ON THE MINERAL NUTRITION OF LOWLAND RICE (*Oryza sativa*) II [1])

GO BAN HONG and J. v. SCHUYLENBORGH [2])

SUMMARY

1. Nitrates produce on acid soil, poor in iron, higher yields than NH_4-fertilizers.
2. The mineral content of paddy is higher in rice, dressed with NO_3-N, when growing on acid soil.

These facts could be discussed on the basis of fig. 1 in the introduction. The secondary effects of nitrates, viz. the physiologically alkaline reaction and the higher redox-potential in the reduced layer, are so pronounced by the setting free of fixed phosphate and the suppression of sulphide-formation, that they overcome the lower efficiency of nitrates as a N-source.

3. On neutral soils, rich in iron, NH_4-fertilizers give higher rice production than nitrates, especially when combined with liming. This could be explained by loss of nitrogen from nitrates by denitrification in the reduced layer of sawah-soil.
4. On neutral or alkaline soils NH_4-fertilizers produce paddy with a higher mineral content than nitrates do.
5. Finally a correlation was found between N/K ratio in the straw and dry matter production.

INTRODUCTION

It has been shown several times that NH_4-N-fertilizers are a better N-source for lowland rice than NO_3-N-fertilizers (a.o. PATRICK and STURGIS, 1954, 1955; MITSUI, 1955; WAHHAB and BHATTI, 1957; GO BAN HONG, 1958). This can be predicted from a scheme, represented by MITSUI (1955) and completed by the present authors.

The profile of a paddy soil in the humid tropics exists principally of four horizons (see fig. 1):

a) the water-layer;

b) an oxidized layer of a, generally, yellowish-red colour and of a thickness of a few millimeters to a few centimeters. The oxidative state is the result of the diffusion of air into the soil from the irrigation-water and from the algae growing on the soil-surface and of the excretion of air by the plant roots (rice possesses an aërenchymatic tissue in leaves and stems, through which air diffuse into the roots). Because of the oxidative state nitrification-reactions occur, lowering the pH of this horizon. Characteristics of this surface-layer are therefore its high E_h and low pH value;

c) a reduced, darker stained or greyish-red coloured horizon (frequently with an H_2S-odour) with, at the bottom, the compact plough-sole. The immediate surroundings of the roots in this layer are generally, in any case in the beginning and during the tillering phase of the growing period, oxidative as a consequence of the above mentioned diffusion of air through the stems, roots, into the soil. In the bulk of the soil, however, reduction processes take place leading to high pH-values. Iron is reduced to the ferrous, manganese to the

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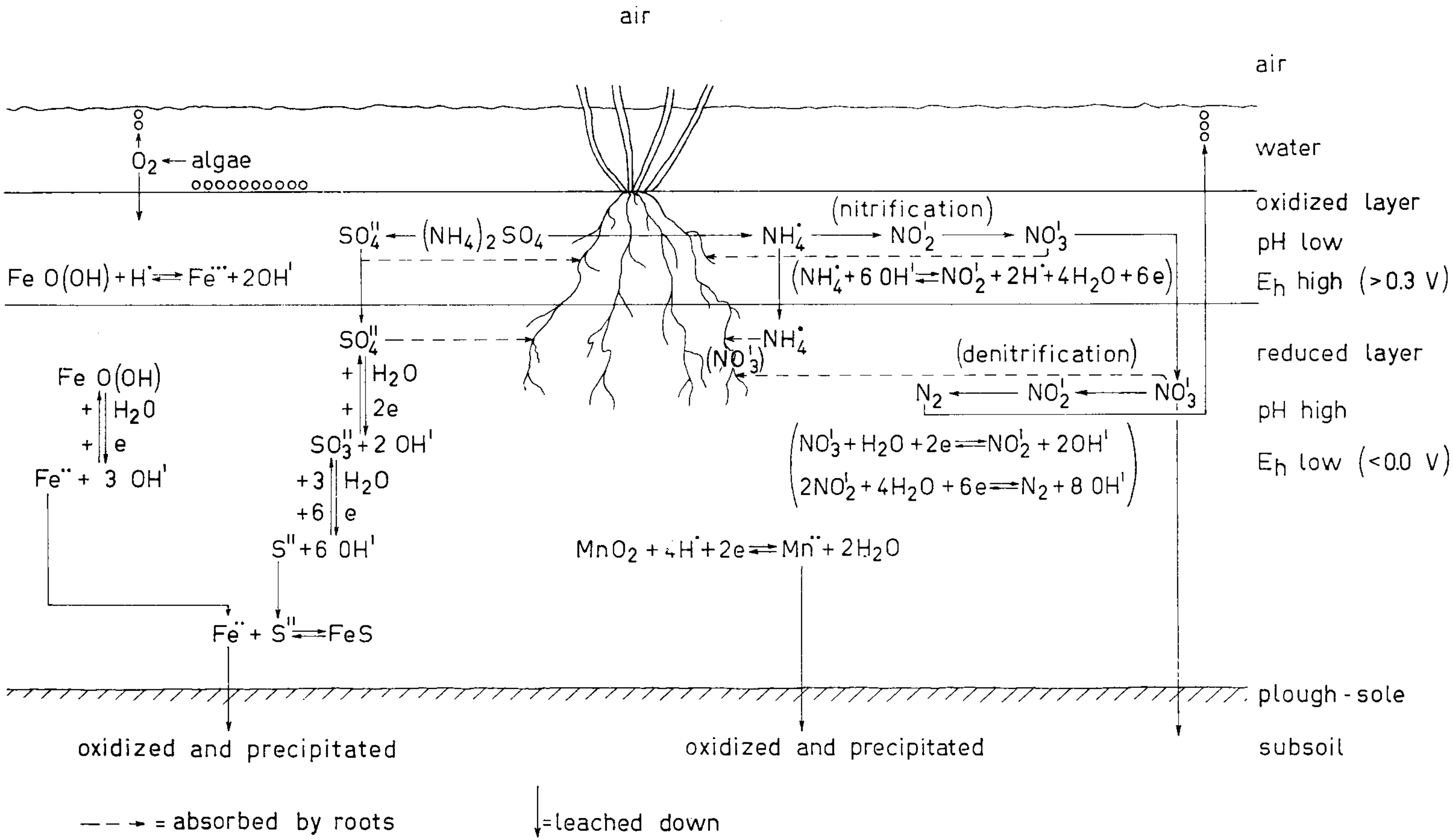

Fig. 1 Chemical processes involved in a sawah-profile.

manganous-state and SO''_4-ions to S''-ions. Ferrous ions react with the S''-ions to form FeS, that gives a greyish colour to the horizon. Characteristics of this horizon are therefore the low E_h and high pH-value, the greyish colour caused by FeS and the occurrence of H_2S;

d) the subsoil, which is generally of a black colour. This is caused by the formation of black coatings on the structural units as a result of the oxidation of ferrous- and manganous-ions, which are leached down with the irrigation-water from the reduced layer. Sometimes a concretion layer is formed here.

It will be evident that the fate of NH_4- and NO_3-fertilizers will be quite different under these conditions (see fig. 1). The NH_4-ions will be partly adsorbed by the exchange complex or directly absorbed by the plant roots. The adsorbed part is nitrified in the oxydative layer and the resulting NO'_3-ions are taken up by the roots and/or leached down into the reduction layer. Here the NO'_3-ions are absorbed by the roots or denitrified (MITSUI, 1955; ISLAM and ISLAM, 1954) and the nitrogen-gas will escape the production process. Finally the nitrate may be leached down into the subsoil, where it is of no use to the plants. If the fertilizer were applied as a nitrate, adsorption by the exchange complex cannot take place and the NO'_3-ions will be very susceptible to washing down and denitrification before taken up by the roots. The efficiency of nitrate-fertilizers is therefore generally smaller than that of NH_4-fertilizers in soils under flooded conditions.

However, there may be conditions where nitrates are more suitable than ammonium-salts. This, too, can be readily seen from fig. 1. Nitrification in the oxidized layer produces H-ions. An originally acid soil will obtain therefore extreme low pH values and this process may render some nutrients (such as PO_4, B) unavailable for the plant. Moreover SO''_4-ions leach down and are reduced to S''-ions, which form H_2S, when not sufficient free ferrous-ions are present to precipitate the harmless FeS. H_2S is a poison and affects root development strongly, especially when the root-surroundings become reductive; this condition starts when the elongation phase of the rice begins. The ever increasing diffusion path through leaves and stems retards the air transportation rate and the roots consume more oxygen than can be supplied. They die and a new root-system is developed in the thin oxidative layer and just over the interphase soil-water (GO BAN HONG, 1958). In this way a considerable soil volume is withdrawn from the production process and the new root system meets poor nutritional circumstances. Thus, acid soils poor in free iron are not very suitable for the use of NH_4-fertilizers. In such soils the physiologically alkaline nitrates may be more suitable if measures are taken to diminish the leaching process. The nitrate-fertilizer shifts the pH to higher values, so that other nutrients become more available. Moreover, $NaNO_3$ retards reduction in the reduced layer and tends to stabilize the redox-potential at 0.2–0.4 V at pH 7 (PEARSALL, 1938; AOKI, 1940; MOORE and RUCHHOFT, 1943); at this value reduction of SO''_4 to S'' does not take place, so that H_2S can do no harm to the roots.

An example of acid soils are the Red- and Yellow Podsolic Soils and especially the yellow member, a soil group, frequently encountered in the humid tropics on acid parent materials under poor drainage conditions. The soils form a topo-sequence, the red members being situated on the tops, the red-yellow ones on the slopes and the yellow members in depressions and valleys of gently rolling areas (v. SCHUYLENBORGH, 1957).

The Red- and Reddish-Brown Latosols, on the contrary, formed on less acid parent materials under conditions of free drainage in the humid tropics, are far less susceptible to the above mentioned oxidation and reduction processes because of their higher pH and free-iron levels. Here, NH_4-fertilizers will produce higher rice-yields, because nitrates are too mobile under the extreme high permeabilities of the soils. Moreover, the danger exists that nitrates render the pH-level too high, leading to a decreased availability of, especially, micronutrients.

It is the purpose of this work to see whether these theoretical considerations are correct or not. Moreover, some work was done with micronutrients.

EXPERIMENTAL

The experimental procedure was the same as described by GO BAN HONG and v. SCHUYLENBORGH (1959), where a Reddish-Brown Latosol was used. In this study the surface 20 cm horizons of a Red-Yellow Podzolic soil and a Red Latosol have been used. The K, Ca and Mg contents are extremely low, whereas the P-content is rather high (see table 1). The Fe_2O_3-content of the Red Latosol is more than thrice that of the R-Y Podzolic soil. The humus content of the latter is also extremely low.

Table 1 Some chemical and physical data of the soils as percentages of oven-dry soil.

	R–Y Podz. soil	Red Latosol
Humus	0.7	2.2
pH (H_2O)	4.3	6.3
Fe_2O_3 (total)	3.3	10.2
Sand (> 50 μ)	1.8	2.8
Silt (50–2 μ)	16.9	12.7
Clay (< 2 μ)	81.3	84.5
PO_4 } extracted with cold 25 % HCl	0.068	0.071
K } extracted with cold 25 % HCl	0.014	0.011
Ca } extracted with cold 25 % HCl	0.060	0.071
Mg } extracted with cold 25 % HCl	0.010	0.032

As rice-variety was again used "Tjina" (GO BAN HONG, 1958; GO BAN HONG and J. v. SCHUYLENBORGH, 1959).

The experiments with the R-Y Podzolic soil were undertaken in 1954 and those with the Red Latosol in 1956 and were pot-experiments in an open greenhouse. The replicates were 10 and 5, respectively. Each series received a NPK-dressing, with the nitrogen either as ammonium sulphate or as sodium nitrate. Moreover, the effects of liming, of magnesium-dressing and of micronutrients were investigated. The objects, therefore, were: 1. a) NH_4PK, b) NO_3PK; 2. a) NH_4PKCa, b) NO_3PKCa; 3. a) NH_4PKMg, b) NO_3PKMg; 4. a) $NH_4PKCaMg$, b) $NO_3PKCaMg$; 5. a) $NH_4PKCaMg$ micro, b) NO_3-$PKCaMg$ micro. For further details it be referred to table 2.

Table 2 Amounts of fertilizers per pot, if supplied.

Element or radical	R–Y Podz. soil	Red Latosol
N	460 mg as $(NH_4)_2SO_4$ or $NaNO_3$ [1])	460 mg as $(NH_4)_2SO_4$ or $NaNO_3$ [1])
PO_4	654 mg as $Ca(H_2PO_4)_2$ [2])	327 mg as H_3PO_4 [3])
K	390 mg as K_2SO_4 [4])	390 mg as K_2SO_4 [5])
Mg	25 mg as $MgSO_4$ [6])	25 mg as $MgSO_4$ [6])
Ca	580 mg as $CaCO_3$ [6])	580 mg as $CaCO_3$ [6])
Micro-nutrients	5 ml of the following solution was supplied: 1.5 mmol $MnSO_4$; 0.25 mmol $CuSO_4$; 0.25 mmol $ZnSO_4$; 10 mmol H_3BO_3; 0.25 mmol $(NH_4)_2$ MoO_4	

1) Supplied in 4 equal and one double portion at 5, 15, 20 (double portion), 35 and 55 days after transplantation.
2) Supplied in 2 equal amounts at 35 and 120 days after transplantation. Phosphoric acid was used here, because it had appeared in culture solutions that mono-calciumphosphate was an inadequate phosphorus-source.
3) Supplied in 2 equal amounts at 10 and 30 days after transplantation.
4) Supplied in 2 equal amounts at 35 and 75 days after transplantation.
5) Supplied in 2 equal amounts at 10 and 30 days after transplantation.
6) Mixed with the soil.

The following data have been collected: a) maximum number of tillers; b) number of paddy bearing tillers (expressed as percentage of the maximum number of tillers); c) number of grains; d) percentage unfilled grains; e) dry matter weight of total plant, straw, and paddy; f) N, P, K, Mg, Ca and SiO_2-contents of roots (not reported here separately), straw and paddy.

Results and discussion

The effects of the fertilizer dressings on the growth and yield of rice are represented in tables 3, 4 and 5. The results are evident: on the red-yellow podzolic soil NO_3-N gives higher yields than NH_4-N notwithstanding NO_3-N shows the tendency to decrease tillerage (tabel 3). NO_3-N seems to lower the percentage unfilled grains especially (table 4) and, therefore, to increase the number of grains. On the latosol, on the other hand, NH_4-N gives the best results; the number of paddy bearing tillers is, true, nearly the same (table 3), but the number of grains per tiller is larger (table 4).

Further it appears that the yields in the red latosol are much higher than on the red-yellow podzolic soil, undoubtly a consequence of the fact that the original N-content of the latter is higher.

The effect of liming is high, especially when NH_4-N is given. Apparently calcium carbonate neutralizes the excess hydrogen-ions, formed in the nitrification process.

Mg-dressing has no influence on yield, whereas micronutrients tends to affect yield only in those objects where yields are high (see table 3, 4 and 5; red latosol with NH_4-N-dressings). Apparently neither micro-nutrients, nor Mg are deficient in the soils, studied under the mentioned conditions. This is rather peculair for Mg, because the Mg-content of the soils, especially of the red-yellow podzolic soil, is very low.

Whether this is caused by the high Mn-content of the rice-plant (the Mn-

Table 3 Effect of fertilizers on the maximum number of tillers (a) and on the percentage of paddy bearing tillers (b).

	R–Y podz. soil				Red Latosol			
	NH_4-N-series		NO_3-N-series		NH_4-N-series		NO_3-N-series	
	a	b	a	b	a	b	a	b
1. NPK	11 ± 0.7	37 ± 4	7 ± 0.2	73 ± 3	19 ± 0.4	82 ± 6	24 ± 3.3	71 ± 10
2. NPKCa ..	12 ± 1.0	78 ± 4	8 ± 0.3	77 ± 7	18 ± 1.2	84 ± 5	18 ± 0.6	76 ± 4
3. NPKMg ..	10 ± 0.8	56 ± 7	8 ± 0.3	79 ± 4	17 ± 1.2	71 ± 7	20 ± 1.0	74 ± 5
4. NPKCaMg	11 ± 0.7	83 ± 5	9 ± 0.5	73 ± 5	19 ± 1.1	84 ± 2	17 ± 0.5	72 ± 6
5. NPKCaMg micro	12 ± 1.0	83 ± 5	8 ± 0.2	81 ± 6	16 ± 1.4	93 ± 2	20 ± 0.4	64 ± 1
mean	11	67	8	77	18	83	20	71
Check			–	–			8 ± 0.7	50 ± 14

Table 4 The effect of fertilizers on the number of grains (c) and percentage of unfilled grains (d).

	R–Y podz. soil				Red Latosol			
	NH_4-N-series		NO_3-N-series		NH_4-N-series		NO_3-N-series	
	c	d	c	d	c	d	c	d
1. NPK	61 ± 9	68 ± 10	348 ± 9	9 ± 2	717 ± 51	37 ± 9	761 ± 64	29 ± 6
2. NPKCa ..	322 ± 11	7 ± 1	436 ± 21	4 ± 0.2	1127 ± 144	13 ± 5	820 ± 64	10 ± 2
3. NPKMg ..	88 ± 12	60 ± 6	397 ± 15	6 ± 0.9	707 ± 45	39 ± 10	562 ± 122	45 ± 8
4. NPKCaMg	358 ± 17	6 ± 0.4	492 ± 21	7 ± 0.8	1003 ± 38	7 ± 1	720 ± 52	14 ± 3
5. NPKCaMg micro	326 ± 13	7 ± 2	460 ± 20	6 ± 0.7	1191 ± 51	5 ± 1	533 ± 35	14 ± 3
mean	231	29.6	427	6.4	949	20	679	22
Check			–	–			136 ± 34	82 ± 7

Table 5 The effect of fertilizers on dry matter weight of total plant and on paddy weight in grams per pot.

	R–Y podz. soil				Red Latosol			
	NH_4-N-series		NO_3-N-series		NH_4-N-series		NO_3-N-series	
	plant	paddy	plant	paddy	plant	paddy	plant	paddy
1. NPK	35.6 ± 1.8	0.8 ± 0.2	40.8 ± 1.0	7.8 ± 0.2	97.1 ± 2.1	11.8 ± 1.3	105.9 ± 2.9	14.3 ± 2.1
2. NPKCa ..	56.7 ± 1.9	7.6 ± 1.0	48.1 ± 1.2	10.4 ± 0.7	119.8 ± 4.0	27.8 ± 2.5	107.3 ± 2.6	18.8 ± 1.9
3. NPKMg ..	34.5 ± 1.7	1.1 ± 0.2	43.0 ± 1.1	9.2 ± 0.4	95.6 ± 2.7	12.3 ± 1.8	97.2 ± 7.4	8.6 ± 1.5
4. NPKCaMg	54.0 ± 0.6	8.1 ± 0.4	48.4 ± 1.1	11.2 ± 0.4	116.4 ± 3.4	24.3 ± 1.4	104.1 ± 4.1	16.0 ± 1.4
5. NPKCaMg micro	57.7 ± 0.9	7.1 ± 0.6	48.7 ± 0.9	10.8 ± 0.4	117.1 ± 2.1	29.3 ± 1.5	91.7 ± 1.8	11.9 ± 0.7
mean	47.7	4.9	45.8	9.9	109.2	21.1	101.2	13.9
Check			2.6 ± 0.1	–			46.2 ± 0.9	1.2 ± 0.4

Table 6 N, P and K contents in straw and in paddy (m.e. per 100 g dry matter) at harvest.

	Red-Yellow podzolic soil											
	NH_4-N-series						NO_3-N-series					
	straw			paddy			straw			paddy		
	N	PO_4	K	N	PO_4	K	N	PO_4	K	N	PO_4	K
1. NPK	38.5	10.0	19.7	97.1	30.6	11.0	25.7	9.7	37.2	64.3	30.6	10.0
2. NPKCa ..	35.7	8.6	21.3	86.4	32.8	10.5	25.0	11.6	30.3	65.7	32.8	11.3
3. NPKMg ..	57.1	8.1	28.5	90.0	34.1	11.0	27.1	8.8	32.6	70.0	31.9	11.3
4. NPKCaMg	36.4	8.6	22.8	91.4	32.2	10.3	25.7	10.6	32.6	69.3	33.4	12.1
5. NPKCaMg micro	37.9	7.5	21.3	93.6	36.9	11.3	27.9	8.4	30.5	80.7	35.3	11.6
mean	41.3	8.6	22.7	91.7	33.3	10.8	26.3	9.8	32.6	70.0	32.8	11.3
Check							87.1	3.7	54.4	–	–	–

	Red Latosol											
	NH_4-N-series						NO_3-N-series					
	straw			paddy			straw			paddy		
	N	PO_4	K	N	PO_4	K	N	PO_4	K	N	K	PO_4
1. NPK	45.7	6.2	15.6	86.4	18.8	11.5	32.9	7.8	10.5	75.7	28.1	12.6
2. NPKCa ..	28.6	3.8	16.7	80.7	20.0	11.0	36.4	9.7	15.1	75.0	28.1	11.5
3. NPKMg ..	47.1	5.9	16.2	92.9	20.3	10.8	40.0	10.0	12.1	80.0	27.5	11.8
4. NPKCaMg	27.9	4.1	18.0	81.4	20.3	10.5	28.6	9.1	14.1	73.6	28.8	11.5
5. NPKCaMg micro	26.4	3.8	17.7	75.7	18.8	10.5	30.0	6.6	12.1	87.1	29.4	11.0
mean	35.1	4.8	16.8	83.1	19.6	10.9	33.6	8.6	12.8	78.3	28.4	11.7
Check							75.0	6.6	17.4	90.7	17.2	10.5

content is of the order of magnitude of the PO_4-content) is a question, not studied by the authors.

The question arises, whether the better results of NO_3-N (as compared with NH_4-N) on the red-yellow podzolic soil is the result of the better utilization of NO_3-N or of secondary effects. Tables 6 and 7 show, that a) the P- and K-contents in the straw are highest in the NO_3-N-series, whereas the N-content is lower. The P- and K-contents of paddy are not influenced by the nature of the N-fertilizer; b) the amounts of P and K taken up by the crop is highest in the NO_3-N-series. The N-uptake is lower; c) liming increases the P- and K-contents in the paddy generally.

These facts support the idea, that the secondary effects of nitrates are more important in increasing rice-yields than the nature of the N-compound. The alkaline reaction of $NaNO_3$ increases the pH considerably and phosphorus is released from its fixed form; ferric and aluminium phosphates hydrolyze and phosphoric acid is set free. The higher absorption of K by the crop has been caused by the exchange of K by the Na-ions of the $NaNO_3$.

Tables 6 and 7 show further, that d) liming suppresses the N-content in the straw, but increases it in the paddy, so that the N-uptake by the crop is increased. Liming has apparently increased the lime- and phosphate-status of the soil; these factors favour nonsymbiotic N-fixation (DHAR 1954; GO BAN HONG, 1958) and, consequently, the crop has more nitrogen to its disposal under these conditions.

Table 6 and 7 finally show, that e) liming increases the uptake of Ca and SiO_2, which is quite understandable; f) liming increases Mg-uptake. This is due to the greater PO_4-absorption by liming (see a.o.: TRUOG et AL, 1947; GO BAN HONG, 1958) and h) micro-nutrients affect composition only slightly, although an indication can be observed, that the effect on nutrient uptake is significant in the NH_4-N-series.

All these facts suggest, that an NH_4-fertilizer is an unsuitable source of N also in flooded acid soils, because it renders the soil too acid and other nutrients (especially phosphate) unavailable. This is shown in table 8, where the amounts of N, P and K, absorbed from the fertilizers, are represented. The fraction absorbed from the phosphate is highest in the NO_3-N-series. Nevertheless it is evident from table 8, that more nitrogen is absorbed from NH_4-fertilizers than from nitrates.

The bad results, obtained with NH_4-N-dressing (especially without liming) is also caused, apart from the reasons already mentioned, by the production of H_2S, that injures the roots. This could be observed when inspecting the different root systems. The root-system of the NH_4-N-series on the red-yellow podzolic soil had a black colour, whereas that of the NO_3-N-series had a brown colour (Fe-hydroxyde precipitate).

The results with the red latosol are different. Tables 6 and 7 demonstrate, that a) NO_3-N causes a depression of the N-content in straw, whereas it increases the PO_4-content. It increases PO_4-content in the paddy and total phosphate-adsorption by the crop. Total N-uptake is depressed by NO_3-N. Apparently some of the nitrate has been denitrified and has escaped the production process. The higher P-absorption in the NO_3-N-series has again been caused by the greater hydrolysation of iron and aluminium phosphates; b) NO_3-N causes a depression

Table 7 Total nutrients in the crop at harvest (milligrams).

	Red-Yellow podzolic soil												Red Latosol											
	NH_4-N-series						NO_3-N-series						NH_4-N-series						NO_3-N-series					
	N	PO_4	K	Mg	Ca	SiO_2	N	PO_4	K	Mg	Ca	SiO_2	N	PO_4	K	Mg	Ca	SiO_2	N	PO_4	K	Mg	Ca	SiO_2
1. NPK	280	107	373	41	40	5250	212	162	467	32	46	6090	935	234	741	136	163	3850	714	351	740	134	217	4650
2. NPKCa ..	363	185	449	53	71	7740	255	197	479	44	66	6720	947	307	792	147	230	3880	788	402	767	134	223	4410
3. NPKMg ..	284	115	372	40	25	4850	242	173	447	41	45	6120	916	234	724	135	193	4050	706	326	720	136	177	4630
4. NPKCaMg	362	189	434	56	68	7240	266	194	519	45	71	6860	900	295	782	160	237	4150	683	374	747	143	221	4900
5. NPKCaMg micro	403	193	493	65	78	8000	297	181	511	48	64	6900	889	300	792	150	245	4290	630	285	695	132	179	4220
mean	338	158	424	51	56	6616	254	181	485	42	58	6538	917	274	766	146	214	4044	704	348	734	136	203	4562
Check							23	2	39	2	4	420							533	91	363	77	66	2650

Table 8 Efficiency of fertilizers.

	Absorbed by crop (mg)				Absorbed by check (mg)		Difference (mg)				Amounts supplied		Absorbed from fertilizer (%)			
	r-y podz.		red latosol		r-y podz.	red lat.	r-y podz.		red latosol		r-y podz.	red lat.	r-y podz.		red latosol	
	NH_4-N series	NO_3-N series	NH_4-N series	NO_3-N series			NH_4-N series	NO_3-N series	NH_4-N series	NO_3-N series			NH_4-N series	NO_3-N series	NH_4-N series	NO_3-N series
N	338	254	917	704	23	533	315	231	384	171	460	460	68.5	50.2	83.5	37.2
PO_4	158	181	274	348	2	91	156	179	183	257	654	327	25.3	27.3	56.0	78.6
K	424	485	766	734	39	363	385	446	403	371	390	390	98.8	100	100	95.1

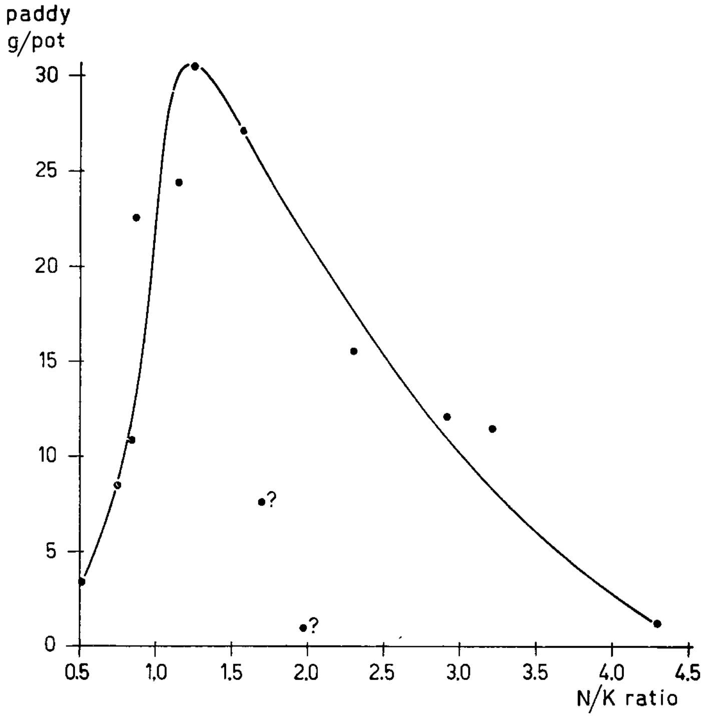

FIG. 2 YIELD OF PADDY AS AFFECTED BY N/K RATIO IN STRAW.

of the K-content in straw and increases it in the paddy, whereas total K-absorption is relatively unaffected. Apparently NO_3-N increases the mobility of potassium in the plant.

Furthermore tables 6 and 7 show, that c) liming decreases N-content of straw and paddy in both series, whereas total N-uptake is unaffected. Possibly, the already favourable conditions for non-symbiotic N-fixation were not favoured further, sothat the lower N-content is caused by the higher production of dry matter; d) liming increases K-content in straw and lowers it in paddy of both series, whereas total K-adsorption has been increased. Apparently, Ca lowers the low mobility of K in the plant as it is (GO BAN HONG and v. SCHUYLENBORGH, 1959) still further; d) on the other hand liming increases P-content in paddy and decreases it in straw. Ca seems to stimulate the high P mobility in the plant as it is; e) micronutrients do not affect nutrient-uptake in the NH_4-N-series, but decreases it considerably in the NO_3-N-series, just as dry matter production (table 5). The concentration of micronutrients seems to be too high under these conditions; f) liming increases Ca- and Mg-uptake, just as in the case of the red-yellow podzolic soil.

Finally table 9 shows that g) accumulation of N and P is favoured by nitrates on the red-yellow podzolic and is decreased by NH_4-fertilizers on the red latosol. Liming invariably favoured the accumulation of N and P in the paddy. This effect is most striking in the NH_4-N-series of the red-yellow podzolic soil. Apparently, Ca increases the mobility of nitrogen in the plant. The unefficient use of NH_4-N on acid soils is diminised by liming, although the production-level of the NO_3-N-series has not been attained.

Table 9 Distribution of nitrogen and phosphorus in the plant (percentages of the total amount absorbed).

	Red-Yellow podzolic soil												Red Latosol											
	N						PO_4						N						PO_4					
	NH_4-N-ser.			NO_3-N-ser.			NH_4-N-ser.			NO_3-N-ser.			NH_4-N-ser.			NO_3-N-ser.			NH_4-N-ser.			NO_3-N-ser.		
	root	straw	paddy	root	straw	paddy	root	straw	paddy	root	straw	paddy	root	straw	paddy	root	straw	paddy	root	straw	paddy	root	straw	paddy
1. NPK	15	83	2	14	56	30	12	84	4	7	51	42	7	78	15	7	73	20	9	65	26	6	61	33
2. NPKCa ..	14	61	23	13	52	33	9	51	40	6	43	51	9	60	31	9	67	24	9	37	54	7	54	39
3. NPKMg ..	16	81	3	12	53	35	14	78	8	5	45	50	5	79	16	7	81	12	6	63	31	7	74	19
4. NPKCaMg	14	59	27	11	51	38	9	51	40	6	37	57	9	61	30	13	65	22	9	41	50	8	56	36
5. NPKCaMg micro	12	67	21	11	51	38	9	51	40	6	32	62	10	56	34	9	69	22	9	35	56	8	56	36
mean	14.2	70.2	15.2	12.2	52.6	34.8	10.6	63.0	26.4	6.0	41.6	52.4	8.0	66.8	25.2	9.0	71.0	20.0	8.4	48.2	43.3	7.2	60.2	32.6
Check				20	80					30	70	—				8	89	3				12	81	7

In the already mentioned earlier paper (Go Ban Hong and v. Schuylenborgh, 1959) a correlation was found between the N/K ratio in the straw and dry matter production of rice. This could be stated in this work. In fig. 2 the yield of paddy is represented in dependance of the N/K ratio in the straw (the limed and unlimed objects were averaged) together with the data of the paper mentioned above. It appears, that the optimum N/K ratio is about 1.25. Lower and higher values reduce yield. Two points do not fit in the scheme. These are just the NH_4-N objects of the red-yellow podzolic soil; apparently the growth conditions are so unfavourable here, that other factors affect the yield.

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