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Rice yield as affected by the split method of "N" application and nitrification inhibitor DCD

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Abstract. Large quantities of N fertilizers may be lost in rice fields by nitrification-denitrification. In this connection, experiments were carried out in order to compare the effects from slow-release N-fertilizers (ISODUR) and products integrated with diciandiamide (DCD), a nitrification inhibitor, with the N splitting method applied in two or three times on the rice growth and yield. The effect of increasing N rate at preplant time compared with the topdressing application was also determined. Experiments were conducted for 2 years on a typical Po Valley sandy soil. Fertilizers treatments were applied on two commercial rice cultivars, *Baldo* and *Panda,* using a split-plot design. Fertilizer treatments replicated four times were main plots; and cultivars were subplots. Different types of N fertilizers through two years experiments were compared with N split applications based on two or three times. Plant growth (height), plant development (days to heading and ripening), rice yield, yield components, and quality were monitored. Results showed that split fertilization with N topdressed at panicle initiation stage was more effective in rice yielding than preplant only application, independently from the N rate. Commercial “slow-release” fertilizer and ammonium sulphate were less effective in rice production. Compared to urea, inhibitor of nitrification, Diciandiammide (DCD) was the top yielding treatment, when applied with the split method. The fertilization method, based on three split N applications, showed no significant yielding differences compared to the two times method.

I – Introduction

Nitrogen is one of the most important nutritional elements for the productivity of cereal crops. In the case of rice, up to two-thirds of the N absorbed by the plant is furnished from the soil, even in fertilized fields. Therefore, natural sources of N, transformation and availability processes of N, markedly influence fertility in paddy fields and the efficiency of the fertilizer nitrogen use for high yields. Response of rice varieties to N in ricefields is generally recognized, but crop recovery of applied N is only 20 to 35% due to the losses in several ways (Ponnamperuma and Deturck, 1993).

For instance, nitrate in flooded soils moves into reduced zone where it is rapidly converted by denitrifying bacteria to N_2 and N_2O gases unsuitable for rice plant. Denitrification is generally reported as a major reason for the low efficiency of applied ammonium fertilizers. Losses of nitrate by leaching can even occur, especially if the submerged soil is sandy. Recent findings suggest that 15 to 45% of surface applied ammonium-N fertilizers may be lost by nitrification-denitrification processes. Nitrate present in dry soil disappears within a few days after flooding (Ponnamperuma, 1965). If N fertilizers are incorporated in dry soil, the soil should be flooded within a few days to minimize nitrification-denitrification losses.

Ammonia volatilization may even cause losses up to 60% of urea-N fertilizers applied to flooded soils. Deep placement of NH_4 fertilizers can reduce losses of N by denitrification and NH_3 by volatilization.

In order to reduce N losses from the soil various slow-release, fertilizers have been developed which would provide a continuous and regular supply of nitrogen during the annual cycle. Among these fertilizers one of the best known is sulfur coated urea (SCU). Other fertilizers are products of urea condensation with formaldehyde or several aldehyde types (Isodur, Ureaform, IBDU, CDU).

Because denitrification is probably the most frequent reason for the N losses in submerged soils, the use of nitrification inhibitors, like diciandiamide (DCD), is recommended too. Another possibility for reducing losses and increasing N fertilizers efficiency is splitting N application in two or three times, part basally and part as topdressing, especially if the soil is sandy. Much research has been done to find the most suitable method for timing and splitting nitrogen application. The benefits from N topdressing at the initial panicle primordium stage are widely recognized. Early studies showed that improvement in the productivity from topdressing depends widely upon the positive effect of N application at panicle initiation stage on both grain number per panicle and total grain number per area unit of productivity components (Russo et al., 1991) *(figures 1, 2, 3)*. However, recently, a series of field trials showed the possibility for splitting N in three times, rather than in two, as a more suitable method to meet special exigencies of the indica type varieties or associated with sandy soils (Moletti et al., l990; 1992).

Great emphasis has been placed, for the Italian rice production, on studies for reducing N losses and enhancing N efficiency. The objective of the present study has been to compare the effects from slow-release N-fertilizers (ISODUR) and products integrated with diciandiamide (DCD), a nitrification inhibitor, with the N splitting method applied in two or three times on the rice growth and yield. We also evaluated the effect of increasing the N rate at preplant time compared with the topdressing application.

II – Material and methods

The experiments were carried out in plots for two successive years in a typical rice field of northern Italy (Po Valley). Some physical and chemical characteristics of the soil are given in *Table 1*. The soil originated from alluvial deposits is a typical sandy soil.

In the 1992 experiment *(Table 2)*, the control and the slow-release fertilizer Isodur (15% N) were compared with two amounts (respectively 75 and 110 kg/ha N) of fertilizer (as urea) applied to each of the following treatments:

1) at preplant time only;
2) two applications: preplant (2/3 N) and panicle differentiation stage (1/3 N);
3) three applications: preplant (1/2 N), beginning tillering (1/4 N) and panicle differentiation stage (1/4 N).

All the experimental plots received the same amounts of phosphorus (60 kg/ha P_2O_5 as superphosphate) and potasssium (250 kg/ha K_2O as potassium chloride). Ferlilizers at preplant time were incorporated into the soil 5 cm deep. Topdressing application was done directly on soil surface.

Two different rice varieties, *Baldo* and *Panda,* were sown on 29 April by the direct broadcast method in each of the four plots of all treatments. The experimental design adopted was a complete randomized split-plot block with 4 repetitions.

During the whole cultural cycle, experimental plots were kept submerged continuously, except for two weeks, because of the chemical weeds control carried out using a mixture of 100 g/ha Bensulforun-methyl and 12 kg/ha Propanil plus a second application of 10 kg/ha Propanil. Recorded observations in each plot included the following agronomical parameters: a) days to flowering; b) days to maturity; c) plant height in cm; d) panicle length in cm; e) number of fertile panicles per m^2; f) percentage of humidity in grains; g) paddy yield [t/ha] at 14% moisture; h) total milling yield (%); i) head rice yield (% whole, milled grain). The recorded data were subjected to a factorial analysis of variance to determine statistical differences.

In the 1993 experiment *(Table 3)*, standard fertilizer treatments in two or three times, as urea, were compared with two new products containing nitrification inhibitors, like LAB D (23°/N) and Basammon Stabil (25% N). Particularly, the latter contains 2% of diciandiamide (DCD) inhibitor. Basammon was used with both two methods of application: at preplant stage only or split in two times. Ammonium sulphate was also applied at preplant stage as a reference for new products. All fertilizers were used at two N rates: respectively, 80 kg/ha, the lowest N dose and 120 kg/ha, the highest N dose, compared with the control.

Fertilizers applied at preplant were incorporated into soil at 5 cm deep. Topdressing application was done directly on soil surface. All experimental plots received, as in 1992, the same amounts of phosphorus (60 kg/ha P_2O_5 as superphosphate) and potassium (250 kg/ha K_2O as potassium chloride). Rice varieties

Baldo and *Panda* were sown on 30 April by the direct broadcast method in each of four plots of all treatments. The experimental design adopted was a complete radomized split-plot block with 4 repetitions.

During the whole cultural cycle in both years, experimental plots were kept submerged continuously, except for two weeks, because of the chemical weed control carried out using a mixture of 100 g/ha Bensulfuron-methyl and 12 kg/ha Propanil plus a second application of 10 kg/ha Propanil 6 days after.

For each variety, the following agronomical parameters were evaluated: a) days to flowering; b) days to maturity; c) plant height in cm; d) panicle length in cm; e) number of fertile panicles per m^2; f) percentage of humidity in grains; g) paddy yield (t/ha) at 14% humidity; h) total milling yield (%); i) whole-kernel rice yield (%). The data obtained were subjected to a factorial analysis of variance to determine statiscal differences. Plots harvesting was done mechanically by plot-combine Iseki.

III – Results and discussion

1. The experiment of year 1992: Results of the 1992 experiment are summarized in *Table 4*

A. Paddy yield

Figure 4 also shows the treatments effect on the average rice production of both varieties. Compared with the control, all treatments, as expected, were significantly higher, except the slow-release fertilizer (Isodur). The highest dose of urea split in three times gave maximum paddy yield, but two times split urea at both low and high doses were very near and not significantly different. In fact, the two methods of split N application appear near enough and statistically not different. The only preplant N treatment gave slower yield than the split application method. This result was very similar to those obtained in previous studies.

Application of slow-release fertilizers (110 kg/ha N) produced a significant decrease of rice yield. Thus, the effect on rice production of the Isodur N release pattern appears insufficient due mainly to the lack of synchronism with the peaks of plant nitrogen demand. The interaction between varieties and treatments resulted statistically insignificant ($p<0.05$).

B. Heading and ripening

Regarding the flowering date, no significant effect from fertilizer treatments was observed compared with the control. However, the N split application in two times has slightly shortened the cycle to heading date. The variety *Baldo* was considerably earlier at heading stage than the *Panda* variety.

Regarding the ripening time, compared with all the other treatments, the control showed significant effect in shortening the cycle duration. No significant differences for the ripening were found among fertilizer treatments for both the *Baldo* and *Panda* varieties.

C. Plant height

Plant height was naturally influenced by fertilizer treatment, in particular the N dose was determinant. But only the control and slow-release fertilizer significantly reduced the plant height compared with other treatments. We can note the poor effect of this last treatment on the plant growth according to lower yield. Generally N application in two or three times increased slightly the plant height. In previous experiments, similar results were explained as a positive effect of N topdressing on increasing panicle length, consequently on increasing the total grain number per plant (Russo et al., 199l).

D. Number of fertile panicles per m^2

This important component of grain production was quite influenced by treatments. The control and lowest preplant N dose reduced significantly the number of panicles per m^2. In general the two or three times N application improved tillering and produced the highest number of fertile panicles.

E. Blast attacks *(Pyricularia oryzae)*

Attacks from Pyricularia were evaluated according to a damaging range from 0 to 5. No important differences were found among the fertilizer treatments. The control and two times N application produced the smallest damaging effects. The *Baldo* variety showed the strongest attacks compared with *Strella*..

F. Lodging effects

The highest N dose at preplant, or split in two or three applications, produced more serious lodging effects due essentially to the higher sensibility of the *Baldo* variety. In general, plots treated with the three times application method appeared to be more lodged.

G. Whole-kernel rice yield

No significant differences were observed among several fertilizer treatments for the whole kernel rice yield percentage, indicating that the late N application does not affect this commercial parameter. Similarly, according to the data recorded in 1993, the effect of variety proved insignificant.

2. Experiments of the year 1993

Results of the 1993 experiments are summarized in *Table 5*.

A. Paddy yield

The level of rice yield was significantly influenced by different fertilizer treatments *(Figure 5)*. Obviously, the control determined the lowest grain production (3,4 t/ha) according to nutrient shortage in the unfertilized plots.

Application of both LAB and Ammonium sulphate fertilizers increased significantly rice yield, but still not sufficiently considering the N rate contribution ranging from 80 to 120 kg/ha.

Also basal application of Basammon Stabil (integrated with the nitrification inhibitor DCD) at both N doses (80 and 120 kg/ha) produced poor increases of rice yield. But split application of Basammon in two times produced a further highly significant increase of yield due essentially to the positive effect of topdressing on the N availability at panicle initiation stage. A similar effect was observed for the N fertilizer applied as urea in two times compared with preplant application.

Application of urea in three times, however, was not able to increase further yield compared with the two times method. This results are consistent with those obtained in the year 1992.

B. Heading and ripening

For the heading date, no significant effect from fertilizer treaments was observed compared with the control. However, the highest basal N doses, or three times application, have slightly prolonged the cycle to the heading date. The *Baldo* variety was slightly earlier at heading stage than the *Panda* variety.

Regarding the ripening time, compared with all the other treatments, the Basammon application at highest rate in two times shortened slightly the cycle duration. The *Baldo* variety also reached ripening stage earlier than the *Panda* variety.

C. Plant height

The effect of fertilizer treatments on plant height was rather clear and statistically significant. The control reduced significantly the plant height compared with all the other treatments. Generally height increase related to the highest N dose provided at preplant time. Generally N application in two or three times increased slightly the plant height. In previous experiments, similar results were explained as a positive effect of N topdressing on increasing panicle length. But the greatest increase of plant height (94.25 cm) was obtained using the highest dose of Ammonium sulphate (120 kg/ha). Thus, appears clearly the stimulating effect of preplant ammonium sulphate application on height increase.

Varietal influence on height was also significant. The average height of the *Panda* variety was about 2 cm higher than for the *Boldo* variety.

D. Panicle length

In this experiment, treatments influenced significantly the panicle length. Treatments based on N fertilizers applied at preplant time (independently from the dose) and unfertilized control, produced the shortest panicle compared with the other treatments. In fact, topdressing fertilizers application (especially at highest N dose) produced, on the average, longer panicles, with a favourable effect on the grain number per panicle. Varietal differences in panicle length were high and significant. The *Panda* variety produced a panicle about 4 cm longer than the *Baldo* variety.

E. Number of fertile panicles per m^2

This parameter, as it was expected, has influenced rice yield quite in connection with fertilizer treatments. In fact, the lowest fertile panicles number was recorded for the unfertilized control. In general, treatments, more productive, gave significant higher panicles number per m^2. The plots fertilized with the highest N rate applied in two times showed the maximum panicles number per m^2. No significant difference in panicles number was observed between the *Baldo* and *Panda* varieties.

F. Blast attacks *(Pyricularia oryzae)*

No significant differences were found for blast attacks among the fertilizer treatments. The control and the lowest N rate showed the smallest damaging effects. The *Baldo* variety showed the strongest attacks compared with *Strella*.

G. Whole-kernel rice yield

No significant differences were observed among several fertilizer treatments for the whole-kernel rice yield percentage, indicating that the late N application does not affect this parameter. However, there was in general evidence for improving this important commercial parameter with the split application of N fertilizers in two or three times. According to the recorded data, in this year, the *Panda* variety showed higher whole-kernel rice yield than the *Baldo* variety.

IV – Conclusions

Results of the events, carried out for two years in a typical sandy soil comparing various slow-release and nitrification inhibitor fertilizers with split N application indicated that the losses of nitrogen in rice fields can be reduced and that the fertilization efficiency can be increased. It appears evident that split fertilization with N topdressed at panicle initiation stage is more effective in rice yielding than preplant only application. Consequently split N use appears a more efficient method of rice fertilization. It seems also effective to prevent or reduce N losses in rice fields.

Generally, commercial “slow-release” fertilizers are poorly effective in rice production. Little is known of this behaviour due, with all probability, to the lack of synchronism wih the peaks of plant nitrogen demand.

Inhibitors of nitrification, like diciandiammide (DCD), seem effective to prevent N losses and increase rice yield, specially when applied with the split method, but are unfortunately still costly. The fertilization method based on three split N applications does not present special advantages compared to the two times method and is generally more costly too.

In conclusion, we can recommend the two split applications method that is generally more effective in rice production: 2/3 N at preplant and 1/3 N at panicle initiation stage. Generally, the most effective dose of N fertilizer in low-medium fertility soils gets at 150 kg/ha with both ways at preplant or two times application.

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Table 1. Some physical and chemical characteristics of experimental soil

Components	**Depth: 0-20 cm**
Clay (%)	8,98
Loam (%)	18,50
Sand (%)	72,49
pH	5,50
Organic matter (%)	2,06
Total nitrogen (‰)	1,37
Total phosphorous (‰)	1,40
Exchangeable potassium (ppm)	159,40

Table 2. Fertilizer treatments - Year 1992

Treatment	**N Dose** (kg/ha)	**Application time**
Control	0	none
ISODUR (slow release)	110	preplant
1 N S	75	preplant
2 N S	110	preplant
1 N 2 times	75	2/3 preplant 1/3 panicle differentiation
2 N 2 times	110	"
1 N 3 times	75	50% preplant 25% tillering 25% panicle differentiation
2 N 3 times	110	"

Table 3. Fertilizer treatments - Year 1993

Treatments	**N Dose** (kg/ha)	**Application time**
Control	0	none
LAB 80	80	preplant
LAB 120	120	preplant
AMMONIUM SULPHATE 80	80	preplant
AMMONIUM SULPHATE 120	120	preplant
BASAMMON 80 Preplant	80	preplant
BASAMMON 120 Preplant	80	preplant
BASAMMON 80 2 times	120	2/3 preplant 1/3 panicle differentiation
BASAMMON 120 2 times	120	"
1 N 80 Preplant	80	preplant
2 N 120 Preplant	120	preplant
1 N 80 2 times	80	2/3 preplant 1/3 panicle differentiation
2 N 120 2 times	120	"
1 N 80 3 times	80	50% preplant 25% tillering
2 N 120 3 times	120	25% panicle differentiation

Table 4. Effect of fertilizer experiments on rice growth and yield - Year 1992

Fertilizer treatments	**Yield** (t/ha)	**Days to heading**	**Days to ripening**	**Plant height** (cm)	**Fertile panicles** (n x m2)	**Blast** (°)	**Lodging** (%)	**Head yield** (%)
Control	4,78	96,00	130,85	96,18	433,50	2,0	1,10	59,10
ISODUR (slow release)	5,32	95,60	132,00	97,39	485,50	3,5	2,60	59,50
1 N preplant	5,57	96,10	133,10	97,72	477,00	3,0	9,75	59,40
2 N preplant	5,80	96,40	132,75	100,74	479,50	3,5	15,40	58,00
1 N 2 times	5,95	95,50	132,60	99,95	488,00	3,0	6,60	59,75
2 N 2 times	6,14	94,75	134,00	100,97	483,50	2,0	20,50	58,40
1 N 3 times	6,05	95,75	132,90	99,40	494,00	3,0	11,10	59,75
2 N 3 times	6,20	96,40	133,75	100,05	496,00	3,0	21,10	58,60
CV (%)	5,73	1,32	0,90	3,07	7,75	—	—	4,82
LSD ($p < 0.05$)	0,57	1,15	2,34	2,48	44,00	—	—	2,69
Cv. Baldo mean	5,95	93,72	133,25	96,74	452,03	4,0	20,50	59,37
Cv. Panda mean	5,50	97,91	132,25	101,36	507,30	1,0	1,50	58,75
Mean	**5,73**	**95,80**	**132,75**	**99,05**	**479,50**	**3,0**	**11,00**	**59,06**

(°) Range of attacks: 0-5

Table 5. Effects of fertilizer experiments on rice growth and yield - Year 1993

Fertilizer treatments	Yield (t/ha)	Days to heading	Days to ripening	Plant height (cm)	Panicle length (cm)	Fertile panicles (n x m2)	Blast (°)	Head yield (%)	Total yield (%)
Control	3,43	94,37	132,50	80,66	17,67	335,50	1,5	58,87	71,00
LAB 80	4,65	93,50	131,87	87,15	17,89	439,00	1,5	58,12	71,00
LAB 120	4,72	93,75	132,62	92,75	18,09	446,00	2,0	54,87	70,50
AMMONIUM SULPHATE 80	4,46	93,37	132,75	89,50	17,95	438,00	1,5	56,37	70,87
AMMONIUM SULPHATE 120	4,78	94,37	131,62	94,25	18,04	438,50	2,0	57,62	71,00
BASAMMON 80 preplant	4,32	93,62	132,00	88,00	18,27	371,50	2,0	59,75	70,87
BASAMMON 120 preplant	4,65	93,50	131,87	88,89	17,74	432,50	1,5	60,12	71,00
BASAMMON 80 2 times	5,11	93,37	132,87	87,80	18,05	446,00	2,0	59,87	71,00
BASAMMON 120 2 times	5,70	92,12	130,75	90,42	18,30	432,00	2,0	59,75	71,00
1 N 80 preplant	4,70	93,50	132,37	89,39	18,27	435,50	2,0	56,50	70,62
2 N 120 preplant	5,05	94,00	132,62	90,80	17,39	428,50	2,0	57,62	71,12
1 N 80 2 times	5,30	93,00	133,12	89,99	18,66	417,00	1,5	57,00	70,62
2 N 120 2 times	5,60	93,87	131,75	92,15	19,24	462,00	2,0	59,62	71,00
1 N 80 3 times	5,14	92,87	131,75	90,36	18,34	425,50	1,5	56,00	70,75
2 N 120 3 times	5,63	94,00	131,25	91,77	18,52	448,50	2,0	60,87	71,00
CV	4,85	0,79	1,00	3,65	4,75	8,07	22,7	3,85	0,49
LSD ($p < 0.05$)	0,51	NS	NS	5,06	0,99	74,00	NS	NS	NS
Cv. Baldo mean	4,97	92,62	130,70	88,48	16,20	414,50	2,5	56,23	71,98
Cv. Panda mean	4,79	94,48	133,47	90,71	20,12	438,00	1,0	60,17	69,80
Mean	**4,88**	**93,55**	**132,08**	**89,59**	**18,16**	**426,5**	**2**	**58,2**	**70,89**

(°) Range of attacks : 0-5

Fig. 1 EFFECT OF PREPLANT AND SPLIT N APPLICATION ON RICE YIELD (average 3 Years 2 Varieties)

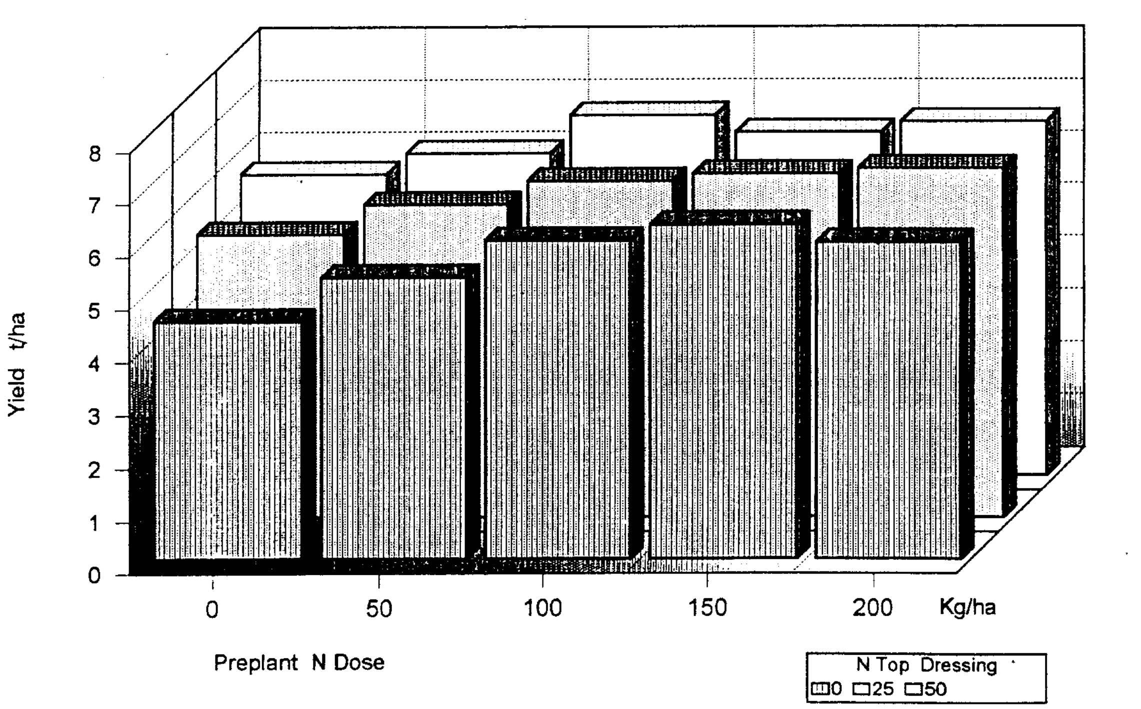

Fig 2. PLANT HEIGHT INFLUENCED BY FERTILIZER TREATMENTS (average 3 years 2 varieties)

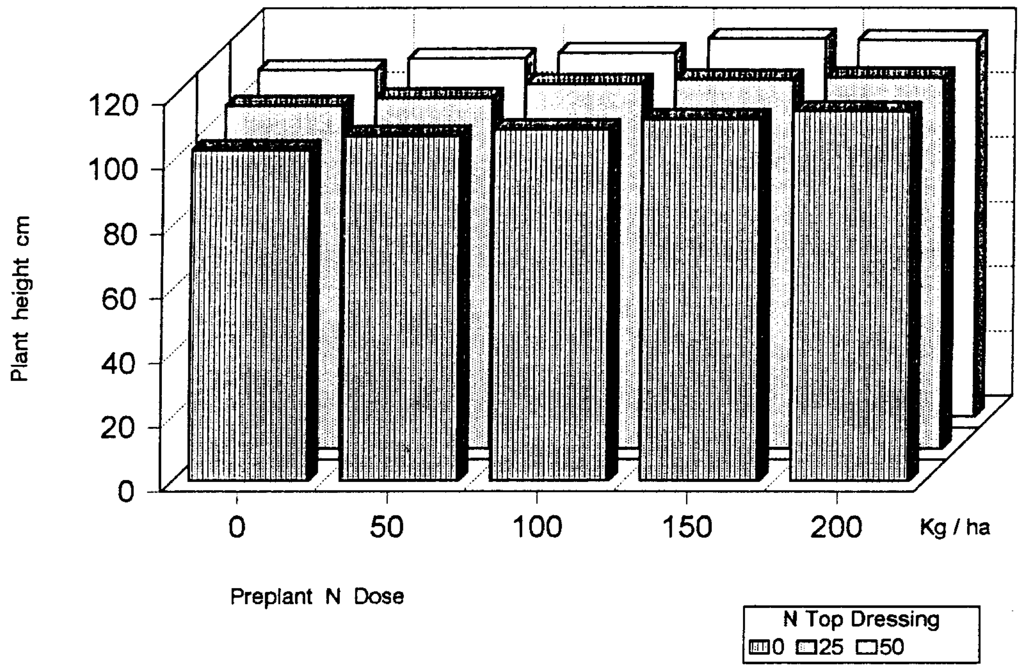

Fig 3. PANICLE LENGTH INFLUENCED BY FERTILIZER TREATMENTS (average 3 years 2 varieties)

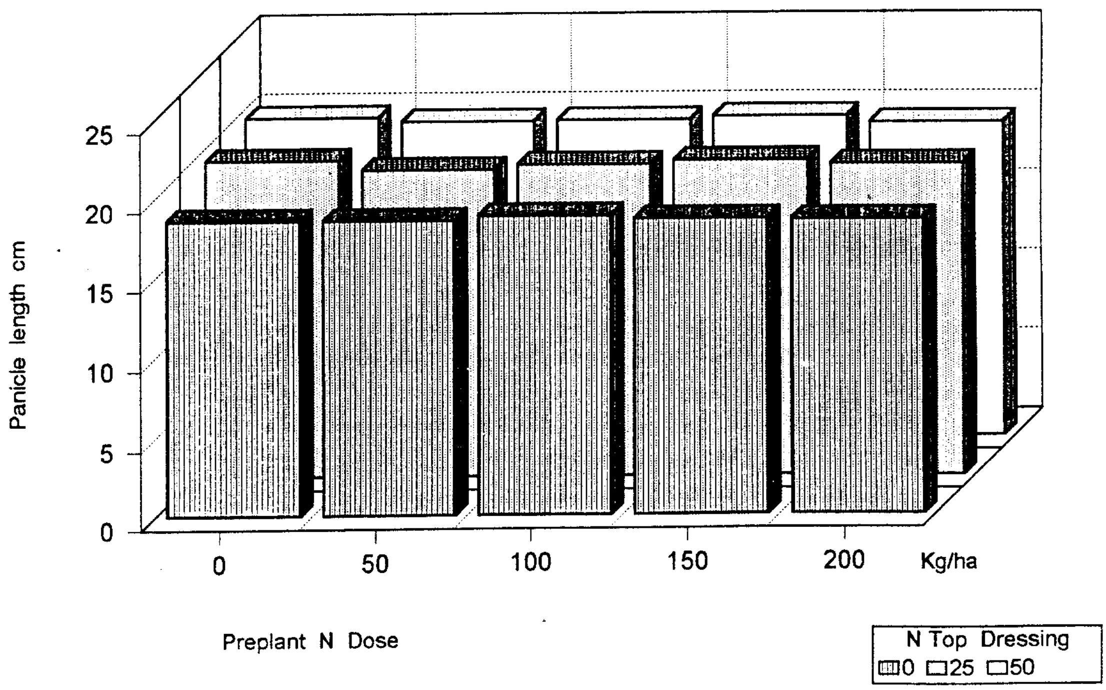

Fig. 4. EFFECT OF FERTILIZER TREATMENTS ON RICE YIELD. YEAR 1992

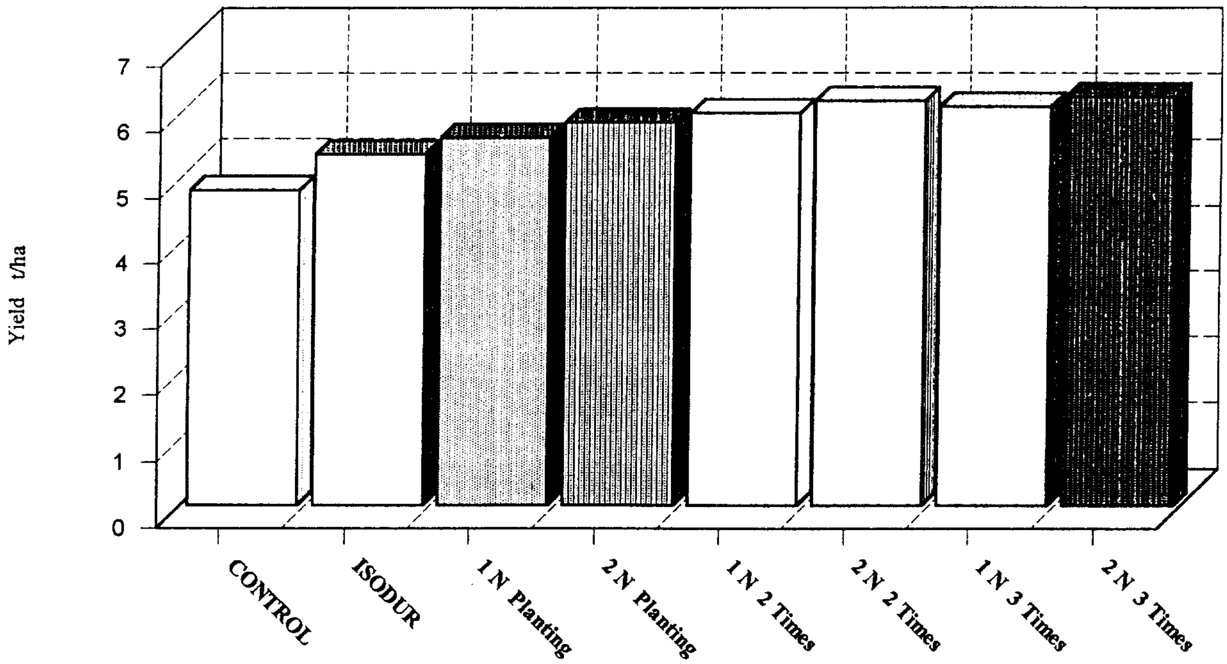

Fig 5. EFFECT OF FERTILIZER TREATMENTS ON RICE YIELD. YEAR 1993