

The influence of variety, fertiliser and season on crop lodging in rice and their effects on yield and other characteristics

(Pengaruh varieti, baja dan musim terhadap kerebahan tanaman padi serta kesannya terhadap hasil dan ciri lain)

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Key words: rice, lodging, yield, varieties, nitrogen, season

Abstrak

Rebah merupakan fenomena biasa dalam penanaman padi. Kejadian rebah menjejaskan hasil. Faktor-faktor yang berhubungkait dengan rebah termasuk ciri varieti, kadar pembajaan nitrogen dan musim penanaman. Hasil daripada kajian menunjukkan bahawa varieti MR 84 dan MR 101 lebih toleran terhadap rebah berbanding dengan varieti MR 81 dan MR 71. Ciri varieti yang berhubungkait dengan kerentanan terhadap rebah ialah ketinggian pokok. Penambahan kadar nitrogen (sehingga 160 kg/ha) meningkatkan kerentanan terhadap rebah (3–38%). Kejadian rebah didapati lebih tinggi pada luar musim. Kesan tindak balas antara musim, varieti dan kadar nitrogen terhadap rebah juga dibincangkan. Berdasarkan hasil daripada kajian, cadangan untuk mengatasi masalah rebah dan meningkatkan hasil dikemukakan.

Abstract

Lodging is a common phenomenon in rice cultivation. Occurrence of lodging reduces yield. Factors associated with lodging include varietal characteristics, rate of nitrogen fertiliser applied and season. Results indicated that varieties MR 84 and MR 101 were more tolerant to lodging than MR 81 and MR 71. Varietal characteristic associated with susceptibility to lodging was plant height. Increasing the nitrogen rates (up to 160 kg/ha) increased lodging susceptibility (3–38%). Occurrence of lodging was found to be more severe in the off-season. Interaction of variety, nitrogen and season effect on lodging is also discussed. Based on the results, recommendations to overcome the lodging problem and thus increase yield are suggested.

Introduction

Lodging is common in present day rice cultivation. Losses due to lodging can be as high as 57.5% (Alias et al. 1989). Studies by Jennings and Sornchai (1964) showed that marked losses in yield resulted from lodging

in weak-strawed varieties at high nitrogen levels. Among the MARDI rice varieties planted, some are found to be more prone to lodging than the others. Seasonal effects on lodging have also been reported (Alias et al. 1989).

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This study was done to determine the influence of variety, nitrogen levels and seasons on crop lodging in rice cultivation in MADA. The influences of these factors on the relevant plant characters related to lodging were also observed. The subsequent effects of lodging on the yield component and thus the yield will also be discussed.

Materials and methods

Four MARDI rice varieties (MR 71, MR 81, MR 84 and MR 101) were selected for the experiment. Selection of the varieties was based on observed resistance to lodging. MR 71 and MR 81 were found to be susceptible while MR 84 and MR 101 were less susceptible. Four nitrogen (N) rates i.e. 0, 40, 80 and 160 kg/ha were tested. Phosphorus and potassium were standard recommendations of 30 kg/ha and 20 kg/ha respectively. The treatments were arranged in a split plot design in three replications, with nitrogen rate as the main plot and variety as the sub-plot.

The experiment was carried out over two seasons, the off-season 1989 (1/89) and the main season 89/90 (2/89), to observe if there was any seasonal influence on lodging. The experimental site was located at Telok Chengai, Kedah (class 1 soil), in the Muda Irrigation Scheme.

Twenty-five-day-old seedlings were transplanted at 25 cm x 25 cm spacing in standard plot size of 5 m by 5 m. Fertiliser was applied in two splits according to the recommended practice. First fertiliser application was at 15 days after transplanting (DAT) including half of the nitrogen and all of the phosphorus and potassium. The other half of the nitrogen was applied at crop panicle initiation stage.

Records on plant height, panicle length, panicle number, spikelet number, percentage of unfilled grains, 1 000-grain weight and plot yield were taken at final harvest. Records on lodging were taken whenever lodging was observed. This was based on the percentage of plants lodged and the growth stage at which lodging occurred.

Analyses of variance for the treatments (variety, nitrogen and season) were computed on all the recorded parameters. This analysis was required to find the parameters influenced by the three factors.

Correlation between lodging and the parameters recorded were also computed to determine which were the recorded parameters related (associated) with lodging and how the treatment factors affected them. Regression between nitrogen rate and yield for each season was also computed.

Results and discussion

Effect of treatment on lodging

For the combined analysis of lodging percentage, the arcsine transformed values were used. Lodging in rice was very significantly affected by variety, nitrogen and season (*Table 1*). Variety MR 71 and MR 81 were more susceptible to lodging the occurrence of which was more prominent in the off-season. Increased nitrogen led to an increase in lodging, from 3% at 0 kg N/ha and reached 38% at 160 kg N/ha.

Significant nitrogen and variety interaction indicates that occurrence of lodging in a variety was also influenced by nitrogen rate. All varieties became more susceptible to lodging with increasing nitrogen rate. Increased nitrogen had greater influence on MR 81 and MR 71 compared with MR 84 and MR 101 (*Figure 1*). Variety MR 81 had no lodging at 0 kg N/ha. However, lodging progressively increased and reached 73% at 160 kg N/ha. Variety MR 71 had 13% lodging at 0 kg N/ha and 46% at 160 kg N/ha. Both MR 101 and MR 84 had no lodging at 0 kg N/ha but 11% and 22% respectively lodged at 160 kg N/ha.

The occurrence of lodging in a variety was also influenced by season, as indicated by the significant season and variety interaction. MR 101 and MR 84 did not lodge in the main season but recorded 7% and 21% lodging respectively in the off-season. MR 71 and MR 81 had lower occurrence of lodging in the main season (8% and 30% respectively) as compared

Table 1. Analysis of variance for yield and other characteristics (F-value)

Source	df	Lodging (%)	Yield	Height	Unfilled grains (%)
Season (S)	1	53.64**	107.76**	470.56**	264.96**
Rep (season)	4				
N-rate	3	19.68**	6.46**	12.56**	14.75**
Season x N-rate	3	3.25ns	9.46**	3.86*	6.12**
Error (a) pooled	12				
Variety	3	36.34**	10.09**	171.99**	29.71**
Season x variety	3	8.17**	11.55**	24.79**	2.03ns
N-rate x variety	9	4.04**	0.31ns	3.48**	4.96**
Season x N-rate x variety	9	1.79ns	0.13ns	3.44**	1.95ns
Error (b) pooled	48				
Total	95				

*significant at $p < 0.05$

**significant at $p < 0.01$

ns = non significant

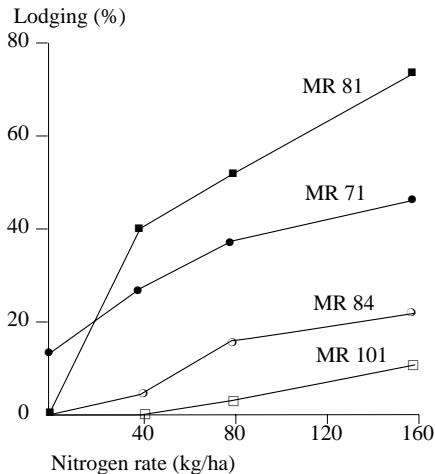


Figure 1. Effect of variety and nitrogen on lodging of four rice varieties

with 55% and 52% respectively in the off-season (Figure 2). This shows that all varieties were more susceptible to lodging in the off-season.

Lodging tolerance is an inherent varietal characteristic. However, environmental factors have been known to influence these characters. Lodging has been observed to occur during the reproductive stage of the crop phase which for the off-season crop falls in July to August. This coincides with the period of heavy rain, high windspeed (>6 m/s) and low sunshine. In

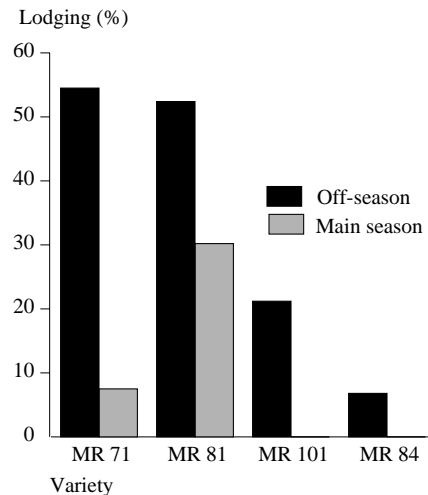
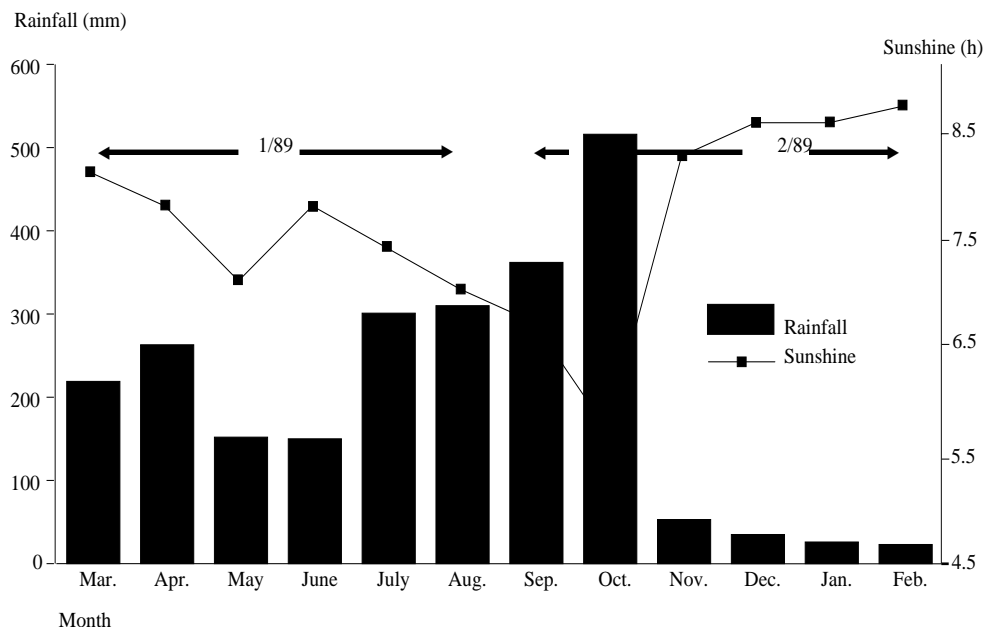


Figure 2. Effect of variety and season on lodging of four rice varieties

contrast, the reproductive phase of the main-season crop occurred in January to February, during which the weather is characterised by dry sunny days with low rainfall and low windspeed of less than 6 m/s (Figure 3 and Table 2). The higher occurrence of lodging in the off-season crop can thus be directly attributed to the direct impact of external forces of wind and rain.

The influence of increased nitrogen on lodging in a variety will be discussed in relation to its indirect influence on parameters associated with lodging.



Source: Malaysian Meteorological Service

Figure 3. Sunshine and rainfall distribution

Table 2. Windspeed from crop heading to maturity in relation to season

Month	Duration (h) of windspeed	
	>6 m/s	5–6 m/s
Off-season (1/89)		
July	3	9
Aug.	4	1
Main season (2/89)		
Jan.	0	29
Feb.	0	8

Table 3. Correlation coefficients of lodging and plant characteristics

Plant characteristic	r-value
Culm height	0.66**
Panicle number	0.03ns
Panicle length	0.23ns
Spikelet number	0.04ns
1 000-grain weight	-0.02ns
% unfilled grains	0.67**
Yield	-0.54**

**significant at $p < 0.01$

ns = non-significant

Plant characters associated with lodging

Significant correlation with lodging was observed only on culm height ($r = 0.06$ at $p < 0.01$), percentage of unfilled grains ($r = 0.67$ at $p < 0.01$) and yield ($r = -0.54$ at $p < 0.01$), as shown in Table 3.

The positive correlation between culm height and lodging indicates that increased lodging is associated with increased culm height (taller plants). Likewise is the positive correlation between percentage of unfilled grains (spikelet sterility) and lodging. Taller plants led to increased

lodging. Increase of unfilled grains is the result of increased lodging incidence. The significant negative correlation between lodging and yield indicates that increased lodging is associated with decreased yield. The complete relationship would thus be: increased plant height led to increased lodging, which in turn led to increased percentage of unfilled grains and ultimately decreased yield. However, it was reported that yield of lodged plants can occasionally be higher than the unlodged plants (Alias et

al. 1989). This usually happens when lodging occurs late (after completion of grain-filling process). However, yield will be reduced when lodging occurs before the grain-filling process is completed. Under such circumstance, lodging interrupts the translocation in the shoot, resulting in high spikelet sterility (Jennings and Sornchai 1964). This leads to reduced yields.

Treatment effect on plant characters associated with lodging

Culm height All treatment factors showed significant effect on height (Table 1). Significant two-factor interactions (season x nitrogen, season x variety, and variety x nitrogen) were also observed. Significant three-factor interactions involving season, nitrogen and variety indicated that nitrogen effect on varieties varied between seasons. In the main season, for varieties MR 101 and MR 84 (shorter culm height), increasing the nitrogen rate caused a progressive increase in culm height, reaching a maximum height at 160 kg N/ha. However for varieties MR 71 and MR 81 (taller culm height), increasing the nitrogen rate through 0 to 80 kg/ha caused an increase in culm height. Further increase in nitrogen did not seem to increase or affect the height (Figure 4).

In the off-season, except for variety 101, varietal response to nitrogen was inconsistent. This could have been confounded by the behavioral response of culm to lodging. However, there is an indication that the response of these varieties were similar to the response of taller varieties (MR 71 and MR 81) in the main season i.e. an initial increase in culm height with corresponding increases in nitrogen rate. Further increase in nitrogen did not give this effect. For all varieties, culm height was always higher in the off-season, at all nitrogen levels.

The two-factor interaction between variety and nitrogen (over seasons) was used to observe an overall effect of nitrogen on culm height of the different varieties, since the response of MR 71, MR 81 and MR 84 in the off-season was not clear. This indicated that, for shorter varieties (MR 101 and MR 84), increased nitrogen led to increased height with a maximum at 160 kg N/ha. For MR 71 and MR 81 (taller varieties), however, increasing nitrogen led to increased height with a maximum at 80 kg N/ha. At higher nitrogen rate, height levelled off (Figure 5).

Chang (1964) also observed the influence of increased nitrogen on increased plant height. Koyama et al. (1973), however, stated that increased nitrogen led

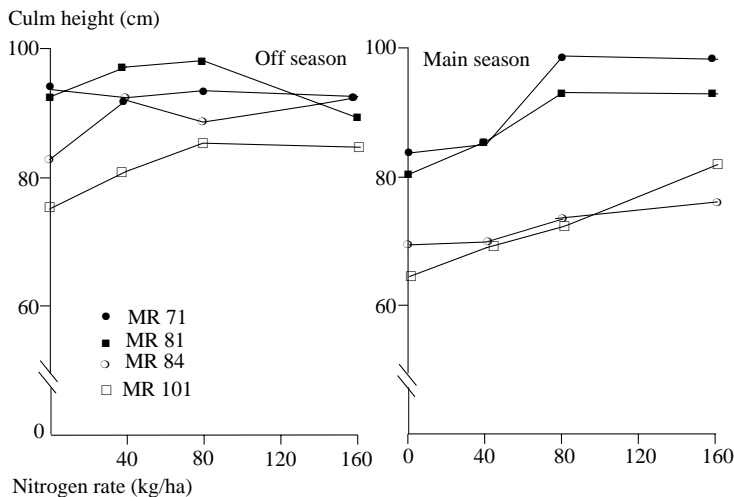


Figure 4. Effects of nitrogen, variety and season on culm height of four rice varieties

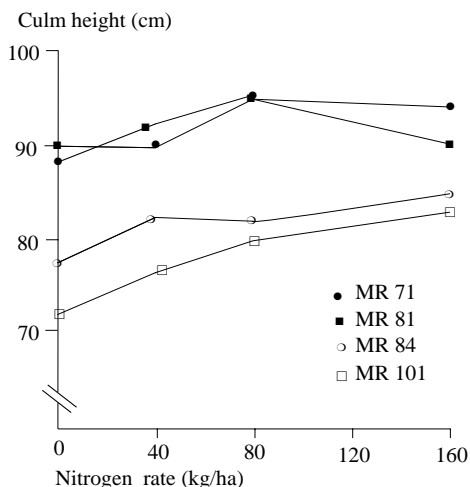


Figure 5. Effect of nitrogen and variety on culm height of four rice varieties

to increased plant height, but this levelled off over the dose of 93 kg N/ha. In this study, quite similar observations were obtained. At shorter culm heights (around 90 cm and below), increased nitrogen led to a small increase in height. However at higher culm heights and high nitrogen rates, increased nitrogen did not give this effect.

It has been shown that lodging was correlated with culm height. However, it was observed that lodging percentage in all varieties increased with an increase in nitrogen rate (Figure 1) even at 160 kg N/ha, where height levelled off for taller varieties. It is thus postulated that the influence of nitrogen on lodging in a variety, apart from causing increased height, was also through cellular changes which were not measured here. Chang (1964) listed lower breaking strength, an increase in outer diameter of culm accompanied by a larger increment of inner diameter, thinner cell walls and thinner sclerenchyma layer as the effect of added nitrogen. The overall effect is increased lodging.

The effect of season on lodging in a variety was thus not just through the direct impact of wind and rain but, in addition, was also due to the increased culm height in the off-season.

Percentage of unfilled grains (spikelet sterility)

All the three factors had significant effect on this parameter which was always found to be higher in the off-season. This was similarly reported by A'aini et al. (1990) and is irrespective of occurrence of lodging. Increasing nitrogen resulted in increased percentage of unfilled grains. This may be associated with increased lodging. Varietal differences in percentage of unfilled grains are inherent and are not an indication of susceptibility to lodging. For example, at the standard fertiliser recommendation of 80 kg N/ha, MR 101 had 29.8% of unfilled grains as compared with 25.8% for MR 71. However, MR 101 had 3.1% of lodging compared with 37.4% in MR 71 (Figure 1).

Significant two-factor interactions between season and nitrogen, as well as between nitrogen and variety were also observed. Season and nitrogen interaction shows that differences in percentage of unfilled grains between season were also affected by nitrogen rate. With an increase in nitrogen rate, the amount of unfilled grains also increased, more so in the off-season, from 25.1% at 0 kg N/ha to 42.1% at 160 kg N/ha, compared with 22.2% to 25.8% in the main season (Figure 6).

Nitrogen and variety interaction indicated that differences in percentage of unfilled grains between varieties were also influenced by nitrogen rate. Except MR 81, all varieties showed increased percentage of unfilled grains with increased nitrogen (Figure 7). A similar interaction effect between variety and nitrogen on lodging was observed. The increase in percentage of unfilled grains can be associated with increased lodging.

Effect of treatment on yield

The analysis of variance indicated that all factors affected yield (Table 1). Significant two-factor interactions between season and nitrogen as well as between season and variety were also observed. Season and variety interaction indicated different

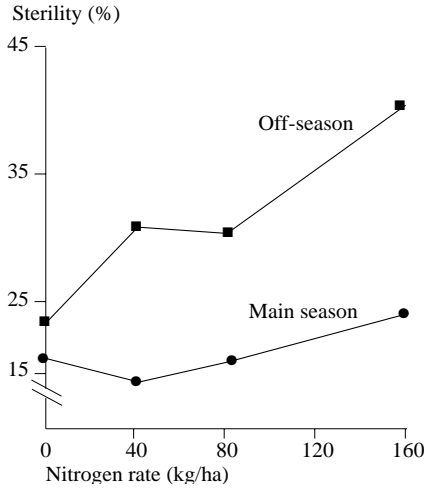


Figure 6. Effect of nitrogen and season on sterility of rice crop

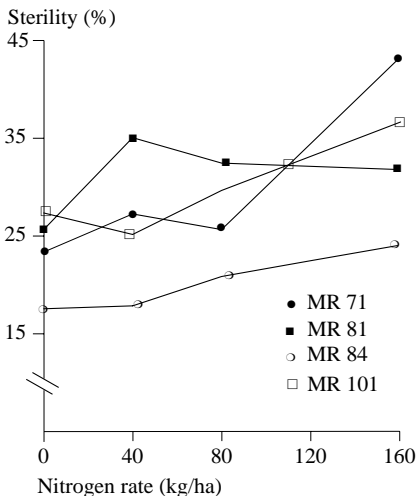


Figure 7. Effect of nitrogen and variety on sterility of four rice varieties

varietal yield performance between seasons. MR 71, MR 81 and MR 84 showed a higher yield in the main season. Differences in yield between the two seasons were 39, 20 and 14% respectively for MR 71, MR 81 and MR 84. MR 101 (least susceptible to lodging), however, showed stable performance between seasons (Figure 8). This reflects that the lodging characteristic of a variety limits its performance in the off-season.

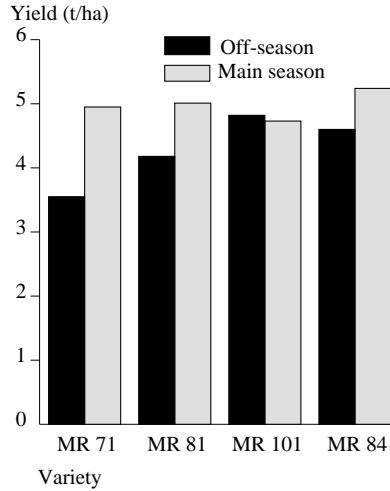


Figure 8. Effect of variety and season on the yields of four rice varieties

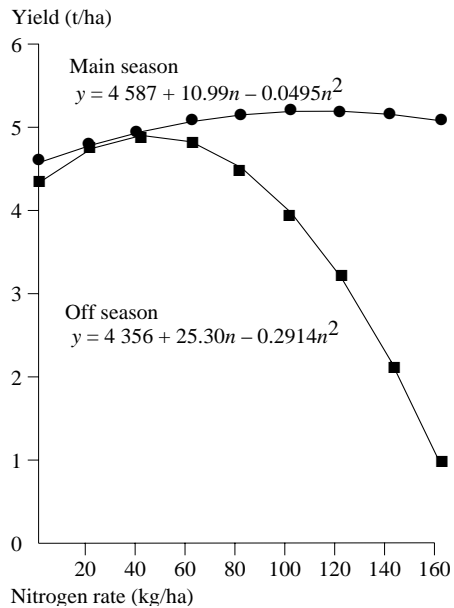


Figure 9. Nitrogen response in each season combining variety

The response to increasing nitrogen level differed between the two seasons. In the off-season, yield response to nitrogen is best described by the following relationship: $y = 4\ 356 + 25.30n - 0.2914n^2$ ($p < 0.05$), where y is the estimated yield and n the nitrogen rate. This shows a maximum yield of 4.9 t/ha at around only 50 kg N/ha after

which there was a negative response with further nitrogen increase (*Figure 9*). This is due to increased lodging at higher nitrogen rate. Occurrence of higher lodging in the off-season thus limits the potential of increasing yield through the use of higher nitrogen. In the main season, the relationship $y = 4\,587 + 10.99n - 0.0495n^2$ ($p < 0.06$), indicated a maximum yield of 5.2 t/ha at around 120 kg N/ha. The main-season maximum yield is 6% higher than the off-season yield. Because of the lesser occurrence of lodging in the main season, a higher nitrogen rate may be used for yield maximisation.

Conclusion

Lodging has been shown to cause yield reduction. Nevertheless, the final outcome of yield is an interrelation of many factors – the effect of the treatments nitrogen, variety and season on lodging and subsequently the effect of lodging on yield. Thus, to achieve maximum yield, it is imperative that the right combination of variety and nitrogen be used for a particular season. Varietal development for lodging tolerance is more important for the off-season because higher occurrence of lodging in this season limits the possibility of increasing rice yields through heavy fertiliser application. The present study indicated that a nitrogen rate of only 50 kg/ha is necessary to achieve maximum yield in the off-season. In the main season, a higher rate than the present recommended rate of 80 kg N/ha can be used to increase yields. However, the economics of marginal increase should be considered. For optimum production, a separate fertiliser and variety

recommendation may be more advantageous. However, since this study covered only class 1 soil, a more comprehensive study on fertiliser rates for the different soil classes in MADA is necessary before a recommendation is made. Recommendation should be for direct seeding management since this is the current practice.

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