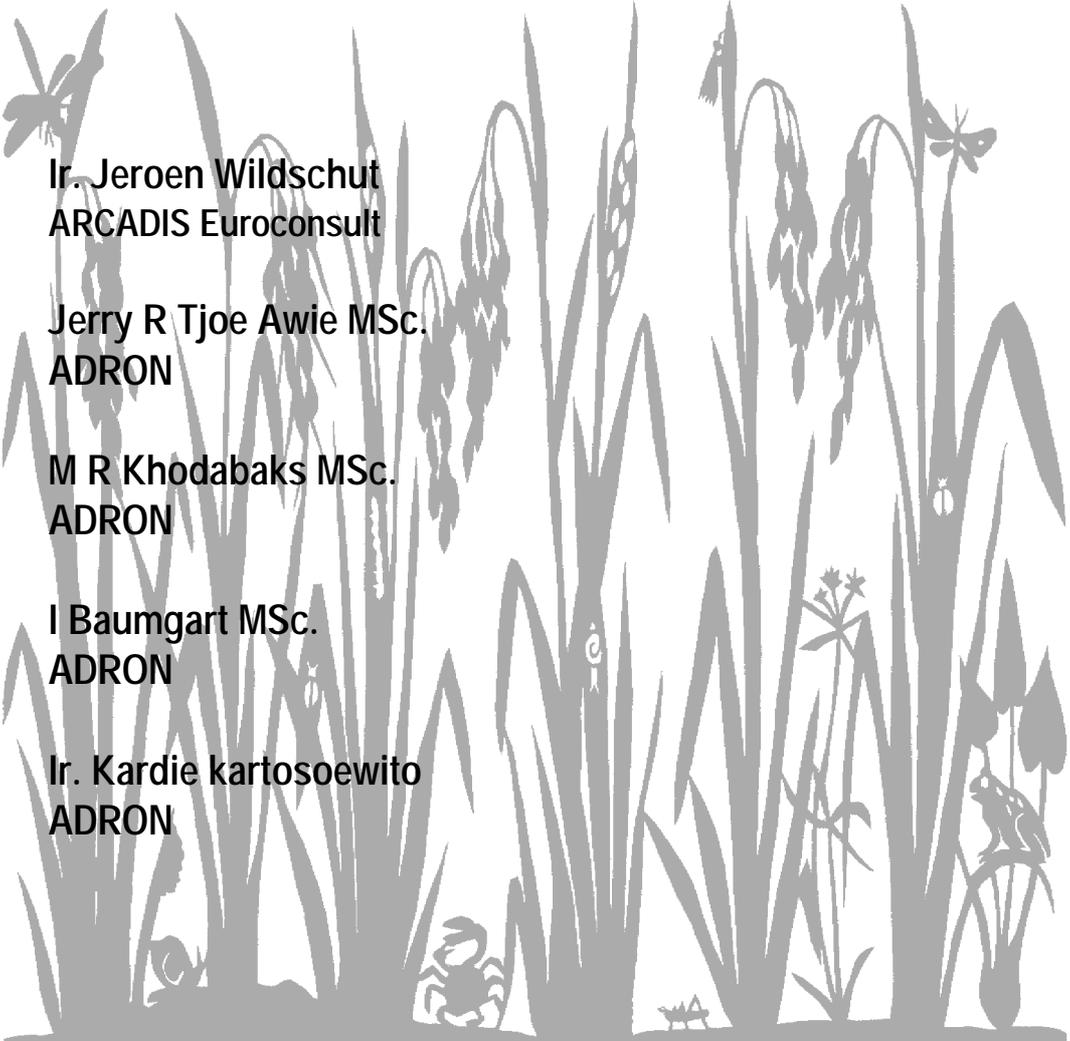


RICE RESEARCH

Papers and summaries

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1 Main Factors Determining Yield Differences between Farmers' Fields in the Nickerie District¹

Jeroen Wildschut² and Jerry R. Tjoe-Awie³

ABSTRACT

The results of a crop production survey, which was conducted in 1996 and 1997 by the 'Anne van Dijk' Rice Research Centre Nickerie (ADRON) showed that the variation in yields across the farmers' fields in the Nickerie district is very high. The average yield of the 30% least productive fields was 2.4 ton/ha whereas an average yield of 5.5 ton/ha was reached by 30% of the highest yielding fields. This variation in yields indicates the possibility that with an optimal application of current cultural practices and varieties the average yield could increase from the actual 4.0 ton/ha up to 5.5 ton/ha.

Soil tillage is intensive and costs are high, indicating that research on minimum tillage could be beneficial.

The sowing period lasts for 12 weeks. The last plantings and the first harvests are only one month apart. The timing of the cultural practices relative to the date of sowing is highly dispersed as well. Relatively late sown fields (more than 6-7 weeks after the first field) yield clearly less. Thus, new varieties which mature earlier (in ± 100 days) could be a solution for 30-40% of the fields.

Due to a poor wet infrastructure, the optimal water management scheme for varieties, which mature in 125 days cannot be realised on most of the fields.

Red rice (*Oryza sativa*) is the most widely spread and economically important weed. Approximately every 1% of red rice reduces the yield with 6%. In importance it is followed by Maraina grass (*Ischaemum rugosum*).

Chronologically, the most frequent pests are: water weevils (*Lissorhoptrus foveolatus*), bibit fly (*Hydrellia sp.*), stemborer (*Rupela albinella*) and seed bugs (*Oebalus poecilus*). The order of economical interest is not clear.

Fungus diseases (*Helminthosporium oryzae*, *Pyricularia oryzae*, *Cercospora oryzae* and *Rhizoctonia solani*) are rarely of economical interest.

Analyses showed that apart from nitrogen and phosphate, the soils in Nickerie are very fertile and homogeneous. Urea is used by all farmers, but efficiency could be improved. Phosphate fertilisers are rarely used.

A conceptual model for increasing the average yield with agronomic measures was constructed from which the order of priority of urgent research topics, to be addressed to with On-Farm and On-Station experiments, was depicted.

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1.1 INTRODUCTION

Suriname has some 50,000 ha of wet rice, most of it in the Nickerie district. Significant production also exist in the districts of Coronie and Saramacca and upland rice is grown at scattered locations inland, in a shifting cultivation system.

From 1950 up to 1980, a highly mechanised and efficient rice production system was built up through research on high yielding varieties at the Foundation for the Development of Mechanised Agriculture in Suriname (SML).

Since 1985, however, various problems caused a sharp decline in research activities, including the development of new varieties. To re-invigorate the rice research, the 'Anne van Dijk' Rice Research Centre Nickerie (ADRON) was established in 1994. Research at ADRON is typically applied research, of which the main objective is to develop technology which increases the profitability of the paddy production through increasing yields and quality and reducing costs, and which is safe for our farmers and environment.

A Crop Production Survey was carried out in order to generate a research agenda which addresses to the most urgent topic's, as well as to involve farmers more directly in research & development,

1.2 METHODS

The crop production survey is based on random crop cuts (5x5m) from a random sample of fields in the Nickerian rice polders. Red rice was harvested separately, insects and weeds were monitored and the water layer was measured. In most cases a soil sample has been taken as well. In addition, the farmer was interviewed on rates and timing of all his cultural practices. Thus, data are collected from which the cropping system can be analysed, bottlenecks in crop production can be identified, and priority research topics can be determined.

The crop production survey was implemented for three consecutive seasons (starting in July 1996) and involved 430 farmers' fields.

Main method for analyses, was "contrast analyses", which compares the 30% of the fields with the highest value of a parameter to the 30% with the lowest value of that parameter, e.g. yield, the number of red rice panicles or time of planting (for continuous variables). Other contrasts are varieties, phosphate class of the soil, etc. (for discontinuous variables).

1.3 RESULTS AND DISCUSSION

High variation in yields

Table 1 shows the variation in yields for the 3 seasons. This variation in yields indicates the possibility that with an optimal application of current cultural practices and varieties the average yield could increase from the actual 4.0 ton/ha up to 5.5 ton/ha.

Main factors related to high yields are: **1)** early sowing, **2)** maintenance of the water layer (both factors imply a good wet infrastructure), **3)** low percentage of red rice and **4)** timely and high urea applications.

Table 1: Variation in yields in Nickerie

Season	least 30 %	average	highest 30 %	number of fields
main-1996	2.6	4.5	6	83
short-1996	2.3	3.8	5.2	144
main-1997	2.4	3.9	5.4	203
average	2.4	4	5.5	430

Production costs are high

The profitability of the current paddy production is low. On one hand because the paddy price is low, on the other hand because the production costs per ton paddy are high. In order to reduce the production costs per ton, it is much more effective to increase yields than to reduce costs per hectare. The highest production costs are for soil tillage.

Long sowing period and poor timing of cultural practices

The sowing period lasts up to 12 weeks and the interval between the last plantings and the first harvests is only one month. This gives rise to a build up of pest populations. The timing of the cultural practices relative to the date of sowing is highly dispersed, indicating that good crop management is a weak point in the current production system. This is mainly due to the poor wet infrastructure. The timely availability of machinery and credits also plays a role.

Intensive soil tillage

Dry soil tillage is carried out with the 3-disc-plough and/or the offset-plough. The wet tillage (puddling) is carried out with the chipper and the weedcutter drawn by a tractor with cage-wheels after which the fields are smoothed with a wooden beam. Four to five soil tillage scenario's can be distinguished, which have their background in the soil humidity and availability of machinery, water and time. Between the scenario's are no significant differences in yields, indicating that the more intensive scenario's are probably not necessary. Fields worked with the 3-disc plough had remarkably more red rice than other fields. In heavily infested fields, repeated puddling as a measure against red rice is not effective. Most likely because though killing red rice seedlings, puddling also brings up new seeds to the soil surface.

Late sown fields have low yields

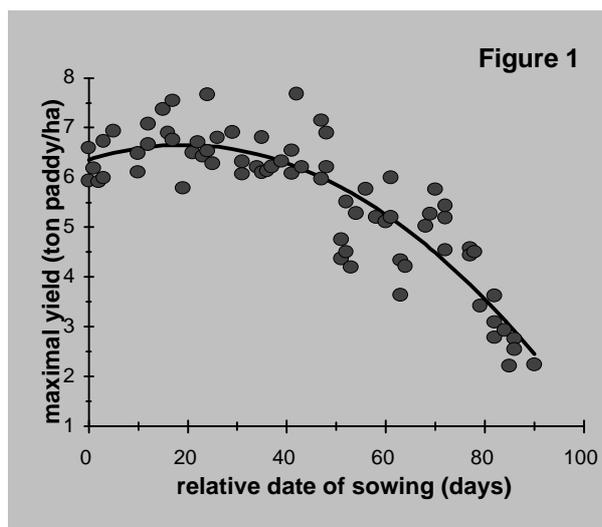
Relatively late sown fields (more than 6-7 weeks after the first field) yield clearly less (*Figure 1*). The panicle weight is lower, which indicates stress conditions during the later growth of the plant: less irrigation water available, unfavourable weather conditions (less solar radiation), insects (paddy bug) and weed competition.

New rice varieties are necessary

Eloni is the most popular variety (75% of the fields). The new variety Groveni (released in 1994) has not been adopted by the farmers. It is grown on less than 10% of the fields. Clearly a demand, and a niche, exist for earlier maturing varieties (e.g. 100 days in stead of 125 days). Such varieties could escape from most of the effects of late sowing. In the present situation this would benefit the production for 30-40% of the fields. However, as lower production costs per ton are first of all based on higher yields per hectare, breeding activities should continue to focus on higher yielding 125-days-varieties (potentially 8-10 tons/ha, compared to Eloni which yields potentially 6-7 tons/ha) as well.

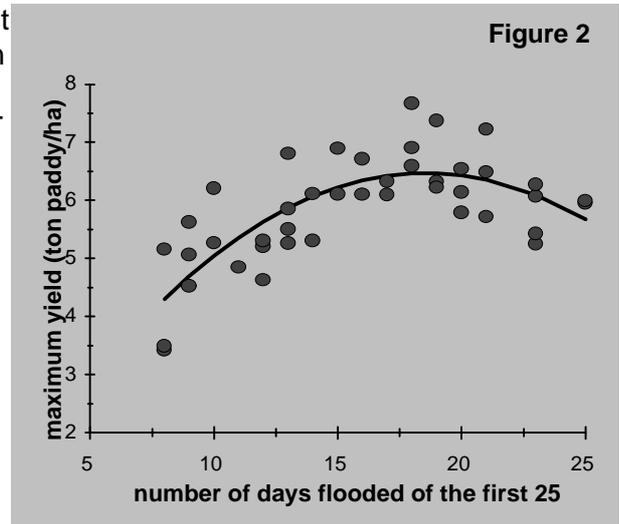
On most fields the ideal water management cannot be realised

Due to a poor wet infrastructure, the optimal water management scheme for varieties which



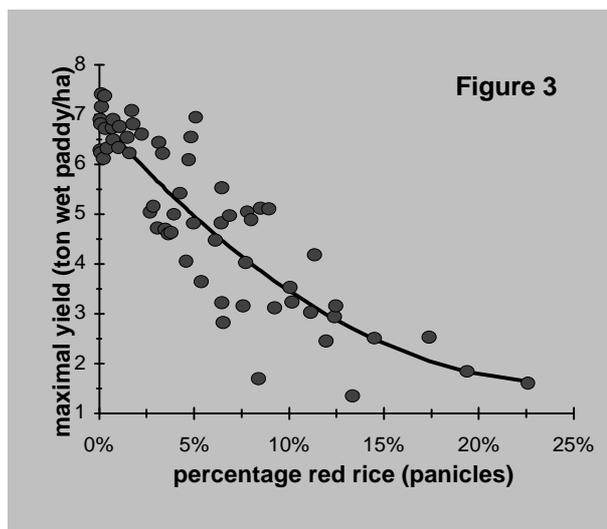
mature in 125 days cannot be realised on most of the fields. Thus, the farmer is deprived of an essential tool for: **1)** stimulating seedling establishment, **2)** controlling red rice and other weeds, **3)** fertilising efficiently with urea, **4)** controlling pests and **5)** avoid high costs for harvesting.

Fields which are drained within 3 days after sowing (32% of the fields) have almost 40% more red rice and a 20% (700 kg/ha) lower yield, compared to fields which are drained within 8 to 20 days after sowing (12% of the fields). However, this type of water management is only possible on properly levelled fields. The longer a field is kept flooded, especially during the period from sowing up to the first urea application, the higher the yields, *Figure 2*.



Red rice reduces yields more than expected

- C the average per percentage of red rice is 2.7%, while 10% of the fields have more than 6% of red rice.
- C every 1% red rice reduces the yield with 6%, *Figure 3*.



- C though red rice originates from contaminated seed, it is only the red rice germinating from the soil which is of economical interest.
- C with a higher seed rate the percentage of red rice is lower.
- C the number of red rice panicles is especially high on fields which are ploughed with the 3-disc plough.
- C repeated puddling as a measurement against red rice in heavily infested fields is not effective.
- C high urea rates on fields which are heavily contaminated with red rice is disadvantageous.
- C not draining the field immediately after sowing, but 8-20 days later, reduces the number of red rice panicles.

Other weeds

After red rice, Maraina grass (*Ischaemum rugosum*) is the most important weed. This weed is abundant especially in late sown fields, due to poor water management. Propanil is used for its control. Most frequent weed is *Fimbristylis*, but it appears to be controlled easily with 2,4D. Minor weeds are *Speanoclea zeylanica*, *Cyperus articulatus*, *Luziola spruceana* and *Nymphaea amazonum*.

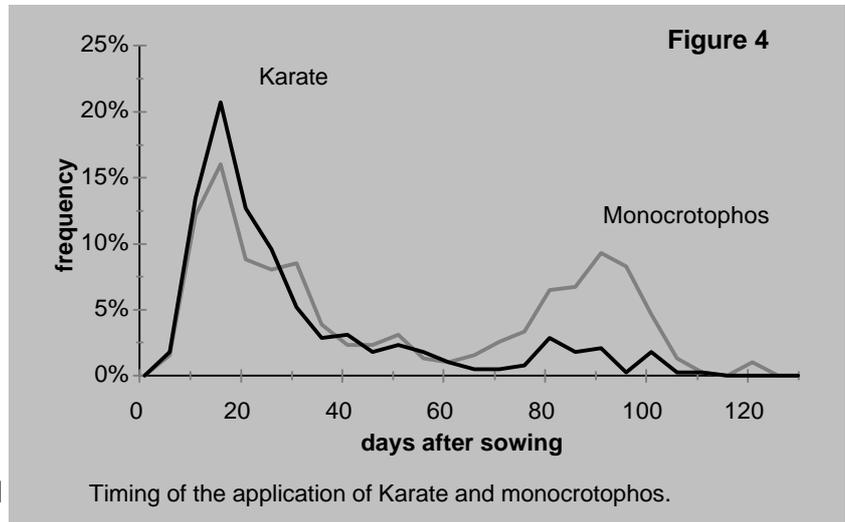
The applied rates of 2,4D (which is used on 62% of the fields) and more so of propanil (which is used on 22% of the fields) are often far under the recommended rate. Most farmers apply herbicides spotwise. On almost 30% of the fields no herbicides are applied.

Insects

Chronologically, the most frequent pests are: water weevils (*Lissorhopterus foveolatus*), bibit fly (*Hydrellia*), stemborer (*Rupela albinella*) and seed bugs (*Oebalus poecilus*). The order of economical interest is not clear. Minor pests are armyworm (*Spodoptera frugiperda*), *Conodephalus spp.*, thrips (*Baliothrips bififormis*) and delphacids (*Sogatodes oryzicola*). Pests typical on late sown fields are bibit fly and seed bug.

A frequently applied method for controlling water weevils, is dripping a mixture of Brestan (Fentin acetate, against snails) and Karate or Twin in field ditches just before sowing. The effectiveness of this method is not clear, but such fields are later on less sprayed, without negative effects on the yield.

Most frequently used insecticides are monocrotophos (for all insects) and Karate (all insects except seed bugs), *Figure 4*. Rates per application for monocrotophos are very low: on 90% of the fields less than 500 ml/ha and on 30% of the fields less than 200 ml/ha. On 40% of the fields the application is repeated within 20 days. Risks of too a low application rate are the build up of resistant populations.



However, on many fields, despite very low rates, high yields are achieved. This indicates ample possibilities for Integrated Pest Management.

Diseases

Fungus diseases (*Helminthosporium oryzae*, *Pyricularia oryzae*, *Cercospora oryzae* and *Rhizoctonia solani*) are rarely of economical interest.

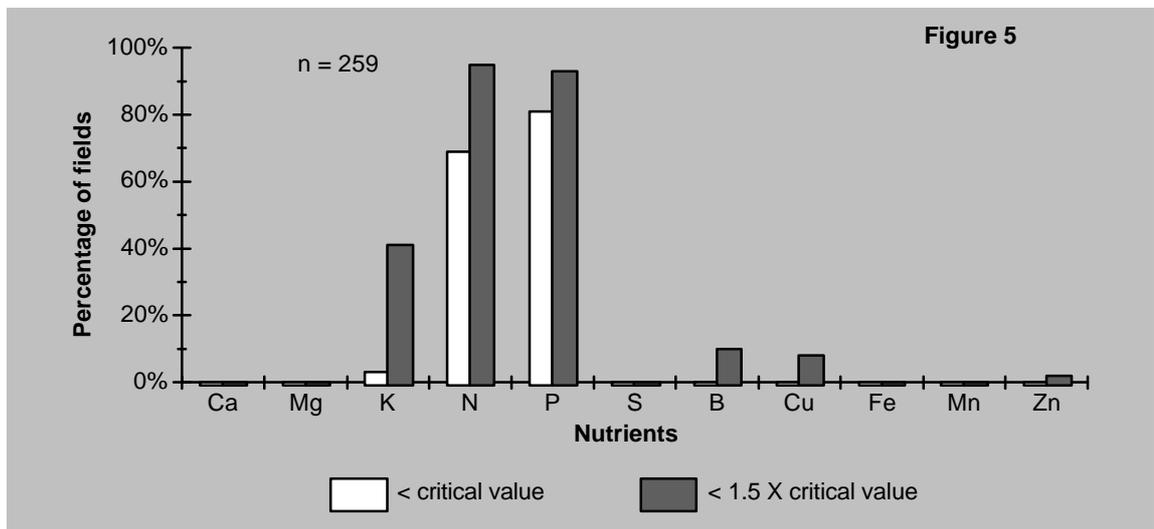
On some fields nutritional disorders are observed, related to a combination of excess of Fe^{2+} , phosphate deficiency, low pH and poor draining. Farmers refer to it as the "red disease". In most cases the symptoms disappear 5-7 weeks after sowing and yields appear not to be affected.

Soil fertility of the rice polders in Nickerie

Apart from nitrogen, phosphate appears to be low in most fields, *Figure 5*. A response to potash, however, is expected only on a few fields. All other nutrients are plenty available. The analyses show that apart from nitrogen and phosphate, the soils in Nickerie are very fertile and homogeneous.

Yield differences between fields or soil types are therefore attributed to differences in crop management (including fertilisation with nitrogen and phosphate) only.

Experimental fields at ADRON have been sampled as well and appear to have a significantly higher phosphate content than farmers' fields, due to phosphate fertilisation in the 1980's. This explains why phosphate trials in 1994 did not show any response. It also demonstrates the imperativeness of on-farm trials.



Fertilisation with urea

Results from the crop production survey confirm earlier experimental research in Nickerie: for the current varieties the optimum rate of urea is ± 300 kg/ha, *Figure 6*. Under optimal conditions, the response to urea is high: the nutrient efficiency is 20.6 kg paddy/kg nutrient (or one 50 kg bag of urea can result in a yield increase up to 450 kg paddy).

Urea is exclusively applied as top-dressings. Ideally it is applied in 3 splits, but on 45% of the fields it is applied in 2 splits (*Table 2*). The perfect water management at fertilisation is to drain the field completely, then apply the urea and subsequently flood.

This way, the urea is brought close to the roots and nitrogen losses are less. Nitrogen uptake is faster the more the root mat is developed, so draining before fertilising might not be necessary for the second or third applications.

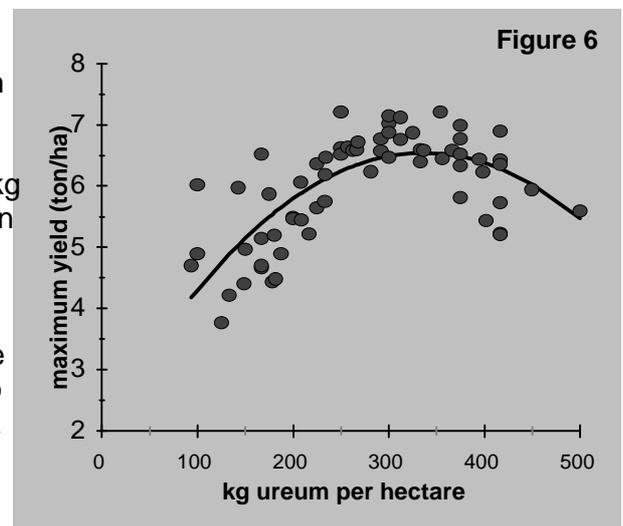
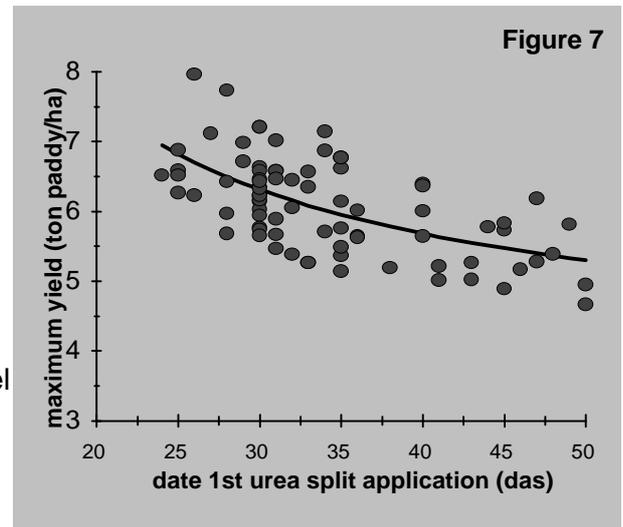


Table 2: Fertiliser application scheme's

	urea/ha per application (kg)	percentage of fields (%)	date of application (days after sowing)		
			1 st	2nd	3rd
2-splits	120	45	36	66	--
3-splits	100	55	32	52	72

At present, the agronomic implications hereof are part of ADRON's research program. For varieties which mature in 125 days, the highest yields are realised with the application in 3 splits at 28, 50 and 70 days after sowing. For earlier maturing varieties the best scheme's and timing

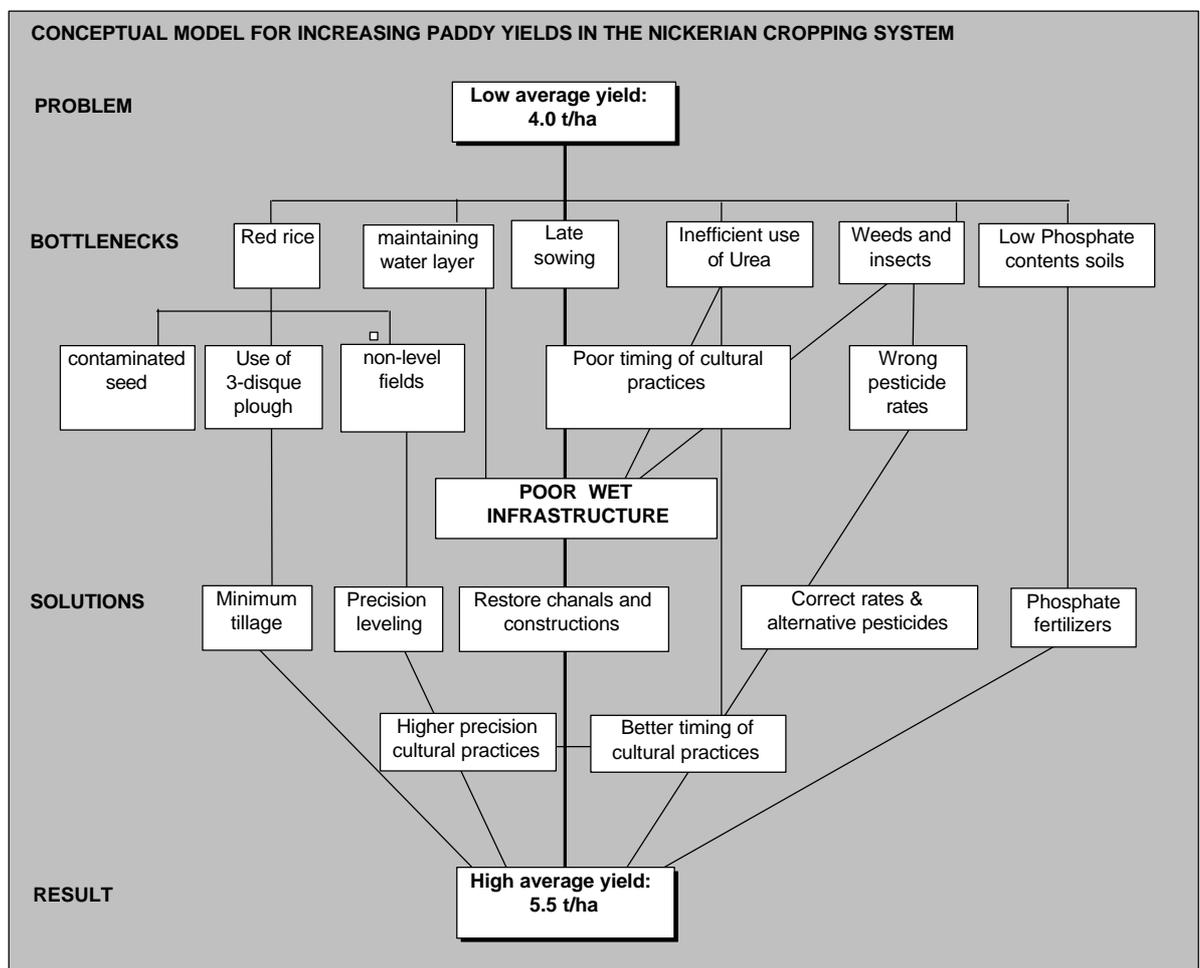
are subject of research. Early application of the first split (not later than 28 days after sowing) is important for obtaining high yields, *Figure 7*. On 40% of the fields the first split is later than 35 days after sowing, which can reduce the maximum yield with up to 800 kg/ha.



1.4 CONCLUSIONS: A conceptual model for increasing the paddy production

Based on these analyses, a conceptual model to increase the average yield of the Nickerian cropping system with agronomic measures was constructed (see diagram below).

The restoration of the wet and dry infrastructure plays a key role in increasing the paddy production in the Nickerie district.



Important improvements on field level are the control of red rice (and other weeds), reducing costs of soil tillage (by replacing one or more runs of tillage by glyphosate), laser guided levelling of fields, increased efficiency of fertilisation with urea, fertilisation with phosphate and IPM. It is estimated that these improvements will increase the average yield from 4.0 to about 5.5 ton/ha. With new varieties included, average yields can even be higher than 6 ton/ha. Both agronomic measures and new varieties will increase the paddy quality as well, so that also higher prices can be realised on the world market. Thus, the profitability of the Nickerian

production system could increase.

From the above, we depicted the order of priority of research topics for agronomy, to be addressed to with **On-Farm** and **On-Station** experiments, as follows:

PRIORITY RESEARCH TOPICS for AGRONOMY

- 1. Red rice and other weeds.**
- 2. Soil tillage (incl. laser guided field levelling).**
- 3. Nitrogen and Phosphate fertilisation.**
- 4. Water management at field level.**
- 5. Integrated Pest Management.**

2 RESEARCH ON NITROGEN FERTILISATION IN THE NICKERIE RICE POLDERS, SURINAM

2.1 INTRODUCTION

Nitrogen is one of the most important inputs for increasing paddy yields. For the last 45 years research in Nickerie on nitrogen was focussed on the optimum fertilisation for newly developed varieties for mechanized paddy production. It dealt mostly with:

- C type and rate of nitrogen fertilizer
- C the number of split applications
- C the timing of the split applications
- C the distribution of nitrogen over split applications
- C the way of application (on a drained or on a flooded soil)

An overview of the type of research, treatments and institutes involved, is given in Table 1.

Table 1. An overview of Nitrogen related research in Nickerie, Surinam, for the last 45 years.

Year	Experimental Design				Institute*
	Type of research	Treatments	N-rate (kg/ha)	number	
1957	On-farm trials	NxP	0, 30	10	1
1958	On-farm trials	NxP	0, 30, 50	27	1
1959	On-farm trials	NxPxVar	0, 20	100	1
1961- 67	On-station trials	NxType of fertlzl	0, 40	24	2
1954-61	On-station trials	NxTiming	0, up to 50	39	2
1958-63	On-station trials	NxWay of appl.	0, up to 50	15	2
1969-70	On-station trials	NxTillagexTimingxDist.	0, 125	8	2
1978-79	Survey	-	farmers' rate	372	3
1980	On-sation trials	NxWay of appl.	?	1	3
1986-87	On-station trials	NxTimingxNr of Splits	120	2	3
1986-87	On-station trials	NxWay of appl.	0 up to 250	119	3
1988-89	Survey	-	farmers' rate	354	4
1993-94	On-station trials	N	0 up to 240	2	5
1996-97	Crop Production survey	-	farmers' rate	414	5
1997-99	On-station trials	NxTimingxDist.	138	3	5
1997-99	On-station trials	NxNr of Splits	100 to 150	4	5

* 1 = Agricultural Experimental Station, 2 = Foundation for the Mechanized Agriculture, Wageningen (SML), 3 = Practical Rice Research (POR), 4 = Multipurpose Corantijn Project (MCP), 5 = Anne van Dijk Rice Research Station Nickerie (ADRON)

2.2 FINDINGS OF EARLIER RESEARCH (1954 - 1994)

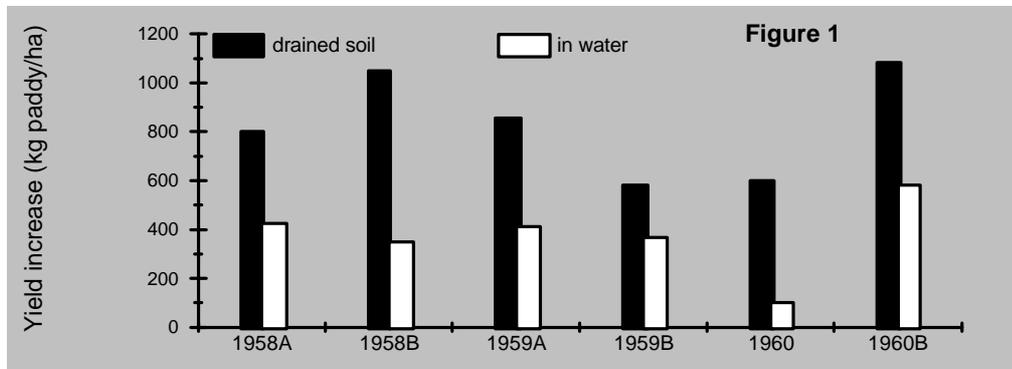
In On-Farm trials in 1957 to 1959, the variety Dima showed a very small and insignificant average response to ammonium sulphate, whereas the traditional variety Skrivimankoti showed a small insignificant negative response (Raktoe & Federer 1965 and 1966). Variation across fields was very high, but there was no correlation between yield increase and the yield of not fertilised plots. It was concluded that:

- C Only when new varieties become available, it is possible that they will respond to fertilisation with nitrogen.

Some results of on-station research conducted by Ten Have (1967) with varieties as Dima and early

developed SML lines (which mature in 130-145 days), can be summarised as follows:

- C The use of urea is more practical than ammonium sulphate (due to its higher N-contents) and both fertilizers are more efficient than nitrate fertilizers.
- C A basal dressing of urea is ineffective, only top dressings are increasing yields.
- C The best way to apply urea is to drain the field completely, apply the urea and relood after two days. If urea is applied directly into the water, the yield increase is only half as much, *Figure 1*.

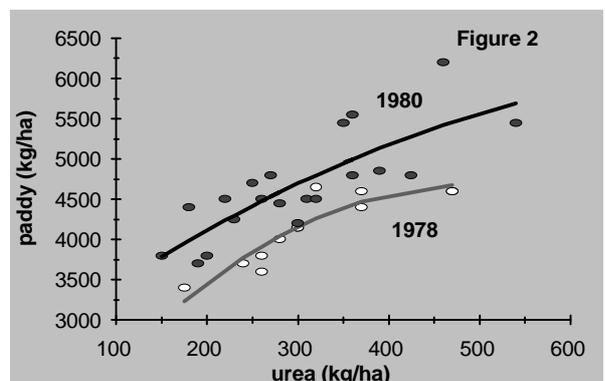


- C If more than 65 kg urea is to be applied, best results are when applied in two equal portions at 48 and 68 (that is at panicle initiation) days after sowing. When more than 130 kg of urea has to be applied, the first portion should be higher than the second.
- C On the linear part of the response curve the average response was 23 kg paddy/kg N.

Scheltema (1974) investigated the interaction between soil tillage and N-fertilisation. Various urea application schemes, urea rates and distributions of urea over split applications were tested on soils which were tilled only dry, only wet (puddled), tilled dry followed by wet and with zero tillage. Some conclusions are:

- C Urea nitrogen, applied to a temporarily drained soil, is transported into the root zone when the soil is relooded and thus nitrification followed by denitrification is avoided.
- C On a soil which is tilled dry, this downwards transportation of nitrogen when relooded is faster than on a soil which is puddled. However, when temporarily drained, nitrogen losses through volatilization are faster as well.
- C Up to mid tillering, the N-supplying capacity of the soil is sufficient when soils are tilled, with zero-tillage availability of soil nitrogen is lower.
- C For the (than current) variety Apura (140 days), the best distribution of urea over split applications was 0 - 60 - 100 urea kg/ha (at active tillering, 30 days after sowing, at panicle initiation, 65 days after sowing and at panicle differentiation, 80 days after sowing respectively) when the soil was tilled only dry or if tilled dry followed by puddling. When the soil was only puddled, the best distribution of urea was 40 - 60 - 60 urea kg/ha.
- C Optimum total urea rates were between 100 and 180 kg/ha.

Van Midde (1981), using data from the department of agricultural statistics on the major season 1978 and the minor season 1980, found that farmers used far higher urea rates than the 200 kg/ha recommended by Soerokarso et al (1976). These farmers grew the 120-days varieties Diwani (released in 1976) or Eloni (released in 1979) with an average rate of 300 kg urea/ha. For both seasons the response to urea was estimated by plotting the moving average (period = 12) of the data of 1978 (n=132) and of 1980 (n=240) against the urea rate, *Figure 2*. It shows that at least up to 300-350 kg urea/ha, the response was linear. A survey held in the western polders in 1988 confirmed that the mean farmers' rate was \pm 300 kg urea/ha (MCP, 1989).



In a trial to compare the application of urea directly into the water to an application on a drained soil after which the soil is reflooded 2 days later, no yield differences were found (van Midde, 1981).

Keisers (1987a) repeated twice a nitrogen response trial with the variety Eloni, in which urea was applied on a drained soil which was then reflooded, compared to urea applied directly into a continuously flooded soil. It was concluded that:

- C A different response to urea when applied directly in water compared to an application on a drained soil, was not detectable.
- C Unless a known problem exists that can be controlled by draining the soil (such as the control of algae, rice water weevil or the removal of anaerobic toxins), applying urea directly in water seems to be farmers' best choice.
- C The rate at which maximum yields were obtained varied from 317 kg urea/ha in the minor season of 1986, to 393 kg in the major season of 1986.

An other repeated trial was set up to determine the optimum timings of various split applications in equal portions at a total rate of 260 kg urea/ha (Keisers, 1987b). The timings were: at mid tillering (28-30 days after sowing), at panicle initiation (52-54 days), at panicle differentiation (60-62 days) and at pollen mother cell differentiation (68-70 days). For the 2 split applications a timing at 52 and 72 days gave the lowest yields, whereas for 3 split applications a timing at 30 - 60 - 72 and 52 - 62 - 72 gave the lowest yields. Best yields were found at a timing at 30 - 52 for 2 splits and 30 - 52 - 72 for 3 splits. The difference between the best 2 split and the best 3 split application was not significant. It was concluded that:

- C A nitrogen top-dressing at mid-tillering (28-30 days after sowing) is a prerequisite for obtaining high yields
- C The best 2 split application is at 30 - 52 days after sowing.

Rees at all (1994) carried out a nitrogen response trial for two seasons with various varieties, among which Eloni and Groveni (released in 1994). Urea was applied in 3 splits of equal portions on a drained soil. For Eloni it was found that the rate at which a maximum yield is found varied from 388 kg urea/ha in the main season to 483 kg urea/ha in the minor season (see also *Figure 8*), for Groveni these figures were 324 and 483 kg urea/ha respectively.

2.3 ACTUAL FARMERS' PRACTICES

A crop production survey, carried out during 3 seasons in 1996 to 1997 (Wildschut, 1998), concluded that the averaged urea rate which farmers apply is 275 kg/ha, while for 10% of the fields rates were higher than 375 kg/ha. The highest yields were found at urea rates of 300 to 350 kg/ha, *Figure 3*. On 45% of the fields urea was applied in 2 splits, on 55% in 3 splits. When applied in 2 splits, the timing of the first as well as the second application is

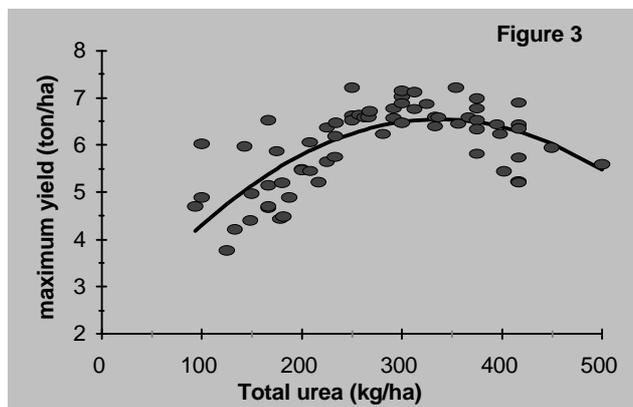


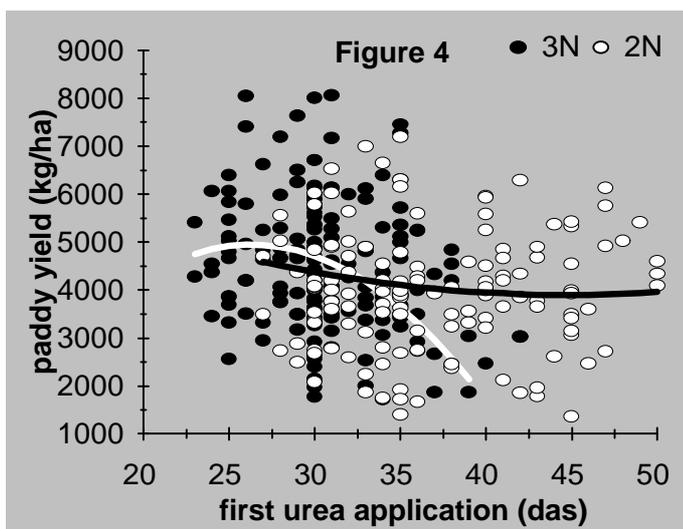
Table 2: Fertilizer application scheme's

	urea/appl (kg/ha)	date of application (days after sowing)			yield (ton/ha)
		1 st	2nd	3rd	
2-splits	120	38	66	--	4.1
3-splits	100	31	52	74	4.5
p-value	0.000	0.000	0.000	--	0.003

delayed and the total urea rate is lower. Yield differences between fields on which urea was applied in 2-splits and in 3-splits were significant (Table 2), and are explained both by differences in rate and in dates of application.

In a 3 split scheme, earlier application of the first split is significantly related to higher yields ($R = 0.460$, $p = 0.000$, $n = 177$, *Figure 4*). This was found for the second split application as well

(varying between 42 and 61 days after sowing), but for the third split (varying between 65 and 83 days after sowing) there was no difference in yields between late and early application.



This relation between timing and yield is not significant for 2 split schemes.

Comparing for the first, the second and the third application the differences between the 30% lowest and the 30% highest urea rates, reveals that for the 3 split application the corresponding difference in yield is small and not significant for the first application only (Table 3). For the second and the third application the differences are increasing in size and significance. This suggests that the highest portion of the urea should be applied in the later applications. For applications in 2 splits differences in urea rates between the lowest 30% and the highest 30% were higher and yield differences are for both splits significant.

Table 3: Relation between yield and the rate of the split applications in 2 and in 3 splits (between brackets), comparing the 30% lowest rates vs the 30% highest rates.

Application	2 Splits yields (ton/ha)				3 Splits yields (ton/ha)			
	30% lowest urea rates	30% highest urea rates	Difference (ton/ha)	p-value	30% lowest urea rates	30% highest urea rates	Difference (ton/ha)	p-value
1st	3.7 (85)	4.4 (162)	0.7	0.007	4.4 (74)	4.8 (137)	0.4	0.075
2nd	3.7 (85)	4.4 (152)	0.7	0.014	4.2 (76)	4.9 (139)	0.7	0.008
3rd	-	-	-	-	4.1 (70)	4.9 (134)	0.8	0.002
Total	3.5 (175)	4.4 (309)	0.9	0.001	4.1 (210)	4.8 (395)	0.7	0.007

Regarding the way of applying urea, it was found that on 65% of the fields the first urea application is applied to a drained soil, for the second and for third application, 54% and 45% of the fields were drained respectively. Differences between fields to which urea was applied directly in water and those which were drained first and subsequently reflooded, are small and not significant, Table 4.

Table 4: Yields (ton/ha) and percentage of fields to which urea is applied on a drained soil.

Application	applied in	on	p-value	number	% on
1st	4.3	4.2	0.696	174	63%
2nd	4.1	4.4	0.092	173	51%
3rd	4.3	4.7	0.210	84	40%

From the above results of observational research it could be depicted that:

- C The highest yields are found on farmers' fields on which 300-350 kg urea/ha is applied.
- C The best timing is around 25-30, 45-50 and 70-75 days after sowing.
- C Probably, the best distribution is such that portions increase from the first to the latest split.
- C Yield differences due to urea application directly into the water compared to application onto a drained and subsequently reflooded soil could not be detected.

Data could suggest however, that farmers judge it more important to drain the field before the first urea application than for the second or the third. This is in accordance with the theory that the more developed the root mat, the faster is urea uptake and the less important it is to bring urea nitrogen towards the roots through draining before fertilization followed by reflooding.

Other farmers practices regarding fertilisation with urea:

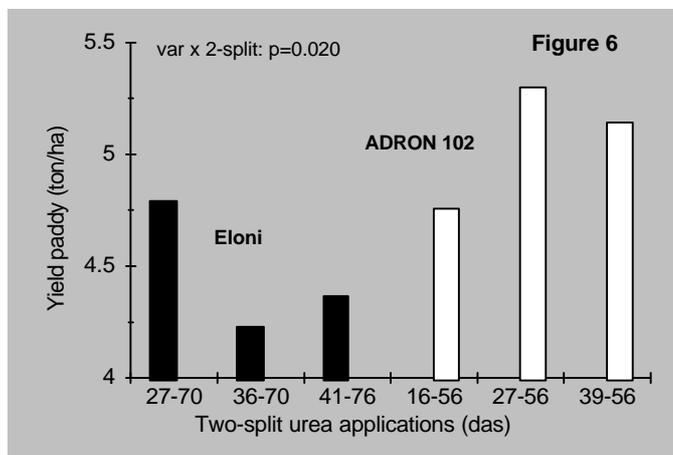
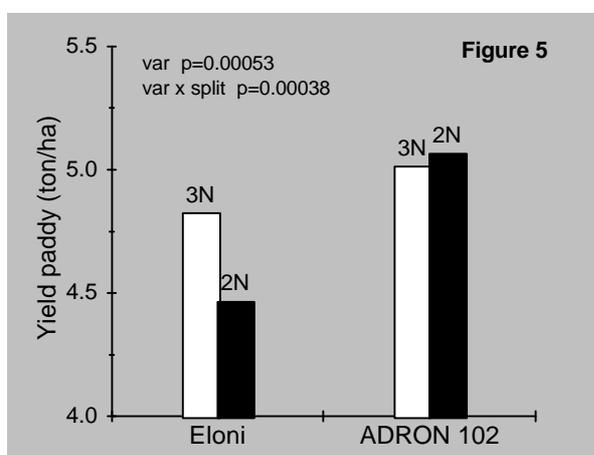
- Ⓒ Late sown fields are fertilised more often in 3 splits, with higher and earlier urea applications.
- Ⓒ The third urea application is higher when paddy is grown for seed.
- Ⓒ If fields are heavily infested with red rice, farmers cut back on the third urea application.

2.4 RECENT RESULTS (1996 - 1999)

During four seasons a trial was carried out at ADRON to determine whether a 2 split application is as efficient as a 3 split application and to determine what is the best timing of the applications, for both the current variety Eloni (120 days) and one of our new lines (ADRON 102, a 100-day variety).

It was found that for the 100-day variety no difference in yields is observed between the average of the 2 split applications and the 3 split application (at 25, 44 and 56 days after sowing). For Eloni, the average yield of 2 split applications is lower than the 3 split application at 30, 56 and 76 days after sowing, *Figure 5*.

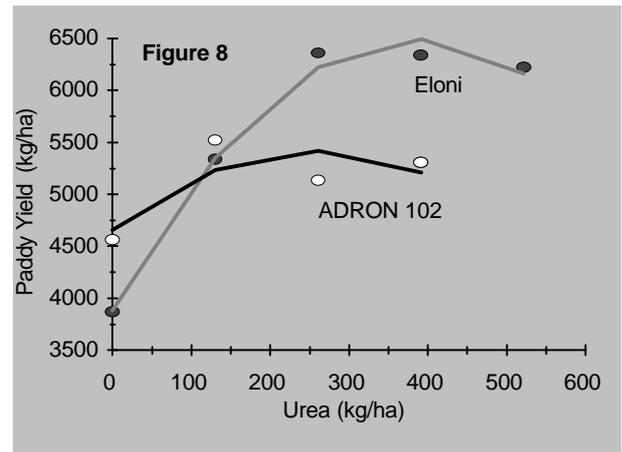
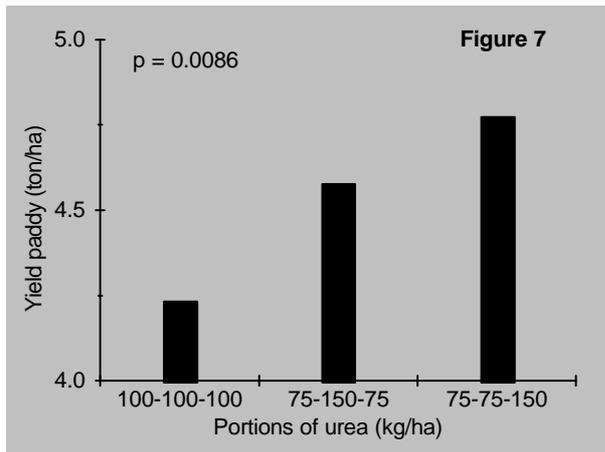
The best timing of the 2 split application for the 100-day variety was at 27 and 56 days after sowing. Both the earlier first application at 16 days after sowing and the late first application at 39 days after sowing gave lower yields.



The best 2 split application for Eloni was at 27 and 70 days after sowing, and did not differ significantly with the 3 split application. Late first split applications (at 36 and 41 days after sowing) reduced the yield of Eloni significantly, *Figure 6*.

For the same varieties, an other trial repeated over 3 seasons, investigated the effect of earlier timing of the first and second urea application in a 3 split scheme, as well as increasing portions for the second or the third application. It was found that:

- Ⓒ For both varieties, increasing the portions of the 2nd or the 3rd split application increases yield significantly, *Figure 7*.



C A timing as early as 14 days after sowing of the first and as early as 44 for Eloni, or 34 days for ADRON 102 of the second application, does not increase yield.

Whether increasing portions in a 2 split scheme increases yields as well, is subject to further research.

From response trials it appears that the response of ADRON 102 to urea is less than for Eloni, *Figure 8*. The response to urea of Eloni was determined in both seasons of 1993 (from Rees et al, 1994), the response of ADRON 102 was determined in the minor season of 1997 and the major seasons of 1998 and 1999 (Wildschut et al, 1999).

2.5 DISCUSSION AND CONCLUSIONS

Overlooking the research on nitrogen for the last 45 years, the following trends could be depicted:

- C The urea rate at which maximum yields are obtained has increased from 60 kg urea/ha for the first SML varieties to up to 200 kg for varieties as Apura, to more than 300 kg urea/ha for the current variety Eloni.
- C As the time to maturation decreases from 155 days for Dima to 140 for Apura to 120-125 days for Eloni to 100-105 days for ADRON 102, optimum timing of the application of the last split was altered accordingly. However, for the first split application, 25-30 days after sowing is still considered optimal.
- C For the first SML varieties one split application was sufficient, later varieties with a higher response to nitrogen were fertilised in 2 splits and for Eloni 3 splits is the most efficient. For 100-days varieties 2 splits are sufficient.
- C Initially, if a 2 split application was considered, it was recommended to give the highest portion in the first split. Later, for 3 splits applications, increasing portions towards the third split were recommended for varieties as Apura. For Eloni, initially equal portions were recommended, but at present ADRON recommends increasing portions.
- C Concerning the way of application, the very consistent and positive effect of applying urea on a temporarily drained soil which is reflooded after 2 days, is later not found in experimental conditions, nor under farmers conditions. Possibly, conditions of newly reclaimed land in Wageningen, as a very high organic matter content, influenced the earlier results. Further research on this topic is needed.
- C At present the best recommendations to farmers are:
 - 1) Total rate: 300-350 kg/ha for Eloni, around 250 kg/ha for ADRON 102.
 - 2) Number of splits: 3 for Eloni, 2 for ADRON 102.
 - 3) Timing: at 25-30, 45-50 and 70-75 days after sowing for Eloni, at 25 and 50-55 days for ADRON 102.
 - 4) Portions: Increasing portions, par example 75, 100 and 150 kg/ha.
 - 5) Way of application: At least the first application on a drained and subsequently reflooded soil. This topic needs further research.

Portions at 2 split applications and the way of application need further research.

C On-farm trials on fertilisation with urea is an under-exploited research tool.

In Surinam, up to now, timing of the split applications of urea is determined by the physiological growth stage of the crop, e.g. at mid-tillering, panicle initiation, panicle differentiation or pollen mother cell differentiation. Which in turn are estimated on a calendar basis. Actual crop nitrogen needs are determined by soil nitrogen supply and fertiliser nitrogen release as well and are probably not so strictly related to the physiological growth stage as suggested. Using at least for experimental purposes the method of measuring chlorophyll intensity could improve fertiliser recommendations.

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3 RESEARCH ON PHOSPHATE FERTILIZATION IN THE NICKERIE RICE POLDERS

3.1 INTRODUCTION

During the last 45 years (that is since the introduction of direct seeded rice), there have been several waves of interest in research on fertilization with phosphate, in which various institutes have been involved. An overview is given in Table 1.

Table 1. Phosphate (P) related research in Nickerie, Surinam, since 1955.

Year	Experimental Design		Observations				Institute*	
	Type of research	Treatments	P ₂ O ₅ -rate (kg/ha)	n	Yields	P-soil		Cult. pract.
1957	On-farm trials	NxP	0, 75	10	✓			LP
1958	On-farm trials	NxP	0, 60	27	✓	✓		LP
1958	On-farm trials	NxP	0, 30, 60	9	✓			LP
1959	On-farm trials	NxPx Var	0, 30	10	✓			LP
1954-58	On-station trials	NxP	0, up to 87	15	✓	✓		SML
1954-61	On-station trials	NxPxK	0, up to 174	22	✓	✓		SML
1954-64	On-station trials	NxPxKxCa	0, up to 87	5	✓	✓		SML
1954-64	On-station trials	NxPxCa	0, up to 78	4	✓	✓		SML
1982	On-farm trials	P	0, 46	39	✓	✓		POR
1982	On-station trials	P	0, 23, 46, 69	3	✓	✓		POR
1984	Soil survey	-	-	11		✓		DBK
1993-94	On-station	NxP	0, 45, 90, 180	2	✓			ADRON
1996-97	Crop Production survey	-	farmers' rate	25	✓	✓	✓	ADRON
1997	On-farm trials	PxN ^{farmer}	0, 40, 80, 120	21	✓	✓	✓	ADRON
1998-99	On-farm trials	PxKxN ^{farmer}	0, 40, 80	62	✓	✓	✓	ADRON
1999	On-station trial	Px tillage	0, 46	1	✓		✓	ADRON

* LP = Agricultural Experimental Station, SML = Foundation for the Mechanized Agriculture, Wageningen, POR = Practical Rice Research, DBK = Dept. of Soil Survey, Min. of Natural Resources, ADRON = Anne van Dijk Rice Research Station Nickerie.

Lowland irrigated rice shows variable response to phosphate, which is only rarely the main factor limiting crop production. At least three conditions could be distinguished under which rice, depending on variety as well, responds to phosphate:

- C An absolute deficiency of the soil (phosphate is the main factor limiting crop production. A response to other production factors as fertilization with nitrogen can be expected only if phosphate has been applied)
- C A relative deficiency of the soil (only at high levels of crop management, e.g. fertilization with nitrogen, a yield increase due to phosphate fertilization is observed)
- C A reduced P-availability, or inhibited P-uptake, induced by extreme or special soil conditions: very low pH, Fe-toxicity, H₂S, drying soils, toxic organic acids due to imperfect decomposition of fresh organic materials, salt, etc.

Whether the response to phosphate is high enough to be economical, depends on the costs of the fertilizer and the value of the paddy yield increase. The latter dropped strongly during the last years.

3.2 FINDINGS OF EARLIER RESEARCH (1954-1992)

Raktoe & Federer (1965 and 1966) analysed 127 on-farm trials which had been conducted

by E. Ubels in 1958 and 1959 with the variety Dima (one of the first varieties selected for mechanised rice culture). They concluded:

- Ⓒ Though significant, the average yield response in farmers fields in Nickerie is low: 90 kg paddy/30 kg P₂O₅ (which is 3.02 kg paddy/kg P₂O₅).
- Ⓒ No relation was found between Total-P (HCl 25%) and yield increase.

Ten Have (1967) carried out at least 46 on-station trials over a period of 10 years and concluded:

- Ⓒ “On the whole, phosphate had no effect on grain yield. This is probably because these soils contain a moderate amount of readily available P₂O₅ and that availability usually increases when the soil is submerged and reduction occurs”
- Ⓒ Per ton of paddy ± 5.5 kg P₂O₅/ha is removed from the soil.

Veltkamp (1975) summarized the results of some trials from the late fifties as:

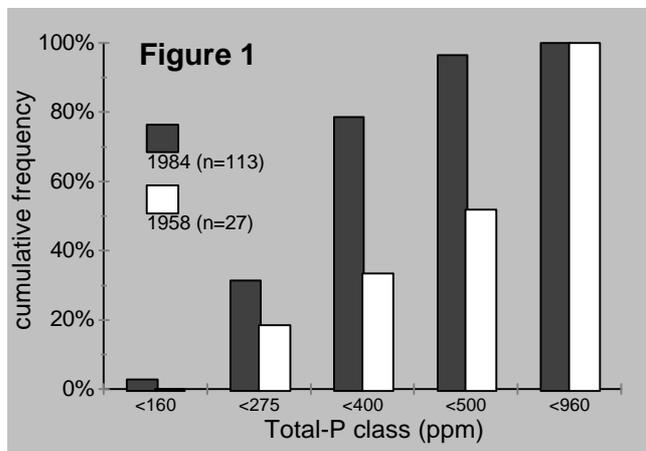
- Ⓒ Renophosphate (a rock phosphate) is as good a P-fertilizer as double superphosphate.
- Ⓒ Residual effects, if any, were found only during the first year after application.
- Ⓒ The P-extraction method “Total-P (HCl 25%)” correlates better with yield increase due to P-fertilizer applications (r = -0.41), than 2% citric acid (r = -0.14). If the soil has a Total P(HCl 25%) < 330 ppm, a response to P-fertilization might be expected (26% of the fields in Nickerie), whereas the minimum response to balance fertilizer costs of 60 kg P₂O₅ was 360 kg/ha (6 kg paddy/kg P₂O₅), which is expected when Total P (HCl 25%) < 230 ppm (0% of the fields in Nickerie).

Keisers (1983) found the response to P₂O₅ in 39 on-farm trials highly variable (from 0 to 131 kg paddy/kg P₂O₅). In addition:

- Ⓒ Grain yields of plots not-fertilized with P₂O₅ were not correlated with one of the 5 P-extraction methods Total P, Bray p1, Bray p2, Olsen P and Truog P. The yield increase to P-fertilization was correlated to Total-P only (r = 0.325).
- Ⓒ On-station trials showed no response.
- Ⓒ On a site with a pseudo-sulphate acid soil (less than 3% of the rice area) a very strong response was found.

A soil survey in the Nickerie rice polders showed Total-P to range from 160 to above 500 ppm (Noordam & Blik, 1985). Based on data from soil pits it was concluded:

- Ⓒ that older rice polders have in general a lower Total-P than younger polders.
- Comparing the soil survey data to data from Raktoc & Federer (1965a), taken in 1958, suggest that indeed Total-P is diminishing, *Figure 1*.



Rees et al (1994) carried out two phosphate response trials at ADRON which showed no response to P₂O₅. It was concluded that:

- Ⓒ “.. continuous rice cropping since 1975 has not resulted in significant loss in the phosphate-supply potential of the soil when flooded.”

3.3 ACTUAL FARMERS' PRACTICES

A crop production survey, carried out during 3 seasons in 1996 to 1997 (Wildschut, 1998), concluded that on 20% of the fields farmers apply P_2O_5 in the form of TSP at an average rate of 33 kg/ha TSP. Contrary to the practices in either on-farm or on-station trials, farmers apply P_2O_5 mixed with urea at the first or the second split application, at 30 or 55 days after sowing, such that a portion of the urea is replaced by TSP.

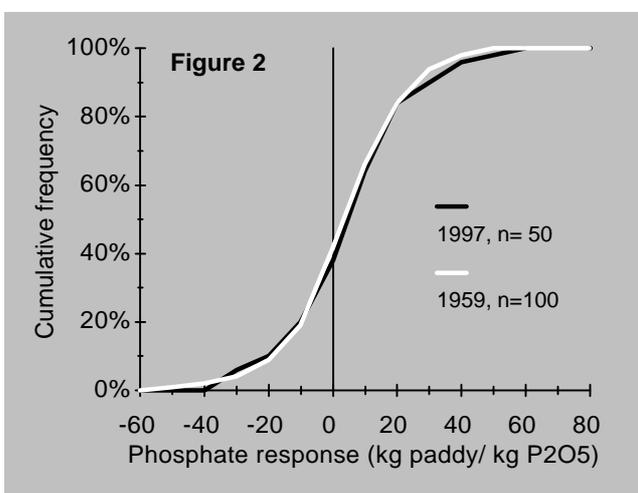
Some farmers claimed that the application of TSP softens the soil, such that at harvest the soil is not in condition for the combine. This was also stated during interviews in a survey on information flow among rice farmers in Nickerie (Jalloh, 1999).

3.4 RECENT RESULTS (1996-1999)

On-farm response

Since 1997, ADRON harvested some 83 superimposed trials on farmers fields throughout Nickerie. Red rice has been harvested separately. Data on rates and timing of all cultural practices were collected through interviews with the farmer. During the first four seasons, 52 trials have been harvested. Analyses of the P-response of these trials showed that the estimated average yield increase at 30 kg P_2O_5 /ha was 140 kg/ha paddy (= 4.66 kg paddy/kg P_2O_5). These figures do not differ significantly from the results of the 127 trials in 1958 ($p=0.612$, t-test).

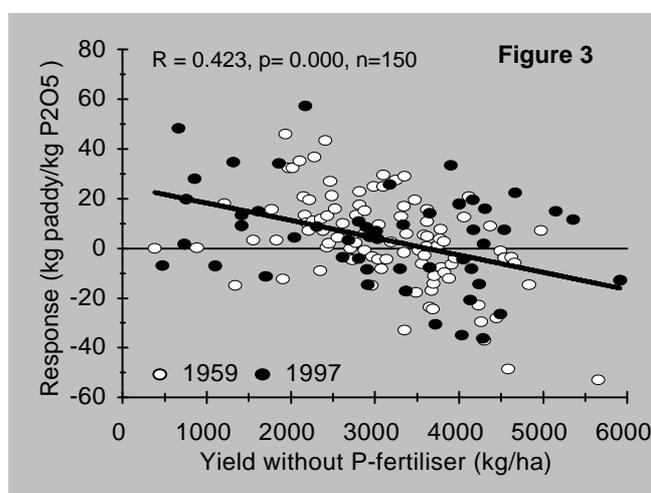
In addition, for both data sets the cumulative frequency of the response to P_2O_5 is practically the same, *Figure 2*. For both sets on $\pm 35\%$ of the fields a response to $P_2O_5 > 10$ kg paddy/kg P_2O_5 is observed.



Comparing the 30% of the fields which showed the lowest response to the 30% of the fields which showed the highest response revealed that the response to phosphate is significantly higher when:

- C Yields from the plots without P_2O_5 fertilization are low ($p=0.011$, $n=50$).
- C The inundation period before sowing is short ($p=0.038$, $n=42$)
- C Fields are sprayed with very low herbicide rates ($p=0.011$, $n=29$)

- C The field is kept flooded when applying the urea top dressings (± 30 and 55 days after sowing)($p= 0.032$, $n=17$).



A higher response to P_2O_5 when not-fertilized yields are low is also observed for the data from 1959, *Figure 3*. Variation around this trend, however, is very high.

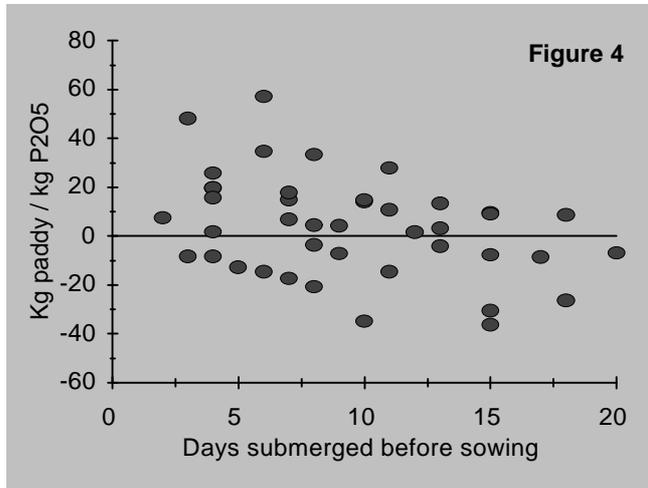
From the crop production survey it was found that low yields of farmers fields were due to:

- C A high percentage of red rice panicles
 - C A low and/or late urea application

- C Late date of sowing, and
- C Keeping the field flooded for only a short period during the first 30 days.

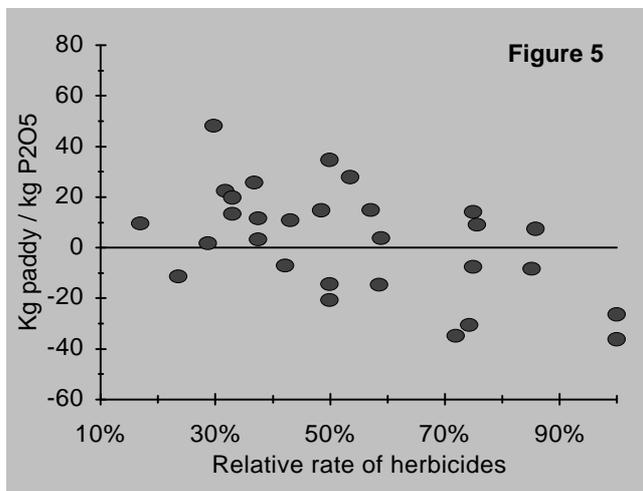
The first two factors do not relate to the response to P_2O_5 . The percentage of red rice was found not to decrease with P_2O_5 fertilization, nor could any interaction of P_2O_5 with the effect of urea be detected.

The last two factors relate to water management, which in turn relates to weed control and to processes which increase P-availability during inundation. Late sowing happens if the farmers' access to water is limited and provokes crop growth and harvest during unfavourable weather conditions as well as population build up of harmful insects, reasons for which farmers who receive water late, will cut back on pre-sowing soil submergence for puddling. A shorter submergence period before sowing will reduce the availability of soil phosphate and increase the response to fertilizer phosphate, *Figure 4*.



In some of the fields where the submergence period before sowing was extremely short, the yield of the plot without P-fertilizer was very low and the response to phosphate was very high. This might be explained by an additional inhibition of P-uptake caused by toxic organic acids (imperfect decomposition of weeds) and/or Fe-toxicity related to a low pH.

That the average response to P-fertilizer is higher when the fields are not drained for the 2nd urea top dressings (± 28 kg paddy/kg P_2O_5 versus -5), might suggest that sorption of fertilizer P_2O_5 in a drying soil is faster than desorption following reflooding.



As the response of rice to P_2O_5 was significantly lower at increasing herbicide rates, *Figure 5*, it follows that a strong interaction exists between weeds and phosphate fertilization. Possibly, under conditions of low phosphate availability to rice, the response to phosphate by the weed vegetation (in general dominated by *Fimbristylis miliacea* and *Ischaemum rugosum*) is very low and/or that the response of rice to phosphate is much stronger, thus favouring its competitive position in weedy conditions.

Soil analyses

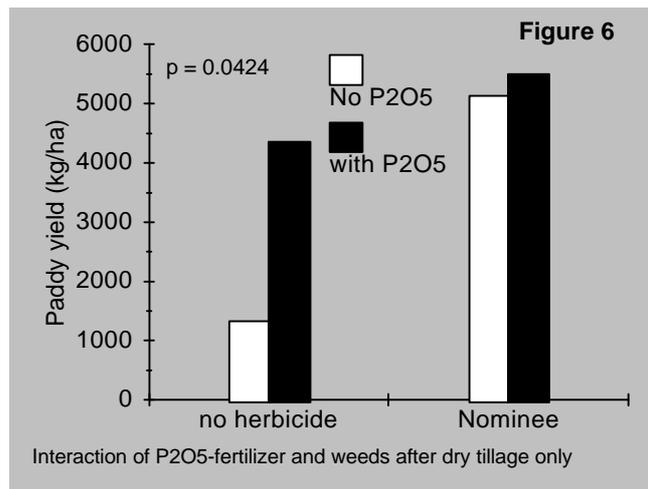
During the crop production survey, a total of 259 farmers' fields have been sampled for soil analyses as well. The samples have been analysed (by AGRO Services International Inc., USA) using an extraction method in which P-available is determined colorimetrically (molybdenum bleu) in an extract of ammonium fluoride, sodium bicarbonate and Na-EDTA ("P-ASI"), results of which correlate very well ($R = 0.900$, $p < 0.01$) to P-Olsen (Noordam, 1998). P-ASI, however, does not correlate at all to crop cut yields ($R = 0.042$, $p = 0.532$, $n=259$). And from the 19 out of the 52 phosphate response trials which have been sampled for soil analyses it was impossible to correlate P-ASI to yield increase due to P_2O_5 ($R = 0.0136$, $p = 0.956$). Apparently this extraction method does not deal with that portion of soil-P

which is limiting paddy production on fields where a clear P_2O_5 -response has been found. In order to verify if phosphate application softens the soil, the shear strength and soil humidity at the time of harvest was measured in 12 trials, on a depth of 10, 20 and 30 cm on 4 spots per plot, for not fertilized plots and on the plots which received 80 kg P_2O_5 . It was found that shear strength was clearly related to soil humidity, but neither of them was related to phosphate.

On-station trial

In a trial at ADRON in 1999 (Wildschut & Khodabaks, 2000), in which rice was sown after various types of dry tillage followed by a pre-planting glyphosate treatment instead of puddling, phosphate fertilizer and various types of post-emergence herbicides were compared to zero herbicide treatment. It confirmed some of the results of the on-farm trials:

- C When soil submergence before sowing is only a short period (or as in this trial even absent) available soil-P is low and the crop shows a strong response to TSP.
- C There is a strong interaction between weeds and phosphate fertilizer under the conditions of no soil submergence before sowing, *Figure 6*, such that the paddy yield reduction due to weeds is stronger in the absence of phosphate fertilizer.



3.5 DISCUSSION & CONCLUSIONS

- C On-Station research, in general carried out under good cropping conditions as good water control, has not been able to detect a response to P_2O_5 , whereas with superimposed on-farm trials it was found that on 35% of the farmers fields an economical response to phosphate can be observed.
- C In the Nickerie rice polders a response to phosphate is due to neither an absolute, nor a relative P-deficiency of the soil, but due to extreme or special soil conditions which reduce P-availability and/or inhibit P-uptake through toxic organic acids and/or Fe-toxicity.
- C A response to phosphate is observed when water control is poor. When the period between the first water intake for puddling and sowing is shorter, the response to phosphate is stronger. Phosphate application can therefor partly compensate for poor water control, or stated inversely: with good water control fertilization with phosphate is generally not necessary.
- C It is recommended to the farmers that a phosphate application of about 100 kg TSP within 10 days after sowing, is worth trying, if:
 - C despite good red rice control, timely and sufficient urea application and other good cultural practices the yields are less 3.5 - 4 ton/ha, or,
 - C submergence before sowing is less than 10 days,
 - . Keeping the field flooded will increase the efficiency of the phosphate fertilizer.
- C For the soils of the Nickerie rice polders, traditional methods for P-extraction as P-Olsen and Bray, are useless to predict phosphate response.
- C From all soil samples taken, a subsample has been stored at ADRON. If better P-available soil test on dried soil samples exist, it might be useful to try them. However, just trying a bag of TSP might be the cheapest and the best test.
- C Comparing the results of trials from the late fifties with the trials of the mid nineties, it is

remarkable how similar the outcomes are. After almost 40 years, and more than 60 crops by which an amount of at least $60 \times 15 = 990$ kg P_2O_5 has been removed from the soil, the P-supplying capacity of the soil has hardly changed. It is not expected to change in the near future.

- C Fertilization with phosphate can play a positive role when puddling is replaced by a pre-planting glyphosate treatment in a minimum tillage system.
- C In conditions as reduced P-availability due to the absence or too short a period of soil submergence before sowing, applying P-fertilizer makes rice more competitive to weeds like *Fimbristylis*, so that less herbicide is necessary.
- C It is not clear how to explain the negative response to P_2O_5 when not fertilized yields are high. An interaction with the growth of algae, or an effect on *Helminthosporium*, could be an explanation.
- C Farmers' claims that phosphate application softens the soil, could not be confirmed and remain mysterious.
- C Several topics need further research, e.g. the fate of fertilizer P_2O_5 after draining the soil for the application of urea top dressings, in which the use of the resin technique might be helpful.

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4 SUMMARY OF RESULTS OF TRIALS WITH RED (WEEDY) RICE

4.1 Introduction

Red rice is one of the most important factors limiting rice production in Nickerie. Red rice

populations are very heterogeneous and cross easily with cultivated rice.

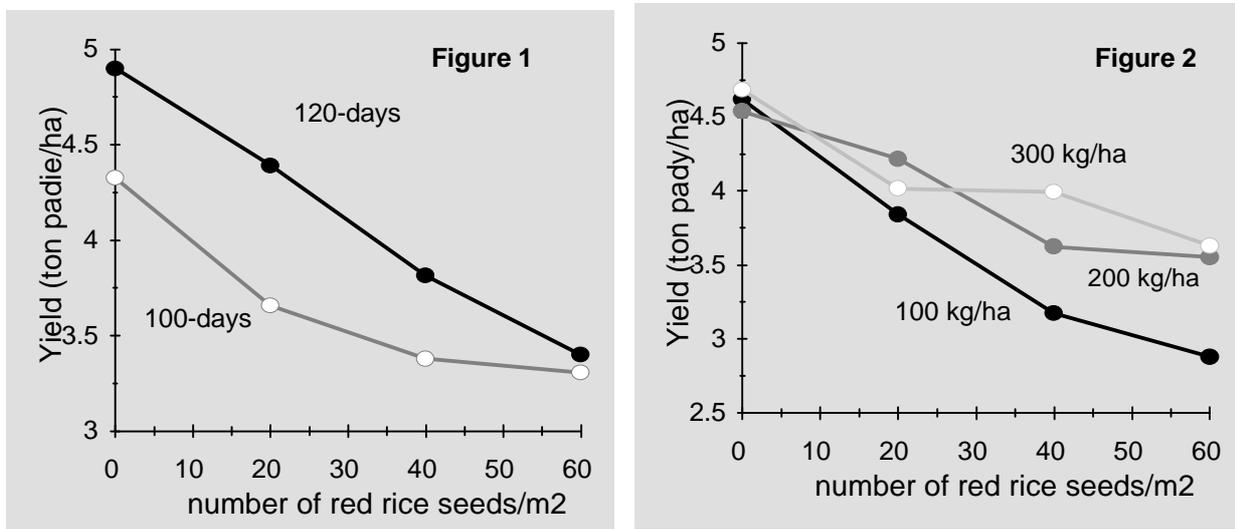
A trial was set up in order to answer the following questions:

- C is a 100-day variety as sensitive to red rice competition as a 120-day variety
- C by how much can we increase competitiveness of rice by increasing the seed density
- C do the two rice varieties have a different effect on red rice

Factors in the trial were Variety (a 120-days variety and a 100-days variety), Seed density (100, 200 and 300 kg/ha) and Number of red rice seeds/m² (0, 20, 40 and 60). The trial was set up in 4 blocks of 12 plots each, the three factor interaction being confounded with the block effect. The trial was repeated over 3 seasons.

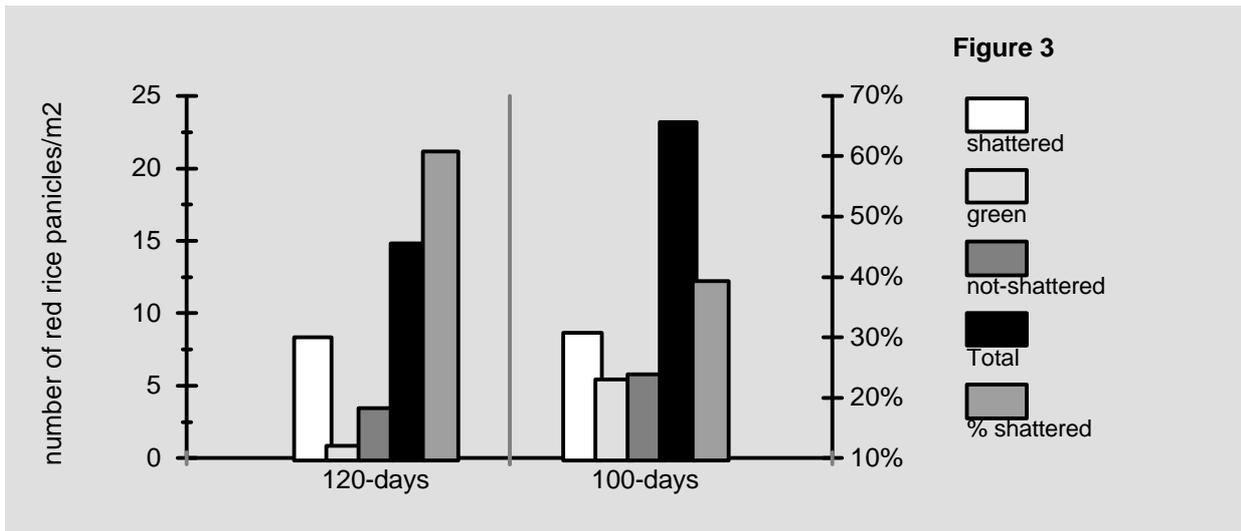
4.2 Results

Results show that yield reduction due to an increasing number of red rice seeds is more or less the same for both varieties, *Figure 1*. Increasing the seed density from 100 to 200 kg/ha reduces yield loss due to red rice for both varieties, *Figure 2*. Yield component analyses showed that yield reduction due to red rice competition is through the reduction of the number of panicles/m². Panicle weight is not influenced by red rice.



It was expected that when harvest is at 100 days, the number of shattered (ripen) red rice panicles would be smaller than if harvest is at 120 days. Thus, a 100-day variety could be of use in an integrated approach to control red rice. The percentage of shattered red rice panicles indeed is lower when harvest is at 100 days, however, this is compensated by a higher total number of red rice panicles, *figure 3*.

An explanation could be that at the end of the growth cycle, competition for growth factors slows down (after all, only the number of panicles/m² and not the panicle weight is reduced by red rice competition). Red rice has a growth cycle which is adapted to competition with 120-days varieties. When competition from the 100-days variety slows down, red rice continues to produce tillers. This



explains also why the higher number of red rice panicles in the harvested 100-days variety does not reduce its yield proportionally: the extra number of red rice panicles is formed after the yield of the 100-days variety was already determined. The extra number of red rice panicles in the 100-day harvest are green and not-shattered, *Figure 3*.

4.3 Conclusions:

- Ⓒ Yield reduction due to red rice is for 100-days and 120-days more or less the same.
- Ⓒ This Yield reduction can be decreased by a higher seed density up to 200 kg/ha.
- Ⓒ The percentage mature red rice panicles at harvest time is lower for a 100-days variety.
- Ⓒ However, because the total number of red rice panicles is higher for the 100-days variety the total number of shattered red rice panicles is the same for both varieties.
- Ⓒ More red rice panicles are harvested while harvesting a 100-days variety from a red rice infested field, than while harvesting a 120-days variety.

A 100-days variety is not useful in an integrated approach to control red rice. In addition, it is known that on the long term red rice will be adapted to a growth cycle of 100 days through natural crossing with 100-days varieties.

5 Summary MINIMUM TILLAGE

5.1 Introduction

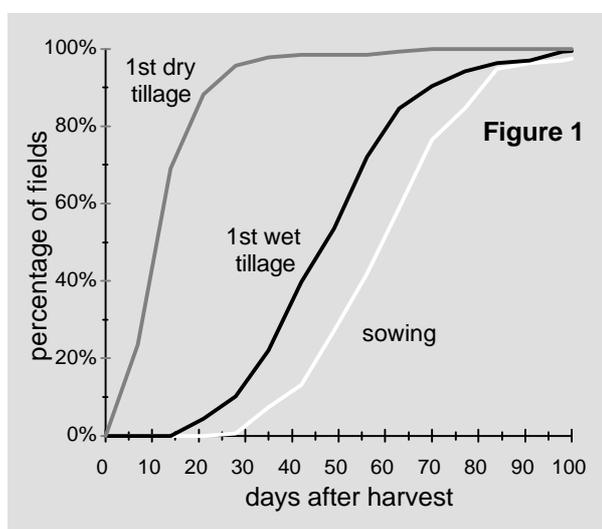
On the very heavy clay soils of Nickerie, costs for the mechanised tillage have the highest share in the total production costs of paddy (up to 30%). If allowed for by wether conditions, farmers perform both dry tillage and wet tillage, if not they practice only wet tillage. Dry tillage is done with a 3-disk plough and/or a Rome-type plough. Directly after water for flooding is available, the first run of field wet tillage is done with a chipper. 5-20 days later the field is puddled with a weed cutter or mud roll followed by levelling with a wooden beam. For the three consecutive seasons 1996A, 96B and 97A, the 5 most frequent soil tillage scenario's were:

- Ⓒ Only wet tillage (17% of the fields),
- Ⓒ one run with the Rome-type plough followed by wet tillage (22%),
- Ⓒ two runs with the Rome-type plough followed by wet tillage (20%),
- Ⓒ one run with the 3-disc plough followed by wet tillage (19%) and
- Ⓒ one run with the 3-disc plough followed by one run with the Rome-type plough followed by wet tillage (10%).

Timing of the tillage operations is determined by soil humidity and the availability of machinery. Normally, the soil is drained 2-3 weeks before harvest with the combine. Subsequently straw is burned and within 20 days after harvest 85% of the fields are dry tilled. As soon as water is available the wet tillage starts. As the wet infrastructure is very poor, the period during which fields are wet tilled is long: the first 10% of the fields are wet tilled within 30 days after harvest, the last 10% not before 70 days after harvest, *Figure 1*.

In too wet seasons, or for late sown and consequently late harvested fields the soil humidity is too high for dry tillage.

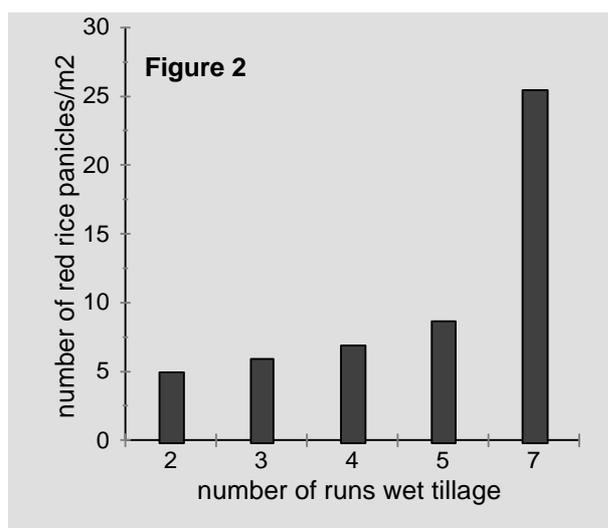
It was found that fields prepared with the 3-disc plough had twice as much red rice than fields prepared with the Rome-type ploughs. In order to exhaust the red rice seed bank in the soil, farmers



often repeat several runs of wet tillage. This appears not to be effective, *Figure 2*, because while killing red rice seedlings, new red rice seeds are worked up to the soil surface.

Other backgrounds of soil tillage practices in Nickerie are that dry tillage directly after harvest destroys stemborers pupa in the stubble. Puddling prepares a weed free muddy seed bed, but often causes deep tracks as well. Through levelling with a wooden beam these tracks, if not too deep and wide, are filled with mud.

In this context of the above mentioned practices ADRON started a research project on Minimum Tillage, to reduce costs and improve timing, red rice control and water efficiency.

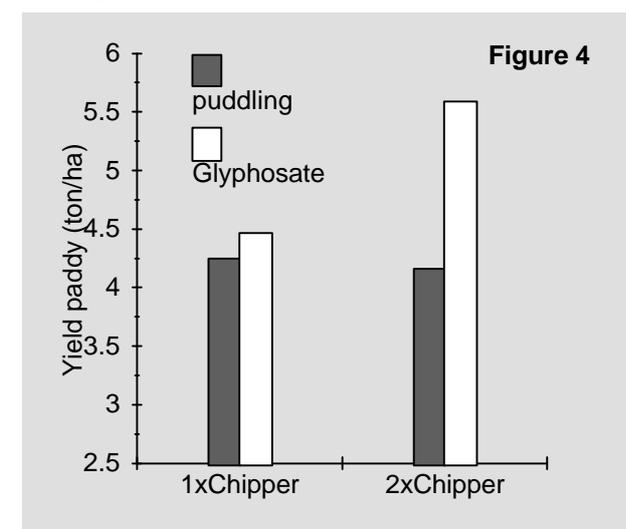
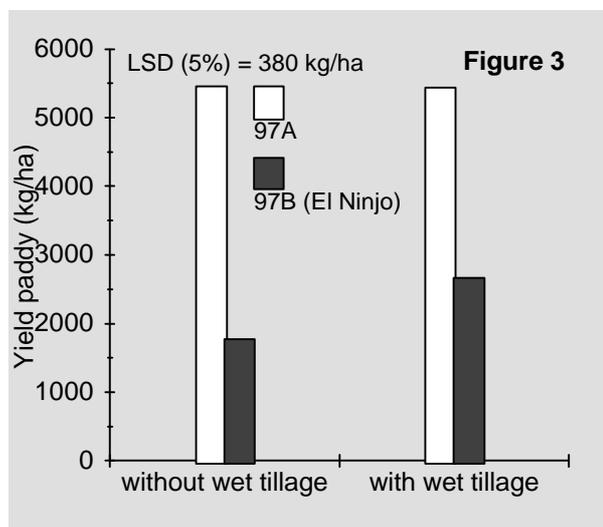


5.2 Minimum Tillage trials

In a first trial on minimum tillage, main season 1997, several types of dry tillage including zero tillage with and without a following wet tillage, were compared. Dry tillage was done directly after harvest, wet tillage as soon as water was available. During this period between dry tillage and wet tillage a weed vegetation developed which consists mainly out of volunteer rice, *Fimbristylis* and *Ischaemum rugosum*. At the time the plots with a scenario which includes wet tillage were flooded, the plots with a scenario without wet tillage were treated with glyphosate. Yields were high for all scenarios and yields of plots with only dry tillage + glyphosate and plots with both dry and wet tillage were equal. But the next season, due to severe drought (El Niño), yields were very low for all scenarios, *Figure 3*.

Yield component analyses showed that for the scenarios without wet tillage the number of panicles/m² was lower, but this was compensated by a higher panicle weight.

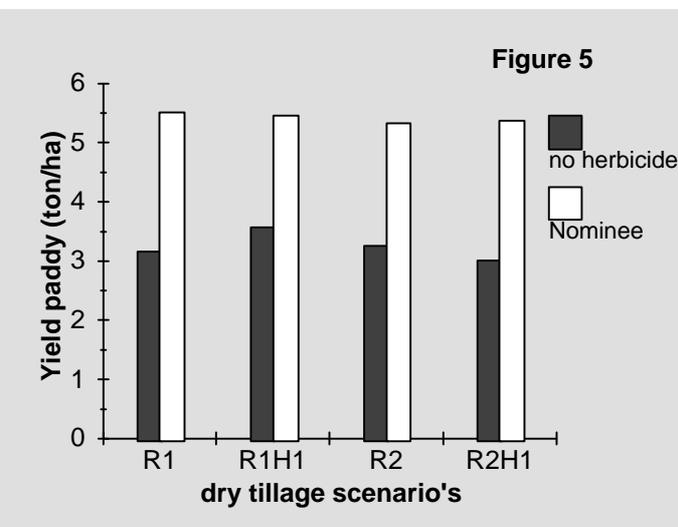
Some seasons (e.g. La Niña) dry tillage is not possible. A trial in a split plot design was set up to see if puddling and beaming can be replaced by a glyphosate treatment after one or two runs with the chipper. On top of these four scenarios of seed bed preparation without dry tillage, 5 post-planting herbicide treatments, including the farmers practice of 2,5D + Propanil, were compared to non treated plots. Yields of non treated plots were very low: an average of 2,6 ton/ha.



However, yields were high from plots which were chipped twice (33 and 20 days before sowing), treated with glyphosate 2 days before sowing and treated with an efficient herbicide at 33 days after sowing. Plots which were chipped only once (33 days before sowing) or which are puddled and levelled in stead of treated with Glyphosate (2 days before sowing) yielded at least one ton/ha less, even when treated with an efficient herbicide (33 days after sowing), *Figure 4*. Yield differences are strongly related to interactions of the treatments with the weed population dynamics before and after sowing. In a similar trial 4 types of seedbed preparation without dry tillage were compared: 1) soil only treated with glyphosate on 12 and 2 days before

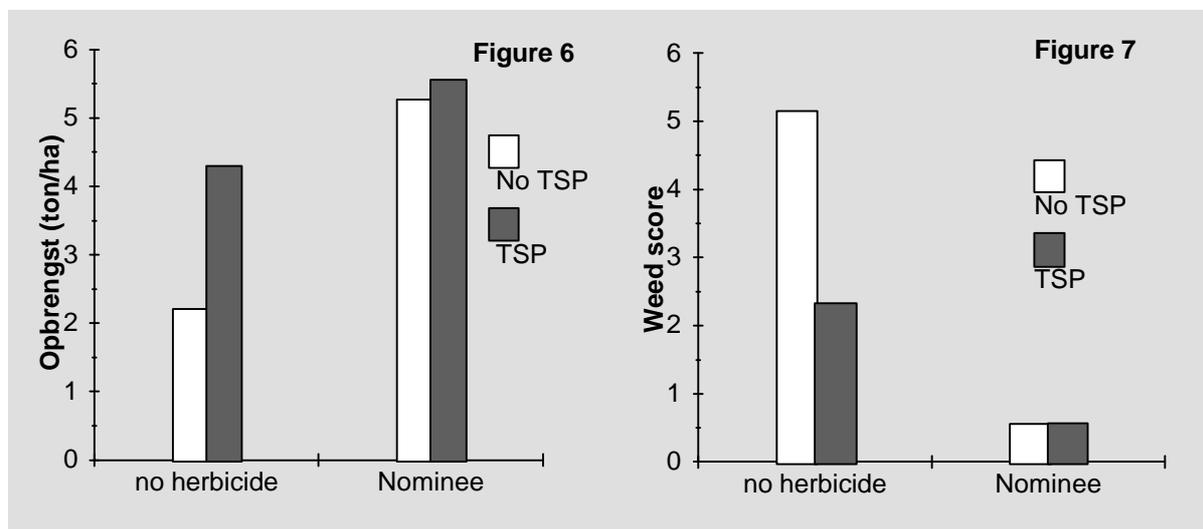
sowing (zero-tillage), 2) treated with glyphosate 12 days before sowing and puddled and levelled with a wooden beam 2 days before sowing, 3) chipped 12 days before sowing and treated with glyphosate 2 days before sowing and 4) chipped 12 days before sowing and puddled and levelled 2 days before sowing (farmers' practice). The highest yield was found for chipping followed by a glyphosate treatment: 4.5 ton/ha, which out yielded farmers' practice with 0.8 ton/ha. Yield from the zero-tillage plots was 3.5 ton/ha and from the plots treated with glyphosate followed by puddling and levelling was 2.5 ton/ha. As the LSD(5%)=1.24 ton/ha, yield differences between the farmers' practice and the alternatives are not significant. Replacing chipping by glyphosate followed by puddling and levelling gives a 2 ton/ha lower yield than replacing puddling and levelling by glyphosate. These results indicate clearly that puddling and levelling (costs of which are ± US\$50,-/ha) can be replaced by a treatment with glyphosate (US\$ 25,-/ha).

From previous trials it was not clear how many runs of dry tillage are optimal for replacing the wet tillage by a glyphosate treatment. On-farm trials with phosphate showed that there is a strong interaction between soil-phosphate availability, the inundation time before sowing and weed growth (see Chapter 3). Hence, a trial which combines these factors was designed: A field was tilled once with the Rome-type plough. One month later it was divided in 6 strips of which 3 were ploughed again. Subsequently one week later the field was divided in four strips at right angles to the 6 other strips of which 2 are disc-harrowed once. Thus, 4 types of dry tillage plots were created: Rome-ploughed once (R1), Rome-ploughed and harrowed once (R1H1), Rome-ploughed twice (R2) and Rome-ploughed twice and harrowed once (R2H1). 32 Days after harrowing the entire field was treated with glyphosate, flooded the next day and sown 3 days later. The in total 24 plots were grouped in 3 blocks of 2x4 plots of which half were fertilized with phosphate (TSP) 6 days after sowing. Superimposed on these plots 5 post-planting herbicides (applied 20-40 days after sowing) were compared to no-herbicide.



Yields were equal for all types of dry tillage, with or without post-planting herbicide treatment, *Figure 5*.

The effect of phosphate, however, depends strongly on the post-planting herbicide treatment. In the absence of such a treatment TSP fertilizer doubled the yield from 2 to 4 ton/ha. If treated well with a post-planting herbicide as Nominee, the effect of phosphate was negligible, *Figure 6*. Weeds scores (0= no weeds, 9 is extremely weedy) were taken just before harvest and correlate well to yields ($R^2=0.621$). The effect of phosphate is reflected in the weed scores, in that without a post-planting herbicide phosphate reduces the weed score (increase the competitiveness of rice to



weeds). When treated with Nominee, the weed score is stronger reduced, *Figure 7*. An other observation from this trial was that the number of *Jussiaea* plants per plot was twice as high for plots ploughed twice followed by disc-harrowing. On yields this had no effect.

5.3 Conclusions and Recommendations

All trials show that puddling and levelling is not necessary. When dry tillage is possible one or two runs with a Rome-type plough or disc-harrowing is sufficient for seedbed preparation if followed by a glyphosate treatment 2 days before sowing. Apart from cost saving in seedbed preparation, this practice requires less water, saves time as one can sow as soon as water is available and one can expect less red rice and other weeds as the soil is not touched after killing weeds by glyphosate. Essential is that after the dry tillage and before the glyphosate as much as possible weed seeds germinate from the soil top layer, either triggered by rains or by pre-irrigation. Deep tracks caused by puddling with too heavy tractors are avoided.

Also when dry tillage is not possible, chipping followed by a glyphosate treatment is sufficient to prepare a seedbed.

In how far these two types of minimum tillage are a remedy for red rice infested fields is still subject to research in farmers fields.

6 PADDY PRODUCTION ANALYSES through conceptual models

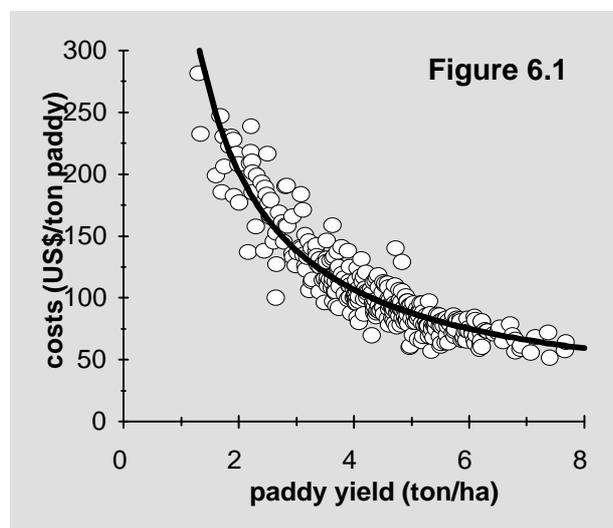
6.1 Introduction

As a result of among others the crop production survey, the survey's on machineries and soil tillage practices and on post harvest technologies, three conceptual models could be constructed on 1) increasing profitability, 2) increasing quantity and 3) improving quality of the rice production in Nickerie. The models serve as a tool for diagnoses of problems and solutions and as such for setting the research agenda of ADRON.

6.2 Increasing Profitability

Model 1 on increasing the profitability of rice production, see diagram on the next page, shows the problem of high costs and low price per ton, bottlenecks, solutions and the anticipated result. Components of the model which are outside the influence of rice research at the Centre and which are a matter of organisation of the rice sector itself and/or a matter of government policies, are left white, the other components are shaded grey.

Soil tillage costs were found to have the highest share in the total production costs/ha, followed by



fertilizer costs. Research is focussing on reducing these costs, hence increasing profitability. However, it was also found that costs/ton are best reduced by focussing on high yields/ha, *Figure 6.1*, e.g. indicating that farmers should not economize on fertilizer, but focus on increasing it's efficiency.

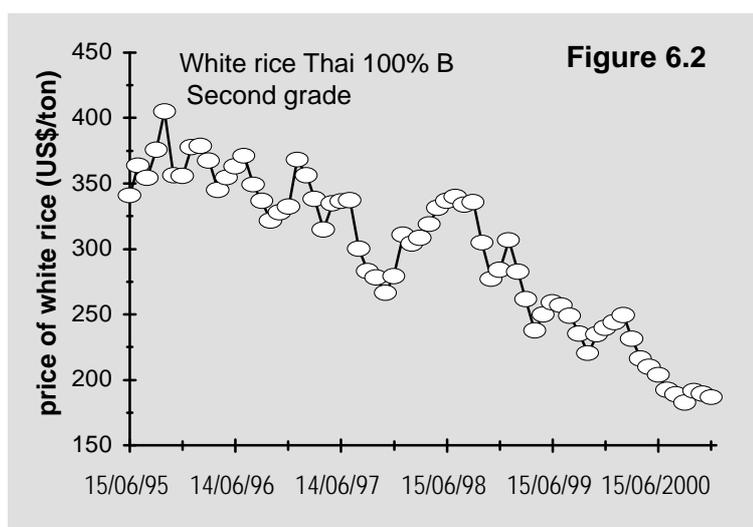
Across farmer fields the variation around the average yield of ± 4.0 ton/ha is high (CV = 29.0 %), whereas the variation in production costs/ha is much lower (CV = 11.4%), indicating serious management problems for many farmers, e.g. timing of operations.

The steady dropping of the world market prices of white rice (shown for White rice Thai 100% B second grade, *Figure 6.2*, to which compared Surinam rice has a 10-15% higher price) and the

high share in production costs of the interest rate (which is up to 40%/year), have a strong

impact on profitability. If, in addition, the street rate of the US\$ is much higher than the official rate and rice export dollars have to be exchanged for this official rate, whereas dollars for inputs are only available at the street rate, profitability will turn into heavy losses, even with very high yields per hectare.

Also the quality of the rice products, processing as well as consumption quality, affects the price.



Model 1: Conceptual Model to increase the profitability of paddy production and processing

PROBLEM

low profitability paddy production

BOTTLENECKS

high costs per ton

low price per ton

high costs per Ha

high interest rates

high costs and margins importers

low yield per Ha

low world market price

high costs and margins millers and exporters

adverse exchange rates

low quality rice product

SOLUTIONS

reduce costs per Ha

reduce interest rates

liberalize import regulations

increase yield per Ha
see model 2

improve marketing strategies

improve post harvest procedures

free exchange rates

improve quality rice product
see model 3

higher technical efficiency soil tillage
minimum tillage

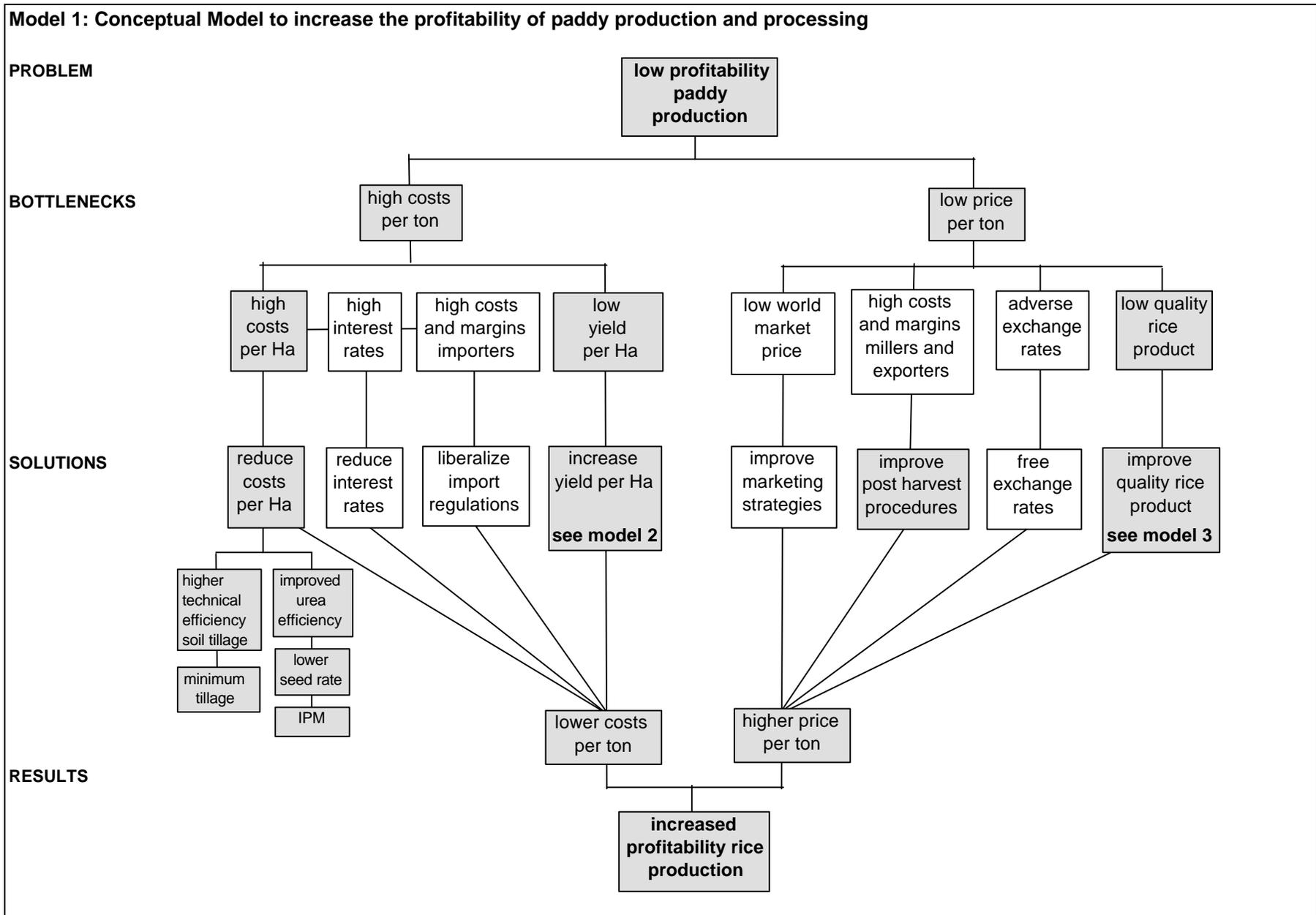
improved urea efficiency
lower seed rate
IPM

lower costs per ton

higher price per ton

RESULTS

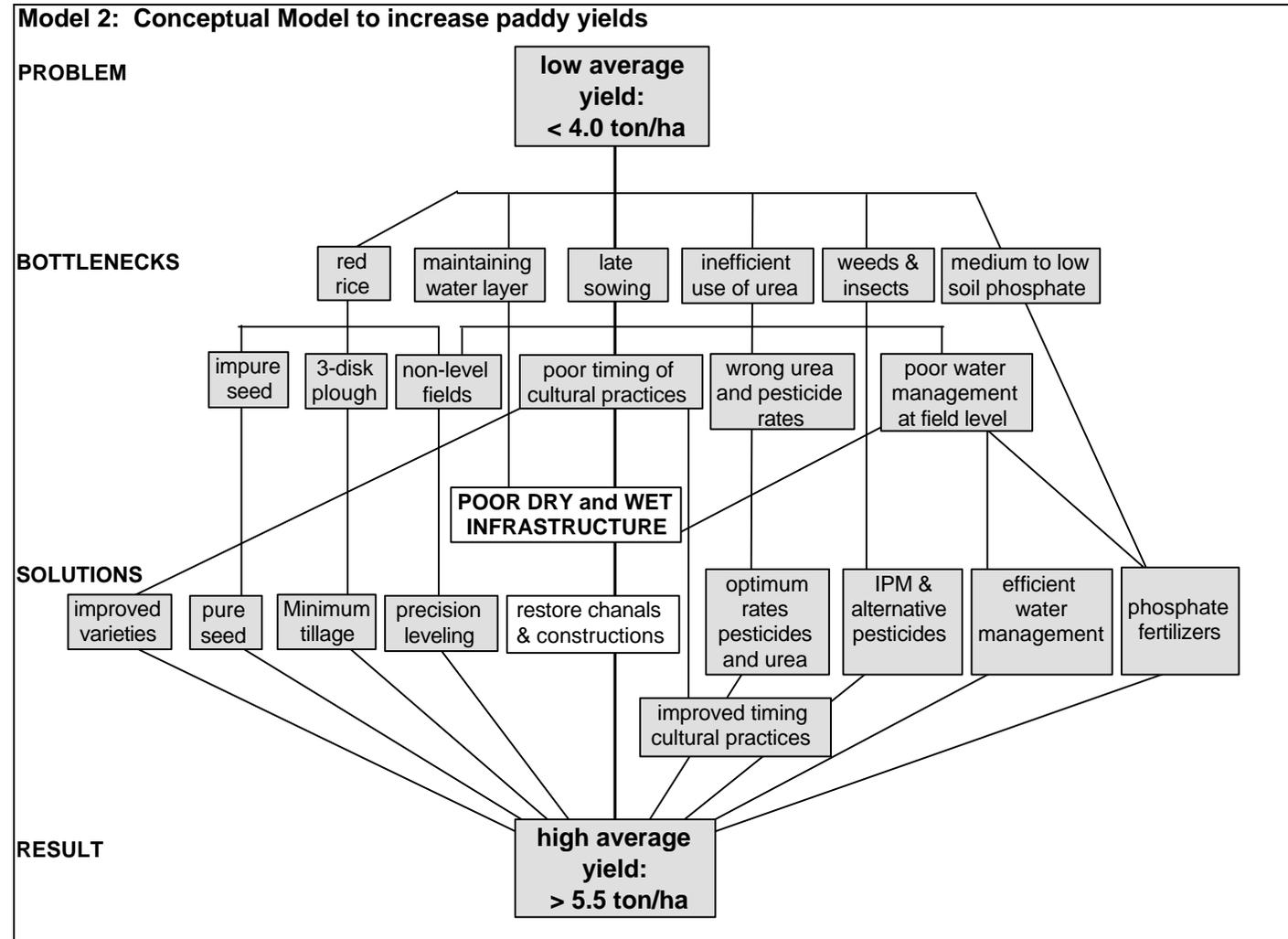
increased profitability rice production



6.3 Increasing Yields

Model 2, see diagram to the right, on increasing paddy yields, shows bottlenecks, solutions and the anticipated result. It shows the infrastructure to be a key factor in increasing the rice production: If properly restored and managed, the average yield could increase with 1.5 tons/ha with optimal application of the current varieties and cultural practices. In addition, the yearly cultivated area (for the year 2000 estimated to be below 100%) could increase to 180% or more. Proper timing of cultural practices within the season as well as after sowing is strongly affected by the infrastructure. But also timely delivering of credits and inputs (urea, pesticides, spare parts) as well as the professionalism of the farmer play an important role.

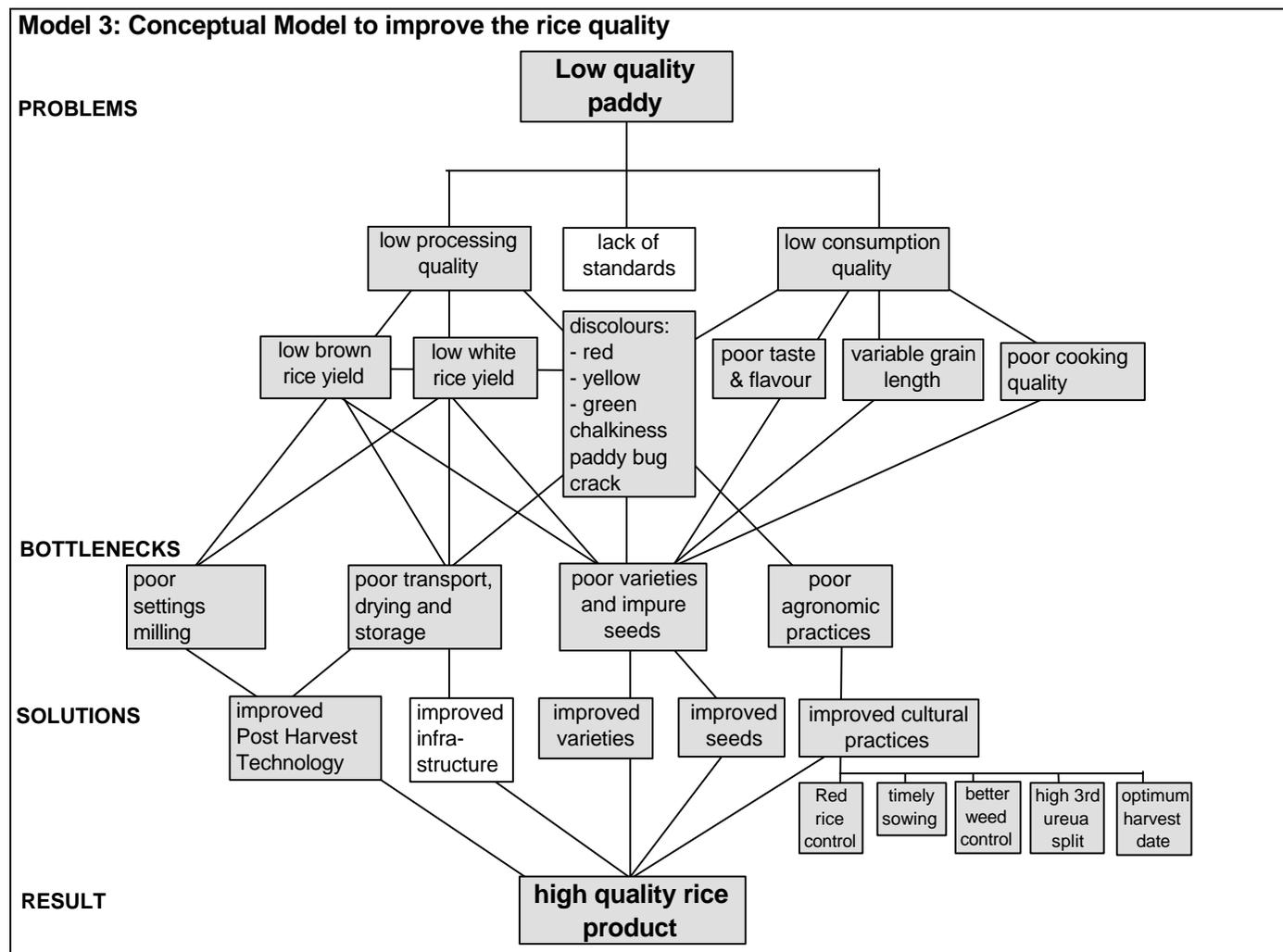
The role of improved varieties in increasing the average yield lies both in a better fit in the cropping calendar (short duration varieties: 100-105 days) and a higher response to improved cropping conditions (long duration varieties: 120-125 days).



6.4 Increasing Quality

Model 3, see diagramme to the right, on improving the quality of paddy and the rice products, shows quality to have multiple aspects, which are related to variety, seed quality and agronomic practices on one hand and to post harvest technology on the other.

High consumption qualities and processing qualities are not always found in the same variety. A good variety (grain length, taste, flavour and cooking quality) and pure seeds are the starting point for high quality. Proper cultural practices create the conditions for high quality yields, avoid red rice and green discolours and reduce chalkiness. Fortunately these conditions coincide with those for high quantitative yields. Improved post harvest technology can avoid yellow discolouring and crack and can increase head yields and thus increase profitability of paddy processing. The lack of quality standards is also a reason for a highly variable rice quality.



7 IPM ORIENTED RESEARCH AT ADRON, SURINAME

7.1 Introduction

Integrated Pest Management (IPM) is a pest management approach by which the farmer controls the size of pest populations through a combination of cultural practices, such that applying pesticides is considered as last option only.

The goal of IPM is to reduce the use of pesticides. Reasons for reducing pesticide use are:

- C reduction of the production costs
- C protection of the health of the farmer and the other members of the rural community
- C environmental safety, protection of the flora and fauna and maintenance of bio diversity
- C to avoid possible pesticide residues in the product.

In Suriname, the costs of the use of insecticides plus fentin acetate to control snails average \pm US\$ 43 per hectare, which is only \pm 7% of the total production costs of US\$ 600/ha. Though across fields the variation in these costs is high (CV = 54% for insecticides), so that costs can be considerably higher for an individual farmer, the arguments for the development of an IPM strategy are not primarily to reduce production costs. More important arguments lay in the field of environmental safety. However, in the long run, it will have serious economical consequences, if these arguments are not taken seriously as well.

7.2 Results from earlier research

Earlier research focussed on identifying and controlling economically important pests and diseases. Up to the eighties, extremely toxic pesticides have been used as Endrin, Dieldrin and Methyl-parathion. Nowadays, the main pesticides used are monocrotophos, synthetic pyrethroids and fentin-acetate.

Pests and diseases, as well as the periods during which the rice crop in Nickerie is susceptible to them, are summarized in Figure 1. Weather conditions and cultural practices affecting pests are summarised in Table 1, those affecting diseases are summarised in Table 2. Both tables show our knowledge to be still incomplete with regard to some pests and diseases.

Table 1: Weather conditions and cultural practices affecting rice pests in Suriname (After Van Halteren, 1972,

PESTS AND DISEASES OF RICE

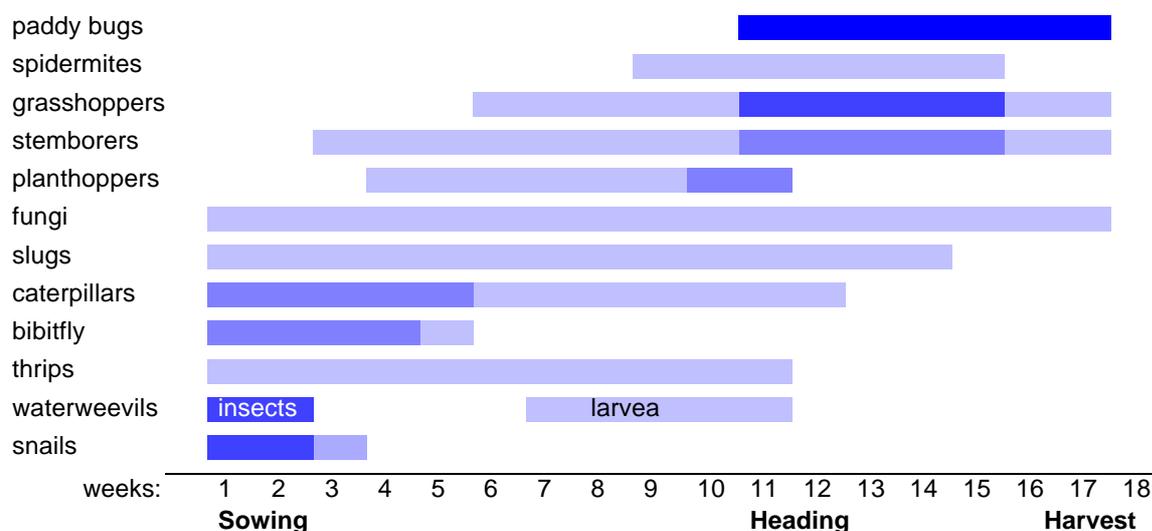


Figure 1: Pests and diseases of rice in Suriname. The coloured bar indicates the period during which rice is susceptible to the pest, especially during the darker coloured periods. (After P. van Halteren, 1972, SML.)

Rank	English and Scientific name	Weather conditions stimulating the pest	Cultural practices stimulating the pest	Cultural practices suppressing the pest	Current chemical control practices	Efficacy chemical control
1	Bibitfly, leafminer (= larvae) <i>Hydrellia deonierie</i> <i>Rambajan.</i>	C heavy rains	C keeping the field flooded after sowing C high water level in the field C late sowing C deep tracs and spots	C early draining the field after sowing C early sowing* C high seed rate	spraying Monocrotophos or Karate	good?
1?	Water weevils <i>Lissorhoptrus oryzophilus</i>	C heavy rains	C keeping the field flooded after sowing C pumping water from the drainage canal?	C draining the field after sowing	dripping Karate into the field drain and other low spots before sowing	good?
1?	Stemborers <i>Rupella albinella</i> <i>Diatraea saccharalus</i> (rare)	C heavy rains	C high Nitrogen fertilisation in 2 splits C staggered planting*	C burning straw directly after harvest, C followed by dry soil tillage C synchronous planting C nitrogen in 3 splits	spraying with monocrotophos	poor
1	Snails <i>Pomacea doliodes</i> <i>Pomacea glauca</i>	C heavy rains	C keeping the field flooded after sowing C high water level in the field C deep tracs and spots	C early draining the field after sowing C wire mesh in the water inlet	dripping Brestan (fentin acetate) into field drain and low spots before sowing	good
1	Paddy bug <i>Oebalus poecilus</i>	?	C late sowing	C synchronous planting C keeping dams etc. weed free	spraying with monocrotophos or pyrethroids	good, except for late sown fields
2	Long-horned grasshopper <i>Caulopsis cuspidata</i>	?	?	?	spraying Malathion or monocrotophos	good
3	Planthoppers (Delphacides) <i>Sogatodes oryzicola</i>	C high temperatures C no winds C high air humidity	C continuous high water table C high plant density C heavy N-fertilisation C staggered planting C early use of heavy broad spectrum pesticides (e.g. curacron)	C synchronous planting C N-fertilisation in 3 splits C normal seed density (120-150 kg/ha) C drain the field C avoid early pesticide applications	spraying with Malathion	poor
3	Armyworm <i>Spodoptera frugiperda</i>	C dry sunny periods C dry soil	C draining the field directly after sowing	C flooding the field	spraying Malathion or monocrotophos	good
3	Thrips <i>Stencheatothrips biformis</i>	C dry weather	C draining the field directly after sowing	C submerge the crop for 2-3 days	spraying monocrotophos	?
3	Leafhopper (Jassides) <i>Draeculacephala clypeata</i>	C more or less like planthoppers	C heavy grass infestation	C synchronous planting	spraying Malathion	?
3	Slugs <i>Omalonyx felina</i>	C high air humidity C rainy periods		C if in early stage: flooding the field C proper weed control	?	?
3	Spidermites <i>Acarina spp</i>	C hot dry weather	?	?	?	?
3	Stembugs <i>Tibraca Limbativentris</i>	?	?	C synchronous planting C increasing the water level in the field	?	?

* A long sowing season in an area smaller than 5x5 km often means strong population built up.

Table 2: Weather conditions and cultural practices affecting fungus diseases (After Van Halteren, 1972, Soerokarso et al, 1976, Anonymous, 1982, Webster & Gunnell, 1992).

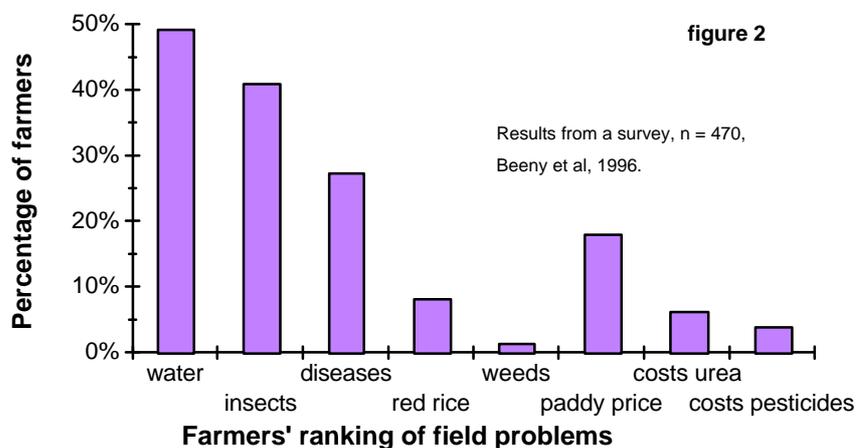
Rank	English and Scientific name	Weather conditions stimulating the fungus	Cultural practices stimulating the fungus	Cultural practices suppressing the fungus	Remark	Chemical control
2	Brown spot <i>Helminthosporium oryzae</i>	?	C sub-optimal urea rates C excess of P-fertiliser C root maggots C recycling of drainage water	C optimal urea rates C dry soil tillage C stubble burning C seed treatment? C resistant varieties	more an indicator of nutritional or physiological disorders than a pathological disease	doubtful
2	Narrow brown spot <i>Cercospora spp.</i>	?	?	C optimal urea rates C dry soil tillage C stubble burning C resistant varieties	id	non
2	Sheath blight <i>Rhizoctonia solani</i>	hot dry weather	C high seed density C high nitrogen levels	C stubble burning C wet fallow C weed free	id	difficult
?	? <i>Fusarium spp.</i>	Hot & humid weather	C high urea rates	?	id	doubtful
3	? <i>Alternaria padwickii</i>	?		C seed treatment	id	doubtful
3	? <i>Curvularia spp.</i>	?	?	?		
3	False smut <i>Ustilagoideae virens</i>	?	?	?	id	doubtful
3	Rice blast <i>Pyricularia oryzae</i>	humid weather	C high nitrogen levels	C limit weed growth during fallow C optimal urea rates C dry soil tillage C stubble burning C seed treatment C resistant varieties	pathogen	doubtful

The economical importance of the pests may vary with the seasons and is also affected by changes in the cropping system. Until the late seventies fields were always drained directly after sowing and reflooded 2 weeks later. Bibitfly and waterweevils were of minor importance whereas armyworm was one of the most serious pests at that time. Stemborers too were a minor pest and easily controlled by proper soil tillage. In the eighties many farmers shifted to keeping the fields flooded after sowing in order to control red rice. This resulted in an increased importance of waterweevils and bibitfly, whereas armyworm practically disappeared as a pest.

7.3 Farmers' perceptions and pesticide application behaviour

Several surveys carried out in the nineties showed contradictory results as far as it concerns farmers' perceptions of the economical importance of pests and diseases, as well as of the efficacy of chemical control.

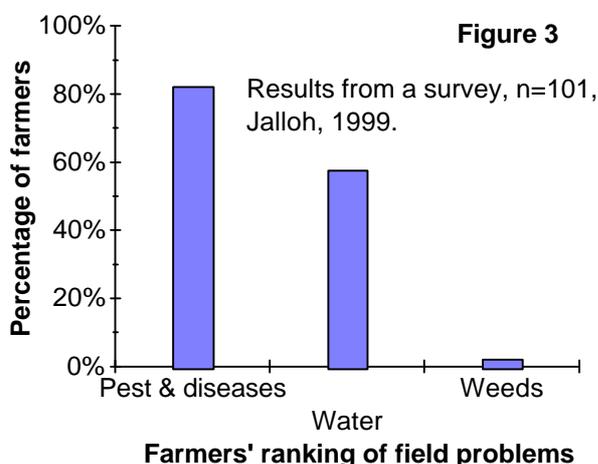
Asked to indicate the most serious field problems (Beeny et al, 1996), about 40% of the farmers mentioned insects (Figure 2). The costs of pesticides, however, was for only 5% of the farmers a problem.



Ⓒ Are pesticides not effective, or do farmers not know how and when to apply?

The only rice diseases which have been observed in Suriname are fungi, which are rarely of economic importance. Still, 25% of the farmers regard diseases as a serious field problem.

Ⓒ Don't farmers make any difference between diseases and insects?

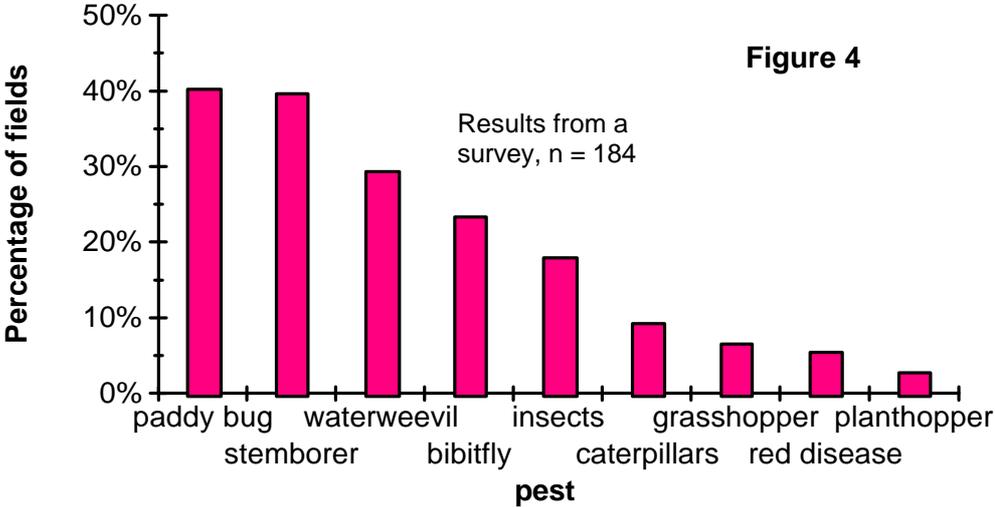


Though water control is the main field problem for 50% of the farmers, still the weed problem is considered a problem by only a few percent of the farmers. A survey by Jalloh (1999) gave similar results, Figure 3.

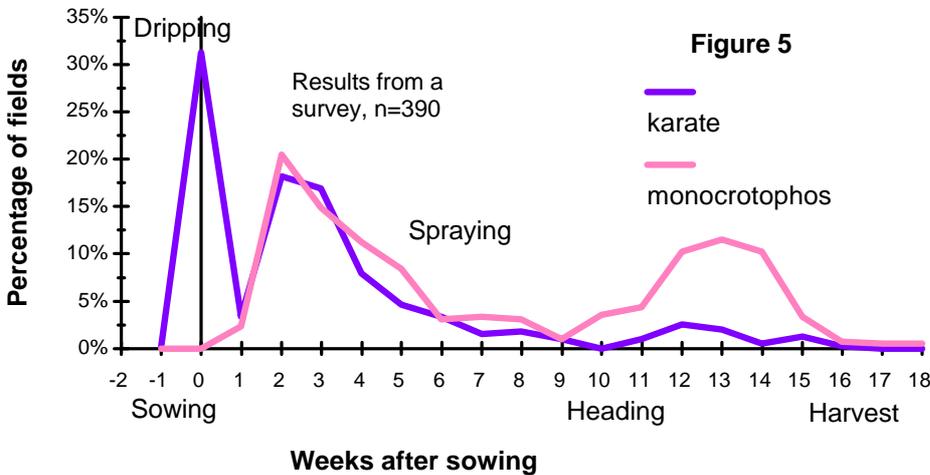
Farmers interviewed during a crop production survey (Wildschut, 1998) claimed that the most frequently observed and chemically controlled pests are paddy bug (on 40% of the fields) and stemborers (also on 40% of the fields), followed by waterweevils (30%) and bibitfly (25%), see Figure 4. According to Van Halteren (1972), however, "Chemical control is not necessary; climatic conditions, dry soil

tillage, burning of the stubble, and parasites keep stemborer populations below the threshold of economic importance”.

On almost 20% of the fields farmers spray against insects which are not known to them. The mentioned “red disease” sometimes observed in the early stages of plant growth, is in fact a nutritional disorder by which phosphate uptake is temporarily inhibited on fields where the submergence period before sowing was extremely short, related to toxic organic acids (imperfect decomposition of weeds) and/or Fe-toxicity.



The timing of the application of the most frequently used insecticides is presented in Figure 5. Farmers claim to control waterweevils effectively by dripping Karate (a pyrethroid) in the field



drain and other low spots, several days around sowing. Does this practice indeed prevent waterweevils and subsequently rootmaggots? Fact is that rootmaggots damage is seen only very rarely.

Early pests are controlled by both monocrotophos (Luxafos, Azodrin or Nuvacron) and Karate, late pests mainly by monocrotophos.

Other findings of the survey regarding the actual use of pesticides:

- ∩ Brestan (fentin acetate) is used on all fields.
- ∩ 13% of the fields are not sprayed at all, 28% are sprayed only once, 32% are sprayed twice,

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Summary IPM Strategy Development

(Ir. K E Neering, short term consultant IPM)

Crop protection in Suriname is still based almost exclusively on pesticide application. As far as known, no research on pests in rice has been conducted since 1974. Developments in the field of rice crop protection in other areas of the world, especially regarding development of IPM and its extension to farmers by the farmers' field school approach, have not or hardly reached Suriname. Since 1974, rice cultivation methods in Suriname changed, resulting in a reported shift in relative importance of different pests. As information available from the sixties and seventies may not be applicable anymore, the economic impact of yield reducing organisms at present should be assessed again. A number of suggestions for research were given to the IPM specialist of ADRON. It was advised to focus research more on performance of the plant or crop than on that of the pest populations. The research may lead to a better understanding of rice-field ecology and result in a more ecologically oriented crop protection as alternative for the present calendar-based chemical control. For easy reference, a literature database with bibliographic information and abstracts on crop protection in rice in the America's, published over the last 30 years, was compiled and left with ADRON.

As information and knowledge of (potential) yield reducing biotic factors was found to be incomplete, a rather large part of the consultancy was used to compile an overview of these and their natural enemies or control mechanisms.

Natural enemies were found to be numerous. The types of organisms were found to be highly comparable to the S-E Asian ones. For that reason, the extensive information on natural control processes, developed in Asia could be applied in Suriname after making some minor adjustments only. Inventory and impact assessment of natural enemies in Suriname will be included in the work programme of ADRON.

In order to achieve more ecologically and less calendar-based chemically oriented crop protection in rice production in Suriname (and maybe in Guyana), it will be tried to find donor funding for an adult training programme for rice producers. For small scale producers, this programme could best focus on the "farmers' field school" approach. For large scale producers, the system of pest-scouting could be more appropriate under condition that the scouts are able to relate their advise also to the presence of natural enemies.

9 The role of a 100-days variety versus the current 120-day variety Eloni

9.1 Introduction

One of ADRON's breeding objectives is to develop a short duration variety (100-105 days) with at least the same yield potential as the current variety Eloni (120-125 days).

Theoretically, such a 100-day variety could have the following advantages:

- C Reduced water use
- C Correction of the cropping calendar. With two crops per year, each of 120-125 days, about 55-60 days for soil tillage are left between crops. Normally this should be enough, but due to a poor dry and wet infrastructure, it is found that 40% of the fields are sown more than 60 days after harvest (see also chapter 5). Late sown fields have a lower yield (chapter 1), but sowing a 100-days variety should result in:
 - S increased chance that the harvest of late sown fields is in the dry period.
 - S increased chance that the harvest can be followed by dry tillage with the rome-type disc ploughs.
 - S reduced exposure to pady bug through escaping high population build up (however, not to bibitfly).
 - S higher total solar radiation during the generative phase.
- C Two in instead of three urea top-dressings will be sufficient.
- C Stem boorers have less time to complete their life cycle.

A possible disadvantage is a lower potential yield than for Eloni and reduced recuperation from insect leave damage during the vegetative stage.

Other characteristics as chalkiness, head yield or resistance to blast are not typically related to growth duration.

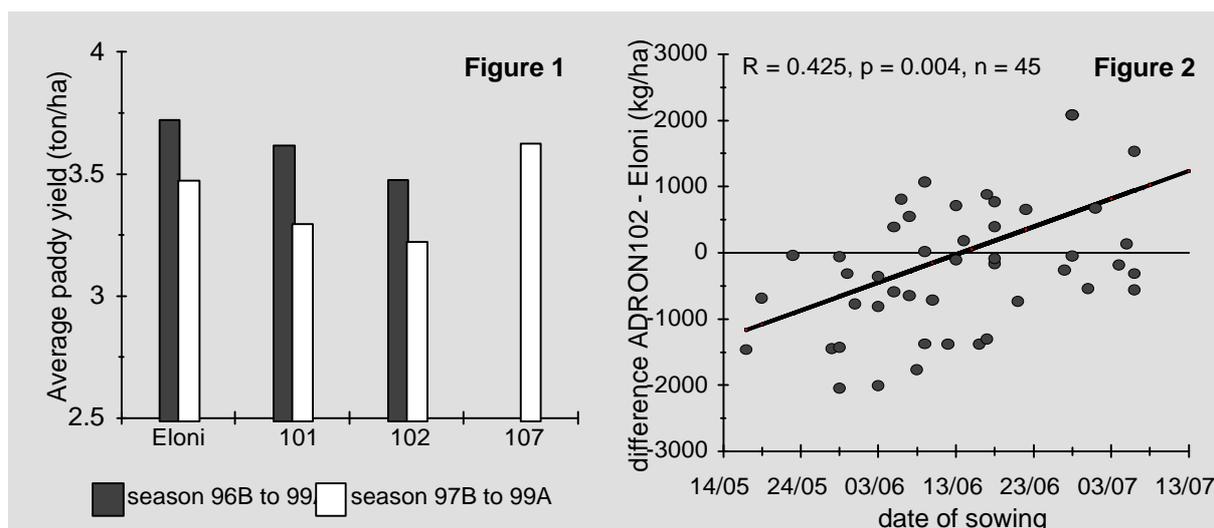
9.2 ADRON-102

Through selection ADRON came to several lines with a growth duration of 100-105 days which since 1996 are compared to Eloni in on-farm variety trials. Most often tested varieties are ADRON-101, -102 and -107, see Table 1.

Table 1: Number of harvested plots per season from on-farm variety trials.

Season	Varieties		ADRON's lines:							
	Eloni	Groveni	101	102	107	108	110	19	216	220
96B	4	4	5	4	-	-	-	3	-	4
97A	7	7	9	9	-	-	-	10	-	10
97B	11	11	14	14	12	-	-	15	14	14
98A	8	-	9	9	9	8	9	-	-	-
98B	7	-	6	7	8	8	7	-	-	-
99A	14	-	13	13	14	-	-	-	-	-
Total	51	22	56	56	43	16	16	28	14	28

The average padie yields of these varieties compared to Eloni are summarised in *Figure 1*. Yield differences with Eloni are not significant. Variation in yields across farmers fields is high. The same questionnaire used for data collection on cultural practices in the Crop Production Survey was used for the on-farm trials. From these data it could be depicted that the yield difference between ADRON-102 and Eloni was positive on late sown fields, *Figure 2*.



9.3 Profitability

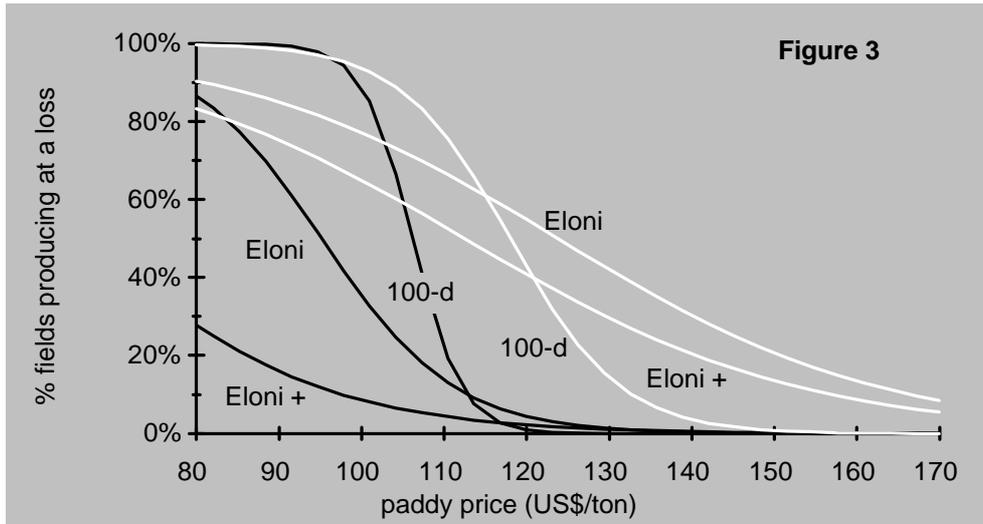
Compared to Eloni, ADRON-102 yields at best 1.5 ton/ha more on very late sown fields. On timely sown fields Eloni yields at best 1 ton/ha more than ADRON-102, *Figure 2*. Based on this relation, as well as on the relation between yields/ha and costs/ton (Figure 2, Chapter 6), an estimation can be made of the profits or losses for the entire rice area in Nickerie if all fields are sown with ADRON-102. Other estimations are 1) if Eloni is replaced by “Eloni+”, a future 120-125 days variety giving higher yields than Eloni on fields where Eloni yields > 4 tons/ha (ADRON’s second breeding objective) and 2) if Eloni is replaced by ADRON-102 only on late sown fields and replaced by Eloni+ on timely sown fields. These estimations are repeated for the condition that the infrastructure is repaired and maintained (which increases the crop index up to 1.8 and reduces the number of late sown fields), *Table 2*.

These estimations show that in any scenario Eloni+ gives higher profits than ADRON-102. Only the combination of ADRON-102 on late sown fields and Eloni+ on timely sown fields avoids losses in the current condition. The interest of a 100-day variety like ADRON-102 is therefor in the field of reducing risks to losses, rather than increasing total profitability.

Table 2: Estimated profits or losses (x US\$ 1.000.000,-) at different paddy prices, for the entire rice area in Nickerie of 50.000 ha, depending variety, infrastructure and reduced costs through minimum tillage.

Conditions	Variety	Paddy price (US\$/ton)		
		US\$ 100,-	US\$ 140,-	US\$ 175,-
Current conditions (Crop Index = 1.4)	Eloni	-4,8	7,1	17,2
	100-days variety	-3,4	8,8	19,2
	Eloni\	-2,3	11,3	22,7
	100-d & Eloni\	3	17,6	29,5
Improved infrastructure (Crop Index = 1.8)	Eloni	5,7	25,4	42,6
	100-days variety	-2	17,3	32,2
	Eloni\	19,9	45,2	65,4
Incl. Minnimum tillage	Eloni\	29,9	55,2	72,7

The effect of decreasing paddy prices on the percentage of fields producing at a loss, under current (white lines) and improved (black lines) cropping conditions, is also demonstrated by *Figure 3*.



It can be seen that under current conditions the difference in percentage of fields producing at a loss between Eloni and Eoni+ is small. If the paddy price is above US\$150,-/ton, only a small percentage of the fields is producing at a loss. If prices are dropping to US\$100,-/ton, only with improved cropping conditions and with a Eloni+ variety paddy production can stay profitable.

9.4 Conclusions and recommendations

Imperative for increasing the profitability of paddy production is the repair and maintenance of the dry and the wet infrastructure. With a Eloni+ variety profitability is then higher than with ADRON-102. Under the current cropping conditions, however, ADRON-102 can play a role in reducing the number of fields producing at a loss.

In the absence of appropriate macro-economic, agricultural, agro-industrial and export policies the effects of rice research are minimal. It puts researchers also in a dilemma: should research develop varieties and technologies that are better adapted to *unfavourable* cropping conditions than the current variety and technologies, or should research develop varieties and technologies that are out yielding the current in *improved* cropping conditions? The first option would probably mean the end of the rice export, the latter requires appropriate policies and sector organisation.

10 Weed control in field ditches and irrigation- and drainage canals

One of the main problems in the rice production in Nickerie is the poor wet infrastructure. Field ditches and irrigation- and drainage canals are most of the time full of weeds. The high costs of weed mechanical control with a drag line, ± US\$ 430/km, single bank, are the major bottleneck, reason for which research on cheaper methods are important.



An alternative is weed control with the herbicide Glyphosate. This herbicide is relatively safe and bio-degradation is fast. ADRON tested chemical control first on a small scale (see first picture). Subsequently this method was applied, in cooperation with MCP, in the Van Wouw canal (12,5 km length, 25 litres of glyphosate, both banks). The costs were around US\$15/km, single bank. More than 55 days after the application Glyphosate the canal was still completely free of weeds (see 2nd picture).



Mechanical weed control should be done twice a year, whereas chemical maintenance 3-4 times a year keeps the canals weed free. Costs per year are around US\$ 800/km and US\$ 45-60/km (single bank) respectively. At present, chemical weed control in canals and field ditches is being adopted by Public Works and farmers.