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FERTILIZATION OF FORAGE MAIZE IN THE NETHERLANDS

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1. INTRODUCTION

Forage or silage maize has become popular and has grown rapidly in importance in the north western European countries over the past 10 to 15 years. In 1982 about 2.3 million ha was grown in France, FR Germany, UK, the Netherlands, and Belgium. In 1983 the area in the Netherlands peaked at 156,000 ha, 7 to 8% of the total agricultural area, and in this country forage maize is contributing substantially to winterfeed production.

The yields of forage maize can vary greatly from one year to the next and from one field to the other. On drought-sensitive fields yield level is especially determined by the amount of precipitation during the growth period. On fields for which the moisture supply is not limiting, however, yield level is determined by the temperature in the summer months: the higher the number of (radiant) heat units, the higher the yield. All this means that yields of forage maize in the Netherlands can vary from 9 to 17 tons of dry matter per hectare. Consequently, there can be large differences in the withdrawal of nutrients from the soil.

Forage maize is grown in the main for fodder on lighter soils on intensive livestock farms. Large amounts of animal manure are applied to the crop; maize reacts well to manure and can withstand excessive applications. Moreover, it can be grown for years on end on the same field without evident disadvantage. This is of great convenience in the management of the farm. On the other hand it makes it difficult to determine the fertilizer requirement. For nitrogen in particular and to a certain extent phosphate are only partly as readily available in animal manure as in fertilizers and these nutrients become available only gradually, either in the year of application or in the subsequent years.

2. UPTAKE OF NUTRIENTS

2.1 Extent of nutrient uptake

The withdrawal of nutrients is determined by the harvested amount of dry matter and the content therein of the nutrients concerned. Assuming an average content of 9.0% crude protein (1.44% N), 0.55% P_2O_5 and 1.80% K_2O, the withdrawal of nutrients by a crop of forage maize with a yield of 10 tons of dry matter per ha is as follows: 144 kg N, 55 kg P_2O_5 and 180 kg K_2O per hectare. For a yield of 15 tons of dry matter per ha, the corresponding figures are 216, 83 and 270 kg per ha respectively.

Uptake of nutrients, however, can vary greatly from one year to the next. This is illustrated by the results of long-term trials on drought-sensitive soils at Maarheeze, where maize was grown for nine successive years on the same plots with differing amounts of cattle slurry (Tables 1 and 19). The yields varied strongly from year to year. They were very low in the extremely dry 1976 season and also in the cool summers of 1978 and 1979.

The contents of nutrients also vary quite markedly. They increase as the level of slurry application increases, particularly for crude protein, NO_3, K_2O and P_2O_5, but hardly at all for CaO, MgO and Cu. For 1980, with a very wet spring, the levels of NO_3, K_2O, CaO and MgO were markedly lower than average. The same holds for 1981, in which year the spring was also very wet.

Quite remarkably, no upward trend can be discerned in the mineral contents over the years, not even for those elements, such as nitrogen, phosphorus and copper, for which one might expect an accumulation in the soil during the course of the trial. The same is true for the uptake figures.

2.2 Course of nutrient uptake

The course of dry matter production and nutrient uptake during the growth period can be derived from data of the long-term trial on 'enkeerd soil'[*] at Milheeze, in which the effect of an annual application of 300 tons pig slurry per ha was compared with that of the application of 200 kg N, 150 kg P_2O_5 and 250 kg K_2O per ha as fertilizer (Table 2). Only 20% of the ultimate amount of dry matter had been produced by 1 July. By then, the crop treated with fertilizer had taken up about 77% of the ultimate amount of potash, about 40% of the nitrogen and 58% of the phosphate. For the slurry-treated crop, the corresponding percentages were lower, but the absolute amounts of nutrients taken up were considerably higher. Especially in the case of the slurry, large amounts of nutrients were taken up after 1 July; this is probably due not only to the more abundant supply of nutrients but also perhaps to the fact that the root system functions for a longer period (see also Chapter 3.4).

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[*] enkeerd soil = sandy soil improved by long-term manuring with heather-sod compost

Table 1 Yields and contents of dry matter (DM), feeding value, and mineral contents (% in DM) for forage maize at increasing annual doses of cattle slurry at Maarheeze. Cultivar LG 11

Cattle slurry t ha^{-1} yr^{-1} *	Year									Average
	74	75	76	77	78	79	80	81	82	74-82
	Dry matter, ton per ha									
50	13.1	15.2	8.7	11.9	10.4	9.1	10.6	11.3	12.0	11.4
100	13.2	15.6	8.8	12.4	10.4	10.6	12.6	13.1	13.9	12.3
150	13.6	15.8	9.5	13.4	11.5	11.6	14.1	14.4	15.2	13.2
200	13.7	16.2	10.0	13.7	12.3	12.3	14.2	14.9	15.0	13.6
250	14.1	16.7	10.2	14.0	12.3	12.4	14.7	14.8	14.9	13.8
300	14.1	16.5	9.4	14.3	12.1	11.7	15.2	14.3	14.5	13.6
	DM, %									
50	26.5	32.2	33.4	32.6	33.3	38.0	34.6	39.6	36.7	34.1
100	26.1	30.8	33.1	32.0	33.0	37.3	33.0	36.6	36.4	33.1
150	26.1	30.7	32.3	31.1	32.1	36.5	31.9	36.2	34.0	32.3
200	25.9	30.5	33.0	30.7	30.2	36.6	30.3	33.7	32.6	31.5
250	25.5	30.5	32.3	31.1	30.6	35.6	30.9	33.9	33.0	31.5
300	25.7	31.0	30.8	30.7	29.5	34.9	31.3	34.7	33.0	31.3
	Crude protein, %									
50	8.5	7.6	9.9	8.2	7.5	6.8	7.3	8.3	8.6	8.1
100	8.4	7.8	10.9	8.0	7.8	7.6	8.2	8.5	8.9	8.4
150	8.3	8.2	11.1	8.0	8.0	7.6	8.7	8.7	8.9	8.6
200	8.6	8.1	11.4	8.4	8.7	8.1	8.9	10.7	9.8	9.2
250	8.7	8.2	10.4	8.8	9.2	8.4	8.9	8.6	10.0	9.0
300	8.7	8.7	12.1	8.5	9.7	9.4	8.4	8.9	10.3	9.4
	NEL, net energy for lactation in VEM units[1)]									
50	960	953	1034	1022	958	942	982	1055	982	988
100	984	934	1049	1014	950	934	1031	1039	1022	995
150	969	944	1053	1006	950	942	1047	1039	998	994
200	958	955	1022	982	942	966	1039	1031	990	987
250	958	926	966	1006	950	958	1039	1022	998	980
300	945	931	958	926	942	982	974	1006	982	961
	NO_3, %									
50	0.37	0.38	0.11	0.14	0.26	0.18	0.04	0.18	0.14	0.20
100	0.52	0.35	0.28	0.09	0.26	0.30	0.12	0.36	0.46	0.30
150	0.37	0.39	0.42	0.14	0.43	0.51	0.20	0.44	0.64	0.39
200	0.39	0.42	0.54	0.30	0.63	0.54	0.27	0.43	0.68	0.47
250	0.44	0.40	0.75	0.52	0.72	0.61	0.30	0.41	0.81	0.55
300	0.56	0.53	0.93	0.50	0.88	0.66	0.50	0.56	0.89	0.67

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1) 1 VEM = 6.9036 kJ per kg DM

Table 1

Continued from page 4

Cattle slurry t ha^{-1} yr^{-1} ★	Year									Average
	74	75	76	77	78	79	80	81	82	74-82
	K_2O, %									
50	1.61	2.02	1.51	1.54	1.71	1.99	1.60	1.38	1.76	1.68
100	1.60	2.45	1.85	1.81	2.03	2.36	1.51	1.65	1.96	1.80
150	1.70	2.52	2.02	1.98	2.32	2.54	1.60	1.84	2.38	2.10
200	1.58	2.59	2.28	2.20	2.57	2.51	1.73	1.84	2.29	2.18
250	1.93	2.62	2.95	2.10	2.60	2.57	1.69	1.80	2.55	2.30
300	2.01	2.73	3.20	2.71	2.77	2.54	2.25	2.07	2.60	2.54
	P_2O_5, %									
50	0.46	0.40	0.41	0.37	0.38	0.34	0.41	0.36	0.32	0.38
100	0.50	0.41	0.43	0.39	0.43	0.38	0.43	0.41	0.35	0.41
150	0.51	0.41	0.39	0.40	0.50	0.43	0.52	0.47	0.42	0.45
200	0.47	0.46	0.42	0.42	0.50	0.51	0.54	0.51	0.49	0.48
250	0.50	0.46	0.46	0.49	0.58	0.50	0.60	0.48	0.53	0.51
300	0.56	0.60	0.52	0.58	0.61	0.59	0.71	0.53	0.55	0.58
	CaO, %									
50	0.36	0.37	0.39	0.26	0.37	0.36	0.24	0.18	0.30	0.31
100	0.31	0.33	0.32	0.21	0.33	0.33	0.18	0.19	0.25	0.27
150	0.32	0.32	0.29	0.18	0.35	0.31	0.17	0.20	0.26	0.26
200	0.34	0.35	0.32	0.21	0.38	0.29	0.18	0.18	0.25	0.28
250	0.35	0.32	0.43	0.18	0.35	0.28	0.17	0.18	0.25	0.28
300	0.31	0.34	0.49	0.23	0.34	0.27	0.23	0.19	0.27	0.30
	MgO, %									
50	0.21	0.26	0.28	0.21	0.24	0.27	0.17	0.18	0.20	0.22
100	0.21	0.23	0.25	0.18	0.24	0.28	0.14	0.18	0.21	0.21
150	0.19	0.22	0.24	0.18	0.25	0.28	0.17	0.19	0.22	0.22
200	0.19	0.25	0.26	0.18	0.25	0.27	0.19	0.20	0.23	0.22
250	0.19	0.24	0.30	0.18	0.26	0.30	0.18	0.19	0.23	0.23
300	0.19	0.26	0.31	0.23	0.25	0.31	0.20	0.21	0.24	0.24
	Cu, mg per kg DM									
50	4.7	5.3	4.5	2.4	4.7	4.7	3.3	2.9	5.4	4.2
100	4.1	4.6	3.8	3.3	4.9	4.1	2.6	2.3	2.9	3.6
150	3.3	4.0	4.7	2.5	5.0	4.1	3.2	2.9	3.0	3.6
200	4.0	4.3	4.7	2.4	4.7	3.7	2.8	2.5	3.1	3.6
250	4.1	3.9	4.8	2.5	5.2	3.4	2.9	2.7	3.5	3.7
300	4.5	4.8	5.0	3.1	5.3	4.1	4.7	3.2	3.6	4.3

★ 50 ton: applied in April
100, 150 ton: 50 t applied in April, the remainder in February
200, 250, 300 ton: 50 t applied in April, 100 t applied in February and the remainder in the preceding December month

Table 2 Course of dry matter (DM) production and nutrient uptake from fertilizer (F) and pig slurry (S) in a long-term trial with forage maize at Milheeze. Results 1982, cultivar LG 11. According to M.P. van der Maas (9)

Date	DM, t ha^{-1}		N, kg ha^{-1}		K_2O, kg ha^{-1}		P_2O_5, kg ha^{-1}	
	F	S	F	S	F	S	F	S
26 May	0.017	0.022	0.8	1.3	0.8	1.2	0.34	0.46
1 July	3.00	3.52	84	127	179	243	33	39
12 August	10.56	12.50	116	313	232	475	48	74
17 September	13.38	15.49	201	325	201	418	56	88

Evidently maize can assimilate large amounts of nutrients in a short space of time; the uptake of potash and to a lesser extent nitrogen runs well ahead of the dry matter production. However, the ability of maize, once growth is well underway, to take up a lot of nutrients in a short time, does not alter the fact that the crop is extremely sensitive to a shortage of nutrients immediately after emergence. The young maize plant is particularly sensitive to phosphate shortage.

3. NITROGEN FERTILIZATION

The nitrogen uptake by a crop of forage maize varies from 150 to 230 kg per ha, depending on the dry matter production. This corresponds with the uptake by a crop of winter wheat with a grain yield of 6 to 10 tons per ha.

In the majority of cases forage maize is fertilized with a combination of large amounts of animal manure and nitrogen fertilizer. To what extent the animal manure has to be supplemented with fertilizer is thus a matter of practical importance. Before addressing this question, we will take a look at how silage maize reacts to fertilizer nitrogen.

3.1 Fertilizer nitrogen

The influence of nitrogen on a number of crop characteristics of importance to the feeding value is illustrated by the results of a trial with the variety LG 11 at Vredepeel in 1975.

Table 3 Influence of fertilizer nitrogen on a number of maize plant characteristics. Experiment at Vredepeel, 1975. Cultivar LG 11

N	DM	% DM		DM yield ear	DCP[1)]	NEL[2)]	N-uptake	LAI[3)]
$kg\ ha^{-1}$	$t\ ha^{-1}$	Whole plant	Ear	% of total DM	%		$kg\ ha^{-1}$	
0	12.8	27.3	49.3	45.5	3.0	977	110	3
90	16.9	27.6	49.9	50.9	4.8	1007	200	4
180	17.4	27.7	50.6	50.6	5.8	1015	242	4
270	17.0	27.3	49.9	52.0	6.0	1005	245	4

1) DCP Digestible crude protein
2) NEL Net energy for lactaction in VEM units. 1 VEM = 6.9036 kJ per kg DM
3) LAI Leaf area index

Table 3 shows that nitrogen influences, in particular, the dry matter yield, the content of digestible crude protein (DCP), nitrogen accumulation, and leaf area index (LAI). Other trials have shown that nitrogen does not affect the firmness of the crop; nor does it affect the development, as manifest by the date of flowering and the degree of ripening, at least not within the customary range of applied nitrogen levels.

The number of trials in which silage maize has been treated with only fertilizer nitrogen is limited.

Table 4 Average dry matter yields (t per ha) of forage maize in the period 1972-1982 on a very light poor sandy soil at Gortel as affected by annual applications of FYM and fertilizer nitrogen. Cultivar Capella

N	Farmyard manure, $t\ ha^{-1}\ yr^{-1}$				
$kg\ ha^{-1}$	0	50	100	150	200
0	4.7	9.6	11.6	12.3	13.0
50	6.8	11.5	12.1	12.9	13.2
100	9.1	12.0	12.6	13.4	13.2
150	9.9	12.0	12.9	12.3	13.7
200	9.6	12.2	12.8	13.1	13.5
250	10.4	12.2	13.0	13.5	13.3

A long-term trial on poor sandy soil at Gortel (Table 4) showed that, over the years, at least 150 kg N per ha was needed; even then the average yield level was short of 10 tons of dry matter per ha. Although the crop was irrigated during dry periods, this yield level is not representative for the soils on which silage maize is mostly grown in the Netherlands.

In another long-term trial on 'enkeerd soil' at Heino silage maize showed a marked reaction to fertilizer nitrogen (Table 5).

Table 5 Influence of increasing amounts of fertilizer nitrogen on dry matter yield (t per ha) of forage maize not treated with animal slurry. Experiment at Heino. Cultivar LG 11

N kg ha^{-1}	1976	1977	1978	1979*	1980	1981	1982
0	10.7	11.9	12.1	-	10.1	9.8	10.4
75	11.2	13.7	14.0	-	12.1	11.8	11.0
150	11.4	13.8	14.5	-	12.4	12.1	11.8
225	10.8	13.6	14.3	-	12.7	13.0	11.9

* In 1979 a grass crop was grown.

In several seasons maximum yield was obtained with 75 or 150 kg N per ha, but after a very wet spring as much as 225 kg N per ha was hardly sufficient. The yield level on the plots at Heino, which are more representative for the soils on which maize is usually grown, was higher than at Gortel, namely 12-13 ton of dry matter per ha.

In trials on reclaimed heath soil at Vredepeel, where as a result of irrigation yields of 17 and 16 tons per ha respectively were achieved in the warm dry summers of 1975 and 1976, at least 180 kg N per ha was required for maximum yield in both years. The optimum nitrogen level was difficult to determine concretely, as the increments in the levels of nitrogen application were relatively large (90 kg per ha).

On light sandy clay soil at Creil in the North-East Polder, where the crop rotation included temporary grassland, the highest yields in the warm summer of 1975 and 1976 were achieved with 90 and 270 kg fertilizer nitrogen per ha respectively (Table 6).

Table 6 Influence of increasing amounts of fertilizer nitrogen on the dry matter yield (t per ha) of forage maize not treated with animal slurry. Experiments at Lelystad, Creil and Vredepeel. All trials with cultivar LG 11

Location	Year	N, kg ha^{-1}			
		0	90	180	270
Lelystad	1973	11.3	13.6	14.0	13.6
	1974	15.4	16.6	16.2	16.3
	1975	8.4	11.7	13.9	14.7
	1976	10.4	14.7	15.9	16.2
Creil	1975*	14.2	16.9	15.7	15.5
	1976*	13.7	18.1	18.2	18.9
Vredepeel	1975*	12.8	16.9	17.4	17.0
	1976*	14.5	15.8	16.6	16.7

* with irrigation.

From the foregoing it may be concluded that, if no animal manure is applied, the fertilizer nitrogen requirement on most soils is 150 to 200 kg N per ha, whereby the upper limit is appropriate after or during a very wet season. In the assessment of the data in Table 6, the following should be taken into account; assuming prices of 300 Dutch florins (Dfl.) per ton of dry matter for silage maize and Dfl. 1.80 per kg fertilizer-N, the production of dry matter has to be at least 6 kg per kg N applied for the extra nitrogen application to be profitable.

Too few trials have been done in order to investigate whether there is a relationship between the requirement for fertilizer nitrogen and the content of mineral nitrogen in that part of the soil profile penetratable by the roots. For comparable yield levels under West German conditions, a fertilizer level is quoted of 240 kg N per ha minus the amount of mineral nitrogen in top one meter of the soil (2, 4). This corresponds to the requirement of a crop of winter wheat with a grain production of 8-10 ton per ha.

Application of soil sampling for mineral nitrogen is complicated in practice by the fact that animal manure is almost always applied in the spring. It has been established empirically that a reasonably reliable soil sample cannot be obtained until 6 weeks after manuring. This is some time after the sowing date, and thus too late for practical advice as to nitrogen fertilization.

3.1.1 *Splitting the application*

In very wet growth periods splitting the application of fertilizer nitrogen can reduce the risk of nitrogen losses through leaching. Supplementary applications can counteract nitrogen shortages after periods of excessive precipitation or in periods in which low temperatures are combined with poor mineralization of soil nitrogen (3). Moreover, it is concernable that, as with other crops, the nitrogen taken up is utilized more effectively in the case of split application. Trials have been done on calcareous clay (Lelystad), sandy calcareous clay (Creil) and sandy soil (Vredepeel) in which half of the nitrogen was applied about sowing time and the other half when the crop had reached a height of 40-50 cm. In general, no clear differences were found between split and non-split nitrogen application. Splitting was favourable in some cases, for instance at Creil in the very dry summer of 1976 during which irrigation was applied, but unfavourable in other cases as at Lelystad and Vredepeel in dry summers during which the crops were not irrigated (Table 7). A favourable effect of split nitrogen

Table 7 Effect of splitting the nitrogen application on the relative dry matter yields of silage maize at various locations. Experiments at Lelystad (1973-1976), Creil (1975 and 1976), and Vredepeel (1975 and 1976). In all trials cultivar LG 11

N kg ha^{-1}	Lelystad 100=15.4 t DM ha^{-1}	Creil 100=17.0 t DM ha^{-1}	Vredepeel 100=17.0 t DM ha^{-1}
0	84	82	80
0+90	93	-	96
90	95	107	96
90+90	99	103	100
180	100	100	100
180+90	101	102	98
270	102	101	99

application in a dry summer probably has to be ascribed to moisture saving: the crop is initially less heavy and hence evaporation losses are lower. In the years covered by the trials, extremely wet conditions in the period May-June did not occur.

Split nitrogen fertilization offers no advantage as a rule and is therefore not advised. Especially in combination with animal manure, split application of fertilizer nitrogen serves little purpose, since at the time of a possible second application the nitrogen in the manure begins to take effect. If, however, a wet period after fertilization has caused leaching of nitrogen a supplementary nitrogen fertilization can be given. The occurrence of substantial losses on light soils is demonstrated by the poor utilization of fertilizer nitrogen in the experiment at Gortel after the very wet spring of 1980 (Table 8). Despite a split nitrogen application utilization was 18% as opposed to the normal level of 60%. A supplementary application of nitrogen to maize was until recently hazardous in view of the likelihood of damage to the hearts of the maize plants; now, however, specially adopted fertilizer broadcasters enable safe application of supplementary nitrogen.

Table 8 Uptake of nitrogen (kg per ha) by forage maize with increasing doses of fertilizer nitrogen, at an average of 0 and 50 ton farmyard manure per ha, after a very wet spring (1980) and an 'average' spring (1981). Experiment at Gortel. Cultivar Capella

N	N uptake, kg ha^{-1}	
kg ha^{-1}	1980	1981
0	60	69
50	82	107
100	91	130
150	86	155
200	86	145
250	112	162
Precipitation (mm) in June + July	218	152

3.1.2 *Date of application*

Trials on sandy soil at Rolde (Table 9) have shown that good results are obtained with nitrogen fertilization from several weeks prior to sowing until just after sowing. Fertilization before sowing, however, is to be preferred in order to avoid damage to the seeded crop by wheelings. Moreover, the nitrogen is worked in better.

Table 9 Influence of the time of nitrogen application on the relative dry matter yields of forage maize. Experiment at Rolde, 1978-1980. Cultivar LG 11

4 weeks before sowing	100
Immediately before sowing	99
Immediately after sowing	100
Immediately after emergence	98
3 weeks after emergence	94
3 weeks after emergence, between plant rows	97

3.1.3 *Placement in the row*

Placement in the row can be considered as a special form of split nitrogen application, in which part of the nitrogen is applied as initial fertilization at a distance of several centimeters to the side of and under the seedrow and the rest is broadcasted round about sowing date or some time thereafter.

The effect of placement of nitrogen in the row was studied in trials in 1973 to 1975 at Lelystad, Creil and Rolde (Table 10). The effect of 22 kg N per ha in the row, supplemented by 158 kg N per ha broadcast, either at sowing or at a crop height of 40 cm, was compared with that of 180 kg N per ha broadcast at sowing. Delay of the major part of the nitrogen application usually led to a lower yield, except under the dry conditions at Rolde in 1974 and at Creil in 1975. This corresponds with the findings with split nitrogen application, whereby a somewhat meagre initial growth with less moisture uptake can be favourable in dry summers. Placement in the row as initial nitrogen fertilization and the rest of the nitrogen broadcast in a single application often gave better results than broadcasting the whole of the nitrogen. This was regularly confirmed in later trials (see Table 22 in Chapter 4.1).

Table 10 Influence of placement of fertilizer nitrogen in the row on the dry matter yields (t per ha) of forage maize. Experiments at various locations. In all trials cultivar LG 11

N, kg ha^{-1}		Lelystad		Creil, 1975		Rolde, 1974
At sowing *	At plant height 40 cm	1973	1974	Not irrigated	Irrigated	
180 br	0	12.8	13.8	11.3	15.8	11.8
(22 row (158 br	0	13.3	13.9	12.4	15.4	12.2
22 row	158 br	-	12.9	13.6	15.8	12.5
0	180 br	11.3	13.2	14.4	15.8	12.0

* br = broadcast; row = placement in the row

3.2 Fertilizer nitrogen together with animal manure

Besides large amounts of animal manure, fertilizer nitrogen is applied to forage maize in practice. There is, however, uncertainty as to the desired level of supplementation with fertilizer nitrogen. The amount of nitrogen available to the crop from the animal manure is determined by the amount and type of animal manure (cattle, pig or poultry slurry), the date of application, the manner of application (broadcast or injection), the weather after application, and the time-span between application and ploughing in. The quality of the slurry is also dependent on the dry matter content and on the nature and composition of the feed ration.

Half of the nitrogen in cattle and pig slurry is present in mineral form, and is thus readily available for the plant. For poultry slurry this share is 70%. As for the remaining share, the organically bound nitrogen, it is assumed that half becomes available to the crop in the year of application and the other, less easily degradable half in the subsequent years. As already mentioned, the availability to the crop of the nitrogen in the slurry is also dependent on the date of application. The earlier in the winter or the autumn the slurry is applied, the greater the risk of losses. Losses can be caused by leaching and denitrification and, in the case of surface application, by ammonia volatilization. Losses through leaching are smaller on moisture-retaining soils (deep "enkeerdgrond"; clay) than on soils which do not retain moisture well.

Estimates have been made of the extent to which the nitrogen in animal manure becomes available to the crop; these estimates, which take the nature of the slurry and the date of application into account, are based on the rate of mineralization and possible losses due to leaching and denitrification. The estimates have led to the guidelines given in Table 11 for the nitrogen (effect)ivity of animal slurry (7). For autumn application, the saving on fertilizer will be less after a wet winter and more after a dry winter than the norm given in Table 11.

Table 11 Potential savings of fertilizer, when animal manure is applied in autumn or spring, expressed as kg N, P_2O_5 and K_2O per ton of manure

Type of slurry	N		P_2O_5 *	K_2O **
	Autumn	Spring	Autumn Spring	Autumn Spring
Cattle	1.0	2.5	1.1	5.5
Pig	1.5	3.5	4.7	5.0
Poultry	2.0	6.4	5.6	5.0

* in the first year
** upon application of potash in the autumn, 10% or more can be lost depending on the type of soil and the amount of precipitation in the subsequent winter

The question is to what extent supplementary fertilization with nitrogen is necessary in the case of regular use of animal manure. The long-term trials at Maarheeze, Heino, Lelystad and Gortel can clarify this.

The trial at Maarheeze (Table 1) shows that in the first years at least 250 ton cattle slurry per ha was needed each year to achieve the maximum yield. Even after 8 to 9 years of slurry application, levels of 150 to 200 ton per ha are needed, despite the fact that the latter level is equivalent to the addition of 800 kg N per ha each year (!). One would expect the nitrogen-supplying capacity of the soil to increase gradually with regular application of high levels of animal slurry. The extent to which this occurs is evidently disappointing. We have to conclude that either the share of the less readily degradable nitrogen fraction in the supply of this element throughout the years is limited, or that this nitrogen fraction becomes available at a later stage of the growth period and thus cannot contribute to the large nitrogen requirement of the young maize plant. Due to the absence of plots with varying amounts of fertilizer nitrogen, the Maarheeze trial does not permit the most suitable combination of animal slurry and fertilizer nitrogen to be determined.

The results at Maarheeze are corroborated by the findings on the trial plots at Heino, where various amounts of cattle slurry were applied also during 9 years, be it with an intermission of one year of grass without manure after every three years of maize. Here again, 150-200 ton of slurry per ha was needed to achieve maximum yield. At a level of application of 100 ton of slurry per ha per year, at least 75 kg N per ha of fertilizer - and in wet seasons as much as 150 kg N per ha - was needed as well to achieve maximum yield (Table 12).

Table 12 Effect of fertilizer nitrogen on dry matter yields (t per ha) and dry matter content (%) of forage maize at increasing annual levels of cattle slurry. Experiment at Heino

N kg ha^{-1}	Cattle slurry, t ha^{-1} yr^{-1}							
	0		100		200		300	
	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
	1976-1978, cultivar Capella							
0	11.6	30.8	13.3	29.8	14.5	30.2	14.2	29.5
75	13.0	32.2	13.7	30.0	14.2	30.3	14.3	29.8
150	13.2	32.7	13.8	30.3	14.8	30.6	13.8	29.8
225	12.9	31.2	13.5	30.2	14.8	29.8	13.7	30.0
	1980-1982, cultivar LG 11							
0	10.1	31.7	12.6	31.6	14.5	30.8	15.4	31.2
75	11.6	33.6	13.4	32.1	15.0	31.7	15.3	31.0
150	12.1	32.9	13.6	32.1	15.8	31.2	15.1	32.0
225	12.5	34.2	14.1	31.8	15.0	31.1	15.8	32.3

On calcareous clay at Lelystad the reaction to animal slurry was less marked than on the sandy soils, but here again 150 ton cattle slurry per ha had to be supplemented with 75 kg fertilizer nitrogen per ha (Table 13).

Table 13 Influence of fertilizer nitrogen on the dry matter yields (t per ha) of forage maize at increasing annual levels of cattle slurry. Experiment on calcareous clay at Lelystad, 1976-1980. Cultivar LG 11

N kg ha^{-1}	Cattle slurry, t ha^{-1} yr^{-1}		
	0	150	300
0	11.0	13.0	13.1
75	12.3	13.5	13.3
150	13.1	13.3	13.7
225	13.0	13.8	13.4

On the light sandy soil at Gortel varying levels of farmyard manure were combined with different amounts of fertilizer nitrogen over a period of eleven successive years. At manure levels of 50, 100 and 150 ton per ha per year, an average of 100 kg fertilizer nitrogen per ha was needed to achieve maximum yield (Table 4). At this trial location, where the crop was irrigated during dry periods, the animal manure turned out to contribute more to the nitrogen supply during warm summers than during cool summers. Accordingly, the reaction to fertilizer nitrogen was smaller in warm summers than in cool summers (3).

These results show that even at levels of 100 ton per ha cattle or pig slurry per year, corresponding with 400 and 700 kg N per ha respectively, an additional 75 kg N per ha in the form of nitrogen fertilizer is still necessary. The probable explanation is that there is a need for an amount of readily available nitrogen to span the period until the roots of the young maize plant reach the ploughed in animal slurry.

The question then arises whether this nitrogen requirement can be met by placement of nitrogen in the row. To this end trials have been conducted for two years at Heino with 30 kg N per ha as NP 20-34 fertilizer placed in the row at sowing, at different levels of cattle slurry and broadcast nitrogen fertilizer. Despite high Pw-values in the soils, placement in the row gave rise to yield increases of about 1 ton of dry matter per ha. The effect of 30 kg N per ha placed in the row was about the same as, or larger than, that of 75 kg N per ha broadcast (Table 14). A further advantage of placement in the row is that one fertilization run can be omitted. Further investigation is in progress.

Table 14 Effect of placement of NP 20-34 fertilizer in the row at the rate of 30 kg N per ha on the dry matter yield (t per ha) of forage maize. Experiment at Heino in 1981-82. Cultivar LG 11

N	Cattle slurry, t ha^{-1} yr^{-1}					
kg ha^{-1}	0		100		200	
	Without NP	With NP	Without NP	With NP	Without NP	With NP
0	10.2	11.5	12.5	13.6	14.5	15.5
75	11.4	12.3	13.0	14.0	15.0	14.7
150	12.0	13.1	13.2	13.6	16.1	16.0
225	12.5	13.5	14.0	14.5	14.7	15.6

In order to prevent damage from excessive salt concentrations, one should avoid giving more than 30 kg N per ha in the row. Preference should be given to an NP-fertilizer with a nitrogen content as high as possible, since a high level of phosphate application is superfluous when fertilization is combined with manuring.

Furthermore, ammonium-containing fertilizers should not be used for placement in the row on calcareous soils, as there is a risk of damage to the roots by the ammonia released (1).

3.3 Specific organic matter effect of animal manure

The long-term trials discussed above show that maize not only tolerates large quantities of animal manure but also reacts very favourably to it. The more animal manure given per year, the higher the yield level. At Maarheeze an average over the nine years of 200-250 ton per ha of cattle slurry was needed for optimum yield, whereas calculations based on the level of nutrients in the slurry indicate that a level of 100 ton per ha should be more than adequate. Furthermore, the trials at Heino and Gortel (Table 15) show that the yields attainable with just basic P and K, and fertilizer nitrogen are not as high as those with large quantities of animal manure. The differences in yield with and without organic manure cannot, however, be wholly ascribed to a 'specific organics effect' or residual effect. For soil and crop analyses on the trial plots at Heino and Gortel showed that, if no animal manure was applied, the basic P and K application was insufficient to prevent deterioration of the P- and K-status in the soil. But upon annual application of 100 ton per ha animal slurry or 50 ton per ha farmyard manure supplemented with increasing amounts of fertilizer nitrogen, with which large amounts of P and K are also supplied, the maize yields attainable were not as high as those obtained with higher levels of animal manure. This suggests that the yield difference with and without organic manure can at least partially be ascribed to the organic matter. Regular application of animal manure markedly increases the content of organic matter in the soil (Table 16). This improves the moisture-retaining capacity of the soil (Table 17); on light soils, which usually demonstrate a shortage of moisture for shorter or longer periods during the growth season, this can help to limit yield losses due to moisture deficiency. This possible explanation is supported by the observation that such an 'organic matter effect' was only weakly apparent on the moisture-retaining clay at Lelystad.

Table 15 Average dry matter yields (t per ha) of forage maize at the highest dosages of fertilizer nitrogen for various annual levels of animal manure. Experiments at Gortel with farmyard manure, 1972-1982; at Heino with cattle slurry

Animal manure ton ha^{-1}yr^{-1}	Fertilizer N, kg ha^{-1}		
	250 Gortel 1972-1982	200 Heino 1976-1978	200 Heino 1980-1982
0	10.4	13.0	12.3
100	13.0	13.7	13.9
200	13.3	14.8	15.4

Table 16 Effect of 11 annual applications of farmyard manure (FYM) on the organic matter content in the plough layer (0-20 cm deep) of the soil at Gortel

FYM, t ha^{-1} yr^{-1}	Organic matter, %
0	4.4
50	5.2
100	5.5
150	6.2
200	6.8

In addition it is being recorded more and more often that the nematode population of the soil is lower in the case of regular manuring with animal slurry than when only fertilizer is applied. It has also been noticed that browning of the roots (due to mould infection) is delayed with animal slurry. Browning might affect the yield level under stress conditions. Application of large amounts of animal slurry, particularly when combined with superficial

Table 17 Moisture content (%) in the plough layer of the soil (0-20 cm deep) at various soil-moisture tensions, both upon application of fertilizer only and upon manuring. Experiment at Milheeze. According to van der Maas (8)

Fertilization	Soil moisture tension (pF)		
	2	3	4.2
Fertilizer only	11.9	8.8	4.2
Animal slurry	17.3	10.2	5.7

Table 18 Carbon dioxide content (vol % CO_2) of soil air at various depths, upon application of fertilizer or animal slurry. Experiment at Milheeze. According to van der Maas (8)

Fertilization	Depth below soil surface, cm	Days after sowing			
		16	37	61	76
Fertilizer	10	0.2	0.3	4.4	0.4
	15	0.2	0.3	4.8	0.7
Animal slurry	10	0.1	0.2	2.5	0.2
	15	3.5	3.8	10.5	2.1

compaction, can lead to 'silage effects'. As a result, high concentrations of CO_2 can occur in the layers under the plough layer (Table 18), which in turn can cause hydrogen sulphide formation and damage to the crop, especially during warm, humid weather. Moreover, losses due to denitrification readily occur under such conditions.

3.4 Effect of fertilization on feeding value and mineral composition

The influence of fertilizer nitrogen and animal slurry on feeding value and mineral composition can be illustrated by the results of, amongst others, the long-term trials at Heino, Lelystad and Maarheeze (see for example Table 1).

Percentage dry matter is reduced hardly at all by fertilizer nitrogen and only slightly by high levels of animal manure. Crude protein content is increased slightly both by fertilizer nitrogen and by high levels of slurry. The parameter Net Energy for Lactation (NEL) per kg dry matter was not influenced by animal slurry on the clay soil at Lelystad but was lowered on sandy soil, while fertilizer nitrogen had no effect on this parameter. The differences in feeding value, however, are very small, especially when the large differences in the level of fertilization are taken into account.

Of the mineral components the levels of K_2O, P_2O_5 and NO_3 in particular increase as more slurry is applied, while the CaO content remains the same (Maarheeze) or decreases slightly (Heino); the MgO content is hardly influenced by fertilization.

Contents of P_2O_5 and, of course, NO_3 are increased by fertilizer nitrogen. Although levels of potash and nitrate are increased by heavy applications of slurry, the increases - about 2% for K_2O and 0.5% for NO_3 at a level of 200 ton cattle slurry per ha - give no cause for alarm as to the quality of the maize.

All in all, feeding value and mineral composition of maize are influenced little by extreme differences in fertilization. In this respect, maize is an exception when compared with crops such as potato, sugar beet, and grass. High levels of animal slurry have a favourable rather than a unfavourable influence in the yield and quality of forage maize. The picture becomes quite different, however, if we look at the balance between supply and uptake of nutrients by the crop at high levels of slurry application.

3.5 Supply and uptake of nutrients at high manure levels

Just how large the supply of nutrients can be with animal manure is illustrated by data derived from the long-term trial at Maarheeze (Table 1). If we compare these data with those for the average annual uptake of nutrients, also derived from the Maarheeze trial (Table 19), we see that, for levels of application of 100 ton cattle slurry per ha and more, supply is much greater than uptake. Frequent heavy applications of animal manure therefore cause enrichment of the soil and losses of nutrients (5,7).

Table 19 Average supply of nutrients and their uptake by forage maize (in kg per ha per year) at various cattle slurry levels. Experiment at Maarheeze, 1980-1982

Nutrient	Supply			Uptake		
	Slurry level, t ha^{-1} yr^{-1}			Slurry level, t ha^{-1} yr^{-1}		
	50	100	200	50	100	200
N	240	280	965	146	180	231
N (water soluble)	120	240	485	-	-	-
P_2O_5	100	200	495	41	52	76
K_2O	270	540	1035	179	226	288
CaO	120	225	425	27	28	30
MgO	60	115	240	21	24	30
Na_2O	55	110	220	2	3	3
Cu	0.27	0.56	1.16	0.044	0.035	0.041
B	0.23	0.49	1.01	-	-	-

The losses of nitrogen are partially due to volatilization of ammonia when the manure is applied. The majority, however, is caused by leaching of nitrogen; the higher the level of manure application and the greater the excess precipitation in the winter, the greater the extent of leaching (Table 20).

Application of 100 ton cattle slurry per ha supplies about 480 kg N per ha. Average uptake by maize amounts to 180 kg N per ha. Table 20 shows that the losses are about 190 kg N per ha (9). The remaining 110 kg N per ha must be ascribed to volatilization of ammonia when the manure is applied and nitrogen volatilization as a result of denitrification. In addition, nitrogen enrichment of the soil occurs. According to the analyses this enrichment

Table 20 Annual leaching of nitrogen (kg N per ha) to the groundwater on plots treated with different levels of cattle slurry. Experiment at Maarheeze. One ton of slurry contains 4.8 kg N. According to Steenvoorden and Oosterom (9)

Year	Precipitation surplus ★	Cattle slurry level, t ha^{-1} yr^{-1}					
	mm	50	100	150	200	250	300
1977/1978	306	150	156	239	257	435	340
1978/1979	240	115	98	170	178	274	348
1979/1980	310	133	154	164	304	410	444
1980/1981	385	150	308	347	554	524	642
1981/1982	356	204	236	353	466	499	510
Average 77-82	320	148	190	255	352	428	457
Average level of leaching (kg N per ton cattle slurry)		-	1.9	1.7	1.76	1.71	1.52

★ Precipitation (mm) - Evaporation (mm)

Table 21 Change in the chemical composition of the soil upon long-term application of increasingly high levels of animal slurry (t per ha per year) at Maarheeze (1973-1982) and Heino (1971-1980)

Layer	Maarheeze				Heino			
cm	1973	1982			1971	1980		
		50	100	200		50	100	200
	Organic matter, %							
0-20	2.8	3.2	3.1	3.6	4.2	4.8	4.9	5.0
20-40	-	2.2	2.3	2.7	-	4.9	4.9	5.1
40-60	-	2.3	2.2	2.5	-	4.7	4.6	4.8
	pH-KCL							
0-20	4.9	4.3	4.3	4.4	4.3★	3.9	4.0	4.0
20-40	-	4.7	4.6	4.5	-	4.2	3.9	4.0
40-60	-	4.7	4.6	4.5	-	3.9	3.9	3.9
	K-content, mg per 100 g air dry soil							
0-20	11	10	13	20	11	5	9	16
20-40	-	5	11	14	-	3	8	20
40-60	-	5	8	12	-	2	5	11
	Pw-value, mg per l soil							
0-20	56	80	100	132	69	78	87	118
20-40	-	17	28	38	-	38	36	59
40-60	-	3	4	3	-	8	8	11

★ 1975

amounts to 200 kg N per ha in the plough layer over a period of 10 years, or in other words, about 20 kg N per ha per year.

Measurements by Steenvoorden and Oosterom (9) have shown that the nitrate content in the groundwater in the layer 1.5 to 2 metres below the soil surface increases markedly with increasing application of animal slurry.

Excess phosphate accumulates in the soil, provided there is no run-off (Table 21). Except on young reclaimed-peat soils, no leaching of phosphate is generally observed. At high levels of phosphate application, however, the saturation point for phosphate can be exceeded and loss of phosphate through leaching may occur.

Although animal slurry supplies a lot of potash, deficiencies can still occur at slurry levels of 50 ton per ha; potash deficiency manifests itself by a gradual reduction of the potassium content of the soil, as was noted both at Heino and Maarheeze. Maize can take up a lot of potash, while on light soils losses due to leaching can occur as well. At higher levels of slurry application, however, not only the plough layer but also the deeper layers of the soil are steadily enriched with potash.

The foregoing demonstrates that dumping of animal slurry leads to wastage of plant nutrients and may lead to high nitrate levels in the groundwater, while there is a possibility of the phosphate-assimilating capacity of the soil being exceeded. With pig slurry there is the added danger of excessive copper accumulation in the soil.

3.6 Improving the efficiency of animal manure

On the basis of the above it can be expected that unrestricted use of animal slurry will be legally restricted. Research is now underway to determine how the utilization of animal slurry can be improved.

Possible approaches are the application of less abundant quantities of manure, application in the spring rather than autumn and winter, and application between rows after emergence of the crop, followed by working in by means of rotary tillage or injection.
In addition, experiments are being conducted with nitrification-inhibitors, with the aim of checking the conversion of ammonium-nitrogen into the more easily leached nitrate form and thus enabling the date of application to be brought forward without an increase in nitrogen losses due to leaching.

4. FERTILIZATION WITH OTHER NUTRIENTS

4.1 Phosphate

On the subject of phosphate fertilization, Arnold and Ten Hag (1) have recenty published a review, which we will draw upon in this chapter.

As Table 1 shows, the phosphate content of maize and, with it, the uptake by the crop can vary quite markedly, depending on the supply of phosphate. Variation in leaf and stalk is larger than in the maize ear. A good crop of forage maize contains between 60 and 100 kg P_2O_5 per ha.

As already mentioned young maize plants react very strongly to phosphate; root development is rather poor while their phosphate requirement is large. Maize therefore reacts favourably to placement in the row whereby the phosphate is brought within direct reach of the roots of the young plants. In the early stages of plant development there is a big difference between the reaction to placement of phosphate in the row and that to broadcast phosphate. Placement in the row advances the date of female flowering and promotes ripening; the crop reaches a given dry matter content sooner. The initial, large differences between the effects of band placement and broadcasting usually level off somewhat during the growth period. For placement in the row to be effective the fertilizer has to be applied sufficiently deep (4 cm) and at a distance of about 5 cm from the seedrow. Particular attention should be paid to this during adjustment of the machine and during sowing. The fertilizer should be a water-soluble phosphate, either a superphosphate or an NP-fertilizer.

To establish the effect of placement in the row trials have been carried out over a number of years, at different locations, on different soils, and for varying phosphate contents of the soil. An example of the effect of broadcast phosphate and phosphate in the row on the development, maturing, yield and feeding value of forage maize is given in Table 22.

Table 22 Influence of placement of phosphate in the row on the growth, dry matter yield, dry matter content, and feeding value of forage maize at Vredepeel in 1977/1978, Pw-values of the soil 51 and 29 in 1977 and 1978 respectively

Treatment	P_2O_5 kg ha^{-1}	Vigour score (June)	Relative DM yield2)	Dry matter %	Ear content % on dry matter basis	DCP3) %	NEL4)	Relative NEL yield5)
Broadcast	0	4	96	26.9	47	6.3	974	96
triple	40	4.5	97	27.5	46	6.3	969	97
superphosphate	80	5.5	100	28.5	47	6.4	974	100
	160	5.5	100	28.4	49	6.4	976	100
Triple	40	6.5	102	29.6	51	6.6	981	103
superphosphate in the row	80	7.5	104	30.7	52	6.5	989	106
NP	40	7	106	31.1	52	6.4	984	107
in the row1)	80	8	107	30.8	51	6.3	982	108

1) Average of mono- and diammonium phosphate; 2) 100 = 12.9 ton per ha; 3) Digestible Crude Protein; 4) Net Energy for Lactation in VEM units, 1 VEM = 6.9036 kJ per kg DM;
5) 100 = 12.6 kVEM per ha

The table shows that phosphate fertilization, particularly in the row, results in a higher dry matter content, a higher dry matter yield and a higher feeding value (expressed as Net Energy for Lactation). There are large differences in the reaction to P-fertilization from trial to trial and from season to season. The effect is generally apparent in an unfavourablé growth season, especially after a cold spring. It seems that the conditions during growth are more important than the phosphate content of the soil in determining the effect of phosphate fertilization.

A review of the results of trials with placement of phosphate in the row is given in Table 23.

Table 23 Influence of placement in the row of different types of phosphate fertilizer on the relative dry matter yield of forage maize. Yield level with broadcast phosphate fertilization is taken as 100. TSP = Triple superphosphate; MAP = Mono-ammonium phosphate; DAP = Di-ammonium phosphate

Year and location	Soil type ***	Pw-value	Control (no phosphate)	Broadcast TSP	Placement in the row				100=dry matter yield ton ha^{-1}
					TSP	MAP 11-52	DAP 18-48	NP 20-34	
1975									
Lelystad*	CC	7	97	100	99	100			14.6
Nijverdal*	S	80	101	100	100	103			15.7
1976									
Lelystad*	CC	17	100	100	98		101		16.2
Nijverdal*	S	50	103	100	97		103		11.8
1977									
Lelystad	CC	15		100	101	98	99	99	14.0
Vredepeel	S	51	99	100	106	106	109		11.8
Nijverdal	S	80	97	100	102	101	100		11.6
Giethoorn	HS	16**	93	100	116	111	111		10.0
1978									
Creil	CC	23	101	100	107	108	105		14.6
Vredepeel	S	29	94	100	103	108	107		14.1
Nijverdal	S	40	102	100	111	119	124		10.1
Rolde *	S	30		100	105	104	103	102	12.4
1979									
Rolde*	S	30		100	106	110	106	108	12.4

* 100 kg P_2O_5 per ha, in all other cases 80 kg P_2O_5 per ha

** 80 kg P_2O_5 per ha as TSP broadcast as basic application over the complete trial area

*** CC = calcareous clay; S = sand; HS = sandy soil with high organic matter content

In some trials there were no differences between the effects of P and NP fertilizers, whereas in the trials at Vredepeel NP fertilizers were found to be more effective. On calcareous soils superphosphate is to be preferred to ammonium phosphate. On these soils the roots of young plants can be damaged by the ammonia released, as a result of which growth can be seriously retarded. This effect was recorded in a trial at Creil in 1978 and on a large number of fields in the North-East Polder in 1981.

Many maize fields receive frequent, heavy applications of animal slurry, as a result of which the Pw-values of the soil can rise markedly. In the trials, however, favourable effects of placement in the row have been observed at Pw-values up to 100. Therefore, even at rather high or high Pw-values, placement of 30-40 kg P_2O_5 per ha in the row is recommended; for soils with normal or low phosphate status, 70-90 kg P_2O_5 per ha in the row is needed.

4.2 Potash

Maize has a low potash requirement, which implies that only low levels of application are needed for optimal yield. These amounts are indicated in the official fertilizer guidelines. Conventionally manured maize contains about 1.8% K_2O on a dry matter basis. This means that at dry matter yields of 10 ton per ha and 15 ton per ha, amounts of 180 kg and 270 kg K_2O per ha respectively are withdrawn from the soil. At high maize yields, uptake of potash can be as high as 300 kg per ha.

If a given situation in the soil is to be maintained, the fertilization should be attuned to the uptake and to the losses through leaching. The latter losses depend on soil-type, date of fertilization, and climate. Although maize has a relatively low potash demand, it seems that uptake is not always compensated, especially when maize culture predominates. Even in regions with manure surplusses there are maize fields showing potash deficiency. Frequent soil sampling is therefore called for.

4.3 Lime

The optimal pH for maize, and the yield reductions for non-optimal pH values, are shown in Table 24 for sandy soil. On this type of soil the optimal pH-KCl for maize is about 5.0.

Table 24 Relative yields of forage maize on sandy soil as a function of the pH

pH-KCl	Relative yield, %
4.4	96.0
4.8	99.5
5.2	100.0
5.6	96.5
6.0	88.0

No data are available for clay soil. In this case a higher pH is often required for optimum structure and cultivatability of the soil. If on sandy soil maize is not grown each year, the pH to be aimed at depends on the other crops in the rotation. In a rotation with sugar beet, for example, the desired pH-KCl is 5.7.

If lime is ploughed in, it will have little effect on the yield of the following crop. At very low pH values lime must be spread both before and after ploughing. Liming is best done in the autumn.

4.4 Magnesium

At harvest about 25 kg MgO per ha is removed with forage maize; in addition, some magnesium can be lost as a result of leaching. Annual application of 50 ton slurry per ha is more than adequate to replenish the magnesium supply (Tables 1 and 19).

4.5 Boron

Lack of boron adversely influences both grain setting and grain filling. Other circumstances, such as drought and shortage of nitrogen, have a similar effect, so the defects observed are not necessarily due to boron deficiency.

Low boron contents occur only in sandy soils. Since organic manure supplies this element (ca 5 g per ton of manure), extra boron fertilization is seldom necessary. Since too much boron can damage the crop, its application is recommended only when soil analysis has shown this to be necessary. In such a case, boron fertilizer can be sprayed. Furthermore, to prevent damage, care must be taken to ensure the fertilizer is spread evenly when applied in solid form.

4.6 Zinc

A factor-analysis study in the Twente region in 1981 has shown that zinc deficiency can cause yield suppression. Such an effect was not found in 1982. A shortage of zinc in the plant can be caused or aggrevated by a high phosphate status of the soil or by heavy phosphate fertilization. Zinc is replenished by organic manure; at a level of 50-60 ton of cattle slurry per ha, the supply of zinc is higher than the uptake. More zinc is supplied with pig slurry than with cattle slurry. Investigations are in progress into the cause of zinc deficiency in the plant and into possible means of correcting or preventing the deficiency.

5. CONCLUDING REMARKS

As forage maize is grown on intensive livestock farms, large amounts of animal manure are given to the crop. The amounts of nutrients thus supplied are in most cases greater than the amounts taken up by the crop. The uptake of nutrients can vary greatly from year to year and from field to field, depending on the weather (temperature and precipitation).

Owing to the limited development of the root system of the young maize plant, the crop reacts favourably to placement in the row of nitrogen and, especially, phosphate, even at a high soil phosphate status. This probably also explains why supplementary nitrogen and phosphate fertilization is required even with heavy doses of animal manure.

Whether, besides 50-100 ton of animal slurry per ha, an additional nitrogen dose of 30 kg N per ha placed in the row is sufficient or whether a higher, broadcast dose of at least 75 kg per ha N is required, is the subject of current research. Larger supplements of nitrogen are certainly necessary in wet seasons.

Although the results on trial plots show that maize reacts favourably to high levels of animal manure, such levels result in wastage of nutrients with the risk of increasing the nitrate content of the groundwater. Research into improvement of the efficiency of (limited amounts of) animal slurry by application in the spring, injection between the seedrows, and/or use of nitrification-inhibitors is in progress.

Potassium uptake at high maize yields is underestimated in practice, as additional losses of K due to leaching have to be taken into account. Frequent soil sampling is therefore called for on fields of forage maize. High phosphate contents in the soil can cause zinc deficiency, a phenomenon which also deserves to be followed carefully.

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