control panels. Sensory specifications are those that can be used to check if a product complies with the stated requirements Costell 2002. The excellent overall acceptability characters were recorded in 'Basmati local', 'Jiresal', 'Kotimirsal', 'Pusa Basmati-1', 'Pusa Sugandh-2', 'Pusa Sugandh-3', 'Pusa Sugandh-5', 'Kasturi' and 'Vasumati'. The good overall acceptability was observed in varieties 'Ek-Kadi', 'Ghansal', 'Girga', 'Masuri' and 'Mugadh Sugandh' (Table 5).

4. Conclusions

The paper has concentrated on the physical, chemical, cooking characteristics and organoleptic test with consumer preferences of traditionally cultivated scented and basmati rice varieties. Among the varieties studied traditionally cultivated aromatic rice 'Ek-Kadi' and 'Ghansal' showed maximum hulling percentage. The AC, ASV and GC were excellent in 'Girga', 'Ek-Kadi', 'Mugadh Sugandh', 'Pusa Basmati-1' and 'Pusa Sugandh-3'. The study revealed that the rice varieties viz. 'Basmati local', 'Jiresal', 'Kotimirsal', 'Pusa Basmati-1', 'Pusa Sugandh-2', 'Pusa Sugandh-3', 'Pusa Sugandh-5', 'Kasturi' and 'Vasumati' with best cooking quality characteristics and consumer's preference. Organoleptic analysis always helps the consumers to select better rice varieties for their consumption and use. It is also emphasized that the training and recruiting the sensory expert panel are important in the process of sensory analysis and organoleptic test (Lefebvre *et al.*, 2010). The present study revealed that some of the indigenous aromatic rice varieties have potential for consumer's preferences and it could be used for breeding programmes and biotechnological research for the improvement of valuable grain quality traits.

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Table 1. The hulling percentage, L/B ratio and grain classification of aromatic traditionally cultivated and basmati rice varieties

Sl. No.	Varieties	Place of collection	Mean Hulling %	Mean L/B ratio	Grain Classification
1	Basmati local	Guirim	72.73±1.62^{f}	3.16±0.04^{f}	Long Slender
2	Ek-Kadi	Junuswada	82.46±1.20^{a}	2.86±0.05^{g}	Long Bold
3	Ghansal	Ajara	80.96±1.96^{ab}	2.16±0.01^{i}	Short Bold
4	Girga	Ajara	79.96±0.32^{bc}	2.74±0.03^{h}	Medium Slender
5	Jiresal	Borim	77.73±2.25^{d}	2.08±0.08^{j}	Short Bold
6	Kotimirsal	Savodam	77.86±2.32^{cd}	2.16±0.01^{i}	Short Bold
7	Masuri	Molem	79.90±1.60^{bc}	2.92±0.02^{g}	Medium Slender
8	Pusa Basmati-1	ICAR	73.40±0.3^{f}	4.85±0.04^{a}	Extra-long slender
9	Pusa Sugandh-2	ICAR	77.46±0.66^{d}	4.43±0.04^{d}	Extra-long slender
10	Pusa Sugandh-3	ICAR	72.50±0.4^{f}	4.34±0.05^{e}	Extra-long slender
11	Pusa Sugandh-5	ICAR	76.46±0.40^{de}	4.50±0.01^{c}	Extra-long slender
12	Mugadh Sugandh	ICAR	76.26±0.11^{de}	4.77±0.06^{b}	Extra-long slender
13	Kasturi	ICAR	72.46±0.45^{f}	4.53±0.04^{c}	Extra-long slender
14	Vasumati	ICAR	74.36±0.47^{ef}	4.46±0.06^{cd}	Extra-long slender

Superscript letters (a-j) indicate significant differences ($p < 0.05$) among different rice varieties. Means with same letter within column are not significantly different ($p < 0.05$), means ± SD.

Table 2. The chalkiness frequency, kernel area of chalkiness, type and percentage of chalkiness in aromatic rice varieties

Sl. No.	Varieties	Frequency	Kernel area (Extent)	Type	Chalkiness %
1	Basmati local	OC	Medium (11% to 20%)	White belly	34.90±2.35^{b}
2	Ek-Kadi	OC	Medium (11% to 20%)	White belly	64.36±2.20^{a}
3	Ghansal	A	None	ND	0.000±0^{h}
4	Girga	VOP	Small (less than 10%)	White centre	10.86±3.09 ^{g}
5	Jiresal	OC	Medium (11% to 20%)	White belly	16.20±0.9^{f}
6	Kotimirsal	A	None	ND	0.000±0^{h}
7	Masuri	VOP	Small (less than 10%)	White centre	13.83±1.50^{f}
8	Pusa Basmati-1	VOP	Small (less than 10%)	White belly	15.30±0.36^{f}
9	Pusa Sugandh-2	A	None	ND	0.000±0^{h}
10	Pusa Sugandh-3	OC	Medium (11% to 20%)	White centre	27.33±1.06^{d}
11	Pusa Sugandh-5	OC	Medium (11% to 20%)	White belly	24.16±0.80^{e}
12	Mugadh Sugandh	P	Long (more than 20%)	White belly	31.26±1.11^{c}
13	Kasturi	P	Long (more than 20%)	White belly	27.30±1.15^{d}
14	Vasumati	OC	Medium (11% to 20%)	White belly	14.43±1.16^{f}

Superscript letters (a-h) indicate significant differences ($p < 0.05$) among different rice varieties. Means with same letter within column are not significantly different ($p < 0.05$), means ± SD, VOP, very occasionally present; OC, occasionally present; P, present; ND, not detected.

Table 3. The alkali spreading value (ASV), gelatinization temperature (GT), amylose content (AC), gel consistency (GC) and aroma in aromatic traditionally cultivated and basmati rice varieties

Sl. No	varieties	ASV	GT	AC	Length of blue gel	GC	Aroma
1	Basmati local	L	H>74 °C	18.31 ± 0.93^{ef}	43 ± 3.60^{c}	Medium	M
2	Ek-Kadi	LI	HI	20.36 ± 0.72^{cd}	55 ± 3^{b}	Medium	M
3	Ghansal	I	I (70-74 °C)	18.7 ± 1.25^{def}	63 ± 3.60^{a}	Medium	O
4	Girga	I	I (70-74 °C)	20.46 ± 0.47^{bcd}	62.3 ± 2.51^{a}	Soft	OTB
5	Jiresal	I	I (70-74 °C)	18.05 ± 2.20^{ef}	62.6 ± 2.51^{a}	Soft	O
6	Kotimirsal	I	I (70-74 °C)	17.26 ± 1.05^{f}	54.6 ± 2.51^{b}	Medium	OTB
7	Masuri	I	I (70-74 °C)	19.40 ± 0.96^{de}	62.6 ± 0.57^{a}	Soft	OTB
8	Pusa Basmati-1	H	L(55-69 °C)	26.43 ± 1.68^{a}	28.0 ± 1^{e}	Hard	S
9	Pusa Sugandh-2	I	I (70-74 °C)	25.84 ± 0.82^{a}	32.6 ± 2.08^{de}	Hard	S
10	Pusa Sugandh-3	I	I (70-74 °C)	26.42 ± 0.50^{a}	33.3 ± 3.51^{de}	Hard	S
11	Pusa Sugandh-5	H	L(55-69 °C)	25.83 ± 0.33^{a}	31.0 ± 1^{de}	Hard	O
12	Mugadh Sugandh	L	H>74 °C	27.69 ± 1.48^{a}	29.3 ± 2.08^{de}	Hard	M
13	Kasturi	I	I (70-74 °C)	21.83 ± 0.70^{bc}	33.6 ± 5.85^{d}	Hard	O
14	Vasumati	H	L(55-69 °C)	22.34 ± 1.12^{b}	33.6 ± 1.52^{d}	Hard	O

Superscript letters (a-f) indicate significant differences ($p < 0.05$) among different rice varieties. Means with same letter within the column are not significantly different ($p < 0.05$), means ± SD, L, Low; I, Intermediate; LI, Low-intermediate; H, High; HI, High-intermediate; M, mild; O, optimal; S, strong; OTB, other than basmati.

Table 4. The volume expansion ratio, kernel length after cooking, kernel elongation ratio and water uptake in aromatic traditionally cultivated and basmati rice varieties

Sl. No.	Varieties	Volume Expansion	Kernel length after cooking	Elongation ratio
1	Basmati local	3.63 ± 0.05^{b}	3.76 ± 0.04^{d}	1.18 ± 0.04^{b}
2	Ek-Kadi	2.36 ± 0.15^{f}	$3.20\pm0.03d^{e}$	1.10 ± 0.02^{cd}
3	Ghansal	3.56 ± 0.15^{b}	$3.08\pm0.08d^{ef}$	1.42 ± 0.03^{a}
4	Girga	4.03 ± 0.05^{a}	2.94 ± 0.04^{ef}	1.06 ± 0.04^{def}
5	Jiresal	4.10 ± 0.1^{a}	2.56 ± 0.06^{ef}	1.22 ± 0.08^{b}
6	Kotimirsal	3.56 ± 0.05^{b}	2.31 ± 0.01^{f}	1.06 ± 0.01^{def}
7	Masuri	4.06 ± 0.11^{a}	2.98 ± 0.01^{ef}	1.01 ± 0.04^{g}
8	Pusa Basmati-1	3.06 ± 0.11^{d}	5.49 ± 0.03^{ab}	1.12 ± 0.02^{c}
9	Pusa Sugandh-2	3.00 ± 0^{d}	4.62 ± 0.04^{c}	1.04 ± 0.01^{efg}
10	Pusa Sugandh-3	3.13 ± 0.05^{d}	$4.81\pm0.01b^{c}$	1.10 ± 0.01^{cd}
11	Pusa Sugandh-5	3.63 ± 0.05^{b}	$4.73\pm0.05b^{c}$	1.04 ± 0.01^{efg}
12	Mugadh Sugandh	2.73 ± 0.11^{e}	$4.93\pm0.04b^{c}$	1.03 ± 0.01^{fg}
13	Kasturi	3.3 ± 0.1^{c}	4.68 ± 0.03^{c}	1.02 ± 0.04^{fg}
14	Vasumati	3.6 ± 0.05^{b}	5.88 ± 1.73^{a}	1.08 ± 0.01^{cde}

Superscript letters (a-g) indicate significant differences ($p < 0.05$) among different rice varieties. Means with same letter within column are not significantly different ($p < 0.05$), means ± SD.

Table 5. Organoleptic analysis of aromatic traditionally cultivated and basmati rice varieties

	Characteristics	Rice Varieties													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	**Appearance**														
5	White														+
4	Creamish white/ brown		+	+	+	+	+	+		+	+		+		
3	Red streaks														
2	White with brown streaks	+							+			+		+	
1	White with black streaks														
B	**Cohesiveness**														
5	Well separated		+	+	+		+	+	+	+	+	+	+		+
4	Partially separated	+				+								+	
3	Slightly separated														
2	Moderately separated														
1	Very sticky														
C	**Tenderness on touching**														
5	Soft					+									
4	Moderately soft	+	+					+	+					+	
3	Moderately hard									+	+	+			
2	Hard			+	+		+						+		+
1	Very soft														
D	**Tenderness on chewing**														
5	Soft		+			+			+						
4	Moderately soft	+					+	+			+	+		+	
3	Moderately hard									+					+
2	Hard			+	+								+		
1	Very soft														
E	**Taste**														
4	Good	+	+			+	+	+		+	+	+		+	+
3	Desirable			+	+				+				+		
2	Tasteless														
1	undesirable														
F	**Aroma**														
5	Strong								+	+	+				
4	Optimal	+										+		+	+
3	Mild		+	+	+	+	+						+		
2	Other than basmati							+							
1	No scent														
G	**Elongation**														
4	Excellent														
3	Good	+			+				+	+	+	+	+	+	
2	Moderate		+	+		+	+	+							+
1	None														
H	**Overall acceptability**														
4	Excellent	+				+	+		+	+	+	+		+	+
3	Good		+	+	+			+					+		
2	Acceptable														

1-'Basmati local', 2-'Ek-Kadi', 3-'Ghansal', 4-'Girga', 5-'Jiresal', 6-'Kotimirsal', 7-'Masuri', 8-'Pusa Basmati-1', 9-'Pusa Sugandh-2', 10-'Pusa Sugandh-3', 11-'Pusa Sugandh-5', 12-'Mugadh Sugandh', 13-'Kasturi', 14-'Vasumati'.

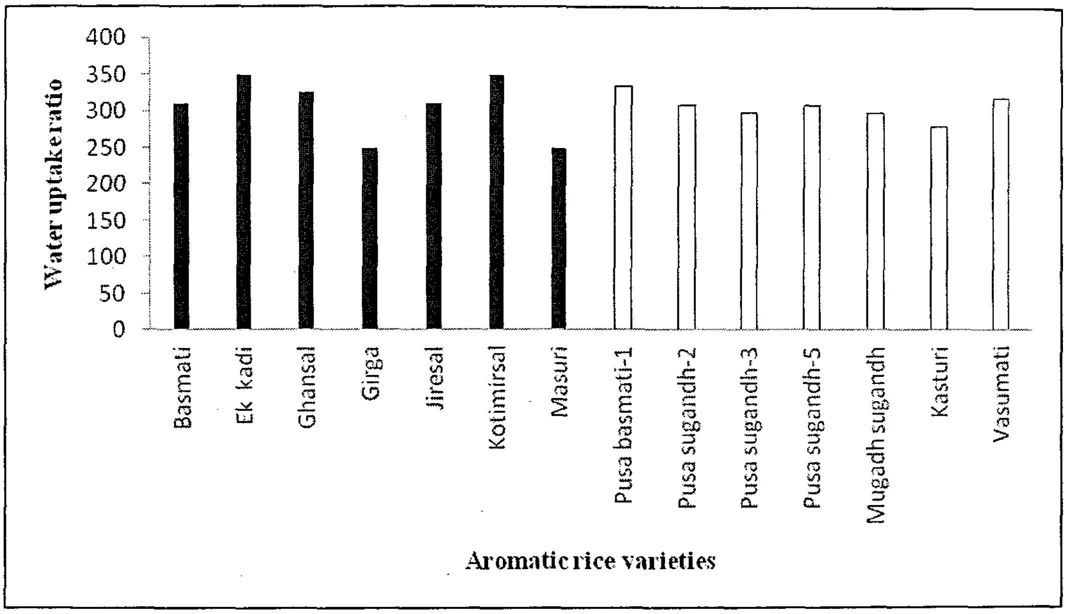

Figure 1. Water uptake in aromatic traditionally cultivated and basmati rice varieties

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AGRICULTURE

GRAIN QUALITY EVALUATION OF TRADITIONALLY CULTIVATED RICE VARIETIES OF GOA, INDIA

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Abstract

The physicochemical characteristics such as physical (hulling, head rice recovery (HR), broken rice (BR), grain classification, chalkiness), chemical (alkali spreading value, amylose content (AC), gel consistency (GC), aroma) and cooking characteristics (volume expansion, elongation ratio, water uptake) were studied for 22 traditionally cultivated rice varieties from Goa, in comparison with high yielding rice varieties Jaya, Jyoti and IR8. The hulling percentage ranged from 63-81% and HR recovery from 45-74%. Among the varieties Length/Breath ratio ranged from 1.5-3.5 and the AC ranged from 14-25%. The lowest percentage of chalkiness was recorded in variety Barik Kudi. Highest GC was recorded in variety Salsi and lowest in Khochro. The kernel elongation ratio ranged from 4.78-1.83 mm and water uptake ratio ranged from 160-390. Some of traditionally cultivated rice varieties are with excellent grain quality characteristics. The rice variety korgut which predominantly grown in khazan lands could be used in breeding programmes to develop high saline varieties.

Keywords: Amylose content, Grain quality, Physicochemical characteristics, Traditional rice varieties

Introduction

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population. About 90% of the world's rice is grown and consumed in Asia [1]. Rice is an economically important food crop with nutritional diversification and helps in poverty alleviation [2]. Rice is ranked as the world's number one human food crop [3].

Rice is the predominantly cultivated food crop of Goa occupying total cultivated area of 39% (52,442 ha) in the state. Grain quality of rice is determined by the factors such as grain appearance, nutritional valve, cooking and eating quality [4]. Specialty rice is a term used to distinguish cultivars of rice that have unique properties like flavor, color, nutrition and chemical composition [5].

The physicochemical characteristics include grain length (L), grain breadth (B), L/B ratio, hulling and milling percentage. The cooking qualities are AC, alkali spreading value, water uptake, volume expansion ratio and kernel elongation ratio. Grain quality is a very wide area encompassing diverse characters that are directly or indirectly related to exhibit one quality type [6]. Different cultivars showed significant variations in morphological, physicochemical and cooking properties [7]. The gelatinization temperature (GT), gel consistency (GC) and amylose content (AC) are major rice traits, which are directly related to cooking and eating quality [8]. On the other hand AC, amylopectin structure and protein composition explained the difference in cooking quality of rice [9].

The cooking quality of rice was determined on the basis of physicochemical properties and AC [10]. Cooked rice is composite food consist of different biopolymers, including starch and proteins along with moisture as plasticizer [11]. GT is responsible for cooking time, water absorption and the temperature at which starch irreversibly loses its crystalline order during cooking. The GC is responsible for softness and the AC for texture of cooked rice [12]. Today, the consumers prefer to eat unpolished rice especially traditional rice because of the nutrient value in the bran and their reputation for nutritional excellence. Therefore the demands for brown and parboiled rice are increasing among the populations [13]. In the present study we have evaluated the rice grain quality characteristics (physical, chemical and cooking) of traditionally cultivated rice varieties of Goa in comparison with conventionally breeded rice varieties.

Materials and Methods

Plant materials

The field survey was carried out at different parts of Goa, for the collection of rice varieties. The rice seeds were dried and stored at 4°C for grain quality studies.

Physical traits

Brown rice (BR) yield

Hundred grams of rough rice seeds were de-hulled using a standard dehusker and the average whole-grain BR yield was determined [14].

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Head rice recovery (HR)

Hundred grams of de-hulled rice grains that had no visible breakage and ¾ size grains were used to determine the head rice recovery. The percentage of HR and broken rice were calculated using the standard formula [14].

Grain classification

De-husked brown rice was used for computing the grain shape and size. Minimum of 10 full grains per replication were measured using dial micrometer and L/B ratio was calculated. Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB) [14].

Chalkiness of endosperm

The degree of chalkiness was determined using milled rice by observing under stereo-zoom microscope. Based on the observation the chalkiness of the endosperm was classified into white belly, white centre and white back [14].

Chalk index determination

Ten de-husked rice grains were placed on light box and visually identified the grain with more than 50% of chalkiness, weighed and percentage of chalkiness was calculated [14].

Chemical traits

Alkali Spreading and Clearing test

Six milled rice were taken in Petri plates and 10 mL of potassium hydroxide (19.54 g of potassium hydroxide dissolve in one liter) was added to the sample. Samples were kept undisturbed for 23 hours in an incubator at 27-30°C [15].

Amylose content (AC)

Hundred mg of rice flour was placed in 100 mL volumetric flasks and added 1 mL of 95% v/v ethanol. Then 9 mL of 40 g NaOH dissolved in one liter was added and heated in a boiling water bath for 10 min. Samples were diluted to 100 mL with distilled water. Later, 5 mL of sample suspension was added to 50 mL of distilled water in a 100 mL of flask and 1 mL of acetic acid (57.75 mL in one liter water) was added to acidify the sample along with 1.5 mL of iodine solution (0.2 percent w/v iodine in 2% potassium iodide). Distilled water was added to make the volume of 100 mL and the suspension was mixed well and kept for 20 min. As a control, NaOH solution was used for the calibration of spectrophotometer and samples were measured at 620 nm. Samples with known values of high, medium and low AC were used to draw the standard AC curve. The AC of different varieties was calculated in comparison with standard graph [16&17].

Gel consistency (GC)

Milled rice was ground to a fine powder using mortar & pestle and sieved with 1 mm sieve. 100 mg of rice flour was taken in long test tube (2×19.5 cm) and added 0.2 mL of ethanol containing 0.25% thymol blue and 2.0 mL of 2.8 g of KOH in 250 mL distilled water was added and mixed well using vortex mixture, kept in boiling water bath for 8 min, cooled for 5 min, mixed and kept in ice bath for 20 min. Later tubes were removed, laid horizontally for one hour and measurements were made using graph paper. The degree of disintegration and the transparency of paste dissolved out of the kernels were evaluated using a 7 point scale [8&18].

Aroma

To 5 g of rice 15 ml of water was added, soaked for 10 min and cooked for 15 min, transferred into a Petri dish and placed in refrigerator for 20 min. Then the cooked rice was smelled by a random panel: strongly scented (SS); mild scented (MS); non-scented (NS) [19].

Cooking characteristics

Volume expansion ratio and elongation ratio

15 mL of water was taken in 50 mL graduated centrifuge tubes and 5 g of rice sample was added. Then initially increase in volume after adding 5 g of rice was measured (Y) and soaked for 10 min. Increase of volume before cooking was noted (Y-15). Rice samples were cooked for 20 min on a water bath and placed on bloating paper. Ten cooked rice kernels were selected (intact at both ends) and length of the kernels measured using graph paper for computing the kernel length after cooking (KLAC). Then all the 5 g of cooked rice were placed in 50 mL water taken in 100 mL measuring cylinder and increase in volume of cooked rice in 50 mL of water was measured (X). Later, the volume raise was recorded (X-50). Then volume expansion ratio and elongation ratio were calculated [20].

Water uptake

2 g of samples were taken in graduated test tubes with 10 mL of water and soaked for 30 min. Boiled for 45 min at 77 to 80°C in a constant temperature water bath. 2-3 test tubes were kept with 10 mL of water as control in the water bath without rice grains. Immediately the tubes were placed in a beaker containing cold water for cooling. The supernatant were poured into graduated cylinder after cooling and note the water level. Water uptake was calculated using the following formula: Water uptake = 100 /2 g × actual water absorbed [21].

Organoleptic test

5 g rice samples were taken in a test tube, 15 mL of water added and soaked for 10 min. Rice samples were cooked in water bath for 15 min and transferred into a Petri dish and scored as per panel test performance [21].

Statistical analysis

Experiments were carried out using three replicates. The data was statistically analyzed using WASP-Web Agri Stat Package 2.0.

Results and Discussion

During this study we have collected 22 traditionally cultivated rice varieties which are unique in their morphological characters of shape, size and color. Most of these traditional rice varieties are found only in Goa region and cultivated in small patches. Out of 22 rice varieties collected, some of the varieties such as Bello, Chudi, Dodga, Khochro and Ner cultivation are becoming rare, if these varieties are not preserved, they may become extinct in due course of time since high yielding rice varieties such as Jaya and Jyoti are predominantly cultivated in the state of Goa. The only rice variety Korgut is still popularly cultivated in khazan lands of Goa due to its high salinity tolerance. Due to the introduction of high yielding rice varieties, the local germplasm and their genetic diversity are being eroded. The collection, documentation, characterization of germplasm is important for utilizing the appropriate attribute based donors in breeding programmes and essential for protecting the unique rice varieties [22].

Physical characteristics

The de-hulling of rice is one of the important post harvest processes. If the hulling percentage is high, then the recovery of rice is also increased. The hulling percentage for 22 traditionally cultivated rice varieties were compared with high yielding varieties Jaya, Jyoti and IR8 (Table 1). Among traditionally cultivated rice varieties, hulling percentage ranged from 63 to 81%. The highest hulling percentage (80.8%) was observed in variety Vadlo kenal and lowest in Dodga (63.1%), whereas Jaya recorded 80.5% and Jyoti (78.3%). The eighty percent or more are the desirable hulling characteristics for rice [22]. The head rice recovery (HR) indicates that weight of whole grains obtained after industrial processing. For quality evaluation, HR recovery is one of the most important characters and more than 65% of HR recovery is desirable. HR is the proportion of the intact grain in the milled rice. HR value ranged from 45-74% in all the rice varieties evaluated during this study. The rice varieties Khochro and Novan showed highest head rice recovery among the traditional rice varieties and lowest in Vadlo Kenal (44.5%), but it is not significant with the variety Barik Kudi (44.9%). HR in Jyoti recorded above 68%. When compared to conventionally breeded rice varieties, the traditional rice varieties recorded higher HR value and showed significant differences (Table 1). It was reported that the quality rice variety should have HR value at least 70%. HR value depends on the grain type, chalkiness, cultivation practices and drying condition [23]. In high yielding rice varieties, the percentage of broken rice (BR) grains ranged from 5.3 to 36.3. Among the traditional rice varieties, lowest breakage was recorded in variety Novan and highest in variety Vadlo Kenal. However, no significant differences were observed for the varieties Revati and Khoncho. In high yielding varieties the BR grains ranged from 10.2-23.16%.

Among the rice varieties studied, the L/B ratio ranged from 1.5-3.5. The traditional rice variety Tamde Jyoti recorded the highest L/B ratio and lowest in Novan. The L/B ratio in high yielding varieties ranged from 2.10 to 3.31 (Table 1). The grain size and shape of most high yielding rice varieties is short to medium bold with translucent appearance [24]. To gain and maintain the optimum milling rice grain quality, rice must be harvested at proper moisture content and should be dried carefully up to 14% moisture level [23]. During this investigation, rice grains were classified into four different categories, eight varieties belongs to short bold, four varieties as long slender, eight varieties as long bold and five varieties as medium slender grains (Table 1).

Chalkiness in endosperm was classified into white belly, white centre and white back based on the position and orientation of chalkiness. The rice varieties having minimum amount of chalkiness is consider as good quality grains in comparison with chalky once which decrease the rice grain quality. In variety Dhave the chalkiness is occasionally present whereas in variety Barik Kudi the chalkiness is very occasionally present. The varieties such as Damgo, Kendal and Khochro recorded 100% chalkiness and least amount was observed in variety Barik Kudi (Table 2). When compared to traditional rice varieties, in high yielding varieties the chalkiness found to be less and ranged from 24.1-85%. Among the varieties studied, white belly type of chalkiness was found to be dominant and it is recorded in eighteen rice varieties. White centre type of chalkiness was observed in varieties such as Barik Kudi, Dodga, Irtal, Kalo Novan, Ner, IR8 and Jaya. Grain shape and endosperm opacity are major attributes that determine the appearance quality. The greater amount of chalkiness in the grain indicates that it is more prone to grain breakage during milling, which results in lower HR recovery [25].

Table 1. The hulling percentage, HR recovery, brown rice, L/B ratio and Grain classification of traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Mean Hulling (%)	Mean Head rice recovery	Mean Broken rice	Mean L/B ratio	Grain Classification
1	Annapurna	74.16±0.75f	51.5±0.46l	22.6±1.17efgh	2.38±0fghi	LB
2	Atthavis	77.23±0.05bcde	52.6±1.16jkl	24.6±1.21de	2.70±0de	LB
3	Barik Kudi	77.03±1.26bcde	44.9±1.51n	32.0±0.72b	3.43±0ab	LS
4	Bello	73.26±0.96fg	47.1±0.75m	26.1±0.30cd	2.86±0.05cd	MS
5	Chudi	76.36±1.15de	54.8±0.60i	21.5±1.75fgh	2.70±0.1de	LB
6	Damgo	77.43±1.36bcde	67.0±0.40c	10.3±1.74jkl	2.26±0.20ghi	LB
7	Dhave	72.40±0.75g	59.6±0.40g	14.5±2.39i	2.46±0.20efgh	MS
8	Dodga	63.16±1.05i	62.2±1.10f	11.9±1.70jk	2.26±0.15ghi	SB
9	Irtal	65.50±1.31h	57.7±0.55h	7.7±1.44mn	2.40±0.26efghi	SB
10	Kala Novan	78.13±0.90bc	51.2±0.95l	26.9±1.61c	2.51±0.17efgh	SB
11	Karz	76.10±1.66e	63.9±0.62e	12.2±2.00jk	2.65±0.18def	MS
12	Kenal	74.36±0.96f	65.4±1.30d	8.9±2.26lm	2.24±0.09hi	LB
13	Kendal	77.23±1.25bcde	68.3±1.00bc	8.9±1.17lm	2.42±0.24efgh	LB
14	Khochro	77.40±1.01bcde	71.8±0.51a	5.6±1.21nop	2.56±0.29defg	SB
15	Korgut	77.86±0.58bcd	68.2±0.65c	9.6±0.81lm	2.40±0.10efghi	SB
16	Mangala	74.30±0.95f	53.3±1.06j	20.9±2.00gh	2.69±0.10de	LB
17	Ner	73.30±1fg	63.4±0.64ef	9.9±1.63klm	2.66±0.25def	MS
18	Novan	78.40±1.08b	73.0±0.47a	5.3±1.19op	1.59±0.19ghi	SB
19	Revati	77.33±1.10bcde	69.7±0.55b	7.6±0.55mnop	2.33±0.35ghi	SB
20	Salsi	72.30±0.9g	51.8±0.51kl	20.5±1.03h	2.66±0.20def	MS
21	Tamde Jyoti	76.73±0.47cde	53.2±0.95jk	23.5±1.13ef	3.51±0.08a	LS
22	Vadlo Kenal	80.86±0.35a	44.5±2.13n	36.3±1.79a	2.40±0.26efghi	LB
23	IR8	76.26±0.20e	63.8±0.58e	12.4±0.6ij	2.10±0.09i	SB
24	Jyoti	78.36±0.321b	68.1±0.1c	10.2±0.25jkl	3.31±0.27ab	LS
25	Jaya	80.50±0.4a	57.3±0.11h	23.1±0.41efg	3.12±0.06bc	LS

Superscript letters (a-n) indicate significant differences ($p \leq 0.05$) among different rice varieties in hulling, head rice recovery, broken rice and L/B ratio. Means with same letter within column are not significantly different ($p \leq 0.05$). SB, short bold; LB, long bold; LS, long slender; MS, medium slender

Chemical characters

The alkali spreading value and GT were calculated for all the rice varieties examined (Table 3). The alkali spreading value was calculated as low, intermediate and high. The low alkali spreading value was detected in varieties viz. Annapurna, Damgo, Kendal, Khochro, Tamde Jyoti, Vadlo Kendal, Karz, IR8, Jyoti and Jaya. The intermediate (>74°C) alkali spreading value was recorded in Atthavis, Bello, Chudi, Dhave, Dodga, Irtal, Kalo Novan, Mangala, Ner and Revati. Rice varieties such as Novan, Jaya and Salsi showed high alkali spreading value. The low-intermediate alkali spreading values was recorded in varieties Barik-Kudi and Korgut. Rice with low GT disintegrates completely in 1.7 percent KOH solution, whereas rice with intermediate GT showed partial disintegration. Rice with high GT remains largely unaffected in alkali solution. In addition, the disintegration of rice starch granules is affected by the fine structure of amylopectin [26]. If the alkali spreading value is low, the GT is high (>74°C). If the alkali spreading is intermediate, the GT is intermediate (70-74°C). If the alkali spreading value is low intermediate then the GT is high intermediate. The different range of drying also affects the GC [27].

Table 2. Chalkiness of endosperm of traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Frequency	Kernel area (Extent)	Type	Chalkiness (%)
1	Annapurna	P	Long (more than 20 %)	WB	84.03±1.60d
2	Atthavis	P	Long (more than 20 %)	WB	65.40±2.53g
3	Barik Kudi	VOP	Small (less than 10 %)	WC	10.23±0.87m
4	Bello	P	Long (more than 20 %)	WB	76.60±1.21f
5	Chudi	P	Long (more than 20 %)	WB	55.23±2.62i
6	Damgo	P	Long (more than 20 %)	WB	100±0.00a
7	Dhave	OC	Medium (11 % to 20 %)	WB	88.40±0.98c
8	Dodga	P	Long (more than 20 %)	WC	84.40±1.01d
9	Irtal	P	Long (more than 20 %)	WC	87.43±1.05c
10	Kala Novan	P	Long (more than 20 %)	WC	33.30±0.90k
11	Karz	P	Long (more than 20 %)	WB	57.40±1.31h
12	Kenal	P	Long (more than 20 %)	WB	87.56±1.51c
13	Kendal	P	Long (more than 20 %)	WB	100±0.00a
14	Khochro	P	Long (more than 20 %)	WB	100±0.00a
15	Korgut	P	Long (more than 20 %)	WB	87.86±0.65c
16	Mangala	P	Long (more than 20 %)	WB	67.40±0.87g
17	Ner	P	Long (more than 20 %)	WC	38.46±1.16j
18	Novan	P	Long (more than 20 %)	WB	91.63±0.66b
19	Revati	P	Long (more than 20 %)	WB	76.50±0.65f
20	Salsi	P	Long (more than 20 %)	WB	93.06±2.67b
21	Tamde Jyoti	P	Long (more than 20 %)	WB	80.73±0.45e
22	Vadlo Kenal	P	Long (more than 20 %)	WB	88.56±0.41c
23	IR8	P	Long (more than 20 %)	WB	81.80±1.15e
24	Jyoti	P	Long (more than 20 %)	WB	85.00±0.75d
25	Jaya	P	Long (more than 20 %)	WC	24.10±1.47l

Superscript letters (a-m) indicate significant differences ($p \leq 0.05$) among different rice varieties in percentage of chalkiness. Means with same letter within column are not significantly different ($p \leq 0.05$). WB, white belly; WC, white centre; VOP, very occasionally present; OC, occasionally present; P, present

Amylose content (AC) is considered to be the single most important characteristic for predicting rice cooking and processing behaviors. The percentage of AC in the present study ranged from 14-25% (Table 3). The variety Mangala showed lowest AC (13.6%), while highest AC was recorded in variety Kalo Novan (23.7%). In high yielding varieties the AC ranged from 17.86-24.75%. Most consumers prefer rice with intermediate AC ranged between 20-25% [28]. The AC in rice ranges between 20.7-21.4% and difference in brightness of the grain is probably due to the higher AC [29].

The GT of the rice samples have been classified as high to intermediate which means the temperature required for normal cooking time is 75-79°C. While the GC of the rice samples is 65-70 mm and categorized as soft, this means the tendency of cooked rice to be soft on cooling. The GC is measured into soft, medium and hard. Among the traditional rice varieties, the length of the blue gel was highest in Salsi (93 mm) but no significant difference with Dodga (91.3 mm) and lowest in Khochro (34.6 mm). In high yielding rice varieties the GC ranged from 44- 64% (Table 3).

Table 3. The alkali spreading value (ASV), gelatinization temperature (GT), amylose content (AC), gel consistency (GC) and aroma in traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	ASV	GT	Amylose (%)	Length of blue gel (mm)	GC	Aroma
1	Annapurna	L	H>74 °C	16.9±0.62fgh	70.3±1.52d	Soft	Mild scent
2	Atthavis	I	I (70-74 °C)	14.8±0.52ijk	84.6±2.51b	Soft	No scent
3	Barik Kudi	LI	HI	14.0±0.87k	62±1efg	Soft	Mild scent
4	Bello	I	I (70-74 °C)	16.0±1.28hij	55.3±1.52h	Medium	No scent
5	Chudi	I	I (70-74 °C)	18.6±1.21bcdef	60.3±0.57g	Medium	No scent
6	Damgo	L	H >74°C	17.2±0.69efgh	75.3±3.51c	Soft	No scent
7	Dhave	I	I (70-74 °C)	17.9±0.61cdefgh	50.6±1.15i	Medium	No scent
8	Dodga	I	I (70-74 °C)	16.7±1.09fghi	91.3±2.30a	Medium	No scent
9	Irtal	I	I (70-74 °C)	16.4±1.09ghij	61±1fg	Soft	No scent
10	Kala Novan	I	I (70-74 °C)	23.7±0.76a	60.3±0.57g	Medium	No scent
11	Karz	L	HI	20.4±0.84b	46±3.6j	Medium	No scent
12	Kenal	L	H >74 °C	16.9±0.75fgh	65±3e	Soft	No scent
13	Kendal	L	H >74 °C	19.9±0.33bc	85±2b	Soft	No scent
14	Khochro	L	H >74 °C	14.6±0.37jk	34.6±0.57k	Hard	No scent
15	Korgut	LI	HI	17.5±1.40defgh	64.6±2.51e	Soft	No scent
16	Mangala	I	I (70-74 °C)	13.6±1.13k	64.6±0.57e	Soft	No scent
17	Ner	I	I (70-74 °C)	19.3±1.31bcd	82±1b	Soft	No scent
18	Novan	H	L (55-69 °C)	17.1±0.84efgh	54.3±4.04h	Medium	No scent
19	Revati	I	I (70-74 °C)	19.0±1.29bcde	83.3±1.52b	Soft	No scent
20	Salsi	H	L (55-69 °C)	18.3±0.35cdef	93±1a	Soft	Mild scent
21	Tamde Jyoti	L	H >74 °C	16.8±0.57fgh	71±1d	Soft	Optimal
22	Vadlo Kenal	L	H >74 °C	16.7±0.93fghi	64.3±2.08ef	Soft	No scent
23	IR8	L	H >74 °C	17.8±0.59defgh	62.6±2.51efg	Soft	Mild scent
24	Jyoti	L	H >74 °C	24.7±4.12a	64.0±4ef	Soft	Mild scent
25	Jaya	H	L (55-69 °C)	23.3±0.88a	44.6±2.51j	Soft	Mild scent

Superscript letters (a-k) indicate significant differences ($p \leq 0.05$) among different rice varieties in AC and length of blue gel in mm. Means with same letter within the column are not significantly different ($p \leq 0.05$)
L, Low; I, Intermediate; LI, Low-intermediate; H, High; HI, High-intermediate

Aroma is another important trait in rice and the aromatic rice has high demand in the market. It was observed in the present study that few native varieties are having aroma, for which these varieties are preferred for consumption by local people. Among the rice varieties examined, Annapurna, Barik Kudi, Salsi, Tamde Jyoti, IR8, Jyoti and Jaya showed the presence of mild aroma (Table 3). It was reported that in basmati rice 2-acetyl-1-pyrroline (2-AP) is the major aroma compound responsible for the fragrance and quantity of 2-AP varies with varieties and climatic conditions [30]. Also reported that the epidermal papillae of lower epidermis of leaf of *Pandanus amaryllifolius* contain similar aroma compounds as present in basmati rice, traditionally it has used during cooking of non-scented rice to get the smell of basmati [31].

Cooking characteristics

The volume expansion ratio ranged from 2-4 mm in traditional rice varieties, while in high yielding varieties 2.0-3.4 mm. Variety Jaya showed 3.4 mm and IR8 with 2.0 mm. The positive correlation of AC with water uptake, volume expansion ratio and alkali spreading value indicates that high amylose rice varieties will absorb more water at low GT and will produce a greater volume of cooked material [32].

Kernel elongation ratio was found to be not related with either AC or alkali spreading value. Kernel length after cooking ranged from 1.8-4.7 mm in traditionally cultivated rice and 2.0-3.4 mm in high yielding rice varieties. Minimum kernel length after cooking was calculated in variety Novan and maximum in variety Bello. Kernel elongation in traditional rice varieties ranged from 1.0-1.6 and high yielding varieties from 1.0-1.1. Highest kernel elongation ratio was observed in variety Bello and lowest in Mangala (Table 4).

Fig. 1 Water uptake in traditionally cultivated and high yielding rice varieties

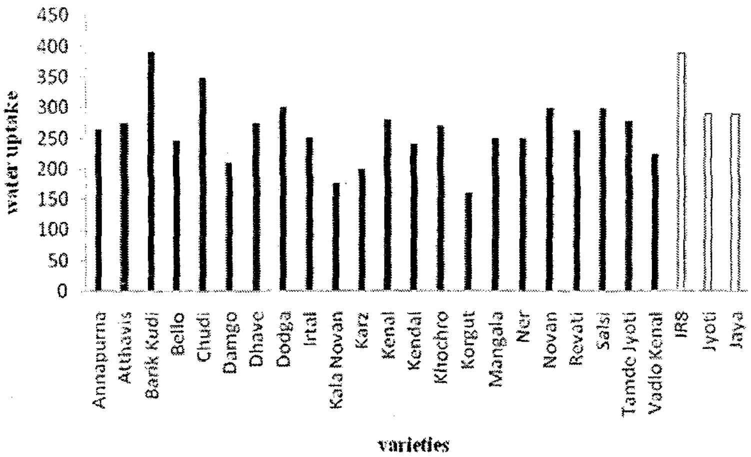

Table 4. The volume expansion ratio, kernel length after cooking (KLAC), kernel elongation ratio (ER) and water uptake in traditionally cultivated and high yielding rice varieties

Sl. No.	Varieties	Volume Expansion	KLAC (mm)	Elongation ratio
1	Annapurna	3.03±0.05d	3.07±0.06defg	1.29±0.02c
2	Atthavis	2.03±0.05fg	2.89±0.04fgh	1.07±0.01fghi
3	Barik Kudi	4.00±0b	3.91±0.07b	1.13±0.02defghi
4	Bello	3.10±0.1d	4.78±0.16a	1.66±0.07a
5	Chudi	2.60±0.1e	3.34±0.03cd	1.23±0.03cd
6	Damgo	2.20±0.1fg	2.76±0.05hi	1.22±0.13cde
7	Dhave	2.00±0g	2.93±0.08fgh	1.19±0.10cdef
8	Dodga	3.03±0.05d	2.50±0.20ij	1.10±0.06efghi
9	Irtal	3.50±0.1c	2.33±0.05jk	1.05±0.06ghi
10	Kala Novan	3.43±0.28c	3.81±0.11b	1.51±0.06b
11	Karz	2.10±0.1fg	3.16±0.10def	1.19±0.11cdef
12	Kenal	4.03±0.05ab	2.92±0.04fgh	1.30±0.04c
13	Kendal	2.03±0.05fg	2.84±0.03gh	1.17±0.10cdefg
14	Khochro	4.06±0.05ab	2.56±0.11ij	1.10±0.04efghi
15	Korgut	2.70±0.1e	2.38±0.33j	1.10±0.10efghi
16	Mangala	4.23±0.15a	2.74±0.15hi	1.03±0.02hi
17	Ner	2.23±0.20f	2.89±0.08fgh	1.08±0.12fghi
18	Novan	4.03±0.05ab	1.83±0.03l	1.16±0.15efghi
19	Revati	2.03±0.05fg	2.50±0.2ij	1.13±0.04defghi
20	Salsi	3.03±0.05d	3.31±0.07cde	1.24±0.11cd
21	Tamde Jyoti	3.50±0c	3.94±0.05b	1.12±0.02defghi
22	Vadlo Kenal	2.16±0.28fg	3.04±0.62efg	1.05±0ghi
23	IR8	2.03±0.05fg	2.45±0.04j	1.19±0.02cdef
24	Jyoti	2.63±0.05e	2.08±0.02kl	1.01±0.04i
25	Jaya	3.46±0.32c	3.48±0.02c	1.14±0.02defghi

Superscript letters (a-1) indicate significant differences ($p \leq 0.05$) among different rice varieties in volume expansion, KLAC, ER and water uptake in ml. Means with same letter within column are not significantly different ($p \leq 0.05$).

In high yielding varieties, water uptake ratio ranged from 290-390 and in traditional rice varieties 160-390. Rice variety IR8 recorded the highest water uptake and among traditional rice varieties the minimum water uptake was noted in Korgut and maximum in Barik Kudi (Fig. 1). When the AC of a variety increases, cooking time is also increase. The Organoleptic test were conducted for appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation and overall acceptability for traditional and high yielding rice varieties (Table 5). The excellent overall acceptability was recorded in the varieties Korgut and Tamde Jyoti. The good overall acceptability was observed in rice varieties viz. Annapurna, Dhave, Kenal, Kendal, Vadlo Kenal, Jyoti and Jaya.

Table 5. Organoleptic test of traditionally cultivated and high yielding rice varieties

Q	Characteristics	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
A	Appearance																									
5	White							+																		
4	Creamish white/ brown	+	+		+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
3	Red streaks																									
2	White with brown streaks			+																						+
1	White with black streaks																									
B	Cohesiveness																									
5	Well separated	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+	+				+		+	
4	Partially separated									+							+			+	+	+		+		+
3	Slightly separated																									
2	Moderately separated																									
1	Very sticky																									
C	Tenderness on touching																									
5	Soft																									+
4	Moderately soft							+														+	+			
3	Moderately hard		+			+			+	+	+		+	+				+	+	+	+					
2	Hard	+		+	+		+					+			+	+	+							+	+	
1	Very soft																									
D	Tenderness on chewing																									
5	Soft																					+	+			+
4	Moderately soft																	+	+	+	+					
3	Moderately hard	+		+	+	+		+	+	+			+	+		+	+							+	+	
2	Hard		+				+				+	+			+											
1	Very soft																									
E	Taste																									
5	-																									
4	Good																					+	+			
3	Desirable	+			+		+	+				+	+	+		+		+	+	+	+			+		+
2	Tasteless		+	+		+			+	+	+				+		+								+	
1	undesirable																									
F	Aroma																									
5	Strong																									
4	Optimal																					+				
3	Mild																									
2	Other than basmati (mild)	+		+																	+			+	+	+
1	No scent		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+			
G	Elongation																									
5	-																									
4	Excellent																									
3	Good						+	+				+				+						+			+	
2	Moderate	+	+	+	+	+			+	+	+		+	+	+		+	+	+	+	+		+	+		+
1	none																									
H	Overall acceptability																									
5	-																									
4	Excellent															+						+				
3	Good	+						+					+	+									+		+	+
2	Acceptable		+	+	+	+	+		+	+	+	+			+		+	+	+	+	+			+		
1	undesirable																									

a, Annapurna; b, Atthavis; c, Barik Kudi; d, Bello; e, Chudi; f, Damgo; g, Dhave; h, Dodga; i, Irtal; j, Kala Novan; k, Karz; l, Kenal; m, Kendal; n, Khochro; o, Korgut; p, Mangala; q, Ner; r, Novan; s, Revati; t, Salsi; u,Tamde Jyoti; v, Vadlo Kenal; w, IR8; x, Jyoti; y, Jaya and Q, quality.

The study revealed that the traditionally cultivated rice varieties Vadlo Kenal, Novan and Tamde Jyoti with maximum hulling percentage, HR recovery and L/B ratio. Maximum AC, alkali spreading value and gel consistency was recorded in traditionally cultivated rice varieties Salsi, Barik Kudi, and Kala Novan. The cooking characteristics indicated that the traditionally cultivated rice varieties Korgut and Tamde Jyoti are with excellent grain quality and varieties such as Annapuma, Dhave, Kenal, Kendal, Vadlo Kenal in category of good cooking quality.

Conclusions

In the present study physical, chemical and cooking characteristics were evaluated for 22 traditionally cultivated and three high yielding rice varieties. Among the varieties studied traditionally cultivated rice varieties such as Vadlo Kenal, Novan and Tamde Jyoti showed good physical characteristics (maximum hulling, HR recovery, L/B ratio). The chemical properties (AC, alkali spreading value, gel consistency) were excellent in varieties Salsi, Barik Kudi, and Kala Novan. The best cooking quality (appearance, cohesiveness, tenderness on touching, tenderness on chewing, taste, aroma, elongation) was observed in the rice varieties Korgut, Tamde Jyoti, Annapuma, Dhave, Kenal, Kendal and Vadlo Kenal. The study revealed that some of the traditional rice varieties are with high grain quality characteristics, which could be used in rice breeding programmes and biotechnological research for further improvement of rice. The Korgut is another traditionally cultivated rice variety showed high grain quality characteristics with high salinity tolerance and could also be used for rice breeding.

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REGULAR ARTICLE

TRADITIONALLY CULTIVATED SALT TOLERANT RICE VARIETIES GROWN IN KHAZAN LANDS OF GOA, INDIA AND THEIR GRAIN QUALITY CHARACTERISTICS

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SUMMARY

The khazan lands (saline lands) have the potential for growing traditional rice varieties which are salt tolerant during rainy season without supplemental irrigation. In khazan land the rice varieties grown are limited, but specific traditional rice varieties like Korgut, Khochro and Assgo are grown predominantly. During this study, we have collected 10 traditionally cultivated rice varieties which grown in saline areas. These varieties were with unique morphological characteristics of shape, size and color. The physicochemical characteristics such as physical, chemical and cooking characteristics were studied. Among the varieties, the highest hulling (80%) was noted in varieties Muno, Shiedi and lowest in varieties Bello and Kalo Damgo (73%). The Length/Breadth (L/B) ratio ranged from 2.02-2.86. The lowest chalkiness was recorded in variety Kalo Novan (33.30%) and highest in variety Korgut (87.86%). Among the varieties studied, the amylose content (AC) ranged from 14.6-23.7% in variety Khochro and Kalo Novan respectively. The gel consistency was highest in traditionally cultivated rice variety Damgo (75.3 mm) and lowest in Khochro (34.6 mm). Kernel length after cooking (KLAC) ranged from 2.38-4.78 mm. The highest KLAC was recorded in Bello and minimum in variety Korgut. Kernel elongation ratio (ER) ranged from 1.03-1.66. The present investigation revealed that the traditionally cultivated rice varieties viz. Bello, Korgut, Khochro and Kalo Novan were with good grain quality characteristics.

Key words: Grain quality, Khazan lands, Physico-chemical properties, Rice diversity

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1. Introduction

Rice (*Oryza sativa* L.) is the principal cereal crop and it is consumed as the whole grain therefore, determination of physical, cooking and nutritional qualities are very important in view point of consumers. Grain quality characters are interrelated among themselves which in turn decides the final cooking and eating characteristics. Rice is the predominant food crop of Goa occupying an area of 39% (52,442 ha) of the total cultivated land in the state and the khazan lands occupy an area of 17,200 ha. Popularly rice varieties grown in khazan lands of Goa are Korgut (with awn), Khochro and Assgo. High soil salinity is a major problem in several rice growing countries, both in the tropics and in temperate regions.

The physio-chemical characteristics of rice grain are important indicators of grain quality. It is mainly determined by combination of many physical as well as chemical characteristics. The physical quality includes kernel size, shape, hulling, milling and head rice recovery. The chemical characteristics are determination of amylose content, gelatinization temperature, gel consistency and cooking behavior [1]. In the context of changing agricultural scenario, there has been increase in demand for the quality rice throughout the world. Grain quality evaluation and organoleptic analysis always helps the consumers to select better rice varieties [2 and 3]. In this paper, we are presenting the finding of grain quality characteristics (physical, chemical, cooking) of the salinity tolerant traditionally cultivated rice varieties of Goa.

2. Materials and Methods

The systematic field survey was carried out and diverse traditionally cultivated rice germplasm was collected from different parts of Goa.

Physical traits

Hulling percentage was calculated by taking the average whole-grain yield. 100 g of rice seeds were de-hulled using a standard de-husker. For Grain classification, ten de-husked entire brown rice grains were measured using dial micrometer. Based on the L/B ratio, grains were classified into long slender (LS), short slender (SS), medium slender (MS), long bold (LB) and short bold (SB). Chalkiness of endosperm was calculated by observing the milled rice caryopsis under a stereo-zoom microscope, based on the orientation of chalkiness, the rice grains were classified into white belly, white centre and white back. To study the Chalk index, ten de-husked rice grains were placed on light box. The visually identified caryopsis with more than 50% of chalkiness was weighed and percentage of chalkiness was calculated [4].

Chemical traits

Alkali spreading value (ASV) was calculated using six milled rice grains in Petri plates. 10 ml of 1.7% of KOH was added and kept in incubator at 27-30°C for 23 hours. Then the alkali spreading value was calculated as low, low-intermediate, intermediate or high [5]. The Amylose content (AC) of different varieties was calculated in comparison with standard graph [6 and 7]. To 100 mg of rice flour 1 ml of 95% ethanol and 9 ml of 1.0 N NaOH was added. This was mixed well and heated in a boiling water-bath for 10 min. Samples were diluted to 100 ml with distilled water. From this suspension, 5 ml of sample was taken and 1 ml of acetic acid (57.75 ml in one liter water) was added to acidify the sample along with 1.5 ml of iodine solution (0.2% iodine + 2% potassium iodide) and the volume was made to 100 ml with distilled water. The samples were incubated at room temperature for 20 min. The absorbance was measured at 620 nm using spectrophotometer. As a control, NaOH solution was used. For Gel consistency (GC), 100 mg of rice flour was taken in test tube (2×19.5 cm), 0.2 ml of ethanol containing 0.25% thymol blue and 2.0 ml of 0.2 N of KOH were added and kept in boiling water-bath for 8 min, cooled, mixed well and kept in ice bath for 20 min. Later the test tubes were laid horizontally for one hour and measurements were made using graph paper. The degree of disintegration of kernel was evaluated using a 7 point scale [8 and 9].

Cooking characteristics

Volume expansion ratio (VER) and elongation ratio (ER): 15 ml of water was taken in 50 ml graduated centrifuge tubes and 5 g of rice sample was added. Initial volume increase was measured (Y) and soaked for 10 min. Then increase in volume before cooking was noted (Y-15). Rice samples were cooked for 20 min in a water bath. Cooked rice was placed on bloating paper. Ten cooked rice kernels were selected (intact at both ends) and length of the kernels measured using graph paper for computing the kernel length after cooking (KLAC). Then the cooked rice was placed in 50 ml water taken in 100 ml measuring cylinder and increase in volume of cooked rice in 50 ml of water was measured (X). Then the volume raise was recorded (X-50). VER and ER were calculated [10].

3. Results and Discussion

During this study we had collected 10 traditional salt tolerant rice varieties which are unique in their morphological characters viz. shape, size and color (Figure 1). All the traditionally cultivated rice varieties are specific to Goa region and cultivated in small patches. Out of 10 rice varieties collected, cultivation of some of the varieties such as Kalo Novan, kalo damgo, and Bello are becoming rare, due to the introduction of high yielding rice varieties, hence local germplasm and their genetic diversity are being eroded. The rice varieties like Korgut, Muno and Assgo are still popularly cultivated in khazan lands of Goa due to its high salinity tolerance. Grain quality is a very wide area which encompasses the diverse characters that are directly or indirectly related to exhibit one quality type [11].

Fig. 1. Salt tolerant rice varieties of Goa

1. Assgo, 2. Bello, 3. Damgo, 4. Kalo Damgo, 5. Kalo Korgut, 6. Kalo Novan, 7. Khochro, 8. Korgut, 9. Muno, 10. Shiedi

Physical characteristics

The hulling percentage for traditionally cultivated salt tolerant rice varieties ranged from 73-80% (Table 1). The highest hulling (80.1%) was noted in varieties Muno, Shiedi and lowest in Kalo Damgo and Bello (73.4 and 73.2%). Milling recovery depends on grain shape and appearance, which has direct effect on the percentage of hulling, milling and head rice recovery [12].

Among the varieties studied, the L/B ratio ranged from 2.02-2.86. The variety Bello recorded the highest L/B ratio and least was found in Muno. Based on the L/B ratio, the collected rice varieties were classified into five different categories: Damgo, Shiedi (long bold); Kalo korgut (long slender); Assgo, Kalo Damgo, Kalo Novan, Khochro, Korgut, Muno (short bold); Bello (medium slender). The grain size and shape are the first criteria for rice quality that breeders consider in developing new varieties for release and commercial production [13]. The hulling percentage, L/B ratio and grain classification of traditionally cultivated rice varieties are summarized in Table-1.

Table 1. Percentage of hulling, L/B ratio and grain classification of salt tolerant rice varieties

Sl. No.	Traditionally cultivated Varieties	Mean Hulling %	Mean L/B ratio	Grain Classification
1	Assgo	74.7±0.43	2.19±0.02	SB
2	Bello	73.26±0.96	2.86±0.05	MS
3	Damgo	77.43±1.36	2.26±0.20	LB

4	Kalo Damgo	73.4±2.25	2.41±0.01	SB
5	Kalo Korgut	75.1±1.80	2.59±0.26	LS
6	Kalo Novan	78.13±0.90	2.51±0.17	SB
7	Khochro	77.40±1.01	2.56±0.29	SB
8	Korgut	77.86±0.58	2.40±0.10	SB
9	Muno	80.16±0.37	2.02±0.015	SB
10	Shiedi	80.1±0.7	2.34±0.03	LB

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

Chalkiness in the rice grain was classified into white belly, white back and white centre. Assgo, Bello, Damgo, Kalo Damgo, Khochro and Korgut belong to white belly type. Varieties Kalo Korgut, Muno, Shiedi recorded white back type of chalkiness and white centre in variety Kalo Novan. The frequency of chalkiness was calculated and the chalky area more than 20% was observed in all the rice varieties studied. The highest chalkiness was recorded in varieties Korgut (87.86) and lowest in Kalo Novan (33.30). Maximum percentage (100%) of chalkiness was recorded in varieties Damgo, Kalo Korgut, Khochro, Muno and Shiedi (Table 2).Chalkiness indicates the loose packing of starch granules, as the width of the rice grain increases chalkiness appears in the grain [14].

Table 2. Chalkiness of endosperm in salt tolerant rice varieties

Sl. No.	Varieties	Type	Frequency	Kernel area (Extent)	Percentage of chalkiness
1	Assgo	White belly	P	Long (more than 20 %)	75.8±2.51
2	Bello	White belly	P	Long (more than 20 %)	76.60±1.21
3	Damgo	White belly	P	Long (more than 20 %)	100±0.00
4	Kalo Damgo	White belly	P	Long (more than 20 %)	58.2±3.35
5	Kalo Korgut	White back	P	Long (more than 20 %)	100±0.00
6	Kalo Novan	White centre	P	Long (more than 20 %)	33.30±0.90
7	Khochro	White belly	P	Long (more than 20 %)	100±0.00
8	Korgut	White belly	P	Long (more than 20 %)	87.86±0.65
9	Muno	White back	P	Long (more than 20 %)	100±0.00
10	Shiedi	White back	P	Long (more than 20 %)	100±0.00

P, present

Chemical characters

The low alkali spreading value (ASV) and high gelatinization temperature (GT) were detected in Assgo, Damgo, Kalo Korgut, Khochro, Muno and Shiedi. The intermediate ASV and GT were noted in varieties such as Bello, Kalo Damgo, Kalo Novan and Khochro. The low-intermediate ASV and high-intermediate GT was observed in variety Korgut (Table 3). The GT, gel consistency (GC) and amylose content (AC) are major rice traits, which are directly related to cooking and eating quality [8]. Based on the amylose content (AC) the rice grains were classified as waxy, very low, low, intermediate and high AC. The lowest AC was recorded in variety Khochro, whereas highest in Kalo Novan (Table 3). The main factor that determines the texture of cooked rice is amylose content. However, the cohesiveness, tenderness, colour and gloss differ greatly based on gel consistency [12].

The gel consistency (GC) was measured into soft, medium and hard. The GC of the rice samples ranged from 34.6-75.3 mm. The length of the blue gel was highest in rice varieties Damgo, Shiedi and lowest in Kalo Korgut (Table 3). Rice with soft to medium gel consistency, intermediate amylase content and intermediate gelatinization temperature is a preferred level for the consumers[15].

Table 3. Alkali spreading value, gelatinization temperature, amylose content and gel consistency in salt tolerant rice varieties

Sl. No.	Varieties	Alkali spreading value	Gelatinization temperature	Amylose in %	Length of blue gel in mm	Gel consistency
1	Assgo	L	H>74 °C	19.57±0.51	48±1	Medium
2	Bello	I	I (70-74 °C)	16.0±1.28	55.3±1.52	Medium
3	Damgo	L	H >74°C	17.2±0.69	75.3±3.51	Soft
4	Kalo Damgo	I	I (70-74 °C)	20.34±0.83	74±2	Soft
5	Kalo Korgut	L	H >74°C	21.78±0.92	44.3±2.51	Medium
6	Kalo Novan	I	I (70-74 °C)	23.7±0.76	60.3±0.57	Medium
7	Khochro	L	H >74 °C	14.6±0.37	34.6±0.57	Hard
8	Korgut	LI	HI	17.5±1.40	64.6±2.51	Soft
9	Muno	L	H >74°C	17.4±1.35	60.0±1	Medium
10	Shiedi	L	H >74°C	21.6±0.762	75.3±3.51	Medium

L, Low; I, Intermediate; LI, Low-intermediate; H, High; HI, High-intermediate; OTB, other than Basmati

Cooking characteristics

The volume expansion ratio (VER) in traditionally cultivated rice varieties ranged from 1.6-4.01. The highest VER was reported in variety Khochro and lowest in variety Kalo Korgut. High amylose rice show high volume expansion and a high degree of flakiness [12]. Kernel length after cooking (KLAC) ranged from 2.50-4.78 mm in rice varieties. The highest KLAC was observed in varieties Bello and Korgut and minimum in variety Kalo Damgo. Kernel elongation ratio (ER) in rice varieties examined ranged from 1.03-1.66, highest in variety Bello and lowest in Kalo Damgo (Table 4). Consumers base their concept of quality on the grain appearance, size and shape of the grain, behavior upon cooking, taste, tenderness and flavor of cooked rice. The cooking quality preferences vary within the country, within ethnic groups and from one country to another or within different geographical regions[16].

Table 4. Volume expansion ratio, kernel length after cooking and elongation ratio in salt tolerant rice varieties

Sl. No.	Varieties	Volume Expansion ratio	Kernel length after cooking (mm)	Elongation ratio
1	Assgo	2.63±0.05	2.85±0.01	1.31±0.005
2	Bello	3.10±0.1	4.78±0.16	1.66±0.07
3	Damgo	2.20±0.1	2.76±0.05	1.22±0.13
4	Kalo Damgo	3.2±0.1	2.50±0.05	1.03±0.01
5	Kalo Korgut	1.6±0.1	2.873±0.04	1.08±0.16
6	Kalo Novan	3.43±0.28	3.81±0.11	1.51±0.06
7	Khochro	4.06±0.05	2.56±0.11	1.10±0.04
6	Korgut	3.10±0.1	4.78±0.16	1.66±0.07
9	Muno	2.16±0.05	2.52±0.005	1.24±0.01
10	Shiedi	3.03±0.05	2.93±0.05	1.24±0.03

4. Conclusions

The paper has concentrated on the physical, chemical and cooking characteristics of salt tolerant rice varieties of Goa. The present investigation revealed that the traditionally cultivated rice varieties viz. Korgut, Khochro, Muno and Shiedi showed good grain quality characteristics. The results imply that three major characteristics such as amylose content, gelatinization temperature and grain shape are involved in grain quality especially these characteristics which influence the physicochemical properties like texture. The present study revealed that some of the indigenous traditionally cultivated salt tolerant rice varieties have potential for consumer's preferences and it could be used for breeding programme for the improvement of valuable grain quality traits.

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Abstracts

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Evaluation of traditional rice varieties of Goa under different land situation

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Rice is the predominant food crop of Goa occupying 39% of total cultivated area. Twenty two traditionally cultivated rice varieties, which are unique in their morphological characters viz., shape, size and color were collected to study the physicochemical characteristics such as hulling, length/breath ratio, grain classification, chalkiness, chalk index, alkali spreading value, amylose content (AC), gel consistency (GC), aroma as well as cooking characteristics viz., volume expansion, elongation ratio, water uptake. Among the varieties, the highest hulling (82.4%) was noted in variety Ek-Kadi and lowest in Salsi and Dhave (72%). The Length/Breadth (L/B) ratio ranged from 1.59-3.43. The chalkiness characteristics were recorded for all the varieties examined. Among the varieties examined, the AC ranged from 14-23.7%. The gel consistency was highest in traditionally cultivated rice varieties Salsi (93 mm) and lowest in Khochro (34.6 mm). Kernel length after cooking (KLAC) ranged from 1.83-4.78 mm. The highest KLAC recorded in Bello and Korgut, and minimum in variety Novan. Kernel elongation ratio (ER) ranged from 1.01-1.66. The present suudy revealed that the traditionally cultivated rice varieties viz. Bello, Korgut, khochro and Kotimirsal showed good grain quality characteristics.

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species of lichens. Many times local people are also responsible for the destruction of mangrove vegetation. Hence, the forest Dept. should take initiative to have people's participation for the protection of mangroves. Further plantation should be carried out in the coasting area where the mangrove vegetation is denuded and thus the fragile ecosystem of Andaman island can be protected.

S.1.P.19

BIODIVERSITY AND GRAIN QUALITY CHARACTERISTICS OF RICE VARIETIES OF GOA

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Rice is the predominant food crop occupying an area of 39% (52,442 ha) of the total cultivated land in Goa. It is cultivated under three distinct ecological conditions viz. lateritic uplands (8,600 ha), lowlands (16,900 ha) and khazan (17,200 ha). About 9,700 ha of land under rice cultivation during rabi season. The morod (upland) crop is purely rain-fed, short duration local rice varieties like Novan, Jiresal, Salsi and Kotimirsal are grown. In kher (lowland), medium duration varieties such as Khochro and Barik Kudi are cultivated. In khazan (saline soil), traditionally cultivated rice varieties like Korgut, Muno and Assgo are predominantly grown. However, high yielding rice varieties such as Jaya, Jyoti, Karjat, MO-7 and scented rice like Pusa Basmati, Pusa Sugandh are grown in all seasons. During this study, we have collected 30 traditionally cultivated and 18 introduced rice varieties from the state of Goa. Each rice varieties have unique morphological characteristics, shape, size and color. The physicochemical characteristics such as physical, chemical and cooking characteristics were studied. The highest hulling (82.4%) was noted in variety Ek-Kadi and lowest in Dodga (63.16%). The Length/Breadth (L/B) ratio ranged from 1.5-4.8, highest in Pusa Basmati-1 and lowest in Novan. No chalkiness was recorded in Ghansal, Kotimirsal and Pusa sugandh-2. The amylose content (AC) was lowest in Barik kudi (14%) and highest in Mugadh sugandh (27.6%). The gel-consistency ranged from 28-93mm. Kernel length after cooking (KLAC) ranged from 1.83-5.88mm, highest KLAC were recorded in Vasumati and lowest in Novan. Kernel elongation ratio ranged from 1.01-1.66. The present investigation revealed that the cultivated rice varieties viz. Bello, Korgut, Khochro, Kotimirsal, Pusa sugandh-1 and 2 showed good grain quality characteristics. Due to introduction of high yielding rice varieties, cultivation of traditional varieties is becoming rare, they are on the verge of extinction.Some of the traditional rice varieties are highly salinity tolerant with high quality characteristics, the preservation of these native rice germplasm are important in the point of view of conservation.

Keywords: Rice diversity, grain-quality, physicochemical properties, khazan, amylose content.
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S.1.P.20

FAMILY POTTIACEAE (MUSCI) IN ANDHRA PRADESH

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Andhra Pradesh state is situated in the middle portion of Eastern Ghats of South Peninsular India covering an area of 2, 75,068 sq km. It lies between the latitudes of 12° 37' N and 19° 54' N , longitudes of 76º 46' E and 84º 46' E and the altitudes of 150m – 1300m above mean sea level. State receives 200mm – 1000mm rain fall. Different types of forest such as semi ever green, moist deciduous, dry deciduous, dry savannah, dry ever

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ABSTRACTS

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Grain quality evaluation of rice varieties of Goa

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Rice is the predominant food crop of Goa, occupying an area about 52,191 ha and of which 34,261 ha are grown during kharif and remaining 17,930 ha is grown during rabi season. About 90% of kharif and entire area of rabi seasons are covered under high yielding rice varieties.rice is grown under three distinct ecological conditions such as morod (uplands), kher (midlands) and khazan (saline lands). The morod crop are purely rain fed, rice varieties like Novan, Muno and Kendal are grown.The other promising rice varieties of morod land include short duration varieties with fine grain like Jiresal, Sal and Kotimirsal. The kherlands are irrigated and varieties such as Khochro and Barik Kudi are grown. In khazans, rice varieties like Korgut, Shiedi and Assgo are commonly grown by the farmers.

In the present investigation we have collected 28 traditionally cultivated and 22 high yielding rice varieties from Goa. All traditionally cultivated rice varieties are unique in their morphological characters of shape, size and color and most of the rice are specifically grown in Goa region in small patches. Out of 28 rice varieties, some of the varieties like Bello, Khochro, Kusago cultivation are becoming rare, due to the introduction of high yielding rice varieties and their genetic diversity are being eroded. During this study, the physicochemical characteristics such as physical (hulling, length/breath ratio, grain classification, chalkiness, chalk index), chemical (alkali spreading value, amylose content (AC), gel consistency (GC), aroma) and cooking characteristics (volume expansion, elongation ratio, water uptake) were studied for 22 traditionally cultivated rice varieties collected specifically from the state of Goa, India.

Among the varieties studied, the highest hulling (80.97%) was noted in variety Ghansal and lowest in Sal and Dhave (72%). The Length/Breadth (L/B) ratio ranged from 1.59-3.69. The chalkiness characteristics were recorded for all the varieties examined. Among the varieties examined, the AC ranged from 14-23.7%, highest in rice varieties Kalo Novan and lowest in Barik Kudi. Kernel length after cooking (KLAC) ranged from 6.76-10.76 mm. The highest KLAC recorded in Barik Kudi and Bello and minimum in variety Jiresal. Kernel elongation ratio (ER) ranged from 1.01-1.66. The present study revealed that the traditionally cultivated rice varieties viz. Bello, Korgut, khochro and Kotimirsal showed good grain quality characteristics.