Morphological Variation and Ecological Adaptation of Weedy Rice Populations in Sri Lanka

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Abstract

Introgression is an important biological process which occurs naturally between closely related plant species. This process is essential for genetic divergence and adaptive evolution of feral species, originated either by endoferality or exoferality. Weedy rice (*Oryza sativa* f. *spontanea*) is a well-known example of ferality. As gene introgression can be influenced by various agronomic and ecological impacts, weedy rice come from different locations may have distinguished adaptive origins. Therefore, a common garden experiment was carried out to observe the morphological diversity and variation patterns of 12 weedy rice populations collected from different locations representing dry zone (Akkareipattu-P9, Ampara-P10, Lahugala-P11, and Damana-P12) and wet zone (Pasgoda-P1, Pitabeddara-P2, Akuressa-P3, Thihagoda-P4, Kirinda-P5, Mulatiyana-P6, Kamburupitiya-P7, Hakmana-P8) of Sri Lanka. All the populations were transplanted in a common field with 4 replicates under completely randomized design and thirteen quantitative and four qualitative characteristics at various growth stages were assessed for phenotypic diversity. The mean comparison of morphological traits among populations revealed that weedy rice coming from different locations of the country has great diversity in morphology, except plant vigor, leaf angle and flag leaf angle. But there was no significant correlation of morphological variation with wet and dry geographic distances. PCA analysis indicated that 07 morphological traits; plant height, no of tillers, no of days to flowering, leaf length at vegetative stage and panicle length, shattering/panicle, no of filled seeds/panicle at ripening stage were the major determinants of the diversity which accounted for 75.8% of total variation. The cluster analysis placed all the accessions into two groups. Clustering was not associated with the geographical distribution. Accessions were mainly grouped due to their morphological differences. All the analysis based on plant morphology suggested that weedy rice in dry and wet zone in Sri Lanka has great variability showing their adaptive co-existence in heterogeneous ecological systems.

Keywords: Introgression, evolution, weedy rice, feral plant

Introduction

Introgression is the transfer of genes between genetically distinguishable populations, (Riesberg *et al.*, 1998) and it is essential for genetic divergence and adaptive evolution of crop species (Barton, 2001 and Charlesworth, 2003). The evolutionary impact of introgression would be particularly significant for feral populations. Feral plants are descendants of domesticated plants that have evolved either by 'endoferality' or by 'exoferality' (Gressel, 2005). The well known example is weedy rice (*Oryza sativa f spontanea*), a feral taxon worldwide (Olofsdotter *et al.*, 2000 and Delouche *et al.*, 2007). Introgression from cultivated rice to weedy rice is frequently reported Langevin *et al.* 1990; Xia *et al.*, 2011), and may have evolutionary impacts on weedy rice populations. Weedy rice tends to converge morphologically with rice varieties grown in the same field after a few generations , Oka and Morishima, 1971; Langevin *et al.*, 1990). Such rapid evolution of "crop mimicry"

(Barrett, 1983) of weedy rice is most likely originated via introgression of alleles from cultivated rice, facilitating the adaptive evolution of weedy rice under natural and human selection (Delouche *et al.,* 2007). The introgressed genes that have a natural selective advantage may enhance fitness and adaptability of plant populations occurring in a particular environment. (Campbell *et al.,* 2006 and Baack *et*

Table 1. Selected morphological traits and their methods of measurement

Trait	de	Method of measurement
Plant height at seedling stage	PH-S	Height from ground level to the tip of the leaf of the tallest tiller at three weeks after transplanting
Plant height at heading stage	PH-H	Height from the ground level to the base of the panicle of the tallest tiller after heading
No of tillers at seedling stage	T-S	Total number of tillers of each plant at three weeks after transplanting
No of tillers at heading stage	T-H	Total number of tillers of each plant after heading
Leaf length	LL	Length of the topmost leaf blade below the flag leaf on the main culm at late vegetative stage
Leaf width	LW	Width at the widest portion of the blade on the leaf below the flag leaf at late vegetative stage
Leaf angle	LA	Angle of openness of the leaf blade tip against the culm below the flag leaf, prior to heading: (1) erect, (5) horizontal, (9) drooping
Flag leaf angle	FLA	Angle between the flag leaf blade and the main panicle axis, after heading: (1) erect, (3) intermediate, (5) horizontal, (7) descending
Seedling vigor	SV	Seedling vigor was recorded by gently pushing the tiller for few times. Two classes were recorded. 1-vigor, 2-not vigor
1000-Seed Weight (g)	S-WT	(Weight of 100 filled seeds/100)*1000
Panicle Length (cm)	PANL	Length was measured from the base to the tip of the panicle. Average length of 05 panicles were recorded
Number of panicles per plant	PAN/P	All number of panicles of each plant at maturity
Seed Shattering per panicle	SS/P	Number of seeds shattered/Number of panicles per plant
Number of filled seeds per panicle	FS/PAN	(Number of filled seeds from 03 panicle/03)+Number of filled seeds shattered/panicle
Number of spikelets per panicle	SPK/PAN	(Total number of seeds from 03 panicles/03)+Total number of seeds shattered/panicle
Presence of awns	AWN	Recorded after full heading: (0) absent, (1) short owned, (2) medium owned, (3) long owned
Number of days to flowering	DTF	Number of days from planting to 50% flowering

al,. 2007). The gene introgression can be influenced by various agronomic and physiological aspects. Hence, the weedy rice come from different locations may have different adaptive origins. Therefore, the present study was carried out to determine the morphological diversity and morphological variation patterns of weedy rice populations in different locations selected from dry and wet zones in Sri Lanka.

Materials and Methods

An extensive field survey was carried out in rice growing areas of Ampara and Matara districts at seed maturity stage and seeds were collected from weedy rice infected locations; Akuressa-P1, Thihagoda-P2, and Mulatiyana-P3 from Matara district and Akkareipattu-P4, Ampara-P5 and Lahugala-P6 from Ampara district representing dry and wet zones. Thirty individuals were collected with about 10m interval for each weedy rice population. All the populations were

Table 2. Mean comparison of morphological traits among 12 populations

Trait	Population											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
PH-S	61.02 ab	53.90 bc	62.65 a	57.31 abc	53.4 bc	54.34 bc	50.51 c	54.10 bc	52.93 c	54.1 bc	42.4 d	57.43 abc
PH-H	152.6abc	141.2bcd	155.1 ab	157.2 a	150.8 abc	153.8 ab	138.8 cd	135.7 d	142.6 abcd	139.0 cd	148.4 abcd	138.4 cd
T-S	1.59 a	1.66 a	1.80 a	1.91 a	1.54 a	1.86 a	1.71 a	1.92 a	1.63 a	2.16 a	2.09 a	2.13 a
T-H	9.45 ab	8.37 bc	6.16 c	7.55 bc	7.11 bc	11.53 a	7.92 bc	7.63 bc	8.74 bc	8.55 bc	11.50 a	7.80 bc
LL	63.51 ab	55.87 abc	56.76 abc	66.61 a	54.8 abc	64.90 a	67.18 a	48.86 c	50.39 c	51.82 bc	48.76 c	51.04 c
LW	1.27 ab	1.13 bcde	1.12 bcde	1.24 abc	1.07 def	1.20 abcd	1.30 a	0.90 g	0.99 efg	0.98 efg	1.10 cde	0.94 fg
S-WT	29.53 a	27.33 ab	29.43 a	25.43 b	24.7 b	26.11 ab	23.98 bc	27.64 ab	25.74 ab	24.59 b	20.99 c	24.87 b
PANL	23.34 bc	24.92 ab	23.91 abc	25.35 ab	23.9 abc	26.26 a	24.14 abc	23.35 bc	24.61 abc	24.22 abc	24.70 abc	22.33 c
PAN/P	8.41 abc	8.35 abc	5.50 d	6.65 cd	7.30 cd	10.86 a	7.13 cd	7.86 bcd	7.04 cd	8.07 bcd	10.51 ab	7.63 cd
SS/P	4.14 e	13.29bcd	15.31bcd	27.86 b	7.95de	15.74bcd	18.25bc	8.55cde	10.99cd	8.56cde	57.74a	10.34cd
FS/P	65.89 ab	61.62 ab	71.17 ab	62.91 ab	54.0 b	63.72 ab	53.61 b	74.65 a	65.71 ab	51.20 b	28.87 c	50.97 b
SPK/P	108.31 ab	94.14 b	105.2 ab	83.12 b	104 ab	133.4 a	92.03 b	104.3 ab	112.2 ab	97.52 b	78.07 b	88.77 b
AWN	137.75ab	150.3ab	204.9ab	220.2 ab	132.1 bc	223.9ab	180.5ab	113.7bc	146.2c	114.2bc	260.5a	109.0bc
DTF	67.667 cd	69.33 bcd	68.50 bcd	74.50 ab	67.25 cd	70.00 bc	77.50 a	62.75 d	66.00 cd	64.00 cd	63.33 cd	63.25 cd

Mean with the same letters are not significantly different (P>0.05).

transplanted in a common field with 4 replicates under completely randomized design. A total of thirteen (13) quantitative and four (04) qualitative characters were measured at various growth stages using the standard evaluation system for rice developed by the International Rice Research Institute (IRRI) as indicated in table1. Data were analyzed using Principle Component (PC) and Cluster Analysis to assess the diversity and pattern of morphological variation.

Results and discussion

The weedy rice coming from different locations of the country has great diversity in morphological characteristics, except plant vigor, leaf angle and flag leaf angle. The significant differences among selected populations were observed in all the other characters (table 2). But there was no significant correlation of morphological variation with geographic distances.

A higher diversity was observed for the plant height at both seedling and heading stages. The highest plant height observed in Akuressa (62.65cm) while significantly shortest plants (42.45cm) were observed in Lahugala at seedling stage. At heading stage, comparatively taller (157.2cm) plants were observed in Thihagoda compared with others. There was no significant difference for the tiller number at seedling stage while at heading stage, highest number of tillers was observed in Mulatiyana (11.53) and Lahugala (11.50). Comparatively higher leaf lengths observed at Matara district populations except Hakmana (48.86 cm) compared to that of Ampara district. Comparatively lower leaf width was observed at Ampara district populations and Hakmana (0.90cm) and Kirinda (1.07cm) in Matara district. A significant difference among populations was observed for thousand grain weight and the highest represented in Pasgoda (29.53g). Significantly lowest thousand grain weights was observed in Lahugala (20.99g) compared to that of other populations except Kamburupitiya (23.98g). Comparatively higher number of panicles (10.86) and long panicles (26.26cm) were observed in Mulatiyana compared to the other areas.

Significantly highest seed shattering per panicle (57.74), lowest filled seeds per panicle (28.87), lowest

Table 3. The Eigen values of the correlation matrix for the 13 quantitative characteristics of 12 populations of Weedy Rice (Values in each parenthesis correspond to the Eigen value and proportion of total variation by each component).

Trait	1st principle component (51.3%)	2nd principle component (24.5%)
Plant height at heading stage (cm)	0.865	0.274
Leaf length (cm)	0.817	-0.085
Days to flowering	0.916	0.049
Panicle length (cm)	0.885	0.289
No of tillers at heading stage	0.336	0.650
Shattering/panicle	0.238	0.864
Filled seeds/panicle	0.443	-0.750

number of spikelets per panicle (78.07) and the highest mean rank for awn length (260.5) were observed in Lahugala population. Significantly higher number of days for flowering was observed in Kamburupitiya (77.50) and Thihagoda (74.50) while lesser number of days was observed in all populations of Ampara district and Pasgoda, Kirinda Hakmana in Matara district. Cao *et al.* (2004) reported that uneven distribution of morphological diversity among weedy rice populations may be related with a number of factors, such as strength of weed management in the area, limited gene flow among weedy populations and introgression with different rice varieties over time.

According to the principal component analysis, first two components accounted for about 75.8% of total variation (Table 3). The first principal component accounted for about 51.3% of total variance and it consisted of plant height at heading stage, leaf length, days to flowering and panicle length while PC2 accounted for 24.5% of total variance and consisted of no. of tillers at heading stage, shattering/panicle and filled seeds/panicle (Table 03). PCA analysis indicated that Days to flowering, Panicle length, Plant height at heading stage and shattering/panicle were the major determinants of the diversity and the most important traits among the 13 quantitative traits measured which accounted for more than 3/4 the all phenotypic variation.

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                 Rescaled Distance Cluster Combine

 CASE    0      5      10      15      20      25
Label   Num +--------+--------+--------+-------+--------+
8       8  -+
9       9  -+-+
3       3  -+ +-+
5       5  -+| |
12      12  -+-+ +-+
7       7  -+  |+---+
4       4  -----+|  +-----------------------------------+
6       6  -------+  |                        |
1       1  -----------+                        |
2       2  ---+---------+                       |
10      10  ---+       +----------------------------------+
11      11  -------------+
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Figure 1: Dendrogram obtained through Hierarchical Cluster Analysis (Ward Method) based on the principal components

According to the dendrogram obtained through agglomerative clustering (Figure 1), 12 populations were grouped into main 02 clusters at a rescaled distance 25. The number of populations per cluster varied from 09 populations in cluster 1 (Hakmana P8, Akkareipattu P9, Akuressa P3, Kirinda P5, Damana P12, Kamburupitiya P7, Thihagoda P4, Mulatiyana P6, and Pasgoda P1,) and 03 populations in cluster 2 (Pitabeddara P2, Ampara P10 and Lahugala P11). The numbers of populations within a cluster were not similar and all populations within a geographical zone were not grouped in to one cluster. Cluster 1 contained all wet zone populations and Akkareipattu (P9) and Damana (P12) from dry zone and cluster 2 contained other dry zone populations and Pitabeddara (P2) from wet zone. Furthermore, Hakmana (P8) population in wet zone and Lahugala (P11) population in dry zone were highly different in their morphology.

Conclusion

The experimental results confirmed that the weedy rice coming from different locations of the country have great diversity in morphology except plant vigor, leaf angle and flag leaf angle. But there was no significant correlation of morphological variation between wet and dry geographic distances. There were 7 morphological *traits viz.,* plant height, no. of tillers, no. of days to flowering, leaf length at vegetative stage and panicle length shattering/panicle, no. of filled seeds/panicle at ripening stage which were highly contributed to the total variation. And there were some isolated populations were observed having with specific morphological characters, such as Lahugala population in the dry zone and Hakmana population in the wet zone.

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