MORPHOLOGICAL DIVERSITY ANALYSIS OF RICE LANDRACES IN BENGUET

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ABSTRACT

The research was conducted to: collect germplasm of rice landraces in Benguet; to characterize germplasm of collected rice landraces in Benguet; to determine diversity in the collections and relationships among the collected rice landraces, and; to maintain a gene bank of collected rice landraces.

Germplasm collection, morphological characterization, diversity and cluster analysis, and bi-plot analysis were performed on 157 rice landraces collected from the 12 municipalities of Benguet.

Most of the rice landraces were collected from Kibungan, Kapangan, and Bakun. The grain characterization of the rice plants revealed that Sabul and Tudoy had desirable characters on high yield and pest resistance. Pitkikil and Mayok, on the other hand, exhibited long roots and high number of tillers.

A low mean diversity index was observed in both the grain and vegetative characters of the rice landraces indicating homogeneity among the landraces collected.

Cluster and bi-plot analysis on grain characters revealed seven clusters. Cluster seven appears to be associated with high yield. In addition, the same analysis on vegetative characters resulted in three clusters with cluster three appearing to be associated with long roots.

KEYWORDS: Rice landraces, morphological diversity analysis, germplasm

INTRODUCTION

Benguet is rich in natural resources. In these natural resources, there exists a great diversity among crop plants. Many of these crops represent important food crops consumed by majority of the tribal people. Agronomic crops such as cereals, legumes, and root crops are mainly grown in the area. The value of the area's genetic diversity goes beyond its potential role in improving food crops.

Production of traditional rice is slow and decreasing due to the introduction of many high yielding rice varieties. However, in Benguet and other provinces of the Cordillera region, indigenous rice is still preferred by the people because of its aroma, good eating quality, minimum in-put and management, adaptability to the locality, stable yield, and use in traditional practices. The introduction of modem varieties is a growing disadvantage to the local rice germplasm pool as the traditional rice is fast vanishing. Before these traditional rice's are lost, collection and characterization should be done.

A number of studies and surveys have shown that highland upland rice farmers still prefer their old traditional varieties in spite of the in-

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troduction of new high yielding varieties (HYV's). Superior eating quality, good adaptation resistance, and low input requirement are among the reasons why they still choose to plant the traditional varieties which are low yielder and have very long maturity (Andam, 1995).

Landraces serve as a source of valuable germplasm that has been collected and stored in gene banks. Plant genetic resources are important in developing new crops in new sustainable production systems. It is important to farming communities not only for food production but also their role in people's culture and traditions. When plant genetic resource diversity is lost, it is not only the genetic base of agriculture that is eroded, but also rural people's identity and knowledge system (Anonymous, 1993).

The collection, conservation, and characterization of important crop germplasm are critical in considering the alarming loss of valuable genetic resource. These germplasm are valuable because they represent products of fine-tuned selection over hundreds of years and have evolved dynamically to counter pest, pathogen, and environmental pressure.

MATERIALS AND METHODS

Germplasm collection

Prior to the collection trips, free-prior informed consent were asked from the mayors of the different municipalities to collect rice landraces in their area of jurisdiction. Verbal and written consent were given to the researchers.

Morphological characterization and diversity analysis

Upon collection, the rice landraces were characterized in-situ using the IPBGR/Bioversity International (2007) descriptors list. Collected rice landraces are being maintained at the BSU experimental station and characterized ex-situ.

Diversity Analysis

Estimate of variability for each qualitative characters were computed using the standardized Shannon-Weaver Diversity Index, designated as H1 and has the formula:

$$H1 = -\sum pi \, (\log_2 pi) / \log_2 n$$

Where:
pi = frequency of proportion of each descriptor state
n = number of states

The Shannon-Weaver Diversity Index has a value ranging from 0 to 1, where 0 indicates the absence of diversity and 1 indicates maximum diversity.

The same formula was applied to the quantitative characters based on the work of Siopongco et al. (1999) by construction of frequency classes with the class boundaries equal to some function of mean and standard deviation. For each character, the overall entry mean (x) and standard deviation (σ) was used to subdivide the accession values (x_1) into frequency classes, with a class width of 0.5σ. The lowest and highest values were considered to determine the number of classes to construct. Thus, ten frequency classes will have a range of class 1 ($x_1 < x-2\sigma$) to class 10 ($x_1 > x+2\sigma$).

Cluster analysis

The Ward's method was used in clustering the collections. The method easily determines the groupings where each collection belongs so that collections in the same cluster are more alike than elements in different clusters. Thus, the resulting clusters shall exhibit high internal homogeneity (within cluster) and high external heterogeneity (between clusters). According to Kaufman and Rousseuw (1990), Ward's meth-od perform well with groups that are multivariate normal and spherical and with equal number of observations. Since the variables in this study were transformed into a standard normal, Z, then the Ward's clustering

method is appropriate. The entire procedure may be presented in a dendrogram.

A measure of similarity and dissimilarity was computed using the squared Euclidian (Minkowski distance metric) formula.

RESULTS AND DISCUSSION

Germplasm collection

Place of collection

The rice landraces were collected at Atok, Bakun, Bokod, Buguias, Itogon, Kabayan, Kapangan, Kibungan, Mankayan, Sablan, Tuba and Tublay. Geographically, these twelve municipalities are adjacent.

Bakun, Kapangan, and Kibungan had the most number of traditional rice landraces collected (Table 1). This could be due to the Municipality of Kibungan's agenda to conserve traditional rice landraces while Bakun and Kapangan are known as rice growing areas.

Modern rice varieties have been introduced in Atok, Bakun, Bokod, Kapangan, Sablan, and Tublay by their municipal agriculturists resulting in rice farmers cultivating hybrid rice varieties instead of the traditional ones.

The municipality of La Trinidad was excluded in the collection trips since the 10.5 ha in Bineng devoted to rice was planted with certified seeds and HYV's. The farmers preferred such varieties since a portion of the planting materials were given free by the Municipal Agriculture Office. In addition, the varieties have short growth duration and high yield.

Rice landraces collected

A total of 157 traditional rice landraces was collected in the 12 municipalities of Benguet (Fig.1 and Table 1). The quantity of rice collections varied among the municipalities. Howev-er, most of the collections were obtained from Kibungan (29), Kapangan (27), and Bakun (23). The collections were usually named in either Kankana-ey or Ibaloi (Fig.2).

Table 1. Place of collection and number of rice landraces collected

COLLECTION SITE	NUMBER OF RICE LANDRACES	ELEVATION OF SITE (masl)
Atok	11	540-2,660
Bakun	23	180-2,600
Bokod	8	580-2,680
Buguias	5	1,240-2,780
Itogon	5	160-2,080
Kabayan	19	840-2,920
Kapangan	27	240-1,740
Kibungan	29	140-2,580
Mankayan	7	540-2,340
Sablan	8	100-1,500
Tuba	6	40-2,240
Tublay	9	480-1,820
TOTAL	157	

Figure 1. Panicle of some rice landraces

Morphological characterization and diversity analysis

Grain Characters

A. Morphological Characterization

Awn color. The awn color of the different rice landraces ranged from gold to brown or black (Fig. 3 and Table 2). Some of the landraces such as Basilyo, Bongkitan, and others have awnless spikelets.

Lemma and Palea pubescence. Most of the rice landraces have short pubescence while some have glabrous pubescence on the grain lemma and palea. Others like Damaso and Talabtab have pubescence on the keel or on the upper portion of the lemma.

100 grain weight. The heav-iest grain weight was exhibited by Sabul and Tudoy which might indicate bigger grains. The grain weights of Kasingey and Mayok was also high (Table 3).

Grain color. The grains of most of the rice landraces were red to dark red. The other landraces have white grains (Fig. 3 and Table 2).

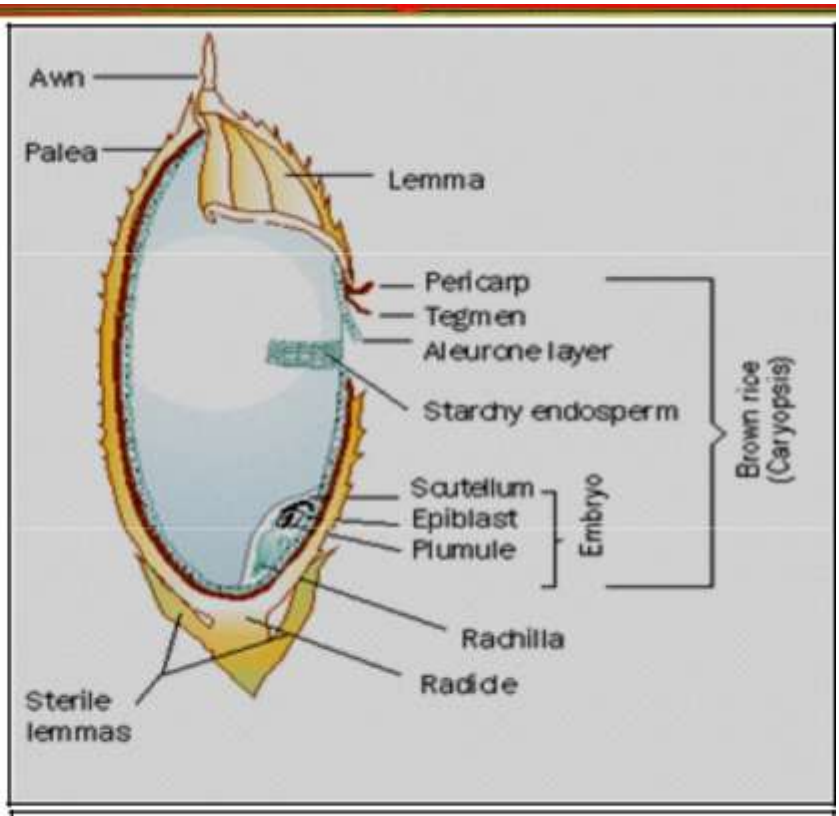

Figure 2. Morphology of rice grain showing variations in awn and grain color (Source: IRRI, 2009)

Figure 3. Grains of the different rice landrace

B. Diversity Analysis

Qualitative Characters

The computed diversity indices for the qualitative characters of the rice grains ranged from 0.10 to 0.80 with a mean diversity value of 0.22 (Table 3). Low variation (0.33 and below) is observed in most of the qualitative characters except for sterile lemma color. The grains of the different rice landraces had varying sterile lemma colors of gold, red, and purple.

C. Cluster Analysis

Quantitative Characters

The mean diversity index for the quantitative characters of the grains of the rice landraces was low (Table 4). The diversity values of the nine quantitative characters ranged from 0.00 (grain thickness) to 0.34 (awn length). Most of the rice landraces had similar if not the same measurements for length and thickness of awn, lemma, and grain.

Table 2. Grain characters of the rice landraces collected from different municipalities of Benguet

RICE LANDRACES	AWN COLOR	LEMMA & PALEA PUBESCENCE	100 GRAIN WEIGHT (g)	GRAIN COLOR
Basilyo	Absent	Short hairs	2.9	Red
Bayabas	Gold	Short hairs	2.8	Red
Bingkawan	Absent	Glabrous	2.5	White
Bongkitan	Absent	Hairs on lemma keel	2.8	White
Botalga	Gold	Short hairs	2.8	Red
Burik	Gold	Hairs on upper portion	1.9	Red
Damaso	Absent	Hairs on lemma keel	3.0	Red
Ginapas(Diket)	Gold	Glabrous	2.5	White
Kabal	Absent	Short hairs	3.4	Red
Kasingey	Absent	Hairs on upper portion	3.5	white
Kintoman	Absent	Hairs on upper portion	3.4	Red
Kombination	Black	Hairs on lemma keel	2.0	White
Kulot	Gold	Short hairs	2.5	White
Labong	Gold	Short hairs	2.6	White
Luk-ab	Gold	Short hairs	3.0	Red
Makanining	Gold	Short hairs	2.8	White
Makunting	Black	Hairs on upper portion	2.7	Red
Mayok	Absent	Hairs on upper portion	3.5	White
Oklan	Gold	Short hairs	3.4	White
Patalinaw	Black	Hairs on lemma keel	2.6	Red
Pitkikil	Black	Hairs on upper portion	2.8	Red
Potian	Absent	Short hairs	3.0	White
Sabul	Brown	Hairs on upper portion	3.8	Red
Talabtab	Gold	Hairs on upper portion	2.8	Red
Talokitok	Black	Hairs on upper portion	2.9	White
Longgot	Absent	Hairs on upper portion	3.0	White
Sakey edeb	Absent	Short hairs	2.8	White
Tudoy	Straw	Hairs on upper portion	3.8	Red

Table 3. Computed diversity indices for the qualitative grain characters of different rice landraces

GRAIN CHARACTER	DIVERSITY INDEX
Awn:colour	0.32
Lemma and palea pubescence	0.16
Lemma and palea colour	0.25
Lemma: anthocyanin colouration of keel	0.10
Lemma: anthocyanin colouration of area below apiculus	0.09
Lemma: colour of apiculus	0.17
Lemma: shape of apiculus	0.10
Sterile lemma shape	0.12
Sterile lemma colour	0.80
Caryopsis: shape	0.14
Caryopsis: pericarp colour	0.25
Mean diversity index	0.22

Cluster membership

The application of Ward's method on classifying 157 rice landraces on grain character reveals seven clusters (Fig. 4 and Table 5). The first and second cluster consists of 83 and 58 rice landraces respectively. It appears that the source of collection did not affect the first and second clustering since the collection sites for these landraces represented all the twelve municipalities of Benguet.

The third cluster constitutes four landraces namely "Aleg," "Ba-ay," "Gal-o," and "Kamoros" which were all collected from Tuba. The fourth cluster includes seven landraces collected from Kapangan, Tublay, Kibungan, and Mankayan. These municipalities are adjacent making distribution and exchange of seeds accessible among the farmers and consumers.

Cluster 5 only includes "Kombinasyon" collected from Kabayan while cluster 6 consists of "Kuwaltian" and "Lablabi" collected from Kibungan. The seventh cluster constitutes only one landrace namely "Lasbakan" which was collected from Bakun.

Table 4. Computed diversity indices for the quantitative grain characters of different rice landraces

GRAIN CHARACTER	DIVERSITY INDEX
Awn length	0.34
Awn thickness	0.12
Sterile lemma length	0.16
Grain: length	0.16
Grain: width	0.13
Grain: thickness	0.00
100 grain weight	0.17
Caryopsis: length	0.23
Caryopsis: width	0.10
Mean diversity index	0.16

Cluster characteristics

Rice landraces in cluster 7 had the longest and thickest awn, sterile lemma, and widest grain (Table 6). Long awns in wild rice may be an indication of resistance to insect pest attack and efficient seed dispersal (Kurakazu, 2009).

Cluster 7 also had the highest 100 grain weight due to the long and thick grains of the collections. The high 100 grain weight of cluster 7 may indicate high yield. Thus, collections under cluster 7 may be associated with high

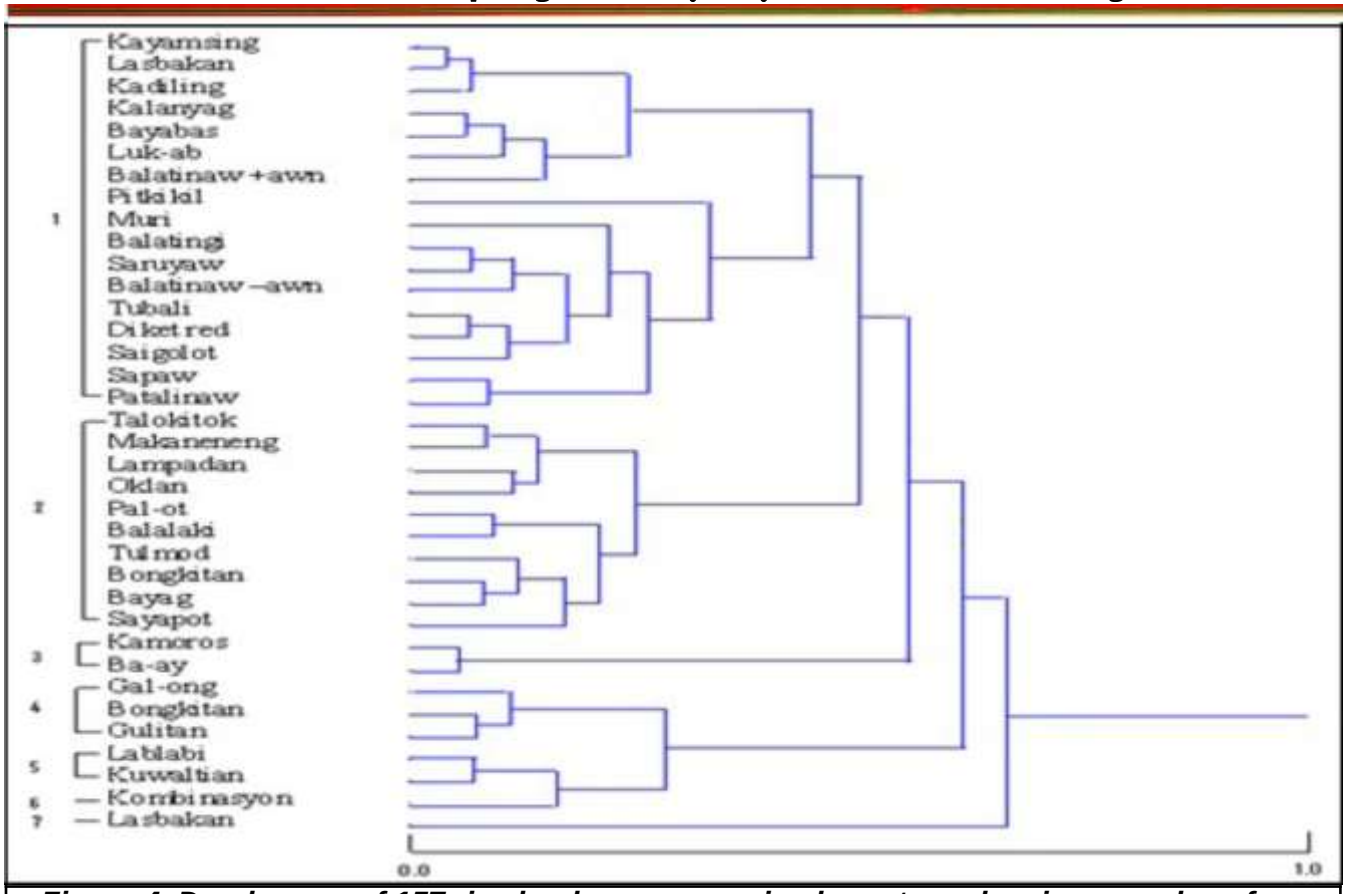

Figure 4. Dendogram of 157 rice landraces on grain characters showing samples of rice landraces for each cluster

Table 5. Total number of rice landraces per cluster and their characters

Cluster	Number of rice landraces	Characters
1	83	Awn length (0 to 7cm) Awn thickness (0 to 2mm) Awn color (Gold to Black)
2	58	Lemma and palea color (straw to purple furrows) Lemma anthocyanin coloration of keel (absent to medium) Lemma anthocyanin coloration of area below apiculus (absent to medium)
3	4	Grain length (5mm to 10mm) Caryopsis length (4mm to 8mm)
4	7	Grain width (3mm to 5mm) 100 grain weight (3g to 5g) Caryopsis width (2mm to 4mm)
5	1	Sterile lemma shape (absent to triangular) Sterile lemma color (straw to purple)
6	2	Sterile lemma length (2mm to 4mm) Lemma shape of apiculus (pointed to curved)
7	1	Lemma colour of apiculus (straw to black)

yield and resistance to insect pest.

Collections in cluster 1 had the longest grains and caryopsis. The rice industry is becoming increasingly interested in the development of long grain rice varieties. Long rice grains tend to be much fluffier and drier with improved canning stability and low washout loss in processing (IRRI, 1985). Long grains also tend to have lower gluten which may be an excellent substitute for low gluten or gluten free diets (Christensen, 2003).

D. Bi-plot analysis

The bi-plot analysis of grain characters of the 157 rice landraces is shown in Fig. 5. The graph shows the association between grain characteristics and the different rice landraces.

Cluster 7 is associated with awn length, grain width and 100 grain weight, hence, may be classified as the most productive and most resistant to insect pests. Cluster 4 has the widest caryopsis while cluster 1 is related to grain and caryopsis length. Thus, collections in cluster 1 may be classified as long grained rice landraces.

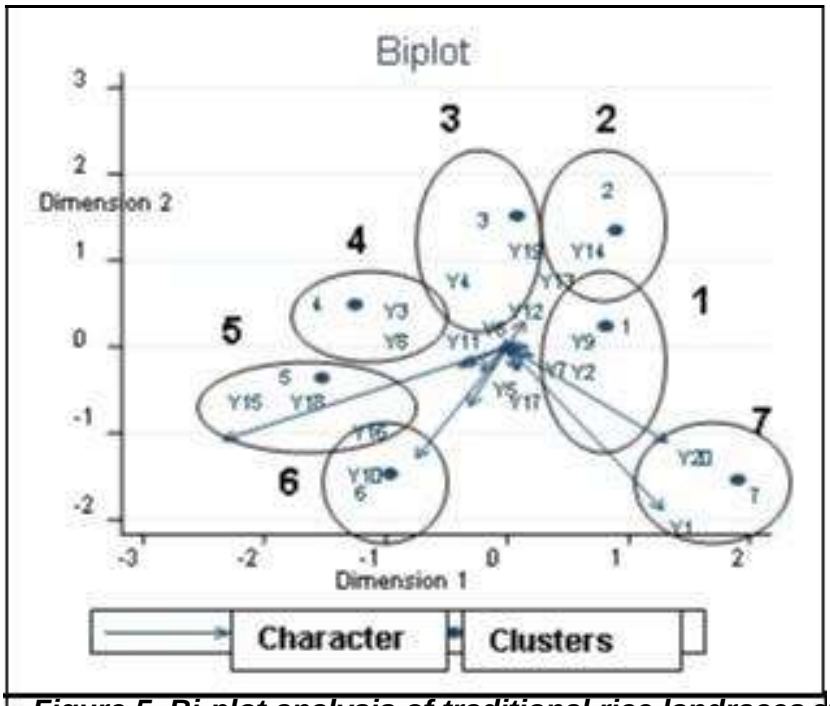

Figure 5. Bi-plot analysis of traditional rice landraces and grain characters

Cluster characteristics

Rice landraces in the second cluster had the longest and widest leaves, tallest plants, and widest stems (Table 8). The condition in La Trinidad where the landraces in this cluster were grown may be ideal for vigorous growth of rice plants.

On root length and number of tillers, Cluster 3 had the longest roots and most tillers. More tillers in a seedling may be an early indication of high productivity.

Table 6. Cluster means involving nine quantitative grain characters in rice landraces

CHARACTER	CLUSTER MEAN						
	1	2	3	4	5	6	7
Awn length	2.78	1.32	0.99	0.54	1.00	4.65	8.30
Awn thickness	0.40	0.37	0.21	0.14	0.50	0.50	0.50
Sterile lemma length	2.85	2.75	2.79	2.57	3.00	3.00	3.00
Grain length	8.43	3.00	8.29	7.57	8.00	7.50	8.00
Grain width	3.25	3.25	3.05	3.42	3.00	4.00	4.00
Grain thickness	2.00	2.00	2.00	2.00	2.00	2.00	2.00
100 grain weight	3.17	3.00	2.86	2.71	2.60	3.00	3.50
Caryopsis length	6.20	3.00	6.12	5.71	6.00	5.50	5.00
Caryopsis width	2.77	2.75	2.74	3.00	2.00	3.00	3.00

E. Bi-plot analysis

The bi-plot analysis between the vegetative characters and the different rice landraces validates the three clusters formed (Fig. 6).

Cluster 3 is associated with root length and number of tillers. Long roots may be an indication for drought tolerance while more tillers may be an early indication of productivity. Hence, landraces in cluster 3 may be a source of selection for drought tolerance and productivity.

Cluster 2 is associated with leaf length and width, plant height, and culm diameter and length. This cluster may therefore be categorized as highly vigorous.

Table 7. Total number of rice landraces per cluster and their characters

CLUSTER	NUMBER OF RICE LANDRACES	CHARACTERS
1	14	Leaf blade length (1cm to 2.5cm) Leaf blade width (0.5cm to 1.7 cm) Leaf length (27cm to 78cm) Initial plant height (13cm to 20) Final plant height (35cm to 95cm) Culm length (10cm to 35cm) Culm diameter (0.4mm to 0.9mm)
2	9	Root length (9cm to 24cm) Basal leaf sheath color (green to purple lines) Leaf blade color (green to purple blotches)
3	4	Number of tillers per plant (4 to 25)

Table 8. Cluster means involving 9 vegetative characters of 27 rice landraces collected from four locations of Benguet

VEGETATIVE CHARACTER	CLUSTER MEAN		
	1	2	3
Root length(cm)	13.35	15.00	17.44
Leaf blade length (mm)	22.42	47.75	34.11
Leaf blade width(mm)	7.00	15.25	10.11
Leaf length(cm)	33.21	73.00	48.88
Initial plant height(cm)	14.42	18.75	15.00
Final plant height(cm)	42.21	87.00	65.44
Culm length(cm)	14.85	28.25	19.44
Culm diameter	4.07	7.50	4.88
Number of tillers per plant	10.57	9.50	12.33

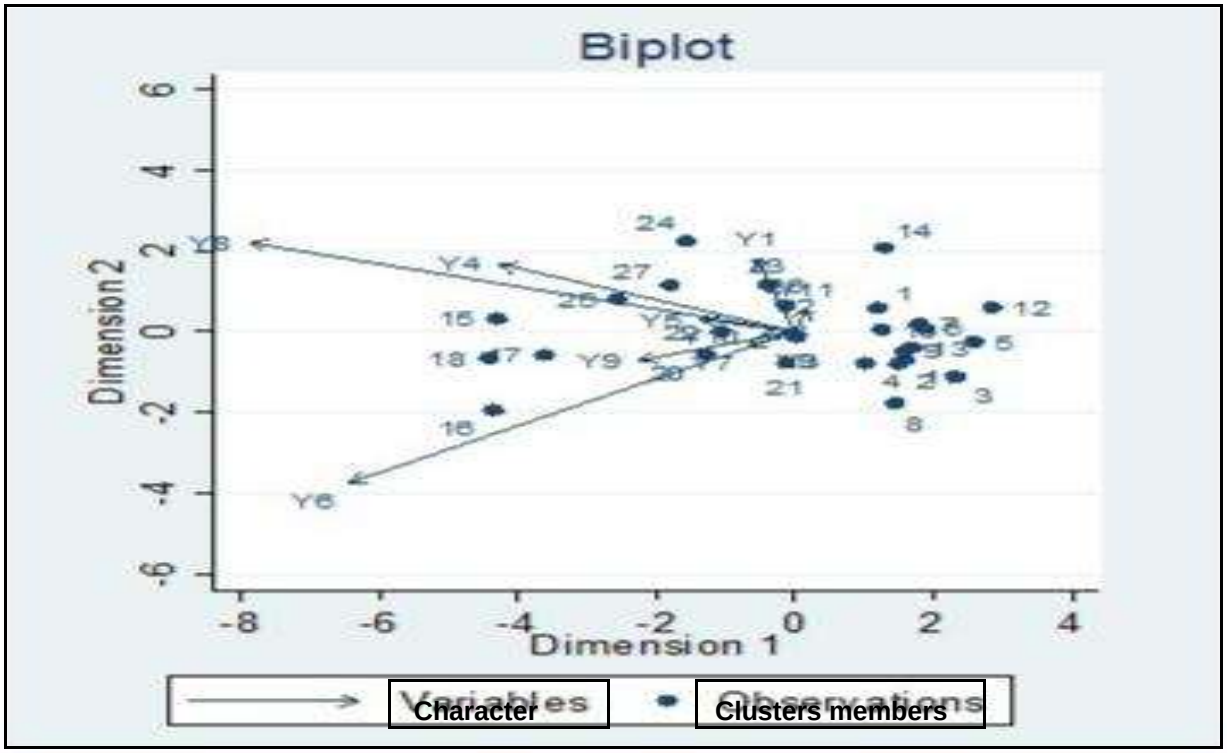

Figure 6. Bi-plot analysis on the vegetative characters of 27 rice landraces collected from four locations of Benguet

SUMMARY,CONCLUSION AND RECOMMENDATIONS

Summary and Conclusion

One hundred fifty seven rice landraces were collected from the twelve municipalities of Benguet. The landraces were mostly found in Kibungan, Kabayan, and Bakun since farmers in these sites prefer traditional varieties over hybrid rice varieties. These sites therefore had high diversity of rice landraces.

Rice landraces in the morphological characterization of grains, "Sabul" and "Tudoy" recorded the highest 100 grain weight indicating big grains and high yield. These two landraces have awned grains which might indicate insect pest resistance. "Sabul" and "Tudoy" may have the characteristics desired by plant breeders.

For the vegetative characters of the landraces, "Pitkikil" had the longest roots which may indicate drought tolerance. "Mayok" which had one of the highest 100 grain weights had the most number of tillers. These two varieties may be good sources of genes for high yield.

The qualitative and quantitative grain characters of the rice landraces revealed a mean diversity index of 0.22 and 0.16, respectively which are indicative of low diversity. Similarly, most of the qualitative and quantitative vegetative characters of the landraces revealed low diversity. Specifically however, sterile lemma color and culm length revealed a high diversity within the rice landraces.

Cluster and bi-plot analysis based on nine grain characters of 157 rice landraces revealed seven clusters. Among the seven clusters formed, cluster seven may be associated with

high yield and pest resistance due to the high 100 grain weight and awned grains exhibited by the landraces in this cluster. Cluster one is associated with long-grained landraces which maybe preferred by processors.

The vegetative characters of the landraces subjected to cluster and bi-plot analysis revealed three clusters. Cluster three which con-stituted landraces with long roots and high tiller number may be associated with drought toler-ance and productivity. Cluster two which includ-ed tall plants which had thick culms and wide leaves may be associated with high vigor.

Thus, cluster seven may be a good source for varieties with high yield and insect pest resistance. Long grained varieties preferred for canning and low gluten diets may be taken from cluster one. Cluster three, on the other hand, may be a source of genes for drought tolerance.

Recommendations

"Sabul" and "Tudoy" possess desirable characters for breeding, thus both may be included in a breeding program for high yield and resistance to insect pest. These two landraces may also be subjected to multi-location evaluation for yield and pest resistance.

In addition, "Pitkikil" and "Mayok" may be recommended for further evaluation due to long roots, more tillers, and high vigor exhibited by the plants. "Pitkikil" may also be explored as source of genes for drought resistance.

Rice landraces with superior characters should be further evaluated in different locations to identify an heirloom rice specifically for Benguet.

Since morphological traits are not always reliable due to their paucity and are easily influenced by the environment, a more reliable way to characterize germplasm would be the use of DNA markers. Profiling of these indigenous germplasm using DNA markers could be done in the future.

Characterization, evaluation and diversity analysis could also be done using other crops of major importance in Benguet and other provinces in the Cordillera.

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Figure below shows the process before a paper could be published in the BSU Research Journal.