THEY STAND AMONG EQUALS: SPATIAL DISTRIBUTION PATTERNS OF NEW BIOTYPES OF WEEDY RICE (*Oryza sativa* L.) IN MALAYSIA

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ABSTRACT. Weedy rice generally includes all the species of genus *Oryza* mimicking commercial rice crops, but with distinct grain-shattering trait with the ability to disseminate their grains before rice harvests, and their continuous infestation reduces yields and quality of rice crops. In Malaysia, weed rice accessions (*Oryza sativa* complex) is one of the most serious threats to rice production. These weedy rice biotypes or accessions in Malaysian rice granaries usually grow distinctly taller than cultivated rice, and can be easily identified. Since 2005, new biotype accessions have since evolved mimicking closely in morphology such as plant height, and grain colours, thus "standing as equals" with that of cultivated rices like MR84, MR 219, MR220 and MR235. A series of surveys was conducted in 2006-2007 in the rice granaries of Selangor North-West Project, Tanjung Karang, Selangor, Malaysia to assess the populations of these new biotypes or accessions and their spatio-temporal patterns of distribution based on selected quantitative dispersion indices, *viz.* importance value index, variance-to-mean ratio (Vmr), Lloyd's mean crowding index (m*) and Lloyd's patchiness (Ip) index. Sixteen morphologically different weedy rice accessions or new biotypes of weedy rice (NBWR) were identified using keys of identification (grain shattering percentage, pericarp colour, awn existence, panicle type and seed size). These NBWRs display opened or closed panicles, >50% or <50% of grain shattering, red or white pericarp colour, awned or awnless grains, and short or long grains. The Acc 8 of NBWR was the most dominant accession compared with other NBWRs based on importance value index throughout the 2006/2007 seasons. The variance-to-mean ratio (Vmr) values showed that all NBWRs aggregated distribution pattern except for Acc 9 and Acc 11 which displayed regular distribution pattern. The values of Lloyd's patchiness (Ip) index were tested for deviation from unity. Most NBWRs showed aggregated distribution patterns based on Ip values, and Acc 9 and Acc 11 showed a regular distributions. It is believed that a close relationship between weedy rice and cultivated commercial varieties prevails, giving a strong indication that evolutionary forces are still operating in the rice ecosystems. These NBWRs are believed to have evolved from cultivated rice as parents over the years and are believed to be derived from hybridization between different cultivars, selection of weedy traits present in cultivars, relics of abandoned cultivars, or to have been brought into the growing region through contaminated seed stocks.

Keywords: Weedy rices, *Orysa sativa*, quantitative and dispersion indices.

BRANCHING PATTERNS OF *MELASTOMA MALABATHRICUM* L. AS INFLUENCED BY DENSITY REGIMES

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ABSTRACT. We assessed branching patterns and developed architectural models of *Melastoma malabathricum* describing branching networks, directionality and dispersion with respect to the mother plant as influenced by density. Matured plants of *M. malabathricum* at the density of 1, 2, and 3 plant box⁻¹ were raised in wooden boxes measuring 1 m x 1 m and 30 cm in depth, previously filled with garden soil of the Malacca series. The primary, secondary and tertiary branches, their respective angles and lengths were measured to assess branching patterns as influenced by density. Mean vectors of branches concentration were measured for every 50 cm intervals of plant pressure of the neighbors. Circular statistics was applied to test whether the plant in a high density would preferentially bend towards the incoming solar radiation or otherwise. Most branches were concentrated in the opposite direction and away from each other with a mean vector of 212.9o. Rayleigh's test (z values) showed the branches were distributed uniformly in different direction (0° -360°) throughout the plant height around the mother plant. An increase in plant density has led to parallel increase in modular competition affecting distribution of branch modules, their directionality and dispersion, registering respective mean vectors of 222°, 208.9° and 214.2° for plants at the densities of 1, 2 and 3 plants box⁻¹. The concentrations of branch modules were quite uniform around the mother plant. Circular linear correlation tests indicated there were significant (p <0.01) correlations between branch axial angle and the length of branch in different plant densities as r = 0.63, r = 0.527, r = 0.488 in plant densities D1, D2 and D3, respectively. No significantly correlations at p<0.05 between horizontal rotation angle and the length of branch in any categories of branches or plant densities were registered. We found that the concentrations of axial branch modules devolved away from the maximum competitive pressure in terms of branch vertical rotation (axial) angle was higher among neighbours at the density of 3 plants/box compared with those plants at the respective densities of 1 or 2 plants box⁻¹. The resultant spatial pattern of competing plants displaying reduced overlapping of branches was a manifestation of the competitive vectors integrating neighbour effects between them.

Key words. *Melastoma malabathricum*, branching networks, directionality, dispersion, neighbours.

INTRODUCTION

Melastoma malabathricum (Fig. 1) is a serious weed in many crops, derelict and abandoned farmlands, and arable lands in Malaysia (Baki 2004; Baki 2006; Faravani and Baki 2007), and elsewhere in the tropics and subtropics (Clausing and Renner 2001; Renner and Meyer 2001). The weed has a propensity to become invasive with adaptive life strategies including robust clonal- and reproductive growths coupled with efficient seed dispersal, often aided by ants and birds, and are attracted by copious production of fruits. This opportunity rarely arises in the native habitat of the species as there tends to be a higher rate of competition from other natives. They are primary colonizers of secondary areas, disturbed habitats, pastures, roadsides, and slides, light gaps and rivers. This species is fast growing, shade tolerant, devoid of natural pests, and sets an abundance seeds with a high rate of germination leading to mono-specific stands easily out-competing native flora putting them at great risk (Penneys 2008).

MATERIALS AND METHODS

Fig. 1. A mature plant of *Melastoma malabathricum*. Inserts: two biotypes *M. malabathricum* in Peninsular Malaysia.

Experimental design. One hundred young seedlings of *M. malabathricum* were collected from the campus of the University of Malaya, Kuala Lumpur, Malaysia, (3° 8' N; 101° 42' E) in May 2006. The most uniform plants were selected and transferred to nine wooden boxes each measuring 72 cm × 72 cm × 30 cm. The experiment consisted of three replications of three density treatments with one (D1), two (D2) or three (D3) plants per wooden box. A single plant was transplanted in the centre of the box for the single plant treatment and plants were arranged 10 cm from each other for the two or three plant treatments. For the branching pattern studies, plant height was divided into 50 cm segments from the soil surface. The position of each branch was characterized by three parameters, related to the degrees of freedom for the displacement of the branch as a solid body: horizontal rotation (φ), vertical rotation (Θ) and translation (branch height). The number of branches for each 50 cm segment (1, 2..,5) was also recorded. Θ was measured with a clinometer.

The horizontal rotation (φ) of the branch was measured from the north direction within 45°, using a home-made circular protractor divided into 8 angular sectors and orientated clockwise (Drouet and Moulia 1997). Spatial analysis of tree trunks and the development of biological branching structures has become an established method to infer tree population dynamics by using different model systems that include plant branches and plant root networks (Giovanelli *et al.* 2006; Getzin and Wiegand 2007; Cornelissen and Stiling 2008). High neighbour-hood plant densities may result in density-dependent mortality or may be compensated by shifting the crown centres away from the main stem because canopy architecture is structured to maximize photosynthesis (Muth and Bazzaz 2002). A plant with a close neighbour responds by investing in branch growth away from the competitive pressure or simply into zones free of neighbors (Brisson and Reynolds 1994; Chelle 2006; Saudreau *et al.* 2007).

In this study we demonstrated that competitive interactions with neighbours may affect spatial arrangement of branching systems in *M. malabathricum* L. We analyzed spatial scales of branches along plant height as well as the directional preferences of bending branches in *M. malabathricum*. For this, circular statistics were used to test whether competing plants expand towards the preferential side of a gap, or otherwise, and display morphological plasticity in their lateral growth.

Data analysis. A group of observations (or individual vectors) have a mean vector (μ) that can be calculated by combining each of the individual vectors. A μ value will have two properties: its direction and its length (often referred to using the letter r). The length will range from 0 to 1; a larger r value indicates that the observations are clustered more closely around the mean than a lower one. Rayleigh's uniformity test was used to calculate the probability of the null hypothesis that the data are distributed in a uniform manner (Batschelet 1981; Jammalamadaka and Sengupta 2001; Gatto and Jammalamadaka 2007). We hypothesized that there is a correlation between a circular variable (horizontal or vertical rotation angle) and linear variable (branch length or translation). The hypothesis entailed the calculation of the circular-linear correlation coefficient (Fisher 1993; Zar 1998; Mardia and Jupp 2000; Jammalamadaka and Sengupta 2001). This correlation coefficient ranges from 0 to 1. Suppose that a linear-circular correlation (Mardia 1976), which is a measure of correlation between a linear and an angular variable, is defined by:

$$r^2 = \frac{r_{xc}^2 + r_{xs}^2 - 2r_{xc}r_{xs}r_{cs}}{1 - r_{cs}^2}$$

Equation 1.
where r_{xc} = corr (x, cos θ), r_{xs} = corr (x, sin θ), and r_{cs} = corr (cos θ, sin θ).

The hypothesis of no circular-linear association is rejected if r2 is too large. The data were processed and displayed with the software ORIANA and the R-Project for statistical computing of the circular data, median, circular mean, and concentration parameter.

RESULTS AND DISCUSSION

Rayleigh's uniformity test showed the distribution of φ and Θ were symmetrical uniform and not uniform respectively in different plant populations and translations which were computed as the length of the mean vector (r) (Tables 1 and 2, Fig. 2). The registered μ values among the three densities for Θ in each 50 cm interval up to 250 cm of translation from base were 60.2°, 49.7°, 40.1°, 30.5° and 22.5°, respectively (Fig. 2).

Table 1. A summary of the horizontal rotation analyzed with circular statistics.

Circular statistics measurement	Plant density D1	D2	D3
Mean vector angle	221.9°	208.9°	214.2°
Length of mean vector (r)	0.032	0.047	0.016
Rayleigh's uniformity test (Z)	0.1	0.28	0.042
Rayleigh test (p)	0.905	0.686	0.958

Table 2. The direction of asymmetric growth for branch axial angle analyzed with circular statistics.

Circular statistics	Plant density D1	D2	D3
Mean vector angle	52.3°	47.8°	41.8°
Length of Mean vector (r)	0.964	0.946	0.988
Watson's U² test (U², von Mises) p= 0.05	5.397	8.872	13.108
Rayleigh's uniformity test (Z)	94.95	152.15	194.94

The lengths of mean vector increased with branch height, and branches were more erect in the top of the plant canopy *vis à vis* those in the lower parts of the canopy. These results are consistent with those obtained by others (Drouet and Moulia 1997; Maddonnia *et al.* 2001; Elmore *et al.* 2005). The result of the approximate ANOVA for the densities showed that the F-value for D1 versus D2 was 3.61, and thus the null hypothesis, i.e. μ1 = μ2 is acceptable since P(F > 3.61) = 0.058 > 0.05. On the other hand, the respective F-values for D1 versus D3, and D2 versus D3 were 26.87 and 10.14, thereby rejecting the null hypotheses, where μ1 = μ3 and μ 2 = μ 3, suggesting that branches became progressively more erect as the plant population increases (Table 2). Other studies have found similar responses, with higher angles of inclination at higher densities (Drouet and Moulia 1997).

Circular-linear correlation between branch lengths with vertical rotation angle. A natural question to address is whether there is a definite relatioship between the lengths and vertical rotation angles of branches. Fig. 3 shows a plot of the vertical rotation angles θ and lengths of branches. We also attempted to establish possible relationships between vertical rotation angle, circular variable and branch length, and linear variable in *M. malabathricum*, as influenced by plant density regimes. Circular linear correlation tests indicated that there were significant correlations between Θ values and the length of branch in different plant densities as r = 0.63, p<0.01; r = 0.53 p<0.02; r = 0.49, p<0.01 in D1, D2 and D3 respectively. Generally most branches are concentrated in the opposite direction and away from each other, with a mean vector value of 212.89° and 46.01° for φ and Θ, respectively. We could not find any significant correlation at p<0.05 between φ and Θ of branches in any translation or under different plant densites.

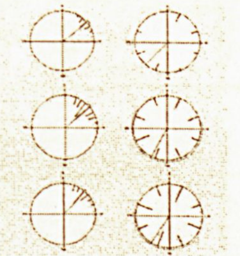

Fig. 2. The extent and direction (φ, θ) in branches of *Melastoma malabathricum*. The horizontal rotation angles were not uniform but distributed symmetrically in plants at D1, D2 and D3 with respective mean direction values of 52.3o, 47.8o and 41.8o (a, b, c). The Rayleigh's uniformity test showed the distribution of φ was uniform, and centrally symmetrical in different plant populations, and the computed mean direction were 212.90, 208.90 and 214.20 for the density regimes of D1, D2 and D3, respectively (d, e, f).

The Scheffe's test indicated that branch lengths significantly (p<0.05) decreased from D1 (40.4 cm) to D2 (30.3 cm) with increasing plant density. However, there was no significant difference between branch lengths among plants at D2 and D3. The highest circular-linear correlation (r = 0.594, p<0.01) between Θ and the length of the branch in different plant densities was observed in the top of the canopy (>150 cm plant height). Invariably, plants at higher density exhibited shorter branch lengths. However, there was no preferential directionality in the distribution of the branches within the crown mass centre from the stem base positions. The linear-circular correlation between the lengths and θ angles is given by r²= 3.0 × 10-3 (Equation 1). Note that although Fig. 4a shows a certain relationship between θ angles and lengths, so the correlation coefficient is fairly low. This difference might be partly because in Fig. 4b, the plots of θ angles is in the form of degrees, whereas the θ angles in linear-circular correlation are expressed as cosines and sines. However, if we re-plot Fig. 3a by transforming the circular variable into cos θ, as shown in Fig. 4b, then there is still no apparent or clear association between the linear and circular variables. We could possibly assume that higher neighborhood densities would lead to smaller crowns. Because stem positions are fixed, high neighbour's densities may result in density-dependent mortality of modules, or plants may compensate by shifting crown centers away from the main stem as the tree expands its branches within canopy gaps in the lower translations or more closely (or erect) to the main stem in the higher translations. Branch systems weremore developed away from the maximum competitive pressure of neighbors., as branch networks develop through plastic responses to a heterogeneous light environment, in order to maximize photosynthesis (*sensu* Harper 1977). Therefore, larger plants beyond immediate neighbours often have the greatest influence on the growth of a focal plant (Callaway and Walker 1997; Rouvinen 1997; Muth and Bazzaz 2002; Getzin *et al.* 2006). Further plant modules tend to expand their growth toward the gaps prevaling in the canopy.

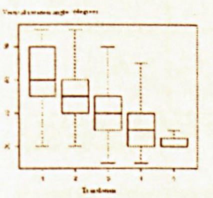

Fig. 3. Box-plots of the vertical rotation angles for each translation in *Melastoma malabathricum*. The bars are stand for minimum value , first quartile (25th percentile), median value (50th percentile) , third value (75th percentile) and maximum value.

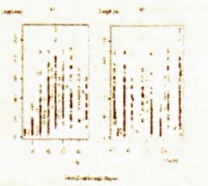

Fig. 4. Plots of the relationship between lengths of *Melastoma malabathricum* branches (cm) against (a) branch vertical rotation angle, and (b) cosines of the vertical rotation angle (in degrees).

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Key words: Weedy rices, *Orysa sativa*, quantitative and dispersion indices.

INTRODUCTION

Weedy rice populations have been reported in many paddy areas in the world where the crop is directly seeded (Pandey & Velasco 2002, Azmi & Baki 2003, Mortimer *et al.* 2000). In 1988, weedy rice in Malaysia was first observed in Sekinchan, Selangor, and later spread to all rice granaries in Peninsular Malaysia (Fig. 1) (Baki 2006). It is one of the most serious threats in paddy field and rice production in Malaysia. Its early growth and easy grain shattering has been the most unwanted traits of weedy rice. Weedy rice in rice-growing field in Malaysia usually grows taller than cultivated rice and easily identified.

The cultural practices of direct seeding and volunteer seeding in 1980's are suspected to be the most possible causes for the origin and spread of weedy rice in Malaysia (Baki 2006). The indiscriminate use of contaminated rice seeds and movement of farm machinery between granaries are also factors contributing to this problem.

Since 2005, new biotypes of weedy rice (NBWRs) stand as tall as the cultivated rice, the former become a new threat for the rice production in Malaysia. These NBWRs are very prevalent in the Selangor North-West Project (PBLS). Morphologically NBWRs mimic cultivated rice standing as equals *vis-a-vis* MR84, MR219, MR220 and MR235 as these weedy rices grow as tall as cultivated rice. These NBWRs, like their taller weedy rice accessions, possess common easy grain shattering trait. Some of these new accessions have a red pericarp but there are also accessions with white or colourless pericarp, closely mimicking the cultivated rice.

OBJECTIVES

(1) To enlist new biotypes of weedy rice (NBWR) in the farm blocks of Selangor's North West Project.
(2) To assess spatio-temporal patterns of distribution of NBWR in the farm blocks of Selangor's North West Project.

MATERIALS AND METHODS

A series of surveys was conducted in during the harvesting period for three consecutive seasons of 2006-2008 in farm blocks of the rice granaries of Selangor's North-West Project (PBLS) (Fig. 1) to assess the population changes and spatio-temporal patterns of distribution of these new biotype accessions of weedy rices (NBWRs). A quantitative analysis was conducted on the collated data based on importance value index, variance-to-mean ratio (Vmr), Lloyd's mean crowding index (m*) and Lloyd's patchiness (Ip) index.

The main morphological traits to identify these NBWRs are the degree of easy grain shattering, colour of pericarp, presence or absence of awns, panicle type, and seed size. Previously, weed rices were taller than commercial rices, hence they were easily distinguishable *vis-à-vis* commercial rices. The NBWRs mimic their commercial counterparts bearing similar plant heights, hence plant height is no longer a useful as a key morphological trait to differentiate from each other.

RESULTS AND DISCUSSIONS

NBWR Entities and General prevalence. Throughout the three seasons in the farm blocks of PBLS from Sawah Sempadan to Bagan Terap, 16 accessions were identified accessions with their special traits, viz. panicle type, colour, presence or absence of awn, seed type and degree of grain based on the key morphological traits. These shattering are shown in the **Table 1.** Further, these accessions exhibited a combination of morphological traits from open panicle, grain with awns, red pericarp, short grain type, to those with grain shattering habit no less than 50%. Others mimic the commercial rices with close panicle, awnless grains, white pericarp, long or short grain-type. Most accessions displayed varying degrees of grain shattering in excess of 50%, except Acc 9 and Acc 12.

Figs. 3, 4, and 5 show some of the traits of new weedy rice accessions in the farm blocks of PBLS. Invariably, the NBWRs strongly mimic commercial rices standing as equals with MR82, MR219, 220 and MR 235. This is especially so in terms of plant height and flag leaf traits. Five or six years ago, weedy rice accessions in Peninsular Malaysia were typically the taller phenotypes, easily recognizable after maximum tillering stage, or even so during booting or grain-filling stage (Fig. 6). With continuous panicle slashing by farmers at booting- or grain-filling stage so as to prevent or reduce seed rain, leaving those NBWRs intact, allowing them to proliferate unabated.

Table 1. Key morphological traits of dominant new biotypes of weed rices prevailing in North West Project, Selangor, Malaysia.

Accessions	Panicle Type	Pericarp Colour	Awn	Seed Type	Shattering %
Acc 1	Open	Red	Awned	Short	>50%
Acc 2	Open	Red	Awned	Long	>50%
Acc 3	Open	Red	Awnless	Short	>50%
Acc 4	Open	Red	Awnless	Long	>50%
Acc 5	Open	White	Awned	Short	>50%
Acc 6	Open	White	Awned	Long	>50%
Acc 7	Open	White	Awnless	Short	>50%
Acc 8	Open	White	Awnless	Long	>50%
Acc 9	Open	Red	Awned	Long	<50%
Acc 10	Close	Red	Awned	Long	>50%
Acc 11	Open	Red	Awnless	Long	<50%
Acc 12	Close	Red	Awnless	Long	>50%
Acc 13	Close	White	Awned	Short	>50%
Acc 14	Close	White	Awned	Long	>50%
Acc 15	Close	White	Awnless	Short	>50%
Acc 16	Close	White	Awnless	Long	>50%

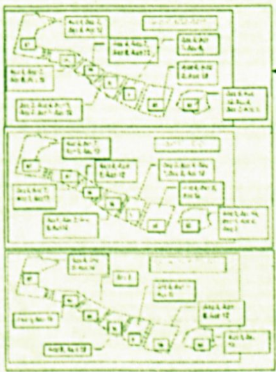

Fig. 1. Rice granaries in Peninsular Malaysia. The study area is denoted as Barat Laut Selangor.

Fig. 2 The spatial distributions of the most common new biotypes of weed rice accessions in 2006-2008 seasons in rice granaries of South West Project, Selangor, Malaysia. Farm Blocks - SS, Sawah Sempadan; SB, Sungai Burong; S, Sekinchan; SL, Sungai Leman; P, Pasir Panjang; SN, Sungai Nipah; BT, Bagan Terap. Acc 1, Acc 2...Acc 12 - Weed rice accessions.

Fig. 2 shows the farm block- and season-mediated differences population counts for each NBWR. Acc 8 has the highest population count in all farm blocks of the PBLS granary for all seasons, while Acc 9 and Acc 11 displayed are the lowest counts. Acc 8 also registered the highest population counts in all farm blocks from Sawah Sempadan to Bagan Terap, and again Acc 9 and Acc 11 have the lowest prevalence. Infestations of other accessions are fluctuated through the farm blocks over seasons. In Sawah Sempadan, most accessions showed a general decline throughout the three seasons except for Acc 10, with slight increase from season 1 to season 2 of 2006/2007. Sungai Burung farm block has a higher population for all accessions in season 2 compared to Season 1 and Season 3. Sungai Burung has the lowest number of NBWR in Season 3. Sekinchan farm block has recorded the lowest number of NBWR (<0.001 plants/m²) for three seasons. This is probably because farm management and crop care in this farm block is nearly optimum, thereby leaving only small numbers of NBWRs unattended or removed.

Population counts for season 1 of 2006/2007 showed that Acc 8 was the highest for all farm blocks. Bagan Terap has the highest population for Acc 8 followed by Sawah Sempadan, Sungai Leman, and Sungai Nipah. Acc 12 also has a high population counts. Sawah Sempadan recorded the highest population for Acc 12 followed by Bagan Terap. Other farm blocks also show a high density values. Sawah Sempadan and Bagan Terap have the highest population for Acc 4 and Acc 7. Infestations of most accessions did not change significantly in season 2. The population counts of NBWR, irrespective of accessions, decreased in season 3 of 2007/2008 for all farm blocks.

Seasonal Prevalence. Fig. 7 illustrates the seasonal dynamics on the prevalence of dominant NBWR accessions. While Bagan Terap farm block, for example, did not record any measurable changes in the dominant NBWR accessions over seasons, the Sungai Leman farm block recorded season-mediated changes in the dominant NBWR accessions. Sungai Leman started with NBWR Acc 3, Acc 4, Acc 5, Acc 7, Acc 8, and Acc 12 in season 1 of 2006/2007, but no measurable records of Acc 3 and Acc 5 were shown in season 2 of 2007. In season 3 of 2007/2008, only Acc 8 and Acc 12 prevailed in the farm block. In Sawah Sempadan farm block, season 3 of 2007/2008 saw much reduced prevalence of NBWRs leaving only Acc 8 and Acc12. Studies by Azmi *et al.* (2007) indicated that such dynamics in the prevalence of weedy rices in Malaysian granaries was very much influenced by control methods being employed by farmers, and those that employed integrate weed management protocols in their weed management regimes, witnessed much reduced infestations of weedy rices.

Importance value (IV) is a measure of dominance of species in an area (Kim & Moody 1983). Acc 8 followed by Acc 4, Acc 7 and Acc 12 are the following accessions with a high IV index were the most dominant accessions compared with other NBWRs based on importance value index (IV) in seasons 1 and 2 of 2006/2007. **Fig. 8** shows IV index for three seasons. The NBWRs had dominated most farm blocks of PBLS, with Sawah Sempadan, Sungai Nipah and Bagan Terap recording heaviest infestations.

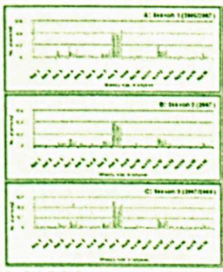

Fig. 7 (A, B, C). Population counts (no. plants/m²) of weedy rice accessions) in different farm blocks and growing seasons of 2006-2008 in Selangor's North West Project, Malaysia. ■ Sawah Sempadan; Sungai Burung; Sekinchan; Sungai Leman; Pasir Panjang; Sungai Nipah; Bagan Terap – Farm Blocks

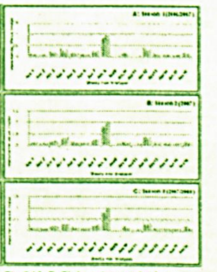

Fig. 8 (A, B, C). Importance value index values of weedy rice accessions in different farm blocks and growing seasons of 2006-2008 in Selangor's North West Project, Malaysia. ■ Sawah Sempadan; Sungai Burung; Sekinchan; Sungai Leman; Pasir Panjang; Sungai Nipah; Bagan Terap – Farm Blocks

Spatio-temporal distribution patterns. The mean-to-variance ratio (VMR) values are indicative of whether the pattern of distribution of NBWR of being random non-random, or regular (Young & Young 1998). Most NBWR accessions displayed highly aggregated distribution patterns with VMR values exceeding 1.0 (*full data not shown*). The Acc 8 of NBWR was the most aggregated among them in all farm blocks. The Lloyd's patchiness (Ip) index is another measure of degree of aggregation of the accessions in the farms blocks. Apparently most accessions displayed aggregated distribution pattern with varying degrees of aggregation in the farm blocks (*full data not shown*), registering Ip values ranging from 0.46 for Acc 9 in Bagan Terap farm block to 4.88 for Acc 11 in Sawah Sempadan farm blocks. Further, the relationship between mean crowding (m*) and mean density (m), we can determine the pattern of distribution of the accessions. Those values located on the Iwao line are accessions displaying random distribution while those below show that these accessions are regular. Accessions displaying values above the Iwao line are indicative of clustered or under-dispersed distribution pattern. Such relationships for the collated data are shown in **Fig. 9**.

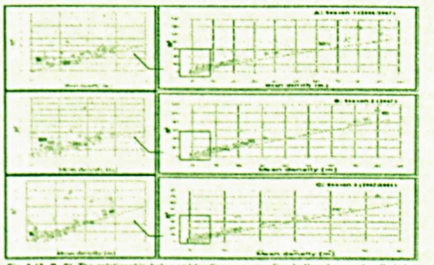

Fig. 9 (A, B, C). The relationship between Lloyd's mean crowding (m*) and mean density (m) values of weedy rice for different farm blocks and growing seasons of 2006-2008 in Selangor's North West Project, Malaysia.

In Sawah Sempadan, all accessions displayed non-random distribution pattern, except for Acc 1, Acc 2 and Acc 15 which showed random distribution. These distribution patterns were repeated in Sungai Burung where only Acc 15 exhibited regularity in distribution pattern. Most accessions in Sekinchan have a clump pattern. Acc1, Acc2, Acc 6, Acc 14 and Acc 15 have a random distribution while Acc11 has a under-dispersed (*sensu* Greig-Smith 1984) distribution pattern. Acc 3, Acc 4, Acc 5, Acc 8, Acc 10 and Acc 12 were under-dispersed in Sungai Leman, while Acc 2 and Acc 11 have regular pattern of distribution and other accessions have a random distribution. The NBWRs in Pasir Panjang farm block show a various distribution pattern. Acc 1, Acc 10 and Acc 14 have a regular distribution pattern, while Acc 2, Acc 5, Acc 6, Acc 13 and Acc 15 have a random distribution. Other accessions displayed under-dispersed distribution pattern.

We believe that a close relationship between weedy rice and cultivated commercial varieties prevails, giving a strong indication that evolutionary forces are still operating in the rice ecosystems. These NBWRs are believed to have evolved from cultivated rice as parents over the years and are believed to be derived from hybridization between different cultivars, selection of weedy traits present in cultivars, relics of abandoned cultivars, or to have been brought into the growing region through contaminated seed stocks.

The present preliminary study is indicative of the spatio-temporal dynamics the NBWRs in the Malaysian rice granaries. We do not know what contribute to these patterns of distribution patterns. We believe that the farmers' agronomic practice and crop care techniques, coupled perhaps with the herbicide application options and *in situ* differences in soils ad water availability both temporal and spatial, contribute to the prevailing differences in distribution patterns of NBWRs in PBLS. Based on the limited data generated from the present study, we advocate that areas like Sawah Sempadan, Sungai Burung, Sungai Nipah and Bagan Terap should focus on very intensive care against further infestation and spread of the scrouge unlike their counterparts in Sekinchan and Sungai Leman where the prevalence of NBWRs are minimal. The efficacious management options are there to be adopted and practiced.

Fig. 3. (A) A panicle of NBWR with heavy grain shattering taking place. Inserts (B) shattered grains; (C) range of grain shapes and sizes; (D) range of colour of pericarps.

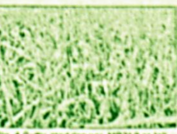

Fig. 4. Cultivated rice var. MR219 as tall as NBWR in PBLS, Malaysia.

Fig. 5. Weedy rice previously grow taller than commercial rice in PBLS, Selangor.

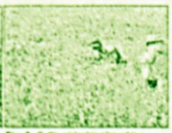

Fig. 6. Cutting/slashing/roughing activities practiced by the farmers to control taller biotype of weedy rices in PBLS, Selangor.

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DIRECTIONALITY AND DISPERSION ANALYSIS ON BRANCHING PATTERNS IN STRAITS RHODODENRON (*Melastoma malabathricum* L.)

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ABSTRACT Straits Rhododenron (*Melastoma malabathricum* L.) is a scourge in arable lands, abandoned farmlands, secondary forest openings and derelict areas in Malaysia. We assessed branching patterns of Straits Rhododenron at three planting densities through directionality and dispersion analysis using circular statistics with ORIANA and S-Plus Computer Softwares. Plants of *M. malabathricum* at the density of 1 (D1), 2 (D2), and 3 (D3) plant box^{-1}were raised until maturity in wooden boxes measuring 1 m x 1 m and 30 cm in depth, previously filled with garden soil. Plant height; primary, secondary, and tertiary branch lengths, numbers, and their respective angles and lengths were measured to assess branching patterns as influenced by density. The position of each branch was characterized by three parameters: horizontal rotation (branch azimuth), vertical rotation (branch base inclination), and translation (branch height). The number of branches for each 50 cm interval through plant height was also recorded. The azimuth of the branch was measured within 45°, using a circular protractor, divided into 8 angular sectors and orientated clockwise. All azimuth angles were measured from the north direction (0°) and the leaf base height above the soil was measured using a rule tape. These plants, either singular or in competition with neighbours did not display any preferentially expansion into the branches of the crown mass center from the stem base positions upwards. Most branches were concentrated in the opposite direction and away from each other with a mean vector of 212.9°.The Rayleigh's uniformity tests showed the distribution of the branch azimuths was centrally symmetrical in plants at the densities D1, D2 and D3 registering respective *r* values of 0.032, 0.047 and 0.014 .The computed *r* values were so small hence, no significant direction of orientation of the branches in a particular preferential direction after 161 days from seedling stage. The axial angles were not uniformly distributed in the plant canopy. The highest circular-linear correlation (r = 0.59, p<0.01) between the axial angle and the length of the branch in different plant densities was observed in the top of canopy, in excess of 150 cm of plant height. The registered mean vector (μ) for each 50 cm intervals of plant height up to 250 cm were 249°, 176°, 231°, 76° and 90°. Watson-Williams F-tests indicated that the branch axial mean was not different between plants at densities D1 and D2, but were significantly different from D3, whereby branches became progressively more erect from 52.27° until 41.81° with the increase in density from D1 to D3. Circular linear correlation tests indicated there were significant (p <0.01) correlations between branch axial angle and the length of branch in different plant densities as r = 0.63, r = 0.527, r = 0.488 in plant densities D1, D2 and D3, respectively. No significantly correlations at p<0.05 between azimuth insertion and the length of branch in any categories of branches or plant densities were registered.

Keywords: *Melastoma malabathricum*, branching networks, directionality, dispersion, uniformity, circular-linear correlation.

INTRODUCTION

Melastoma malabathricum L. (Fig.1) otherwise known locally as the Straits Rhododenron, is a common pioneer shrub species in arable lands, abandoned farmlands, secondary forest openings and derelict areas in Malaysia and elsewhere, especially in tropical and sub-tropical forests of India, Southeast Asia and Australia (Gross 1993; Meyer 2001; Baki 2004). *Melastoma malabathricum* has terminal branch flowers, and after flowering, commonly old branches at the base and inside of canopy die. This plant displays both terminal- and axillary-flowers. The branching pattern of *M. malabathricum* illustrates that of Leeuwenberg's model, consisting of equivalent orthotropic modules, each of which is determined in its growth by virtue of ultimate production of a terminal inflorescence. The angular rotation radial increments were measured from branches systematically sampled between the stem apex and stem base. Spatial analysis of tree trunks and development of biological branching structures has become an established method to infer tree forest communities by using different model systems that include plant branches and plant root networks (Giovanelli *et al.* 2006; Caplat *et al.* 2007; Getzin & Wiegand 2007). Spatial relationships between crown–trunk locations is complex and may be determined by small- and large-scale heterogeneities in light, and even by mechanical constraint (Rudnicki *et al.* 2001; Rock *et al.* 2004; Getzin & Wiegand 2007). Azimuthal movement or horizontal rotation of individual branches does occur during development, as claimed by Baki (1986). However, under field conditions without water stress, branches do not converge into a universal movement to a favoured mature azimuth. On the contrary, there is a trend toward azimuthal dispersion. Azimuthal movement of branches is sensitive to initial clumping of foliage, being triggered initially, and more importantly, when the initial clumping is strong (Chelle 2006; Saudreau *et al.* 2007).

Fig. 1. A mature plant of *Melastoma malabathricum*. Insert – flower clusters.

Observations on two-dimensional directions are called circular data, and these can be represented as angles measured with respect to some suitably-chosen "zero direction", *i.e.*, the starting point and "sense of rotation", *i.e.*, whether clockwise or counter-clockwise, and this is taken as a positive direction (Jammalamadaka & Sengupta 2001).
In this study, We analyzed the spatial scales of branching patterns of *M. malabathricum* as influenced by translation, their horizontal rotation angles, vertical rotation angle, and translation of branches over different densities. These were checked for possible adaptive re-positioning of successive branches, and their directional preferences in relation to different plant densities and light regimes at the stand level, based on the hypothesis that branch orientation is a selected trait that permits changes in the vertical and horizontal angle to achieve adequate light interception, during the initial 161days after transplanting.

MATERIALS AND METHODS

Study site and experimental design. The experiment was conducted in an insect-proof house with 12 hours of natural sunlight (mean midday radiation of 622 and 125 μ mole photon m^{-2} s^{-1} outdoor, respectively, and mean ambient temperatures of 33±2°C (day) and 25±2°C (night) at Rimba Ilmu, University of Malaya, Kuala Lumpur (3° 8' N; 101°42 ' E), Malaysia. Uniform cohorts of of *M. malabathricum* were selected in May 2006 and transplanted into wooden boxes, each measuring 72 cm × 72 cm × 30 cm at the density of 1(D1), 2(D2) and 3(D3) plants per box^{-1}, each with 3 replications. The plants were transplanted into the centre of the box for the single plants, while for 2 or 3 plants per box the plants were spaced equidistant at 10 cm from each other. The plants were watered once daily, in the morning from above with a fine rose. The boxes were arranged in a completely randomized design. For the branching pattern studies, each plant was progressively divided into 50-cm heights from the soil surface, and denoted accordingly. A circle of transparent plastic sheet divided into 8 sectors, each with a 45° degree angle, was prepared (Girardin & Tollenaar 1994; Drouet & Moulia 1997). Overlays were prepared to assess branching patterns of *M. malabathricum* with this plastic sheet. The direction and branch angles (primary branches with respect to the mother plant) in each quadrant were recorded with the aid of a compass oriented clockwise. The vertical rotation angles were measured with a clinometer

Measurements
Branching morphology and ordering scheme. A ll horizontal rotation angles were measured from the north direction (0°) and the branch-base height above the soil was measured using a rule tape. Growth parameters, *viz.* plant height; lengths of primary and secondary branches, and reproductive traits (time and duration of flowering, number of flowers branch^{-1} or flowersplant^{-1}) were recorded (Figs. 2 and 3).
Data analysis. The data were processed and displayed with the software ORIANA and the R-Project for statistical computing of the circular data, median, circular mean, and concentration parameter.
The hypothesis that there is a correlation between a circular variable (horizontal or vertical rotation angle) and linear variable (branch length or translation) entails the calculation of the circular-linear correlation coefficient (Fisher 1993; Zar 1998; Mardia& Jupp 2000; Jammalamadaka & Sengupta 2001)

Fig. 2. The botanical branching order by position in *Melastoma malabathricum* (redrawn from (Loehle 1994). This algorithm is used to define stem size based on branches hierarchy, with the main stem classified as order 1. Where the main stem bifurcates, giving to two smaller branches, the first branch above this point is of order 2. Similarly, bifurcation of the first branch gives rise to branch order 3. Subsequent branching and bifurcations give rise to higher order branches in a similar manner.

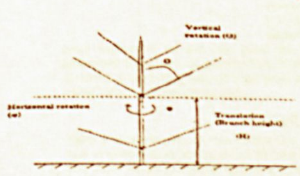

Fig. 3. Three parameters of the horizontal rotation angle "ϕ", the vertical rotation angle "θ", and translation (H) measured from the north direction during plant growth to describe the development of the aerial structure of *Melastoma malabathricum*.

The mean direction of branches is denoted by mean vector values, defined as follows: Let θ_1 ... θ_n be the angular observations expressed in the form of radians [0, 2π]. Then, the mean direction, $\bar{\theta}$, is defined by

$$\bar{\theta} = \arg\left\{\sum_{j=1}^{n} \cos\theta_j + i\sum_{j=1}^{n} \sin\theta_j\right\}$$

where i is the imaginary unit, i.e. $i^2 = -1$

The sample mean is obtained by treating the data as vectors of length as one unit and using the direction of their resultant vector *r* that it lies in the range (0, 1). Resultant vector *r* is a measure of concentrations 1-*r* is a measure of dispersion. Lack of dispersion 1-*r* = 0, and maximum dispersion is 1 - *r* = 0. The angular variance is defined as $s^2 = 2(1-r)$. Mean directions were compared with uniform circular distribution using a unimodal Rayleigh's test. We employed the Watson-Williams test (Batschelet 1981; Mardia & Jupp 2000; Jammalamadaka & Sengupta 2001) to test the mean directions of two or more samples of *M. malabathricum* branches orientation from each other.

RESULTS AND DISCUSSION

Horizontal rotation of plant branches. The Rayleigh's uniformity test showed the distribution of φ was centrally symmetrical in different plant populations, and the computed lengths of mean vector (r) were 0.032, 0.047 and 0.014 for the density regimes of D1, D2 and D3, respectively, and the association between density regimes and horizontal rotation angle (φ) (Table 1). The angular observations were calculated by Equation 1. Fig. 4 displays box-plots of (φ) for each density of the branches. The (φ) values seem to imply that they are not dependent on, or influenced by, the density of branches. The circular ANOVA test applied to the horizontal rotation angles registered non-significant F-values implying that the mean directions for all three densities are not different from each other for each planting density of *Melastoma*. Similar patterns of symmetrical distributions were registered in the different translations irrespective of density regimes, which the plants were subjected. The registered horizontal rotation angles (mean direction) for the translations 1-5 were 249.3°, 175.9°, 230.6°, 75.8° and 90.0°, respectively.

The means of algebraic values of the horizontal rotation angles between two successive branches were not significantly The means of algebraic values of the horizontal rotation angles between two successive branches were not significantly different, irrespective of the plant density, with a mean vector angle of μ_ϕ = 212.89° some 161 days after transplanting. The mean directions of branches were significantly different for D2 and D3, and for D1 and D3.

Table 1. Directions of symmetric growth for the horizontal rotation angle of *Melastoma malabathricum* as measured by descriptive statistics.

Circular statistics measurement	Plant density D1	D2	D3
Mean vector angle	221.9°	208.9°	214.2°
Length of mean vector (r)	0.032	0.047	0.014
Rayleigh's uniformity test (Z)	0.1	0.38	0.042
Rayleigh test (p)	0.905	0.684	0.959

Table 2. Circular statistics measurements as indicators of the orientation of branches and their uniformity as influenced by density regimes.zzz

Circular statistics measurements	Plant density D1	D2	D3
Mean vector angle	52.3°	47.8°	41.8°
Length of Mean Vector (r)	0.944	0.946	0.968
Watson's U² test	5.4**	9.67**	13.11**

Watson's U² test p< 0.005

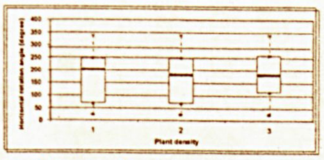

Fig. 4. Box-plots of the horizontal rotation angles of branches (ϕ) as a function of planting density in *Melastoma malabathricum*. The bars are stand for minimum value, first quartile (25th percentile), median value (50th percentile), third value (75th percentile) and maximum value.

Effect of density on vertical rotation of plant branches. When plants of *M. malabathricum* were subjected to density stress, the ensuing competition between branches led them to be more erect in stature as in D3, with measurably smaller vertical rotation angle θ values. The same result was observed in that the branches of density-stressed plants had an inward curving of the branch planes (Ezcurra *et al.* 1991). When plant population increased, branches became progressively more erect with the mean angles decreasing from 52.27° to 47.8° and 42° (Table 2).
Relationship between vertical rotation angles, translations and length of branches. The lengths of mean vector increased throughout the translation from the base to the top of plant height. It was also observed branches were more erect in the top of the plant canopy *vis-à-vis* those at the base, arguably for optimization of light interception.

Also there is an inverse significant relationship between translation and *θ* values in *M. malabathricum*, in which the vertical rotation angle, *θ*, decreases with the increase in plant height, especially from 0 to 150 cm, a suitable strategy for plants of *M. malabathricum* to achieve enough light to ensure ensuing growth of leaves down inside the canopy, where self-shading leads to lower light availability than at the top of the plant canopy. These results were consistent with those obtained by Drouet & Moulia (1997); and Maddonnia *et al.* (2001), who studied the effect of developmental plasticity in crown asymmetry both by the directionality of solar radiation geometry and by local competition between individual plants and their modules (Neufeld *et al.* 1988; Ezcurra *et al.* 1991). Branches in the top of the canopy were more erect than their counterparts at lower heights, arguably for optimization of light interception. Such orientation and distribution of branches allow the gradual warming of leaf surfaces during the morning, with maximum light interception (Ezcurra *et al.* 1991).
Evaluating the influence of plant density on branch length. With increasing plant density, branch length significantly decreased (p<0.05) from D1 at 40.4 cm, or D2 at 30.3 to D3 at 28.6 cm, although there were no significant difference between the length of branches in D2 and D3 as shown by a box-plot of lengths of branches for each density, explicitly showing that the higher the planting density, the shorter was the length of branches of *M. malabathricum* (Table 3).

Table 3. Length of branches of *Melastoma malabathricum* as influenced by density regimes.

	1st Qtr+	Median	3rd Qtr+	Max++	Mean length (p<=0.05)
D1	23.3	42.0	52.8	100.0	40.4 a
D2	20.0	33.0	42.0	111.0	30.3 b
D3	15.8	27.0	41.0	88.0	28.6 b

The correlation between the lengths and θ angles is given by $r^2 = 3.0 \times 10^{-3}$. The highest circular-linear correlation (r = 0.594, p<0.01) between the vertical rotation angle values and the lengths of branches in different plant densities was observed in the translations exceeding 150 cm of the plant height, linear-circular correlation indicating a inverse relationship between the lengths and vertical rotation angles of branches. Generally, the higher the translation of the canopy, the shorter branches were in length.

Vertical rotation angles were proportional to branch lengths when the Θ values did not exceed 50°. If Θ is in excess of 50o, the branch length decreases slightly as Θ increases. However, a circular–linear correlation coefficient shows that there is no clear association between vertical rotation angle Θ and branch lengths. Plant density has a negative effect on the length of branches, but horizontal rotation angles φ were dependent on density to which the plants of *M. malabathricum* were subjected. The Watson-Williams test (Batschelet 1981) (or the, circular ANOVA equivalent) indicated that the plots of the vertical rotation angles showed that the observations were uni-modal, and were symmetrically distributed, thus fortifying the assumption that the observations are approximately distributed as per the von Mises distribution. However, length mean vector r in θ is large, that is close to 1, this indicates a large degree of straightness about a line passing through (0,0) with a slope of 45°. Asymmetric tree growth is an adaptation to maximize photosynthesis in response to the presence of gaps and neighbours, Compensatory growth of modules, expanding on the crown centres away from the main stem as the tree expands branches on the side of canopy gaps in the lower translations. If this happens, asymmetric distribution of the horizontal rotation angle to the gap direction of the canopy as branch networks develop through plastic response to a heterogeneous light environment because canopy structure is mainly subjected to maximize photosynthesis. Further plant modules tend to expand their growth toward the gaps prevailing in the canopy. Competitive interactions with neighbours affect the spatial arrangement of branch systems in *M. malabathricum*, although this competitive pressure was not strong enough to translate into asymmetry in crown shape. The resulting spatial pattern tended to reduce the overlap between neighboring branch systems. A plant with a close neighbour responds by investing in branch growth away from the competitive pressure or simply into zones free of neighbours (Brisson & Reynolds 1994). Under this model, two plants can be close to each other but did not compete. Competition in the population is for space, and only occurs when a plant branch system is crowded on all sides. It would be interesting to see the photosynthetic efficiency of branches subjected to different light regimes within the translations, and relate branch growth and dispersion into the gaps or away from the competition zones. It would be equally interesting to assess the azimuthal positioning of branches in relation to their photosynthetic efficiency, or whether uniformity in branch alignment and symmetry within a canopy are actually translated into photosynthetic efficiency or biomass production among competing plants.

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ALLELOPATHIC POTENTIAL OF *Brassica juncea* (L.) CZERN. VAR. ENSABI AS A NATURAL HERBICIDE

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ABSTRACT. The wild brassica (*Brassica juncea* (L.) Czern. var. Ensabi) with its pungent and slightly bitter aromatic taste has been domesticated as a local vegetable and planted between rows in hill paddy by Malays and natives in the Malaysian states of Sabah and Sarawak. Laboratory experiments were conducted to assess the allelopathic potential of *Brassica juncea* (L.) Czern var. Ensabi extracts as a natural herbicide. The aqueous extracts of fresh and and dried leaves, stems and roots were prepared, with deionized distilled water as a control. Seeds of barnyardgrass (*Echinochloa crus*-galli L. Beauv.) and radish (*Raphanus sativus* L.) were exposed to these extracts, and the ensuing seed germination and seedling growth were recorded. The extracts from dried leaves of Ensabi exhibited the highest suppression of seed germination and seedling growth of *E. crus-galli* and *R. sativus*. Aqueous extracts of the dried leaves, stems and roots of Ensabi, each at 300g L^{-1} strongly inhibited germination of barnyardgrass and radish seeds. Highly significant deleterious growth effects were registered on seed germination, dry weights and lengths of radicle and hypocotyls of barnyardgrass and radish seedlings when exposed to aqueous extracts of dried Ensabi leaves, stems and roots, each at 300g L^{-1}. Measurable concentration-mediated reductions in seed germination, radical and shoot lengths of radish and barnyardgrass were registered with increasing concentration of aqueous extracts of dried and fresh Ensabi. The potentials of Ensabi extracts as a component of the cultural management of weeds in hill paddy are discussed.

Keywords: Allelopathy, *Brassica juncea, Echinochloa crus-galli, Raphanus sativus* seed germination, seedling growth.

INTRODUCTION

Plant allelopathy may be used as a cultural weed control method in the agro-ecosystems and reduce the perceived hazardous impacts from herbicides and insecticides (Xuan *et al.* 2005), and searching for novel natural plant products to develop bio-herbicides is an important trend (Khanha *et al.* 2005). Crop allelopathy may be useful in minimizing serious problems in agricultural production such as environmental pollution, unsafe products, human health concerns, depletion of crop diversity, soil decay and reduction of crop productivity (Khanh *et al.* 2005). Several *Brassica* species are known to possess allelopathic properties affecting growth of other plant species and reduce seed germination of small-grain crops when they grown in rotation (Bialy *et al.* 1990; Turk *et al.* 2005). Some plants from the *Brassicacea* family such as mustard (*Brassica juncea*) have a high potential to be used in alternative weed management systems (Brown and Morra 1995; Kirkegaard and Sarwar 1998). Mustards have been genetically bred for increased glucosinolate content in roots and shoots. The glucosinolates that produce by *B. juncea*, as an allelochemicals, can control weeds (Brown and Morra 1995). Allelochemical-based herbicides are natural products and thus could be broken down easily by microorganisms, making them less persistent in the environment (Chon *et al.* 2002; Singh *et al.* 2003; Xuan *et al.* 2005; Khanh *et al.* 2007).

OBJECTIVES

(i) To assess the allelopathic potential of *B. juncea* as a natural herbicide.
(ii) To assess the effects of aqueous extraction of root, stem and leaf of *B. juncea* on seed germination and seedling growth of radish and barnyardgrass.

MATERIAL AND METHODS

Plant sampling and preparation of extracts: Plants of *B. juncea* (Fig. 1) were harvested at a vegetative stage from an insect-proof house, Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia. These plants were immediately washed with tap water to remove any soil or other adhered material and dismembered into leaves, stems and roots.

Fig. 1. *Brassica juncea* (L.) Czern. var. Ensabi. Inserts (a) floral clusters, and (b) seedling .

Fresh materials: Twenty grammes of fresh materials (leaves, stems and roots) (hereafter referred to as FME) of Ensabi was chopped into small pieces (1–2 cm size), grinded and extracted with 100 ml distilled water at 25°C for 24 h in a shaker.. The extract is filtered through four layers of cheese cloth to remove the fibre debris, and centrifuged at 3000 rpm for 4 h. The supernatant was vacuum filtered again through Whatman No. 42 paper. Stock extracts were prepared from fresh for each experiment.

Dried materials: Dried materials (leaves, stems and roots) of Ensabi (hereafter referrred to as DME) was chopped into small pieces (1–2 cm size), dried in an oven at 40° C for 48 h, grinded into fine powder using a Wiley mill to pass a 1 mm screen and then stored in a refrigerator at 2° C in darkness until used (Chung *et al.* 2001; Chon *et al.* 2002). Twenty grams of dried stems, leaves and roots are extracted by soaking in 200 ml deionized water at 25° C for 24 h in a shaker to give a concentration of 20 g dry tissue/100 ml. The extract is filtered through four layers of cheesecloth to remove the fi debris, and centrifuged (by Centerfuge Eppendorf, 5804 R) at 10,000 rpm and 4° C for 10 min. The supernatant is vacuum filtered through Whatman no. 42 paper.

Treatments: Solutions of 0, 50,100,150, 200 and 300 g L^{-1} concentrations from FME or 40, 80,120, 160, 200 and 300 g L^{-1} from DME of Ensabi were prepared separately based on the methods of REFS from root, stem and leaf components and applied on radish (*Raphanus sativus)* and barnyardgrass (*Echinochloa crus-galli*). Thirty radish or barnyardgrass seeds were sown in each 9 cm petri-dishes lined with filter paper, and 10 ml of each extract was added. The petri-dishes were transferred to a growth chamber (set at 25° C, 4000 lux, for 12 hrs daily) for 7 days. Germination percentage, shoot and root length, and dry weights 7 days after treatment were recorded for all treatments. The inhibitory magnitude of each plant part is averaged from their inhibitory levels on germination, root length, plant height and dry weight of the indicator plant.

Data analysis: Germination counts were performed for a period of 8 days for the radish seeds and 28 days for the barnyardgrass seeds, although calculations were based on the longest time taken to achieve maximum germination at 14 days after treatment. The following parameters were calculated for barnyardgrass and radish based on Jefferson & Pennacchio (2003): (a) Rate of germination (RG); (b) Final germination (FG)%: mean percentage of seeds that germinated during the experiment. FG was expressed as a percentage after statistical analyses, were performed on the raw data; (c) Mean period of final germination (MPFG) and (d) percentage inhibition/stimulation of germination. Homogeneity of variances was tested, and those data not normally distributed were log_{10} transformed prior to one-way ANOVA. Differences between means were determined using Tukey's Compromise test.

RESULTS AND DISCUSSION

Table 1 illustrates the effects of different concentrations of aqueous extraction FME and DME of Ensabi on rate of germination, mean period of final germination, final germination (%), radicle and shoot lengths, root and shoot weight of barnyardgrass and radish. Application of 40 gL^{-1} aqueous extract DME had no significant (p<0.01) stimulatory effect on seed germination of radish as opposed to the significant (p<0.05) effects of 160, 200 and 300 gL^{-1} aqueous extract of root or stem or leaf and 120 gL^{-1}o f DME on seed germination of radish seeds. The 50 gL^{-1} of aqueous extract FME had lowest effect on radish seeds germination inhibition (95.2 %) virtually registering similar value as that of the control at 94.4%.
The aqueous extract of DME of Ensabi at 120, 160, and 300 gL^{-1} significantly inhibited germination of barnyardgrass seeds, with the latter treatment registering only 5.6% germination. Intriguingly, aqueous extracts of DME at 80 or 200gL 1 had a more significantly effect on inhibition of seed germination of barnyardgrass (Table 2). Increased concentrations of FME from 50 to 300 gL^{-1} and DME from 40 to 300 gL^{-1} of Ensabi decreased the germination capacity of radish and barnyardgrass seeds, demonstrating the allelopathic potential in suppressing seed germination of the test plants. These results are in agreement with the published work of (Ahn and Chung 2000; Chaves *et al.* 2001; Chung *et al.* 2003; Asghari and Tewari 2007). In the same vein, aqueous extract of DME at 50 and 80 gL^{-1} or FME at 150 gL^{-1}s ignificantly affected early root growth of radish seedlings and increased them. At 160 gL^{-1} had a significantly decrease root length of radish. Complete inhibition of root growth of radish was registered with DME treatment at 300 gL^{-1} (Table1).

Root growth of early seedlings of barnyardgrass was enhanced when treated with 50 gL^{-1} of aqueous extract of FME of Ensabi, and this enhancement was measurably higher than other concentrations of the extracts. Greater stimulation in root growth was observed among seedlings exposed to 300 gL^{-1} of DME (Table 2). Invariably, root growth of barnyardgrass was relatively more sensitive to *vis-à-vis* than was hypocotyl length at different concentrations of DME or FME extractions from root, stem and leaf of Ensabi. These results are in concordat with other studies of water extracts of allelopathic plants had more special effects on root growth than on shoot growth (Chung and Miller 1995; Turk and Tawaha 2003; Turk *et al.* 2005). Such as this result might be expected, because it is likely that roots are the first to absorb the allelochemicals or autotoxic compounds from the environment (Turk and Tawaha 2002).

	Aqueous extract concentration (g L-1)	Final germination (%)	Germination inhibition/ stimulation (%)	Root length (cm)	Shoot length (cm)	Root weight (mg)	Shoot weight (mg)
Control	0	94.44 AB	0	8.74 AB	4.19 BCD	8.5 BC	7.6 AB
Fresh extract (%)	50	95.19 A	+ 0.79	8.73 AB	4.37 ABCD	8.5 BC	7.5 AB
	100	93.33 AB	-1.18	8.41 ABC	3.84 CDE	8.6 BC	7.7 AB
	150	91.48 AB	-3.13	9.27 A	4.97 ABC	8.4 BC	7.5 AB
	200	81.48 C	-13.72	6.52 BCD	5.48 AB	14 A	8 A
	300	58.52 E	-38.03	5.97 CD	5.75 A	2 AB	8.1 A
Dried extract (g/L)	40	96.72 A	+1.05	9.41 A	4.80 ABC	9.8 ABC	7.9 AB
	80	89.26 B	-5.48	10.03 A	5.47 AB	9.8 ABC	7.7 AB
	120	68.52 D	-27.45	5.95 CD	4.25 BCD	10 ABC	7.8 AB
	160	48.15 F	-49.01	5.13 D	3.33 DE	10 ABC	7.8 AB
	200	22.22 G	-76.47	7.81 ABCD	2.08 E	11 ABC	8.3 A
	300	0 H	-100	0 E	0 F	0 D	0 C
Ls. p = 0.05		1.2		0.54	3.07	0.08	0.02

Table 1. Effect of Ensabi aqueous extracts of root, stem and leaf on germination and seedling growth of radish. Figures followed by the same upper case letters in a column are not significantly different at p<0.05. Negative values indicate inhibitive effects, while positive values indicate stimulative effects.

	Aqueous extract concentration (g.l-1)	Final germination %	Germination inhibition / stimulation (%)	Root length (cm)	Shoot length (cm)	Root weight (mg)	Shoot weight (mg)
control	0	97.04 A	0	6.82 B	2.30 B	7.23 A	7.33 AB
Fresh extract (%)	50	80.00 ABC	+8.09	8.65 A	2.04 AB	7.18 AB	5.44 B
	100	83.37 AB	+4.29	7.19 AB	2.73 AB	7.17 AB	4.87 B
	150	77.04 BC	-11.40	7.40 AB	2.56 AB	7.17 AB	5.99 AB
	200	66.93 D	-24.35	4.71 CD	3.72 A	7.15 ABC	6.79 AB
	300	47.41 F	-43.53	3.2 DEF	3.32 AB	7.14 BC	5.00 B
Dried extract (g.l-1)	40	80.37 ABC	-7.66	5.00 C	2.63 AB	7.18 AB	7.33 AB
	80	75.19 C	-13.61	3.89 CDE	2.49 B	7.17 AB	8.33 A
	120	67.78 D	-22.13	2.80 EF	2.64 AB	7.15 ABC	7.34 AB
	160	57.04 E	-34.47	1.84 FG	2.93 AB	7.15 ABC	6.68 AB
	200	44.81 F	-48.52	1.23 GH	3.25 AB	7.10 BC	7.32 AB
	300	3.30 G	-93.81	0 G	0 C	0 C	0 C
Ls. p = 0.05		1.97		0.73	0.20	1.89	0.56

Table 2. Effect of Ensabi aqueous extracts of root, stem and leaf on germination and seedling growth of barnyardgrass. Figures followed by the same upper case letters in a column are not significantly different at p<0.05. Negative values indicate inhibitive effects, while positive values indicate stimulating effects.

The species-mediated differential response in terms of seed germination of radish and barnyardgrass seeds when exposed to FME of Ensabi is denoted in Fig. 2. Aqueous extracts of stem and leaves significantly inhibited seed germination to compare to root extracts. Significant differences were not observed in the effect of stem and leaf extractions on seed germination of both targets.

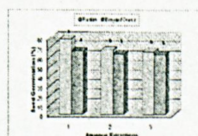

Fig. 2. Effect of water soluble extracts from different plant parts of *Brassica juncea* on seed germination of radish and barnyard grass: 1- Root extract, 2- Stem extract, 3- Leaf extract.

CONCLUSIONS

Our experiments demonstrated that:
1) *Seed Germination:* The aqueous extracts of *B. juncea* can reduce seed emergence of radish and barnyardgrass through the allelopathic effects. By increasing in concentration of root, stem and leaf aqueous extracts in excess of 300 gL^{-1} of Ensabi, prevented radish and barnyardgrass seed germination. At lower concentrations, the extracts, reduced the rates of seed germination, albeit at insignificant levels. Delayed seed germination also occurred.
2) *Radish and Barnyardgrass:* Roots were more sensitive than shoots to application of aqueous extracts of Ensabi. In the same vein, the extracts in excess of 300 gL^{-1} of Ensabi killed roots and shoots of emerged seedlings in radish. Exposure to 200-300 gL^{-1} Ensabi extracts prevented root formation in barnyardgrass.
The highly significant deleterious effects registered on seed germination, dry weights and lengths of radicle and hypocotyls of barnyardgrass and radish seedlings when exposed to aqueous extracts of Ensabi plants each in excess of 300g L^{-1} make the extracts a potential natural herbicide. It would be interesting to identify the active allelochemicals found in Ensabi. This remains a new frontier of further research activities.

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