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Determination of host-associated variability in the shape of the mandible of white rice stem borer *Scirpophaga innotata* (Lepidoptera: Pyralidae)

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Abstract. Host-plant modifications are known to promote high taxonomic diversity and ecomorphological disparity among its insect-herbivores. Studies on mouthpart morphology specifically the mandible are central to understanding these adaptive modifications as they are used as major feeding apparatus. In this study, mandible shape of a monophagous white rice stem borer, *Scirpophaga innotata* Walker (Lepidoptera: Pyralidae) which were obtained from different host-plant rice cultivars were assessed using image analysis and Elliptic Fourier techniques. Contours of the mandibles were extracted via chain-coding and principal component analyses were performed to determine patterns of shape differences. Observed variation ranges from the arrangement and length of its teeth, from the basal and external margins and the contour of the side of attachment from the body. The greatest variations accounted by the first two principal components (PC's) are on the arrangement, length and number of its teeth which is attributable to continuous wear of the individual mandible in effect of the biochemical properties of the plant. Intra-population variation is associated with the influence of rice plant morphological characteristics associated with resistance or susceptibility to white stem borer.
Key words: *Scirpophaga innotata,* elliptic Fourier descriptors, insect-resistant *Oryza* cultivars.

Introduction. The monophagous white stem borers *Scirpophaga innotata* Walker (Lepidoptera: Pyralidae) are serious pest insects of Asian cultivated rice, *Oryza sativa* L. (Cohen et al 2000; PHILRICE 2001; Khan et al 2005) that infest the host at all stages of growth (Amuwitagama 2002; Cohen et al 2000; Pathak & Khan 1994). Ecological and physiological factors like high fecundity (Cohen et al 2000), and long diapauses favoring climatically diving long fallows (Litsinger et al 2006) contribute to its persistence and severity. The larvae injure the rice stem causing drying of the central whorl and discolored panicles with empty and partially filled grains (PHILRICE 2001).

The persistence over centuries (Amuwitagama 2002), increased outbreaks (Pathak & Khan 1994; Amuwitagama 2002), almost null effect of natural enemies (Kfir et al 2002) and change of insect-pest complex had lead to rigid multilateral approach of integrated pest management topping the direction of continued development of insect-resistant rice cultivars (Sakai & Itoh 2010).

Earlier screening of rice germ plasm for developed cultivars and even modern semi dwarf showed only resistance scores varying from highly susceptible to moderate resistance (Chaudhary et al 1984; Cohen et al 2000). Efforts to produce highly resistant varieties through conventional breeding and wide hybridization with wild rice species have not been successful (Cohen et al 2000). Differences in varietal resistance are thought to be quantitative and polygenic in nature.

Anatomical characteristics of rice plant is working in general association with borer resistance. Generally, tall varieties with long wide leaves and large stem are more susceptible while those with more layer of lignified tissue, a greater area under sclerenchymatous tissue and large number of silica cells are more resistant

(Schoonhoven et al 2006). Further, a rice plant biochemical oryzanone (p-methylacetophenone) was identified as an attractant to ovipositing moths and to larvae while the presence of allomones or pentadecanal inhibited oviposition and disturbed the insect growth and development (Schoonhoven et al 2006). Strain resistance development and changes in insect pest complex were revealed in the study of Pathak & Khan (1994). Several species which once were considered minor pests are now considered major. These counter resistances of pest population may suggest forms of adaptations, genetic polymorphisms or speciation.

The different selective regimes to insect-herbivores brought about by host-plant artificial and natural phenotypic and genotypic modifications may result to various degrees of host specificity (Rhoades 1985) and significant intraspecific morphological differences (Medina 2005). Recent reviews have emphasized that induced responses of plants have profound evolutionary consequences for various traits of plant-associated herbivorous insects (Agrawal 2001; Fordyce 2006). Previous studies have shown that induced plant responses have a potential to affect the evolution of resource-utilizing traits of herbivores (Bolter & Jongsma 1995; Broadway 1995; Chambers et al 2007).

Among class Insecta, mouthpart morphology is pronouncedly adapting and evolving to specific food types (Snodgrass 1935; Smith & Capinera 2005). Having elevated taxonomic diversity and ecomorphologic disparity, insect mouthparts represent a broad spectrum of feeding modes that are ideal for comparative studies. Stem borers make use of their mandible as the major feeding apparatus primarily facilitating the biting, chewing and severing of food. Bernays (2001) showed the frequency with which certain mandible types have evolved in separate insect lineages with similar types of food indicates the adaptive value of this structure. Several authors had documented dramatic differences in the shape of feeding apparatus (size-adjusted head width and mandible length) among polyphagous insects such as caterpillars and grasshoppers as host specific adaptations to overcome host specific defenses. Recent studies on mandibular morphology of grasshoppers (Barcebal 2010) and cockroaches (Tanqueing 2010) showed a diet-related influence on shape variability. However, Smith & Capinera (2005) stressed the ability or tendency of grasshoppers to change host is partly limited by the structure of their mandible’s wear and tear.

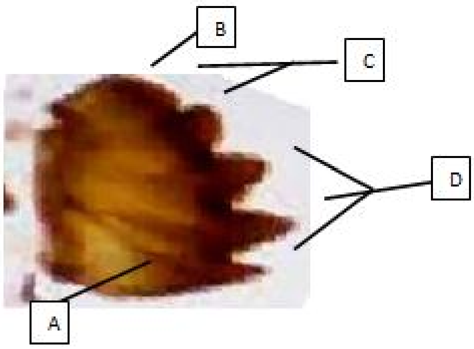

Fig. 1. The basic external morphology of an stemborer mandible (points of articulation with the head not shown). A: external margin; B-D: parts of the internal margin: B: basal margin; C: basal angle; D: teeth.

Implications on mandibulate morphological variations may suggest host associated genetic or phenotypic differentiations as stem borer damages are managed mainly by host genetic modification by rice cultivar development. This is of particular importance since successful control of any pest is based on correct identification and inability to recognize distinct population can have drastic and costly consequences for pest management (Menken & Ulenberg 1987). In addition, considerable effort in understanding economically related consequences of insect feeding, particularly in agricultural fields such as pest control, crop pollination, and the transmission of insectvectored diseases, historically has required a fundamental understanding of mouthpart structure and function (Labandiera 1997).

Understanding quantitative genetics of variation in biological shapes has been a continuing scientific interest since it can provide a linkage between genotype and environment (Cardini & Slice 2004). Geometric morphometrics can integrate these quantitative descriptions of any morphological trait combined with appropriate statistical analysis to compare geometric form of objects, to test congruence between morphological and molecular data, to study the ontogeny of organism shape and the evolutionary forces modeling biological forms (Bookstein 1991; Rohlf & Marcus 1993; Corti et al 2000; O'Higgins 2000; Cardini & Slice 2004). Outline-based morphometric analysis is the common approach to include all meaningful biological shape points. Further, captured outlines are analyzed using shape variables, such as generated by an Elliptic Fourier descriptors tied with image analysis captured in digital properties gives good representation of contour shapes. This can describe an overall shape mathematically through transforming coordinate information concerning its morphological outlines into Fourier coefficients (Kuhl & Giardana 1982). The transformed coefficients by Principal Component Analysis can then be extracted to layout the independent shape characteristics.

This study aimed to determine which parts of the mandible give significant variations and determine and describe patterns of mandibular variations and to determine intra-population variability of the mandible associated with the different rice host varieties.

Material and Method. Stem borer larvae (*Scirpophaga innotata)* were randomly collected from different sites of Sibugay, Zamboanga del Sur from its rice host plants namely, PSB RC18 (Ala), NSIC RC122 (Angelica), PSB RC26H (Magat), RC 124H (Mestizo 4), PSB RC82 (Penaranda) and B1 (Table 1). The collected samples were placed in plastic containers containing prepared fixative (70% ethyl alcohol + 30% glacial acetic acid) for preservation.

The larvae were processed by boiling it in 5% NaOH solution until it will become transparent. Mandibles were removed by lifting the labrum and pulling out each mandible separately with dissecting pins. These were mounted on glass slides added with glycerol to prevent dissection. Acquisition of the image was done using a MicronCAM by Dr. Nietzie Bebing of the Institute of Biological Sciences, University of the Philippines Los Banos College, Laguna, Philippines which was connected in Leica Stereoscopic zoom dissection microscope.

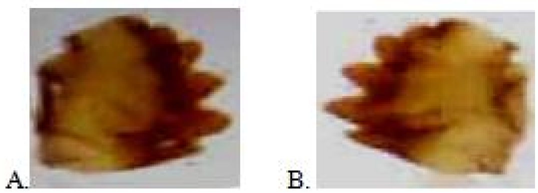

Figure 2. Images showing the right mandible (A) and left mandible (B).

The images produced by the MicronCAM attached to the stereomicroscope were converted to a 24-bitmap type and change into a gray scale pictures. The outlines of each mandible were digitized using the software package SHAPE version 1.3 (Iwata & Ukai 2002) to examined variation in shapes. The objects of interests were distinguished using the technique segmentation done by "thresholding procedure" where a parameter called the brightness threshold is manually chosen from brightness histogram and applied. Undesirable marks also termed as "noise" were found on the transformed binarized images and consequently eliminated by erosion-dilation filter process. After noise reduction, the closed contour shape of each mandible were extracted by edging the binary image and was then described by chain-code matrix.

A chain coding technique was used which relies on a contour representation to code shape information. The method tracks the shape of the mandible and represents each movement by a chain code symbol ranging from 0-7. The set of possible movement depends on the type of contour representation, a pixel based contour representation was used in this study wherein eight movements were needed using an 8-connected chain code. The outline of each mandible with this approach was described using a number of chain codes, the number of which depended on the size of the mandible. Then the codes were analyzed by elliptic Fourier analysis using the first 20 harmonics.

Differences in shape among mandibles were determined using a non- parametric form of the analysis of variance (ANOVA) called Kruskal-Wallis test performed on the Principal Component Scores (PC). Box and whisker plots were also illustrated as represented by each decomposed principal component scores pertaining to shape differences.

Results. Six (6) population of rice white stemborer *Scirpophaga innotata* were collected from different rice host varieties namely PSB Rc18 (Ala), PSB Rc26H (Magat), PSB Rc82 (Peǹaranda), NSIC Rc122 (Angelica), NSIC Rc124H (Mestizo4) and variety "B1" coined by the local farmers. These rice varieties are distinctive on their characteristics such as maturity, height and average yield per hectare (Table 1).

A total of 764 left and right mandibles were calculated to obtain standardized elliptic Fourier coefficients. The observed reconstructed mandible shape displaying substantial variation among varieties examined in this study is provided through three distinct analyses. These include a quantitative description analysis on the variation for the overall shape, with symmetrical and asymmetrical components groups. Tables 2 and 3 show the results for the overall observations of PCA scores based on elliptic Fourier descriptors. It provides mathematical representations of the reconstructed mandible contours, indicating that the first eleven components for the left and right mandibles derived good measures of the mandible shape variations and characterizations.

Table 1

List of Philippine Seedboard (PSB)/NSIC rice varieties and their corresponding morphological characteristics

VARIETY	*AGRONOMIC CHARACTERISTICS*					*DISEASE AND INSECT PEST REACTIONS***					
	Ave. Yield (t/ha)	Max.Yield (t/ha)	Maturity (DAS)	Height (cm)	Tillers #	Blast	BLB	Tungro	BP	GL	Stem borer
PSB RC18 (ALA)	5.1	8.1	123	102	15	I	I	I	I	I	MS
NSIC Rc122 (ANGELICA)	4.7	5.0	121	106	14	R	I	I	I	I	R
PSB RC26H (MAGAT)	5.6	7.6	110	88	17	R	I	S	I	I	MS
NSIC Rc124H (MESTISO 4)	6.2	9.5	110	120	12	R	I	I(S)	MS	I	S
PSB RC82 (PEÑARANDA)	5.4	12.0	110	100	15	R	I	S	I	MS	I

Legend: I- Intermediate Resistance; R- Resistant; MS- Moderate Resistance; S- Susceptible

Source: PHILRICE (2001)

Table 2

The Eigenvalues and percentage of the total variance for the right mandibles in the overall distribution as well as the symmetrical and asymmetrical group per principal component

		PC	Eigenvalue	Proportion (%)	Cumulative (%)	Total Variance (x10^2)
RIGHT	Overall					
		1	6.04E-03	26.2416	26.2416	2.300872 (100%)
		2	5.25E-03	22.8123	49.0539	
		3	3.02E-03	13.1157	62.1696	
		4	2.17E-03	9.4128	71.5824	
		5	1.24E-03	5.3699	76.9523	
		6	9.19E-04	3.9928	80.9451	
		7	6.53E-04	2.8394	83.7846	
		8	4.73E-04	2.057	85.8415	
		9	3.70E-04	1.608	87.4495	
		10	3.11E-04	1.3498	88.7994	
		11	2.99E-04	1.2991	90.0985	
	Symmetrical					
		1	5.32E-03	44.7166	44.7166	1.190275 (51.73%)
		2	3.13E-03	26.3245	71.0412	
		3	1.17E-03	9.839	80.8802	
		4	4.68E-04	3.9283	84.8085	
		5	3.34E-04	2.81	87.6185	
		6	2.98E-04	2.5037	90.1221	
	Asymmetrical					
		1	4.83E-03	43.4495	43.4495	1.110597 (49.27%)
		2	2.66E-03	23.9112	67.3607	
		3	1.05E-03	9.4885	76.8492	
		4	8.64E-04	7.78	84.6293	
		5	3.45E-04	3.1073	87.7365	

Table 3

The Eigenvalues and percentage of the total variance for the left mandibles in the overall distribution as well as the symmetrical and asymmetrical group per principal component

	PC	Eigenvalue	Proportion (%)	Cumulative (%)	Total Variance (x10^2)
LEFT	Overall				
	1	5.13E-03	23.3425	23.3425	2.197325 (100%)
	2	4.06E-03	18.4637	41.8062	
	3	3.36E-03	15.3102	57.1165	
	4	2.44E-03	11.1119	68.2284	
	5	1.28E-03	5.8305	74.0588	
	6	1.02E-03	4.6442	78.703	
	7	7.28E-04	3.3138	82.0168	
	8	4.75E-04	2.1636	84.1804	
	9	3.44E-04	1.5634	85.7439	
	10	3.35E-04	1.5264	87.2702	
	11	3.23E-04	1.4717	88.742	
	Symmetrical				
	1	4.03E-03	37.3314	37.3314	1.08080 (49.18%)
	2	3.17E-03	29.3752	66.7066	
	3	1.17E-03	10.8002	77.5068	
	4	5.29E-04	4.8987	82.4054	
	5	3.43E-04	3.178	85.5834	
	6	3.11E-04	2.8809	88.4643	
	Asymmetrical				
	1	4.33E-03	38.7861	38.7861	1.116524(49.82%)
	2	2.92E-03	26.1396	64.9257	
	3	1.09E-03	9.7203	74.6461	
	4	1.04E-03	9.2726	83.9187	
	5	3.43E-04	3.0726	86.9913	

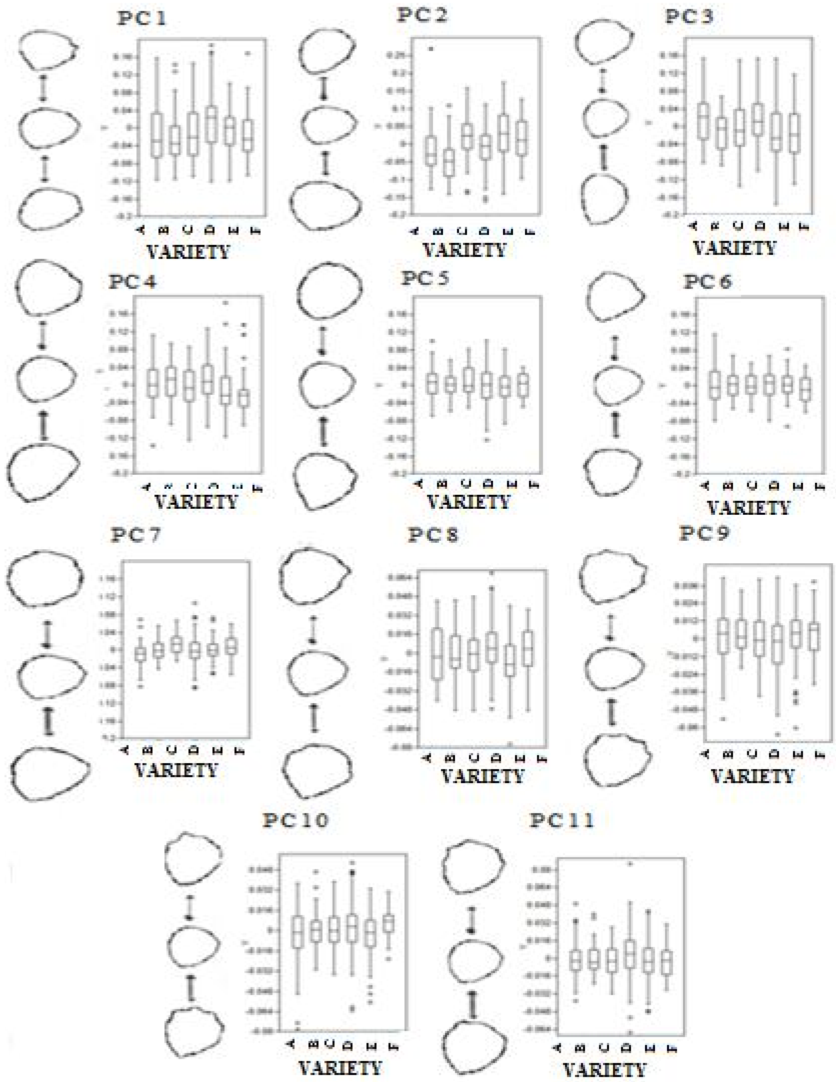

Figure 3. Box and whisker plot of the effective components of the left mandible: A-PSBRC18(Ala); B-PSBRC26H(Magat); C-PSBRC82(Penaranda); D-NSICRC122(Angelica); E-B1; F-RC124H(Mestizo4)

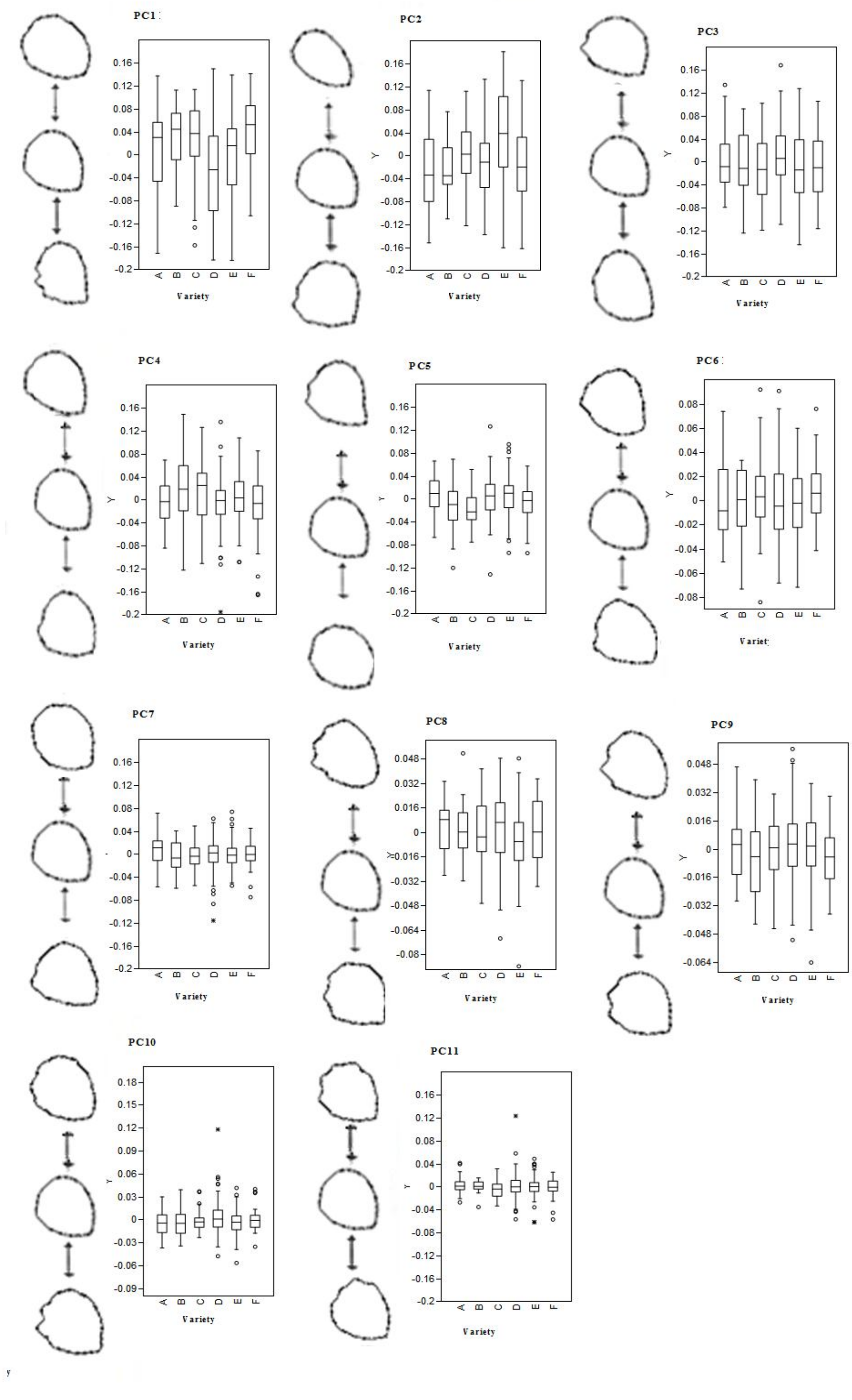

Fig. 4. Box and whisker plot of the effective components of the right mandible: A-PSBRC18(Ala); B-PSBRC26H(Magat); C-PSBRC82(Penaranda); D-NSICRC122(Angelica); E-B1; F-RC124H(Mestizo4)

In the use of PCA-EFA, the first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. The shape variations accounted for by each principal component can be visualized as reconstructed contours as shown in Figure 3 and Figure 4.

The shape variables of the left mandibles showed eleven significant components providing a sufficient summary of data, accounting for 88.74% of the observed variation. The major contributor of the variation in the shapes of the mandibles was related to the differences in the mandible's internal margin particularly the basal angle (blunt to pointed) and number of teeth and the form of the side of attachment as described by the first principal component. Aspect ratio (length-width) and the prominent basal angle variations were both accounted by PC2 and PC3, showing an 18.46% and 15.31% respective proportions. PC4 however summarizes narrowing to blunted internal margins that is described by an 11.11%variation.Minimal variations were accounted by the rests of the principal components. A distinctive protrusion of teeth to blunt and distinctive internal margins and form of side of attachment is accounted by PC5 and PC6 with 5.83% and 4.64% proportions. PC7 signifies a blunted to more rounded internal margins. Very subtle variations specified by PC8, PC9, PC10, PC11 describe the differences in the form of side of attachment, number of protruding teeth and angle of internal margin which proportionally account for about 4.64%, 3.31% and 2.16%.

The shape variables of right mandibles also showed eleven significant components that are providing a sufficient summary of data, accounting for 90.10% of the observed variation (Figure 4). The aspect ratio (length-width) and number of teeth are accounted by PC1 by its 26.24% proportion. The variation of the aspect ratio with distinct to blunted tooth are accounted by PC2 having a 22.81% proportion while PC3 describes variation of aspect ratio (length-width) and rounded to pointed tooth accounting a proportion of 13.12%.PC4 summarizes the variation of degree angle to rounded internal margins and blunted teeth which has 9.41% proportion. Though of subtle variation, PC5 and PC6 describes the differences in form of the side of the attachment, however, PC5 has pointed to blunted teeth while PC6 has blunt to pointed internal margin. It accounts to 5.4% and 4.0% proportions respectively.PC7 shows a blunted to rounded internal margins accounting to 2.84% while PC8 shows the variation of basal margin having blunt to pointed teeth with 2.06% proportion. The rests of the PC's, PC9, PC10, PC11 show variation in the degree internal margin's angle and distinction and number of teeth with respective accounted values of 2.06%, 1.61%, 1.35% and 1.3% proportions. It must be emphasized that, while shape trends along principal component axes frequently correspond with observed morphologies, they do not represent the actual appearance of the mandible. Rather the reconstructed contours illustrate the different patterns of shape variability along a subset of all possible axes of shape variation. Generally, observed variation ranges from the arrangement and length of its teeth, from the basal and external margins and the contour of the side of attachment from the body.

Over all sources of variation were also disintegrated by separating symmetrical and asymmetrical sources of variations. The results in table 2 and 3 showed, that both symmetrical and asymmetrical variations contribute almost significantly the same to the total variation for both left and right mandible. Symmetry is a basic property of shapes and structures and seems to imply stability and natural development while asymmetrical variations may arise as a result of the inability to control development under genetically and environmentally stressful conditions. Reconstruction of the shape of the left and right mandible using the symmetric and asymmetric components is respectively shown in Figure 6.

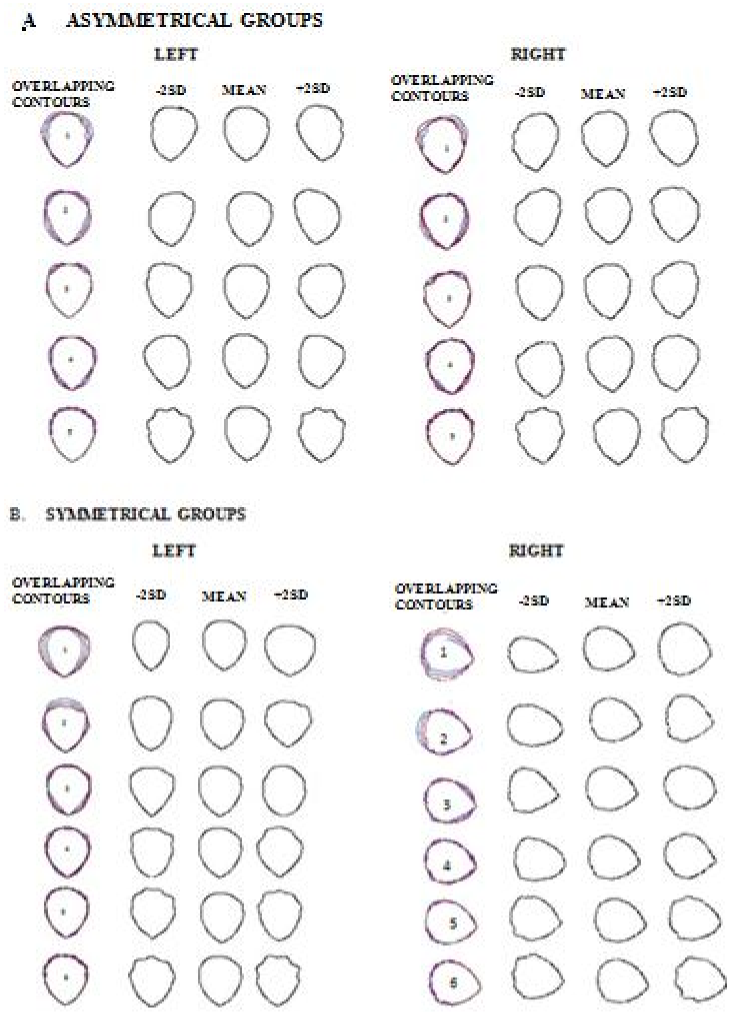

Figure 6. Variations explained by each principal component on while stemborer's mandible shape shown as ±2 standard deviations from the mean mandible shapes. The numbers correspond to the significant principal components, respectively. (A) Asymmetrical variations of the left and right mandible from the symmetrical group coefficients and (B) asymmetrical variations of the left and right mandible from the asymmetrical group.

Further analysis was carried out using Kruskal-Wallis (non-parametric ANOVA). Table 4 revealed the results of this test performed on each principal component scores. From obtained results only PC1 and PC2 remarkably showed statistically significant ($P<0.001$) variations for both left and right mandibles while the remaining principal components showed a statistically non-significant variations for either one or both mandibles.

Table 4

Results of the Kruskal-Wallis test testing for significant differences in the shapes of the mandible among the six populations of stem borers. Upper triangular matrix-left mandible; lower matrix-right mandible

PC1	**PSB Rc18 (MS)**	**PSB Rc26H (MS)**	**PSB Rc82 (I)**	**NSIC Rc122 (R)**	**B1**	**NSIC Rc124H (S)**
PSB Rc18 (MS)		0.4394	0.9815	**0.02557**	0.2363	0.8455
PSB Rc26H (MS)	0.2933			**0.001368**	**0.01647**	0.3674
PSB Rc82 (I)	0.2565	0.9844		0.01818	0.2552	0.8961
NSIC Rc122 (R)	**0.00277**	**0.0004828**	**5.143E-05**		0.02274	**0.03628**
B1	0.2594	**0.03491**	0.01256	0.002943		0.328
NSIC Rc124H (S)	**0.04692**	0.5525	0.5467	**3.904E-06**	**0.0008296**	
PC2	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		**0.01242**	**0.001642**	0.1773	**3.164E-05**	**0.028**
PSB Rc26H (MS)	0.7202		**1.01E-05**	**0.0002957**	**1.271E-07**	**0.0003508**
PSB Rc82 (I)	**0.02444**	**0.09037**		**0.003393**	0.2903	0.5551
NSIC Rc122 (R)	0.222	0.4809	0.08208		7.47E-06	0.1337
B1	**5.113E-05**	**0.003814**	**0.01952**	7.47E-06		0.1333
NSIC Rc124H (S)	0.6831	0.9938	0.1124	0.699	0.0007575	
PC3	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122(R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		**0.02049**	0.09864	0.9449	**0.006294**	**0.03562**
PSB Rc26H (MS)	0.7826		0.5567	**0.01269**	0.8638	0.7434
PSB Rc82 (I)	0.2665	0.3235		**0.04875**	0.4216	0.4426
NSIC Rc122 (R)	0.1437	0.3734	**0.01768**		**0.0007372**	**0.01202**
B1	0.3332	0.4806	0.7018	**0.01668**		0.9881
NSIC Rc124H (S)	0.9277	0.7753	0.3501	0.2016	0.5765	
PC4	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.9032	0.2617	0.3255	**0.014**	**0.00836**
PSB Rc26H (MS)	0.2026		0.2563	0.559	**0.0278**	**0.01747**
PSB Rc82 (I)	0.07312	0.8394		**0.02529**	0.2647	0.08962
NSIC Rc122 (R)	0.7176	0.09479	0.01409		**4.679E-05**	**0.000107**
B1	0.4499	0.3629	0.1981	0.126		0.4035
NSIC Rc124H (S)	0.6764	0.1406	**0.04558**	0.8913	0.2698	
PC5	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122(R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.4922	0.9288	0.436	0.2491	0.4071
PSB Rc26H (MS)	**0.03821**		0.6654	0.9101	0.5101	0.8648
PSB Rc82 (I)	**3.247E-05**	0.33		0.3595	0.2319	0.3607
NSIC Rc122 (R)	0.4734	0.08642	**7.403E-05**		0.7255	0.852
B1	0.8337	**0.04123**	**9.324E-06**	0.6047		0.7595
NSIC Rc124H (S)	**0.04897**	0.6269	0.04894	0.1146	**0.04387**	
PC6	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.8352	0.84	0.7616	0.8325	0.3391
PSB Rc26H (MS)	0.7557		0.9068	0.97	0.8738	0.2384
PSB Rc82 (I)	0.5262	0.8908		0.7497	0.9876	0.1539
NSIC Rc122 (R)	0.6754	0.4962	0.2691		0.6472	0.181
B1	0.7569	0.5419	0.3534	0.7905		0.1494
NSIC Rc124H (S)	0.1976	0.5838	0.4101	**0.04554**	0.08569	
PC7	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.1411	**1.424E-05**	0.1595	**0.01431**	**0.01461**
PSB Rc26H (MS)	0.06785		**0.0048**	0.0783	0.608	0.2754
PSB Rc82 (I)	0.05325	0.5519		0.0006476	**0.002048**	0.1934
NSIC Rc122 (R)	0.1676	0.2021	0.3597		0.3146	0.1654
B1	**0.02893**	0.05244	0.9278	0.1832		0.3773
NSIC Rc124H (S)	0.2114	0.2674	0.4877	0.8432	0.3731	
PC8	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.9094	0.7582	0.4536	0.2152	0.4332
PSB Rc26H (MS)	0.5298		0.8358	0.06122	0.1605	0.4762
PSB Rc82 (I)	0.4113	0.7289		0.08827	0.05996	0.4489
NSIC Rc122 (R)	0.8144	0.4869	0.3579		2.176E-06	0.476
B1	**0.006677**	0.1419	0.1491	**0.001463**		0.02481
NSIC Rc124H(S)	0.5615	0.9692	0.9679	0.4604	0.1301	
PC9	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.8845	0.5624	0.06103	0.8294	0.9675
PSB Rc26H (MS)	0.2933		0.6013	0.09034	0.6263	0.7863
PSB Rc82 (I)	0.2565	0.9844		0.2343	0.3744	0.5621
NSIC Rc122 (R)	**0.002778**	**0.0004828**	**5.143E-05**		**0.009344**	0.0746
B1	0.2594	0.03491	**0.01256**	**0.002943**		0.9881
NSIC Rc124H (S)	**0.04692**	0.5525	0.5467	**3.904E-06**	**0.0008296**	
PC10	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122 (R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.866	0.9288	0.2867	0.6479	0.1224
PSB Rc26H (MS)	0.9815		0.9569	0.4066	0.4837	0.09988
PSB Rc82 (I)	0.6254	0.5784		0.2893	0.4832	0.07839
NSIC Rc122 (R)	0.1026	0.09099	0.1196		0.04489	0.3258
B1	0.6484	0.5647	0.8929	0.07074		**0.0135**
NSIC Rc124H (S)	0.4452	0.5525	0.6731	0.2477	0.6291	
PC11	PSB Rc18 (MS)	PSB Rc26H (MS)	PSB Rc82 (I)	NSIC Rc122(R)	B1	NSIC Rc124H (S)
PSB Rc18 (MS)		0.9718	0.4327	0.8308	0.6829	0.7384
PSB Rc26H (MS)	0.8098		0.3534	0.1379	0.5612	0.626
PSB Rc82 (I)	**0.02788**	0.1063		**0.01139**	0.6421	0.7913
NSIC Rc122 (R)	0.2683	0.6274	0.1482		**0.01633**	0.05077
B1	0.4926	0.7565	0.05609	0.6961		0.8728
NSIC Rc124H (S)	0.5254	0.7871	0.195	0.836	0.8948	

Discussion. Six (6) population of rice white stemborer *Scirpophaga innotata* were collected from different rice host varieties namely PSB RC18 (Ala), PSB Rc26H (Magat), PSB RC82 (Peṅaranda), NSIC Rc122 (Angelica), NSIC Rc124H (Mestizo4) and variety "B1" coined by the local farmers. These rice varieties are distinctive on their characteristics such as maturity, height and average yield per hectare. As inferred in Table 1, these varieties showed a varying resistant/susceptibility scores against white stem borer. NSICRc122 (Angelica) is seen to be most resistant while PSBRc18 and PSBRc26 showed moderate susceptibility/moderate resistance scores, PSBRc82 to have intermediate resistance and NSIC Rc124H (Mestizo4) to be most susceptible. These rice samples with varying resistance scores serve as considerable factor to determine morphological mandibular differences based on the resistance or susceptibility characteristic of the rice type.

The first principal component for both left and right mandibles, which is accounting for most of the observed over all variation, describe the variation of the number of teeth that ranges from a more fused to a protruding distinctive one while the second principal component for both left and right mandibles is describing the variation of the aspect ratio (length-width). This over all variation in shape is expected to allow optimal exploitation to certain types of food plant as individual plants also vary. Induced plant responses often yield variation in terms of nutritional status, secondary substances and physical characteristics of host plants (Karban & Baldwin 1997; Ohgushi 2005). The observed range of variation is in effect presumably to produce an efficient masticatory mechanism to an almost fused incisor dentes forming a continuous cutting edge producing a scissor-like cutting mechanism. As major tool feeding apparatus, mandibles are subjected to continuous wear and tear in effect of the biochemical properties of the plant. Amorphous silicon present in most species of Poaceae, plant family of *Oryza*, can serve as harsh abrasive that may cause a tearing or even to the extent of loss of mandibular teeth during feeding process (Schoonhoven et al 2006) and only those species with larger mandibles can overcome such defense (Klapper & Denno 2001). And since there is a heterogeneity of chemical distribution over plant cells and tissues, in effect, this is attributable to individual differences in mandible morphology. Plant chemical qualities highly influence the individual mandible shape.

Further, from the Kruskal-wallis result in Table 4, NSIC Rc122 (Angelica), which is inducing much resistance to stem borer damages and PSB Rc18 (Ala) and PSB Rc26H (Magat) with moderate susceptibility/moderate resistance (Table 1) have shown such discriminate significant variation between and among other varieties. It can be deduced that the degree of resistance and susceptibility of rice varieties is contributory to the shape difference of the mandible. Khush (1984) revealed that resistance to stem borers, however appears to be under polygenic control. Many morphological, anatomical, physiological and biochemical factors have been reported to be associated with resistance, each controlled by different sets of genes (Chaudhary et al 1984).

In the study of Shahjahan (2004), on the influence of the anatomical characteristics of rice plants resistance and susceptibility to yellow stemborer, has revealed that those rice varieties with thicker schrenchymatous hypodermis, compact parenchyma cells of ground tissue, small air spaces in the ground tissue, more vascular bundles and narrower pith are considered to be characters for resistance while those with thinner sclerynchymatous hypodermis, loose parenchyma cells of ground tissue, larger spaces between bundles, wider pith and larger air cavities, might be responsible for its susceptibility. This may indicate that the failure or success of insect resistant rice cultivars to curtail stem borer damages is correlated to the number of protrusion of teeth and aspect ratio as describe by the first two significant principal components. For resistant varieties, a more distinctive and protruding teeth may indicate success to worn out its thicker and compact plant tissues.

The influence induced by plant genotype either due to environmental stress or its genetic make up leading to the differences of nutritional quality and defensive chemistry characteristics of rice cultivar may promote potential fitness consequence to stem borer leading to host- associated differentiation favoring sympatric speciation (Kohnen et al 2011). The strong mandibular variation in this study may possibly suggest that they may belong to more than one species as this mouthpart structure is known to be highly adaptive to differing food types (Snodgrass 1935; Smith & Capinera 2005).

Conclusions and Recommendations. Host-plant modifications are known to promote high taxonomic diversity and ecomorphological disparity among its insect-herbivores. Studies on mouthpart morphology specifically the mandible are central to understanding these adaptive modifications as they are used as major feeding apparatus.

Randomly collected white rice stem borer (*Scirpophaga innotata*) larvae were prepared for dissection, mandible removal, mounting and image acquisition. The outline of the mandibles were extracted via chain-coding and principal component analyses were performed to determine patterns of shape differences. Observed variation ranges from the arrangement and length of its teeth, from the basal and external margins and the contour of the side of attachment from the body. The greatest variation accounted by the first PC is on the arrangement, length and number of its teeth which is attributable to continuous wear of the individual mandible in effect of the biochemical properties of the plant. Plant chemical qualities highly influence the individual mandible shape. Intra-population study has shown that that the degree of resistance and susceptibility of rice varieties is contributory to the shape difference of the mandible.

It is recommended to include the over all mouthparts of the stemborer for such as the labium and maxillae to have a better assessment and additional analysis, support and comparison. Consideration of ontogenetic development of stem borer and allometry is of value to eliminate factor of size-related shape change. Furthermore, it is also recommended to assess the usage of chemical control programs such as pesticides, biocontrol programs and other practices that might affect the morphological traits of the white rice stem borer populations. Physico-chemical factors also of the area should be included in the study to understand more the modification of the populations of white stem borer.

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