Effect of rate of application of organic and inorganic nitrogen on crop production and quality

L.C.N. DE LA LANDE CREMER
Institute for Soil Fertility, Haren (Gr.), The Netherlands

1. INTRODUCTION

The consumption of concentrated feeds by Dutch cattle operations has increased strongly since 1950. Furthermore, on the mixed farms in the sandy areas of The Netherlands considerable expansion and concentration took place of housed livestock enterprises which are not dependent on land (pigs, poultry, feeder cattle, etc.). This results in a situation in which more nutrients are produced in manure than can be utilized by crops grown on or around these enterprises. There is a surplus of manure which must be removed from these farms and areas on the basis of agricultural and ecological considerations.

During the same period new systems were developed for manure collection and storage. Mixed storage as slurry, being cheaper and requiring less labour, replaced separate storage of solid and liquid fractions. However, an important disadvantage of the slurry system is its bulkiness resulting from uncontrolled dilution with water (drinking water, wash-water, precipitation). Slurry is therefore, per unit of volume, less valuable than solid manure, which in turn means that slurry can only be economically utilized within short distances from the site of its production. This makes disposal of surpluses difficult and can lead to excess applications on available land. Some consequences of excess rates of manure application on yield and quality of field crops will be discussed below.

2. NITROGEN IN ORGANIC MANURE

In terms of permissible amounts of manure, nitrogen is by far the most common factor that limits yield and quality of field crops.

In organic manure, nitrogen is present both in inorganic and organic form. The former is immediately available to the crop, the latter must first be mineralized. About 50% of the organic fraction can be expected to be mineralized already in the year of application (Sluijsmans and Kolenbrander, 1976). The other, more difficultly decomposable half will be transformed in the course of subsequent years. Thus, organic manures usually have a greater or lesser residual effect (Table 1).

TABLE 1. Residual effect on winter wheat, unfertilized in 1974, of cattle and poultry slurry applied in the autumn of 1972.

Type of manure	Quantity, autumn '72, t/ha	Additional yield as %-age of unmanured
Cattle slurry	50	13
	100	25
	150	27
Poultry slurry	20	15
	40	23
	60	37

Preceding crop in 1973 : potatoes
Soil type : clay, 55% particles <16 μm
Grain yield, unfertilized : 5768 kg/ha for cattle slurry
5545 kg/ha for poultry slurry

When organic manures are used only once every 3 or 4 years on the same field, their residual effect is usually not taken into account. However, where surpluses exist large amounts of organic manure will be used annually on the same field; a store of nitrogen will be built up in the soil which will gradually become available to the crop. If it is not taken up, it will be lost by leaching. The residual effects will increase until an equilibrium has been reached between N-input via manure and output through uptake by crops and losses. If these residual effects are ignored, one may be faced with undesirable effects of excessive nitrogen levels on yield and quality of crops and/or losses to the environment. In cereals, too high a level will become evident first in the form of an increasing sensitivity to lodging. In root crops, yield reductions as well as quality deterioration may be the result. The nitrate content of fodder crops may become undesirable high for cattle.

Table 2 shows the accumalation of available nitrogen in the profile of a sandy soil following application of different amounts of cattle slurry to maize during three years.

TABLE 2. Amounts of residual plant-available nitrogen in a sandy soil (0-80 cm) in kg/ha following application of different amounts of cattle slurry on maize

	Amount of cattle slurry, t/ha.yr		
	50	200	300
9-10-1973	117	186	240
31-10-1974	167	269	352

The amounts of available nitrogen shown above were found in the soil after the maize had been harvested in the autumn! A part of this nitrogen may remain in the soil for utilization by crops in the following year, but, depending on weather conditions, another important part may be lost to the environment during winter.

3. EFFECT OF ANIMAL MANURES AND FERTILIZERS ON SOME QUALITY CHARACTERISTICS OF POTATOES

The underwater weight (u.w.w.) of a given quantity (here 5 kg) of potatoes is a measure of the specific gravity, which in turn is correlated with dry-matter and starch content. The u.w.w. is especially important to growers of industrial starch potatoes, who are paid on the basis of u.w.w. Figure 1 shows the effect of application of fertilizer nitrogen, nitrogen contained in cattle slurry and poultry slurry, and combinations of inorganic and organic

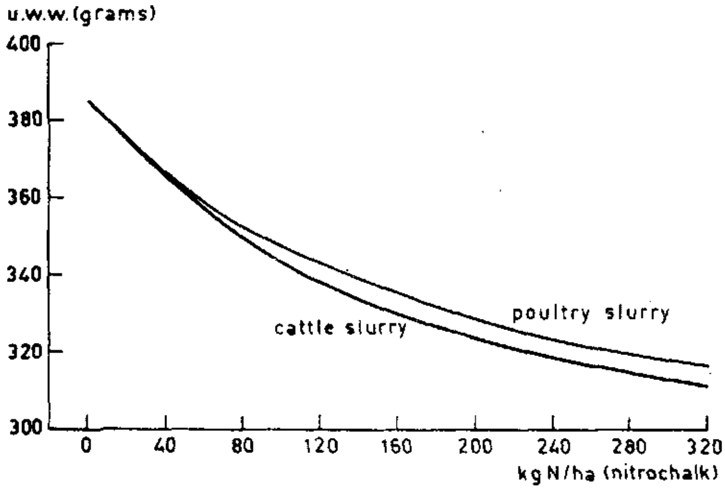

Fig. 1. Effect of applications of nitrogen, cattle slurry and poultry slurry on underwater weight (u.w.w.) of 5 kg ware potatoes, var. Bintje, 1973.

nitrogen on the underwater weight of ware potatoes grown on a clay soil containing 55% particles <16 μm. The amounts of inorganic nitrogen ranged from 0 to 200 kg per ha, of poultry slurry from 0 to 60 tons per ha, and of cattle slurry from 0 to 160 tons per ha. The organic manure was applied in the preceding autumn.

A very close correlation was found, regardless of the N-source; therefore no separate data points are shown in the figure. There is a slight difference between the two types of organic manure with respect to their effect on the u.w.w.

In that experimental year (1973) no investigation was yet made of the amount of plant-available (= nitrate) nitrogen present in the profile. Hence no relation can be shown here between the amount of soil nitrogen added to the fertilizer applied and yield of potatoes. A number of other experiments clearly demonstrates the presence of such a relationship (figure 2). In 1973, for instance, it was apparent that on a loam soil (29% particles <16 µm) a total of about 280 to 300 kg available soil-N plus fertilizer-N was needed

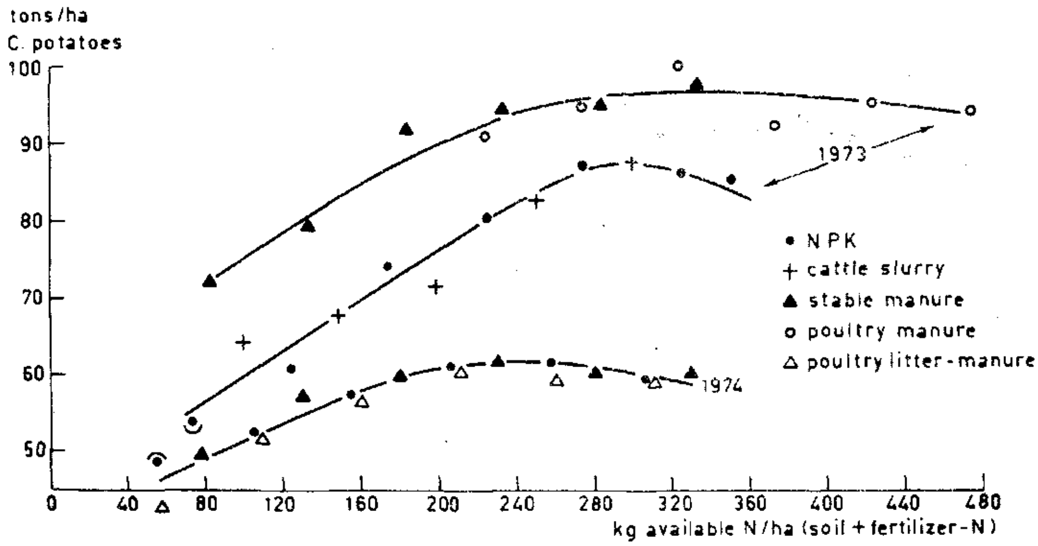

Fig. 2. Relationship between available nitrogen in soil (0-60 cm) in spring plus fertilizer-N and the yield of ware potatoes in 1973, and 1974. Loam soil (29% particles <16 µm)

to obtain the maximum yield. In 1974, on a similar soil, at a lower yield level, 220 kg sufficed. Furthermore, in 1973 the yield level was lower for fertilizer and cattle slurry than for farmyard manure and poultry slurry, while the amount of available soil-N present in spring was the same. Thus, although a clear relation exists, it is not yet possible to predict with certainty how much available nitrogen is needed in a given year to obtain maximum production.

It should be noted that the peak of the yield curve for the lower level is so broad, that a few dozen kilograms of nitrogen in excess of need would only cause a limited reduction in yield (figure 2). However, the dry-matter and starch contents would be distinctly reduced by such an excess! (figure 1).

In tables 2 and 3 several other quality characteristics of potatoes are reported, determined after the experiment with cattle

TABLE 2. Quality of potatoes (var. Bintje) in a trial with cattle slurry

	N-application (kg N/ha) as nitrochalk					
	0	40	80	120	160	200
Rating for blackening (<10 = good)						
fertilizer	2.3	0.5	-	0.0	-	0.0
cattle slurry, 50 tons/ha	1.2	0.5	-	0.7	-	0.3
" " , 100 "	1.2	1.7	-	1.0	-	0.0
" " , 150 "	0.0	0.3	-	0.0	-	0.3
Boiling test (1 = firm, 5 = broken; f = floury, fi = firm, sw = somewhat wet						
fertilizer	3-f	4-f	2-fi	2-fi	2-fi	1-fi
cattle slurry, 50 tons/ha	2-fi	1-fi	2-fi	2-fi	2-fi	1-fi
" " , 100 "	2-fi	2-fi	1-fi	1-fi	2-fi	1-sw
" " , 150 "	2-fi	2-fi	3-fi	2-fi	2-fi	3-f
Chip colour (1 = darkbrown, 9 = yellow; <5½ = unacceptable)						
fertilizer	5	4	5	5	5	4
cattle slurry, 50 tons/ha	5	5	5	5	5	5
" " , 100 "	5	5	4	4	4	4
" " , 150 "	5	5	5	4	3	3
Scale (scale 1-10; 10 = good)						
fertilizer	7.7	8.3	8.5	8.7	8.7	8.2
cattle slurry, 50 tons/ha	8.7	8.3	8.5	8.5	8.5	7.7
" " , 100 "	8.5	8.2	8.5	8.7	8.7	8.3
" " , 150 "	8.7	8.8	8.8	8.5	8.8	9.0

TABLE 3. Quality of potatoes (var. Bintje) in a trial with poultry slurry

	N-application (kg N/ha) as nitrochalk					
	0	40	80	120	160	200
Rating for blackening (<10 = good)						
fertilizer	0.5	0.5	-	0.7	-	0.0
poultry slurry, 20 tons/ha	2.8	0.8	-	0.2	-	0.3
" " , 40 "	0.5	0.0	-	0.0	-	0.0
" " , 60 "	0.8	0.3	-	1.0	-	0.3
Boiling test (1 = firm, 5 = broken; f = floury, fi = firm, sw = somewhat wet, sf = somewhat floury)						
fertilizer	3-sf	2-fi	2-fi	3-fi	2-fi	1-sw
poultry slurry, 20 tons/ha	2-fi	3-fi	2-fi	2-fi	2-fi	2-sw
" " , 40 "	2-fi	2-fi	2-fi	1-sw	2-sw	1-sw
" " , 60 "	2-sf	3-fi	2-fi	2-fi	1-fi	1-sw
Chip color (1 = darkbrown, 9 = yellow; <5½ = unacceptable						
fertilizer	5	5	5	4	5	5
poultry slurry, 20 tons/ha	6	5	5	5	5	5
" " , 40 "	5	5	5	5	5	3
" " , 60 "	6	5	5	6	5	4
Scab (scale 1-10; 10 = good)						
fertilizer	8.5	8.5	8.3	8.3	8.5	8.2
poultry slurry, 20 tons/ha	7.7	7.7	8.5	8.5	8.7	8.8
" " , 40 "	8.2	8.2	8.3	8.5	8.7	8.3
" " , 60 "	8.0	8.0	8.3	8.2	8.0	8.8

and poultry slurry mentioned earlier.

The sensitivity to *blackening* was slight and became still less following a heavier (inorganic nitrogen) fertilization.

Boiling quality improved with increasing organic and inorganic nitrogen application. However, potato texture changed from floury to firm to somewhat wet. The tubers did not turn grey, and taste and flavour were good regardless of types and amounts of manure used.
For the preparation of chips and French fried potatoes, *colour of the chip* is an important aspect of quality. A rating lower than 5½ is unacceptable. For all treatments in this trial, including the check, chip colour was insufficient. Probably the rather immature polder soil contained so much available nitrogen that also the unfertilized potatoes could not meet this quality requirement.

The incidence of *scab* was slight. there was hardly any effect of fertilization. There was slightly less scab in the heaviest treatments.

Tuber *shape* was good and was even somewhat better at the higher levels of manure combinations.

The *keeping quality* of 20 kg-lots of potatoes, obtained from a trial in which since 1971 increasing amounts of pig slurry in combination with mineral nitrogen had been applied, was tested in cold storage in the autumn of 1975. After at least 5 months of storage weight losses and numbers of rotten tubers were noted (table 5).

The weight losses were found to have risen with increasing amounts of pig slurry from 6.5% to 8%.When the slurry applications were combined with 100 and 280 kg inorganic nitrogen, the losses for all quantities of slurry did not exceed about 6%. Also the number of rotten tubers was lower when organic and inorganic applications were combined.

4. EFFECT OF ANIMAL MANURES AND FERTILIZERS ON SOME QUALITY CHARACTERISTICS OF SUGAR BEETS

The content of amino-N in the juice of sugar beets is one of the criteria used by the sugar refinery for the extractability of the

TABLE 5. Losses in weight as a percentage of the initial weight and numbers of rotten tubers in a storage trial with ware potatoes (14-10-1975 to 22-3-1976)

Fertilizer treatments kg/ha			Pig slurry treatments tons/ha			
N	1PK[†]	2PK[†]	40 sp[††]	80 au[††]	80 sp[††]	160 au[††]
Weight loss, %						
0	-	9.3	6.5	8.1	6.7	8.0
100	-	-	5.8	6.0	5.9	6.3
280	6.5	6.3	-	-	-	-
Number of rotten tubers						
0	-	7	5	8	3	12
100	-	-	3	3	1	8
280	3	4	-	-	-	-

[†] 140 P_2O_5 and 140 K_2O; 280 P_2O_5 and 280 K_2O, kg/ha
[††] sp = applied in spring; au = applied in autumn

sugar. As this content increases it becomes more difficult to obtain pure sugar, while greater losses occur, ending up in the molasses. About 200 mg amino-N per 100 g sugar is considered the maximum acceptable amount. The amount of amino-N is related to the sum of the available nitrogen present in the soil (to 60 cm) in spring and the amount of fertilizer nitrogen applied (figure 3). The data are from a trial with poultry slurry (0-60 tons/ha) in combination with fertilizer nitrogen (0-200 kg/ha) on a clay soil (55% particles <16 µm). The content of amino-N (mg) corresponds in this case to 12.5 × the amount of available N (kg).

As the content of amino-N in beet juice increases, the sugar content decreases (figure 4). Although a clear relationship exists regardless of the N-source (soil, animal manure, or fertilizer), considerable scatter around the mean is evident (± 0.4% sugar). The two outer lines in this figure constitute the limits within

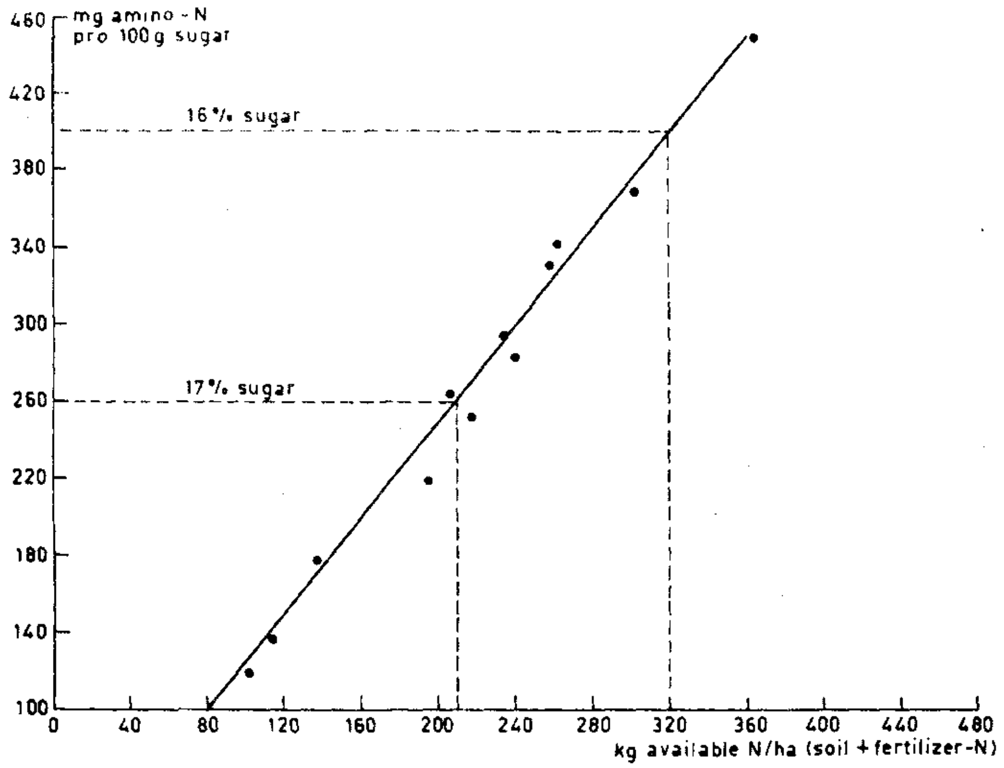

Fig. 3. Relationship between available nitrogen in soil (0-60 cm) in spring plus fertilizer-N and the content of amino-N in juice of sugar beets. Experiment with poultry slurry on clay soil (55% particles <16 µm).

which 96% of the 144 individual observations made in this trial occur regulary.

Figure 5 shows the relation between the amount of available soil-plus-fertilizer-N in spring and yield of sugar. In 1975 the maximum sugar yield was obtained with about 220 kg available N in spring. According to figure 3 this corresponds to an amino-N content of 274 mg, which according to figure 5 corresponds to a sugar content of 16.94% (possible range 16.54% to 17.34%). The content of amino-N is considerably higher than the 200 mg considered acceptable by the refining industries. If we take this value as the limit, then at most 160 kg of soil-plus-fertilizer N should have been available in the spring of 1975. This quantity corresponds to a sugar yield of 97% of the maximum production obtained in that year (figure 5).

Although a rather close correlation exists between the content of amino-N in beet juice and the sugar content in a given year and on

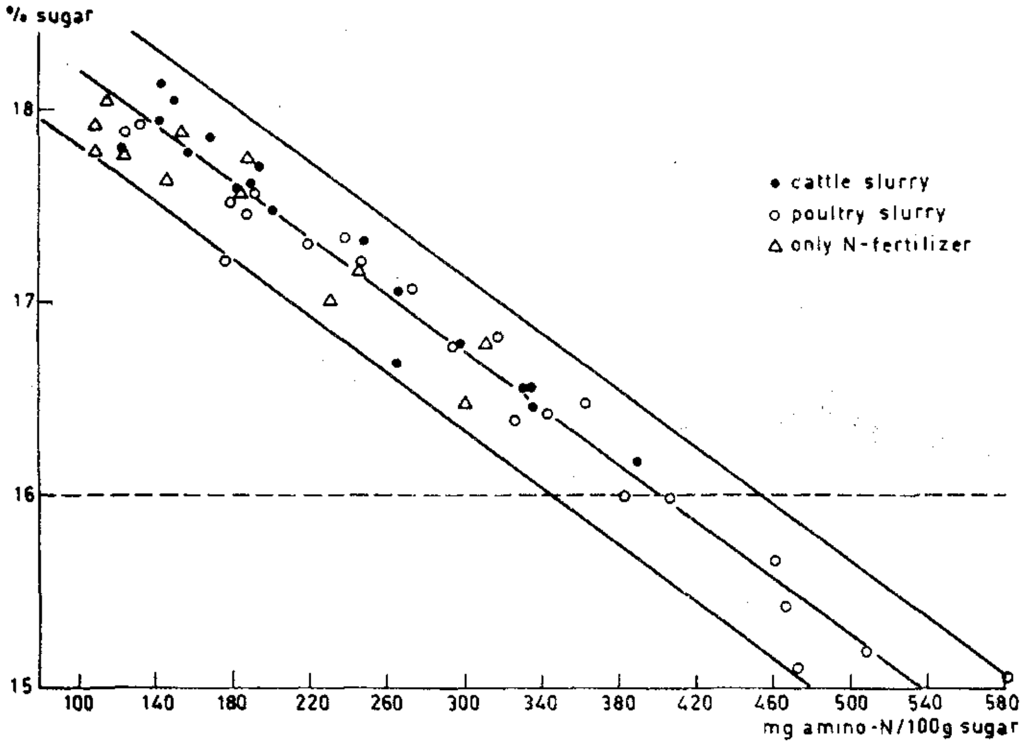

Fig. 4. Relationship between the content of amino-N in the juice of sugarbeets and the sugar content. Experiment with poultry- and cattle slurry on clay soil (55% particles <16 µm).

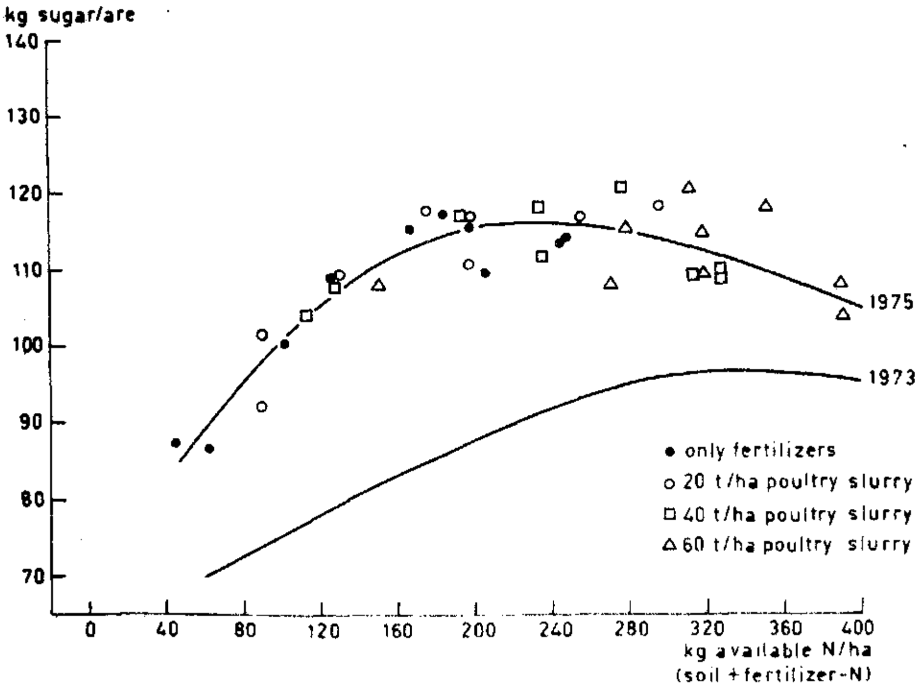

Fig. 5. Relationship between available nitrogen in soil (0-60 cm) in spring plus fertilizer-N and the yield of sugar. Experiment with poultry slurry on clay soil (55% particles <16 µm).

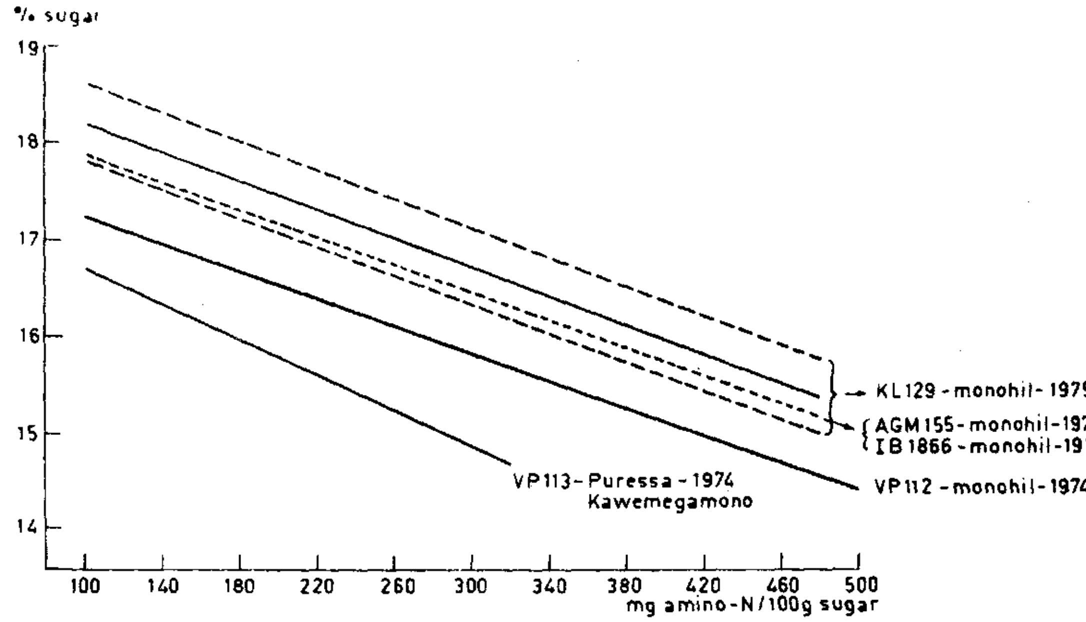

Fig. 6. Relationship between the content of amino-N in juice and the sugar content of different varieties of sugar beets grown on different soils, in different years and with different nitrogen fertilizers (organic and inorganic).

a given trial field, considerable difference in response occur between years and trials (figure 6). As long as these differences cannot be explained, it will be impossible to establish N-fertilizer recommendations on the basis of soil analysis that will be acceptable both to the growers of sugar beets and the beet processing industry!

6. SUMMARY AND CONCLUSIONS

Annual applications of considerable amounts of animal manure to the same field may give rise to a large accumulation of plant-available nitrogen in the soil. Part of any unused surplus will disappear at the end of the growing season. If this store of nitrogen is disregarded in the calculation of the necessary amount of fertilizer, yield and quality of crops will suffer. Various quality characteristics of potatoes and sugar beets have been found to be related to the amount of available soil-N present in spring and the fertilizer applied. In principle, two possibilities exist to prevent excess applications of animal manure. The first consists in gradually assuming higher nitrogen-effectiveness coefficients (=effect relative to mineral nitrogen) for the nitrogen contained in animal manure; indoing so, the cumulative residual effect of this nitrogen is taken into account (Sluijsmans and Kolenbrander, 1976). The second method consists in determining the amount of available N in the soil profile before the start of the growing season; the amount of additional nitrogen needed in the form of fertilizer is then calculated. Yield and quality of crops from the same trial and grown in the same year have been found to be well correlated with the amount of availbale N, regardless of its source (soil, fertilizer, organic manure). As far as quality aspects are concerned, considerable variation between trials and years exists, sofar making practical application of the correlation impossible!

7. LITERATURE

Sluijsmans, C.M.J. en Kolenbrander, G.J. 1976. De stikstofwerking van stalmest op korte en lange termijn. Stikstof 7, no. 83/84: 349-354.