

CHANGES IN NITROGEN FERTILIZATION IN DUTCH ORCHARDS

Piet Delver
Institute for Soil Fertility
Haren (Gr.)
Stationed at the
Research Station for Fruit Growing
4475 AN Wilhelminadorp (Z.)
The Netherlands

Introduction

During the last twenty-five years nitrogen fertilization in Dutch orchards has changed considerably. This was largely related to changes in choice of rootstocks, increased plant density, improved soil conditions and large-scale switch-over to the grass strip system. Field experiments leading to a better evaluation of fertilizer effects, and a better estimation of nitrogen requirement also played a role. For a good understanding of the following explanation some acquaintance with Dutch orchard conditions is indispensable.

The Fruit Industry

Pome and stone fruit in 1981 comprised 59 000 acres, which is only 36% of the acreage of 1950. Apples cover 69%, pears 24% and plums and cherries 7%. In spite of the decreased fruit area production has not diminished but even increased somewhat since 1950. Productivity per acre and per man-hour have improved substantially. For instance, in apple orchards with high standard trees, production per man-hour in 1950 was 33 lbs only. The present score is 198 lbs in very dense plantings.

Main factors responsible for this drastic development are increased plant densities (Table 1), earlier cropping made possible by using the dwarfing rootstock M.9 for apple and quince MA for pears, and introduction of more productive cultivars. The increase in tree numbers coincided with a change-over from vigorous rootstocks (M.11, 16) via semi-vigorous (M.1, 2, 4) to the dwarfing M.9. After world war II the use of M.9 increased rapidly and, since 1960, it is almost the only rootstock considered.

Climate

Holland has a humid marine climate with relatively cool summers and mild winters. Table 2 characterizes the Dutch climate but considerable year-to-year variations occur. Annual precipitation, 29 inches on average, varies between 20 and 39 inches. Dry periods of several weeks, mostly in May-June, may affect shoot growth. Drought later in the season may affect fruit growth, but less often. Extremely dry growing seasons occur only once in every 8-10 years (1947, 1949, 1959, 1976). July, August and, somewhat less often September, may be very wet with more than 6 inches of rain in each of these months. This may hamper trafficability of the orchard during picking time.

un-609050

Orchard Soils

Table 3 gives an estimated distribution, showing that the great majority of orchard soils contains clay. Loess soils in the southeast, and the reclaimed virgin sea-bottom soils of the IJsselmeer polders, totalling 16%, are considered the best because of their excellent water holding capacity. Only 5% is extremely drought-susceptible and another 10% is considered moderately susceptible (mostly shallow-rooted soils underlain with sand, and heavy river clay with poor structure). Of the remaining 69% of the orchard area 40% has good moisture properties. Almost all orchards have tile-drainage. Capillary rise of ground water into the root zone is an important source of moisture in most orchards.

Soil Management Systems

Until 1960, an estimated 75% of all mature orchards were under overall grass. In some of them, a narrow strip along the tree rows was rotovated to reduce grass competition for moisture and nitrogen, and to facilitate mowing. Grassing-down, some 3-6 years after planting followed a period of intercropping or clean cultivation. Despite a growth check often experienced after grassing down, and in dry years, grass was maintained because many of these clay soils were hard to work, often not too well drained and, after being tilled inaccessible to heavy implements during wet periods. On light, sandy or shallow-rooted, droughty soils overall mechanical cultivation, intercropping and green manuring were the predominant systems.

About 1960, herbicides were introduced and, between 1960 and 1965, the above systems were rapidly abolished. A massive change-over to the herbicide strip system with grass in the alley followed. At present it is still practised in 85% of all orchards, mainly on fairly moist soils. Under dry conditions trees are in overall herbicide-treated soil whereas on heavy soils, to some extent, even the all grass sward still exists. Tillage is very seldom done.

The question is sometimes asked why in Holland the grass strip system is so predominant because even with wide herbicide strips, competition by the grass alley may still affect the crop. The answer is that most soils have reasonable or good water holding capacity and capillary supply but are susceptible to deterioration of structure and rutting, brought about by frequent and heavy traffic, such as the tractor with fork lift to carry off the crop. As 66% of the apple area and 60% of the pears is to be picked after mid-september, and a great proportion of this even in October, there is a good chance of moisture saturation and rutting on herbicide-treated alleys after rainfall. Compared with the overall grass sward, competition by grass covering about 50% of the area is far less and the risk of lagging growth resulting in too small trees is largely compensated by dense planting. The grass strip is therefore considered a good compromise between the practical advantages of continuous good trafficability and the disadvantages of competition. Be it as it may, it cannot be denied that dense planting resulting in a substantial increase of production level, and the grass strip, render orchards relatively susceptible to drought compared with wide planting and overall herbicide treatment.

Consumption of Nitrogen Fertilizers

From 1958 to 1965, the Agricultural Institute for Economic Research collected data from the book-keepings of a large number of modern fruit farms throughout the country. From these, accurate calculations could be made of fertilizer dressings in separate plantings grouped according to age, type of planting, and soil management system.

Figure 1 gives averages for mature spindle-bush apple orchards. The lines refer to the four main fruit areas 1-4 mentioned in Table 3. In 1958-1965, over 200 separate orchards belonging to some 100 farms were involved, but in later years the investigation was terminated so that estimations had to be made from inquiry data collected by extension services. Although somewhat less accurate than the book-keeping data, they give a good impression of the rapid decrease in nitrogen consumption following the even more rapid increase between approx. 1960 and 1965. The same tendency was found for pears and, much less marked, for wide-planted high standard apple trees on vigorous rootstocks. Although differences in average nitrogen consumption among the four areas were more or less as expected in view of the different growing conditions, it was striking that within each area the soil management system, for instance the degree of grass cover, only slightly influenced the amount of nitrogen given.

About 1975, dressings reached a minimum level, even considerably lower than in the years before 1960. Some growers with extremely good, mainly loess and young, reclaimed sea-bottom soils, after having practised high dressings even went to the other extreme by entirely omitting fertilization or, at best, replacing it by late urea sprayings. Since 1975 nitrogen consumption has remained practically constant although after the extremely dry year 1976 the number of "zero-nitrogen"-growers has decreased. According to a comprehensive inquiry overall consumption in orchards averaged 68 lbs N per acre in 1979.

Which factors have influenced the differences between the four fruit growing areas and induced the radical changes in fertilizer use within such a short period? Before answering these questions I have to remark that intensive fertilizer research has been carried out during the past twenty-five years. There have always been good mutual contacts between researchers, extension services, and growers. The latter showed a keen interest in research progress and in general were ready, sometimes too rash, to adopt findings which they thought useful.

Research on Nitrogen Nutrition and Fertilization

Since 1950, over a dozen field trials have been carried out on different soils and with nitrogen quantities and soil management systems as variables. Initially, several of these trials were located on river clay, where growth was not vigorous and grass was predominant. Later trials were also done on far better soils and attention was increasingly focussed on the herbicide strip system. Detail problems were also investigated and concurrent background research on nitrogen nutrition was conducted in pot experiments. The findings, whether or not correctly interpreted, had a

great influence on growers' fertilizer practice.

The Grass Orchard

Figure 2 gives a general view of relative fertilizer effects (yield at optimum dose = 100), in ten field trials with mature apple plantings, separated into effects in the second and third year after grassing down (A) and those in the succeeding years (B). The left figure demonstrates the well-known check effect on production exerted by a young sward, particularly enhanced when sub-optimum nitrogen dressings are given. It mainly results from reduced flower initiation and biennial bearing. Although less pronounced, positive fertilizer effects in Figure 2B suggest that also orchards in older, "settled" grass swards require high dressings for maximum production, probably 150 lbs N per acre or more. Furthermore, there is a tendency that apples on M.2 and 7 (dashed lines) respond less pronounced to low dressings than those on the dwarfing M.9 (full lines). Apparently the latter require more nitrogen for optimum performance. This is an important observation because until 1960-1965 increasing numbers of apple orchards were on M.9 and moreover, often in overall grass. Herbicides were not yet commonly used.

In the phenomenon of competition, the susceptibility of the rootstock also seems to play an important role. Yet, little comparative fertilizer research with rootstocks varying in vigour has been done. Some information on this subject was obtained in a pilot experiment done in 1967 and 1968, in an old apple orchard that was known as the very first experiment with Malling rootstocks on the European continent. The trees, two apple cultivars on sixteen different EM rootstocks, were planted in 1925/26 in the experimental garden at Wilhelminadorp. In 1967, after 41 years as a consequence of differences in vigour, the trees had reached widely varying sizes and trunk diameters. In that year half of the experimental area was sown with a strongly competitive grass mixture and received no further nitrogen dressing. On the other half, the usual overall herbicide treatment and fertilization were continued. Trees of only part of all cultivar-rootstock combinations occurred on both halves. Soon after the grass developed, the trees on this half started to show nitrogen deficiency but the degree varied amongst the different rootstock combinations. Figure 3 represents the difference in nitrogen contents in the leaves in 1968 between nitrogen-deficient trees on the grassed half and non-deficient trees of the same rootstock combination on the other half, as related to average trunk diameter. The latter is a measure for vigour. It is obvious that the drop in nitrogen content of the trees in grass was most marked in small trees such as those on M.9 and far less in the large trees f.i. on M.11 and 16. The relationship more or less supports the idea that fruit trees are more susceptible to competition, therefore require higher nitrogen dressings and possibly better soils, the more dwarfing their rootstock is.

When nitrogen fertilization proved to be such an important factor in grass orchards, particularly with trees on semi-dwarfing and dwarfing rootstocks, efforts were made in experiments to partly avoid competition for nitrogen. For instance, frequent mowing and very early dressing on deep soils turned out effective, but fertilizer placement in bands was not promising. Nitrogen deficiency in the leaves could be corrected by urea

sprayings and at present this is still practised to some extent.

In one of these experiments on a deep marine silt loam with apple roots to a depth of 30", fertilization early in January compared with February-March resulted in a 10% higher yield, averaged over several years. The fruits were also less russeted. The explanation of this phenomenon is that early-applied nitrogen during winter penetrates deeper into the apple root zone, out of reach of the shallow grass root system. It therefore benefits the tree rather than the grass. February-March-applied nitrogen promotes more abundant grass growth. Early fertilization has been successfully practised by growers in orchards on heavy, deep-rooted soils.

Impact on Growers' Fertilizer Practise

Soon after the first results of the experiments in grass orchards became known, growers started to raise their nitrogen dressings, even in orchards with a less competitive soil cover such as grass alleys with cultivated tree strips, green manure crops etc. (Fig. 1 1960-1965). An extra impetus came from drought in 1958 and 1959 when large-scale symptoms of nitrogen deficiency were observed in grass orchards in particular on heavy, poorly drained soils in the central river clay area. In this area the majority of mature spindle-bush apple orchards was still in overall grass or narrow cultivated tree strips, and the trend of considerably increasing nitrogen dressings was probably justified. In other areas however, the influence of degree of grass cover on competition and fertilizer requirement was taken too little account of (f.i. area No.3, many sandy soils with clean cultivation, and No 4 with wide, cultivated or herbicide-treated tree strips). Figure 4 demonstrates that in these years of increased dressings within the river clay area, there also was a great variation in nitrogen quantities given to different apple orchards. It reflects a large diversity in soil and orchard (rootstock-) conditions and, of course, little unanimity amongst growers about the necessity of high nitrogen dressings.

The Grass Strip System

In the mid-sixties most growers had already grown accustomed to the use of herbicides. Many had started to change over to weed control on the tree strips, regardless of what they had been doing before. The alley, covering 45-50% of the orchard area, was grassed down either with a natural vegetation or, by sowing a suitable mixture (containing mainly smooth stalked meadowgrass, *Poa pratensis*).

From about 1960 to 1980, several fertilizer trials with the new system were carried out under different soil and orchard conditions. Details were studied concerning f.i. the influence of the width of the herbicide strip on nitrogen requirement; soil tillage versus non-tillage (herbicides); mulching the grass on the herbicide strip or on the alley; differences in competition between grass species, and suitability for frequent traffic, a.s.o..

It soon became evident that with wide, weed-free tree strips where no tree roots are damaged by mechanical cultivation, nitrogen requirement is far lower than in the overall grass orchard. For instance, on somewhat

droughty soils optimum yields were obtained with dressings of some 100 lbs per acre. Under normal weather conditions, unfertilized plots showed yield depressions of 10-15% at most. In years following an extremely dry year these depressions were more severe. On good moist soils however much less nitrogen was needed for maximum yield, and on excellent soils fertilization was sometimes unnecessary. On moist, deep loess and on the virgin sea bottom soils (Table 3) it could even induce too vigorous growth.

A major factor determining the need for fertilization is the relative width of the weed-free herbicide strip. Figure 5 demonstrates this influence in an experiment with Belle de Boskoop apples on M.9 planted in 1972 with 753 trees per acre in single-rows, 11½' apart and at 4½' within-row distance. Two widths of the herbicide strips, 16" and 71" were compared, and the grass alley covered 88% and 49% of the orchard area, respectively. In the narrow tree strips about 60 lbs more N per acre was required to attain the same nitrogen level in the leaves compared with wide strips.

In the same experiment, nitrogen requirement in relation to plant density was investigated. The five nitrogen dressings were applied to three single-row systems with 449, 753 and 1186 trees per acre. Because the grass alleys covered the same relative orchard area, viz., 49%, 49% and 50%, the herbicide strips were not equally wide: 79", 71" and 59", respectively. Figure 6 shows nitrogen contents in the leaves as an average of eight years. N percentages were lower as plant density was higher, particularly when small dressings were given. The effect was probably due to differences in available moisture per tree which affected nitrogen uptake. Tensiometer readings at 10" depth, and soil moisture determinations showed that in an area within 2' from the trunk, the soil dried out more quickly as tree spacing in the row decreased. Yield data in this experiment showed that trees tend to biennial bearing the more so as they are planted more closely and this is considerably enhanced by nitrogen deficiency. The risk of reduced flower formation as a consequence of nitrogen deficiency is further enhanced by drought and heavy yields such as appeared in 1976 and 1978. Neglecting nitrogen supply therefore holds a greater risk in close than in wide plantings.

The recycling effect of nitrogen in mown grass has been thoroughly investigated. Under normal rainfall conditions, when mulched on tree strips the grass decomposes readily. It then constitutes an additional source of easily absorbed nitrogen in quantities of 10-20 lbs of slowly released N per acre of tree strip area. It particularly promotes formation of nitrogen reserves in the tree. When left on the alley it brings about a 20-30% higher grass production compared with mulching on the herbicide strip. The dense-rooted upper two inches of the untilled herbicide strip is of special importance because nutrients originating from fertilizers and mulch not only accumulate in this layer but are also easily absorbed. Change-over from mechanical to chemical weed control, for instance, resulted in less iron deficiency, higher N-, P-, K-leaf contents, better moisture uptake and growth but, unfortunately, also more bitter pit.

Improved Soil Conditions

A gradual move of fruit farms to better soils, for instance the settlement from 1955, of many growers in the newly reclaimed IJsselmeer polders, and improved drainage conditions particularly in the river clay area, have certainly contributed to a decrease in fertilizer need. Currently some 90% of all orchard soils are tile drained. Deeper and more intensive drainage resulted in better rooting and less root damage from excessive rainfall on the one hand, and more available nitrogen mineralized from soil organic matter on the other. Most soils contain 2-4% humus which is a potential source of nitrogen.

The effect of deep drainage on nitrogen requirement is demonstrated in an experiment on sea bottom soil. The polder was reclaimed in 1957 and the experiment was planted to apples on M.9 in 1965. Since then, three fertilizer levels were established on plots where various constant groundwater levels during two periods, respectively during winter and summer were maintained by drainage and infiltration. The experiment was terminated in 1980. Table 4 shows that under the experimental conditions of excellent water holding capacity and deep rootability of the soil, drainage leads to substantial decrease in nitrogen fertilizer need. With groundwater kept at a constant deep level there even was no need for additional nitrogen at all.

Cutting down on Nitrogen, present Fertilizer Practice

Growing practical experience, and evidence in fertilizer trials on the favourable availability of nitrogen in herbicide strips soon induced growers to cut down on fertilizer expenses. Growers in the IJsselmeer polders were the first to reduce their nitrogen dressings. Because experience with the exceptional vigorous growth on the virgin soil was lacking, they initially followed the general trend of increased dressings, although they exclusively practised grass strips. In many cases fertilization had resulted in too much growth, and the following heavy winter pruning had made trees grow even more vigorously. Within a few years dressings were reduced from about 200 lbs in 1964 to the present amount of some 30 lbs N per acre. Other areas soon followed but nowhere was the reduction so spectacular as in the IJsselmeer polders. The process was probably accelerated by low fruit prices due to the European fruit crisis and an increasing consideration of adverse nitrogen effects on fruit quality. Moreover, in the former wide plantings promotion of vigour during the juvenile phase, to let the trees better fill their allotted space, had been an important argument for high dressings. In the close plantings this function of fertilization became less relevant.

The present-day fertilizer practice does not differ much from the one calculated from the 1977 inquiry data. Current differences in nitrogen use between fruit areas mainly reflect the influence of natural soil conditions on vigour. Annual dressings are now mostly within the range of 45 to 110 lbs N per acre and soil moisture conditions, vigour, cropping level and plant density are the main factors considered. Under exceptionally good conditions even lower dressings are justified such as in the IJsselmeer polders and on deep loess soils. Quite a few growers here, in other areas also in orchards with apple on M.2 and 4, have indeed tried to omit fertilization.

After the dry year 1976 some of them had to reconsider that attempt because in that year their trees started to show symptoms of nitrogen deficiency. To prevent too vigorous growth they now give small dressings in the course of the summer, sometimes on the herbicide strips only. Urea is sometimes sprayed to correct the nutritional status of the orchard. Also, calcium nitrate frequently sprayed to control bitter pit should not be overlooked as an additional nitrogen source. During winter, microscopic examination of buds is sometimes used as an aid to estimate flower initiation and to decide upon pruning intensity and sometimes spring dressing. Early winter dressing, once successfully practised in the former grass orchard, is not done anymore. Determination of mineral nitrogen in the root zone of the herbicide strip in spring has been proposed as a method of estimating fertilizer requirement but it has not yet proved promising. Under the present conditions of high plant densities the role of fertilization has shifted, from promotion of growth to support of flower formation. In the latter, drought and high tree yields are important variables. Fertilizer recommendations should be better attuned to fluctuations in these two variables, but great changes in fertilizer use are not to be expected in the future.

Table 1. Percentage distribution of plant densities in apple orchards used in successive planting periods. Source: CBS inquiries in 1974, 1977 and 1980.

number of trees per acre	Planting season						Total May 1980
	1951/'52* and earlier	'52-'53 '61/'62	'62-'63 '71/'72	'72-'73 '74/'75	'75/'76 '76/'77	'77/'78 '79/'80	
<162	68	8	1	1	1	-	-
162-324	23	38	16	10	8	4	22
324-648	8	51	62	46	45	30	48
648-971	1	3	{21	{43	{46	45	24
>971	-	-				21	6

* inaccurate, because of preferential grubbing of widely planted out-of-date orchards between 1951 and inquiry in 1974.

Table 2. Climatic profile of The Netherlands, average of 30 years.

	J	F	M	A	M	J	Jl	A	S	O	N	D
rainfall, inches	2.6	1.9	1.7	1.8	1.9	2.1	3.0	3.2	2.8	2.9	2.8	2.4
evaporation, inches	0.2	0.7	1.6	3.0	4.3	5.0	4.7	3.9	2.5	1.2	0.4	0.2
daily av. temp., °F	35	36	40	47	53	59	62	62	58	50	43	38
sunshine, hours	52	68	123	164	212	223	202	191	146	101	49	40
rel. air humidity, %	87	85	81	77	75	76	78	80	82	85	87	89
radiation, KJ. cm ⁻²	7	13	26	39	51	53	49	43	30	18	8	5

Table 3. Orchard soils in The Netherlands, area in per cent.

Fruit growing area	sand- l. sand 3-8% humus	marine clay (sl, l, cl, sil, clay)		river clay (l, cl, sil, c, sic, 15-45% clay)	loess (wind blown depo- sits) (sil)	total
		older polders	re- claimed sea bottom			
1. Central river clay area	3.2			35.1		38.3
2. West- and Southwest Netherlands	0.1	31.1				31.2
3. South- and Southeast Netherlands	9.0			3.7		20.0
4. IJsselmeer polders			8.9			8.9
5. Northeast Netherlands	0.2	1.0		0.4		1.6
Total	12.5	32.1	8.9	39.2		100.0

Table 4. Average annual yield of two apple cultivars in the twelfth-fifteenth year after planting (1977-1980) as influenced by ground-water level and nitrogen fertilization. Virgin IJsselmeer sea bottom soil, silty clay loam. Yield in 42 lbs bushel/acre. Grass strips, grass mulched on herbicide strips.

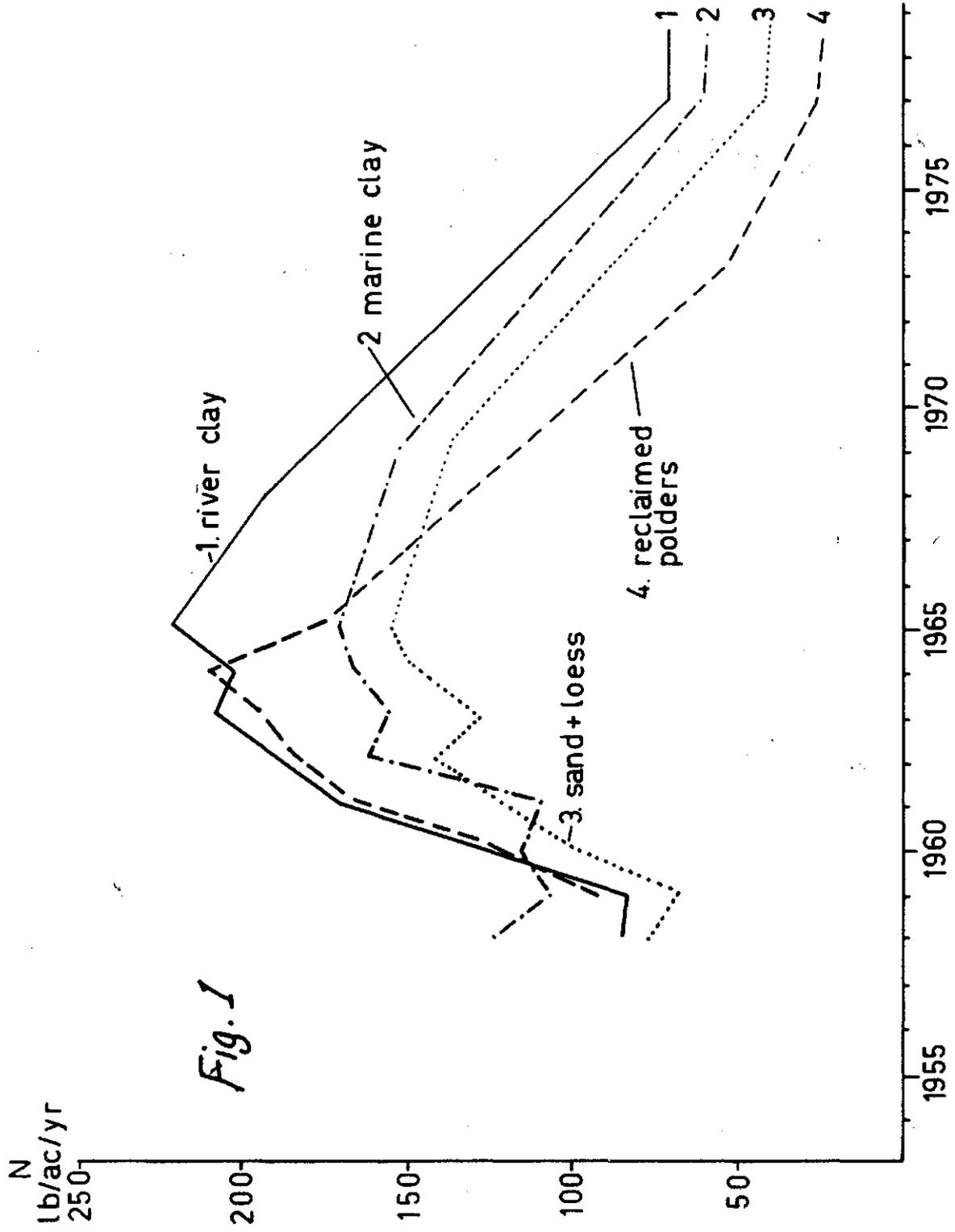
Ground water level in winter/summer*	Annual nitrogen dressings lbs N/acre					
	Golden Delicious M.9			Cox's Orange Pippin M.9		
	0	45	135	0	45	135
shallow level 16/16; 16/28; 28/28**	990	1130	1175	722	884	888
deep level 39/51; 54/51; "without infiltration"	1115	1113	1083	858	862	801

* inches below surface, kept constant during winter (November-March) and summer (April-October), respectively.

** average yield of three regimes.

Legends to figures.

- Figure 1. Nitrogen fertilizer use in four apple growing areas. Spindle-bush apple orchards initially on rootstocks M.2, 4 and 7, later predominantly on M.9. Various soil management systems.
- Figure 2. Yield response of apple on M.2 and 7 (---) and on M.9 (—) rootstocks to nitrogen dressings, in percent of highest yield. Grass orchards, A: in 2nd and 3rd year after grassing down (check effect), B: in later years.
- Figure 3. Response of 42-year-old apple trees Belle de Boskoop bush form to nitrogen competition from a young grass sward, as related to growth vigour for various Malling rootstocks (type numbers indicated). Vigour apparent from trunk diameter. Response expressed by difference in N-content in the leaves of trees in fertilized weed-free soil, and trees in unfertilized grass.
- Figure 4. Nitrogen dressings in the river clay area as related to age of the orchard. Soil management system indicated.
- Figure 5. Nitrogen contents in leaf of Belle de Boskoop apples, as influenced by nitrogen dressings and width of the herbicide strip. N% in August in basal leaves on annual shoots.
- Figure 6. Nitrogen contents in leaf of Belle de Boskoop apples in single-rows with wide herbicide strips, as influenced by nitrogen dressings and plant density. N% in August.



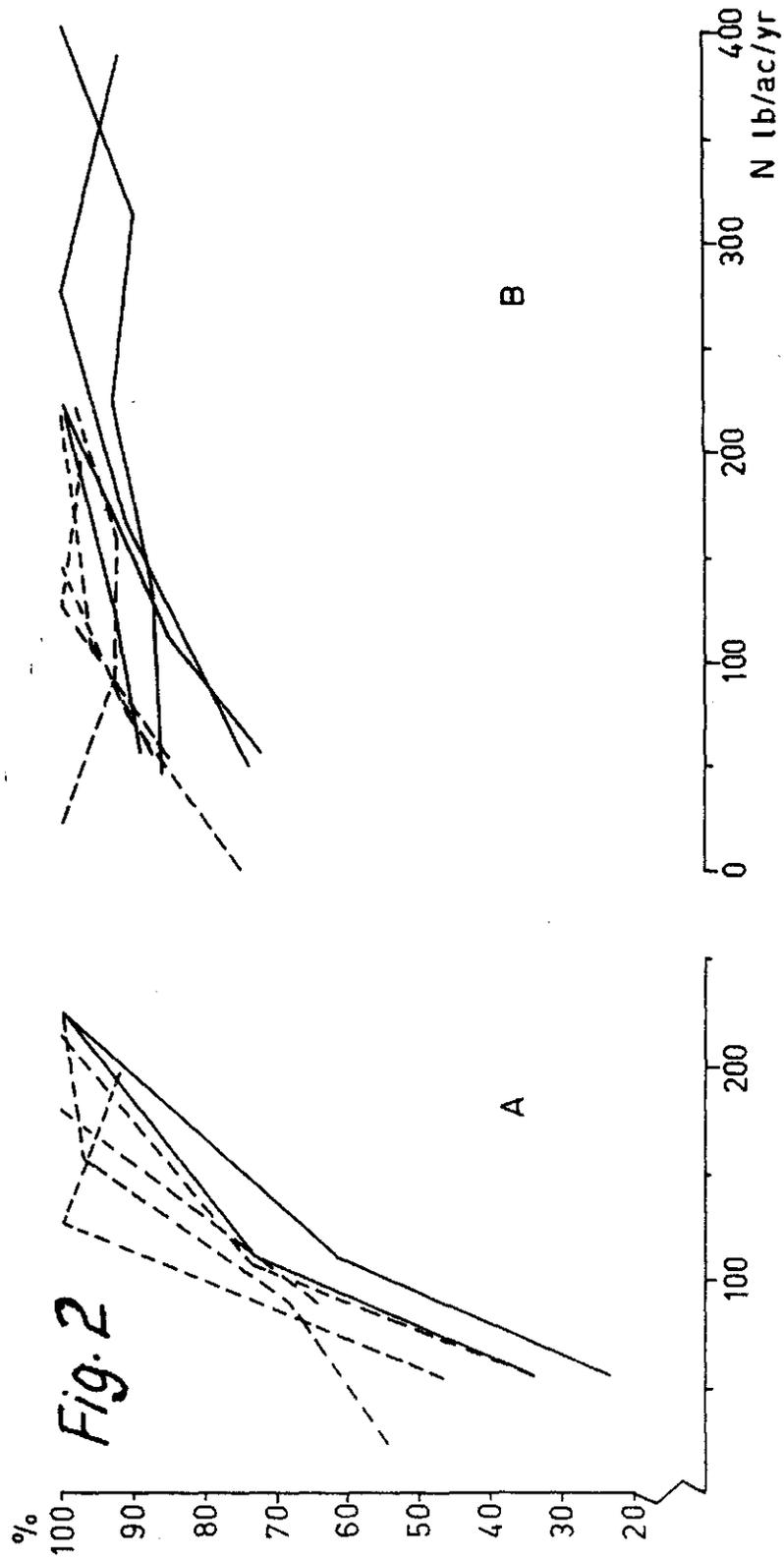
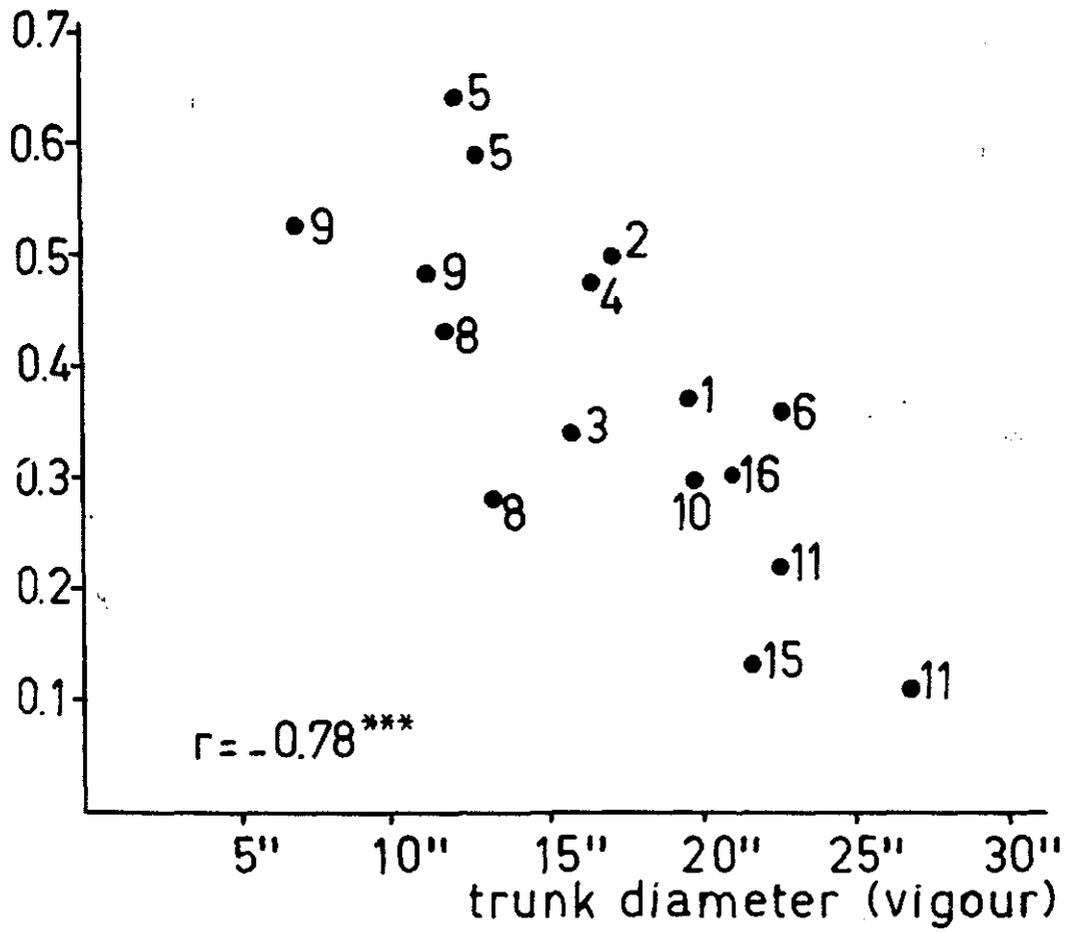


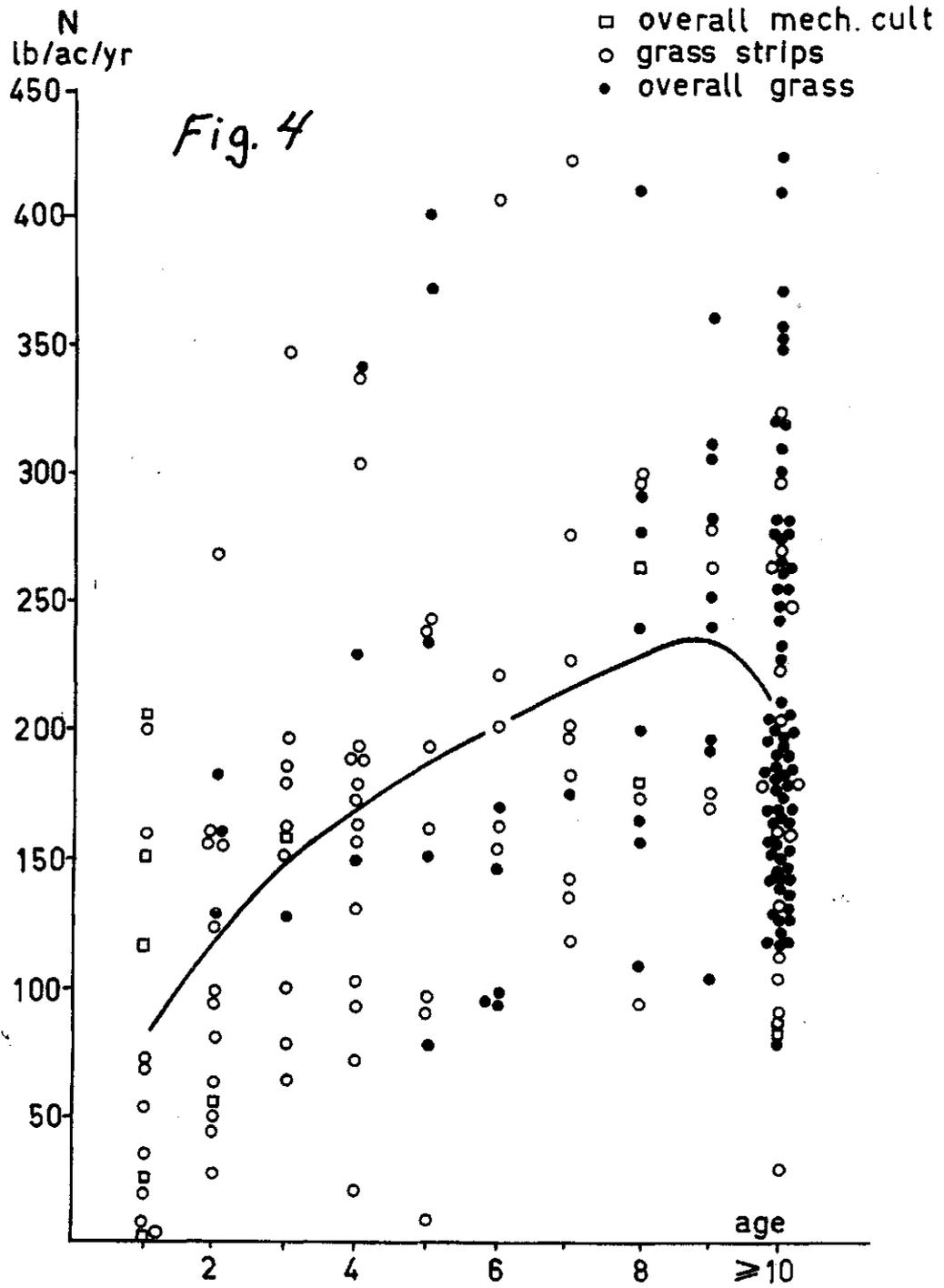
Fig. 2

difference
cultiv. - grass *Fig. 3*

% N in leaf



Spindlebush apple orchards M 9,2,4,7
River clay 1961-65



% N in leaf 1973-80 Fig. 5

