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2 - 4

2. RESPONSE OF RICE VARIETIES TO NITROGEN
AND PHOSPHATE FERTILIZER ON EUROPOLDER
CLAY SOIL

D.J. Rees, M.R. Khodabaks & C.L.M. van den Bogaert

3. THE EFFECTS OF SEED SOURCE AND CROP
DENSITY ON RICE GROWN ON RED RICE-
INFESTED LAND IN NICKERIE, SURINAME

D.J. Rees & M.R. Khodabaks

4. A STUDY OF THE RICE CROP CALENDAR OF
NICKERIE, SURINAME, WITH RESPECT TO RAINFALL,
IRRIGATION AND DRAINAGE REQUIREMENTS

E.R. Witter & D.J. Rees

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**RESPONSE OF RICE VARIETIES TO NITROGEN AND
PHOSPHATE FERTILIZER ON EUROPOLDER CLAY SOIL**

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SUMMARY

Fertilizer response trials were conducted with five Suriname rice varieties on a coastal clay soil at Europolder, Suriname in 1993 and 1994. None of the rice varieties showed any response to applied phosphate, but marked responses to applied nitrogen were observed. Biological maximum yields varied from 5.4 to 7.6 t/ha, and economic maximum yields varied from 5.2 to 7.5 t/ha at nitrogen application rates of 120 to 190 kg/ha. The variety/land-race Marshall showed less response to nitrogen than the varieties developed in Suriname. Averaged over both seasons, economic optimum nitrogen rates were 110-120 kg/ha for Marshall, and 160-170 kg/ha for the other varieties, compared to the current recommendation of 120 kg/ha. Marginal rates of return on the additional investment in fertilizer were high, 0.9-1.9 in the 1993 long season, and 0.7-1.1 in the 1993/94 short season.

INTRODUCTION

Concern has been expressed by farmers, Ministry of Agriculture officials and others involved with rice in Suriname that current fertilizer recommendations may no longer be accurate, as a result of both continuous double-cropping, and of the changing economic environment for farming. In particular, some farmers and officials are concerned that continuous double-cropping of rice may have depleted soil phosphorus reserves to the point where P fertilizer may be needed on the soils of Europolder and other old polders (Noordam & Blik, 1985).

Several varieties are available for farmer use in Suriname, but descriptions of their relative responses to fertilizer are not available. The most commonly grown variety is Eloni, an extra-long grain, 120-130 day variety developed in Suriname. Many farmers are increasingly growing a variety referred to as Marshall, a long-grain 110-120 day variety that has not been officially released in Suriname, and is thought to be an informal release of the line CICA-4 developed in Columbia. Two other varieties, Diwani and Ferrini, and a new variety, Groveni, all extra-long grain varieties developed in Suriname are also available.

The current Ministry of Agriculture recommendation is for 260 kg/ha urea (120 N/ha) applied in three doses, for all varieties and soils. In 1989 in the Van Wouw area 55% of farmers applied two doses of urea (4 & 7 weeks after sowing), and 43% applied three doses (4, 7 and 10 weeks after sowing), with application rates up to 400 kg/ha (OAS, 1989). Keisers (1987, 1988) reported maximum yields at 180 N/ha with the rice variety Eloni grown on Europolder clay, similar to the highest doses used by farmers as reported by OAS (1989). None of these studies considered the cost of the fertilizer in relation to the value of the rice, however.

A limited soil survey suggested that responses to P fertilizer might be expected on the more acid soils of Corantijn, Hamptoncourt, Prins Bernard and other young polders (Noordam, 1985). Field trials gave variable results, with increases in grain yield shown on the soils of Nanni Polder, Paradise and Longmay, but not on the Europolder soil (Keisers, 1985).

Trials were initiated at the Anne van Dijk Rijstonderzoekscentrum, Nickerie, in 1993, with the objective of developing a data-base of rice responses to N and P fertilizers that would be accessible to farmers, covering all rice growing areas of Nickerie, and all the varieties currently in use. This report covers the first three trials for 1993 and 1994, carried out at Europolder.

MATERIALS & METHODS

The trials were carried out on coastal clay soils (fine clay, isohypothermic Typic Tropaquept) in Nickerie (5°57'N, 57°02'W). The 0-30 cm layer was characterized by Noordam (1985) as: 64% clay, 35% silt; pH 5.1; organic matter 4.2%; EC 0.54 mS/cm; total N 0.24%; and total P (25% HCl) 534 ppm. Two rainy seasons are distinguished; the long season from April to August, and the short season from November to January, with an average annual total of 1830 mm, and peak 10-day totals of 50-90 mm from May 10 to July 20 and 25-50 mm from November 10 to January 30 (50% exceedence probabilities). Monthly average temperatures are 25-26 C during January and February, and 27-28 C from August to October.

In the 1993 long rainy season, a split-split-plot factorial trial (five nitrogen fertilizer rates x five varieties x 4 phosphate fertilizer rates) with three replicates was sown with pre-germinated seed at Europolder, Nickerie on July 1 1993. In the 1993/94 short rainy season, the trial was divided into two, with responses to P₂O₅ and N evaluated separately. The nitrogen response trial was planted as a split-plot factorial with four replicates, with the same varieties and nitrogen fertilizer levels, on December 15. The phosphate trial was superimposed on neighboring commercial paddy production fields, with five replicates of four P₂O₅ levels applied separately to Eloni, Ferrini and Groveni varieties. This trial was analyzed as a two factor split plot. Plot sizes were 18 and 21 m² in the long and the short rainy seasons, respectively.

The phosphate was applied manually at rates of 0, 45, 90 & 180 kg/ha P₂O₅, broadcast onto the drained soil one day after sowing in the first trial, and five days after sowing in the second trial. The nitrogen was applied at rates of 0, 60, 120, 180 and 240 kg/ha N as urea (46% N) split into three doses applied at 35, 50 and 72 days after sowing, broadcast onto the soil after field-drainage. Propanil and 2,4-D amine were applied at 10-14 days after sowing for early weed control, and 2,4-D amine was re-applied at 28-30 days after sowing. 0.5 kg/ha fentin acetate was applied three days before sowing for snail control. Insect pests (*Hydrellia* spp., *Caulopsis cuspidata*, and *Oebalus poecilus*) were controlled with monocrotophos and/or lambda-cyhalothrin. Red rice (*Oryza sativa*) weeds were removed manually between 70 and 90 days after sowing.

The timing of flowering was monitored by visual estimates of the percentage of stems showing at least 1/3 of their inflorescence, taken every 3 days from 72 days after sowing. Separate logistic curves (equation 1) were fitted to the data of each replicate by least-squares linear regression, and the time to 10%, 50% and 90% flowering determined from equation 1.

$$Y = \frac{Y_M}{1 + e^{-(b_0 + b_1 X)}} \quad (1)$$

where Y is percentage plants flowering, Y_M is 100% flowering, X is days after sowing, and b_0 and b_1 are empirically determined coefficients.

The crops were harvested manually between 120 and 130 days after sowing. In the first season yields were sampled from 1 m² sub-plots, subsequent yield estimates were made from the whole plots. Rough rice yields were determined after threshing and winnowing and corrected to a standard moisture content of 14%.

Yield responses to N were evaluated by fitting quadratic curves (equation 2) to the data by least-squares multiple regression. Although quadratic functions have the drawback that the coefficients do not have a precise biological meaning, they are the most widely used functions for modelling fertilizer responses as they generally provide good fits to fertilizer response data, and to facilitate determination of biological and economic optima (e.g. Landsberg, 1977; Nelson *et al.*, 1985; Schmilde, 1987; Scharf *et al.*, 1993).

$$Y = b_0 + b_1 X + b_2 X^2 \quad (2)$$

where Y is rough rice grain yield (kg/ha); X was fertilizer applied (kg/ha); and b_0 , b_1 and b_2 were empirically determined constants.

The rate of change of yield with change in fertilizer application, dY/dX , is zero at maximum yield, therefore Y is maximum when:

$$X_M = -\frac{b_1}{2b_2} \quad (3)$$

where X_M is the nitrogen fertilizer application rate for maximum biological yield. Equations 2 and 3 describe the biological response to fertilizer. Maximum *economic* yield, however, is also dependent upon the cost of the fertilizer, the cost of application, and the price of the rice. Maximum economic yield occurs when the rate of change in crop value (Yc_Y) equals the rate of change in fertilizer cost (Xc_X), where C_X and C_Y are the costs of the fertilizer and of the rice, respectively (equation 4).

$$C_Y \frac{dY}{dX} = C_X \quad (4)$$

Differentiation of equation 1 and rearrangement of equation 4 gives:

$$X_E = \frac{C_X / C_Y - b_1}{2b_2} \quad (5)$$

where X_E is the nitrogen fertilizer rate for maximum economic yield.

The estimation of maximum economic yields was complicated by the rapid changes of prices then current in Suriname. Accordingly, two separate analyses were carried out. One was based on Ministry of Agriculture estimates of the prices prevailing during each cropping season, incorporating exchange rate subsidies. The second analysis was based on cost estimates for a "post-structural adjustment" scenario, in which all prices were expressed in US\$ based on european/american costs of agricultural machinery plus 6% import duties, 32% handling/transport fees, and a unified "free" exchange rate for all items, including fuel, labour and credit (Table 1).

Table 1. Financial costs of rice production, "post-structural adjustment".

Activity	US\$/h
Land preparation	102.89
Snail control	15.18
Seed sowing	43.81
Ditch maintenance	1.50
Weed control	40.87
Pest control	37.55
Fertilizing	112.42
Water pumping	87.15
Red rice control	4.50
Transport	4.48
Harvesting	77.32
Infrastructure	3.00
Land lease	1.54
Insurances	0.30
Depreciation	1.21
Labour	31.86
Interest 6%	33.93
Farmers margin 10%	59.95
Total costs per ha	659.46
Average cost per ton ¹	157.01

¹ Assumes an average yield of 4.2 t/ha

RESULTS AND DISCUSSION

Response to phosphate fertilizer

The application of phosphate fertilizer did not have a significant effect on crop development (time of flowering) or yield for any of the varieties (Table 2), in agreement with the data of Keisers (1985). Analyses of soil P contents were not possible, but these results suggest that continuous rice cropping since 1985 has not resulted in significant loss in the phosphate-supply potential of the soil when flooded. Similarly, there is no indication of any change in the geographic locations of rice showing phosphate deficiency symptoms in Nickerie, suggesting that there is little likelihood of any major change in the need for phosphate fertilizer in the near future.

Table 2. Rough rice yields (t/ha) at different levels of phosphate application, 1993 long season (average of five varieties) & 1993/94 short season (average of three varieties)

P ₂ O ₅ kg/ha	1993	1993/94
0	5.90	4.53
45	5.73	4.46
90	5.95	4.41
180	5.60	4.49
Mean	5.79	4.47
S.E.	0.103	0.120

Response to nitrogen fertilizer

Flowering. The logistic function gave an excellent fit to the flowering data (Figure 1). The timing of crop development, as measured by the time to 50% flowering, was significantly different between varieties, between nitrogen levels and between seasons. In both seasons Marshall showed the least response to nitrogen, and Groveni showed the greatest response to nitrogen. Averaged over all varieties flowering was delayed by 0.3 and 0.07 days for every 10 kg/ha nitrogen applied in the 1993 long season and the 1993/94 short season, respectively. Differences between varieties were not consistent over both seasons, although the variety Diwani was one of the earliest to flower. The duration of flowering (time from 10% to 90% flowering) averaged nine days in both seasons, and Groveni showed a significantly longer flowering period than the others in both seasons. This together with the greater responsiveness to nitrogen fertilization suggests an increased sensitivity to environmental variations compared to the established varieties.

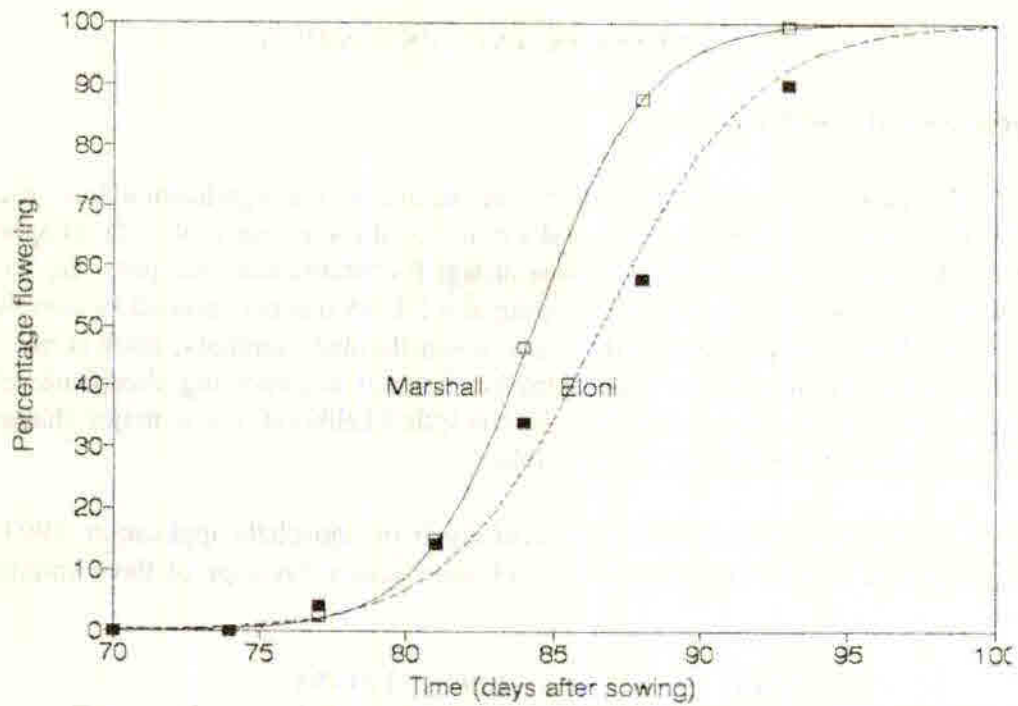


Figure 1. Flowering behaviour of two varieties at 120 kg/ha N, 1993 long season

Table 3. Times of 50% flowering (days after sowing), and duration of flowering (time from 10% to 90% flowering).

N kg/ha	Eloni	Diwani	Ferrini	Marshall	Groveni	Mean
1993 long season						
0	83	76	84	84	80	81
60	84	76	84	84	82	82
120	86	79	87	84	85	84
180	88	79	91	85	88	86
240	91	80	93	85	90	88
mean	86	78	88	84	85	84
	S.E. variety 0.58 *		S.E. N 0.24 *		S.E. VN 0.54 *	
1993/4 short season						
0	92	85	86	88	74	85
60	90	84	85	88	75	84
120	90	84	85	89	78	85
180	92	85	86	89	79	86
240	91	85	86	89	79	86
mean	91	85	86	89	77	85
	S.E. variety 0.15 *		S.E. N 0.21		S.E. VN 0.46	
Duration of flowering period (days)						
1993	9.3	9.1	9.2	7.1	11.4	9.2
	S.E. variety 0.25 *		S.E. N 0.25 *		S.E. VN 0.55 *	
1993/94	9.8	8.1	7.1	8.1	11.1	8.8
	S.E. variety 0.16 *		S.E. N 0.23 *		S.E. VN 0.52 *	

* Significantly different at $P < 0.005$.

