Original Article

Anatomical and Morphological Characteristics for Malaysian Weedy Rice (*Oryza sativa* L.) Identification

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ABSTRACT

This study was conducted to determine the suitable anatomical and morphological characteristics of Malaysian weedy rice to identify weedy rice in the field. The field work was conducted at paddy seed producer farms in Kedah, Penang, Kelantan, and Terengganu, Malaysia. Seeds of dominant weedy rice varieties were collected from the field and grew in the greenhouse. Leaf blades and stems of weedy rice and cultivated rice were sampled at the flowering stage for preparing cross-section specimens. Three morphological characteristics (plant height, stem and leaf color, and flag leaf inclination angle of weedy rice and cultivated rice) were recorded at three stages of plant life (vegetative, flowering, and ripening stage). The study revealed that only a few varieties of weedy rice showed differences in terms of the epidermis thickness between weedy rice and cultivated rice. There was no apparent difference between weedy rice and cultivated rice in terms of the number of bulliform cell groups, vascular bundles, and aerenchyma cells in the leaf blade or stem. The differences in anatomical characteristics were inconsistent. In the field, most of the weedy rice was taller than cultivated rice. The study found that the color of the leaves and stems of weedy rice was yellow-green at all growth stages, but the leaves and stems of cultivated rice were green. Most of the weedy rice flag leaves started inclining 60 days after sowing. The finding indicated that the weedy rice leaf and stem color index can be a practical guideline for farmers to identify weedy rice in fields quickly.

Introduction

The weedy rice (*Oryza sativa L.*), known as "padi angin" in Malaysia, was first discovered in Projek Barat Laut, Selangor, Malaysia in 1988 [1]. Two years later (in 1990), weedy rice was detected in Muda area, Malaysian biggest rice granary [2]. Rapid growth, early maturity, easy shattering, and seed dormancy were unique characteristics of weedy rice. Azmi and Rezaul (2008) reported that yield losses in rice fields with moderate weedy rice infestations (15-20 panicles/m^2) ranged from 12-15%; yield losses under high infestations (21-30 panicles/m^2) ranged from 15-22%. If heavily infested (more than 50 panicles/m^2), weedy rice might result in complete yield loss [3]. Weedy rice

could compete with rice in all growth stages [4]. Most previous studies found that weedy rice was more competitive than cultivated rice [5].

According to Abd Hamid *et al.* (2007), the scanning electron microscope (SEM) comparison did not show anatomical differences among Malaysian weedy rice varieties for both seed and leaf surfaces. However, the growth patterns among the various weedy rice varieties or between weedy rice and cultivated rice differed [6]. Hussain *et al.* (2010) conducted a morphological study on the relationship between weedy rice and commercial rice. They found that the arrangement of culm angles of weedy rice, wild rice, and commercial rice differed from erect to semi-erect or procumbent growth. They also discovered that most of the weedy rice was taller than cultivated rice and wild rice species, and the flag leaf length varied among all weedy rice varieties [7].

Even though Malaysian weedy rice has been the subject of numerous investigations, little is known about its anatomy. Most previous studies related morphology variation, competition, diversity, and distribution [8,9,10]. Hoagland and Paul (1978) and Abd Hamid *et al*. (2007) separately conducted a comparative scanning electron microscope (SEM) study between the seed and leaf of weedy rice and cultivated rice but did not study the anatomy of weedy rice [6,11]. Anatomical information on Malaysian weedy rice has never been reported. Understanding the anatomical structure of weedy rice variations can be used as guidance or fundamental knowledge in developing practical weedy rice control approaches, especially in herbicide formulation. For example, a thick epidermis prevents herbicide from penetrating weed leaves [12]. It is possible to design herbicides to control weedy rice without harming cultivated rice using the knowledge of the differences between the anatomical features of weedy rice and cultivated rice.

This study aimed to compare weedy rice's anatomical and morphological characteristics with cultivated rice plants and to determine suitable anatomical or morphological characteristics of weedy rice as a guideline for weedy rice identification in the field. The morphological characteristics can be a noticeable component for quick weedy rice identification guidance in the field. Researchers can use weedy rice anatomical features knowledge for weedy rice identification confirmation and further in-depth study of control weedy rice.

Materials and methods

This study was conducted at several Malaysian paddy seed producer farms in Kedah, Penang, Kelantan, and Terengganu, Malaysia, from 2017 until 2022. It consisted of two parts: (i) to compare the anatomical characteristics between weedy rice varieties and cultivated varieties, and (ii) to determine the suitable morphological characteristics of weedy rice for weedy rice identification in the field.

Anatomical comparison between weedy rice and cultivated rice varieties

Seeds of nine dominant weedy rice varieties were randomly collected from Malaysia Muda Agricultural Development Authority (MADA) District I, II, III, and IV rice granary areas (Table1).

Table 1. Weedy rice seeds from Malaysia Muda Agricultural Development Authority (MADA)

No.	Location MADA District I (Mi), MADA District II (Mii), MADA District III (Miii), MADA District IV (Miv)	Morphological Characteristic Same height as cultivated rice MR220CL2 (SH), taller than cultivated rice MR220CL2 (TH), open panicle (OP), compact panicle (CP) awnless (AL), and awned (AD)
1	Mi	SH, OP, AL
2	Mi	TH, CP, AL
3	Mii	TH, OP, AL
4	Mii	TH, CP, AL
5	Mii	TH, CP, AD
6	Miii	TH, CP, AL
7	Miv	SH, CP, AL
8	Miv	TH, OP, AL
9	Miv	TH, CP, AL

The two well-known cultivated varieties of rice, MR220CL2 and MR219, were selected for this anatomical comparison. MR219 and MR220CL2 seeds were provided by MARDI Gene Bank, Seberang Perai, Pulau Pinang, Malaysia.

The seeds of the weedy rice and cultivated rice varieties were grown in the greenhouse at MARDI Seberang Perai. At the flowering stage, the leaf blade and stem of the weedy rice and cultivated rice were sampled for preparing cross-section specimens. The method by Johansen (1940) and Sass (1958), with appropriate modifications, was used for the fixation and embedding of preparing cross-section specimens [13,14]. The epidermis (ep) thickness of the stem's outer layer, midrib, vein, and lamina (abaxial (ab), and adaxial (ad)) were randomly measured five times. The number of bulliform cell groups (bc), vascular bundle (vb), and aerenchyma cells (ar) of the whole weedy rice and cultivated rice specimen was counted once. The significant difference between the means of epidermis thickness was analyzed using the LSD test at a significant level of 0.05 (SAS statistical software).

Identify the suitable morphological characteristics for weedy rice identification

Nine Malaysian paddy seed producer farms were selected to record the morphological characteristics of weedy rice and cultivated rice. The locations were in Kedah, Penang, Kelantan, and Terengganu, Malaysia: (i) Sg Limau Dalam, Kedah, (ii) Tanjung Radin, Pendang, Kedah, (iii) Kg Alor Sekawan, Kedah, (iv) Pematang Tok Brain, Penaga, Pulau Pinang, (v) Pematang Sintok, Penaga, Pulau Pinang, (vi) Ladang Merdeka Mulong, Kelantan, (vii) Padang Bongor, Kelantan, (viii) Gong Guchil-Site 1, Terengganu, and (ix) Gong Guchil-Site 2, Terengganu, Malaysia. Three morphological characteristics, viz (i) percentage of weedy rice taller than cultivated rice or same height as cultivated rice (plant height comparison), (ii) stem and leaf color index, and (iii) the percentage of flag leaf inclination angle (0^0, 45^o, 90^0, and 135^0) of weedy rice and cultivated rice were recorded at three stages of plant life (vegetative stage – below 50 days after sowing (DAS), flowering stage – approximately 55DAS, and ripening stage – more than 90DAS). The data were recorded on different days after sowing because of unexpected factors such as rainy days, spraying of pesticide or fertilizer applications, etc. which did not allow the research team to record experimental data. The color index was recorded by refereeing the IRRI Leaf Color Chart, which has four green strips ranging from index 2 (yellow-green / light green) to index 5 (dark green). All the color indices were recorded before or two weeks after fertilizer application. Based on the authors' observation, weedy rice was very responsive to fertilizer. Weedy rice leaves turn green within a few days after fertilizer application and back to standard color one week later. Due to the permission and requirement from the paddy field owners, the data sampling points were limited from 5 to 15 points per plot, depending on the plot size and weedy rice population or area conditions.

The weedy rice plants were randomly determined (based on experience) and marked at the vegetative stage. The same point was subsequently used to record the morphological data at the flowering and ripening stages. The marked weedy rice point would be dropped once it was found that it was not weedy rice.

Results and discussion

Anatomical comparison between weedy rice and cultivated rice varieties

Figures 1, 2, and 3 demonstrate the cross-section of weedy rice and cultivated rice stem's outer layers, midribs, and laminas. Table 2 shows the epidermis thickness of weedy rice varieties and cultivated rice. All stem's outer layer epidermis, either in weedy rice or cultivated rice MR220CL2, were thicker than the midrib, vein, and lamina. When compared to the compact-panicle (CP) weedy rice varieties and cultivated rice, the stem's outer layer epidermis thickness of the open-panicle (OP) weedy rice varieties (ranged from 9.26 to 12.50 µm) was relatively thinner. There was no apparent difference between the stem's outer layer epidermis thickness of the same-height weedy rice varieties (same height as cultivated rice MR220CL2, SH) and the tall weedy rice varieties (taller than cultivated rice MR220CL2, TH).

The epidermis thickness of midrib, vein, and lamina of weedy rice varieties did not show clear or consistence different with cultivated rice (Table 2).

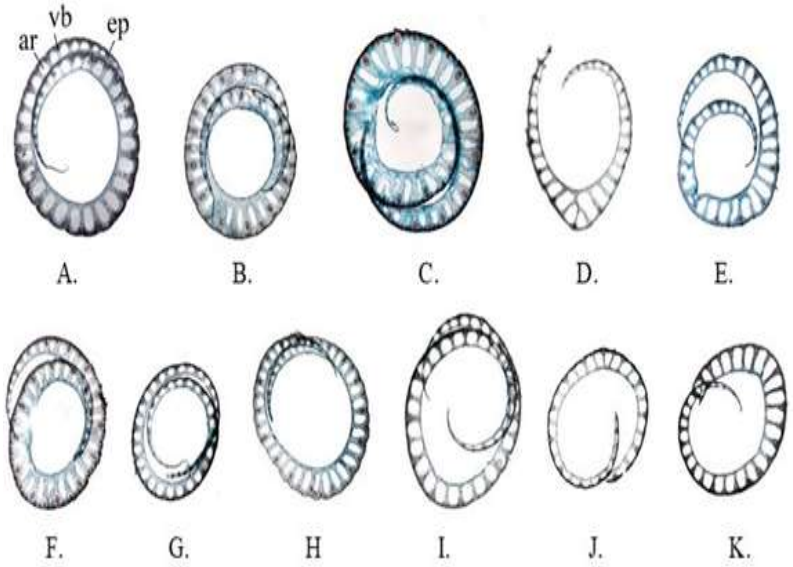

Figure 1. Cross section of the stem's outer layers of weedy rice and cultivated rice. (A) Mi-SH-OP-AL, (B) Miv-SH-CP-AL, (C) Mii-TH-CP-AD, (D) Mi-TH-CP-AL, (E) Mii-TH-CP-AL, (F) Miii-TH-CP-AL, (G) Miv-TH-CP-AL, (H) Mii-TH-OP-AL, (I) Miv-TH-OP-AL, (J) MR220CL2, and (K) MR219

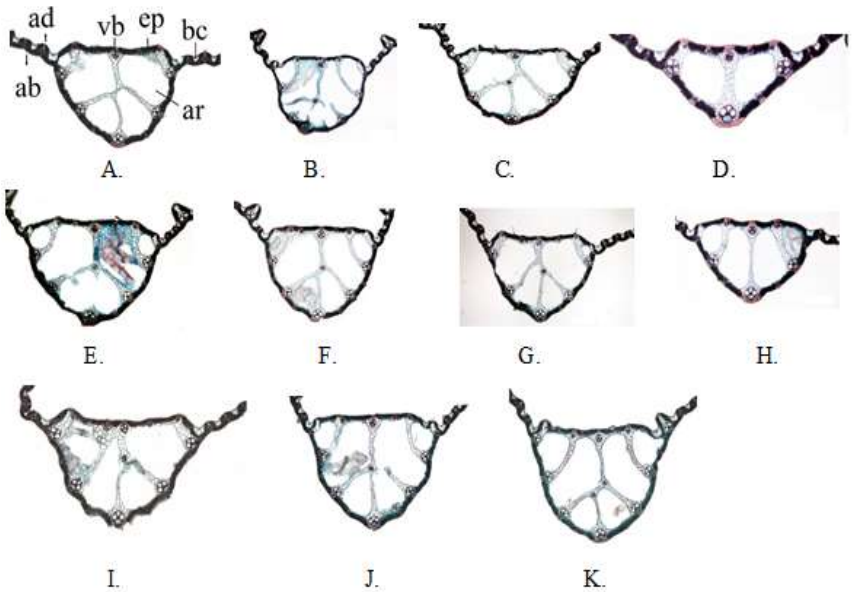

Figure 2. Cross section of the midribs of weedy rice and cultivated rice. (A)Mi-SH-OP-AL, (B)Miv-SH-CP-AL, (C) Mii-TH-CP-AD, (D)Mi-TH-CP-AL, (E) Mii-TH-CP-AL, (F) Miii-TH-CP-AL, (G) Miv-TH-CP-AL, (H) Mii-TH-OP-AL, (I) Miv-TH-OP-AL, (J) MR220CL2, and (K) MR219

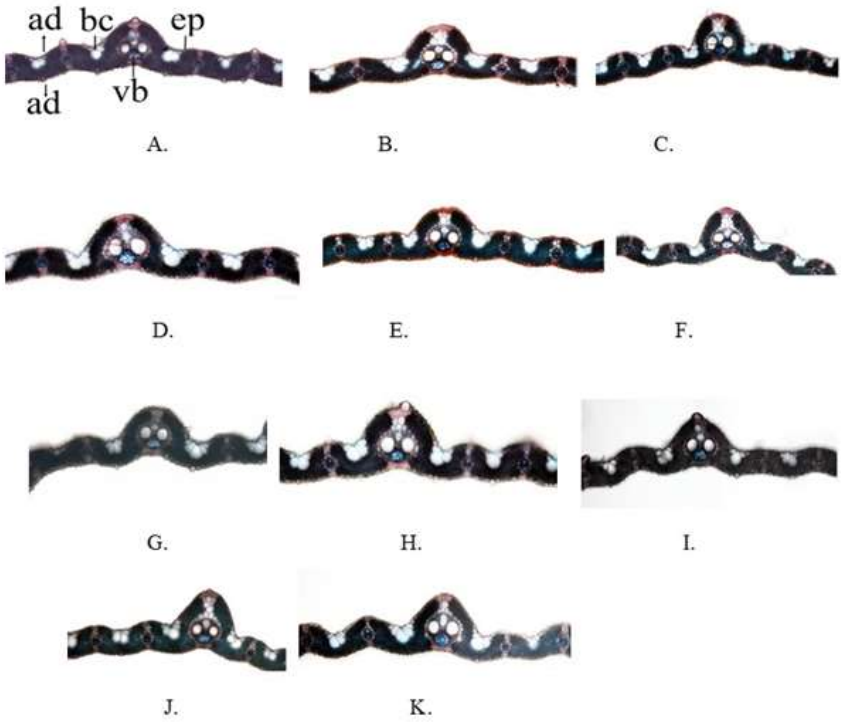

Figure 3. Cross section of the laminas of weedy rice and cultivated rice. (A)Mi-SH-OP-AL, (B)Miv-SH-CP-AL, (C) Mii-TH-CP-AD, (D) Mi-TH-CP-AL, (E) Mii-TH-CP-AL, (F) Miii-TH-CP-AL, (G) Miv-TH-CP-AL, (H) Mii-TH-OP-AL, (I) Miv-TH-OP-AL, (J) MR220CL2, and (K) R219

Table 2. Epidermis thickness of stem (outer layer), midrib, vein, lamina of weedy rice, and cultivated rice

Weedy rice / cultivated rice varieties	Epidermis thickness (µm)						
	Stem's outer layer	Midrib		Vein		Lamina	
		Adaxial	Abaxial	Adaxial	Abaxial	Adaxial	Abaxial
Mi-SH-OP-AL	12.50^{d}	6.90^{cd}	6.90d^{ef}	5.71^{a}	7.14^{a}	9.04^{a}	5.24^{b}
Miv-SH-CP-AL	26.21^{b}	8.70^{ab}	8.70^{bc}	2.04^{e}	2.04^{c}	2.04^{fg}	2.04^{e}
Mii-TH-CP-AD	14.47^{cd}	6.67^{cd}	6.67^{ef}	2.17^{e}	2.17^{c}	2.17^{fg}	2.17^{de}
Mi-TH-CP-AL	24.49^{b}	4.00^{e}	4.00^{h}	1.67^{e}	1.67^{c}	1.67^{g}	1.67^{e}
Mii-TH-CP-AL	24.24^{b}	8.00^{abc}	8.00^{bcd}	2.13^{e}	2.13^{c}	2.13^{fg}	2.13^{de}
Miii-TH-CP-AL	56.55^{a}	6.67 ^{cd}	6.67^{ef}	5.42^{ab}	2.08^{c}	4.17^{c}	4.17^{c}
Miv-TH-CP-AL	22.62^{cb}	7.41^{bcd}	7.41^{cde}	4.00^{cd}	4.00^{b}	2.80^{ef}	2.80^{d}
Mii-TH-OP-AL	9.26^{d}	6.15^{d}	5.13^{gh}	1.67^{e}	1.67^{c}	1.67^{g}	1.67^{e}
Miv-TH-OP-AL	10.00^{d}	3.03^{e}	6.06^{fg}	4.00^{cd}	2.00^{c}	4.00^{cd}	2.00^{e}
MR220CL2	15.38^{cd}	9.23^{a}	9.62^{b}	4.70^{bc}	6.27^{a}	3.14^{de}	7.06^{a}
MR219	13.33^{d}	8.00^{abc}	16.00^{a}	3.75^{d}	4.17^{b}	6.25^{b}	4.17^{c}
$LSD_{0.05}$	8.44	1.59	1.32	0.86	1.05	0.97	0.72

Means within a column followed by the same letter are not significantly different (LSD, $p < 0.05$)

Table 3. Number of bulliform cell groups, vascular bundles and aerenchyma cells of weedy rice, and cultivated rice

Weedy rice / cultivated rice varieties	Bulliform Cell group	Number of Vascular Bundle		Aerenchyma Cell	
	Lamina	Lamina	Midrib	Midrib	Stem (Outer Layer)
Mi-SH-OP-AL	40	43	14	4	41
Miv-SH-CP-AL	31	51	13	6	37
Mii-TH-CP-AD	32	44	18	6	40
Mi-TH-CP-AL	56	58	10	2	29
Mii-TH-CP-AL	37	32	15	7	42
Miii-TH-CP-AL	43	59	17	6	41
Miv-TH-CP-AL	40	43	15	4	40
Mii-TH-OP-AL	38	49	10	4	44
Miv-TH-OP-AL	58	37	14	5	42
MR220CL2	45	49	16	6	29
MR219	47	49	22	6	31

Table 3 indicates the number of bulliform cell groups, vascular bundle, and aerenchyma cells in the leaf blade and stem's outer layer of weedy rice and cultivated rice. The numbers of bulliform cell groups of both weedy rice and cultivated rice varied from 31 to 58 and 45 to 47, respectively (Figures 1, 2, and 3). The data indicated that the bulliform cell group number in weedy rice did not differ from that in cultivated rice. Similar results were also noted for the vascular and aerenchyma cells. The number of vascular bundles and aerenchyma cells in weedy rice was identical to that of cultivated rice. The diversity of weedy rice may cause anatomical variation. The results of this study cannot be compared to other reports because there is a lack of anatomical data on weedy rice. To the best of the authors' knowledge, there has never been a report on the cross-section anatomy of a weedy rice leaf or stem. The most pertinent research was conducted by Abd Hamid *et al*. (2007). They used a scanning electron microscope to investigate the seed and leaf surfaces of 10 varieties of weedy rice in Malaysia. They discovered that these varieties possessed the same characteristics as the cultivated rice MR219 variety [6]. Another relevant work was an electron microscopy (SEM) study on the surfaces of seeds and coleoptiles of weedy rice and cultivated rice done by Hoagland and Paul (1978) [11]. However, previous works did not study the cross-section anatomy of weedy rice. Current study shows that some weedy rice and cultivated rice varieties have anatomical similarities. The anatomical data did not have a clear relationship with the height of weedy rice. In other words, weedy rice of various heights exhibited the same anatomical characteristics. The similarities could be explained by the fact that weedy rice may have evolved from cultivated rice.

Many studies found that weedy rice developed from cultivated rice varieties, e.g., Zhiwen *et al*. (2016) reported that Chinese weedy rice evolved from Chinese rice varieties [15]. The DNA analysis by Abdullah *et al*. (1994) indicated that Malaysian weedy rice could have originated from cultivated rice [16]. It will be more challenging to distinguish between the anatomical characteristics of weedy rice and cultivated rice due to the diverse anatomical features of weedy rice varieties. There is a need for additional research on physiology and ecology to compare weedy rice and cultivated rice to learn more about the biology of weedy rice. In this study, the anatomical information of weedy rice could not contribute much to weedy rice identification. However, this anatomical data could be fundamental information for further research, especially Malaysian weedy rice.

Identify the suitable morphological characteristics for weedy rice identification

Table 4 presents the plant height of weedy rice compared to cultivated rice. Most weedy rice was taller than cultivated rice since the vegetative stage. Among the study sites, only Ladang Merdeka Mulong noticed that 100% of the weedy rice was higher than cultivated rice in the planting season. Weedy rice's height varied even in the same location with the same cultivated rice variety.

For example, in Gong Guchil Site 1 and 2, the paddy fields were planted in the same variety, but the percentage of weedy rice height (either taller than cultivated rice or as tall as cultivated rice) compared to cultivated rice during the planting season differed. Weedy rice also demonstrated different heights in the same location, where was planted different rice varieties. For example, in Sg Limau, Kedah, the weedy rice height in paddy fields planted with UKMRC variety differed from that planted with MR219.

Table 4. Height of weedy rice compared to cultivated rice and leaf and stem color index of weedy rice and cultivated rice at vegetative, flowering and ripening stages

DAS (Days after sowing)	Average paddy plant height (cm)	Height of weedy rice compared to cultivated rice		Leaf and stem color index: Leaf Color Chart (IRRI)	
		Taller than paddy	Same as paddy	Cultivated rice	Weedy rice
Sg Limau Dalam, Kedah (Variety: UKMRC8)					
41	77.0 ± 8.3	83.30%	16.70%	3	2
55	89.1 ± 4.6	83.30%	16.70%	3	2
84	99.2 ± 9.2	100.00%	0%	3	2
Sg Limau Dalam, Kedah (Variety: MR219)					
50	67.8 ± 5.2	100.00%	0%	3	2
71	86.6 ± 2.4	61.50%	38.50%	3	2
100	107.8 ± 4.5	60.00%	40.00%	3	2
Tanjung Radin, Pendang, Kedah (Variety: MR297)					
39	52.7 ± 5.2	69.20%	30.80%	3	2
79	87.2 ± 4.4	100.00%	0%	3	2
96	105.4 ± 3.9	100.00%	0%	3	2
Kg Alor Sekawan, Kedah (Variety: MRQ76)					
29	60.5 ± 5.5	66.70%	33.30%	3	2
61	95.3 ± 4.2	100.00%	0%	3	2
93	114.5 ± 10.6	70.00%	30.00%	3	2
Ladang Merdeka Mulong, Kelantan (Variety: MR297)					
47	64.6 ± 2.2	100.00%	0%	3	2
75	94.5 ± 9.0	100.00%	0%	3	2
108	99.2 ± 2.4	100.00%	0%	3	2
Padang Bongor, Kelantan (Variety: MR297)					
32	48.0 ± 2.9	50.00%	50.00%	3	2
62	87.6 ± 1.8	100.00%	0%	3	2
97	103.0 ± 7.6	100.00%	0%	3	2
Gong Guchil (Site 1), Terengganu (Variety: MR269)					
36	29.2 ± 5.2	33.30%	66.70%	3	2
64	76.0 ± 3.3	83.30%	16.70%	3	2
99	103.4 ± 6.1	75.00%	25.00%	3	2
Gong Guchil (Site 2), Terengganu (Variety: MR269)					
36	43.3 ± 4.3	41.70%	58.30%	3	2
64	86.4 ± 1.7	100.00%	0%	3	2
99	116.4 ± 4.6	100.00%	0%	3	2
Pematang Tok Brain, Penaga, Pulau Pinang (Variety: MR297)					
29	61.5 ± 2.1	100.00%	0%	3	2
72	114.3 ± 5.7	91.70%	8.30%	3	2
92	115.4 ± 5.3	87.50%	12.50%	3	2
Pematang Sintok, Penaga, Pulau Pinang (Variety: MR297)					
30	60.8 ± 6.4	46.20%	53.80%	3	2
75	89.1 ± 5.9	100.00%	0%	3	2
90	104.6 ± 2.8	100.00%	0%	3	2

Several studies reported that some morphological characteristics of weedy rice, e.g., plant height, were markedly different from cultivated rice [17]. However, this project data found that only some, but not all, weedy rice grew taller than cultivated rice. A study done by Ahmed *et al.* (2012) on vegetative and reproductive growth of weedy rice in Selangor, Malaysia reported that wide range of weedy rice plant height recorded [8]. The height of weedy rice may be determined by abiotic factors such as soil nutrients, water level in paddy fields, farm management approach, and so on. According to Yusoff *et al.* (2019), the growth of weedy rice was affected by environmental factors. They reported that temperature and flooding depth affect the vegetative growth of weedy rice. Environmental factors may significantly determine the height of the weedy rice rather than the genetic factor [18].

Table 5. Leaf inclination angle (°) of weedy rice and cultivated rice at vegetative, flowering and ripening stages

DAS (Days after sowing)	Leaf inclination angle (°)							
	Cultivated rice				Weedy rice			
	0°	45°	90°	135°	0°	45°	90°	135°
Sg Limau Dalam, Kedah (Variety: UKMRC8)								
41	100.0%				100.0%			
55	100.0%				100.0%			
84	20.0%	80.0%			10.0%	50.0%	30.0%	10.0%
Sg Limau Dalam, Kedah (Variety: MR219)								
50	100.0%				100.0%			
71	100.0%				100.0%			
100	100.0%				0	50.0%	50.0%	
Kg Alor Sekawan, Kedah (Variety: MRQ76)								
29	100.0%				100.0%			
61	100.0%				100.0%			
93	100.0%				30.0%	30.0%	40.0%	
Tanjung Radin, Pendang, Kedah (Variety: MR297)								
39	100.0%				100.0%			
79	100.0%				0	66.7%	33.3%	
96	60.0%	40.0%			0	54.5%	27.3%	18.2%
Pematang Tok Brain, Penaga, Pulau Pinang (Variety: MR297)								
29	100.0%				100.0%			
72	100.0%				36.4%	36.4%	18.2%	
92	100.0%				37.5%	25.0%	37.5%	
Pematang Sintok, Penaga, Pulau Pinang (Variety: MR297)								
30	100.0%				100.0%			
75	100.0%				45.5%	27.2%	27.3%	
90	50.0%	50.0%			11.1%	66.7%	22.2%	
Ladang Merdeka Mulong, Kelantan (Variety: MR297)								
47	100.0%				100.0%			
75	100.0%				57.1%	42.9%		
108	100.0%				44.4%	33.3%	22.3%	
Padang Bongor, Kelantan (Variety: MR297)								
32	100.0%				100.0%			
62	100.0%				100.0%			
97	60.0%	40.0%			40.0%	30.0%	30.0%	
Gong Guchil (Site 1), Terengganu (Variety: MR269)								
36	100.0%				100.0%			
64	100.0%				100.0%			
99	60.0%	40.0%			16.7%	66.6%	16.7%	
Gong Guchil (Site 2), Terengganu (Variety: MR269)								
36	100.0%				100.0%			
64	100.0%				100.0%			
99	100.0%				40.0%	60.0%		

Data from Permatang Tok Brain and Permatang Sintok, which both planted the same variety, proved that the height difference between weedy rice and cultivated rice depended on the abiotic factor in a paddy field. In most studies site, most of the weedy rice was same height as cultivated rice at the vegetative stage (less than 50 days after planting).

At the ripening stage, the height of some weedy rice was equal to that of cultivated rice. Since some of the weedy rice was as tall as cultivated rice and others were taller than cultivated rice, the height of weedy rice was not a reliable characteristic for weedy rice identification in fields. However, if taller than cultivated rice, the height of weedy rice could be a supporting characteristic for confirming weedy rice identification. The weedy rice of the same height as cultivated rice will be more difficult to be traced.

The result found that the stem and leaf of weedy rice were consistently yellow-green (light green) at all locations and stages of plant life. While the cultivated rice, regardless of varieties or location, was green during the planting season (Table 4). Perhaps Wahab and Suhaimi (1991) initially reported that some Malaysian weedy rice varieties posed a light green color of their leaves, but they did not clearly explain the leaf color at seedling or mature stages [1]. A survey by Watanabe (1995) reported that farmers in Tanjung Karang, Selangor, Malaysia, identified weedy rice early by detecting the light green color leaf, but there was no detailed information on the weedy rice leaf color at every stage of plant life [19]. The project data showed that weedy rice leaves and stems were yellow-green in whole growth stages. This finding is contrary to other works. For example, Wahab and Suhaimi (1991) reported that not every weedy rice leaves were light green; some were green cultivated rice in Projek Barat Laut Selangor, Malaysia [1]. The different findings may be due to the timing of data recording, as our experience or the data reported by other research that weedy rice was very responsive to fertilizer. Fertilizers applied to the field may be rapidly absorbed by weedy rice, causing the leaves to turn green. Among the morphological characteristics recorded, the color of the leaves and stems of all weedy rice, regardless of location or varieties, has demonstrated a very consistent result, viz its color was yellow-green at all stages of plant life. In contrast, cultivated rice's leaves and stems were always green. The yellow-green color of the weedy rice stem and leaf could be a helpful indicator and practical guideline for detecting weedy rice in the field.

The study found that at 70 days after sowing, weedy rice flag leaves started to incline (Table 5). Some cultivated rice also started to incline approximately 84 days after sowing, but the inclination degree was less than weedy rice. The inclination degree of the weedy rice flag increased along the planting period, and some achieved 135^{o} at ripening. The weedy rice flag leaf demonstrated different inclination degrees even in the same location and planted the same variety, e.g., the inclination degree of the weedy rice flag leaf in Gong Guchil Site 1 and Site 2 differed. Flag leaves of weedy rice from the same location that planted different varieties also demonstrated different inclination degrees, e.g., at Sg Limau, planted with UKMRC and MR219. Data showed that the inclination degree of the weedy rice flag leaf was inconsistent and varied.

The study found that the percentage of weedy rice flag leaf inclination in paddy fields was inconsistent, and some flag leaves of cultivated rice were also inclined at the flowering or ripening stage. Only some, but not all, weedy rice flag leaves started inclining at the flowering stage. There was no publication on the percentage of weedy rice flag leaf inclination in paddy fields. However, several studies have reported that flag leaves of weedy rice could be categorized as erect, horizontal, or descending [1,9]. According to work done by Wahab and Suhaimi (1991), they recorded that all the weedy rice inclined, horizontal, or descending at mature stages [1]. This study's findings differed from the data report by Wahad and Suhaimi (1991). The present project data revealed that a few flag leaves of weedy rice were erect even in the ripening stage. The inclination degree of the weedy rice flag leaf is not a reliable characteristic for detecting weedy rice in the field, especially at an early stage of plant life where all the flag leaves of weedy rice were erect.

Conclusions

The study revealed that weedy rice varieties displayed inconsistent anatomical characteristics. This finding indicated that anatomical characteristics not a reliable characteristic for

weedy identification. The diversity of weedy rice may cause the variation in weedy rice anatomical characteristics. Regardless of location or growth stage, the leaf and stem of weedy rice were always yellow-green. The consistent color of weedy rice leaf and stem can be a practical weedy rice identification guideline that will help farmers or seed producers identify weedy rice quickly. Once the weedy rice is detected in the field, an appropriate approach can be used to control the weedy rice effectively.

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Conflicts of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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