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Morphological characterisation of weedy rice morphotypes of Kerala

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ABSTRACT

Weedy rice (*Oryza sativa* f. *spontanea*) has emerged as a major threat to global rice production and has already established in the major rice growing tracts of Kerala, *viz*. Palakkad, Kuttanad and Kole lands. The main objective of the study was to compare the morphological characteristics of weedy rice morphotypes across the state so as to chalk out morphometric relationship between the weedy and cultivated rice at different stages of plant growth. Different morphotypes of weedy rice were collected from the major rice tracts of the state and characterization was done, both for qualitative and quantitative (morphometric) traits. The study revealed similarity in most of the qualitative traits observed for weedy and cultivated rice. The morphometric characters that varied significantly between weedy and cultivated rice during the initial stages of growth included thickness of culm and length of ligule. Most striking difference observed was in the number of tillers/plant with 87 per cent of weedy rice morphotypes recording higher tiller number (ranged from 11 to 20) compared to cultivated rice (10 and 9 for '*Jyothi* (Ptb-39) and '*Uma-MO-16*, respectively). Studies also revealed that weedy rice plants were lanky, taller (105 to 115.67 cm) with more round culm, with or without anthocyanin pigmentation at the nodal region, short ligule, early flowering compared to cultivated rice, more number of tillers per plant and mostly with awned grains. Similarities between weedy and cultivated rice were found to increase after every cultivating season due to the repeated back crossing and gene flow between the two plant types as evident from compact panicles and awnless grains observed among the morphotypes. As weedy rice invasion reduces crop yield substantially (40-70 percent), its management is an urgent need of the hour. Some of the morphological adaptations exhibited by the morphotypes in response to the prevailing ecological situations clearly indicated the possibility of weedy rice becoming a persistent threat to rice cultivation. Morphological characterization could help in identifying the competitive traits of weedy rice morphotypes which can be used in advanced breeding programmes for developing ecofriendly weedy rice management strategies.

INTRODUCTION

The introgressed product of wild and cultivated rice widely known as weedy rice (*Oryza sativa* f. *spontanea*), was first documented in North Carolina, USA as early as in 1846 (Smith 1981). However, reports of weedy rice emerging as a major weed in the direct-seeded rice tracts of South East Asia appeared after more than a century.In direct seeded rice, this noxious weed emerged as a major threat with its huge seed bank in cropped fields favouring persistent invasion. In Asia, weedy rice infestation was first reported from Malaysia in 1988, Philippines in 1990, and Vietnam in 1994 (Saha *et al*. 2014). In India, the first attempt of identifying and characterizing different types of weedy rice in farmer's field was done in Madhya Pradesh (Varshney and Tiwari 2008). In South India, especially Kerala weedy rice infestation and spread has reached an alarming proportion in major rice tracts during 2007-08. The weed then evolved as a major problem in the rice fields reducing the yield from 30 to 60 per cent at an infestation rate ranging from 3 to 10 mature plants per square metre (Abraham *et al*. 2012). Of late, it has infested large rice growing areas across the major rice belts of Kerala, *viz*. Palakkad, Kuttanad and Kole lands with

diverse morphotypes. Weedy rice has competitive advantage over cultivated rice as it grows taller and faster, tillers profusely and competes with cultivated rice for nutrients, water, light and space (Abraham and Jose 2015).It flowers much earlier than cultivated rice and produces grains that shatter easily, favouring soil seed bank. Early shattering of the grain and variable seed dormancy are the important weedy traits favouring its invasion (Chauhan 2013). As weedy rice is morphologically similar to cultivated rice at the early growth stages hand weeding becomes ineffective and incomplete as it mimic cultivated rice. Moreover, the genetic and biochemical similarity of weedy rice to cultivated rice makes herbicidal control impossible. Though the marked visual difference between the plants at the time of panicle emergence in weedy rice (55-65 DAS) favour hand weeding it does not favour yield increase; prevents seed shattering. In this backdrop, the present study on characterization of different weedy rice morphotypes was initiated to study the quantitative (morphometric) and qualitative characters of weedy rice in comparison to cultivated rice.

MATERIALS AND METHODS

Morphological characterization of weedy rice morphotypes was done by conducting pot culture experiments at College of Agriculture, Vellayani, Thiruvnanthapuram during October-January, 2015 and 2016. The experimental field is located at 8^0 25'49'' N latitude and 76^0 39' 04'' E longitudes at an altitude of 29 m above the mean sea level. The experiment was laid out in Completely Randomised Design with eight morphotypes of weedy rice along with two cultivated rice varieties, replicated thrice. The weedy rice morphotypes 1 and 2 were collected from the rice fields of Thiruvananthapuram ($8^0$43'N,$76^0$99'E) Kuttanad region in the Alleppey district 3 from kuttanad region ($9^0$35'N,$76^0$40'E), 4 from Kole lands of Thrissur district ($10^0$30'N, $75^0$58'E), 5 and 6 from Palakkad ($10^0$78'N,$76^0$65'E), 7 from Kozhikode ($11^0$25'N, $75^0$78'E), and 8 from Kaipad lands (Ezhome) of Kannur ($12^0$04'N,$75^0$29'E). The experiment consisted of raising weedy rice morphotypes using seeds collected from the major rice belts of Kerala along with the popular short duration rice variety '*Jyothi-Ptb39'* and the popular medium duration rice variety '*Uma-MO-16*'. Weedy rice seeds were allowed to germinate after breaking dormancy. The pre germinated seeds (two seeds per pot) were sown in earthen pots of 50 cm depth and 30 cm diameter and filled with clayey soil collected from non-infested rice fields. Flooded situation was maintained throughout the growth period and all cultural operations including liming, manuring, fertilizer application and irrigation were followed as per KAU (2011). Pots with weedy rice morphotypes and cultivated rice were raised side by side to observe the morphological differences. Morphometric characters like length of ligule, culm thickness, plant height, number of tillers per plant, days to 50% flowering, panicle length and awn length were observed at periodic intervals and measured quantitatively/recorded for both weedy rice and cultivated rice. Alternatively, qualitative characters like attitude of leaf blade, anthocyanin pigmentation, colour of ligule, pigmentation of awns were scored in as per the Descriptors for wild and cultivated rice (*Oryza* spp.) by Bioversity International, IRRI and WARDA (2007). Attitude of leaf blade was measured as the angle of attachment between the leaf blade and the main panicle axis. Various classes included were erect, semi-erect (intermediate), horizontal and descending. Anthocyanin colouration was measured as the presence and distribution of purple colour (anthocyanin) on the outer surface of the nodes on the culm. The data recorded were subjected to Analysis of Variance techniques (ANOVA) as applied to completely randomized design. The treatment *vs*. control comparison is denoted as 'S' when significant and 'NS' when not significant.

RESULTS AND DISCUSSION

Morphometric characters

Among the morphometric characters, plant height of weedy rice morphotypes ranged between 105 to 115.67 cm, while the height of cultivated rice varieties '*Jyothi-Ptb39'* and '*Uma-MO-16'* were 96 and 91 cm, respectively (**Table 1**). Jose *et al.* (2013) reported that weedy rice variants from Kuttand were usually taller (130 to 145 cm) than cultivated rice. As plant height is a competitive trait in plant communities,taller weeds tend to offer more competition reducing the crop yield. Short varieties are more susceptible to weedy rice competition than tall ones (Saha *et al*. 2014). This taller growth habit of weedy rice results in competition between them for above ground growth factors *ie.*, light, space and other growth resources. Taller weedy rice plant shades and lodge over the rice plants reducing photosynthetic ability and yield of rice. However, some dwarf weedy rice morphotypes were also observed by Jose *et al.* (2013), which might be due to the repeated back crossing between weedy rice and cultivated rice or due to the late emergence from soil seedbank. Chauhan (2013) opined that weedy rice morphotypes were more tolerant to shade than cultivated rice.

Other morphological traits which were analyzed quantitatively were ligule length and culm thickness. Significant variation was observed in the length of ligule during initial stages with 75 per cent of weedy rice morphotypes having smaller ligules compared to cultivated rice varieties. During the initial period up to 15 DAS, shorter ligule could be used as a demarcating character between weedy rice and cultivated rice. However, at later stages this difference becomes less significant. Jose *et al*. (2013) reported that ligule length ranged from 2 to 20 mm at 55 DAS for weedy rice collected from Kuttanad region and in the present study ligule length of 3.7 mm to 13.7 mm was recorded for weedy rice and 9.7 and 6.7 mm, respectively, for '*Jyothi-Ptb39*' and '*Uma-MO-16'* (**Table 1**). Culm of weedy rice exhibited distinct cylindrical appearance measured on the basis of length and breadth of cross section of culm compared to cultivated rice, which usually possesses flattened culm in the vegetative phase. Abraham and Jose (2015) also observed more brittle and round culm for weedy rice types of Kerala compared to cultivated rice. Most of the weedy rice morphotypes recorded higher culm thickness ranging from 2.27 to 3.37 cm compared to cultivated rice varieties (1.93 to 2.27 cm) both at initial as well as later growth stages and this character could be used for differentiation of morphotypes from cultivated rice.

Number of tillers per plant varied widely between weedy rice and cultivated rice (**Table 1**). Higher tiller number was observed in weedy rice compared to cultivated rice during initial as well as later stages of growth. About 87 per cent of weedy rice morphotypes had more tiller count (ranged from 11 to 20) compared to cultivated rice (10 and 9) and the only morphotype from Ezhome recorded less tiller count. Hence, high tiller count could be utilized as a trait to differentiate weedy rice from cultivated rice in specific tracts.

Early flowering was observed in weedy rice morphotypes compared to cultivated rice. Fifty percent of weedy rice population flowered in between 49 to 51 DAS, while '*Jyothi-Ptb39*' and '*Uma-MO-16*' flowered at 61 and 82 DAS (**Table 1**). It was observed that the weedy rice plants had very early flowering in the pot culture compared to that it usually had in the cultivated fields of the region (55-60 DAS), which might be due to the stress for various resources. Early flowering resulted in early grain maturing and seed shattering. Shattered seeds added to soil seed bank would intensify the problem in future (Perreto *et al*. 1993). Early flowering in weedy rice is an additional advantage for its survival in rice fields. The results are in confirmation with the findings of Olguin *et al*. (2007) who observed earliness in panicle emergence and asynchronisation of grain maturity in weedy rice compared to cultivated rice.

Weedy rice had short panicles compared to panicles of cultivated rice and morphotype from Palakkad only recorded more length of 22.13 cm (**Table 1**). This might be due to the early invasion of weedy rice in Palakkad region compared to other tracts and repeated back crossing between the weedy lines and cultivated lines might have imparted longer panicle to weedy population, resembling cultivated rice. Rathore *et al*. (2016) reported that there was marked difference in the panicle length and number of panicles in rice and weedy rice.As per morphometric descriptors of IRRI, panicle type of weedy rice can

Table 1. Comparison of morphometric characters of weedy rice morphotypes and rice varieties

Treatment	Length of ligule (mm)		Culm thickness (cm)		Plant height (cm)	No. of tillers/plant at 50% flowering	Days to 50% flowering	Panicle length (cm)	Awn length (cm)
	15 DAS	50% flowering	15 DAS	50% flowering					
Weedy rice morphotype 1	5.70	11.00	2.43	2.57	108.97	15.67	51.43	17.43	4.31
Weedy rice morphotype 2	10.30	14.00	1.57	3.23	115.67	16.67	51.03	17.67	7.41
Weedy rice morphotype 3	6.70	7.30	2.00	3.37	110.20	13.67	50.36	16.83	3.48
Weedy rice morphotype 4	3.70	5.00	2.40	2.43	110.80	16.00	49.63	16.83	4.11
Weedy rice morphotype 5	4.00	5.30	1.73	2.47	113.27	19.67	50.13	17.57	6.69
Weedy rice morphotype 6	6.00	22.30	2.30	2.57	112.77	13.00	50.19	22.13	2.38
Weedy rice morphotype 7	4.00	4.30	2.07	2.27	108.83	11.67	51.13	16.80	7.36
Weedy rice morphotype 8	13.70	14.30	1.57	2.43	105.07	8.33	50.43	18.17	9.23
LSD (p=0.05)	1.90	1.60	0.41	0.22	2.19	2.68	NS	1.51	0.12
Control									
Cultivar–1 (Jyothi)	9.70	10.30	1.87	1.93	96.17	10.33	61.58	23.00	Absent
Cultivar–2 (Uma)	6.70	7.70	2.20	2.27	91.17	9.00	81.88	23.73	Absent
C-1 vs treatments	S	NS	NS	S	S	S	S	S	-
C-2 vs treatments	NS	S	NS	S	S	S	S	S	-

be compact, intermediate or open.The type of panicle varied among the morphotypes with most of them having open or intermediates panicles unlike compact panicles in cultivated varieties. Kuttanad morphotypes recorded an intermediate panicle type in the present study. However, Jose *et al.* (2013) recorded open or compact weedy rice panicles among the weedy rice variants from Kuttanad. Morphotypes from Thiruvananthapuram, Kole and Palakkad recorded compact type of panicle as that of cultivated rice. This clearly indicated that weedy rice morphotypes of these locations are acquiring characters more similar to cultivated rice by repeated back crossing.

Weedy rice and cultivated rice are usually differentiated with the presence of awns. Most of the cultivated rice varieties lack awns except for few traditional varieties which bear very short awns, while most of the weedy rice morphotypes had awns. Awn length of the weedy rice morphotypes exhibited wide variation and it ranged from 2.38 to 9.23 cm (**Table 1**). These findings are in concurrence with the studies of Jose *et al.* (2013), who reported an awn length of 2.5 to 8 cm for the weedy rice variants of Kerala. It was observed that there was no direct correlation between awn colour and anthocyanin pigmentation at the nodal region. In some cases morphotypes with nodal pigmentation exhibited colourless or white awns and this was in confirmation with the findings of Larinde (1979). Some weedy morphotypes from Thiruvananthapuram and Kuttanad were noticed with reduced or no awns, which might be due to the repeated back crossing between weedy rice and cultivated rice resulting in the absence of that particular character.

Qualitative characters

Among the qualitative characters, attitude of leaf blade was found to vary widely among various weedy rice morphotypes. Most of them exhibited semi erect or intermediate attitude, similar to cultivated rice. Marked difference was recorded by the morphotypes collected from Palakkad and Ezhome, while, that from Kozhikode had erect attitude (**Table 2**). The distribution of the culm angle in weedy rice morphotypes ranging from open to erect suggested that the erect growth habit is recessive to that of a spreading or procumbent growth habit (Adair and Jodon 1973). The presence of erect plant types could be due to back-crossing between accessions or with the commercial rice cultivar (Gealy *et al.* 2006). In the present study, variations in the morphology among morphotypes might be due to the variations in the agro-ecological situations in which the morphotype was developed and/or the rice variety cultivated. As weedy rice emerges by natural hybridization between wild rice and cultivated rice, the weedy rice morphotype present in a location will have characters of the most common cultivated rice variety of that location. Variations observed among morphotypes of the same location corroborated the findings of Estorninos *et al.* (2002) and Chauhan (2013) that weedy rice might vary among different variants. It could also be attributed to the variation in the availability of resources, *viz.*, space, light, moisture, nutrients etc., for plant growth and staggered emergence pattern of weedy rice in cropped field.

Anthocyanin pigmentation at the nodes could also be used as a character to differentiate weedy rice and cultivated rice in Ezhome, which exhibits an intense purple pigmentation at the nodal region (**Table 2**). However, morphotypes from Thiruvananthapuram white, Kuttanad and Kozhikode lacked anthocyanin pigmentation at the nodes. Certain rice varieties, *viz. Purple Puttu* and *Violet Sundhari* also possess anthocyanin pigmentation in the plant parts. As weedy rice morphotypes with and without

Table 2. Attitude of leaf blade and anthocyanin pigmentation of nodes in weedy rice morphotypes and rice varieties

Treatment	Attitude of leaf blade				Anthocyanin pigmentation			
	Erect	Semi erect (intermediate)	Horizontal	Descending	Absent	Purple	Light purple	Purple lines
Weedy rice morphotype 1	-		-	-	-	Thiruvananthapuram red		-
Weedy rice morphotype 2	-	Thiruvananthapuram white	-	-	Thiruvananthapuram white	-	-	-
Weedy rice morphotype 3	-	Kuttanad	-	-	Kuttanad	-	-	-
Weedy rice morphotype 4	-	Kole	-	-	-	-	Kole	-
Weedy rice morphotype 5	-	Palakkad red	-	-	-	-	Palakkad red	-
Weedy rice morphotype 6	-	-	-	Palakkad white	-	-	-	Palakkad white
Weedy rice morphotype 7	Kozhikode	-	-	-	Kozhikode	-	-	-
Weedy rice morphotype 8	-	-	-	Ezhome				
Control								
Cultivar - 1	-	-	Jyothi	-				
Cultivar - 2	-	-	Uma	-				

pigmentation in the nodal region were observed, the presence of anthocyanin pigmentation at the nodal region alone could not be considered as a morphological character for differentiation of rice and weedy rice. In heavily infested areas, cultivating pigmented rice can ease the rogueing of non-pigmented weedy rice from the infested fields.

Colour of ligule is another character which could be used for the differentiation of weedy rice and cultivated rice. Ligule colour ranged between whitish to purple among morphotypes (**Table 3**). The morphotypes from Ezhome, Kozhikode and Kole lands could be differentiated from the cultivated rice using the purple shaded ligule pigmentation. Purple pigmentation in the leaf sheath, leaf margin and culm region of weedy rice morphotypes have been reported by Burgos (2005).

Diversity of awn colour in the same field revealed that weedy rice morphotypes were not structured to a geographical region. Morphotypes collected from Thiruvananthapuram and Palakkad exhibited both white and red awn colour. This can be attributed to the seed contamination of cultivated rice and emergence of weedy rice from soil seed bank. Apart from this, wide variation in awn colour was observed ranging from whitish to black. Morphotype from Thiruvananthapuram and Kuttand had straw coloured awns; Kozhikode with whitish awns; Kole had brown awns; Palakkad had light green and Ezhome possessed purple coloured awns (**Table 3**). Larinde (1979) reported about the variation in awns with short awns or without awns, which might be the result of segregation after natural crossing. In the present study, some morphotypes were observed with very short awns or without awns. Colour of pericarp was mostly varying shades of red in all morphotypes. Repeated back crossing between weedy rice and cultivated rice varieties might have imparted the awnless nature of cultivated rice to weedy rice making it very similar to cultivated rice.

In addition, certain demarcating characters were observed in some weedy rice morphotypes like distinct black ring at the nodal region (morphotype from Palakkad and Kole), characteristic bend at the nodal region (morphotype from Kozhikode), presence of adventitious roots (morphotype from Kuttanad), apiculus colouration (for all morphotypes) and presence of very short awns (morphotype from Thiruvananthapuram).Presence of adventitious roots for morphotypes from Kuttanad helped them to thrive under below sea level rice farming situation of the region. These characters might have emerged as an adaptation to the ecological situation in the prevailing tract. Hence, a thorough knowledge of the ecosystem and cultivation practices of a particular area is essential to differentiate and manage weedy rice in cultivated fields. Microscopic analysis of rice and weedy rice grain surface revealed that grain surface of weedy rice is hairy with trichomes which help for easy dispersal. Jose (2015) has also reported the presence of trichomes and long awns on the surface of weedy rice grains favouring its dispersal through fur of animals, machinery and water. Microscopic analysis also exposed the superior size of pollen sacs of weedy rice compared to cultivated rice variety '*Uma-MO-16*'.

The study documented the existing variations among the weedy rice morphotypes of Kerala and

Table 3. Colour of ligule, panicle type and pigmentation of awns in weedy rice morphotypes and rice varieties

Treatment	Colour of ligule						Panicle type	Pigmentation of awns								
	Ab-sent	Whitish	Yellowish green	Purple	Light purple	Purple lines		Ab-sent	Whitish	Straw	Gold	Brown	Light green	Red	Purple	Black
Weedy rice morphotype 1	-	-	TVM red	-	-	-	Compact	-	-	-	-	-	-	TVM red	-	-
Weedy rice morphotype 2	-	TVM white	-	-	-	-	Inter-mediate	-	-	TVM white	-	-	-	-	-	-
Weedy rice morphotype 3	-	Kuttanad	-	-	-	-	Inter-mediate	-	-	Kuttanad	-	-	-	-	-	-
Weedy rice morphotype 4	-	-	-	-	-	Kole	Compact	-	-	-	-	Kole	-	-	-	-
Weedy rice morphotype 5	-	-	PKD red	-	-	-	Compact	-	-	-	-	-	-	PKD red	-	-
Weedy rice morphotype 6	-	PKD white	-	-	-	-	Inter-mediate	-	-	-	-	-	PKD white	-	-	-
Weedy rice morphotype 7	-	-	-	-	Kozhi-kode	-	Open	-	Kozhi-kode	-	-	-	-	-	-	-
Weedy rice morphotype 8	-	-	-	Ezhome	-	-	Open	-	-	-	-	-	-	-	Ezhom e	-
Control																
Cultivar – 1	-	-	Jyothi	-	-	-	Compact	-	-	-	-	-	-	-	-	
Cultivar – 2	-	-	Uma	-	-	-	Compact	-	-	-	-	-	-	-	-	

PKD: Palakkad; TVM: Thiruvananthapuramm

found that weedy rice had many characters very similar to cultivated rice and it was not possible to differentiate between them using a single character. Similarities between weedy and cultivated rice increased year after year due to the repeated back crossing and gene flow between two plant types. The weedy rice morphotype of Kuttanad and Thiruvananthapuram has acquired characters of cultivated rice like compact and awnless panicles making it so difficult to identify even after flowering. However, a combination of morphological traits could be used for the identification of weedy rice from cultivated rice. There existed high phenotypic diversity in weedy rice accessions across different countries, both within and among geographical regions (Song *et al*. 2014). Of the various quantitative traits studied, length of ligule and culm thickness were significantly different for weedy rice during the early growth stages. It was also observed that most of the weedy rice morphotypes studied had short ligule at early stages, tall plants (105 to 115.67 cm), lanky with more round culm and more number of tillers per plant. Among the qualitative characters studied, anthocyanin pigmentation at the nodal region was not distinct among the morphotypes but weedy rice exhibited earliness in flowering (49-51 DAS), more number of adventitious roots under waterlogged condition, characteristic bend at the nodal region with awned grains possessing apiculus pigmentation. The morphological adaptations exhibited by the morphotypes in response to the prevailing ecological situations clearly indicated the possibility of weedy rice becoming a persistent threat to rice cultivation. The morphological diversity unveiled in the present study will help to elucidate the distinguishing traits of weedy rice that could be used for marker assisted selection programmes for developing more competitive varieties of rice.The study revealed the invasive nature of weedy rice and urgent need to strengthen the seed distribution system to prevent the further spread of the noxious weed. The results of the study calls for urgent adoption of integrated weedy rice management strategies.

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