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in

Chataigner J. (ed.).
Perspectives agronomiques de la culture du riz en Méditerranée : réduire la consommation de l'eau et des engrais

Montpellier : CIHEAM
Cahiers Options Méditerranéennes; n. 15(1)

1996
pages 53-64

Effect of applied before seeding nitrogen fertilization on rice yield components

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Abstract. The effect of eight nitrogen fertilization doses on five rice varieties from Japonica and Indica subspecies in the Sacramento Valley (California), under Mediterranean-type weather conditions was studied. The five Indica type rice varieties responded up to 120–150 lb/acre of nitrogen, while the Japonica ones only responded up to 120 lbs/acre (1 pound = 453.6 g.; 1 acre = 4047 m^2; therefore 1 lb/acre is approximately equal to 1.12 kg/ha). The cycle, the plant height, the lodging and moisture content of the grain increase with the fertilizer, although from 120-150 lb/acre upwards the differences are of little significance, with some differences between varieties. The Indica cultivars are shorter, with lesser lodging, and are slightly less productive than Japonica ones. The number of panicles/m^2 is the component more influenced by nitrogen and the most influent on grain yield. Indica cultivars showed the higher values of this component, although they have lower values in grains filled per panicle and in the weight of 1000 grains. They also have a higher percentage of blank grains.

Keywords. Rice – Nitrogen –Yield components – Lodging

I – Introduction

In southern Spain, and especially in Andalusia, most of the long grain rice is of Californian origin. The cultivation techniques are similar and only the somewhat drier climatic conditions of the region of Andalusia distinguish the two rice growing areas. Thus the results of this research may be considered to be a good point of reference for rice growing in Andalusia where other works on agronomic aspects have, as yet, not been carried out.

In California, in permanently flooded rice fields, the normal levels of nitrogen fertilization consists in using doses of between 110–150 lbs/acre, approximately 120–165 kg/ha, depending on the variety and the fertility of the soil. This fertilization is normally carried out before sowing. Very rarely is fertilizer applied after sowing. In other countries where the climate is also Mediterranean, farmers tend to use similar applications (Tinarelli, 1989).

Given the importance of nitrogen fertilization on the yield in grain from the rice plant, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and other agronomic parameters such as the cycle, plant height, lodging and moisture content of the grain, in order to obtain better knowledge of said productive response.

Tanaka et al. (1966) showed that the height of a rice plant is positively correlated to the length of the maturation cycle. A taller plant is more susceptible to lodging and responds less well to nitrogen (Yoshida, 1978). Panicles with a low percentage of sterile flowers permit the application of higher doses of nitrogen and produce better yields (Yoshida, 1981). In experiments carried out by this researcher in 1972 at the IRRI (Philippines), it was shown that the number of spikelets per square meter is the most important yield component, closely followed by the percentage of filled grains. The weight of 1000 grains is a relatively less influential component. In some areas and under certain weather conditions percentage of filled grains may even become the most limiting factor in yield (Yoshida, Parao, 1976).

According to Yoshida et al. (1972), as the amount of nitrogen absorbed by the crop even until heading increases, there is an increase in the number of panicles per square meter, although with very high doses these increments are not significant.

When high doses of nitrogen are applied, there is an increase in the percentage of blank grains, some varieties being very sensitive in this respect. In general, the weight of 1000 grains is a stable feature of every variety (Sasaki, Wada, 1975).

This study was designed to find out the effect of a wide range of nitrogen doses on agronomic behaviour, especially in those aspects related to yield, of different Indica and Japonica type rice cultivars in California (USA), and under Mediterranean weather conditions.

II – Methods and material

The field experiments were carried out in Biggs and Dingville, in the Sacramento Valley (California) in 1990. The soil is alluvial and clay textured representative of this, the most important rice growing area in California. The sowing date in Dingville was May 12th, and in Biggs May 23rd. The statistical design was split plot, with four repetitions, the main plot corresponding to the nitrogen doses and the sub-plot to the variety. The surface area of the elemental plot was 10 x 27 feet (1 foot = 30.48 cm). The different doses of nitrogen were applied using a six furrow essay fertilizer, the machine being previously calibrated. The nitrogen was applied before seeding. Sowing was carried out manually applying a dose of 160 kg/ha.

Harvesting took place on the 23rd and 24th of September with an essaying harvester. The remaining farming practices were carried out as normal for the area and were identical for all the elemental plots.

Eight doses of nitrogen were applied, in the form of 46% urea, which expressed in pounds of nitrogen per acre are: 0-30-60-90-120-150-180-210.

The five varieties essayed were: L-202, Indica type, early cycle and long grain; M-202 and M-203, both Japonica type medium grain and early cycle; 88-Y-774, Indica type long grain and very early cycle which is now denominated L-203; and finally M-103, Japonica type medium grain and very early cycle.

The parameters taken into consideration and the sample taken are detailed as follows with the exception that yield results were only obtained from two (L-202 and M-202) of the five varieties essayed:

1) Heading cycle, considering the number of days from the date of sowing to 50% of the plants in heading phase. Samples were taken from 50 plants every two days after heading had begun.

2) Plant height, considering the distance between the soil surface and the tip of the erect panicle. This was measured immediately before harvesting on a sample of ten plants.

3) Percentage of lodging in the harvest. Quantified *de visu.*

4) Grains moisture content on harvesting, taken from a sample of 100 g.

5) Number of panicles per square meter, taking a sample of 0.5 m^2 using a metal hoop.

6) Number of filled grains per panicle. To do this, an air jet grain separator and a methacrylate column were used to separate the blank grains from the full ones. The percentage of blank grain was also calculated.

7) Weight of 1000 grains, using the previously mentioned full grains and a precision scale.

8) Yield: kg/ha of grain (14% moisture content) in the whole elemental plot.

The statistical analysis was carried out according to Snedecor, Cochran (1976) and Steel, Torrie (1985). The comparisons between measurements were made using LSD test at a probability level of 5%.

III – Results and discussion

1. Cycle to heading

Later sowing in Biggs led to a shortening of the cycle to heading. This was due to the higher temperatures which tend to occur at this time of year if compared to those of Dingville. Significant differences were found between the crops, M-103 was the earliest variety and L-202 the latest. The cycle was lengthened on increasing the dose of nitrogen. Variety L-202 was found to be the most sensitive with a difference of 8 days between extreme doses of nitrogen, while M-203 showed practically no variation *(Tables 1 and 2).*

In Biggs a significant correlation was found between the doses of nitrogen and the cycle to heading *(table 4)*.

This cycle is positively correlated to the number of panicles/m^2 and the percentage of blank grains. In Dingville there is significant correlation with yield, although in Biggs no significant correlation was detected, perhaps due to the increase in the percentage of blank grains. A negative correlation was found in relation to the lodging, grains/panicle and weight of 1000 grains *(table 3)*.

2. Plant height

In both places, M-203 is the tallest crop and L-202 the shortest. By increasing the doses of Nitrogen the plants height is increased, although the difference in height related to the higher doses of nitrogen are not significant. In fact a slight reduction in height was detected in Biggs related to nitrogen doses of over 180 lbs/acre *(tables 1 and 2).* This result coincides with that indicated by Tanaka et al. (1966).

The plants height is correlated with the lodging and the moisture content of the grain on harvesting *(table 3)*, these results are similar to those obtained by Yoshida (1978).

3. Lodging on harvesting

Varieties M-203, M-103 and M-202 are the most susceptible, and L-202 and 88 and 774 are the most resistant. Lodging increased with the higher doses of nitrogen although in Biggs this was shown to stabilise with the intermediate doses. L-202 notably increases lodging at doses of nitrogen of 180 lb/acre *(tables 1 and 2)*.

In any case lodging caused a considerable decrease in yield in Biggs. To the contrary, there is a positive correlation between lodging and moisture content in the grain in both areas *(table 3)*. This carries out more diseases incidence and poorer quality grain.

4. Grain moisture content in harvest

The cooler climate in Biggs and the later sowing date, in general, causes a higher moisture content in the grain in relation to Dingville. There are no great differences between the essayed varieties because they are of early or very early cycles. In both places 88-Y-774 have a lower moisture content than the remaining varieties, the difference being notable in Biggs. On increasing the nitrogen doses the moisture content in the grain is also increased, although over 120 lbs/acre the differences are not significant.

Moisture content is also correlated to plant height and lodging. This correlation between the different yield components differs according to the area.

5. Panicles per square meter

L-202 achieved higher values than M-202 *(figures 1 and 2)*. A significant correlation was seen between the number of panicles per square meter and the cycle to heading as well as the percentage of blank grains, that is to say, the more panicles the higher the proportion of blank grains. There is a negative correlation with the weight of 1000 grains and in Dingville, when the number of panicles increases, there is an increase in grain yield *(table 3)*. This positive correlation between number of panicles and production coincides with the findings of other researchers such as De Datta (1986). If the doses of nitrogen are increased, likewise are the number of panicles *(figures 1 and 2)* according to the results obtained by Yoshida et al. (1972).

6. Filled grains per panicle

On the contrary to what was seen in the previous yield component, M-202 achieves higher values than L-202. There is a parabolic relation between doses of nitrogen applied and filled grains per panicle. In Dingville a stabilization can be observed, and even a slight reduction in the number of filled grains over 150 lbs/acre. In Biggs the number of filled grains decreased slightly as the doses of fertilizer were increased *(figures 3 and 4)*.

In Dingville a correlation was observed between the cycle and the weight of 1000 grains, this was not seen in Biggs *(table 3).*

7. Weight of 1000 grains

M-202 reached significantly higher values than L-202. As the doses of nitrogen were reduced the weight of the grain fell *(figures 5 and 6)*.

8. Percentage of blank grains

In both areas L-202 reached the highest values. As the applications of nitrogen were increased, the percentage of blank grain increased likewise in Biggs *(figure 7)* and in Dingville *(figure 8);* although there it is only very slight, there was a tendency to the same in M-202.

There was no significant correlation observed with regards to yield, although there was a negative correlation to the weight of 1000 grains and a positive correlation with the cycle to heading *(table 3)*.

9. Production

88-Y-774, marketed at present as L-203, is significantly the most productive in both places followed by L-202, both of Indica type.

The fertilizer increases the grain yield up to doses of 150 lbs/acre of nitrogen in Dingville, except in the case of M-202. Over and above these levels, the yield decreases in all five of the crops essayed *(figure 10)*, these results are similar to those described by Tinarelli (1989). In Biggs different behaviour patterns were observed between varieties: M-203 maintains an almost constant decrease in yield as the dose of fertilizer is increased, while M-202 and M-104 begin to show a negative response to the nitrogen at relatively low doses.

L-202 and 88-Y-774 present a similar pattern to that observed in Dingville *(figure 9)*. The negative effect of very high doses of nitrogen on production can be explained by the reduction in the number of filled grains on the panicle and the weight of the grain, as well as the increase in lodging.

In general, the Indica type varieties essayed need higher doses of nitrogen than the Japonica type.

In Dingville, though not so significantly in Biggs, there is a very close relation between the yield and its components, especially with panicles per square meter followed by the number of filled grains per panicle, in accordance with what De Datta described (1986). The correlation of the yield with the rest of the studied parameters also varies depending on the place. So, in Biggs, a negative effect of the lodging on the yield can be observed and in Dingville there is a positive correlation between the yield and the height of the plants, because the low doses of nitrogen lead to less plant growth *(table 3)*.

IV – Conclusion

The long grain Indica type cultivars reach maximum yield with doses of nitrogen fertilizer applied before sowing lower than those necessary for Japonica type varieties, medium or short grain, which tend to be more susceptible to lodging. On increasing the doses of fertilizer, the cycle to heading is lengthened and the plant height, lodging and moisture content in the grain at harvesting are all increased, although over 120–150 lbs/acre the increase is hardly significant, with small varietal differences. The number of panicles/m^2 is the yield component most affected by the nitrogen fertilization and in turn also has a direct influence on the grain yield. The Indica type varieties reach higher values in number of panicles/m^2 than the Japonica types although on the other hand they have a far lower filled grain/panicle ratio and a lower weight per 1000 grains. It is also of note that the percentage of blank grains is also higher. The Indica type varieties essayed gave a slightly higher yield than the Japonica types.

The same long cultivars are sown in the south of Spain (Andalusia) as in California; those used in the essays, using the same farming techniques and the edapho-climatological conditions are also similar. Therefore, the results of this investigation may be considered a good point of reference for rice farming in Andalusia.

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Table 1. Effect of nitrogen rate on cycle, plant height, lodging, grain moisture and grain yield of five rice cultivars. Biggs 1990.

Cultivar	Nitrogen rate (lb/acre)	Days to flowering	Plant height (cm)	Lodging in harvest (%)	Grain moisture (%)	Grain yield (kg/ha 14% moisture)
	0	82,2	61,1	8,2	17,1	7132
	30	83,6	84,5	19,5	17,4	8238
	60	84,9	87,7	45,5	18,5	9051
	90	85,2	88,9	45,5	19,6	8745
	120	86,3	90,5	57	20,8	8328
	150	87,2	91,4	54	20,9	7956
	180	87,4	93	55	20,6	7856
	210	87,9	91,3	57	20,9	7856
L-202		90,6	80,3	8,1	19,5	8167
M-202		84,3	90,1	57,5	20,3	8000
M-203		84,1	90,9	78,9	19,7	7851
88-Y-774		87,7	84,9	4,4	18,4	9072
M-103		81,2	83,8	72,2	19,3	7511
	C.V. (%)	1,6	6,3	62,7	5,2	7,2
	LSD N (0.05)	0,9	21,5	13,5	0,9	487
	LSD C (0.05)	0,7	2,7	13,5	0,5	286
	MDS NxC (0.05)	1,7	7,6	38,5	0,7	873

Table 2. Effect of nitrogen rate on cycle, plant height, lodging, grain moisture and grain yield of five rice cultivars. Dingville 1990.

Cultivar	Nitrogen rate (lb/acre)	Days to flowering	Plant height (cm)	Lodging in harvest (%)	Grain moisture (%)	Grain yield (kg/ha 14% moisture)
	0	88,6	66,9	1,0	15,2	3981
	30	88,3	75,3	1,0	14,1	6340
	60	88,3	83,6	11,4	13,9	8639
	90	89,4	87,3	29,9	14,5	9465
	120	90,1	92,5	50,6	16,7	10166
	150	90,7	94,3	60,6	17,0	9952
	180	92,0	90,4	65,2	17,7	9599
	210	91,9	96,7	81,6	17,1	8782
L-202		96,6	81,1	8,0	15,5	8668
M-202		88,0	87,7	51,6	16,3	8365
M-203		87,1	91,1	61,3	16,2	7828
88-Y-774		93,0	84,7	20,2	15,0	9560
M-103		85,2	84,9	47,4	15,7	7410
	C.V. (%)	1,8	6,1	43,2	6,9	11
	LSD N (0.05)	1,2	12,1	8,8	1,7	657
	LSD C (0.05)	0,8	12,6	8,1	0,6	491
	MDS NxC (0.05)	2,2	7,3	22,8	1,8	1389

Table 3.- Correlation matrix. Values above diagonal belong to Dingville trial, the ones below to Biggs. Average of five rice cultivars. 1990.

Character	1	2	3	4	5	6	7	8	9
1 Days to flowering	-	0,06	-0,24	0,01	0,77**	-0,46*	-0,89**	0,62*	-0,43*
2 Plant height	0,28	-	0,74**	0,53**	0,69**	0,70**	-0,26	0,3	0,74**
3 % Lodging in harvest	-0,37*	0,57**	-	0,80**	0,19	0,75**	0,06	0,14	0,28
4 % Grain moisture	0,39*	0,68**	0,59**	-	0,31	0,52*	-0,2	0	0,18
5 Panicles/ m2	0,69**	0,38	-0,01	0,57*	-	0,09	-0,74**	0,60*	0,72**
6 Filled grains/ panicle	-0,67**	0,17	0,4	-0,23	-0,75**	-	0,33	-0,31	0,62*
7 1000 grains weight	-0,71**	-0,18	0,11	-0,34	-0,77**	0,76**	-	-0,57*	-0,26
8 % Blank grains	0,60*	0,31	0,11	0,69**	0,75**	-0,71**	-0,93**	-	0,1
9 Kg/ha at 14% moisture	0,26	0,12	-0,41*	-0,21	0,06	0,43*	0,21	-0,29	-

* Significant 5%
** Significant 1%

Table 4.- Correlation between nitrogen rates and other parameters. Average of two rice cultivars, L-202 and M-202. 1990.

	Biggs	Dingville
Days to flowering	0.50**	0.29
Days to flowering	0.50**	0.29
Plant height	0.69**	0.84**
Lodging (%)	0.38*	0.72**
Panicles/m2	0.74**	0.81**
Filled grains / panicles	0.63**	0.68**
1000 grains weight	-0.75**	-0.44
Blank grains (%)	0.86**	0.51*
Kg/ha at 14% moisture	0.57**	0.90**

* Significant 5%
** Significant 1%

Fig. 1. Effect of nitrogen rate on panicles/m2 of two rice cultivars. Biggs 1990

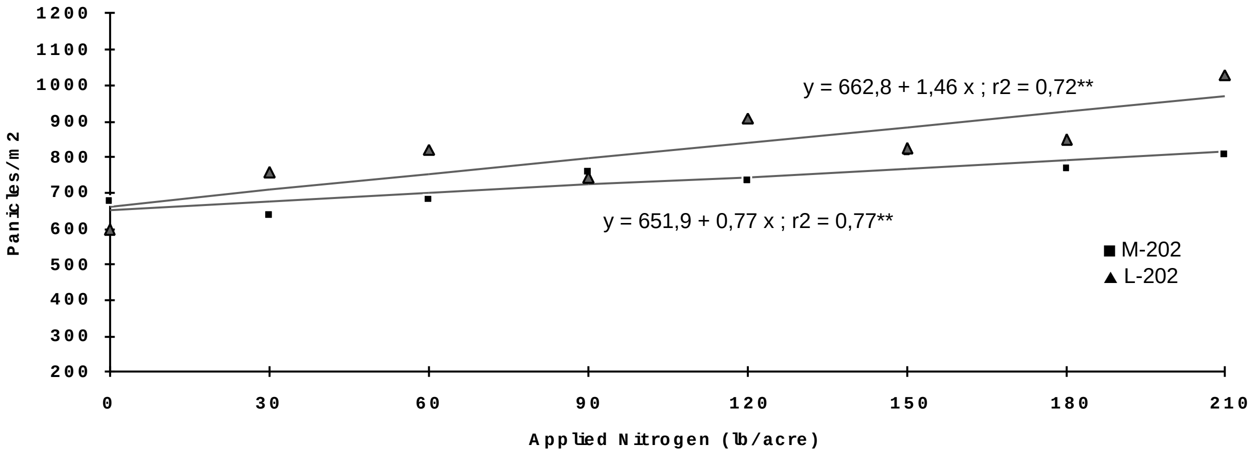

Fig. 2. Effect of nitrogen rate on panicles/m2 of two rice cultivars. Dingville 1990

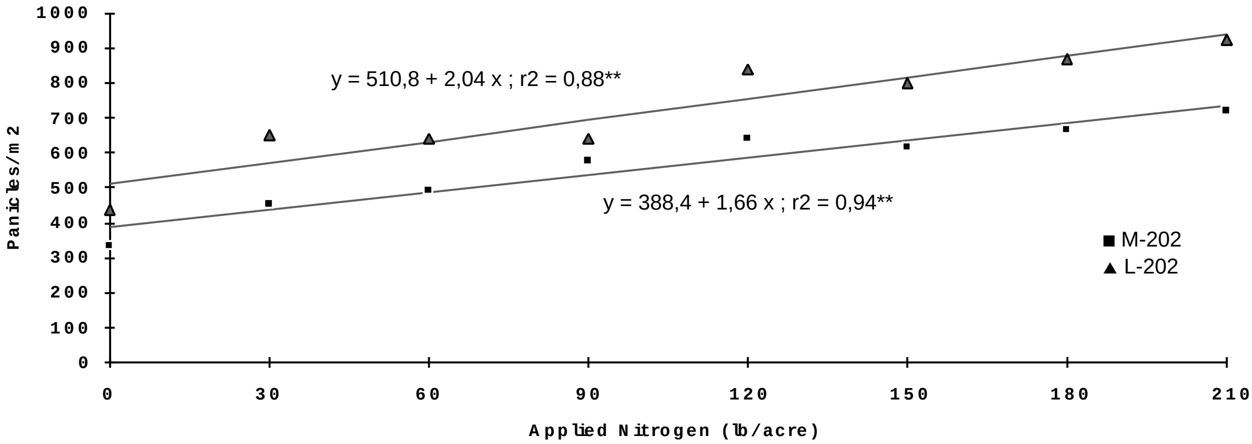

Fig. 3. Effect of nitrogen rate on filled grains/panicle of two rice cultivars. Biggs 1990

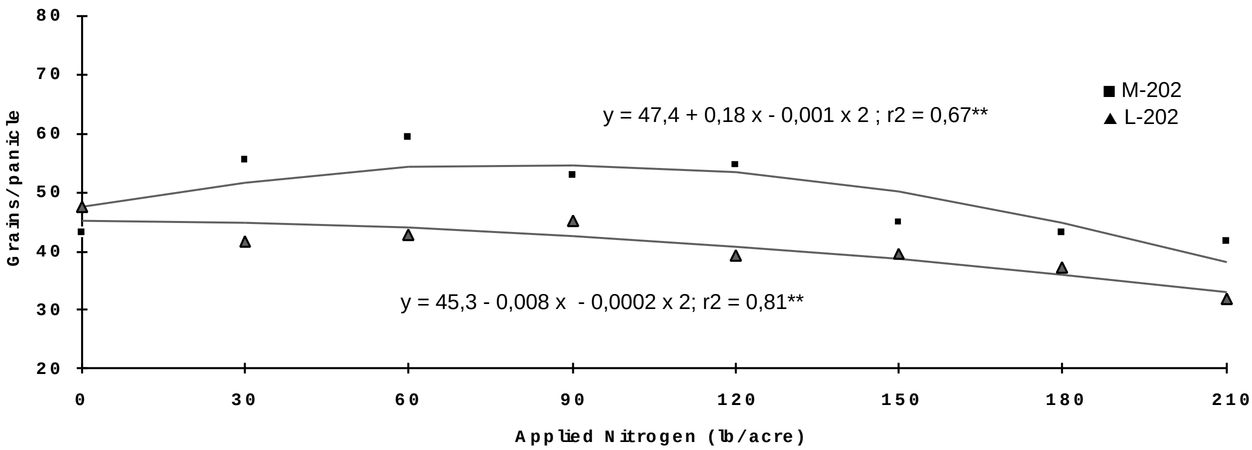

Fig. 4. Effect of nitrogen rate on filled grains/panicle of two rice cultivars. Dingville 1990

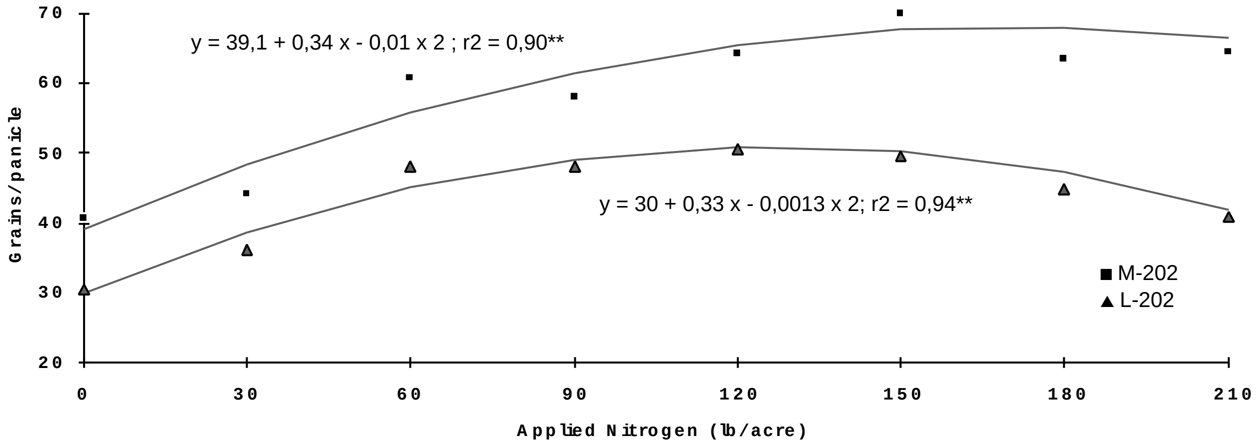

Fig. 5. Effect of nitrogen rate on 1000 grains weight of two rice cultivars. Biggs 1990

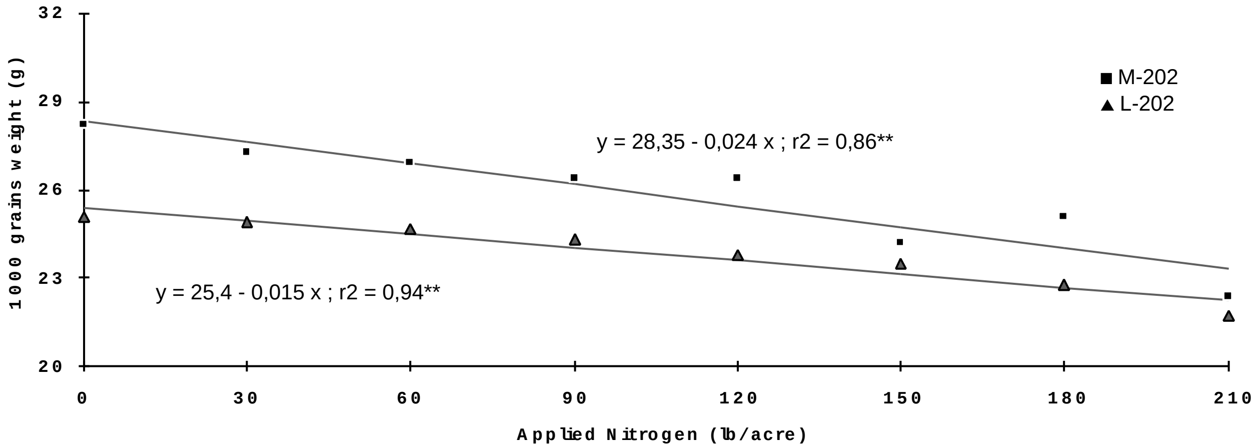

Fig. 6. Effect of nitrogen rate on 1000 grains weight of two rice cultivars. Dingville 1990

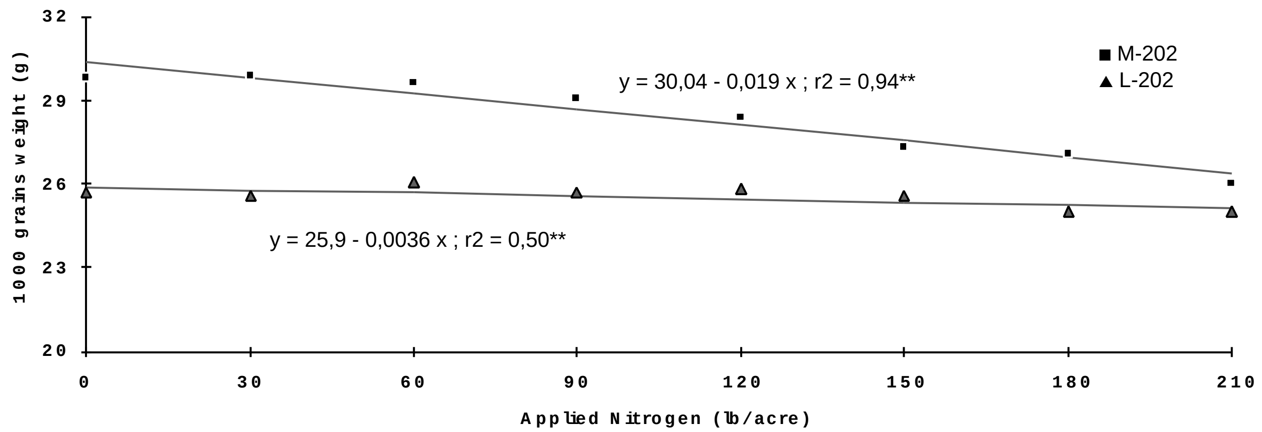

Fig. 7. Effect of nitrogen rate on blank grain percentage of two rice cultivars. Biggs 1990

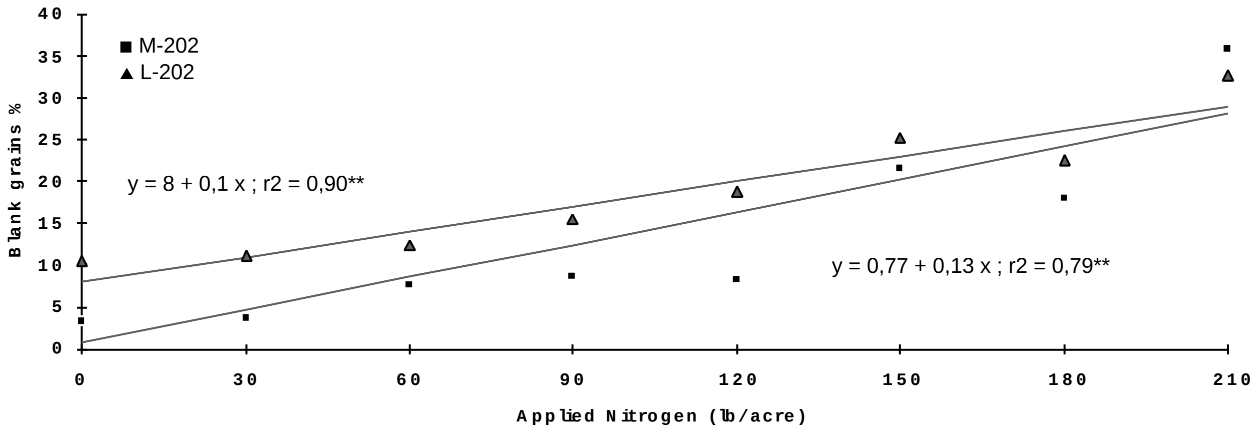

Fig. 8. Effect of nitrogen rate on blank grain percentage of two rice cultivars. Dingville 1990

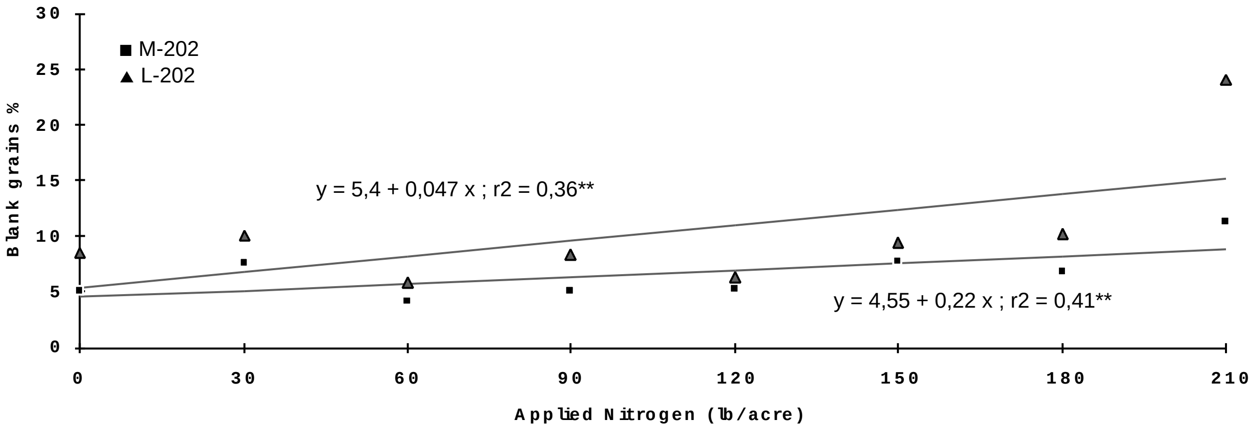

Fig. 9. Effect of nitrogen rate on grain yield (at 14% moisture) of five rice cultivars. Biggs 1990

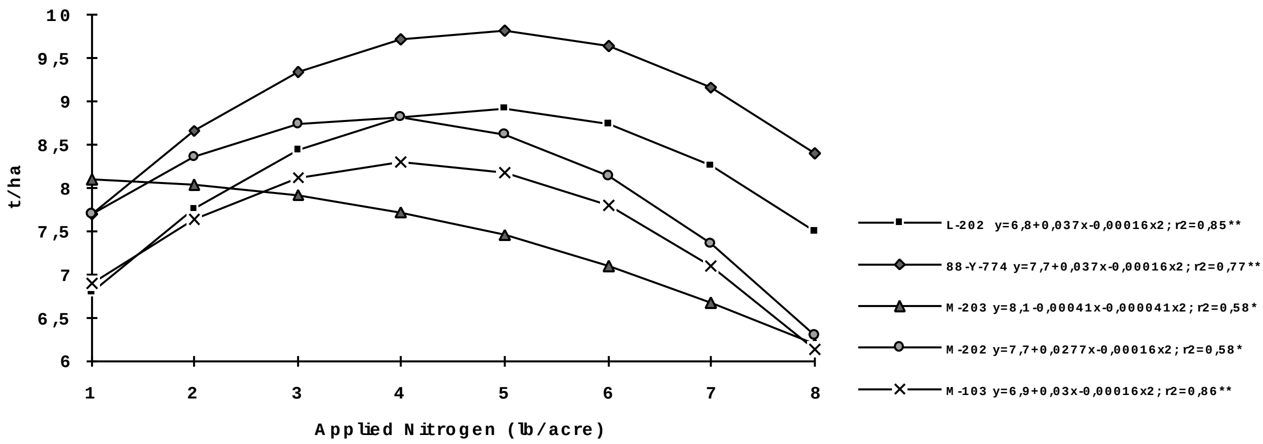

Fig. 10. Effect of nitrogen rate on grain yield (at 14% moisture) of five rice cultivars. Dingville 1990