AGRONOMIC DIVERSITY AMONG RICE (*ORYZA SATIVA* L.) LINES IN A GERMPLASM COLLECTION FROM KENYA

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Abstract

Landraces are precious genetic resources, because they contain huge genetic variability which can be used to complement and broaden the gene pool of advanced genotypes. Knowledge of the genetic diversity and population structure of germplasm collections is an important foundation for crop improvement. The aim of this study was to morphologically characterize the Kenyan rice germplasm collection for identification of important agronomic traits for improved yield. Field experiments were carried out in order to study the diversity in morpho-physiological characteristics of rice genetic material collected from different Kenyan rice growing regions. A total of 50 lines were used in this study. The experiment was carried out at the JKUAT rice experimental field. Each line was sown in single plots that were 2m long at spacing of 20cm with rows 0.4m apart. The time to heading and to maturity significantly differed between the varieties tested ($p<0.05$) ranging from 75 - 140 days and the time to maturity from 120 - 185 days. Most of the lines were resistant to lodging and to shattering. Significant variability was observed for "panicle length" ($p< 0.01$) that ranged from 16 to 30 cm. Over 50 % of the lines tested showed well-exserted panicle. The glumes were less than grain in all lines evaluated. Over 90 % of the lines did have apiculus color. Differences among lines were also observed for "leaf blade anthocyanin coloration", where over 90% showed no blade anthocyanin coloration. There was significant difference for the "awning" characteristic ($p<0.05$) with over 50 % being awnless. Results from the study indicate that genetic variability exists within the Kenyan rice germplasm which form a good source of materials that could be screened for useful traits and exploited in the rice breeding programs.

Key words: Rice germplasm, agronomic diversity, characterization, breeding

1 Introduction

Rice (*Oryza sativa*, L; *Oryza glaberrima*, Steudel) is vital to more than half of the world's growing human population. Its values lie in food grain in the diets of millions of Asians, Sub Sahara Africa and Latin Americans living in the tropics and subtropics. It is likely that rice will continue to remain a major source of their daily food since population growth in these areas is increasing at a high rate (Sasaki.2002). Rice contributes towards achieving food security, employment and income for the poor rural dwellers.

In 2002 world rice production began to increase once again, following three consecutive years of declining production and in 2005 the world production stood at around 614 million tonnes of paddy rice (FAOSTAT, 2005). World average yield in 2005 was projected to rise above 4 tonnes ha^{-1}. Considering that rice is grown on over 150 million ha under a wide variety of conditions from irrigated to dry land to floating, an average yield of 4 tones ha^{-1} is indeed a significant achievement. Rice production in sub-Saharan Africa continues to be outpaced by consumption; imported rice accounts for 50 percent of sub-Saharan Africa's rice requirement (FAO, 2006). In Kenya rice is the third most important cereal crop, after maize and wheat. It forms an important diet for a large proportion of our urban dwellers and is gaining popularity even among those living in the rural areas. Consumption of rice in Kenya has continued to rise over the last fifteen years and it is now estimated to stand at 400,000 metric tons per annum (MOA 2008). Land and water resources for rice production are diminishing and global climate changes may have a major effect on rice production. However, a wide range of technologies available such as SRI, carbon trading and the super yielding varieties for reducing these adverse consequences of rice production have not been extended to majority of rice growers (FAO, 2006). Several factors contribute to the decline of the area under rice cultivation and yield. The most important of these factors are: limited returns in respect to yield potential of the high yielding varieties, declining productivity in intensive rice production systems, pressures from abiotic and biotic stresses, low returns, increasing production costs, and increasing public concern for the protection of environmental resources. One of the most effective means of addressing the issues in rice cultivation and raising the average yields at the farm level is through research and subsequent dissemination of the resulting data (Nguyen and Ferrero, 2006).

Padulosi (1993) noted that successful breeding program should consider genetic diversity of a crop for achieving the goals of improving the crop in terms of yield and resistance to biotic and abiotic stresses. This will refocus the effective utilization of a number of landraces being cultivated locally and rapidly being replaced by improved cultivars which has narrowed the genetic base of cultivated rice. Singh (1989) also reported that, reduced genetic variability underscores the need to collect landraces for *ex situ* conservation and to characterize them for future rice breeding programs at morphological and molecular levels because the evaluation of phenotypic diversity usually reveals important traits of interest to plant breeders. The field results on rice accessions will help to create useful genetic database for future breeding programs, geared towards genetic improvement of local rice varieties for increased food production at house-hold level.

A cardinal objective of any breeding program is to produce high yielding and better quality lines for release as cultivars to farmers for increased food productivity. The prerequisite to achieve this goal is the presence of sufficient amount of variability, in which desired lines are selected for further manipulation that leads to achieving the target objectives. Therefore, the introduction of new populations can be easily made from one region to another and may be used for further manipulation to develop breeding lines. Emphasis should, therefore be placed on increasing productivity per unit area by enhancing growth requirements and developing new cultivars that are efficient in making use of available resources for increased yields. The latter goal can be achieved by evaluating new and adapted germplasm for specific growth and yield traits.

In view of this, genetic characterization of morphological and physiological traits and evaluation will enable Kenyan rice breeders exploit a wide range of genotypic diversities to further crop improvement practices. Through morpho-agronomic characters rice can be categorized into low and high yielding varieties as was described by Tsunoda, (1964) in the "plant type" concept which categorized low nitrogen responders as those possessing long, broad, thin, drooping, pale-green leaves and tall, weak stems and high nitrogen responders as having erect, short, narrow, thick, dark-green leaves, and sturdy stems.

Therefore, it is necessary to evaluate rice germplasm within Kenya in order to select superior lines of early maturing and high yielding breeding materials as strategy for rice improvement. The strategy should combine specific agro-ecological adaptations of local rice varieties to identify high yielding rice varieties for local introduction and varietal improvement. The knowledge of these varieties' morpho-agronomic characteristics will further contribute towards creating genetic database for improved breeding programmes in Kenya and East Africa region. The objective of this study was to characterize and evaluate the morpho-agronomic parameters of rice germplasm collection from Kenya using the rice descriptor suggested by Bioversity International (2007).

2 Materials and Methods

Field visits were carried out in the major rice growing regions in Kenya: Nyanza, Western Kenya, Coast and Mwea irrigation scheme, to identify the various varieties. Seeds from rice growing in the fields were sampled and packed in sample bags and taken to the Jomo Kenyatta University for field evaluation. Other rice variety collections were done from the various National Irrigation Board rice research centers. 78 different collections of rice varieties were received from the different growing regions. The collections were categorized into 50 varieties which were evaluated during the trial (Table 1).

Table 1: List of varieties that were evaluated for morphological diversity

SNO.	VARIETY NAME	SNO.	VARIETY NAME	SNO.	VARIETY NAME
1	Abedi	21	Madevu	41	Sigae nyeupe 2
2	Anguri	22	Matako nyeusi	42	Sigae tune
3	Basmati 217	23	Moshi	43	Sigaya
4	Basmati 370	24	Mtumbatu	44	Sigaye
5	Bibi wa muhaka	25	Mzungu	45	Sindano
6	Bw 196	26	Nerica 1	46	Sindano bahari
7	Chijego	27	Nerica 10	47	Supa
8	Chinga cha moshi	28	Nerica 11	48	Supa saro
9	Cushe	29	Nerica 4	49	Usinicheleweshe
10	IR 2793	30	Niwahi	50	Uzungu
11	Ita 310	31	Pachanga		
12	Japan 54	32	Pachanga supa ya pamba		
13	Japan 64	33	Pamba		
14	Kanja	34	Pishori		
15	Kibawa bawalanzi	35	Pumba la muwa		
16	Kichana chawa	36	Ringa		
17	Kigamti	37	Riziki		
18	Kijego	38	Sifara		
19	Kitumbo	39	Sigae nyekundu		
20	Macho ya wanda	40	Sigae nyeupe 1		

The materials were direct-seeded on 26th January 2012 into the nursery and transplanted into the field on 13th march 2012 in a randomized complete block design (RCBD). The basal fertilizer of 18.6 kg/ha (NPK 15-15-15) was top dressed 21 days after sowing. The second 9.9 kg/ha and third 12.9 kg/ha (Urea) were also top dressed at tillering and prior to panicle initiation. Weeding was performed by hand and plots were maintained, pest and diseases free until harvest. The observable traits data was collected when varieties attained a 5-leaf seedling stage until crop maturity.

2.1 Morphological Traits

Morphological analysis was done using both quantitative and qualitative characters collected during the different growth stages of the varieties. These included; Intensity of the green color of the leaves, Leaf blade anthocyanin coloration, Lemma (apiculus) color, Lemma and Palea color , Culm strength , Panicle exsertion, Panicle length , Awning , Days to heading and Days to maturity.

3 Data Analysis

The data were statistically analyzed using Excel-Stat-pro software. The software helped to calculate the means, standard error, standard deviation and coefficient of variations. The Least significance difference (LSD) test at 5% probability was used to separate means. Frequency distributions were computerized to categorize the variety traits into classes. A dendrogram was constructed by the Unweighted Pairs Groups Method of Arithmetic Averages (UPGMA) based on morpho-agronomic similarity of the 50 rice varieties

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3 Results

The frequency distribution for the traits showed a lot of variability within the varieties evaluated. 30% had medium intensity of green leaf blade color, 2% light intensity while 68 % had dark intensity
96 % had no leaf blade anthocyanin coloration while the remaining 4 % had blotches only. Only 46 % of the varieties had awns which ranged in color from whitish to purple.

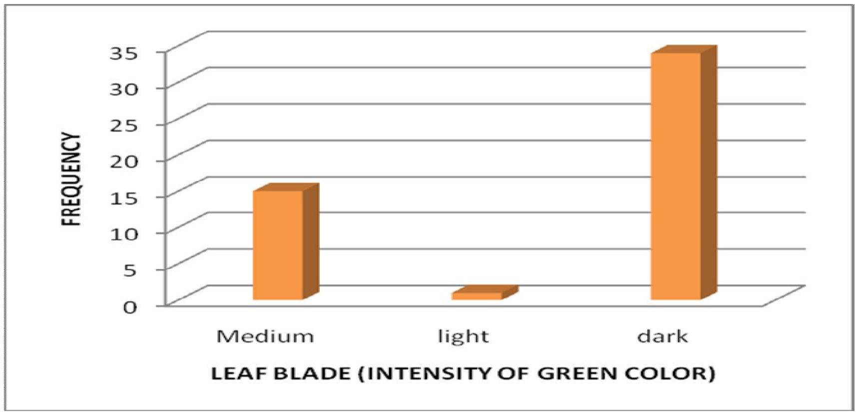

Figure 1: Difference in the intensity of green color on the leaf blade and its distribution among the fifty rice varieties

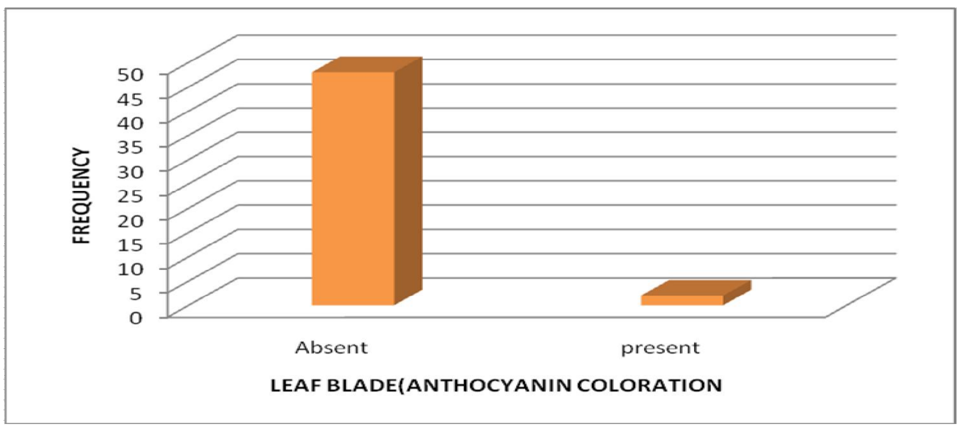

Figure 2: Difference in distribution leaf blade anthocyanin colouration among the fifty rice varieties

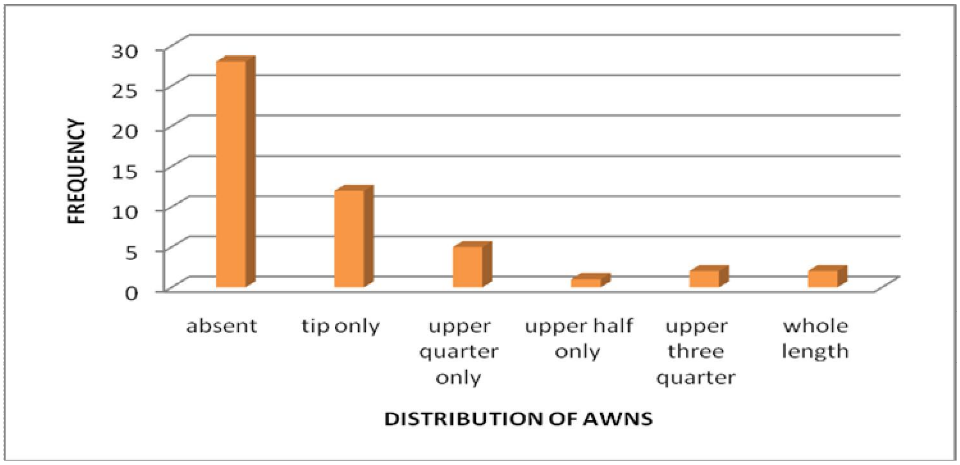

Figure 3: Difference in distribution of awns among the fifty rice varieties

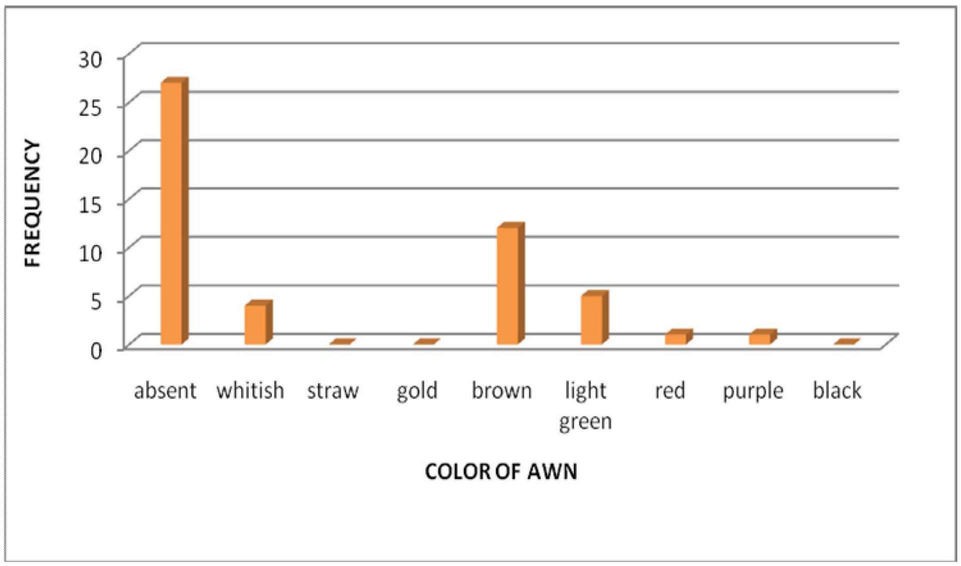

Figure 4: Difference in distribution of awn color among the fifty rice varieties

Awning is considered a nuisance during milling by many farmers but it has been reported to play a role in preventing birds from sucking the milk-stage rice during grain filling. Breeders may therefore select the short-awned types as a compromise during cultivar development. The lemma (apiculus) also had different shades of colors.

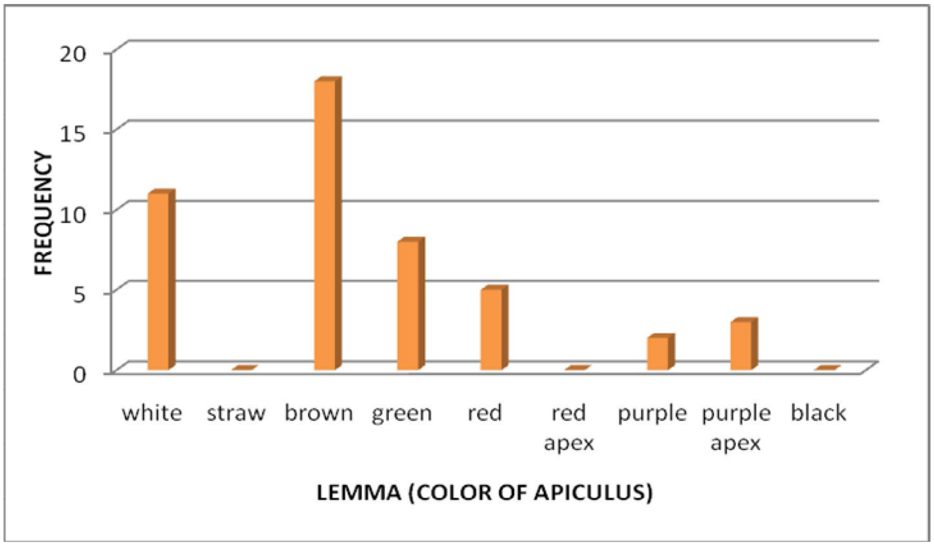

Figure 5: Difference in distribution of lemma color trait among the fifty rice varieties

In terms of culm lodging resistance (culm strength) 14 % of the varieties had very strong culms, 54 % strong and only 32% had intermediate strength

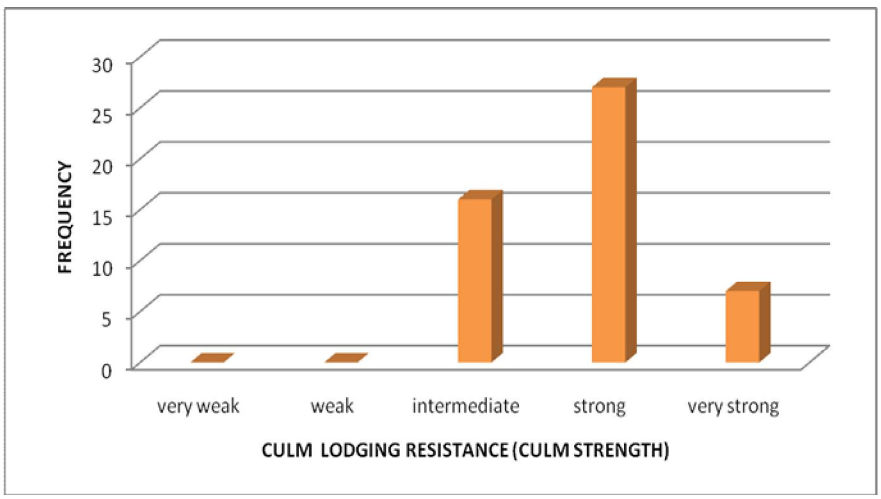

Figure 6: Difference in distribution of the trait culm strength among the fifty rice varieties

For panicle exsertions, it was observed that (12 %) were well-exserted, (28%) moderately well-exserted and 26 % partly exerted.

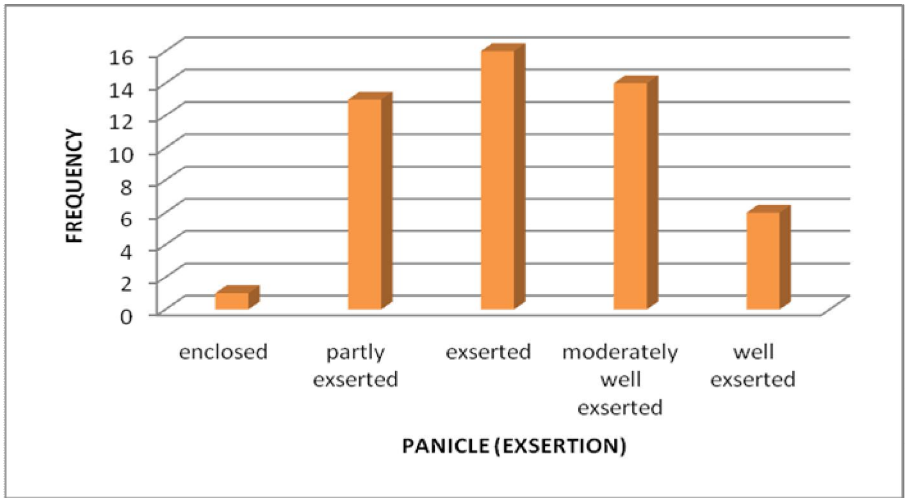

Figure 7: Difference in distribution of panicle (exsertion) trait among the fifty rice varieties

Ilhamuddin *et al*. (1988) found panicle exsertion a conspicuous character for identification of the rice cultivars. The panicle height of main axis ranged from short to medium with 86 % having medium sized panicles and 12 % having short panicles.

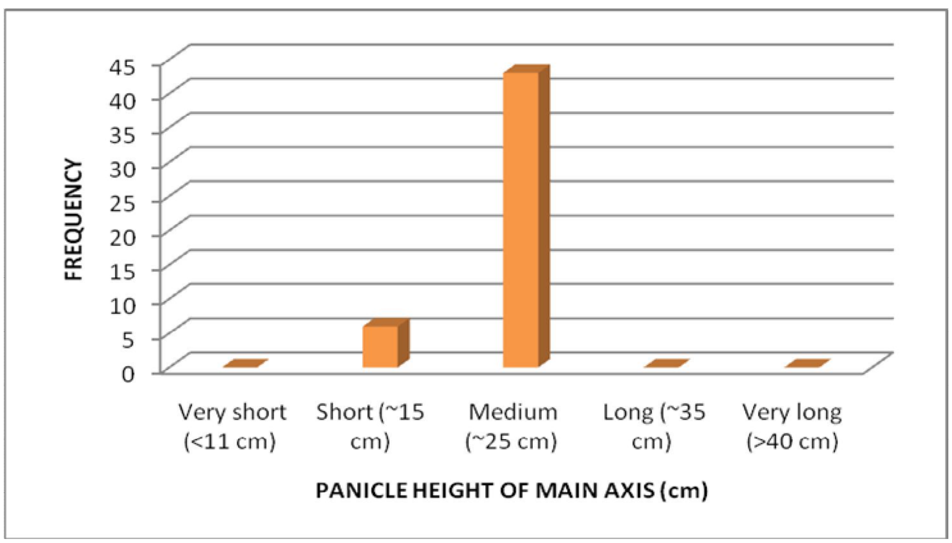

Figure 8: Difference in distribution of panicle height (length) among the fifty rice varieties

The culm number per plant ranged from intermediate (44%) to high (40%)

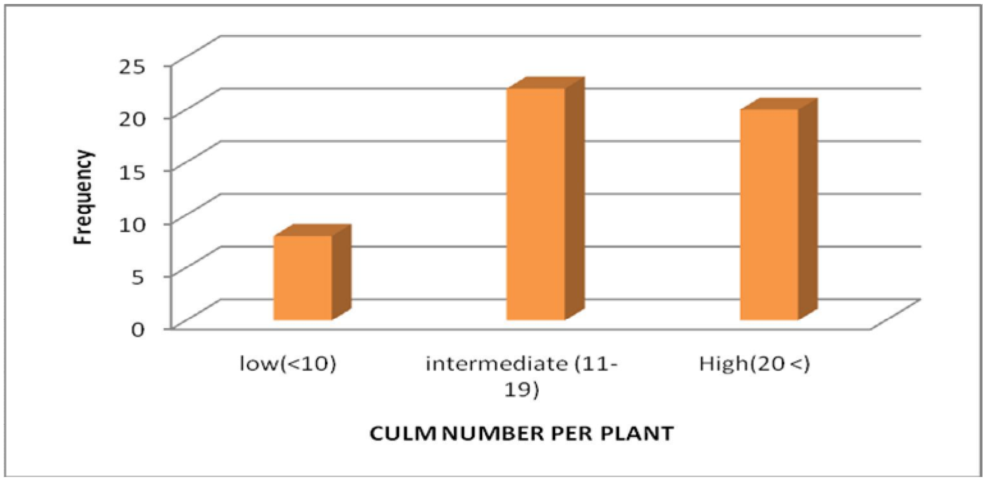

Figure 9: Difference in distribution of number of culms per plant among the fifty rice varieties

The analysis of variance shows significant genetic variations ($P < 0.05$) among the varieties for the quantitative traits assessed. The length of the panicles was significantly different for the varieties ranging from 16.9 – 29.6 and a mean of 22.5

Table 2: Analysis of different quantitative traits for fifty rice varieties during pre-harvest and post harvest stage

PLANT ATTRIBUTES	**Minimum**	**Maximum**	**Mean**	**Sample Variance**	**Standard Deviation**	**Standard Error**	**$L.S.D_{0.05}$**
Panicle length (cm)	16.9	29.6	22.5	16.0	4.0	0.6	1.1
Culm diameter at basal inter-node (mm)	4.7	10.5	7.5	1.8	1.3	0.2	0.4
Culm number per plant	4.6	48.6	19.3	74.7	8.6	1.2	2.5
Panicle number per plant	1.3	34.4	15.8	55.8	7.5	1.1	2.1
Days to flowering	75.0	140.0	118.1	216.4	14.7	2.1	4.3
Days to maturity	120.0	185.0	163.1	216.4	14.7	2.1	4.3
100 grain weight(g)	1.3	3.4	2.5	0.2	0.4	0.1	0.1

Number of days to flowering ranged from 75 to 140 while the days to maturity ranged from 120 to 185 days from effective seeding date. The mean of 2.5 was recorded for 100 grain weight of the varieties with a range of 1.3 -3.4 g and standard deviation value of 0.4. The grain length ranged from 5.4 – 10.7mm and width 2.0 -3.8 mm (Table 2).

3.1 Phenotypic Diversity based on Morpho-agronomic characteristics of Rice Accessions

Clustering of the 50 rice varieties was done using the Unweighted Pairs Groups Method of Arithmetic Averages (UPGMA) based on morpho-agronomic similarity. The dendrogram revealed six main cluster groups of the varieties evaluated

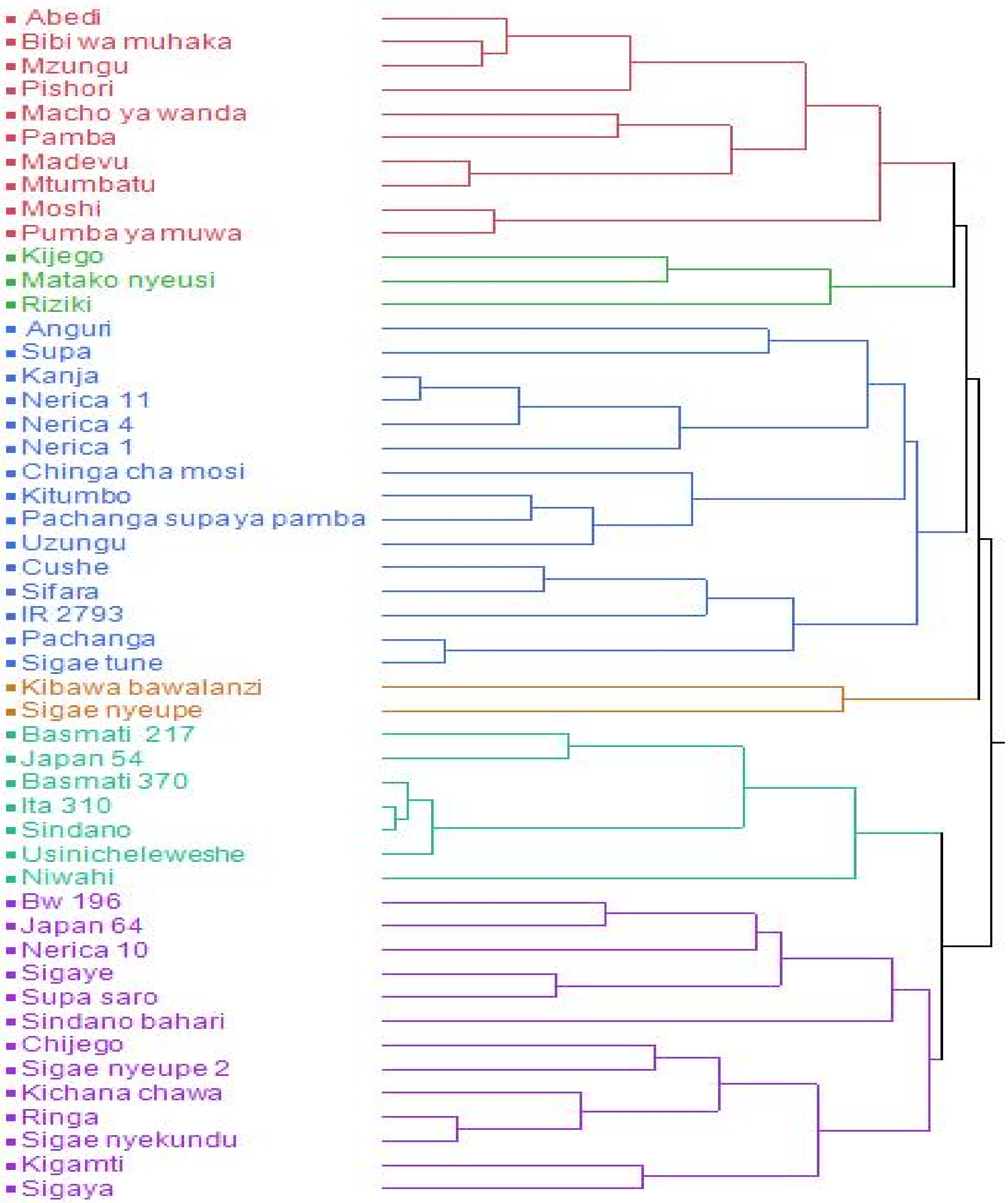

Figure10: Dendrogram showing six clusters of 50 rice varieties classified based on morphological traits

The clusters identified varied in the number of varieties falling into each cluster with the cluster having the lowest number being 2 and the highest having 15 varieties. Basmati 370 clustered together with six other varieties which can be termed as low nitrogen responders however Sindano which clustered in the group is a very early maturing plant which is a very good trait.

4 Discussion

Number of days to flowering ranged from 75 to 140 (Table 2). Similar results were reported by Tahir *et al.* (2002) in rice. This type of variability might be due to the genetic makeup of the landrace lines and genotypic environmental interactions. Early maturing genotypes exist in the collections and could be exploited for cultivar development.

Analysis of data on days to grain maturity exhibited high range of 120-185 days with an average of 163 days. Ten percent of the varieties showed shorter maturity period 120 -140 days. The minimum value for days to maturity genetically reveals that the varieties have benefit of early seeds ripening, compared to 90 percent with late maturity. Early maturing plant types could be selected for areas with short rainy seasons in the rain fed ecologies. Such genotypes will also be suitable in areas where farmers grow a second crop to take advantage of residual water after harvesting the early rice crop.

A mean of 2.5 with a standard deviation value of 0.4 was recorded for 100 grain weight for the varieties with a range of 1.3 -3.4 g (Table 2). These differences were due to grain size and grain shape. It could be concluded that varieties observed possessing longer and slender grains generally have lower grain weight. The long grain and translucent types could be used in grain quality development to meet the consumers' preference.

Evaluation of genetic diversity within rice varieties using agglomerative hierarchical clustering (AHC) gave six clusters based on the variations in morphological properties). The dendrogram generated from similarity matrices provided an overall pattern of variation as well as the degree of relatedness among the 50 varieties. However because morphological characters are mostly subjected to environmental influences (Anna *et al*., 2002), there is the need to conduct molecular studies to gather more evidence on the distinctiveness of the varieties from each cluster.

5.0 Conclusion

Morpho-agronomic characterization is an important prerequisite to evaluate phenotypic` diversity within germplasm collection. It creates the basis to ensure effective utilization of the crop germplasm by both farmers and breeders otherwise unevaluated germplasm remain mere curiosities to the breeding programs.

Evaluation of the fifty rice varieties revealed significant amount of information for breeding programs interventions. There was wide genetic variability in the rice varieties for all the traits evaluated. Differences among the varieties were observed for characters like; awning, leaf blade green colour intensity and leaf sheath anthocyanin coloration. 70% of the rice accessions possessed erect to semi-erect leaves and moderately strong sturdy culms; 56 % showed awnlessness, 72 % were found with well exserted panicle, 6% with semi-compact and 74 % intermediate panicle types respectively. These phenotypic traits could be explored for the rice improvement.

Over 60% of the varieties classified were associated with the dark green color and erect leaf pattern with sturdy stems and less than 5 % with pale green color with droopy leaf pattern and weak stems. Based on the "plant type" concept, the latter group would be categorized as low nitrogen responders and will require improvements. Basmati 370 the most preferred variety in Kenya falls into this category. There were variations in regard to grain characteristics. Variation in the grain length and width did exist as shown in their values obtained (Table 2). The long grain and translucent types could be used in quality grain development.

There was presence of varieties which were early maturing (120 -140 days). These varieties could be used by farmers to evacuate crop for next cropping season, escape insect pest population and other adverse environmental factors. In conclusion genetic variability was observed within the Kenyan rice germplasm based on the morphological traits evaluated which form a good source of materials that could be screened for useful traits and exploited in the rice breeding programs.

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