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Effect of Plant Spacing on the Competitive Ability of Rice Growing in Association with Various Weed Communities at Different Nitrogen Levels

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雜草群落型別로 본 窒素施肥量과 栽植密度가 水稻의 競合力에 미치는 影響

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ABSTRACT

All types of weed community became dominant by *Monochoria vaginalis* (Burm.) Presl. as the nitrogen level increased. The importance value (I.V.) of *M. vaginalis* rapidly increased with increasing nitrogen level whereas the I.V. of other weed species decreased.

At the 10 x 10cm plant spacing, *M. vaginalis* was almost totally suppressed at all nitrogen levels. At the 20 x 20cm plant spacing, the degree of suppression declined with increasing nitrogen level. At the 30 x 30cm plant spacing, there was no suppression of *M. vaginalis* at the highest nitrogen level.

The yield obtained at the 10 x 10cm plant spacing when *M. vaginalis* was present was not significantly different from that obtained from the weed free plot for all rice cultivars while it was significantly reduced by *M. vaginalis* competition at the 20 x 20cm and 30 x 30cm plant spacings.

The difference in yield caused by *M. vaginalis* competition was primarily due to a reduction in the number of panicles at all nitrogen levels.

There was a high negative correlation between grain yield and weed weight at heading. The yield reduction due to weed competition varied depending upon the nitrogen level.

INTRODUCTION

Modern rice (*Oryza sativa L.*) cultivars are less competitive against weeds than traditional cultivars because of their short stature, high fertilizer requirement, early maturity and erect leaf orientation. Competitiveness is desired to partially control weeds but yield should not be sacrificed to overcome weeds by increasing the competitive ability of a cultivar. Moreover, competitiveness may be undesirable as it could mitigate against realization of some of the major objectives of breeding programs; lodging resistance, nitrogen responsiveness and high yield potential.

The competitive ability of rice needs to be enhanced by manipulating cultural practices such that condition are favorable for rice growth and unfavorable for weed growth. Generally, the competitive ability of rice is influenced by density of both crop and weeds, age of crop and weeds, spatial pattern, cultivar grown, weed species, growth rate of crop and weeds, time of emergence of weeds and crop and fertilizer level.

Ghosh et al. (1979) reported that the highest grain yield was obtained at a spacing of 15 x 15cm at 50kg/ha of N and a spacing of 20 x 20cm at 100kg/ha of N. Choubey et al. (1967) found that the highest grain yield was obtained at a plant spacing of 23 x 23cm. However, Baccam et al. (1975) found that grain yield was unaffected by plant spacing. Ghosh and Sarkar (1975) reported that the best weed control was achieved at a 10 x 10cm plant spacing. Estorninos and Moody (1976) also found that the closer rice is planted, the more competitive it is against weeds. Weed competition decreased appreciably when the plant spacing decreased from 25 x 25cm to 15 x 15cm. Decrease in yield due to weeds, compared with yields of the weed free check plot, averaged 18, 30, and 52% for plant spacing of 15 x 15cm, 20 x 20cm, and 25 x 25cm, respectively (Estorninos and Moody, 1976).

A greater response to weeding is also exhibited by the modern cultivars (Ghosh and Sarkar, 1975, Hoque et al., 1976; De Datta et al., 1969; Roxas and Genesila, 1977). Moody (1977) reported a highly significant negative correlation between yield reduction caused by weeds and plant height. Nitrogen application may also affect weed infestation. For rice, as nitrogen level increased, the amount of weed growth increased resulting in higher yield reductions at higher levels of nitrogen (De Datta et al., 1969; Okafor and De Datta, 1976).

In this paper an ecological approach to weed control in transplanted rice is explored.

MATERIALS AND METHODS

The experiment was conducted during the 1978 wet season at the experimental farm of the International Rice Research Institute. Three nitrogen levels (0,80, and 160kg/ha) were used as the mainplots while four weed communities (*Echinochloa* sp., *M. vaginalis, Echinochloa* sp. + *M. vaginalis* and weed free) were used as the subplots. Different rice cultivars (None, IR32, IR38, and IR32 + IR38) grown at various crop spacings (10 x 10, 20 x 20, and 30 x 30cm) were used as the sub-subplots. The mixture of the two rice cultivars was achieved by planting alternate rows of each cultivar. To ensure the desired weed community, seeds of *M. vaginalis* and *Echinochloa* sp. were applied to the different plots just after transplanting. Hand weeding in the weed free plot was done 20 and 40 days after transplanting (DAT).

The field was plowed once and harrowed three times at 7 to 10 day intervals. The final harrowing was done 1 day before transplanting to level the field and to incorporate the basal doses of fertilizer and insecticide. Nitrogen was applied in three equal splits for all nitrogen levels, basally, at maximum tillering, and at panicle initiation while 40kg/ha of P_2O_5 and 40kg/ha of K_2O were applied as basal applications.

For insect control, carbofuran (2, 3-dihydro-2, 2-dimethyl benzofuran-7-ylmethylcarbamate) at 1.5kg active ingredient (a.i.)/ha was applied basally and ethylan/1,1-dichloro-s,s-bis (4-ethyl phenyl) ethane/ at 0.75kg a.i./ha was applied at 2 – to 3 – week intervals.

For rice and weeds, plant height, number, leaf area index (LAI), and dry weight were determined at 40 DAT, at rice heading, and at maturity of rice. Light transmission ratio (LTR) was measured at rice heading using the Friend method (1961). The vertical structure of rice and weeds was measured at rice heading using the sakai method (1953). For this, rice and weeds were clipped at 20cm intervals from ground level and separated into photosynthetic non-photosynthetic organs, dried, and weighed.

RESULTS AND DISCUSSION

The three different weed community types were analyzed using the importance value based on weed weight and Simpson's index (Cited in Whittaker, 1965) (Table 1). Despite applying weed seeds to each community, the results were not satisfactory since natural competition inhibited the growth of the *Echinochloa* species. As indicated by Simpson's index, the concentration of dominance of all community types increased as the nitrogen level increased. All community types became dominated by *M.*

Table 1. The summed dominance ratio (SDR) and the degree of dominance of weed species in different weed communities.

Community type	Weed species	Summed dominance ratio Nitrogen level (kg/ha) 0	80	160
Echinochloa	Echinochloa sp.	9.1	16.7	13.4
	Monochoria vaginalis	60.0	69.3	80.4
	Sedges	30.9	14.0	6.2
	$C = \Sigma (Y/n)^2$	0.47	0.53	0.67
Monochoria	Echinochloa sp.	6.9	4.3	2.6
	Monochoria vaginalis	64.9	86.2	93.4
	Sedges	28.2	9.5	4.0
	$C = \Sigma (Y/n)^2$	0.51	0.75	0.87
Echinochloa + Monochoria	Echinochloa sp.	11.4	6.7	6.0
	Monochoria vaginalis	50.6	88.4	90.4
	Sedges	38.0	4.9	3.6
	$C = \Sigma (Y/n)^2$	0.42	0.79	0.83

$$\text{Summed dominance ratio} = \frac{\text{Relative dry weight} + \text{Relative density \%}}{2}$$

Simpson's index: $C = \Sigma(Y/n)^2$

C is a measurement of concentration of dominanee

Y is the importance of a given species

n is the sum of the importance values for all species in sample.

vaginalis as the nitrogen level increased. The importance value of *M. vaginalis* rapidly increased with increasing nitrogen level whereas the importance values of other weed species decreased implying that the plasticity of *M. vaginalis* was much greater than the other weed species. Because of the dominance of *M. vaginalis* in all weed communities, further discussion will concentrate primarily on this weed. The response of the weed communities was the same for each rice stand used. Further discussion will deal with IR32 unless otherwise stated.

The height of *M. vaginalis* increased with increasing nitrogen for all rice spacings and when no-rice was planted except at the closest plant spacing (Fig. 1). The maximum height of *M. vaginalis* was reached at rice heading at 0kg/ha of N. However, when 80 or 160kg/ha of N applied, the height continued to increase up to maturity (Fig. 1).

At 160kg/ha of N *M. vaginalis* reached a height of about 110cm in both the 30 x 30cm plant spacing and the no rice plot. These plants were taller than

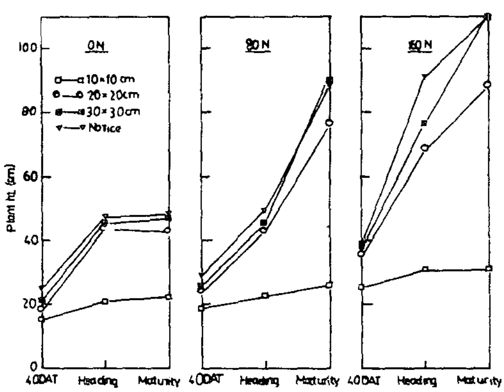

Fig. 1. Height of *M. vaginalis* at various growth stages as affected by crop spacing and nitrogen level. IRRI, 1978 wet season.

rice. The plant height of *M. vaginalis* also increased with increasing plant spacing although little difference in plant heights was observed between the 20 x 20cm plant spacing, the 30 x 30cm plant spacing and the no-rice plot (Fig. 1) At the closest rice spacing, *M. vaginalis* growth was greatly reduced even though it was not affected for the first 10 days by the

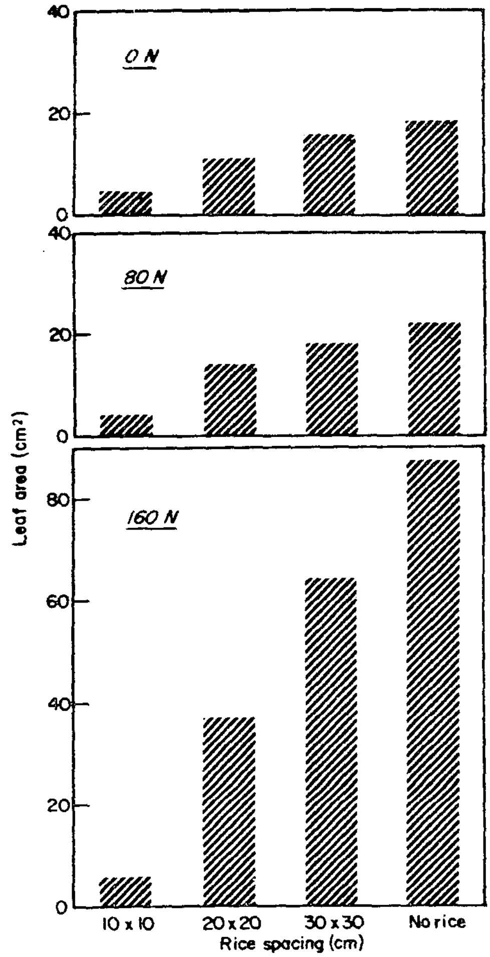

Fig. 2. Average leaf size of *Monochoria vaginalis* as affected by crop spacing and nitrogen level.

spacing variable. The most likely reason for the suppression of *M. vaginalis* at the closest rice spacing was the rapid closing of the rice canopy. When the rice canopy intercepted most of the light, only the far-red light penetrated the rice canopy causing inhibition of photosynthesis by *M. vaginalis.* The greatest leaf area per *M. vaginalis* plant was obtained at the highest nitrogen level for all plant spacings although increases were very small at the closest spacing (Fig. 2). At the widest plant spacing and in the no-rice plot as more nitrogen was applied, the larger was the size of individual *M. vaginalis* leaves.

At the highest nitrogen level, the individual leaf size was almost four times as large as that at the other nitrogen levels except at the closest rice spacing. At the closest rice spacing, the leaf area per individual *M. vaginalis* leaf was the smallest and it was virtually unaffected by increase in nitrogen level. Leaf area also increased with increasing plant spacing (Fig. 2), the largest leaves being found in the no-rice plots. The total number of *M. vaginalis* per unit area decreased greatly with increasing nitrogen except at the closest spacing (Fig. 3). The number of *M. vaginalis* per unit area at 80 and 160kg/ha of N decreased from 40 DAT to rice heading while it increased at the 0 nitrogen level (Fig. 3).

Thus, *M. vaginalis* showed not only plastic response

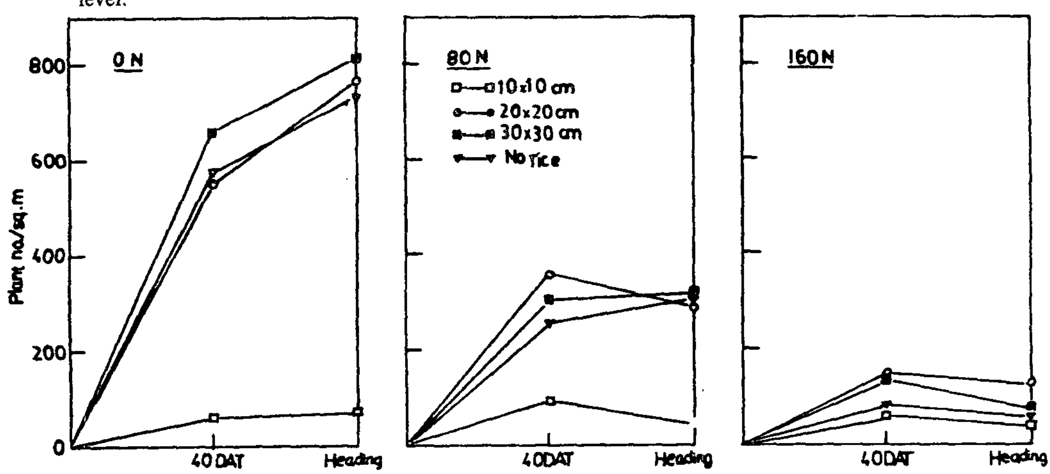

Fig. 3. Number of *M. vaginalis* plants per m^2 at 40 DAT and the heading stage of rice as affected by nitrogen level. IRRI, 1978 wet season.

but also a mortalistic response to increased nitrogen level. Individual *M. vaginalis* plants increased rapidly in dry matter as the nitrogen level increased at all rice spacings except at the closest spacing (Fig. 4).

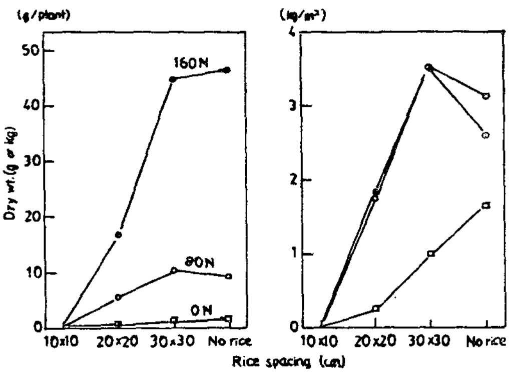

Fig. 4. Dry weight of *M. vaginalis* per plant and per m^2 at rice maturity as affected by crop spacing. IRRI, 1978 wet season.

This increase in size was inhibited at the closest rice spacing. The weight of individual plant also increased as plant spacing increased although there was very little difference in weight between the plants growing in association with the rice that was transplanted at a 30 x 30cm plant spacing and the no-rice plots.

In terms of dry weight per square meter, however, there was no difference between 80 and 160kg/ha of N because there were more plants per unit area at 80kg/ha of N than at 160kg/ha of N (Fig. 4). At the 10 x 10cm plant spacing, *M. vaginalis* was almost totally suppressed at all nitrogen levels (Table 2) and possibly regulated by intraspecific competition.

Table 2. Degree of suppression of *Monochoria vaginalis* due to different crop spacings.

Nitrogen level (kg/ha)	Crop spacing (cm)	Degree of suppression (%)
0	10 x 10	99
	20 x 20	80
	30 x 30	39
80	10 x 10	100
	20 x 20	45
	30 x 30	0
160	10 x 10	100
	20 x 20	28
	30 x 30	0

At the 20 x 20cm plant spacing, the degree of suppression declined with increasing nitrogen level. At the 30 x 30cm plant spacing, there was no suppression of *M. vaginalis* when 80 and 160kg/ha of N was applied. For the widest spacing at 80 and 160kg/ha of N, the population of *M. vaginalis* was

Table 3. Seed production of *Monochoria vaginalis* at various crop spacings and nitrogen levels.

Nitrogen level (kg/ha)	Crop spacing (cm)	No. of fruits per plant	No. of seeds per fruit	Total No. of seeds per plant	No. of seeds per sq. m.	No. of potential[1] weeds per sq. m.
0	10 x 10	0	0	0	0	0
	20 x 20	6.5	202.7	1,327	1,023,117	716,182
	30 x 30	10.5	225.4	2,362	1,920,306	1,344,214
	No rice	14.1	225.2	3,183	2,329,956	1,630,969
80	10 x 10	0	0	0	0	0
	20 x 20	15.6	221.0	3,466	1,008,606	706,024
	30 x 30	31.8	229.7	7,314	2,362,422	1,653,695
	No rice	34.2	247.4	8,476	2,686,892	1,880,824
160	10 x 10	0	0	0	0	0
	20 x 20	41.0	292.5	11,999	1,511,874	1,058,312
	30 x 30	58.7	297.0	17,394	1,304,550	913,185
	No rice	77.9	295.7	22,996	1,264,780	885,346

[1] No. of potential weeds were computed based on 70% of viability.

not by competition from the rice. The number of seeds per fruit and the number of seeds per individual plant increased as the nitrogen level and plant spacing increased in the no-rice plot and all plant spacings except the closest plant spacing (Table 3). Pancho (1964) reported that the seed production of *M. vaginalis* was approximately 6,000 per plant. A similar number was observed in this study when 80kg/ha of N was spaced at 20 x 20cm. Even though the number of seeds per plant increased as nitrogen level increased, the total number of seeds per square meter decreased at 160kg/ha of N compared to 80kg/ha of nitrogen because there were less plants per unit area at the highest N level. In a germination test, there was no difference in the viability of *M. vaginalis* seeds at the different rice spacings and nitrogen levels. The germination percentage was always about 70%. Based on this percentage, the number of potential *M. vaginalis* plants per unit area was computed (Table 3). The number of potential plants of *M. vaginalis* per unit area was not significantly different between 0 and 80kg/ha of N for each plant spacing while the number was significantly lower at 160kg/ha of N for the 20 x 20cm and 30 x 30cm plant spacings.

The changes of the productive structures of rice caused by different plant spacings and the presence of *M. vaginalis* were similar for all rice cultivars. Generally, the leaves and culms of rice were severely depressed by *M. vaginalis* as nitrogen level increased at the 20 x 20cm plant spacing and the 30 x 30cm plant spacing (Figs. 5, 6, and 7).

At 0 and 80kg/ha of N, the canopy level of the *M. vaginalis* was located below the rice canopy. At 160kg/ha of N, however, this situation was reversed; the rice canopy was located below the *M. vaginalis*

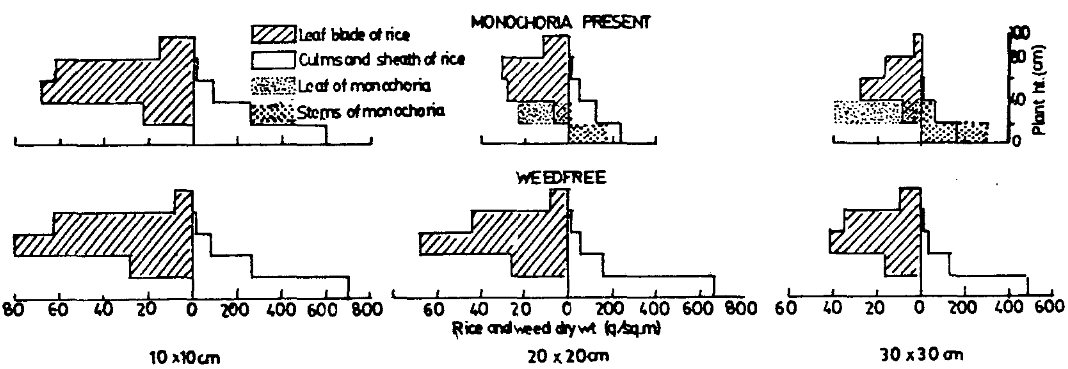

Fig. 5. Changes in the productive structures of IR32 rice as affected by crop spacing and competition with *M. vaginalis* at 0 kg N/ha. IRRI, 1978 wet season.

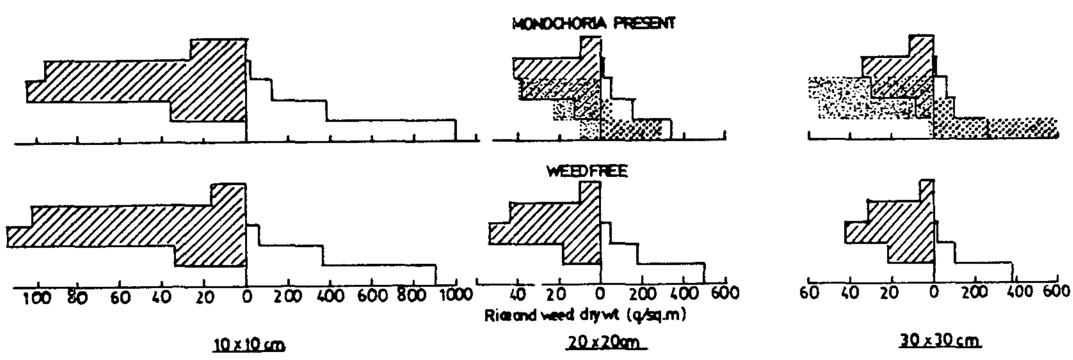

Fig. 6. Changes in the productive structures of IR32 rice as affected by crop spacing and competition with *M. vaginalis* at 80 kg N/ha. IRRI, 1978 wet season.

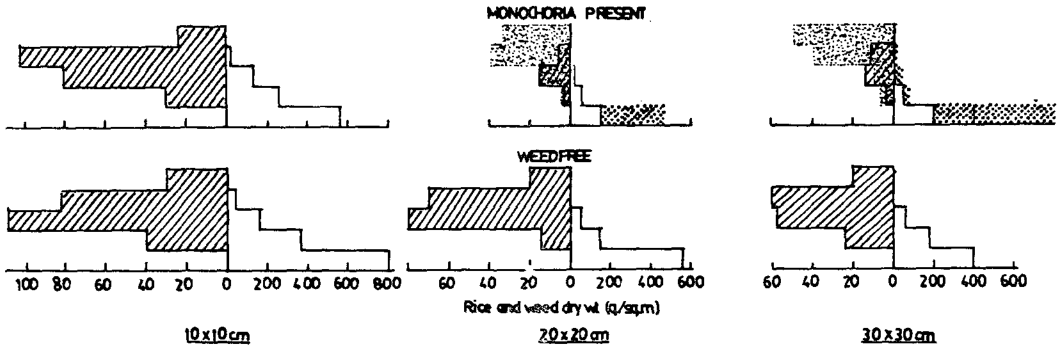

Fig. 7. Changes in the productive structures of IR32 rice as affected by crop spacing and competition with *M. vaginalis* at 160 kg N/ha. IRRI, 1978 wet season.

canopy indicating that *M. vaginalis* was much more competitive for light at the highest level of applied nitrogen. These results disagree with previous reports that *M. vaginalis* could not compete for light as well as *Echinochloa* sp. due to its short plant height (Chisaka, 1966; Lubigan and Vega, 1971; Arai and Kawashima, 1956). The LTR increased with increasing plant spacing and decreased with increasing nitrogen level in the weed free plots (Fig. 8). In the presence of *M. vaginalis* at the highest

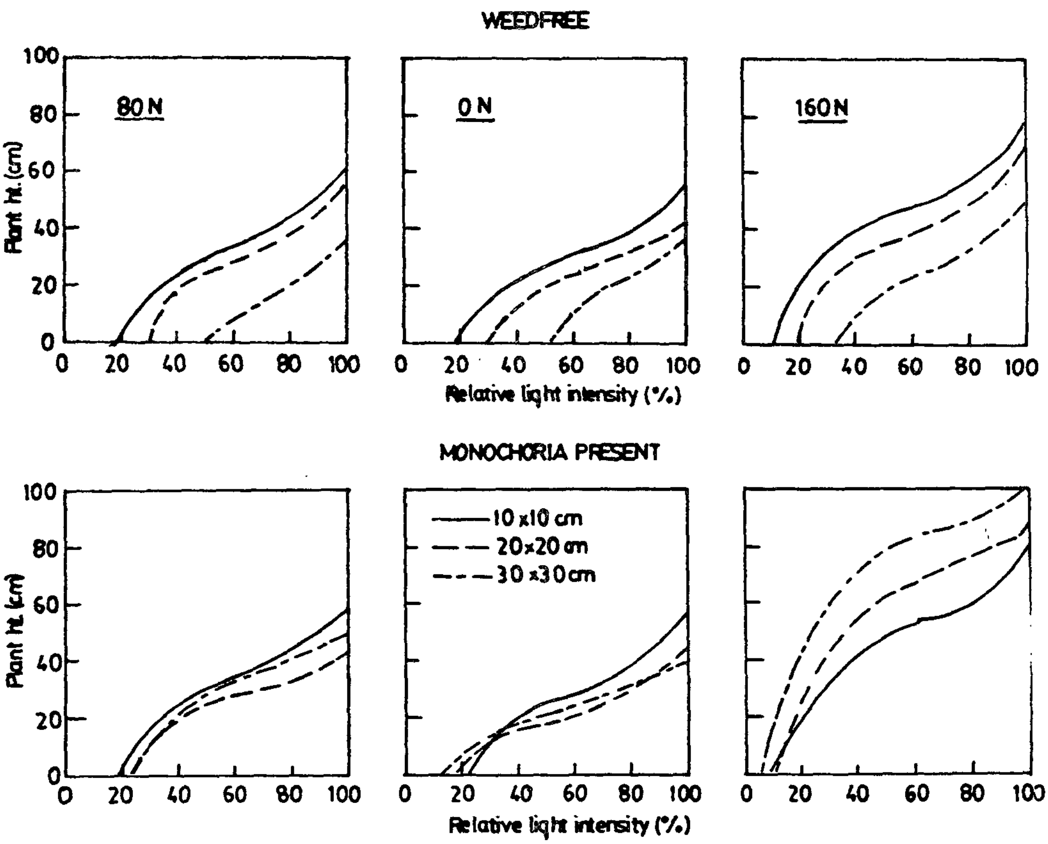

Fig. 8. Light transmission ratio of IR32 rice at heading stage as affected by nitrogen level and competition with *M.* vaginalis. IRRI, 1978 wet season.

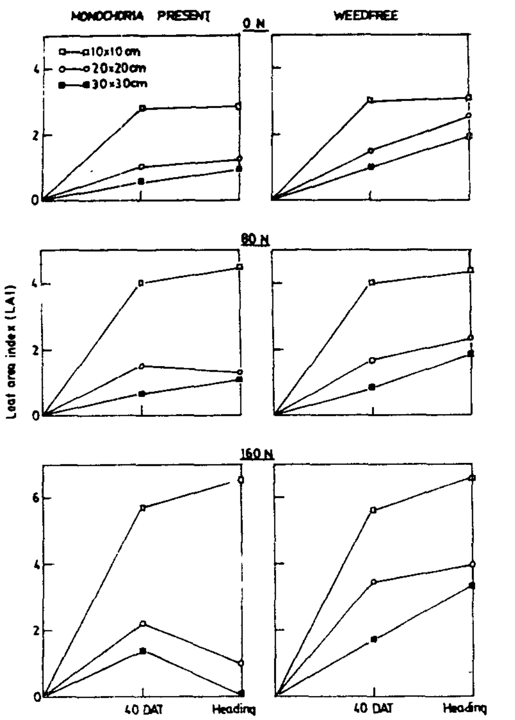

Fig. 9. Leaf area index of IR32 rice as affected by crop spacing and competition from *M. vaginalis* at different nitrogen levels. IRRI, 1978 wet season.

nitrogen level, this trend was reversed. The lowest LTR was obtained at the widest rice spacing due to heavy infestation of *M. vaginalis.* The highest LAI of rice was obtained at the closest plant spacing in the presence and absence of weeds (Fig. 9). In the weed free plot, the LAI increased up to rice heading for all plant spacings. In the presence of *M. vaginalis,* the LAI showed the same relationship as the weed free plot for the 10 x 10cm plant spacing. Similar trends were also observed for the 20 x 20cm and 30 x 30cm plant spacings at 0 and 80kg/ha of N. At 160kg/ha of N, however, the LAI decreased from 40 DAT at the 20 x 20cm and 30 x 30cm plant spacings due to competition. The percentage decrease in the LAI at heading due to competition from *M. vaginalis* was about 40% at the 20 x 20cm and 30 x 30cm plant spacings at 0 and 80kg/ha of N while it was about 75% for 20 x 20cm plant spacing and 94% for the 30 x 30cm plant spacing at 160kg/ha of N. Yield reduction of IR32 and the mixture of the two rice cultivars due to *M. vaginalis* competition increased as the plant spacing tended to increase as the fertility level

Table 4. Grain yield at various rice spacings and nitrogen levels in the presence of *Monochoria vaginalis*.

Rice cultivar		Crop spacing (cm)	Grain yield (t/ha)[1] Nitrogen level (kg/ha) 0	80	160
IR32	*Monochoria* present	10 x 10	2.9a	3.9a	3.3a
		20 x 20	2.2 b	2.3 c	0.5 b
		30 x 30	1.1 c	1.7 d	0.0 c
IR38		10 x 10	2.7a	2.9 b	3.1a
		20 x 20	1.5 c	1.8 d	0.6 b
		30 x 30	0.4 d	1.1 e	0.0 c
IR32	Weed free	10 x 10	2.7a	3.6a	3.1a
		20 x 20	2.5ab	3.0 bc	3.1a
		30 x 30	2.3 b	2.9 cd	2.5 b
IR38		10 x 10	2.6ab	2.9 cd	3.1a
		20 x 20	2.0 bc	2.0 e	2.5 b
		30 x 30	1.6 c	1.7 e	1.9 c

[1] In a column within a weeding regime, means followed by a common letter are not significantly different at the 5% level.

increased except at the 10 x 10cm plant spacing where yield decrease was not observed (Table 4). At the closest plant spacing, the yield obtained from the plot of *M. vaginalis* was present was not significantly different from that obtained from the weed free plot. In the weed free plots, the yield did not differ between plant spacings at 0kg/ha of N. At 80kg/ha of N, significantly higher yield was obtained from the 10 x 10cm plant spacing than the 20 x 20cm and 30 x 30cm plant spacings which did not differ significantly from each other. No difference was observed between the 10 x 10cm and 20 x 20cm plant spacings at 160kg/ha of N but the 30 x 30cm plant spacing significantly yielded less. IR38 showed the same trend as for IR32 when *M. vaginalis* was present. However in the weed-free plot, significantly higher yield was obtained at all nitrogen levels from the 10 x 10cm plant spacing than the other plant spacings which did not differ significantly. The difference in yield caused by weed competition was

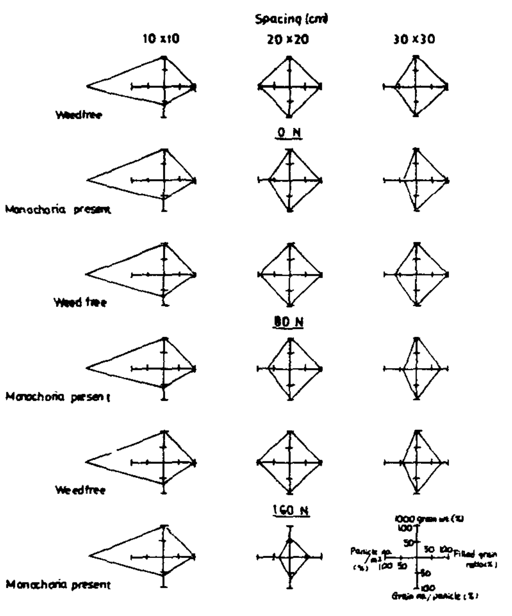

Fig. 10. Changes in yield components of IR32 rice as affected by competition with *M. vaginalis* at various plant spacings and nitrogen levels. (Each yield component is assumed to be 100% under weed free conditions at the 20 x 20cm spacing in each nitrogen levle.) IRRI, 1978 wet season.

primarily due to a reduction in the number of panicles at all nitrogen levels (Fig. 10). At the 10 x 10cm plant spacing, in the presence and absence of *M. vaginalis*, the number of panicles increased at all nitrogen levels while the number of grains per panicle decreased compared with the 20 x 20cm and 30 x 30cm plant spacings. The weight of 1000-grains was not affected by the various treatments except at the highest nitrogen level at the 20 x 20cm plant spacing in the presence of *M. vaginalis*. These results were similar to those reported by Noda (1968) and Kim et al. (1977). The degree of reduction in panicle number per unit area due to weed competition and plant spacing increased as the fertility level increased except at the 10 x 10cm plant spacing where the presence of *M. vaginalis* had no effect on the number of panicles. The greatest reduction was observed at the 30 x 30cm plant spacing. There was a high negative correlation between grain yield and weed weights at heading (Fig. 11). The yield reduction due to weed competition varied depending upon the nitrogen level. The yield reduction at 0 and 160kg/ha of N was about the same while it was lower at 80kg/ha of N The weed weights required for 50% yield reduction were approximately 330g/m^2 for 0 and 160kg/ha of N and 520g/m^2 for 80kg/ha of N. This could possibly be explained by the fact that at 0kg/ha of N, nitrogen will be the most limiting factor for growth. The available nitrogen will be exhausted rapidly by the weeds and the rice, therefore, less weeds will be needed to severely inhibit rice growth than at a higher nitrogen level. At 80kg/ha of N, competition will be less severe between rice and weeds and therefore, more weed weight will be required to decrease the rice yield the same amount as at 0kg/ha of N. At 160kg/ha of N, however, the pattern of competition was different from the lower nitrogen levels (see Fig. 7). The primary competition was for light at 160kg/ha of N while it was for nutrients at 0 and 80kg/ha of N. Because of these different competition patterns, less weed weight was required to reduce the rice yield at 160kg/ha of N compared to 80kg/ha of N.

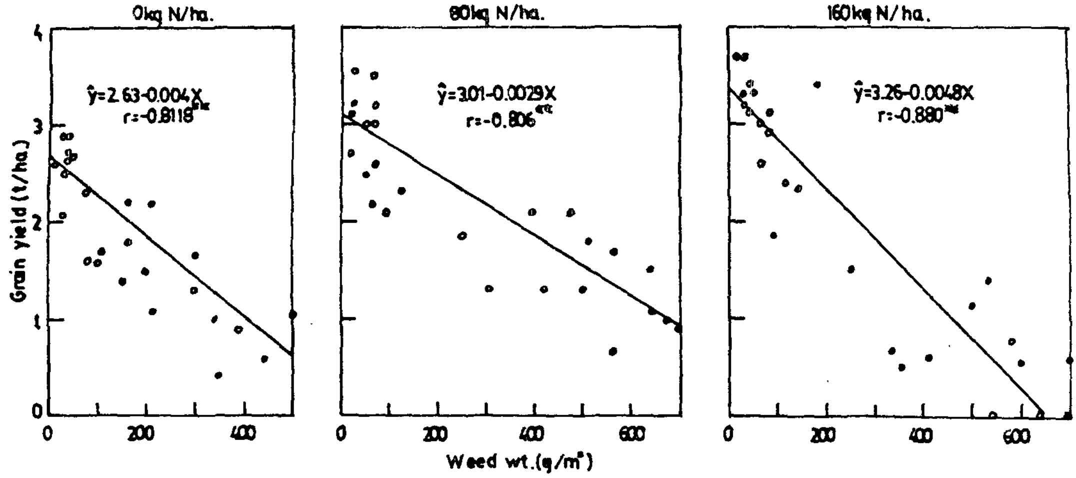

Fig. 11. Relationship between grain yield and weed weight at various nitrogen levels. IRRI, 1978 wet season.

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摘　　要

雜草群落型別(피, 물달개비, 피+물달개피群落型), 窒素施肥量(0, 80, 160 kg/ha)에 따른 水稻栽植距離(10×10 cm, 20×20 cm, 30×30 cm)가 雜草와의 競爭에 미치는 影響을 究明하고자 1978年에 필리핀所在 國際米作硏究所(IRRI) 試驗圃場에서 圃場實驗으로 實施한 結果를 要約하면 다음과 같다.

1. 雜草의 優點度는 窒素施用量에 따라 差異가 있었는데 窒素施用量이 增加될 수록 물달개비의 優點度는 높아졌으나, 피와 방동산이科 雜草는 減少되었다.

2. 栽植距離 10×10 cm區에서는 雜草發生 抑制效果가 窒素施用量이 增加할 수록 低下되었으며, 30×30 cm多肥區(160 kg/ha)에서는 전혀 雜草抑制 效果가 認定되지 않았다.

3. 栽植距離 10×10 cm區에서는 除草區와 無除草區間의 收量差異가 없었으나, 栽植距離 20×20 cm와 30×30 cm區에서는 無除草區에서 顯著한 收量減少를 招來하였는데, 그 程度는 30×30 cm區에서 더욱 컸다.

4. 雜草와의 競爭에 依한 水稻收量減少는 收量構成要素中 穗數減少가 가장 큰 要因이었다.

5. 雜草發生量과 水稻收量減少率과의 關係는 負의 相關關係가 있었는데, 그 程度는 施肥量이 增加할 수록 컸다.