

LIFE CYCLE AND MORPHOLOGICAL CHARACTERISTICS OF WEEDY RICE (*ORYZA SATIVA* COMPLEX, LOCALLY CALLED PADI ANGIN), A NOXIOUS WEED OF RICEFIELDS IN MALAYSIA

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Abstrak: Kajian telah dijalankan di rumah tumbuhan dan makmal di Pusat Pengajian Sains Kajihayat, Universiti Sains Malaysia (USM), Pulau Pinang terhadap percambahan biji benih, pembentukan biji benih dan corak pertumbuhan *Oryza Sativa* complex (padi angin). Padi angin merupakan salah satu rumpai yang bermasalah dalam penanaman padi tabur terus di Malaysia. Terdapat sepuluh varian padi angin berdasarkan ciri-ciri morfologi, iaitu jenis tangkai terbuka, tangkai tertutup dan jenis yang mempunyai jejanggut. Perbandingan melalui mikroskop elektron pengimbas (SEM) tidak menunjukkan perbezaan anatomi antara varian padi angin terhadap biji dan permukaan daun. Walau bagaimanapun, struktur rerambut jelas kelihatan pada jenis jejanggut berbanding varian yang lain dan *Oryza Sativa* (padi biasa). Padi biasa dan semua varian mempunyai stoma di kedua-dua belah permukaan daun, adaksial dan abaksial. Namun, kepadatan *epicuticular waxes* banyak terdapat di bahagian adaksial permukaan daun berbanding bahagian abaksial. Padi angin menghasilkan biji yang banyak, iaitu 220–220 biji per tangkai bagi jenis jejanggut, 190–210 biji bagi tangkai terbuka dan 210–230 biji bagi tangkai tertutup. Semua varian melengkapkan kitar hidup dalam masa 85–95 hari selepas bercambah.

Abstract: Studies were conducted at the plant house and the laboratory at the School of Biological Sciences, Universiti Sains Malaysia (USM), Pulau Pinang to evaluate seed germination, seedlings establishment and growth patterns *Oryza Sativa* of (weedy rice). Weedy rice is rated as one of the most troublesome weeds in direct seeded fields in Malaysia. Evidently, there are 10 variants of weedy rice based on morphological characteristics. Morphological structures of weedy rice namely open panicle type, compact panicle type, and awn type were examined. The comparison using scanning electron microscope (SEM) did not show anatomical differences between weedy rice variants for both seed and leaf surfaces. However, the hair or trichomes structures are clearly shown in awn type compared with other variants and *Oryza Sativa* (cultivated rice). Cultivated rice and all variants have stomata on both adaxial and abaxial leaf surface. However, more dense deposits of epicuticular waxes were found on the adaxial surface of a leaf compared with the abaxial surface. The result of growth pattern showed that the variants of weedy rice produce an abundance seeds, as high as 200–220 numbers of spikelets per panicle for awn type, 190–210 spikelets for open panicle type and 210–230 spikelets for compact panicle type. All variants complete their life cycles within 85–95 days after emergence.

Keywords: Weedy Rice, Awned and Non-Pigmented Type, Compact Panicle, Open Panicle, Scanning Electron Microscope (SEM), Life Cycle

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INTRODUCTION

Weedy rice (*Oryza sativa* complex) is an annual grass which is relatively similar with cultivated rice (*Oryza sativa*). Therefore, it also has the same pattern of growth such as vegetative phase (from seed germination to panicle), reproductive phase (from panicle initiation to anthesis) and ripening phase (from anthesis to full maturity). The life cycle of the plant considered to be completed when the components of the life cycle such as timing of germination, seedling, adult survival, age of flowering and seed numbers are determined during the life span of the plant (Sabrig 1980; Silvertown & Doust 1993; Silvertown & Charlesworth 2001). Besides, Radoservich and Holt (1984) noted that the life cycle is the fundamental descriptive unit of an organism, and in an individual plant. This is the result of a series of processes that begin at fertilization and continue through embryonic growth, seed germination, seedling establishment, development into adulthood, and finally senescence and death. However, a number of life form and timing of stages of development have been observed for *Echinochloa crus-galli* (Azmi 1994; Itoh 1991), *Ischaemum rugosum* (Nabi & Baki 1995; Baki & Nabi 2003), and *Leptochloa chinensis* (Pane 1997), but life cycle for the weedy rice has not been reported. Therefore, this is one of the reasons this study was initiated.

Morphological and topographical characteristics of plant organs such as the shape and size of seeds and the structure of incidental features have been useful weapons in identifying and classifying the plant and weed species (Noda et al. 1985). Therefore, understanding reproductive biology is important for constructing models for weed life cycles which are used for developing control strategies. This information is needed to determine the relative importance of seedling and vegetative reproduction, as well as to predict the temporal factors when various control strategies are employed. This will give some ideas of how to obtain more effective and efficient control of weedy rice. Knowledge on germination behaviour of seeds, propagules and other aspects of weed biology can help to gain insight into the mechanism of specialization and distribution of the species. Such studies will offer an opportunity to locate vulnerable points in the life histories of weeds when they can be successfully attacked for their control (Silvertown 1987; Gibson 2002). The purpose of this study was to obtain additional information on morphological characteristics of different types of weedy rice and to increase understanding of the growth patterns of weedy rice (the variant of weedy rice). Knowledge of the reproductive biology of weedy rice is an important criterion for constructing models for weedy rice life cycle in order to enhance the success of developing effective control strategies, particularly in the agroecosystem of direct seeded rice culture.

MATERIALS AND METHODS

The growth development of weedy rice's variants was conducted at the plant house of the School of Biological Sciences, USM, Pulau Pinang, from February 2005 to June 2005. Environmental data were recorded at the plant house during study period for light intensity (LX-101 Lux meter), air temperature and relative

humidity (Higro-Thermometer). In the morning and afternoon, mean temperature ranged from 27°C to 30°C, mean relative humidity ranged from 73% to 87%, and light intensities ranged from 55,400 to 58,100 lux; whereby during midnight, the temperature and relative humidity remained the same as aforementioned, but light intensities ranged from 1 to 2 lux.

Seeds from mature plants (at shattering stage) of weedy rice variants which are named: (1) open panicle, non-pigmented, (2) compact panicle, pigmented, and (3) awned, close panicle, non-pigmented were collected from Guar Chempedak, Yan, Kedah. In the laboratory, the seeds of weedy rice were soaked in water for 24 hours before seeding and subsequently were subjected to air dried for 48 hours in order to produce pre-germinated seeds. Five pre-germinated seeds were sown in 5 kg soils in a plastic bucket (24 cm diameter and 23 cm height). The soil was collected from Guar Chempedak ricefield which was clay (65% clay, 30% silt and 5% sand) of Guar Chempedak Soil Series with pH 4.75 which was free from weedy rice seeds (first season 2004 of seed bank study). The soil contained 0.26% N, 0.14% P, 582.34 ppm K and 1.74% organic matter. One week after sowing, the seedlings were thinned leaving one seedling/plastic bucket. The treatments were arranged in a randomized complete block design (RCBD) with five replicates and the positions of the plastic buckets were changed every week to minimize edge effects. The experimented weedy rice seedlings were applied with basal fertilizations of 0.3 g urea (135 kg N ha⁻¹), 0.3 g triple super phosphate (TSP; 45 kg P₂O₅ ha⁻¹) and 0.3 g muriate of potash (MOP; 60 kg K₂O ha⁻¹) in order to enhance the plant growth (Ramasamy *et al.* 1997). Individual plants in the plastic buckets were kept flooded at about 5 cm of water depth daily. Furadan, at the rate of 20 kg ha⁻¹, was applied when required to control and protect plants from pests.

Growth and development of weedy rice plants were closely observed and monitored from seedling stage to maturity. Time to seedling emergence, tillering, flowering and seed maturity were recorded for each plant. Plant height was measured weekly based on the length from the soil surface to the apex of the leaf. Growth parameters such as number of tillers, number of leaves, number of seed/plants, internode length, leaf length, leaf width, main culm diameter, culm height (length), tiller diameter, panicle length, number of spike/inflorescence, number of spikelets/inflorescence, number of spikelets/panicle, number of fully filled grains/inflorescence, and ligule length were measured. Each of the growth parameter was recorded at 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 days after seeding (DAS).

Consequently, a linear regression of number of tiller production against time (t) could be shown the rate number of tiller increase per unit time. Therefore, the equation was calculated as follows:

$$\text{Increase in number of tiller} = \frac{[dT/dt]}{T}$$

Where dT/dt = the slope of number of tiller against time curve

T = total number of tiller

t = time (days of seeding)

Seed and leaves samples of three variants were thoroughly studied by using scanning electron microscope (SEM) (JSM-T20). The leaf samples were cut into small pieces 5 × 5 mm from the area between midvein and leaf edge. The added samples were fixed with 2% glutaraldehyde and subsequently followed by 2% osmium tetroxide. Both solutions were placed in 0.1 M phosphate buffer (pH 7.2). After that the samples were dehydrated through alcohol series (50%–100% ethanol) to achieve a critical drying point. Then the samples were coated with gold-palladium alloy and examined under SEM (Galuert 1975; Hayat 1989).

RESULTS

Morphological and Topographical Characteristics of Weedy Rice

The observations showed that no significant differences existed concerning various morphological features between variants of weedy rice (awn, open panicle and close panicle) used in this study. All variants of weedy rice and cultivated rice (MR219) had similar seed and leaves characteristics (Plate 1–Plate 7). These plates give a view of the overall seed and leaf surface at different magnification. The awn panicle seed averaged 10.0 mm in length, slightly larger than close panicle and open panicle with 9.0 mm each. The width of awn type grain also showed slight difference in average width compared to compact and open panicles with 2.85 mm, 2.80 mm and 2.70 mm, respectively. Seen under the SEM, the topographies of leaf surface in all variants and cultivated rice showed almost similar characteristics. Generally, observations on the studied species have stomata on both adaxial and abaxial leaf surface. However, more dense deposits of epicuticular waxes usually were found on the adaxial surface of a leaf compared with the abaxial surface. Based on the photograph, the size of stomata did show a distinct difference among all the variants of weedy rice and cultivated rice. The lengths of stomata produce from cultivated rice, open panicle, compact panicle and awned were 12.07 µm, 15.48 µm, 13.26 µm and 15.79 µm and the widths were 783.6 nm, 794.9 nm, 894.9 nm and 819 nm, respectively (Plate 7).

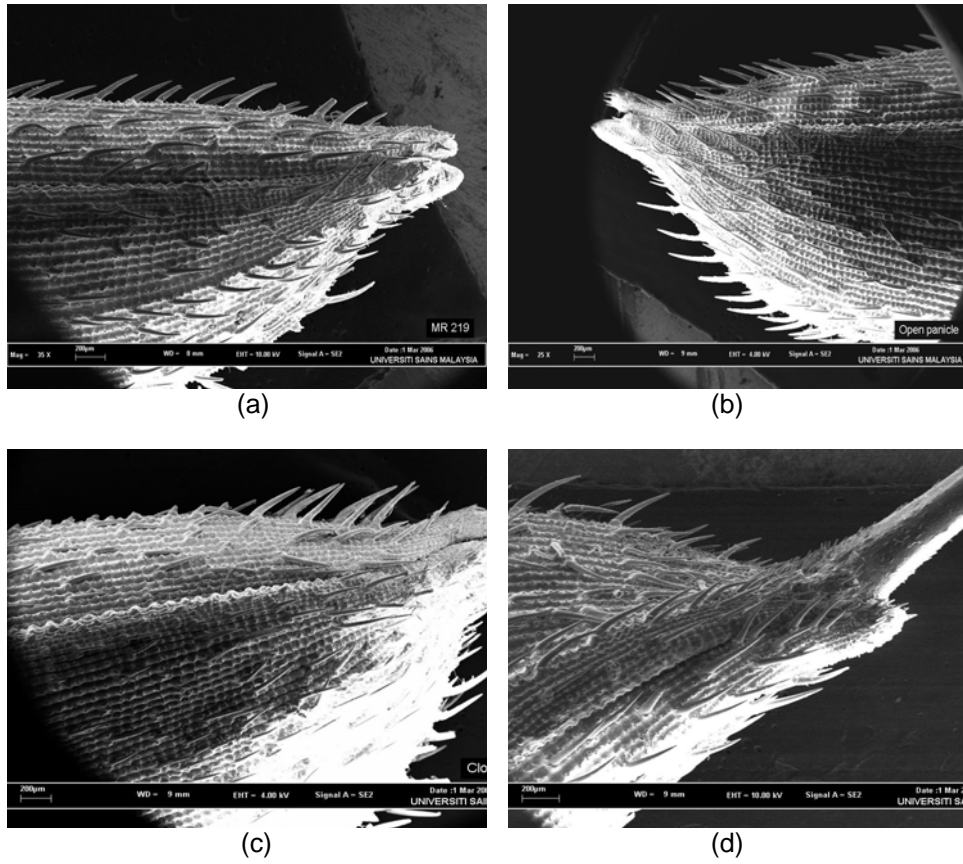


Plate 1: Scanning electron micrographs of weedy rice show morphological differences of seed surface with microhairs. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 200 μ m

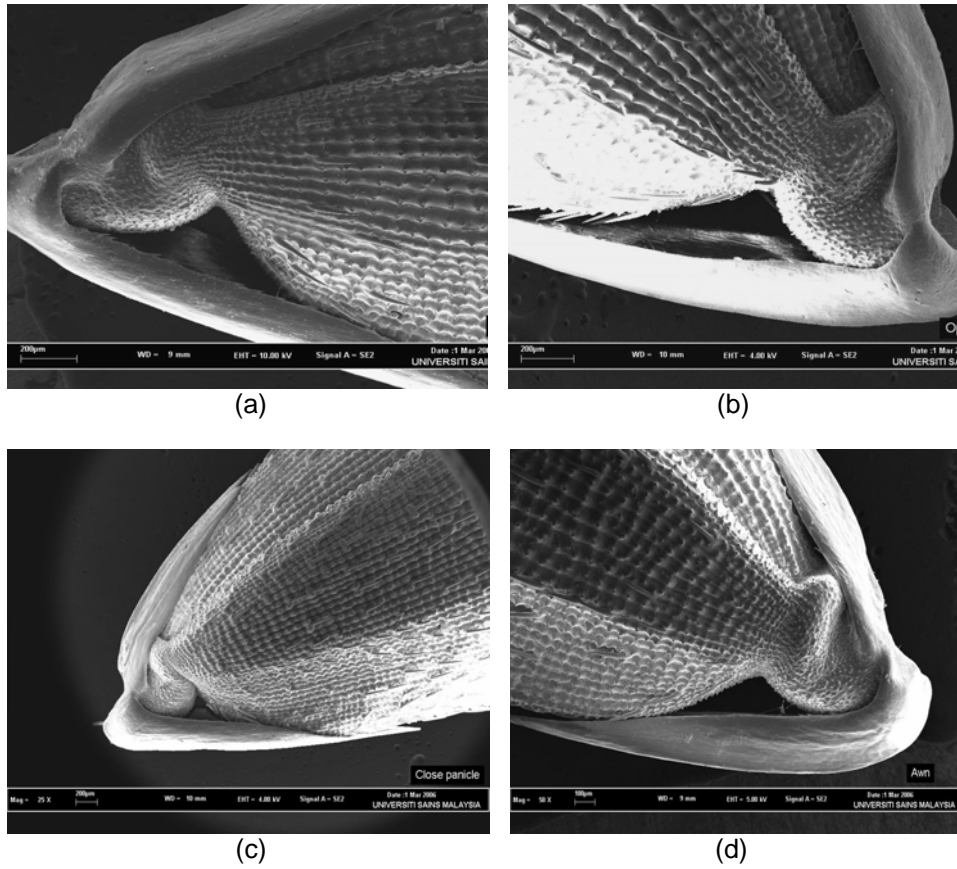


Plate 2: Scanning electron micrographs show morphological differences of weedy rice seed glume. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 100 μ m

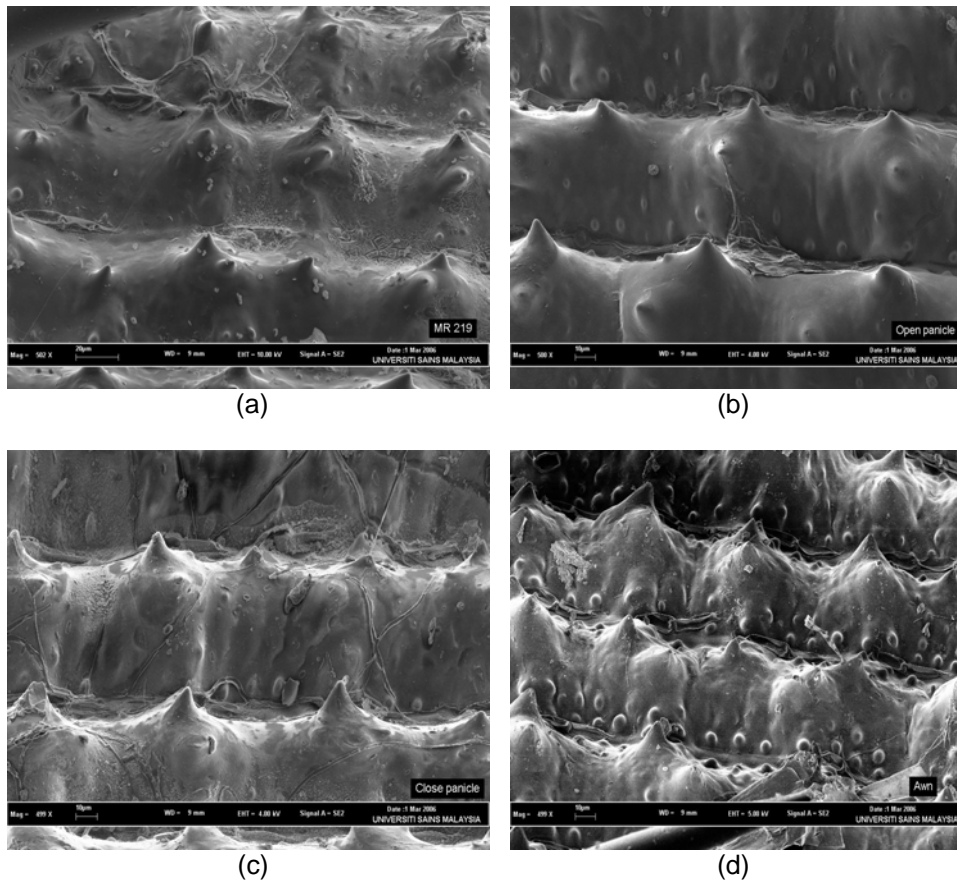


Plate 3: Morphological differences of seed surface with gemmate papillae regularly arranged. Close-up of parallel rows of tubercles/trichomes. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 10 μm except (a) = 20 μm

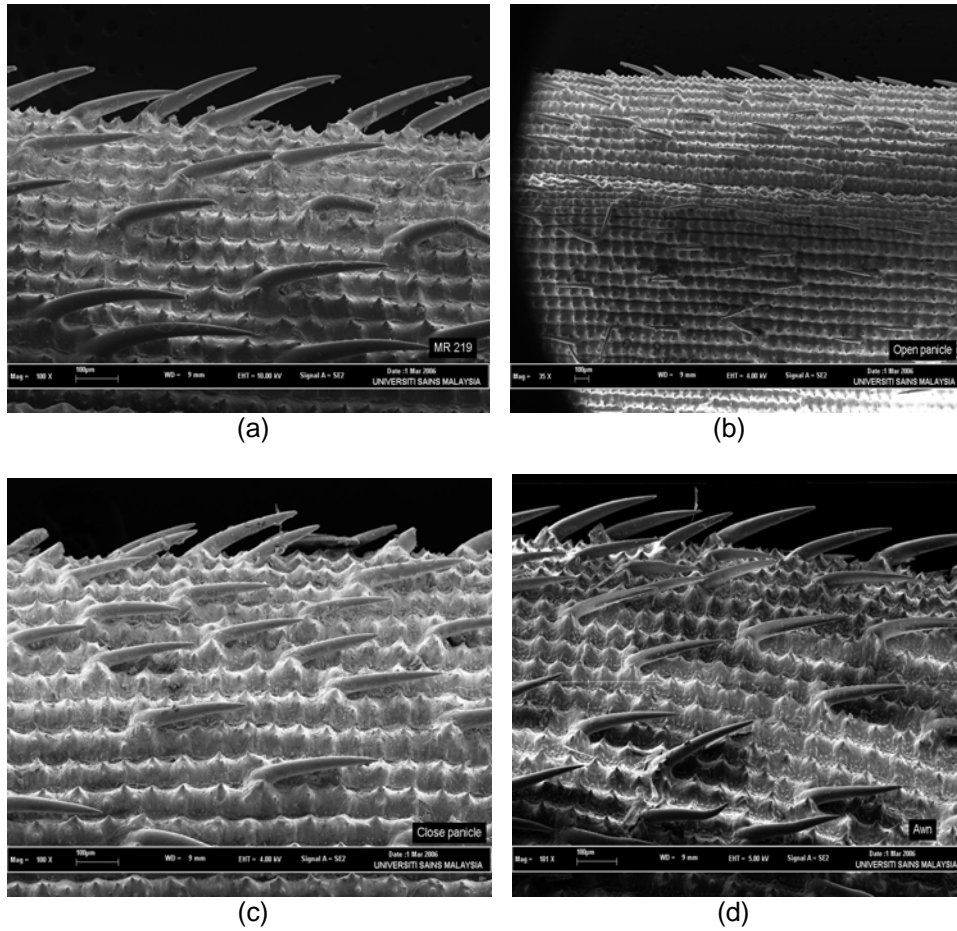


Plate 4: Morphological differences of seed tip gemmate papillae regularly arranged. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 100 µm

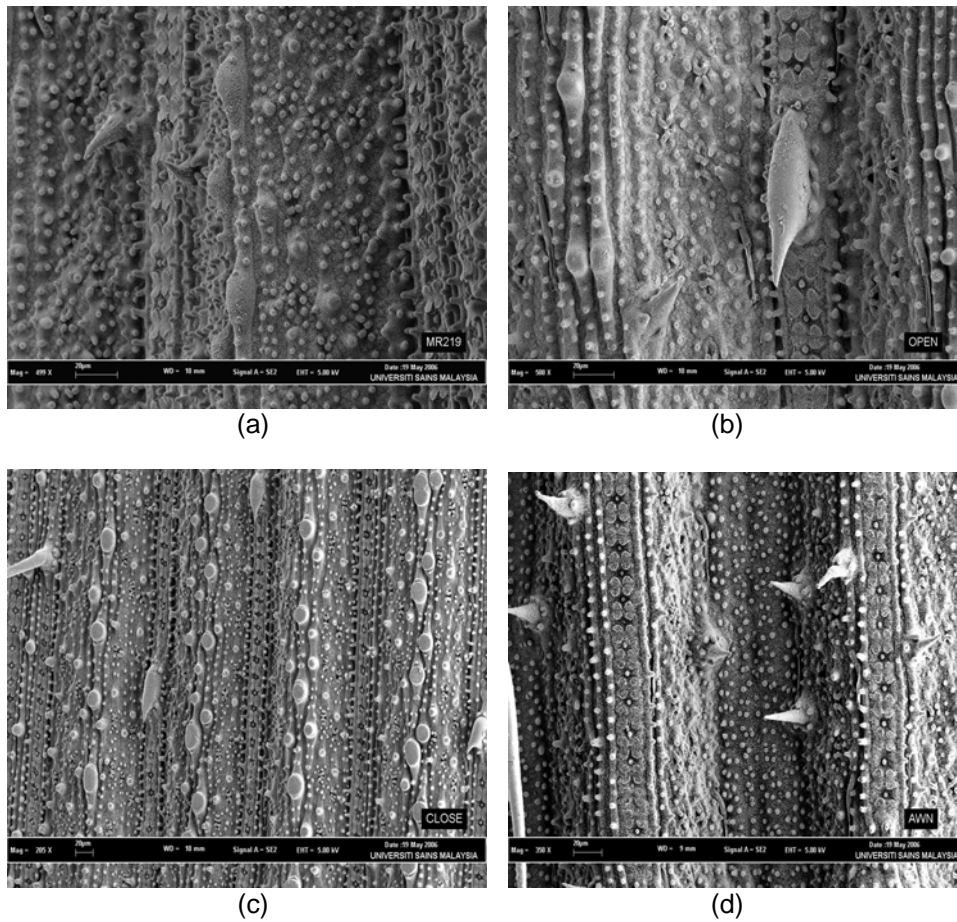


Plate 5: Morphological differences of adaxial leaf surface views of weedy rice, with epicuticular cell layers covered with waxes, microhairs/spines located shatteringly and the rows of silica knobs can be distinctly seen. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 20 µm

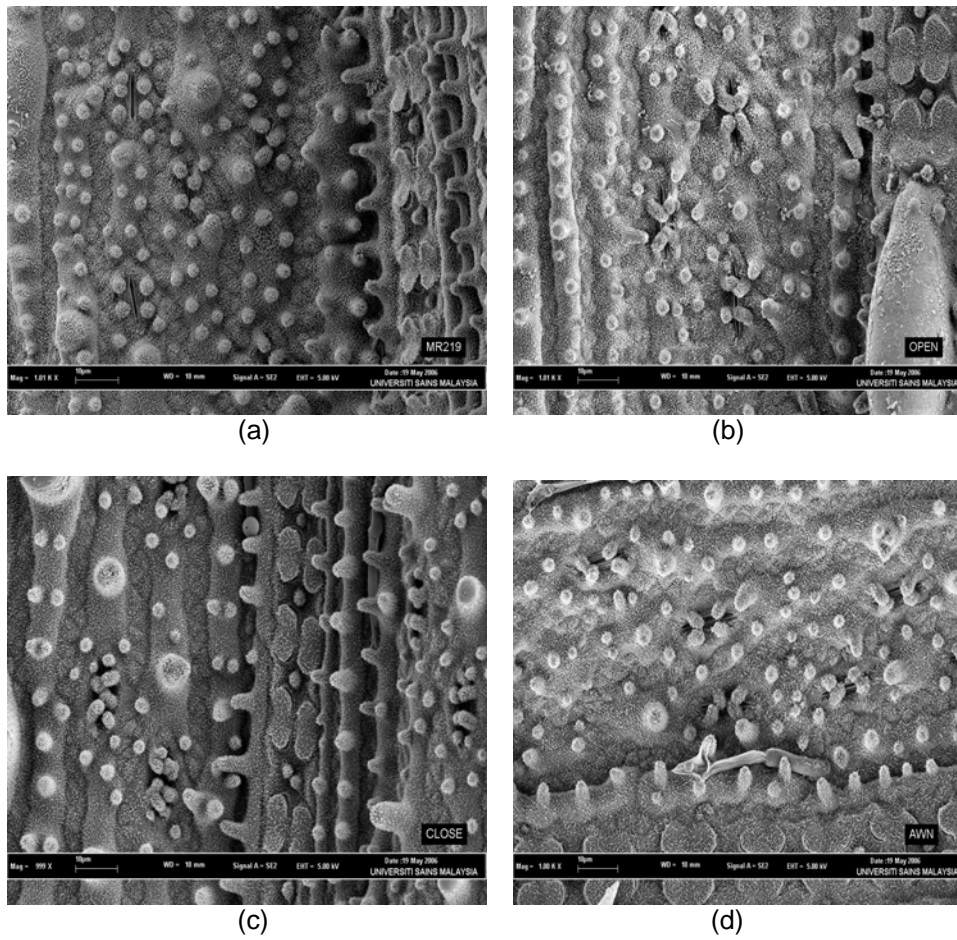


Plate 6: Morphological differences of weedy rice abaxial coleoptile surface sizes with the parallel rows of various of papillae stomata and microhairs, and generally covered with wax. (a) Cultivated rice (MR219) (b) Open panicle (c) Compact panicle (d) Awn. Bar = 10 μ m

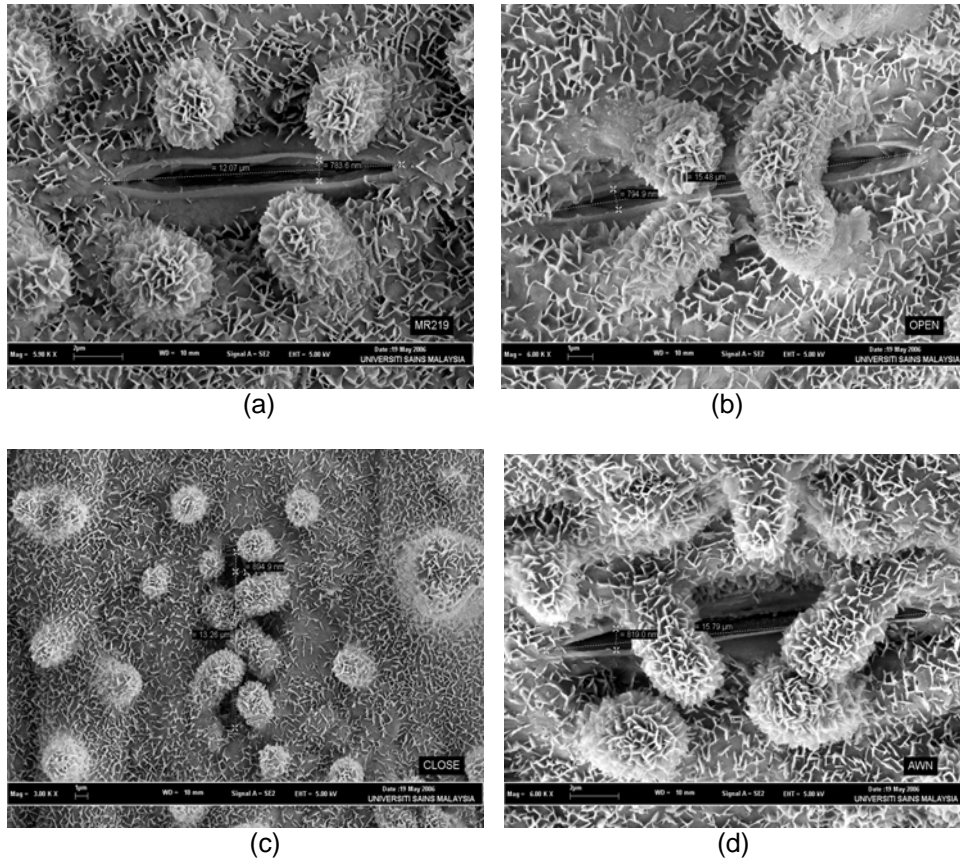


Plate 7: Morphological differences of weedy rice stomata on abaxial surface covered with the dense wax deposits and with many silica knobs excluded the surface of guard cells. Four knobs except (c) located at the four corners of peristomatal rims. (a) Cultivated rice (MR219), (b) Open panicle (c) Compact panicle (d) Awn. Bar = 1 μm (b and c), 2 μm (a and d)

Growth Pattern of Weedy Rice

Observation shows that the stem of all variants are erect and slender or stout as well as tall. It is glabrous and has a well-developed membranous ligule. The leaves are composed of blades, leaf sheath, ligule, and auricle. The long membranous ligule that is triangular in outline. Some hairs occur in the collar regions. The presence of auricles and tall membranous ligule are characteristics that help in the identification of weedy rice. The leaves are flat with parallel veins. The inflorescence is an erect panicle and it is composed of spikelets. Spikelet may or may not have awns.

All variants of weedy rice slightly differ in time to maturity, height, tillering habit and size of panicles and seeds. The first two or three leaves were produced based on the plant heights and root length. Weedy rice showed relatively similar growth pattern, particularly from 10 DAS to 30 DAS. The plants grew slowly

especially in terms of root lengths and elongation of shoots. The major growth characteristics of weedy rice recorded are listed in Table 1. The studied species did not differ in number of tillers produced and in mean size of tiller produced by individual. However, the tiller size was more variable in individuals of compact panicle type than in awn and open panicle types (20 DAS) and the tillers reached the maximum formation within 100 DAS (Fig. 1). here was a significant correlation between the days of seeding and number of tiller of all variants. When the number of tiller was regressed, the rate of increase due to number of tiller added every 10 DAS has been given by the slope of the number of tiller versus DAS curve with the values of $dT/dt = 0.1817$ for open panicle type; 0.1667 for awn type and 0.1997 for compact panicle type (Fig. 2). The result shows that the rate of tiller production by compact panicle has increased more than others variants. However, in each 10 DAS the rate number of tiller increased obtained was 0.96%, 0.88% and 1.00%, respectively.

Table 1: Comparison of growth pattern of weedy rice sown in plant house condition.

DAS	Growth stages of the plants	Types of variants		
		Awn	Open panicle	Compact panicle
0	Seeding	-	-	-
3-8	Germination	4-8	4-7	3-5
10	2-3 leaves	Plant height (16.9-18.9 cm) 1-2 leaves leaf area (2,226-3,960 mm ²)	Plant height (14.9-16.4 cm) 2-3 leaves leaf area (2,975- 3,726 mm ²)	Plant height (8.9-11.5 cm) 2-3 leaves leaf area (2,366-3,616 mm ²)
20	4-6 leaves Early tillering	Plant height (49.4-53.1 cm) 4 leaves 3-5 tillers with leaf area (2,276 -3,971 mm ²)	Plant height (50.5-59.6 cm) 6-8 leaves 1-2 tillers with leaf area (2,983-3,764 mm ²)	Plant height (57.9-59.4 cm) 5-6 leaves 2-3 tillers with leaf area (2,406-3,670 mm ²)
30	Tillering	Plant height (68.7-72.4 cm) 5 leaves 10-14 tillers with leaf area (2,528-4,160 mm ²)	Plant height (61.6-65.3 cm) 5 leaves 6-8 tillers with leaf area (3,776-3,840 mm ²)	Plant height (65.4-68.6 cm) 5-6 leaves 7-9 tillers with leaf area (2,421-3,685 mm ²)
40	Active tillering	Plant height (88.0-91.6 cm) 12-14 tillers with leaf area (4,002- 4,360 mm ²)	Plant height (78.9-80.9 cm) 8-10 tillers with leaf area (4,480-5,112 mm ²)	Plant height (84.1-86.4 cm) 10-12 tillers with leaf area (5,896-6,020 mm ²)
50		Plant height (99.7-105.9 cm) 12-14 tillers with leaf area (4,728- 4,812 mm ²)	Plant height (99.7-103.6 cm) 12-14 tillers with leaf area (7,180- 7,360 mm ²)	Plant height (99.6-105.4 cm) 12-15 tillers with leaf area (6,590-3,960 mm ²)

(continue on next page)

Table 1 (continued)

DAS	Growth stages of the plants	Types of variants		
		Awn	Open panicle	Compact panicle
60	Heading	Plant height (117.4–141.3 cm) 12–15 tillers with leaf area (10,296–13,215 mm ²)	Plant height (104.0–128.3 cm) 11–14 tillers with leaf area (11,580–12,557 mm ²)	Plant height (117.1–123.5 cm) 14–18 tillers with leaf area (9,097–11,606 mm ²)
70		Plant height (125.9–151.2 cm) 13 tillers with leaf area (11,580–14,850 mm ²) flowering (2 no. of inflorescence)	Plant height (110.5–129.1 cm) 14 tillers with leaf area (10,220–14,960 mm ²)	Plant height (117.3–127.3 cm) 15–18 tillers with leaf area (8,580–10,530 mm ²)
80	Start of senescence	Plant height (129.5–149.0 cm) 14–16 tillers with leaf area (11,570–14,092 mm ²) flowering (2–4 no. of inflorescence)	Plant height (108.8–134.2 cm) 4–16 tillers with leaf area (10,700–12,490 mm ²) flowering (2 no. of inflorescence)	Plant height (125.0–133.1 cm) 16–20 tillers with leaf area (11,030– 12,200 mm ²) flowering (2 no. of inflorescence)
85–95	Maturation	Plant height (144.9–160.0 cm) 14–18 tillers with leaf area (14,700–18,492 mm ²)	Plant height (136.8–143.7 cm) 14–18 tillers With leaf area (12,440–14,580 mm ²)	Plant height (137.9–150.0 cm) 18–20 tillers with leaf area (12,070–13,092 mm ²)
100	Senescence of the leaves	Plant height (158.3–160.4 cm) 16–20 tillers with leaf area (12,350–14,400 mm ²)	Plant height (150.7–155.8 cm) 16–20 tillers with leaf area (10,670–12,560 mm ²)	Plant height (153.8–159.1 cm) 18–22 tillers with leaf area (9,470–11,492 mm ²)
Size seeds				
Length		9.0–11.0 mm	8.0–9.0 mm	8.0–9.0 mm
width		2.7–3.0 mm	2.5–2.9 mm	2.6–3.0 mm
width/length ratio		0.30	0.32	0.33
Weight of 1000 seeds		25.959–25.976 g	20.180–20.309 g	22.681–22.782 g
No. of spike/inflorescence		9–12	8–12	10–12
No. of spikelets/inflorescence		25–35	20–25	25–40
No. of spikelets/panicle		200–220	190–210	210–230
No. of fully filled grains/inflorescence		15–20	15–20	15–30
Others selected growth characteristics	Tiller diameter	0.5–1.0 cm	0.4–0.7 cm	0.3–1.0 cm
	Main culm diameter	1.4–2.0 cm	1.5–1.8 cm	1.5–2.1 cm
	Ligule length	1.9–3.0 cm	2.2–2.5 cm	1.9–3.1 cm
Grain shattering	Panicle length	30–31.8 cm	32.9–33.5 cm	26.0–26.8 cm
	spontaneous shattering	spontaneous shattering	spontaneous shattering	spontaneous shattering

Observation at 40 DAS showed that rapid plant growth occurred. Individual height growth rates varied between 158.3 cm and 160.4 cm in awn type, 150.7 cm and 155.8 cm in open panicle type and between 153.8 cm and 159.1 cm in compact panicle type. In spite of the higher growth of some individuals of weedy rice, the growth rate of the three variants was similar. Generally, the average height of weedy rice was 158.0 cm and increased with time (Fig. 3). The plant height obtained significantly increased by the increased of days of seeding for all weedy rice variants. Relationships among all weedy rice variants were shown in Figure 4. There was a significant correlation between the days of seeding and plant height of all variants. However, open panicle type had a strong effect on the plant height obtained i.e., $y = 1.3989x + 21.073$; $r^2 = 0.9432$ compared to the other variants, $y = 1.4151x + 21.42$; $r^2 = 0.9323$ for compact panicle type and $y = 1.4998x + 22.683$; $r^2 = 0.9351$ for awn type.

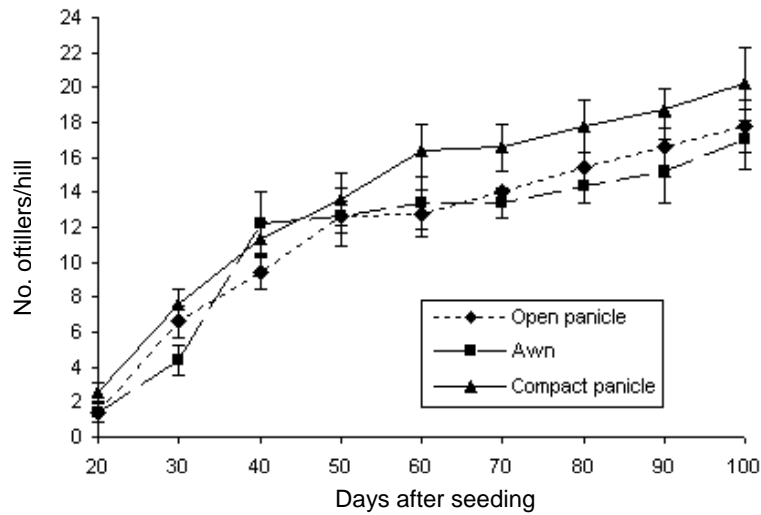


Figure 1: Comparison of tiller production of weedy rice variants planted in plant house condition.

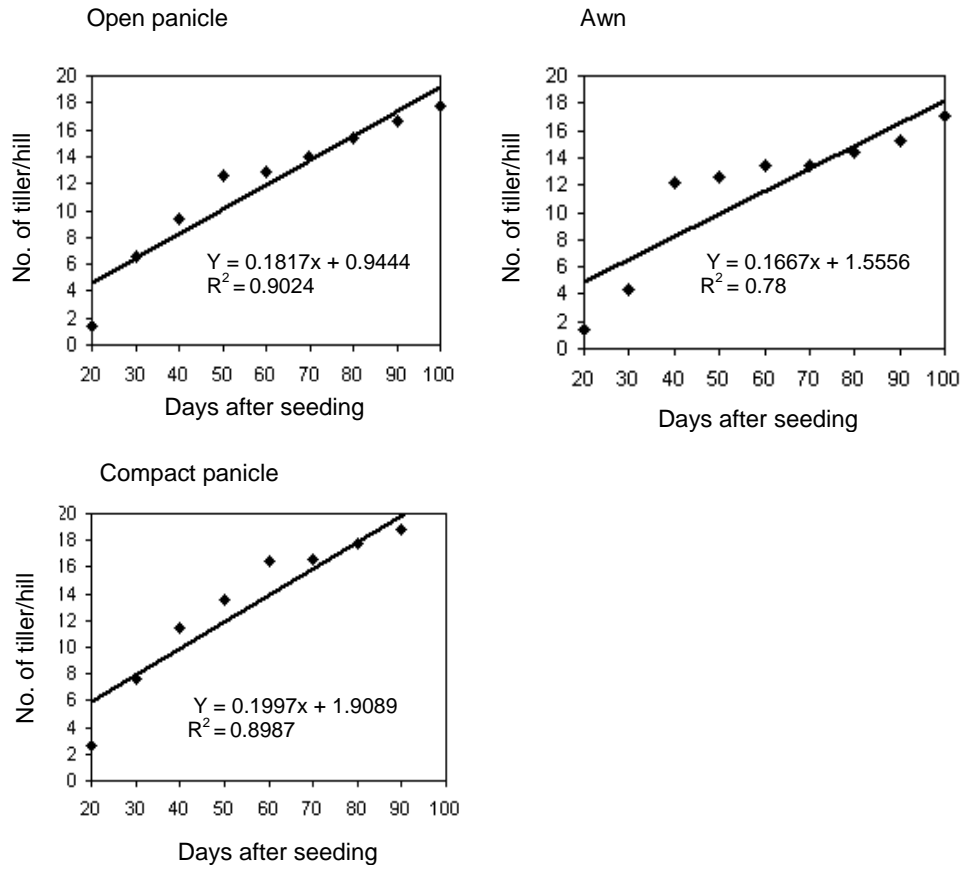


Figure 2: Linear regression of number of tiller production by weedy rice variants.

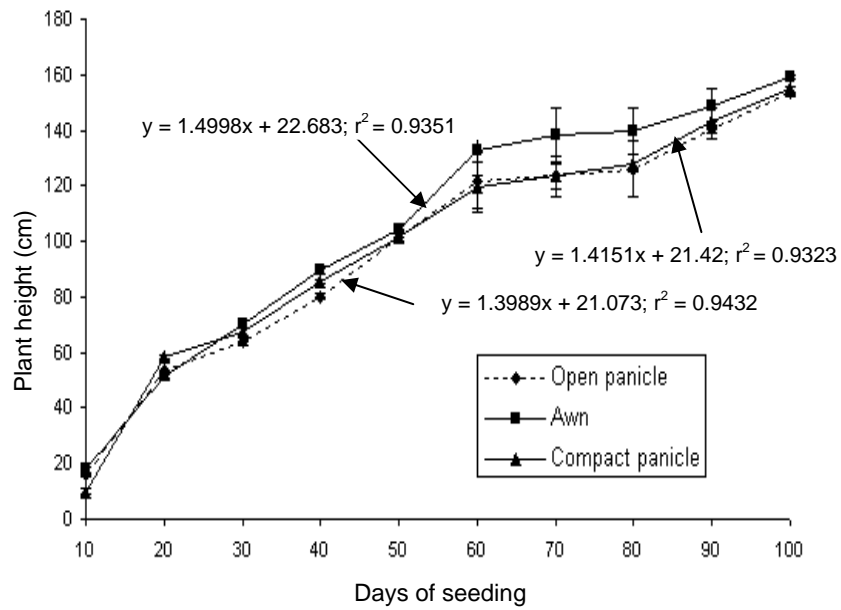


Figure 3: Comparison of plant height of weedy rice variants planted in plant house condition.

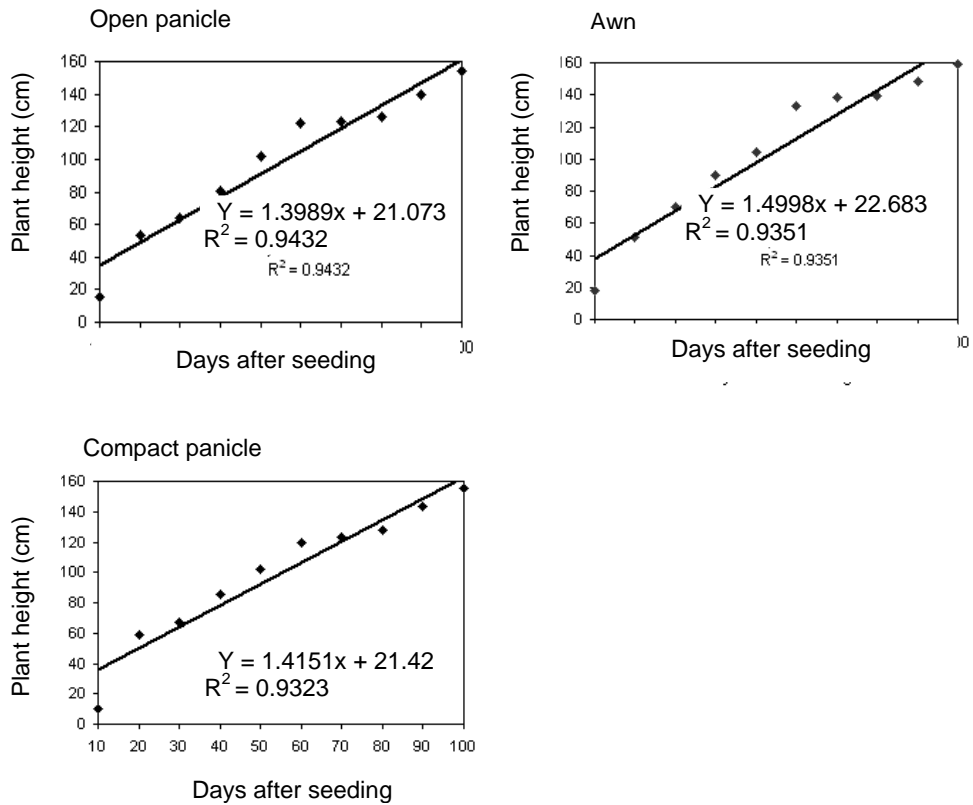


Figure 4: Relationships between plant heights of weedy rice variants and days after seeding.

At 80 DAS some leaves started to senescence, while at 90 DAS the seeds from all variants started to mature and were available for germination. As mentioned previously, weedy rice is an annual plant, so this plant completed the life cycle within 90–100 DAS. A schematic diagram of the life cycle of weedy rice is presented in Figure 5.

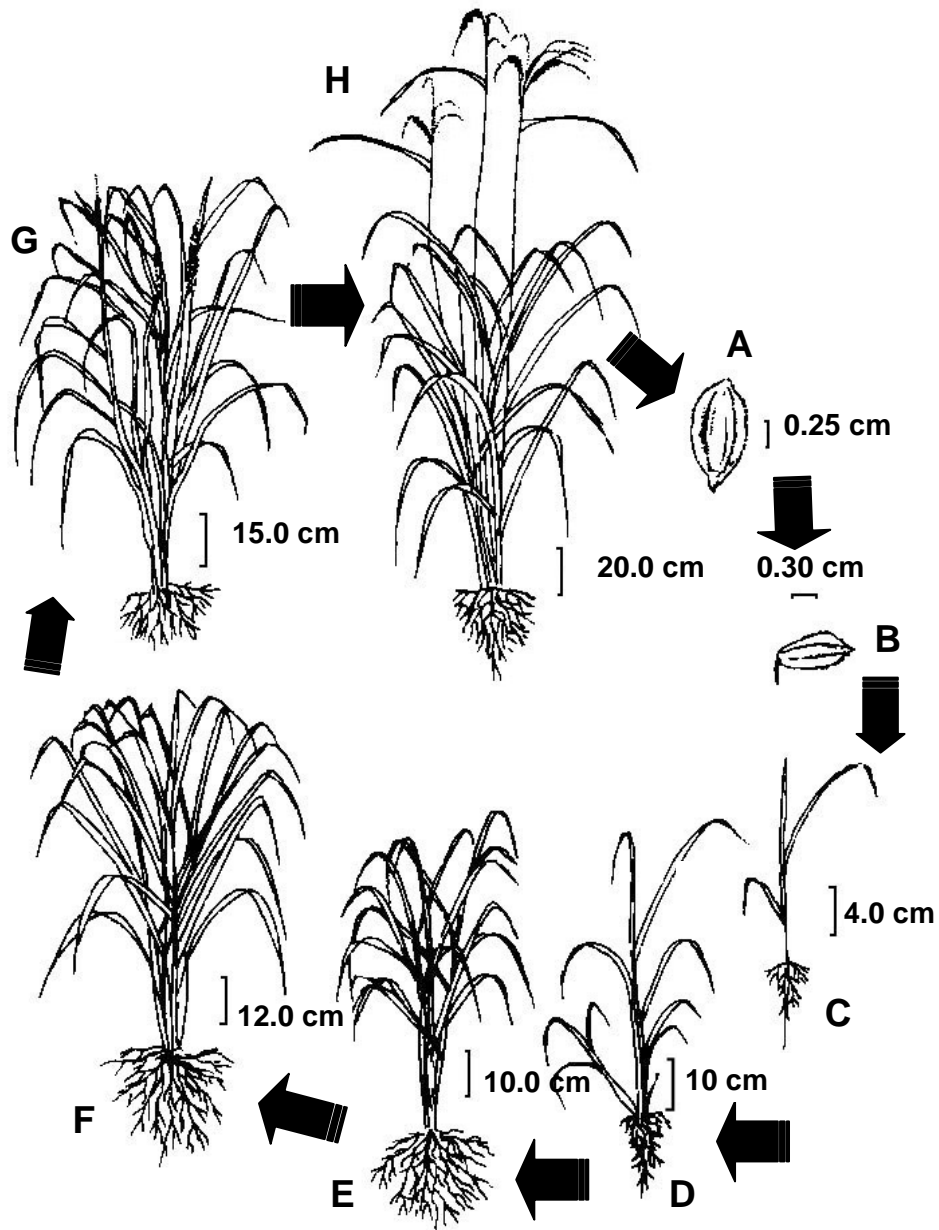


Figure 5: Schematic representation of the life cycle of weedy rice (open panicle type). A = seed; B = pregerminated seed (3–8 DAS); C = 2–3 leaf-stage (7–10 DAS); D = 1–2 tillers stage (15–20 DAS); E = active tillering stage (25–30 DAS); F = maximum tillering/booting stage (40–50 DAS); G = heading stage (55–60 DAS); and H = flowering/maturation stage (60–95 DAS). A–E = Vegetative phase; E–F = reproductive phase; F–H = ripening phase.

DISCUSSIONS

Morphological and topographical characteristics of weedy rice

The weedy nature of weedy rice is emphasized by a high biomass production, a tall plant type and the shattering of its grains. There are 10 variants of weedy rice found in rice granary areas in Muda area. Observation conducted by Muda Agricultural Development Authority (MADA) revealed that weedy rice has four important characteristics, namely easy shattering, plant height, pigmented grain and long awn (Md. Zuki *et al.* 1995). The experiments indicate that weedy rice is a successful weed of cultivated areas because it has variability in morphologies, growth and well establishment of reproduction. Based on the photographs taken, the morphological structure of leaves was not much difference among the variants of weedy rice except for epidermal hairs or spines where the awn type has much longer than others. These characteristics make weedy rice an ideal weed and could compete with other weeds in ricefields.

Generally, seedlings can germinate and quickly develop a deep tap-root to access moisture for growth and survive during intra-competition under ideal conditions in plant house. Plant house observations suggest that early seedling growth of weedy rice especially of compact panicle type is quick compared to many annual weed seedlings such as *Echinochloa crus-galli* (Azmi 1994), *Leptochloa chinensis* (Pane 1997) and *Ischaemum rugosum* (Nabi & Baki 1995 and Baki & Nabi 2003). This is because germination and early seedling development are critical periods of plant growth. The most competitive weeds appear to be the earliest to emerge (Ross & Harper 1982). Therefore, this species could survive with other weeds during competition in ricefields for several planting seasons.

Seen under the SEM, there is a similar structure of seeds among the weedy rice variants and cultivated rice. There are structures like hair or papillae/trichome/tubercle regularly arranged on the surface of the seed. Most probably, these structures could function to grab the soil or substrate during germination. Therefore, it avoids the grains from being washed away during heavy rainfall in ricefields. These structures may function in maintaining water balance or temperature regulation and in protecting them from mechanical damage or insect predation. Wilson (Hoagland & Paul 1978) suggested that in functional anatomy, the seed coat and pericarp are of main importance to physiological and morphological changes associated with seed dispersal and germination. The seed coat and anthocarp may exert an influence on germination since these parts can regulate water uptake, gas exchange, nutrient absorption and light requirements of the seed in the soil. In addition, these features of weedy rice seeds, revealed in this study, may be important in mechanisms of dispersal. In consideration of this, a detailed investigation using SEM was provided and may be useful in understanding its dormancy as well as to control the germination. This is because weedy rice seeds can stay dormant in the soil, which allows them to germinate at various time.

The physical properties of leaf surfaces are markedly influence by their roughness (Table 2).

Table 2: Summary of roughness present on the leaf surface.

Leaf surface features	Characteristics
Venation	Variation in form and prominence Parallelvenation systems – monocotyledons Reticulate venation systems – dicotyledons
Surface of epidermal cells	May be flat, convex or papillose. Epidermal cell diameter governs the degree of configuration when surface convex or papillose
Cuticle surface	May be smooth, granular, grooved or ridged
Trichomes	May be present or absent. When present, considerable variation in size, shape, form, frequency and distribution
Surface wax	May be present or absent. When present, variation in size, shape and distribution of the crystalline or semi-crystalline formations projecting from the cuticle surface

source: Holloway (1971)

In the study, leaf surface analysis of these three weedy rice variants and cultivated rice indicate that no significant features are distinctly different, even though the plant surface morphology (leaf surface) waxes vary considerably among species. Based on the photograph, all species with epidermis on leaves have the same general properties. Mauseth (1988) mentioned that because of the leaf is dorsiventral, the epidermis on the upper (adaxial) surface is in an environment that is different from the epidermis on the lower (abaxial) surface, and it has different functions. The abaxial epidermis typically has many stomata whereas the adaxial epidermis has few stomata. During the day, most leaves are warm as the surrounding air, so convection currents rise from them, and even a mild wind would carry any transpired water vapor away from the leaf. The water that is lost cannot be carried away by convection currents. Moreover, the abaxial epidermis is frequently covered with thick layers of trichomes or epidermal hairs trichomes that further avoid air movements from sweeping water away. Furthermore, Noda *et al.* (1985) and Mauseth (1988) reported that thicker cuticle and more dense deposits of wax were found on the adaxial surface of a leaf compared with the abaxial one. This phenomenon occurs because the amount of wax deposits on the surface of leaves is closely associated to the entry of systemic herbicides into plants. Another explanation on this is probably both to prevent transcuticular transpiration and to reflect away excessive sunlight. Referring to the epicuticular waxes, Holloway (1971) observed that the plant waxes differ from one another in both qualitative (chemical composition of wax) and quantitative (percentage of total wax) composition. The wax composition may change as leaves grow and may differ on the adaxial and abaxial epidermis of the same leaf. All these characteristics were found in compact panicle and awned variants. This result explains why weedy rice become more competitive than cultivated rice in ricefields and considered as a noxious weed in Malaysia. In this study, indicates are different generally in shape, size and distribution. In this

case, similar findings by Holloway (1971) where the structural differences occur among plant species, and among varieties of the same species, vary with position on the plant, age or environment, and may be induced by chemicals. Shepherd and Griffiths (2006) also observed that epicuticular waxes usually have a microcrystalline structure, sometimes arising from underlying amorphous layer. This is a very important feature in determining the entry point by pesticide absorption, translocation and selectivity in plants (Hoagland & Paul 1978; Sanyal *et al.* 2006).

Growth Pattern of Weedy Rice

According to Radoservich and Holt (1984) the growth patterns of evolutionary development of annual plants involve major activities that require resource allocation, starting from seed. The processes of dispersal, dormancy, germination, seedling establishment, vegetative plant, resource capture, growth, flowering, seed production continue and ended with the seed. Seemingly, the weedy rice growth pattern was similar as reported by Radoservich and Holt (1984). From observation, the plants were stunted after emergence (3–8 DAS) and increase in plant height was slow for the first three weeks (10–20 DAS). After 20 DAS, rapid increase in plant height was observed and continuously increased until the plant reached maximum height (153–160 cm) at 100 DAS. The maximum number of spikelets is determined by the differentiation of branches and spikelets (Diarra *et al.* 1985). Consequently, compact panicle type with high numbers of panicle has a greater potential grain yield than awn and open panicle types. The former type was found to produce seeds up to 2,760 seeds/plant followed by awn type with 2,640 seeds/plant and open panicle type with 2,520 seeds/plant, respectively, indicating that weedy rice plants had high competitive ability in the ricefield. All variants of weedy rice slightly differ in time to maturity and complete their life cycles within 85–90 days after emergence (DAE) for open and compact panicles type, and 90–95 DAE for awn type. Variability in grain width/length ratio indicated that grain shape of compact panicle type was more rounded than open panicle type and awn type with ratio of 3.3, 3.2 and 3.0, respectively. However, the most significant difference among the three variants of weedy rice based on the morphological characteristics is awn with compact panicles type, awnless with compact panicles type and awnless with open panicles type.

Harper (1977) and Silvertown and Charlesworth (2001) reviewed that a single unit of clonal growth (allowing plants to grow and branch vertically, meristem allow plants to proliferate and spread horizontally) was called a “ramet” and genetically distinct individuals were called “genets”. Silvertown and Doust (1993) added that “genets” could control rates of shoot production and the spatial distribution and density of their ramets. In other words, survival and reproduction of the genet depends on the behavior of “ramets”, and “ramets” depend on the behavior of their parts, so as one might expect, densities are usually kept below the point that would cause mortality. When clonal plants do occasionally reach self-thinning densities their behavior appears to be similar to that of non-clonal plants. Larcher (1975) added that in an annual plant the foregoing phases of the life cycle follow one another in uninterrupted sequence. After germination, the

vegetative organs acquire their form and multiply in number. When the intensive growth of the shoot occurs, it could reduce the formation of plant flower.

Weedy rice has life-form class recognized as “therophytes” which is an annual plant species where the unfavorable seasons are passed as an embryo in the form of seeds and completes its life cycle during favorable seasons (Goldsmith *et al.* 1986). In addition, Silvertown and Doust (1993) reported that it also belongs to “semelparous” or “monocarpic” plant where it reproduces only once in its life time, and die shortly after reproduction (the “genet” dies after flowering). Radoservich and Holt (1984) and Groves (1992) mentioned that the plants which belong to the *r*-selection leads to short-lived plant that occurs in open habitats and early stages of succession. Mortality occurs at early stage with rapid development, therefore, a large amount of energy is allocated to sexual reproduction and usually the population is regulated by physical factors. Moreover, *r*-selection species is also characterized by rapid growth rates, high photosynthetic rates, small wind dispersal and easily adapted to disturbance. Weeds associated with agricultural land seem to fit most closely the characteristics of *r*-selection where weedy rice has most of the characters mentioned. As a result, it can be concluded that the weedy rice possibly belongs to the *r*-selection.

As a result, the seedling growth and growth pattern of weedy rice are well adapted to disturbed environments created by annual cropping. Therefore, weedy rice could survive and establish well in ricefields and are considered to be the most troublesome weed in ricefields particularly in direct-seeded rice in Malaysia (Wahab & Suhaimi 1991; Vaughan *et al.* 1995a, b; Watanabe *et al.* 1996, 1999; Azmi *et al.* 2000; Azmi & Abdullah 2002). Therefore, an understanding of the growth and development of weedy rice from seed to maturity is desirable due to develop an understanding of the importance of stage of growth to create weed management in future. However, more in-depth studies would be necessary to clearly define and compare all the variants of weedy rice based on topographical features. The information could be useful to predict a potential weed growth in field particularly weedy rice as the dynamic of a species, which is based on the estimation of the final size of growth production during its life-span.

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