Nitrogen decreases deep irrigation efficacy in reducing low temperature damage in rice

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Abstract

Deep water irrigation during microspore development in rice (*Oryza sativa* L.) is widely believed to reduce low temperature damage in temperate rice production. Three experiments were conducted to investigate the effects of nitrogen (N) and water depth on panicle position during microspore development and the effect of root temperature on spikelet sterility caused by low air temperature in rice. Application of N before flooding and deep water irrigation increased panicle height during microspore development. Maintaining a shallow water depth (8 cm) until the beginning of microspore development reduced the depth required for complete insulation of the panicle. It appeared that high water temperature rather than depth of water alone increased panicle height. Low panicle temperature directly decreased the number of engorged pollen grains, while low root temperature had indirect effect by reducing pollen production. Deep warm water increased the number of engorged pollen grains at low air temperature when there was complete coverage of the panicles.

Key words

Rice, panicle height, microspore, nitrogen, low temperature, pollen.

Introduction

Pollen development, particularly the microsporogenesis period which occurs about 10 – 12 days before heading, is the most sensitive stage to low temperature in rice (1, 4). Evidence exists that there is more low temperature damage with high nitrogen (N) application (1, 6,). However, high N can still lead to high yield provided the microspores are protected from low temperature damage by deep water practice, which submerges young panicle (6). Water temperature tends to be 3-4 ?C higher than night air temperature (5). Hence deep water irrigation during pollen development is widely regarded as a counter measure to low temperature damage.

This paper reports the results of three experiments providing the information on panicle position and the consequences of low temperature at microspore attributed to the incomplete protection of young panicles. The deep water can raise the position of the panicle while increased root temperature mitigates the damage cause by low panicle temperature.

Material and methods

Two field experiments were conducted during the summers of 1998/1999 (Experiment 1) and 1999/2000 (Experiment 2) in which there were two sowings on a red-brown earth (Birganbigil clay loam, vanDijk 1961; Dr 2.23) (3) soil at Yanco Agricultural Institute (YAI) (34?37'S., 146?25E.). The experimental site had been cultivated for at least the previous 6 years. In Experiment 1, the N treatments were 0+0, 150+0 and 150+150 kg N ha^{-1} applied at preflood (PF) and panicle initiation (PI) respectively. In Experiment 2, there were three N treatments, 0, 50 kg N ha^{-1} x 3 times and 150 kg N ha^{-1} applied in deep (25 cm) and shallow (8 cm) water in both experiments.

In a glasshouse experiment (Experiment 3), plants in the microspore development were exposed to low air temperature for 7 days while two depths of irrigation were used. Panicle temperature was maintained at high/low independent of root temperature by varying water depth and temperature.

Results

In Experiment 1, the application of N at PF raised the position of panicle as a result of increased culm length (Figure 1). Panicles were completely exposed to air irrespective of the N applied in shallow water while partial insulation was achieved in deep water. The first three stages of the microspore development period (Stage 14 to 16) were submerged, when N was not applied in 25 cm depth of water during microspore development. Experiment 3 results showed that the deep warm water increased the culm elongation rate more than three fold compared with deep cold water (Table 1). When the root and panicle temperatures were maintained at 23 ?C by deep warm water while the air temperature was low (17.5/12.9 ?C) in Experiment 3, more than 800 engorged pollen grains per anther were recorded. This occurred irrespective of the N applied. However, low root and panicle temperatures decreased ($p<0.05$) the number of engorged pollen grains to less than 200 per anther. This reduction in engorged pollen number was associated with increased spikelet sterility (> 30%), while warmer root temperature reduced ($p<0.05$) the damage by limiting sterility to 25%. More than 400 engorged pollen grains per anther were recorded when root temperature was increased to 23 ?C by shallow warm water treatment while the panicle temperature was low.

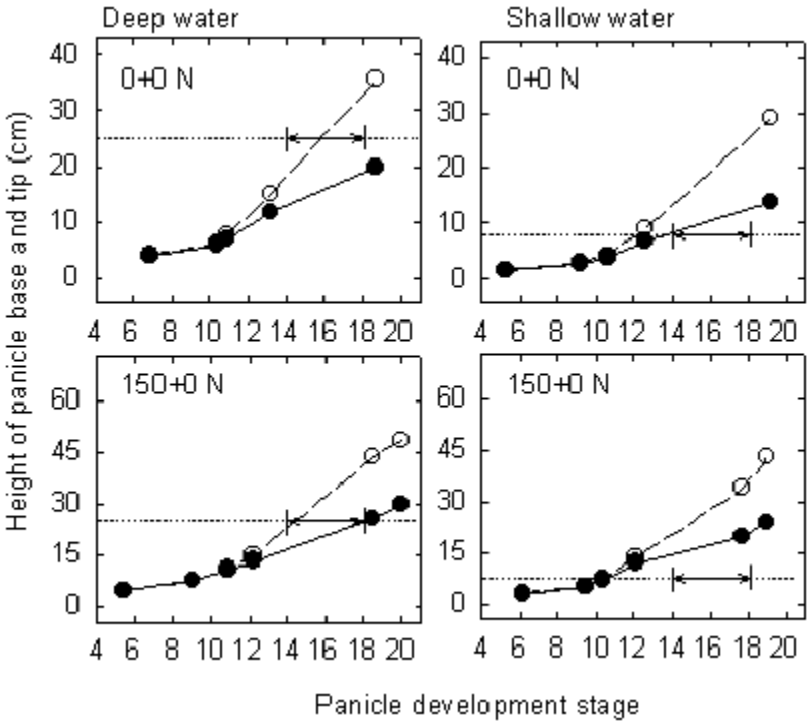

Figure 1. Experiment 1. The height of panicle base (●) and panicle tip (○) from the culm base as affected by nitrogen (PFN+PIN kg N ha^{-1}) and water depth. Horizontal dotted lines show the irrigation water level. Horizontal arrows show the microspore development period (2).

In Experiment 2, temperature determination on 2 days (viz. 20 – 21 Jan.) during microspore showed that the minimum air temperature occurred just before dawn and water temperature was 3.5 ?C warmer than air and panicle temperature (Figure 2). Panicle was above water and average minimum panicle temperature was 0.4 ?C lower than air temperature during microspore development. There were smaller differences in air, water and panicle temperature when temperature was high.

The highest number of engorged pollen was obtained in deep water without N, followed by shallow water without N and where N applied in deep water (Figure 3). The lowest number was obtained in shallow water where N was applied. In each condition, low temperature reduced the number of engorged pollen grains except in deep water without N.

Table 1. Experiment 3. The effects of water depth and average root and panicle temperatures (12-h day / night ?C) during microspore development on the culm elongation, engorged pollen number and spikelet sterility. Air temperature was 17.5/12.9 (? 0.51/0.20) ?C.

Nitrogen (kg ha^{-1})	Water depth* & temperature (?C)	Root temperature (?C)	Panicle temperature (?C)	Culm elongation (cm d^{-1})	Engorged pollen / anther	Spikelet sterility (%)
0	deep-warm	22.9/22.8	22.9/22.8	1.2	976c	8a
150	deep-warm	22.9/22.8	22.9/22.8	1.3	833c	11a
150	shallow-warm	22.9/22.8	17.5/12.9	NA	425b	25b
150	deep-cold	16.2/15.3	16.2/15.3	0.3	200a	33c
150	shallow-cold	16.2/15.3	17.5/12.9	0.2	141a	48d

* Deep water was varied from 20 to 32 cm; shallow water was at 3 cm; NA, data not available; in a column value followed by a common letter are not significant.

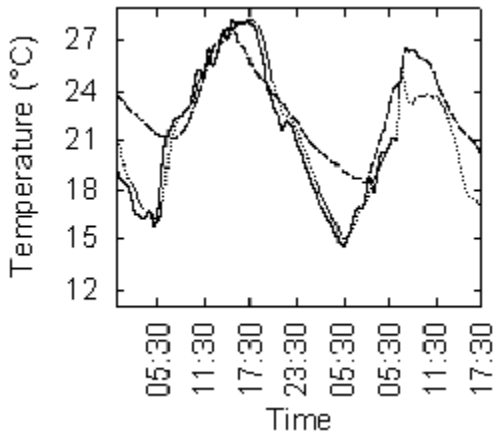

Figure 2. Experiment 2. Diurnal air (…), panicle (—) and water (---) temperature. Panicle temperature was recorded from the panicle above the surface of shallow water.

Discussion and conclusions

High N can lead to increased yield provided deep water irrigation (> 20 cm) is applied during pollen development to protect the young panicles from low air temperature (6). Distal floret sterility is uncommon despite the partial submergence of panicles by deep water (6) perhaps due to the warmer water vapor protecting the panicle to some extent. Water depths of 20 to 33 cm of irrigation can protect the panicles completely during microspore when shallow water is practiced until the beginning of the microspore development period. It appears, however, that irrigation water has to be increased from 30 to 40 cm throughout microspore development to achieve complete insulation of young panicles where N has been applied at PF. Added advantage of complete panicle insulation over partial insulation needs to be further investigated.

Culm elongation is particularly rapid after panicle initiation. Hence, in case of deep irrigation aiming to achieve complete insulation of young panicles should be carried out in a stepwise manner to avoid

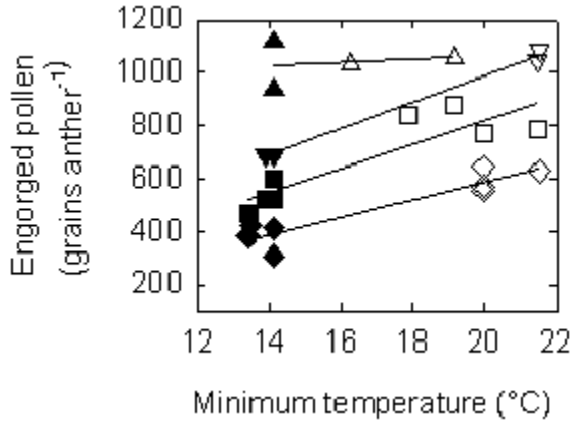

Figure 3. Experiment 2. The relationship between the average minimum temperature for the microspore development and the number of engorged pollen grains per anther as affected by nitrogen and water depth (◆◇, N applied-shallow water; ■❑, N applied-deep water; ▼▽, no N-shallow water; ▲△, no N-deep water) in early (solid symbols) and late (open symbols) sowing. Equations are: ◆◇ , Y = -67.0 + 32.7 x (r = 0.93); ■❑, Y = -73.5 + 44.7 x (r = 0.88); ▼▽, Y = -8.2 + 49.8 x (r = 0.99); ▲△, Y = 942 + 5.9 x (r = 0.19)

exposure of panicles to air as a result of raised position of panicles. Deep water can increase soil temperature and this may have rather large effect reducing sterility in low temperature event while there may also be some protective effect from warm water vapor particularly with absence of nocturnal wind. The average water temperature was > 21 ?C in the field when minimum air temperature was below 17 ?C (Figure 2). The Experiment 3 results predicted that the culm length can be increased > 9 cm over 1 week at this temperature.

The indirect effect of warm root temperature when the panicle temperature was low (Experiment 3) may have been more contrasting if the 12-h day temperature had been high (i.e. > 30 ?C) as frequently observed under field conditions. Warm water was beneficial in increasing root zone temperature during night time and hence despite partial insulation of panicles by deep water practice it still could indirectly reduce the spikelet sterility.

It is concluded that N application raises the position of panicle. The raised position of panicles is increased with added N fertilizer and therefore, it is likely that the risk of low air temperature is increased.

Acknowledgement

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References

1. Heenan, D. P. 1984. Aust. J. Exp. Agric. 34, 917 -19.

2. Matsushima, S. and Manaka, T. 1966. In: Crop Science in Rice. (Ed. S. Matsushima) (Fuji Publishing Co., Ltd: Japan). pp.62 – 72.

3. Northcote K. H. 1979. In: A Factual Key for the Recognition of Australian Soils. 4th Ed. (*Rellin Technical Publications:* Glenside, South Australia)

4. Satake, T. and Hayase, H. 1970. Proceedings Crop Science Society, Japan. 39 (4), 468-473.

5. Satake, T., Lee, S. Y. and Koike, S. 1988. Japan. Jour. Crop Sci. 57 (1), 234 – 241.

6. Williams, R. L. and Angus, J. F. 1994. Aust. J. Exp. Agric. 34, 927 -932.