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Nitrogen in orchard soils

Summary

The quantity of nitrogen available in the soil under a grass sward is often limited as a consequence of rapid uptake by the grass. Orchards in a complete sward may therefore easily suffer from nitrogen deficiency especially in the second half of the growing season.
The degree of nitrogen competition is determined by the management and the nature of the sod: fertilization, mulching, age, grass species, light and moisture conditions.
With grass strips, a system that is increasingly applied in modern orchards with dwarfing fruit trees, approximately half of the soil surface (the tree strip) is clean weeded and free of nitrogen competition during the greater part of the growing season.
It is demonstrated by an experiment with young Conference pears, that fruit trees may provide for their need for nitrogen by uptake from only a small circular shaped surface of clean weeded soil. The fertilization and the nature of the grass strips therefore do not necessarily influence the nitrogen nutrition of the fruit trees as long as nitrogen in the tree strips is available in abundance.

Introduction

Soil management in the modern fruit plantation has developed from two original situations. On deep rooted moist soils such as river clay, fruit growing usually started in combination with cattle farming. The soil was completely covered with a pasture vegetation and the moderately kept standard trees became productive only after some ten years. For the sake of the income, cattle was kept in the orchard.
In areas with dryer soils such as shallow or light marine and sandy soils, in view of competition for moist and nitrogen no grass was allowed under the trees. When the trees were still young and initial income was obtained from intercropping (currants, goose berries, strawberries, agricultural crops). After some years the soil was clean cultivated by frequent tilling during the first dry months and weed growth or green manure crops were applied from the summer.
In the modern fruit plantation the early fruiting of dwarf trees has decreased the need for intercropping. Moreover the better care, e.g. the frequent control of diseases, resulting in passing through the orchard with heavy implements often more than 40 times a year, has increased the need for a continuous passability of the soil.
From this situation the system of grass strips has developed as a compromise. Grass, either developed from a weed vegetation or sown in as a well-chosen mixture of persistent and strong grasses, is kept in strips between the tree rows. The strips have a varying width, usually half of the row distance. Grass strips are applied to an increasing extent especially since chemical weed control on the clean cultivated tree strips has made it one of the cheapest soil management systems. They are a necessity on moist clay soils with a weak structure and carrying-capacity. Transitions between grass strips and a complete grass cover also occur. For reasons of easier mowing

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for instance, a small band of 2-5 dm on both sides of the tree row is sometimes chemically kept free of vegetation.
It is a well-known phenomenon that the quantity of nitrogen available under a sward essentially differs from a clean cultivated soil. As a consequence of uptake, the quantity of soluble nitrogen under grass rapidly decreases. In a soil which is only partially covered with grass this results in a dualistic growth medium as far as nitrogen is concerned. Some aspects of nitrogen uptake of fruit roots under a complete or a partial grass cover are discussed in this paper.

Nitrogen below a grass sod

As a consequence of the much earlier growth in the spring, the high nitrogen and water consumption and the more dense root system in the upper soil, grass

Table I. **Schematic presentation of the total nitrogen uptake at different dates per ha of a complete sward of smooth-stalked meadow grass (Poa pratensis) and of an apple orchard in full production under conditions of abundant nitrogen availability in the spring.**

	kg nitrogen uptake per ha from 1 Jan. date indicated									
	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10	1/11
Smooth-stalked meadowgrass	0.5	3	20	80	185	220	255	280	295	300
Apple orchard	0.5	1.0	2.0	5	17	37	62	82	94	100

may severely compete with fruit trees for nitrogen [2, 3, 5, 6, 7, 9, 10]. This may be demonstrated by the estimated data of Table I, which has been drawn up from known differences in the speed and level of nitrogen uptake by a grass cover and by an apple orchard in full production. It is clear that the nitrogen competition is to a great deal due to the earlier nitrogen uptake by grass in spring. The situation usually is, that under a sward nitrogen from fertilization in the late winter or early spring, is only available for the fruit trees during a limited period.
In a number of fertilization experiments in orchards, nitrate nitrogen in the soil under the sward has been determined at intervals and in different layers. The data from these experiments have been summarized in Fig. 1. The experiments, carried out between 1960 and 1965 have been arranged according to the level of nitrogen fertilization. Within each group, however, the conditions in relation to the moment of fertilization, the grass vegetation, the soil and the weather (leaching of nitrogen) varied widely. The data refer to the 0-40 cm soil layer only since a few shallow-rooted orchards were included. The nitrate concentrations have been expressed as kg N/ha under the assumption of a uniform volume weight of 1.5 kg per dm^3 of soil.
As can be seen from the left upper part of the graph, dressings in the spring, not exceeding 100 kg N/ha, invariably result in a very low amount of nitrogen available for the fruit tree throughout the season and consequently nitrogen deficiency will be visible in most cases. Between 100 and 200 kg N/ha in some cases adequate nitrogen is available during the spring but the nitrate concentrations usually become 'critical' early in the season. Even sometimes with dressings between 200 and 300 kg N/ha, e.g. as a consequence of leaching of very early dressings, the quantity of nitrate-nitrogen may become too low even before the trees are in full leaf.
The question whether from such curves the nitrogen status of the trees in the summer can be predicted is rather difficult to answer since the quantity of nitrogen taken up in the early months of the season, the effect of mulching and of nitrogen from deeper soil layers and various other factors are involved too. The 'critical level for adequate nitrogen uptake' therefore is only a rough aid for interpretation of the concentrations, indicating that as soon as under a sward this level is reached the nitrogen supply for the fruit tree is on a low level. It strongly depends on the moment when this level is reached and on the growth of the tree after this moment, whether or not nitrogen deficiency will become perceptible.
Under conditions of a complete grass cover, a good correlation may be expected between nitrate in the soil and the leaf nitrogen percentage in the summer. In Fig. 2 this relation is demonstrated for a deep-rooted orchard with Golden Delicious apples in two different years. The curves suggest that the said correlation is best if nitrate in the soil is determined early in the season and that the critical level of nitrate should be higher when the sampling is done earlier.
The situation that as a rule, the nitrogen supply of fruit trees in a complete grass cover is only abundant in the first months of the season may have certain plant-physiological consequences. Apart from a supposed favourable influence on the colour and keeping quality of the fruit, the possibility for the tree to store nitrogen in the woody parts and roots will be restricted. Weak fruit buds and a low fruit set in the following spring may be the consequence of this situation [4, 8, 11].

Factors affecting the nitrogen competition by grass

There are distinct differences in the degree of competition related to the nature of the grass vegetation. Some of these factors will be mentioned briefly.

(1) The age of the sod tends to weaken the competition for nitrogen. The main reason for this phenom-

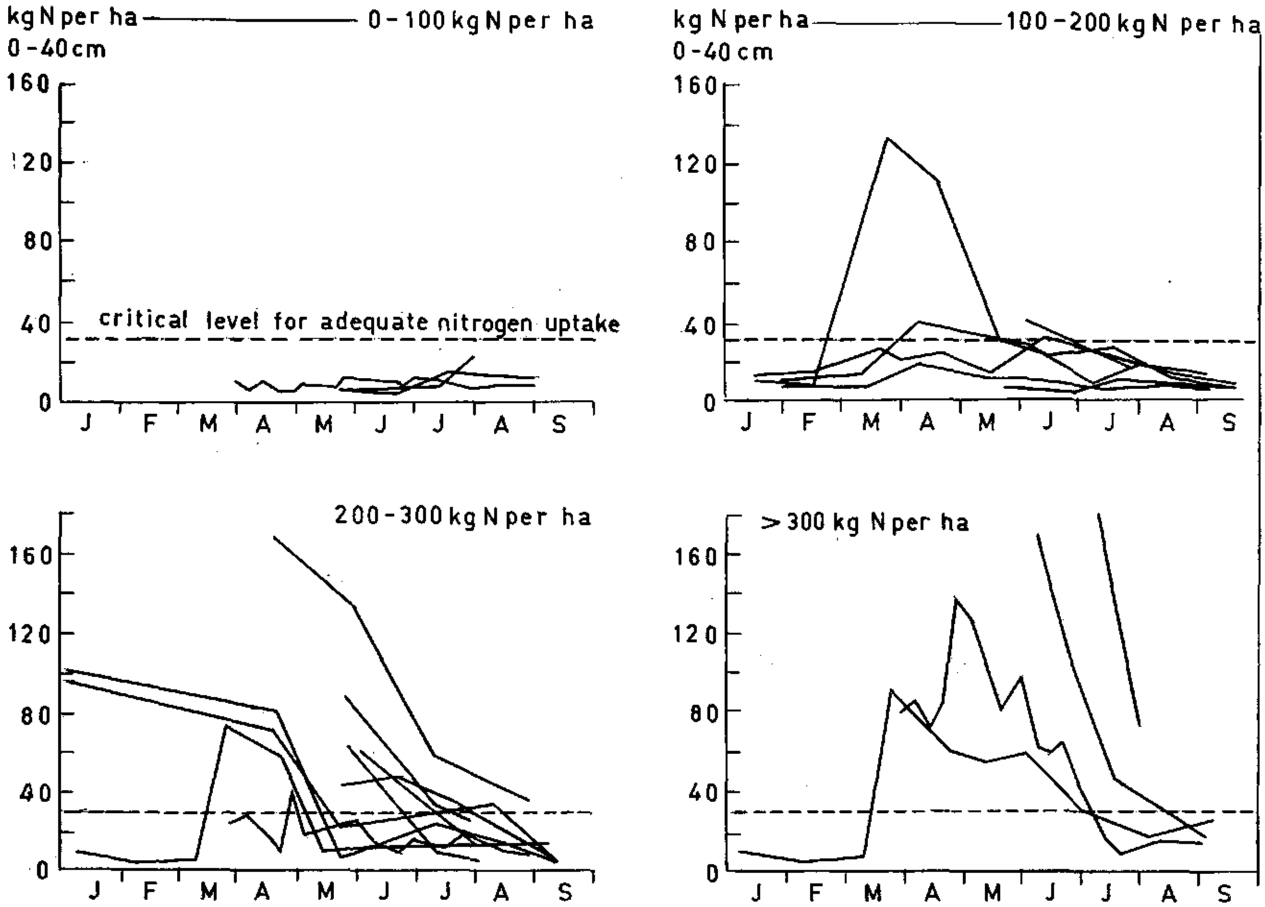

Fig. 1. Nitrate-nitrogen expressed as kg N/ha in the 0-40 cm topsoil under different grass swards in different years (1960-1965) as related to fertilization and date of sampling.

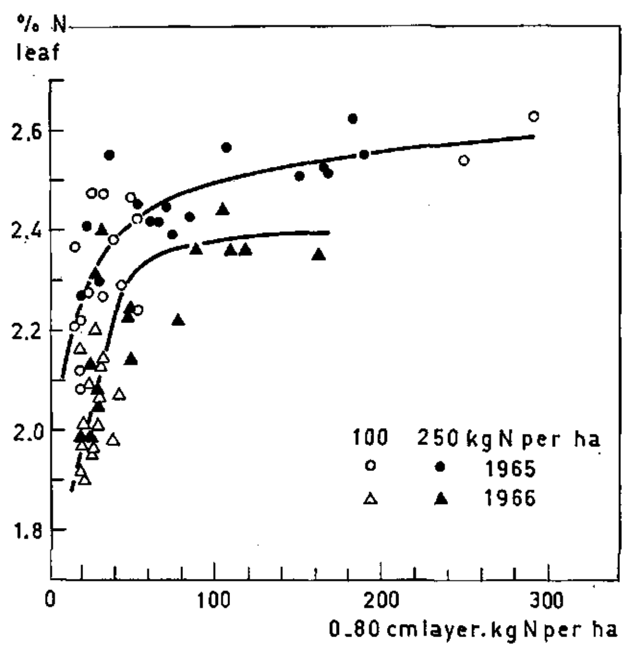

Fig. 2. Relation between the nitrogen percentage in the leaves of Golden Delicious apples in July and the nitrate-nitrogen concentration in the 0-80 cm soil layer expressed as kg N/ha. The soil was sampled 31 May (1965) and 25 July (1966). The two plots represented by the two open dots at the extreme right of the upper curve have probably erroneously been fertilized twice (100+250 kg N/ha). Grass orchard, Heijningen. Experiment with nitrogen dressings applied at different dates.

enon is, that the production of organic matter more in particular mulching of the grass, adds a secondary nitrogen source to the soil, that becomes more important the more grass has been produced. The release of nitrogen from accumulated organic matter may reach such a level that the need for fertilizer nitrogen decreases with 100-150 kg N/ha as compared with a young sod. Removing of the grass consequently means aggravation and continuation of the competitive effect of the sod [9]. On the other hand promoting the grass production by heavy nitrogen dressings in the first years accelerates the decrease in competition [1, 10].
Cattle grazing as practised in the old orchards with standard trees will more or less have the same effect as removing of the grass. However, in the modern orchard with grass strips too, the grass is removed: mowing with a rotary mower, as is usually practised, means removing the mulch from the grass strips and placing it for the greater part on the clean cultivated tree strips.

(2) The grass growth and consequently the uptake of nitrogen may be strongly influenced by conditions such as moisture supply, light intensity as affected by the age and the plant distance of the trees, and to a certain extent the time of the nitrogen fertilization.

(3) Great differences in nitrogen competition are related to the plant species in the sod. Under practical circumstances a grass sward is often obtained from a natural weed vegetation. Apart from many weeds such a sod often contains annual meadowgrass *(Poa annua)* or smooth-stalked meadowgrass *(Poa pratensis)*. These grasses are relatively weakly competitive. Sometimes however the very harmful couchgrass *(Triticum repens)* dominates. An impression of differences in nitrogen competition exercised by a few grass species is given in Fig. 3. Seven grasses were sown in two rows of young James Grieve apples in 1965. In the next spring when all the swards had fully developed, a moderate nitrogen dressing of 120 kg N/ha was given. This quantity enabled an equal start of the leaf colour in the early season, but during the summer differences in nitrogen uptake between the grass species were reflected by the leaf colour of the trees. A certain quantity of nitrogen must have been released by the soil organic matter (2%), since other experiments in the same, but clean cultivated soil showed almost no response to nitrogen fertilization.
From Fig. 3 it can be concluded that rough-stalked meadowgrass *(Poa trivialis)* has to be considered as weakly competitive. Moderately competitive are thimothy *(Phleum pratense)*, smooth-stalked meadowgrass *(Poa pratensis)* and bent (browntop, *Agrostis tenuis)*. A strong competition is experienced by perennial ryegrass *(Lolium perenne)*, meadow fescue

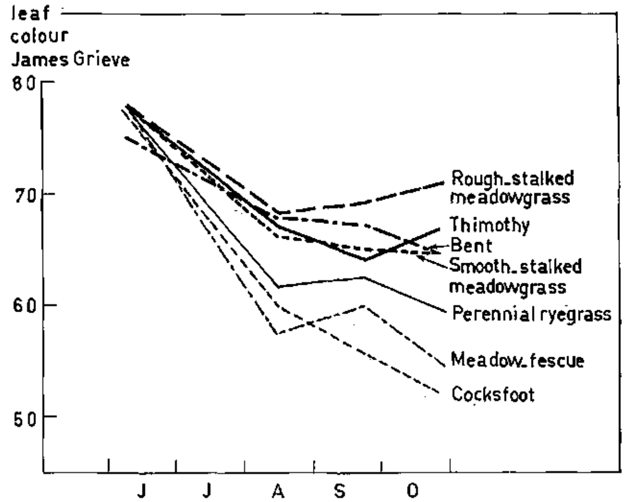

Fig. 3. Leaf colours of four years old James Grieve (Lired) apples on rootstock MM 106 in a complete cover of different grass species. Fertilization on 14 March 120 kg N/ha.

(Festuca pratensis) and cocksfoot *(Dactylis glomerata)*.
Not shown by the graph but from a fruit nutrition point of view not unimportant is the fact that interactions exist between competition and the time of the year. In the spring, for instance, perennial ryegrass is more competitive than cocksfoot, whereas in the summer cocksfoot is more competitive than perennial ryegrass.
Finally it should be mentioned that under conditions of a moderate nitrogen fertilization the presence of clover in the sod may substantially contribute to the nirogen supply of fruit trees.

Nitrogen uptake in a soil with a partial grass cover

The preceding discussion on the nitrogen competition by grass only dealt with fruit trees in a complete sward. The question now arises to which extent this competition will be experienced by trees where the soil is only partly covered with grass. Due to the common use of chemical weed control this situation occurs in the majority of modern fruit plantations in the Netherlands.
Where grass strips are applied, it may be assumed that removing the mulch from the grass strips by a rotary mower and applying moderate, only one-time nitrogen dressings, will lead to a soil under the grass strips that is relatively poor in nitrogen. On the other

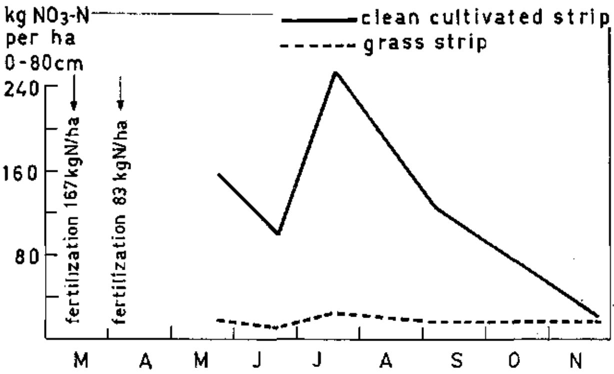

Fig. 4. Nitrate nitrogen in the 0-80 cm soil layer expressed as kg N/ha under a clean-cultivated and a grass strip, both fertilized with 250 kg N/ha. Soil management experiment, plots 6+16, Wilhelminadorp, 1960.

hand, fertilization, mineralization of nitrogen from soil organic matter, mulching and the absence of competition will result in tree strips where the soil is markedly rich in nitrogen. This difference is demonstrated by Fig. 4 in which nitrate-nitrogen quantities in a 0-80 cm soil layer are given both for the clean cultivated and for the grass strips of plots fertilized with 250 kg N/ha.

In the same fertilizer experiment three nitrogen dressings of 62.5, 125 and 250 kg N/ha were broadcast on plots with three different systems of soil management: a clean cultivated soil, grass strips (50% grass) and a complete grass cover. The grass-mixture (containing mainly perennial ryegrass) was sown in 1959, the nitrogen dressings and the leaf nitrogen percentages refer to 1960. The two apple varieties Golden Delicious and Cox's Orange Pippin on rootstock M IX were five years old. Leaf sampling was carried out on 22 June, 21 July and 30 August. In

Table II. **The influence of two nitrogen dressings applied to three soil management systems on the leaf nitrogen percentage of two apple varieties. Soil management experiment, Wilhelminadorp, 1960.**

Soil management system	Golden Delicious kg N/ha		Cox's Orange Pippin kg N/ha	
	62.5	250.0	62.5	250.0
clean cultivation	2.30	2.33	2.37	2.41
grass strips	2.33	2.39	2.27	2.35
grass	1.91	2.14	1.88	2.01

Table II the effect of the lowest and the highest nitrogen dressing on the average nitrogen percentages in the leaves is given. From these data it becomes obvious that on the plots with grass strips, the response of the trees to a higher nitrogen dressing is only weak and much more similar to the response on the clean cultivated plots than on the grass plots. Since it must be assumed that the trees already had many roots under the grass strips, the row distance being 4, the width of the strips 2 m, it seems that the lack of available nitrogen in the soil under the grass was compensated by uptake of nitrogen from the clean cultivated strips.

The phenomenon that plants may provide for their nutrient needs by uptake from only a part of the root zone is known from the application of fertilizer placement. A physical theory on this subject has been given by De Wit [12]. The same principle may underly the response of fruit trees to nitrogen fertilization in an orchard with grass strips. To investigate the importance of nitrogen, available in only a part of the root zone, the following experiment has been carried out.

Young Conference pears on rootstock quince A were planted in the spring of 1963. The soil, a shallow marine silty clay loam, was clean cultivated until 1965. Smooth-stalked meadowgrass was sown in March 1965. A complete sward had developed by the end of the growing season of 1965. In 1966 no nitrogen was given but on 16 March a part of the young sod was superficially dug under. After that, this part of the soil was chemically clean-weeded. The area of the clean-weeded soil varied as indicated in Fig. 5. There were fourteen treatments according to three systems: discs of clean-weeded soil around the tree, increasing in size from 0-12.6 m^2, rings of clean-weeded soil starting at 200 cm from the stem and with decreasing inner radius and sectors of clean-weeded soil with a radius of 200 cm. The clean-weeded soil has to be considered as the only nitrogen source for the trees, since the young grass was not fertilized and consequently strongly competitive. The moderate quantity of nitrogen available in the clean-weeded part of the soil originated from mineralization of soil organic matter and of the young sod that was worked under.

The treatments comprised only three replicates of single trees. The system of clean-weeded rings of soil with decreasing inner radius was applied to enable an estimation of the horizontal extension of the tree roots.

Soon after leafing the trees showed distinct differences in leaf colour that were related to the treatments. Nitrogen percentages in leaves sampled during the summer ranged from 1.32 to 1.84% N, and were in accordance with colour differences. The percentages were low because the experiment was carried out without nitrogen fertilization and the trees were non-bearing. The relation between the leaf colour at

the end of the summer and the treatments is given in Fig. 6.
It should be kept in mind that this relation is also influenced by the horizontal extension of the tree roots in the course of the summer.
From the data referring to the clean-weeded rings, e.g., it can be concluded that a decrease of the inner radius from 187 to 142 cm is not attended with a distinct response of the trees whereas a further decrease to 100 cm from the stem gives a much darker leaf colour. This means that a clean-weeded ring up to 100 cm overlaps an important part of the root zone

Fig. 5. Scheme of an experiment with four years old Conference pears. The clean-weeded part of the soil is indicated by hatching. The rest of the soil around the trees is covered by unfertilized smooth-stalked meadow grass. The estimated horizontal extension of the tree roots at the end of the growing season of 1966 is indicated in the leftmost figure. Experiment Wilhelminadorp.

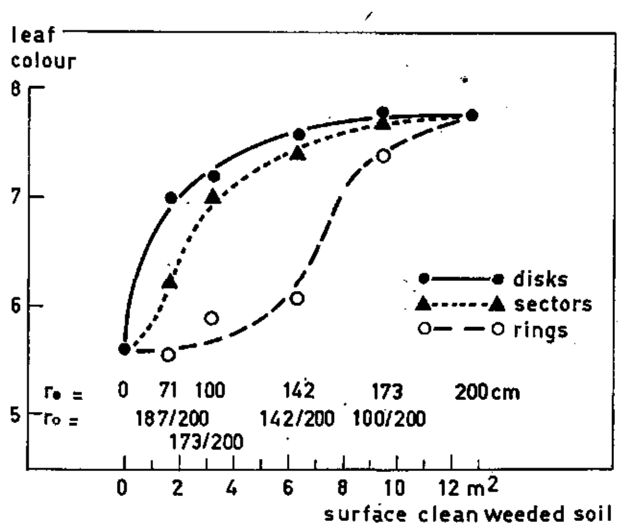

Fig. 6. Leaf colour of unfertilized Conference pears in grass on 16 September as influenced by size and shape of clean weeded area; r = radius of clean-weeded surface in cm from tree.

whereas a ring up to 142 cm hardly overlaps the roots. For further calculations therefore it was assumed that at the end of the growing season the extension of tree roots active in nitrogen uptake was 150 cm and the area of the rooted zon 7.1 m^2.

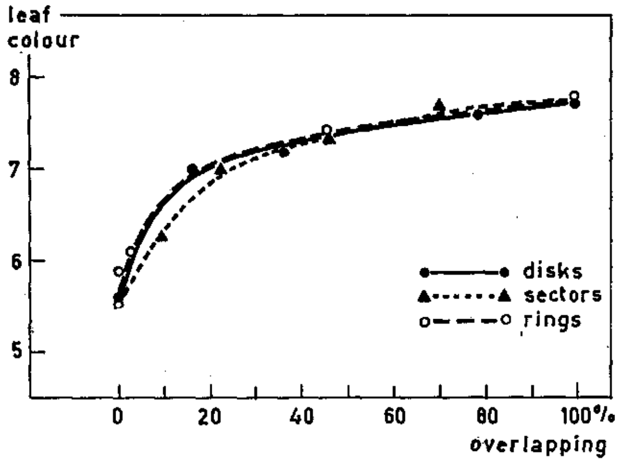

Fig. 7. Leaf colour of unfertilizer Conference pears as related to degree of overlapping of the root-zone by clean-weeded soil (cf Fig. 5 and 6).

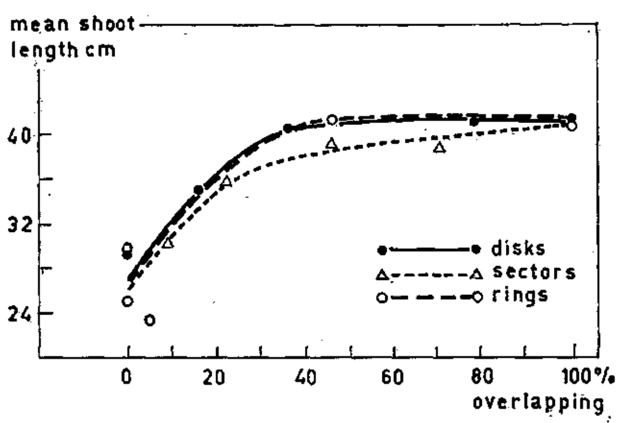

Fig. 8. The relation indicated in Fig. 7 for the mean shoot length.

From the curves in Fig. 6 referring to the system of disks and sectors it can be further concluded that already a relative small surface of unfertilized soil without competition has a strong effect, 1-2 m^2 giving an almost normal leaf colour. From the estimated extension of the pear roots and assuming that the fringe-effect of the nitrogen competition reaches up to 10 cm from the border of the grass, the relative overlapping of the roots by clean-weeded soil was calculated for the different treatments. In Fig. 7 the relation between the leaf colour and in Fig. 8 between the mean shootlength and the overlapping by soil without competition is given.

Although with disks and rings the improvement of the leaf colour increases with increasing overlapping, the transition from 50-100% has only a very small effect on the leaf colour and no effect on the mean length of the shoots. The curves for the clean-weeded disks and rings practically coincide and suggest that it makes little difference whether the overlapping refers to the central or peripheral part of the root zone. Root studies have not been carried out yet and therefore no conclusions relating to the distribution of small feeding roots within the rooted area can be drawn. From the slight deviation of the curve for the clean-weeded sectors from the two other curves, however, it may be concluded that the shape of the overlapping zone has some influence on the response of the trees. A circular overlapping has more effect than a sectorial overlapping. This difference no doubt has to be attributed to the radial character of the root growth. With clean-weeded sectors certain main roots including all their lateral ramifications will not profit from the nitrogen supply in the clean-weeded part of the soil and therefore the corresponding part of the tree crown will not respond to the possibility for nitrogen uptake. Indeed with the system of clean-weeded sectors differences in leaf colour within the tree crown were observed, the part corresponding to the clean-weeded area showing a darker colour than the part turned to the grass area.

The data presented by this experiment give rise to some provisional conclusions that are valuable for the interpretation of fertilization practices. With the system of grass strips where approximately 50% of the surface is occupied by grass, the quantity of nitrogen available under the grass and consequently the fertilization and the nature (grass species) of the sod is of little importance for the nitrogen uptake of the fruit tree as long as the nitrogen supply in the soil of the tree strips is adequate. Under practical circumstances of fertilization and management in orchards with grass strips this condition seems to be satisfied in the majority of cases. This judgement, however, only refers to the nitrogen supply but does not at all justify neglect of the fertilization of the grass strips. Little is known yet of the behaviour of the root system. If, under conditions of a too moderate fertilization of the grass strips, the root growth would remain more or less restricted to the tree strips, this would result in a limitation of the moisture supply in dry periods. On this aspect of grass strip fertilization much research still has to be done.

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