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Importance of tiller habit in semideep water environment
(Pentingnya tabiat bilah anak padi terhadap keadaan separa tenggelam)

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Key words: tiller habit, compact, spreading, crop height

Abstrak
Kajian menggunakan 11 varieti padi terpilih telah menunjukkan bahawa jenis padi yang berbilah anak padat lebih tahan terhadap keadaan separa tenggelam pada peringkat akhir beranak dan peringkat bunting. Penukaran parameter bentuk pokok iaitu bilah anak dan daun, tidak akan menjejaskan bentuk pokok berbanding dengan yang bersifat berkembang (spreading). Sekembang dan Mat Candu menunjukkan rangsangan yang sama terhadap keadaan separa tenggelam walaupun tabiat bilah anak diubah daripada tabiat biasa. Sigadis dan FR 13A merupakan varieti yang mempunyai bilah anak yang cepat membesar.

Abstract
This study using eleven selected varieties showed that the intermediate compact tiller habit plant type was more tolerant to partial submergence at the late tillering to booting phases. Changes in tiller and leaf parameters in this plant type were not detrimental compared to those in the spreading tiller habit plant type. Sekembang and Mat Candu showed similar responses to partial submergence even when their tiller habit was changed. Sigadis and FR 13A were two entries with large tiller elongation capability.

Introduction
Many studies have been conducted with respect to growth physiology of floating rice, but studies for rice in the 'submerged areas' (Vergara et al. 1976) are less abundant if not scarce. This study, particular to Malaysian conditions, is a small contribution to the identification of important crop parameters for such areas.

In earlier studies on semideep water effects on rice growth, it was noticed that tiller death, leaf death and lodging after partial submergence were common. In this pond study in the main season of 1983–84, the primary objective was to identify which of the two tiller habits, compact and spreading, was more susceptible with respect to semideep water influences during the late tillering to booting phases.

Materials and methods
Eleven selected varieties were used. These were divided into two groups: **intermediate compact** and **spreading.** This division was based on the score for culm openness (tiller habit) in the germplasm record *(Table 1)*. For the **intermediate compact type,** small metal rings (diam. 4.5 cm) were wedged *within* each hill near its base. This caused the outer tillers to spread out. For the **spreading type,** larger

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Table 1. Tiller habit of varieties used in this study

Variety entry	Genetic stock accession no.	Main season maturation	Country origin	Tiller habit score*
Anak Anak	27	140	M	7
Jintang Koreng	594	136	M	7
Bengawan	200	140	IN	8
FR 13A	4 532	119	T	8
Sigadis	1 700	137	IN	7
Mat Candu	823	146	M	5
Sekembang	–	140	M	5
Hitam Sarawak A	528	138	M	5
Mayang Batir	871	157	M	5
Gading	448	157	M	5
Rempah	1 468	134	M	6

M = Malaysia IN = Indonesia T = Thailand
* Tiller habit scored on a scale of 1 to 9
1 = compact tiller habit
5 = intermediate compact tiller habit
9 = spreading tiller habit

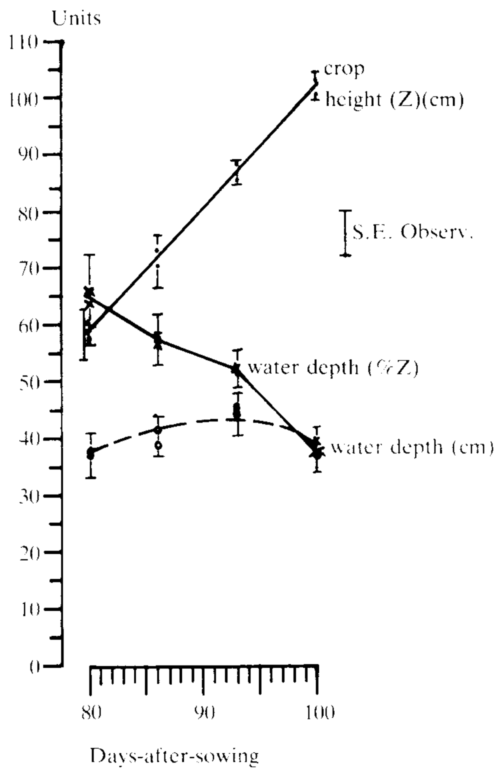

Figure 1. Crop height and water depth variation during the 20 days partial submergence treatment. (Pot study involving 11 entries M/S 1983–84)

metal rings (diam. 10 cm) were mounted at 10 cm above the pot soil surface and at 50% plant height of each hill in the pot. These rings closed the tillers of this tiller type. These tiller habit manipulations were carried out after the full manifestation of the tiller habit in the variety at 45 days after transplanting (DAT).

At 50 DAT the pots of both groups were immersed into the pond. The water depth in the pond varied from 37 cm to 45 cm, which correspond to 65% to 38% of crop height respectively, during the 20 days of partial submergence *(Figure 1)*. This 65% to 38% crop height variation was unavoidable and was incurred in the attempts to maintain 50% crop height immersion during this period of deep water treatment. As the crop height increased in response to deep water, even at the maximum water depth in the pond (45 cm), only 38% crop height immersion was achieved for the crop heights then. For all varieties, two hills spaced at 15 cm apart in the pot were the norm.

Fertilizer applications at 10 DAT were the equivalents of 40N, 30P and 20K kg/ha per pot, size 30 cm upper diameter, 26 cm lower diameter and 29 cm height. The fertilizers used were urea, Christmas

Table 2. Responses of compact and spreading tiller habit plant types in a semideep water environment. (Pot study in pond, Main season 1983–84)

Parameter	Treatment	Tiller habit		LSD 5% (Tr x TH) int'x
		I. Compact	Spreading	
Culm openness (°)	BC	55.0	61.1	3.2
	AC	36.3	39.5	
Tiller elongation (cm)	AC	31.4	39.9	2.7
	AT	32.3	48.0	
Tiller no./hill	BC	14.0	15.0	2.0
	BT	16.0	17.0	
	AC	13.0	13.0	1.0
	AT	15.0	13.0	
Tiller size (g/tiller)	AC	3.41	3.08	ns
	AT	3.05	3.23	
Tiller cross-section length (cm) (L)	AC	1.03	1.05	0.06
	AT	0.98	0.93	
Tiller cross-section width (cm) (W)	AC	0.75	0.72	0.04
	AT	0.74	0.66	
Tiller cross-section shape (L/W)	AC	1.38	1.47	0.07
	AT	1.30	1.42	
Leaf blade dry matter (%)	AC	42.6	33.7	ns
	AT	42.3	35.3	
Living leaves (%)	AC	22.1	19.9	ns
	AT	22.0	18.9	
Dead leaves (%)	AC	20.6	13.8	2.0
	AT	20.4	16.4	

C = non-altered state of tillers T = tillers made compact/spread out
B = before submergence treatment A = after submergence treatment
ns = interaction not significant
When the time (before/after submergence) is not indicated, all the data presented are for 5 days after recovery from submergence

Island Rock Phosphate and Muriate of Potash. Seedling age at transplanting was 30 days after sowing (DAS).

Culm openness was measured by the method of Mazaredo and Vergara (1977): the smaller the angle from the vertical axis the more compact the tiller habit. For each hill within the pot, five measurements were made. For determining the individual tiller height and tiller cross-section length and width, five randomly selected tillers per hill were used. These tiller cross-section parameters were measured at a height of 5 cm from the root-shoot junction. Tiller elongation was determined by the difference between tiller height before and after partial submergence. Tiller cross-section shape was determined by the ratio of tiller cross-section length and width. Tiller size was given by the dry weight in grammes of the tiller. Leaves were considered dead when more than half their laminae had died. All the leaf parameters were expressed as percentages of the total plant dry weight. All the parameters were measured both before immersion into the pond and at 5 days after recovery from the pond, except for tiller size, tiller cross-section and leaf parameters. The latter three parameters were recorded at 5 days after recove:y from the pond.

The layout in the pond was of a completely randomised design with eight pots per variety. Statistical analysis included comparisons of responses between the two tiller types. The 'control treatment' (C) was the one in which the tiller habit of the entry was not artificially altered.

Results and discussion

Responses of different tiller habit types

As indicated in *Table 2*, when the plants were immersed into the pond for 20 days (80–100 DAS), the intermediate compact plant type became more compact (36.3°), because of the buoyancy effect, compared with the spreading plant type (39.5°). This was so in spite of the lesser increase (18.7°) in compactness in this plant type compared with that (21.6°) in the spreading plant type. Even when the compact plant type were made spreading there were lesser induced tiller elongation (AC 31.4 cm to AT 32.3 cm) and induced tiller death (BC 14 to AC 13 or BT 16 to AT 15). There were also hardly any influence on leaf survival or tiller size, both in terms of weight per tiller or tiller cross-section length and width. Tillers of this phenotype tend to become slightly roundish, tiller cross-section shape index of 1.30 as opposed to 1.42 in the spreading plant type. Hence, if the water level should subside after 100 DAS (not tested here) it is likely that lodging will not occur as a result of culm weakness or too great an increase in crop height. According to Chang (1964), symmetrical culms possess greater buckling load than asymmetrical culms, and as such were more resistant to lodging. A decrease in plant height would decrease the bending moment at the lower internodes and hence makes the plant less likely to lodge.

In contrast, the semideep water environment induced greater tiller elongation (AC 39.9 to AT 48.0) and more tiller death (BC 15 to AC 13 or BT 17 to AT 13) in the spreading plant type even when these plants were made more compact. Tiller cross-section length and width were of lower values than those of the non-altered tiller treatment. However, tiller cross-section shape was not disturbed. Leaf death was enhanced in this plant type. Thus this phenotype will be more prone to lodge after the water level had subsided.

In floating rice, it has been reported that the plants which had more tillers suffered greater tiller loss when submerged than those which had lesser number of tillers (Chowdhury and Zaman 1970 as cited in Vergara et. al. 1976). A survey in Thailand by IRRI scientists (Anon. 1974) indicated that for floating rice low tillering was not associated with elongation ability. As floating rice tends to acquire a spreading tiller habit under deep water condition, the low tiller number may be a consequence of mutual shading caused by the spreading habit (Vergara et al. 1976). Thus, even in floating rice the spreading habit is not a positive factor for increasing the yield potential, but may be important in suppressing the weeds.

Interaction responses

Significant (variety x tiller manipulation) interactions were detected in culm openness, tiller elongation, tiller cross-section length and width, and percentage of dead leaves *(Table 3)*.

Culm openness When subjected to partial submergence, the intermediate compact tiller habit entries became more compact, smaller culm openness angle, with non-significant differences in culm openness among themselves. In the spreading tiller habit entries and except for Bengawan, a similar response was observed. There was no significant differences in culm openness between Mat Candu, Sekembang and FR 13A either in terms of their openness angle after the submergence treatment (AC) or in the 'improvement' (BC minus AC) of culm openness. Bengawan while being the most compact of this group after the submergence treatment, actually showed a magnitude (18.1°) of improvement in

Table 3. Influence of a 20-day period of partial submergence on culm openness and tiller characteristics of 11 varieties (Pot study in pond; Main season 1983–84)

Parameter	Treatment	Spreading tiller habit type					Intermediate compact tiller habit type						CV x %	LSD 5% (Tr. x V) Int'x
		AA	JK	BG	FR	SI	MC	SE	HS	MB	GA	RP		
Culm openness	BC	62.1	69.4	51.1	67.8	55.1	57.9	56.8	55.0	54.9	55.1	51.3	16.5	7.6
(degrees)	AC	39.9	39.9	33.0	41.5	43.1	35.5	34.4	34.9	36.5	36.6	39.8		
Tiller elongation	AC	33.7	37.8	20.9	48.8	58.3	43.3	28.1	30.9	28.6	22.1	35.4	17.2	6.3
(cm)	AT	37.7	44.9	26.4	62.0	69.0	42.7	28.4	32.3	27.4	26.4	36.6		
Tiller no./hill	BC	16.0	16.0	15.0	13.0	13.0	18.0	17.0	11.0	12.0	12.0	14.0	26.5	ns
	BT	19.0	15.0	18.0	17.0	14.0	18.0	19.0	15.0	12.0	13.0	16.0		
	AC	13.0	12.0	12.0	15.0	12.0	17.0	14.0	11.0	11.0	11.0	15.0	23.5	ns
	AT	13.0	12.0	13.0	17.0	12.0	18.0	15.0	15.0	13.0	15.0	14.0		
Tiller size	AC	3.25	3.05	2.35	2.74	3.99	3.20	2.50	3.66	3.38	4.62	3.12	41.7	ns
(g/tiller)	AT	3.38	3.19	3.12	2.64	3.82	3.16	2.95	2.92	3.26	2.64	3.36		
Tiller cross-section	AC	0.95	1.10	1.44	0.84	0.93	1.01	0.83	0.91	1.28	1.24	0.91	14.3	0.14
length (cm) (L)	AT	0.93	0.93	1.14	0.76	0.88	1.03	0.79	0.99	1.04	1.13	0.88		
Tiller cross-section	AC	0.71	0.74	0.90	0.58	0.65	0.70	0.61	0.69	0.93	0.89	0.70	14.2	0.07
width (cm) (W)	AT	0.68	0.68	0.75	0.54	0.64	0.74	0.63	0.74	0.75	0.86	0.70		
Tiller cross-section	AC	1.34	1.51	1.60	1.47	1.43	1.48	1.36	1.35	1.38	1.39	1.31	11.3	ns
shape (L/W)	AT	1.37	1.38	1.53	1.43	1.38	1.39	1.27	1.35	1.21	1.32	1.26		
* Leaf blade dry	AC	34.9	35.1	40.8	25.5	32.0	36.8	45.1	49.2	39.9	41.5	43.3	13.6	ns
matter (%)	AT	34.5	36.5	45.3	29.8	30.3	39.1	42.6	48.0	38.0	45.6	40.6		
* Living leaves (%)	AC	22.9	22.7	24.8	12.6	16.6	25.6	18.8	19.7	26.5	23.9	18.1	17.8	ns
	AT	24.2	21.8	23.7	11.5	13.4	24.8	17.0	22.4	25.7	24.5	17.3		
* Dead leaves (%)	AC	12.0	12.5	16.0	12.9	15.4	11.2	26.3	29.5	13.4	17.6	25.2	24.4	4.2
	AT	10.4	14.7	21.6	18.3	16.9	14.4	25.6	25.6	12.7	20.7	23.2		

AA = Anak Anak JK = Jintan Koreng BG = Bengawan
FR = FR 13A SI = Sigadis MC = Mat Candu
SE = Sekembang HS = Hitam Sarawak A MB = Mayang Batir
GA = Gading RP = Rempah
B = before submergence treatment C = non-altered state of tillers
A = after submergence treatment T = tillers made compact/spreading
* expressed as % total plant dry weight at 5 days after submergence treatment

culm openness similar to Mayang Batir (18.4°) and Gading (18.5°). Sigadis and Rempah responded similarly.

Tiller elongation, tiller cross-section length and width In the semideep water environment, it is important that increase in plant height be minimal to avoid lodging when the water subsides. This important criterion was evaluated by the tiller elongation parameter *(Table 3)*. Among the entries tested, FR 13A and Sigadis elongated the most for both tiller manipulations. Mat Candu and Sekembang hardly differ in the magnitude of elongation between tiller manipulations. Hitam Sarawak A, Mayang Batir and Rempah responded similarly as did Bengawan and Gading.

FR 13A and Sigadis which elongated the most were among the entries with small tiller cross-section lengths and widths irrespective of the tiller manipulations (AC and AT). Mat Candu and Sekembang again hardly differ in the magnitudes of these parameters between tiller manipulations. Bengawan with the least elongation values for the two tiller manipulations, also had large tiller cross-section parameters. Making the tiller habit more compact (AT) resulted in greater tiller elongation (20.9–26.4 cm) with concomitant reduction in tiller cross-section length (1.44–1.14 cm) and width (0.90–0.75 cm) in this entry. For Mayang Batir, making the tiller more spreading (AT) resulted in lesser tiller elongation (28.6–27.4 cm), tiller cross-section length (1.28–1.04 cm) and width (0.93–0.75 cm). The rest of the entries did not show any significant differences in tiller cross-section parameters between tiller manipulations. Hence, there was no relationship between degree of tiller elongation and tiller cross-section length and width.

Tiller cross-section shape When a cross-section of a tiller is made, the shape described is actually the result of two overlapping leaf sheaths and this shape varies from roundish to elliptical. This shape, to a certain extent, is described by the ratio of tiller cross-section length and width. While changes in tiller cross-section parameters occurred in some of the entries, the tiller cross-section shape at the 5-cm mark above the root-shoot junction, did not significantly change in any particular entry *(Table 3)*. Only when group comparisons were made *(Table 2)* was it realised that the intermediate compact tiller habit entries tended to become more roundish. Karin et al. (1982) showed that in the seedling stage, the ratio of the culm width-thickness was negatively correlated to the percentage seedling survival when submerged for 6 days at 30-cm water depth. The submergence tolerant varieties tend to be circular in their culm width-thickness ratio as opposed to the slender or flat shape of the susceptible varieties. They also attributed culm stiffness to the greater overlapping of the leaf sheaths. In later growth stages, cylindrical culms, degree of covering of the internodes by the leaf sheaths, tightness of the wrapping, and freshness and turgor of leaf sheaths are some of the important morphological factors for resistance to lodging (Chang 1964).

Leaf parameters Leaf parameters such as glabrousness, erectness and stiffness are important in the semideep water environment. For the submerged leaves, the degree of glabrousness will determine the amount of suspended materials in the water which will be trapped on the leaf surface and hence cut down photosynthesis leading to leaf death. Leaf erectness and stiffness will determine whether the leaves will be above the water surface as plant height increases or remain 'glued to' the water surface should plant height increase be minimal. Leaves which are not above the rising water surface would eventually die. Compacting the tiller habit may or may not ameliorate this constraint; leaf angles do not necessary relate to tiller habit.

In this study, the percentage of dead leaves was independent of the tiller manipulations in the intermediate compact tiller habit entries while in the spreading tiller habit entries percentage of dead leaves increased even when the tillers were made compact *(Table 2)*. Bengawan and FR 13A showed the greatest increase in the percentage of dead leaves *(Table 3)*. This is interesting given the fact that either entry was at the two opposing extremes of tiller elongation: Bengawan the least and FR 13A second only to Sigadis. The reason for this similar response by these two entries is not known.

It should also be noted that the percentages of leaf blade dry matter and living leaves tend to be higher in the intermediate compact tiller habit entries than in the spreading tiller habit entries irrespective of the tiller manipulations *(Table 2)*.

In complete submergence studies by Mazaredo and Vergara (1982), it was established that in submergence tolerant varieties like FR 13A, the seedling height increased rapidly to protrude its leaves above the water surface. In this way it ensures that photosynthesis continues to take place thereby aiding in rapid recovery from submergence. Submergence susceptible varieties did not rapidly increase in height and they could not replenish the depleted carbohydrates. Hence these entries could not recover. However, in this study the varieties were never completely submerged and it remains speculative if similar physiological mechanisms can be used to explain the responses.

Responses of Mat Candu and Sekembang

The overall consensus from the results presented in *Table 3* strongly showed the closeness in responses of Mat Candu and Sekembang. Herein lies one of the reasons why Sekembang was acceptable as a replacement for Mat Candu by the farmers of the Kerian Irrigation Scheme when it was released in 1979. Sekembang also yields higher than Mat Candu.

Conclusion

This study clearly indicates the importance of a compact tiller habit plant type for semideep water environment or an environment prone to flash floods during late tillering. The tiller elongation capability of FR 13A and Sigadis may be exploited if so desired.

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