

An alternative hypothesis for the nitrogen by environment interaction in rice

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Summary. Grain yield of some older rice cultivars (e.g., Inga) was limited by excess vegetative growth early in the season, which led to large respiration losses and low growth after anthesis. This resulted in low floret fertility and reduced grain yields. In varieties with improved canopy structure, it has been widely accepted that yield losses due to excessive biomass production prior to anthesis are uncommon. However, new cultivars continue to display a large nitrogen by environment interaction. Low temperatures at the critical reproductive stages of microspore development and flowering which reduce the number of filled florets, do not completely explain the interaction. Evidence is presented for a reduced biomass accumulation after anthesis in some modern varieties and this results in high levels of floret sterility and lower yield. The physiological principles influencing yield in cultivars with poor canopy structure should be re-examined.

Introduction

Nitrogen fertiliser usage is one of the main determinants of yield and profitability of rice growing in the NSW industry. However, management of nitrogen application rates from year to year is difficult due to a large nitrogen by year interaction, which results in severe yield reductions in cool years when large amounts of fertiliser are applied.

Inga, an older cultivar with poor canopy structure, had a positive yield response to low rates and a negative yield response to high rates of nitrogen applied during early growth (2). Yield losses were related to a reduction in the number of filled florets and were associated with rank early vegetative growth and tiller production. Excessive vegetative growth, particularly in the early stages, has often been associated with mutual shading and its adverse effects on grain yield (4,5). It was hypothesised that excessive early growth of the crop led to an imbalance of pre-and post-anthesis growth.

There is evidence that the large year to year variation in rice grain yield and the nitrogen by environment interaction is induced by low temperatures during the reproductive stage (1). Low minimum temperatures (below 15°C) during the reproductive stage have a large effect on yield of rice crops in southern New South Wales. Industry average yields are correlated with average minimum temperatures during the period which encompasses the reproductive stages of the entire rice crop. Low temperatures during microsporogenesis and anthesis are related to reductions in filled florets of Inga, and sensitivity to low temperatures was greater with high nitrogen supply (3). Even in the absence of low temperature, high nitrogen levels led to reduced numbers of filled florets due to a photosynthesis-respiration imbalance brought about by rapid early growth.

This work examines cultivars with improved plant type and investigates yield variability over a range of environments for the reproductive and grain filling phases. This was achieved by the use of a range of sowing times. We explore the balance of pre- and post-anthesis growth, in combination with low temperature effects, to more fully understand the observed nitrogen by environment interaction.

Methods

Two trials were carried out at Yanco Agricultural Institute during the summers of 1983-84 and 1984-85, to examine the interaction between sowing time, nitrogen application and cultivar. The cultivars used included Pelde and M101. Pelde is a long grain cultivar which grows to approximately 1 m in height at maturity. Although tall, it does not have the excessive early growth of Inga, the cultivar it replaced. M101 is a semi-dwarf medium grain cultivar, approximately 80 cm in height at maturity, resistant to lodging at high levels of nitrogen application, and with shorter growth duration than Pelde. Sowing dates were 18

October, 14 November and 5 December 1983, and 26 September, 15 October, 12 November and 3 December 1984. Nitrogen rates were 0, 75, 150, and 225 kgN/ha applied as urea (46%N).

Seed was drill sown in all experiments at a rate of 120 kg/ha using an eight-row cone seeder with 17.8 cm row spacing. Nitrogen fertiliser treatments were applied as urea onto the dry soil surface immediately prior to permanent water (when the rice was at the three-leaf stage) in both experiments. All the fertiliser was applied at this time and no other fertilisers were used. Control of Barnyard grass, *Echinochloa* spp., was achieved by applying Molinate (S-ethyl hexahydro-1H-azepine-l-carbothioate) with a boom spray prior to permanent water. Designs for both experiments were split plot with sowing time as the main plots.

Crop development was measured by taking three 1 m rows (approximately 0.5 m²) from each plot at flowering and harvest. Outside rows were not used. Only above ground plant material was sampled. Tiller number, leaf area and dry weight were measured on the flowering sample, while measurements on the harvest sample also included full and empty florets. Yield was determined by cutting 6x2 m rows at ground level (excluding the outside rows). Grain weight was adjusted to 14% moisture for yield comparisons.

Results and discussion

Grain yield

There was a significant nitrogen by environment interaction for yield for both M101 and Pelde. In all sowings, the yield of M101 ranged from 6-8 t/ha when no fertiliser was applied. With increasing N application the range of yields increased. At 225 kg N/ha the range in yields due to changes in sowing date was from 3-13 t/ha, resulting in a large interaction (Fig. 1). Similarly for Pelde, the range of yields increased with increasing nitrogen application with the exception of the 5 December 1983 sowing, where yield was uniformly low under all nitrogen treatments.

Post-anthesis growth

Grain yield was similar to the change in total dry matter from anthesis to maturity for all M101 and Pelde plots sown 26 September, 12 November and 15 October 1984 and 18 October 1983. All plots at these sowing dates produced at least 6 t/ha of grain. Grain yield at these planting dates was largely in balance with dry matter production after anthesis. However, for sowings on 14 November and 5 December 1983 and 3 December 1984, the relationships between grain yield and post-anthesis growth were different.

For M 101 these plantings translocated between 2-5.5 t/ha of pre-anthesis material into the grain. In one extreme case, the crop lost dry matter from anthesis to maturity, but still produced 4 t./ ha of grain. The increase in translocation in the late plantings was correlated with decreasing post-anthesis growth ($R=-0.821$). The large amounts of translocation for the low yielding plots suggests that low yield resulted from a lack of carbohydrate to fill the grain and was not due to insufficient numbers of fertile florets. Grain weights also declined significantly with later plantings. It appears that low temperature induced sterility did not limit yield in this data set for M 101. This suggests that the limitation to yield in some of the environments sampled in this trial was the lack of carbohydrate to fill the grain.

For late planted Pelde, where post-anthesis growth was not in balance with grain yield, significant translocation into the grain occurred for the 14 November 1983 planting. In the December planting of each year significant storage of post anthesis growth occurred in non-grain parts of the crop. This indicates that for all nitrogen rates at these sowing dates the crop was sink limited, with the plant producing more post-anthesis dry matter than required to fill the available florets, and then storing the excess carbohydrate in the stems and leaves. Low temperature induced sterility is the probable cause of the reduced floret fertility and consequent low yield for Pelde at these sowing times.

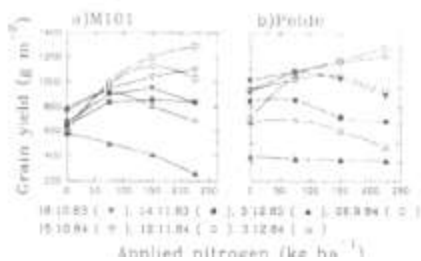


Figure 1. Grain yield of M101 and Pelde over four nitrogen applications and seven sowing dates.

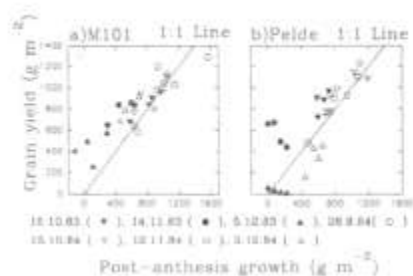


Figure 2. Grain yield versus post-anthesis growth for M101 and Pelde over four nitrogen rates and seven sowing dates.

Nitrogen and environment both influenced post-anthesis growth. For both cultivars increasing nitrogen application led to increased dry weight at anthesis. The relationship between post-anthesis growth and dry weight at anthesis was influenced by sowing date. When grain filling occurred under warmer conditions (i.e., sowing dates 26 September, 15 October and 12 November 1984 and 18 October 1983), post-anthesis growth increased with increasing dry weight at anthesis. However, in the remaining sowing dates post-anthesis growth tended to decline with increasing dry weight at anthesis (Fig. 3). Thus the environment during grain filling and the size of the crop at anthesis both influenced post-anthesis growth. Since the size of the crop at anthesis was related to the nitrogen application, this explains the observed interaction between nitrogen application and environment in this data set.

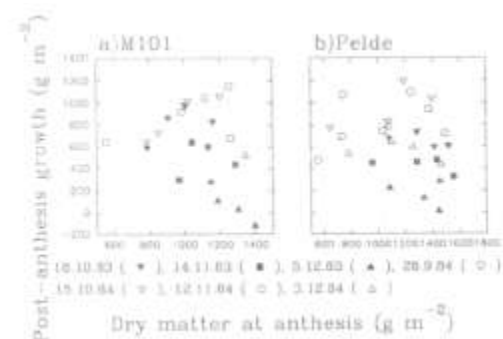


Figure 3. Post-anthesis growth versus dry weight at anthesis for M101 and Pelde over four nitrogen applications and seven sowing dates

These results indicate that a number of mechanisms are implicated in the year to year variation in nitrogen response in NSW. Low temperatures at critical growth stages lead to reduced yields via a reduction in numbers of filled grains. This essentially imposes a sink limitation on the crop. However,

measurement of pre- and post-anthesis growth indicates that a source limitation also occurs under late sown conditions. While improvement in plant type has minimised the problem of yield reduction due to mutual shading, even in the newer cultivars added stresses such as low solar radiation in combination with a reduction in photosynthesis due to low temperatures during grain filling, may sufficiently alter the balance between assimilate required to maintain the plant and that required to fill the grain. This imposes a source limitation on the crop, and translocation from stems and leaves is required to fill the grain.

Thus the physiological principles which applied in cultivars with poor plant type are relevant to current cultivars, and the integration of old and new knowledge is essential in gaining a better understanding of rice yield variation in response to applied nitrogen.

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