Morphological Relationships between Weedy Rice Morphotypes and Commercial Rice Varieties in Perak, Malaysia

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Abstract

Weedy rice has become a major problem in Malaysia for the last few decades. A comparative morphological study was conducted to characterize weedy rice population by collecting weedy rice morphotypes from six sites among the Perak rice granaries in Malaysia. 420 plant accessions were collected and scored based on the plant height, panicle type, lemma and palea color, and presence of awn and apiculus color. Total 14 weedy rice morphotypes were identified from these six sites based on 27 morphological characteristics. Four commercial rice varieties MR84, MR185, MR211 and MR219 were also planted for comparison. A Principle Component Analysis explained 52.46% of the total variation observed among the studied population. Three principal components factorial values clearly separated commercial varieties from weedy rice morphotypes. Most of weedy rice population matured early with less percentages of filled grain and had greater percentage of shattering. Besides, most of weedy rice plants had longer ligule length, panicle exertion, culm length, flag leaf and leaf 1 length. Some weedy rice plants were characterized by having different lemma and palea color, smaller grain size, lower thousand grain weight and presence of awn. All of these morphological characteristics of weedy rice might help us to identify and control them effectively in the farmers' field.

1. Introduction

Over the years, many rice morphotypes have appeared in paddy fields due to the autocratic nature of the rice plant. However, some of these morphotypes are problematic weeds and those which pose serious threat are commonly called as weedy rice (*Oryza sativa* L.) which has aggravated with the increase of direct-seeded culture technique (Ho et al., 1999). Besides, the presence of weedy rice in paddy fields is frequently the result of the predominant use of self-supplied seeds by farmers (Yu et al., 2005). It increases from season to season because weedy rice seeds shatter easily and are easily carried by wind and when touched by human or machines. It is well documented that weedy rice stands significantly reduce crop yields and quality in several countries of the world (Delouche et al., 2007).

Recently, in Malaysia, weedy rice has been emerging as a serious weed in rice fields. According to Wah (1998), the production of direct-seeded land under rice cultivation is believed to be highest in Peninsular Malaysia amongst all the Asian countries. Currently, in Malaysia, agricultural areas cover 4.64 mha and approximately 14% (622,500 ha) of this area is dedicated to rice cultivation. There are eight granary areas as permanent rice producing areas (Itoh, 1991). Among these, Kerian (24,010 ha), Seberang Perak (9,510 ha) and Sungai Manik (6,510 ha) are situated in Perak which are highly infested by weedy rice morphotypes (Karim et al., 2004).

Weedy rice plants are usually taller than the commercial varieties, have more tillers and panicles plant^{-1} (Noldin et al., 1999). In addition, seed dormancy favors the maintenance of weedy rice seeds in the soil banks for long periods, while seed shattering favors dissemination within fields (Montealegre and Vargas, 1992). Weedy rice morphotypes can also be distinguished based on panicle structure such as open or compact panicle and grain color such as pigmented and non-pigmented and presence or absence of awn. Understanding the morphometric diversity and the origin of weedy rice is helpful in designing an effective strategy to manage this weed (Pyon et al., 2000). Characterizing weedy rice population is very much important for basic studies of their morphology. For this a detailed research was conducted including the identification and collection of seeds of the common weedy rice population grown in Perak and growing them in the field laboratory of Universiti Sains Malaysia (USM).

2. Materials and Methods

Plants of weedy rice were collected from different locations of the rice granaries in Perak, Malaysia during September, 2009. Geographical location of weedy rice collecting sites was recorded with a global position system Garmin, GPS12XL™. The six rice fields which were infested by weedy rice at a distance of at least 1 km from each other were randomly selected for the plants and their seeds (Figure 1). Four hundred and twenty accessions of weedy rice were collected from the sampling sites. Seeds of each morphotype were scored for plant morphological

characteristics such as plant height, lemma and palea color, and awn and apiculus color. The panicles of each accession were threshed manually. The seeds were dried overnight and stored at 4°C until they were used. Seeds of commercial rice varieties MR84, MR185, MR211 and MR219 were supplied by the Department of Agriculture, Malaysia and the Malaysian Agricultural Research and Development Institute.

Three replicates of 300 seeds each of similar weedy rice groups were sown in plastic trays containing well-puddled muddy soil. Germination was recorded for a six month period from October, 2009 to April, 2010. Seedlings of both the weedy rice and commercial varieties were grown until 25 days old before final transplantation. Seedlings of each accession were transplanted at 30×25 cm^2 spacing during October, 2009 in plastic pots (30 cm deep) containing well-puddled clay soil. Crop management was done following the standard cultivation practices. Fertilizers were applied 3 times at 14 days after planting (DAP), 35 DAP and 65 DAP @ 120 kg N ha^{-1}, 45 kg TSP ha^{-1} and 60 kg K_2O ha^{-1}.

Visual observation for 27 characteristics (Table 1) were determined and recorded during different growth stages of the plants using the description of rice cultivars provided by the IRRI (1996). Ten plants $replication^{-1}$ were randomly selected to record the data on yield component at harvest. The collected data were analyzed following the analysis of variance (ANOVA) technique using SPSS package and the mean differences at 5% level of significance by Duncan's Multiple Range Test. Principle Component Analysis (PCA) was applied to the 27 morphological traits to analyze the morphometric relationship among the morphotypes. Coefficient matrix of three principle components was used to draw a scatter plot for representing the relationships graphically between weedy rice morphotypes and commercial rice varieties. All these analyses were done using computer program SPSS version 13.0 (SPSS, 2004).

3. Results and Discussion

3.1. Weedy rice morphotypes identification

Fourteen weedy rice morphotypes were identified using plant height, panicle type, awn presence, days of maturity and apiculus, lemma and palea color (Table 2). Study of all the morphological traits instead of only studying the plant height and seed characteristics can be helpful to differentiate weedy morphotypes much efficiently. Although, morphological characters are valuable for taxonomic classification and crop management, these do not provide substantial information for the origin of weedy rice (Suh et al., 1992; Chen and Zhu, 1990).

The clear and distinct separation observed between weedy rice morphotypes and commercial varieties confirmed the results obtained by Arrieta-Espinoza et al. (2005). Weedy rice morphotypes showed rapid emergence followed by vigorous, competitive vegetative growth. Weedy rice morphotypes were found comparatively much taller than short commercial varieties. Weedy morphotypes PWR03, PWR09 and PWR10 were intermediate and only morphotype PWR12 was similar to the commercial varieties which were semi-dwarf. Morphotypes PWR06 and PWR13 population produced both tall and intermediate plants. All weedy rice morphotypes except PWR12 were typically 20-66 cm taller than the four commercial varieties. Height differences between weedy rice morphotypes and commercial varieties might be due to the competition for nutrients and sunlight, or heterosis pressure present in some morphotypes. Wide variation of plant height was observed among weedy rice morphotype population (Shivrain et al., 2010). However, all morphotypes produced lower number of tillers compared to the commercial varieties. Besides, they produced less ineffective tillers. This may be due to the diversity and changeability of weedy rice population produced by natural crossing among themselves or with cultivated varieties

Table 1: Morphological traits scored at different growth stages of weedy rice morphotypes and commercial rice varieties		
Sl.	Variables	Characteristics used for each variable
1	Plant height (Ht)	Measured from soil surface to the tip of the leaf height before heading, and to the tip of tallest panicle (awns included) after heading. Three classes: 1 semi-dwarf (low-land: less than 110 cm; up-land: less than 90 cm), 5 intermediate (low-land: 110-130 cm; up-land: 90-125 cm), 9 tall (low-land: more than 130 cm; up-land: more than 125 cm)
2	Leaf 1 length (L1L)	Measured from the topmost leaf blade below the flag leaf (cm)
3	Leaf 1 width (L1W)	Measured at the widest portion of the blade on the leaf below the flag leaf (cm)
4	Flag leaf angle (FLA)	Measured near the collar as the angle of attachment between the flag leaf blade and the main panicle axis, four classes: 1 erect, 3 intermediate, 5 horizontal, 7 descending
5	Flag leaf length (FLL)	Measured from the topmost leaf blade (cm)
6	Flag leaf width (FLW)	Measured at the widest portion of the blade (cm)
7	Ligule length (LiL)	Measured from the base of the collar to the tip (mm)
8	Ligule shape (LiS)	Three classes: 1 acute to acuminate, 2 two-cleft, 3 truncate
9	Culm angle (CA)	Five classes: 1 erect, 3 intermediate, 5 open, 7 spreading, 9 procumbent
10	Culm length (CL)	Measured from ground level to the base of the panicle (cm)
11	Number of culms (CN)	Record of culm number plant^{-1} at different stages of growth (n)
12	Number of panicles (Npa)	Record of number of panicle plant^{-1} (n)
13	Panicle length (PaL)	Measured from the base of the panicle to base of the flag lead (cm), from the principal culm
14	Panicle type (PaT)	Three classes: 1 compact, 5 intermediate, 9 open
15	Panicle exertion (PaE)	Measured from the base of the panicle to base of the flag leaf (cm), from the principal culm
16	Panicle secondary branching (PAB)	Record of number of secondary branching panicle-1 (n), from the principal culm
17	Panicle shattering (PaSh)	Five classes: 1 very low (less than 1%), 3 low (1-5%), 5 moderate (6-25%), 7 moderate high (26-50%), 9 high (more than 50%)
18	Total grain panicle^{-1} (TGP)	Record of total number of grain by panicle (n)
19	Panicle fertility (PaF)	Counts of well developed spikelets in proportion to total number of spikelets. Five classes: 1 highly fertile (90%), 3 fertile (75-90%), 5 partly sterile (50-74%), 7 highly sterile (<50% to traces), 9 completely sterile (0%)
20	Grain awn distribution (AWDiL)	Distribution of seed with awns. 0 absent, 1 short and present in less than 50% of spikelets, 5 short and present in more than 50% of the spikelets, 7 large and present in less than 50% of the spikelets, 9 large and present in more than 50% of the spikelets
21	Awn length (AwL)	Measured on 3 seeds
22	Awn color (AWC)	Six classes: 0 awnless, 1 straw, 3 brown, 4 red, 5 purple, 9 black, measured on mature seed
23	Apiculus color (ApC)	2 straw, 3 brown (tawny), 4 red, 6 purple
24	Lemma and palea color (LPC)	Measured on mature seed. Ten classes: 0 straw, 1 gold furrows on straw background, 2 brown to yellow, 3 brown furrows on straw background, 4 brown (tawny), 5 reddish to light purple/to orange, 6 purple spots on straw, 7 purple furrows on straw, 8 purple, 9 black, 10 white
25	Grain length (GrL)	Measured as the distance from the base of lowermost sterile lemma to the tip of the apiculus (mm)
26	Grain width (GrW)	Measured as the distance across the fertile lemma and the palea at the widest point (mm)
27	Grain color (GrC)	Seed coat color of dehulled grains classified into: 1 white, 2 brown to yellow, 3 brown furrows to gray, 4 brown, 5 red, 6 variable purple, 7 purple

Table 2: Description of weedy rice morphotypes and rice varieties					
Variety	Plant height	Panicle type	Awn	Apiculus color	Lemma and palea color
PWR01	Tall (9)	Open (9)	Awnless (0)	Straw (2)	Straw (0)
PWR02	Tall (9)	Open (9)	Awnless (0)	Straw (2)	Straw (0)
PWR03	Intermediate (5)	Intermediate (5)	Awnless (0)	Brown (3)	Brown (2)
PWR04	Tall (9)	Intermediate (5)	Awnless (0)	Brown (3)	Brown tawny (4)
PWR05	Tall (9)	Open (9)	Straw (1)	Straw (2)	Straw (0)
PWR06	Tall (9)	Compact (1)	Straw (1)	Straw (2)	Straw (0)
PWR07	Tall (9)	Open (9)	Awnless (0)	Red (4)	Reddish (5)
PWR08	Tall (9)	Intermediate (5)	Awnless (0)	Brown (3)	Brown tawny (4)
PWR09	Intermediate (5)	Intermediate (5)	Awnless (0)	Straw (2)	Straw (0)
PWR10	Intermediate (5)	Open (9)	Awnless (0)	Brown (3)	Straw (0)
PWR11	Tall (9)	Open (9)	Awnless (0)	Straw (2)	Straw (0)
PWR12	Semi-dwarf (1)	Open (9)	Awnless (0)	Straw (2)	Straw (0)
PWR13	Tall (9)	Open (9)	Awnless (0)	Brown (3)	Straw (0)
PWR14	Tall (9)	Compact (1)	Awnless (0)	Brown (3)	Brown tawny (4)
MR84	Semi-dwarf (1)	Intermediate (5)	Awnless (0)	Straw (2)	Straw (0)
MR185	Semi-dwarf (1)	Intermediate (5)	Awnless (0)	Straw (2)	Straw (0)
MR211	Semi-dwarf (1)	Intermediate (5)	Awnless (0)	Straw (2)	Straw (0)
MR219	Semi-dwarf (1)	Intermediate (5)	Awnless (0)	Straw (2)	Straw (0)

(Delouche et al., 2007).

Most weedy rice morphotypes were characterized by having either open or compact panicle type. However, morphotypes PWR03, PWR04, PWR08 and PWR09 produced intermediate panicle type similar to all commercial rice varieties. Presence of awn could help in identification of weedy rice morphotypes. Grains having both small and large awns were found in the present study. Two major groups were identified according to awn presence with short (2-12 mm) and long (21-30 mm) awns. Morphotype PWR05 had short awns present in less than 50% of spikelets and morphotype PWR06 had long awns present in more than 50% of the spikelets.

Weedy rice morphotypes matured early had longer and wider leaves and wider flag leaf and culm angle (Juan et al., 2008). Weedy rice morphotypes matured at different dates among themselves and commercial varieties, while morphotype PWR04 matured 10 days later than commercial varieties. Besides, most weedy rice morphotypes showed high and moderately high grain shattering percentage. However, morphotypes PWR04, PWR06, PWR07 and PWR12 were found with moderate shattering percentage similar to that of all the commercial rice varieties. The increase of leaf length and width might be due to the increase of plant height or due to their vigorous growth. Morphotypes also produced a wide range of variation in flag leaf with intermediate to descending type. Some morphotypes produced erect flag leaf similar to the commercial varieties. Besides, some morphotypes differed in plant types such as erect plant type and intermediate plant type. The presence of erect plant type and flag leaf could be due to the back crossing between morphotypes or with commercial rice varieties.

Further, morphological variation was observed in apiculus color. Weedy morphotype PWR07 had red apiculus, while PWR03, PWR04, PWR08, PWR09, PWR10, PWR13 and PWR14 had brown apiculus, and rest of weedy rice morphotypes had straw apiculus similar to that of the commercial varieties. Pericarp color also varied from brown to red in most morphotypes. However, the presence of individuals with small awn and white pericarp could be the evidence of hybridization between rice varieties and weedy rice. Some weedy rice morphotypes produced longer panicles and higher total grain panicle^{-1} compared to the commercial varieties. They however, produced a high percentage of sterility due to large number of unfilled grains. Some weedy morphotype seeds were small (7-9 mm) which ultimately produced lower thousand grain weight.

Weedy rice morphotypes seeds germinated and emerged more slowly than the commercial varieties (Delouche et al., 2007). They had intense and prolonged seed dormancy that maintains the shattered seeds on or in the soil (Montealegre and Vargas, 1992). All weedy rice morphotypes had a lower germination percentage within first 30 days followed by 9-45% and 5-24% increase during 90 days and 180 days, respectively (Table 3). Morphotypes PWR07 and PWR14 had germination percentage of above 70% within 30 days and increased to above 80%

Table 3: Panicle shattering and germination percentage of weedy rice morphotypes and commercial varieties				
Variety	Panicle shattering (PaSh)	Seed germination percentage		
		30 days	90 days	180 days
PWR01	9	35	38	47
PWR02	7	46	62	68
PWR03	7	37	48	48
PWR04	5	52	59	64
PWR05	7	42	56	60
PWR06	5	38	55	59
PWR07	5	74	81	85
PWR08	9	48	54	58
PWR09	9	35	39	48
PWR10	9	53	61	65
PWR11	7	54	68	72
PWR12	5	48	56	63
PWR13	7	44	52	58
PWR14	5	71	80	85
MR84	5	88	91	92
MR185	5	87	92	92
MR211	5	85	91	93
MR219	5	90	92	93

Five classes of PaSh: 1=very low (<1%), 3=low (1-5%), 5=moderate (6-25%), 7=moderately high (26-50%), and 9=high (>50%)

after 90 days. The remainder of morphotypes had a germination percentage ranging from 35%-54% within 30 days. All commercial rice varieties had germination percentage of above 80% within 30 days and crossed 90% within 90 days. The intensity and period of dormancy appeared in weedy morphotypes might be controlled by genetic or environment interactions. Some morphotypes could even germinate after 4-6 months and consequently hamper the seed purity of the following season's harvest.

The growth and development performance of weedy rice morphotypes in this study indicate that they are well adapted to the environment. These weedy rice morphotypes might have evolved from crossing among themselves and cultivated rice (Vaughan et al., 1995). Over time, they became persistent with special adaptability to the natural forces and human activities involved in rice culture. The study of their morphological characteristics would be of great help in their effective control.

3.2. Morphometric relationships among weedy rice morphotypes

Principle Component Analysis (PCA) revealed that weedy rice complex had a wide variation among themselves and between themselves and commercial varieties. The regression factor scores of these three components were set in a 3-D scatter plot (Figure 2). Eigenvectors of the traits for each component are shown in Table 4. The PCA demonstrated the morphological similarities and differences between weedy rice and commercial rice. Three principal components explained 52.46% of the total

Table 4: The eigenvalues of the correlation matrix for 25 morphological characters of weedy rice morphotypes and commercial rice varieties				
Sl. no.	Variable	Principal component* (eigenvalue and proportion of explained variance)		
		1	2	3
1	Ligule length	0.405	0.498	0.067
2	Total grain by panicle	0.192	0.477	0.634
3	% of filled grain	0.773	0.138	-0.045
4	Rachis number	0.349	0.562	-0.292
5	Culm length	0.246	-0.027	-0.277
6	Panicle excertion	0.267	-0.165	0.037
7	Panicle length	0.048	0.682	0.161
8	Panicle type	0.165	0.638	-0.274
9	Tiller number	-0.851	-0.040	0.165
10	Leaf 1 length	0.742	0.130	0.342
11	Leaf 1 width	-0.465	0.265	0.344
12	Flag leaf length	0.572	0.251	0.504
13	Flag leaf width	-0.337	0.306	0.014
14	Flag leaf angel	0.695	0.215	0.154
15	Panicle secondary branching	-0.014	0.682	0.190
16	Panicle shattering	0.569	0.457	-0.156
17	Grain awn distribution	0.243	-0.467	0.751
18	Awn length	0.283	-0.451	0.772
19	Awn color	0.323	-0.359	0.699
20	Apiculus color	0.359	-0.176	-0.702
21	Lemma and palea color	0.338	-0.286	-0.514
22	Grain length	-0.569	0.618	0.235
23	Grain width	-0.287	-0.289	0.140
24	Grain color	0.242	-0.173	-0.096
25	WTS	-0.710	0.427	0.245

Coefficient with absolute value greater than or equal to 0.498 are shown in bold values; 1: 1st (5.28, 21.10%); 2: 2nd* (4.01, 16.07%); 3: 3rd* (3.82, 15.29%)

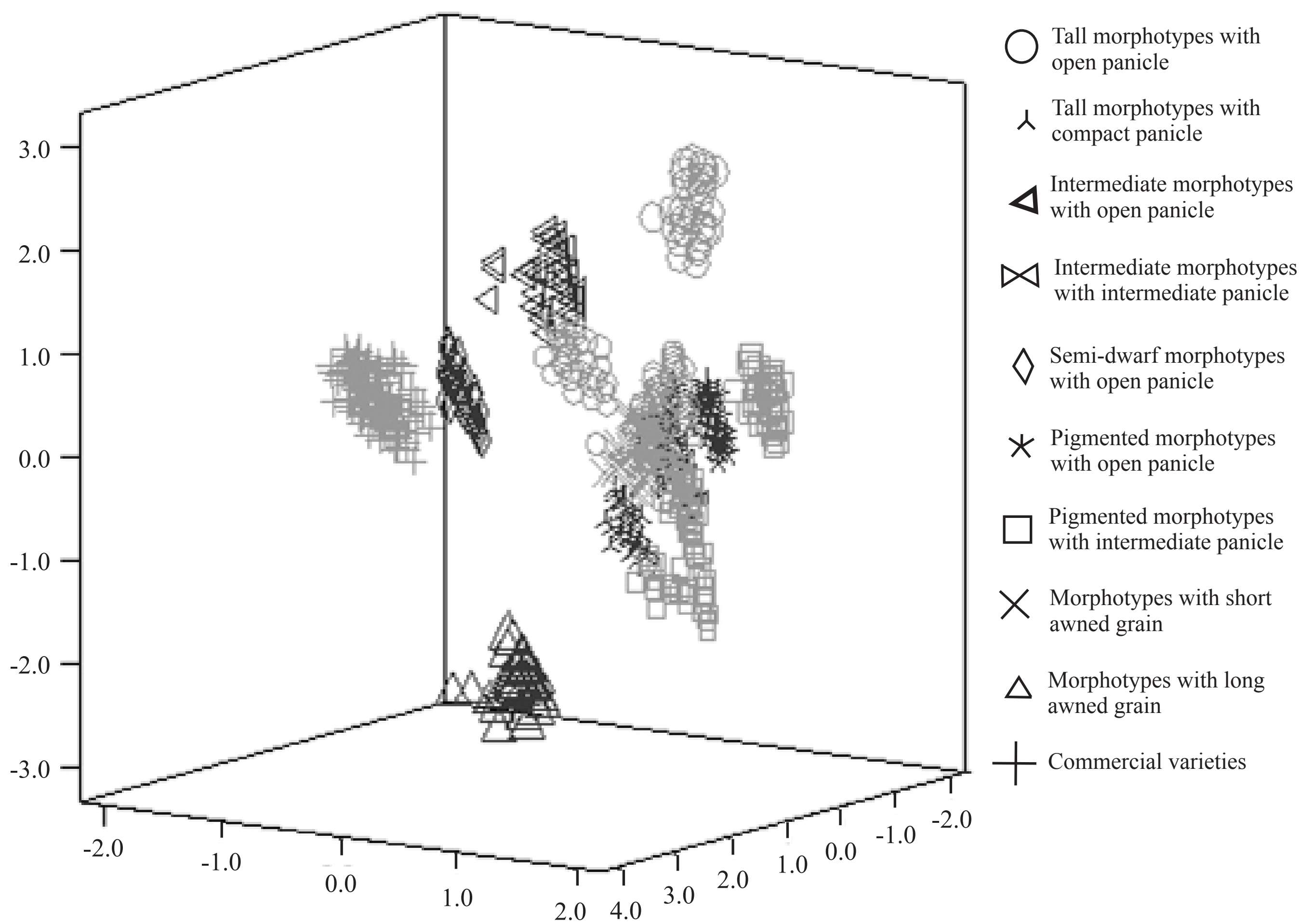

Figure 2: 3-D scatter plot showing the distribution of weedy morphotypes and commercial rice varieties

variation observed among the studied population.

The first component showed 21.10% variation and was characterized by filled grain percentage, tiller number, leaf 1 length, flag leaf length, flag leaf angel, panicle shattering, grain length and thousand grain weight. The second component accounted for 16.07% of the variation and was characterized by ligule length, rachis number, panicle length, panicle type, panicle secondary branching and grain length. Lastly, the third component was accounted by total grain by panicle, flag leaf length, grain awn distribution, awn length, awn color, apiculus color, and lemma and palea color.

The first and second components together explained 37.17% of the variation. Most of weedy rice morphotypes were clustered together. This was observed due to taller plant height, longer leaf 1 and flag leaf length, variation in flag leaf angle, higher panicle shattering, more panicle secondary branching, variation in lemma and palea color, and grain color, short and intermediate grain length, and lower thousand seed weight. PCA showed the morphological relationships among weedy rice morphotypes and commercial rice varieties which also documented important information about the diversity of these weedy rice morphotypes (Arrieta-Espinoza et al., 2005). Some weedy rice morphotypes with awned grain were separated each other which is mainly characterized by different awn size and distribution of awn in grains. Similar results were also observed by Zainudin et al. (2010). Commercial rice varieties were also observed apart from weedy rice (Londo and Schaal, 2007). This separation is supported by shorter plant height, intermediate panicle length, lower panicle shattering percentage, higher number of tillers and higher percentage of filled grain.

4. Conclusion

The information obtained from the morphological characterization of weedy rice complex represents an initial step for understanding its diversity and complexity. Aggressive growth and development of weedy rice morphotypes makes unequal competition among themselves and commercial rice varieties. High seed shattering percentage coupled with prolonged dormancy can make these morphotypes available even in the next season. Most weedy morphotypes were found taller with open type panicle, different lemma and palea color and grain color. Besides, they had less tillers, percentage of filled grain, thousand grain weight and long ligule, and leaf and flag leaf. Some weedy rice morphotype were also found having grains with short and long awns. These characteristics will help us to identify weedy rice morphotypes from rice fields to follow successful management strategy. The morphometric study of weedy rice morphotypes available in Perak granaries and commercial rice varieties will represent an initial step for understanding its diversity and complexity. This wide range of highly diverse weedy rice accessions could be a source of valuable germplasm for rice improvement. These studies will also be valuable for designing a gene flow study to confirm the relationships described in this study.

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