Distribution and re-distribution of dry matter in perennial fodder crops[1]

A. SONNEVELD

Institute for Biological and Chemical Research on Field Crops and Herbage, Wageningen, Netherlands

Summary

Although a closed green cover is present with perennial fodder crops almost during the whole growing season, the actual yield is considerably lower than that potentially possible, especially later in the season.

In autumn reserves are accumulated in the parts which cannot be harvested (roots, stubble). In spring these reserves are used for the formation of a new assimilation system and, consequently, can be harvested then. As growing conditions as a rule are favourable at that time, rather high yields may be gained in that part of the season. At each harvest the plants are deprived of their assimilation system, which is reconstructed as soon as possible with the help of the reserves still present or those formed in the meantime.

Meanwhile, however, an amount of sun energy has been lost to the plant, which reduces the yield. Too frequently harvesting exhausts the plants. In late summer and autumn new reserves are accumulated in those parts which remain alive during winter. Consequently, a part of the assimilates stored cannot be harvested.

As certain differences exist between various plant species, the course of matters with three crops, *viz.* grass, lucerne and red clover, are treated more extensively.

1. Introduction

Fodder crops, as is indicated by the word, form a group of crops the green parts of which, and consequently the assimilation system, are regularly harvested for feeding cattle, either as a fresh product or after preservation. The perennial habit implies that during the whole growing season a more or less closed green cover is present in the field. Harvesting, however, causes interruptions and the treatise of the consequences of these interruptions forms an important part of this paper.

2. Potential and actual production

DE WIT (1959) described a method for the calculation of the potential rate of photosynthesis from the incoming radiation. ALBERDA and DE WIT (1961) used this method for calculating the potential dry-matter increase (production) of a grass sward, green and closed during the whole growing season. FIG. 1 shows the results. The potential dry-matter increase being high already in early spring, still increases afterwards, but begins to decrease in July already and finally falls at a rapid rate in autumn. It should be taken into account that this curve is based on the weather conditions and the corresponding radiation in a certain year. The line, however, does roughly indi-

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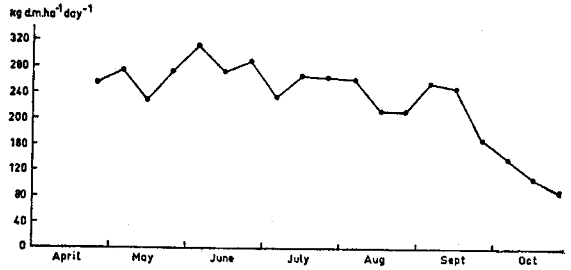


FIG. 1.
The potential production of a sward, closed and green during the whole growing season, calculated for the Netherlands and 1960 (After ALBERDA and DE WIT, 1961)

cate what is to be expected every year at our degree of latitude. Only the detailed trend may vary from year to year.

The trend of the dry-matter increment actually measured is different, and especially when only the harvested parts are taken into account. In the first place a considerable part of the dry matter formed is transported to the underground parts. These parts easily escape attention in fodder crops, as they are not harvested. Moreover, another part, the stubble, remains on the field after harvest. As will be shown later, this part of the plant should certainly not be left out of consideration. To illustrate what is actually harvested some data on a few crops are summarized in FIGS. 2, 3 and 4.

FIG. 2. Average growth curves of grasslands in different parts of the Netherlands for the years 1946—1958 (After VAN STEENBERGEN, 1961)

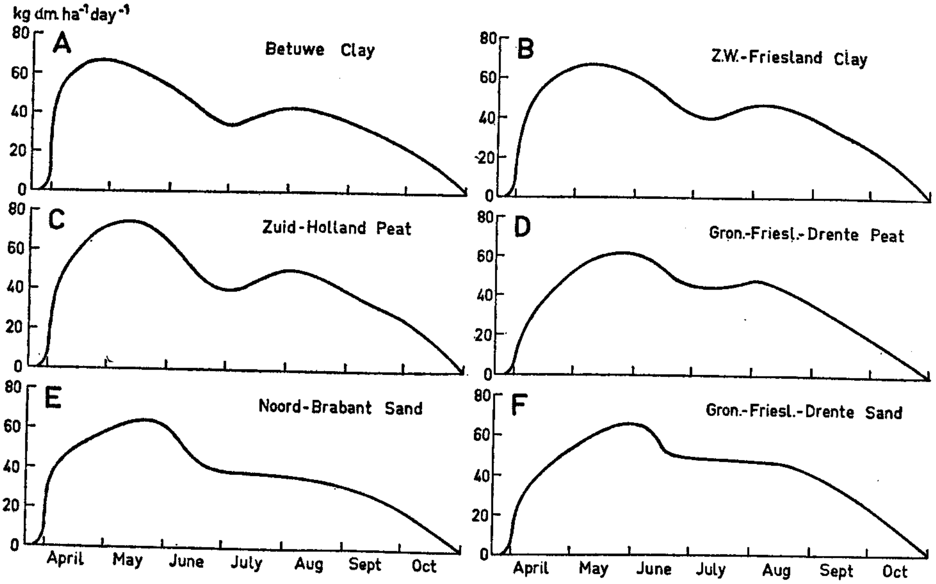


FIG. 2 has been taken from VAN STEENBERGEN (1961) and shows the yields on dry matter of grassland in various parts of the Netherlands averaged over 13 years, this grassland being subjected to standardized treatment and fertilization. The amount of dry matter harvested lags considerably behind that potentially possible. The lines roughly show an accelerated decrease and a more irregular trend with an obvious depression in early summer. Some data taken from MEYERS (1936) on lucerne are

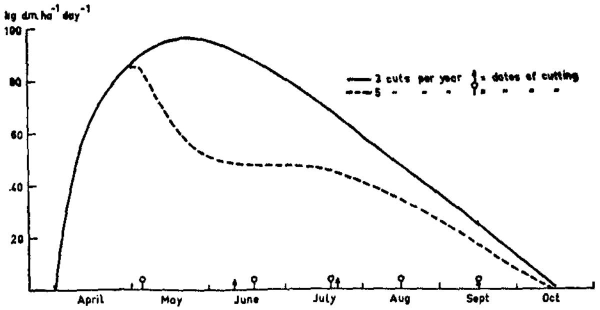
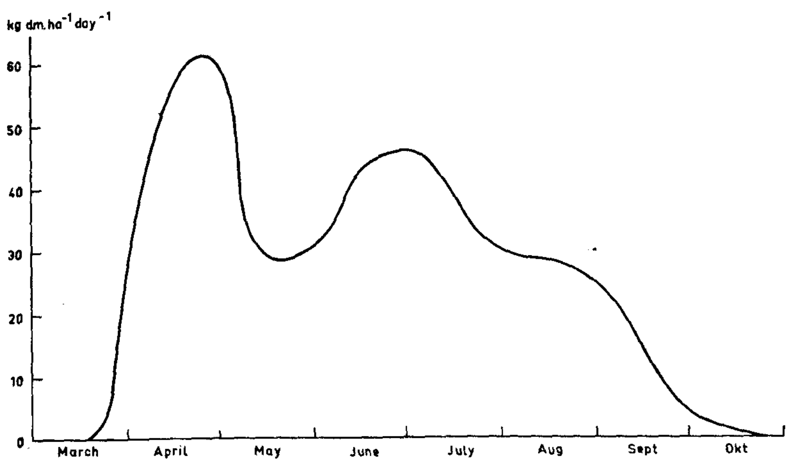


FIG. 3.
Growth curves of lucerne in the Netherlands with 3 or 5 cuts per year (After MEYERS, 1936)

FIG. 4. Growth curve of red clover in the Netherlands in 1952



summarized in FIG. 3. Here too the decrease in the daily dry-matter increase is much more rapid in the course of the season than could be expected when considering FIG. 1. Apparently, it makes a great difference whether the crop is cut three or five times annually. Finally, FIG. 4 reflects the trend in the daily dry-matter increase of *red clover* as it was found on an experimental field in 1952. Here the dry-matter increase was accurately determined with a great number of grass and clover species and mixtures of these. The sharp fall in the second part of May was caused by intensive drought and night frosts. Leaving this period with a low dry-matter increase out of consideration, also with red clover, in general, a more accelerated decrease in conformity with FIG. 1 is found. It is most striking that in grassland as well as in lucerne and red clover the rate of increase in dry matter obtained is greatly accelerated in spring when growth has started and extremely high values are reached soon. Similar values cannot be observed anymore later in the season.

3. Dry-matter increment in spring

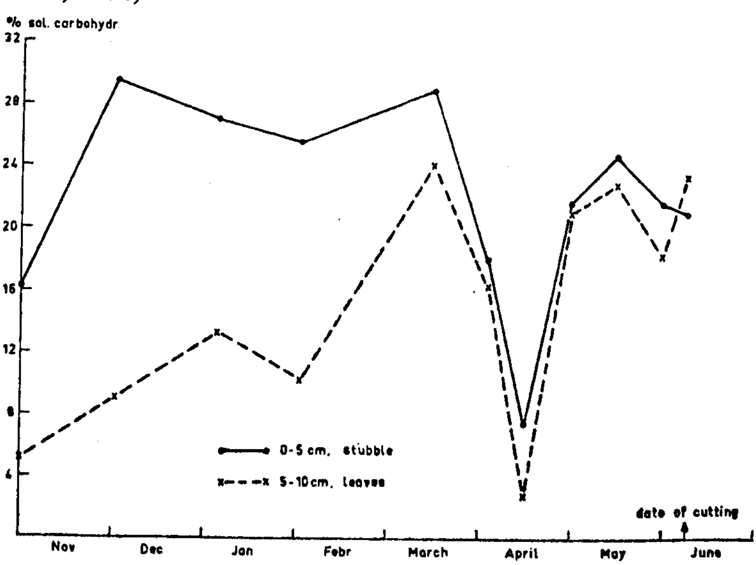
In spring a very rapid growth may be observed. Due to the higher temperature the rate of cell division and elongation increases. The reserves of carbohydrates accumulated in the hibernating parts enable a favourable supply with energy. Since at

that time the availability of water and ions (suitable fertilization) is optimal and root activity rather intensive, the supply with these essentials is guaranteed.
As a consequence, the formation of a new assimilating system or the rapid development of such a system already present is possible. Since radiation intensity and duration increase also, a high level of dry-matter production may be obtained. Certain differences, however, exist between the various crops. In the following the course of matters will be examined more closely for three crops.

3.1. Grassland

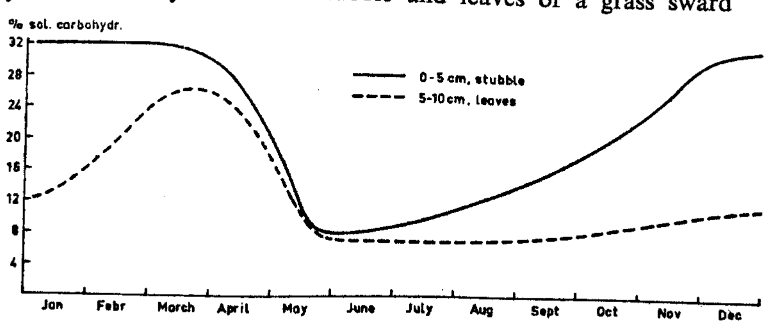
Although many grass species occur in the Netherlands only a few species have been investigated more intensively. Most is known about perennial rye-grass. It appeared that as far as the following is concerned interspecific differences exist. For all is known at present, however, these especially differ merely in degree and the general trend is more or less the same.
With reference to matters mentioned before the behaviour of the reserves in autumn, winter and spring is of first importance. In FIG. 5 some data taken from ALBERDA (1955, 1956) are summarized.
In late autumn the content of reserves in the overground parts which mainly consist of carbohydrates soluble in water (poly-saccharides) increases at a rapid rate in perennial rye-grass as well as in many other grasses. This occurs mainly in the lower 5 cm which, as a rule, remain on the field after harvest and, therefore, are called the stubble. However, the reserves also increase in the higher situated green parts. From laboratory experiments obvious indications were obtained that the same also happens in the roots. Determination on the field of the latter is difficult because grass roots can hardly or not at all be secured in a completely clean state. The green assimilating parts largely remain in a good state during autumn and winter. Although incoming radiation at that part of the year is slight and, conse-

FIG. 5. Percentage of soluble carbohydrates during winter and spring in the dry matter of stubble and leaves of a sward of perennial ryegrass (After ALBERDA, 1955, 1956)



quently, relatively little energy is recieved, assimiliation continues at a low level. Owing to the low temperature, growth and root activity and, accordingly, uptake of water and ions goes on at a still lower level. Therefore, the assimilates for the greater part cannot be used for growth and are accumulated as reserves. Dependent on the weather conditions in winter, however, now and again a little will be used, because the temperature allows some growth even then. As the various grass species make different demands on temperature, these fluctuations in the content of reserves are a little larger with one species than with another. In general, however, it may be said that the large reserves accumulated during late autumn and early winter are not consumed during winter. However, as soon as the temperature rises in spring the reserves are transported to higher situated parts in the plant and their amount decreases rapidly. The decrease in FIG. 5 is very rapid and considerable. This is the result of a very favourable growing period in the beginning of April that was followed by a period of cold and bleak weather as a result of which growth almost stopped again. In the meantime, the days grew longer and the sun's altitude was rather high, so that incoming radiation was fairly high. Consequently, the plant started to form reserves again with assimilates which could not be used for growth owing to weather conditions. Such a trend is not usual. When the change-over from winter to summer is normal and more gradual, the reserves are also used more gradually and are not accumulated again to such a large extent. A more normal trend has been schematically recorded in FIG. 6. Dependent on weather conditions the actual trend from year to year will deviate from these schematic lines. However, important is that the reserves accumulated during autumn and kept at a high level during winter are used in spring for the formation of a new assimilation system by a more or less vigorous growth as a preamble to the supreme effort consisting of the formation of flowering culms and inflorescences.

FIG. 6. Schematic curves of the percentage of soluble carbohydrates over the whole year in the dry matter of stubble and leaves of a grass sward



3.2. Lucerne

The growth of the overground parts of lucerne also stops in the course of autumn. Similar to developments with grasses, the green parts of lucerne continue assimilation. Here too the assimilates which cannot be used for growth anymore are stored as reserves. Accumulation mainly takes place in the hibernating roots and, beside these also in the crown buds which develop in the ground in autumn. These buds remain there during winter, emerge in spring and thus giving a fresh appearance to the lucerne crop. Contrary to what happens with most grasses, the old assimilation system of lucerne dies in late autumn and winter.

The data in FIG. 7 which have been taken from GRANDFIELD (1943), show the trend of the reserves in roots and crown buds. It is most striking that the total carbohydrate content in the roots already decreases in late autumn and early winter while it continues to increase in the crown buds; reserves are transported from the roots to the buds. The plant is already preparing for the growth effort to be made in spring: developing a new assimilation system as soon as possible when temperature rises to such an height that growth is possible.

Interesting, though of minor importance in this connection, is the transformation of starch into sugars in the course of the winter. This raises the resistance of the plant to severe frost.

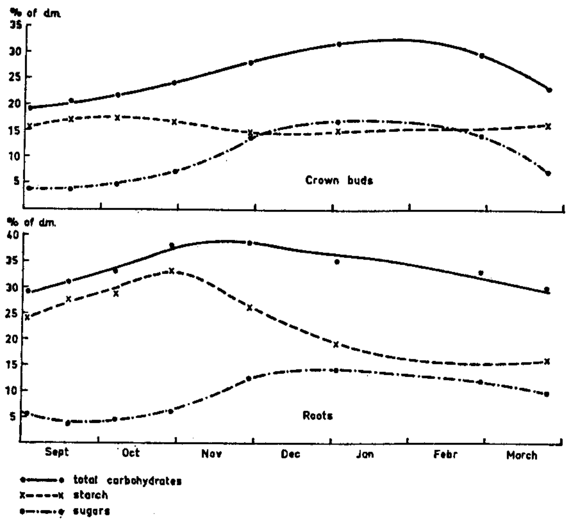


FIG. 7.
Total carbohydrates, starch and sugars as percentages of dry matter in crown buds and roots of lucerne during autumn and winter (After GRANDFIELD, 1943)

FIG. 8, composed from data taken from GRABER *et al.* (1927), shows that when growth is possible in spring, the reserves in the roots are depleted soon. When a sufficiently large assimilation system has been formed these reserves are restored again. This will be referred to later.

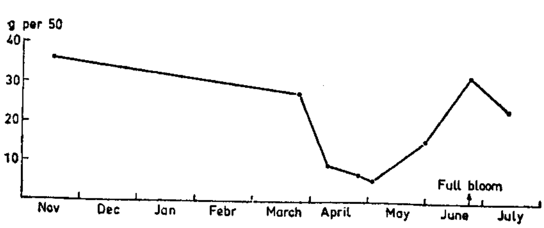
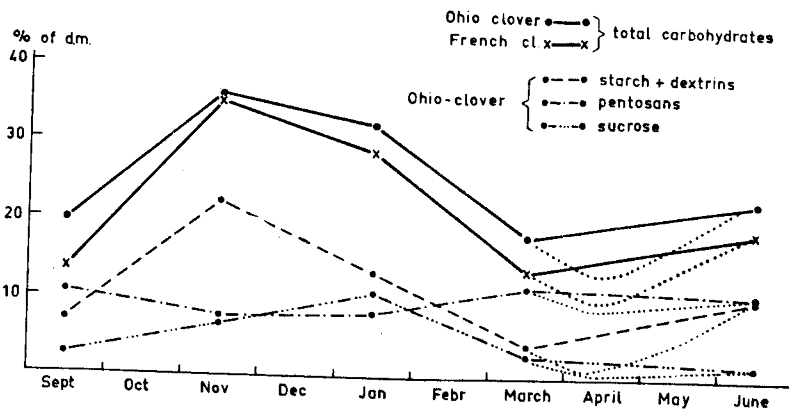


FIG. 8.
Total amount of available carbohydrates in the roots of lucerne during winter and spring (After GRABER a.o., 1927)

3.3. Red clover

Similar to lucerne the red clover also stores reserves in the roots in autumn. This can be seen from FIG. 9 which has been composed of data taken from GREATHOUSE and STUART (1936) who worked with clovers from two origins: one from Ohio (U.S.A.) and one from France. The reserves in the clover from French origin appeared to remain constantly on a lower level than those of the clover from Ohio. This was not only the case with the content of total carbohydrates but also with the various

FIG. 9. Total carbohydrates, starch and dextrins, pentosans and sucrose as percentages of dry matter in the roots of red clover between September and June (After GREATHOUSE and STUART, 1936)



substances composing the reserves. This trend has not been indicated in the figure for the French clover in order to prevent confusion. Also with red clover a decrease in total carbohydrates as well as the starchy part and the dextrins may be observed from November onwards. On the other hand, and similar to developments in lucerne, also in the clovers the sugar content (sucrose) continues to rise until a later moment. An obvious difference with lucerne, however, is that the content of total carbohydrates in red clover decreases more rapidly in the course of winter than with lucerne. This has been found by various investigators and seems to be a principal difference in both plants. SMITH (1950) assumes that red clover maintains a relatively high metabolic activity during the rest period in winter. Moreover, SMITH surmises that this might be the cause of the slighter hardiness and the decreased resistance to diseases of red clover during winter.

As appears from FIG. 9, GREATHOUSE and STUART unfortunately did not take any samples between half March and half June. If they would have done so, they would probably have found a trend as indicated by the dotted lines. This appears among others from the research of SMITH (1950), who did not take samples in winter but at various dates in spring. Some of his results have been summarized in FIG. 10. Also with red clover it appears that in the period that the new assimilation system is developed, *i.e.* in early spring, the reserves in the roots are depleted to a very low level, while with this species these are restored again as soon as the assimilating parts start their work.

Summarizing, it may be said that with grassland as well as perennial fodder crops, such as lucerne and red clover, considerable reserves are accumulated in the stubble and/or roots during autumn and in early winter. Depending on the species, these are not or only for a small part consumed during winter. In late winter and early spring the reserves gradually and partly are transported to those parts which provide the new assimilation system. When temperature rises to such a height that growth is possible, the greater part of the reserves are used to stimulate a vigorous development of the fresh assimilating organs. This is necessary within a short time in order to enable the plant to produce culms and inflorescences, in other words, to enable

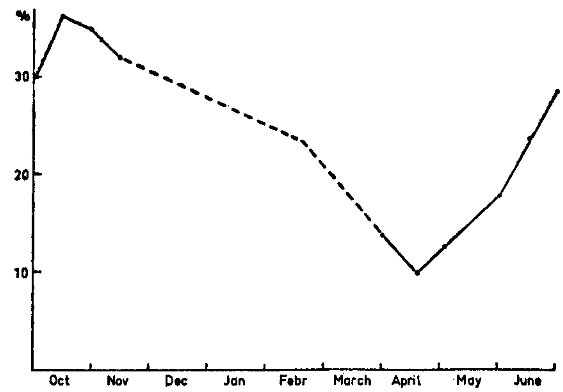
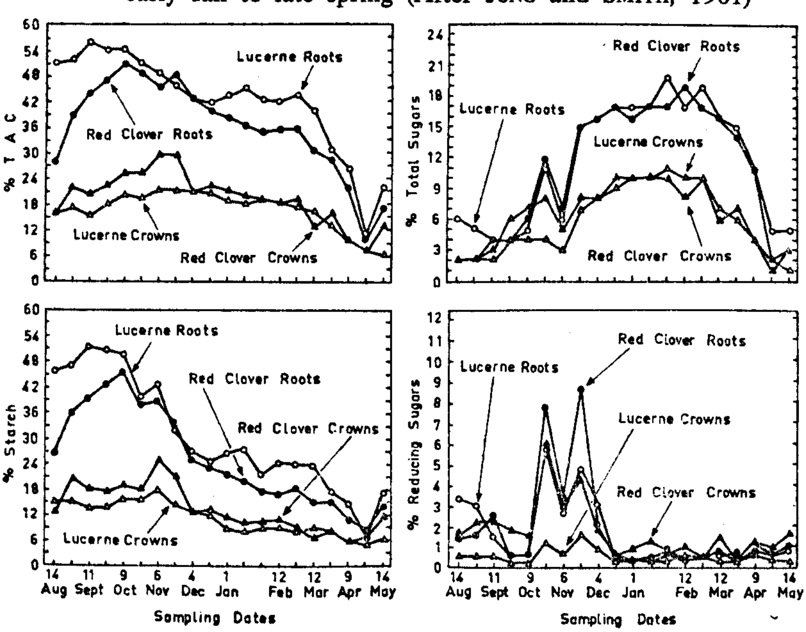


FIG. 10.
Total available carbohydrates as percentage of dry matter in the roots of red clover (After SMITH, 1950)

the plant to form its generative parts in time. Consequently, considerable amounts of dry matter are transported to the underground parts in autumn and are transported again to the overground parts in late winter and early spring. A confirmation and summary of the facts above mentioned may also be found in FIG. 11, which has been taken from a recent publication of JUNG and SMITH (1961).

FIG. 11. Total available carbohydrates, starch, total sugars and reducing sugars as percentages of dry matter in lucerne and red clover roots and crowns from early fall to late spring (After JUNG and SMITH, 1961)



4. Distribution of dry matter in the growing season

4.1. Grasses

In FIGS. 5 and 6 it was shown already that after the sharp decrease in the reserves of grasses during the beginning of regrowth a gradual increase occurs specially in the stubble. The farmer, however, does not leave the grass to undisturbed growth but cuts it for silage or hay or allows cattle to crop it. When it is mown, the green parts are removed completely and the plant has to develop a new assimilation system. This is done with the aid of the reserves in stubble and root. As has been proved by ALBERDA (1957) in experiments in the phytotron, the formation of new tillers is stopped immediately after mowing. Under the conditions of ALBERDA's experiments tiller formation only after 5 weeks started again to make up arrears at an accelerated rate. One thing and another have been summarized in FIG. 12.

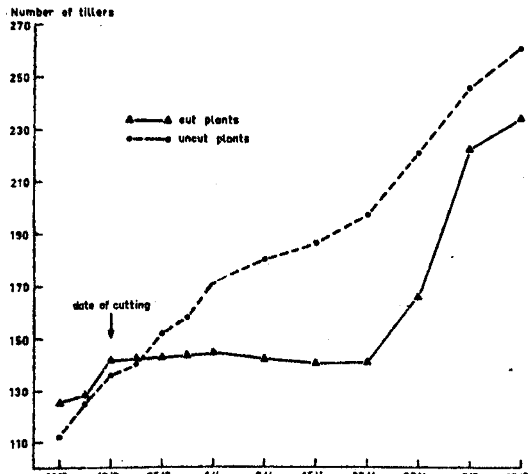


FIG. 12.
The number of tillers on uncut and cut plants of perennial ryegrass (After ALBERDA, 1957)

The number of tillers plays an important part in the life cycle of grasses. Soon after growth has started in spring new tillers are formed. As soon as the flowering culms start elongation, however, similar to cereals new tiller formation stops and a part of the tillers present is even emptied and spent. The data in the TABLE show this. These data have been derived from own research on the growing of red fescue for seed.

The total number of sterile tillers and culms at harvesting was considerably lower than on March 11 and, with most treatments, even lower than on November 28 of the previous year. The treatments are less important in this connection and concern diverging amounts of nitrogen which were applied at different times.

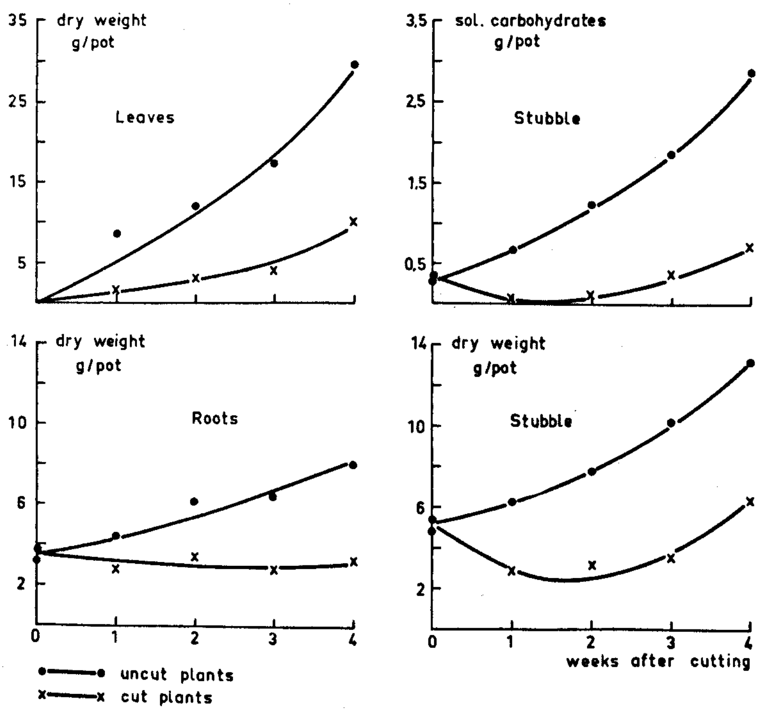
At culm formation, accordingly, dry matter is transported from near the soil to the flowering culms which are easy to harvest. When a shooting crop is harvested, consequently, less dry matter remains in the stubble. On one side this is favourable for a high yield, but on the other side it is unfavourable for the crop, because to the plant deprived of its assimilation system less reserves are left. The later a plant shoots, the more time there will be available beforehand for the formation of new tillers, resulting in more tillers present at mowing time and, accordingly, more reserves remain after mowing. When crops are mown in the shooting stage, a crop having started its shooting late as a rule will recover better than a crop shooted early unless it is cut very late; by then a great many tillers of the late shooting crop may have been destroyed by light deficiency.

As has been mentioned before, the reserves in a plant play a great part in the

TABLE. Number of tillers on plants of *red fescue* at different dates

Treatment	Number of tillers per plant		Harvest July 1957		
	28. XI, 1956	11. III, 1957	Number of culms	Number of sterile tillers	Total per plant
a	64	77	31	23	54
b	91	104	58	25	83
c	103	128	47	32	79
d	125	127	68	31	99
e	103	128	65	22	87
f	98	135	52	30	82
g	64	77	40	29	70

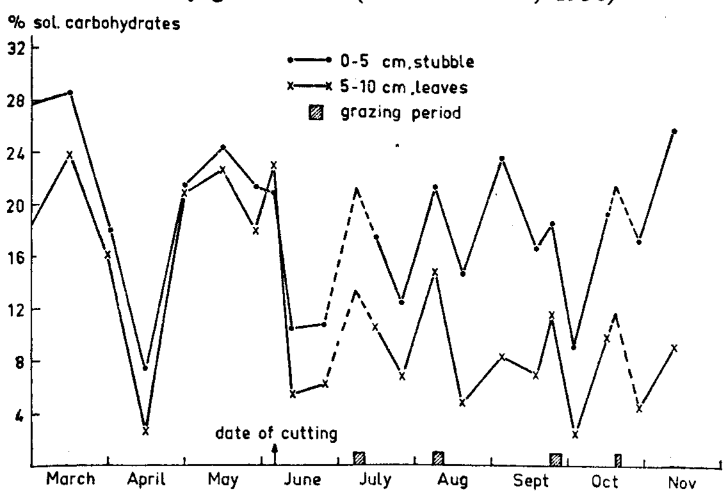
FIG. 13. Dry weight of leaves, stubble and roots and amount of soluble carbohydrates in the stubble of uncut and cut plants of perennial ryegrass (After ALBERDA, 1957)



recovery after removal of the assimilation system. Much research was also carried out on this subject among others by ALBERDA (1957). FIG. 13 reflects some of his results. The amount of new leaves increased again immediately after cutting, but to a much lower degree than with uncut plants. The assimilation system is reconstructed at the expense of the reserves in root and stubble. The soluble carbohydrates in the stubble are almost completely consumed with the result that the stubble weight is decreased. The root weight too has a tendency to decrease. Only after three weeks approximately the reserves begin to recover.

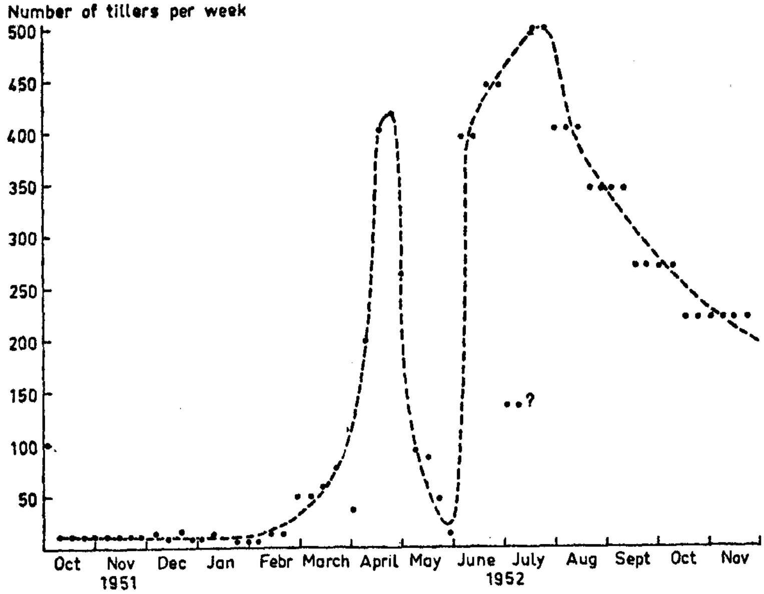
The fact that this process does not only occur in laboratory experiments is proved by FIG. 14, which reflects the results of a field experiment of ALBERDA (1956). This fig. corresponds with FIG. 5. In relation to the latter figure the accelerated decrease in April and the subsequent abnormal increase in the carbohydrate content, as a result of drought and much depressed growth, has already been mentioned. After cuttings and grazings distinct decreases in the reserves occur. Dry matter from the roots and especially from the stubble are transported and transformed in fresh leaves which initially have a low content of soluble carbohydrates. Thereafter, the content gradually rises again in all parts of the plant. The observation that the decrease is less considerable after grazing than after cutting, is due to the fact that many green parts, as a rule, are left behind after grazing. These enable assimilation which is not the case with the stubble remaining behind after cutting. It is self-evident that too frequent grazing and, especially, mowing will finally lead to exhaustion. Besides fluctuations due to cutting and grazing, also fluctuations occur as a result of changes

FIG. 14. Soluble carbohydrates as percentage of dry matter in the leaves and stubble of a perennial ryegrass sward (After ALBERDA, 1956)



in growing conditions. Favourable weather conditions of adequate moisture supply and optimal temperatures cause decreases, in other words, dry matter is transported from the stubble and the roots to the higher parts of the plant which can be harvested. Liberal ion supply has the same effect, for instance N-fertilization. BROUWER (1962) has indicated the influence of the nitrogen supply on the sprout/root-ratio and, consequently, also the relation between the parts which are to be harvested and those which are not. Previously, the formation of fresh tillers has been mentioned already. Also in other regards the number of tillers is important, especially to the farmer. For in the new tiller formation in grasses a cyclic trend can be observed. A picture of this is given by FIG. 15, composed of data of LANGER (1956). It refers to observations on separate plants of timothy S 48, a pasture type. A large number of new tillers was still formed in early spring by young plants. In May, however, during the shooting of the plants the new tiller formation nearly stopped. As has previously been mentioned, at that time even many tillers are spent. This

FIG. 15. Number of newly formed tillers per week on 100 plants of timothy, sown in September 1951 (After LANGER, 1956)



is not shown in the figure as it only deals with new tillers. From June onwards many new tillers are formed again and this process continues until far in autumn.

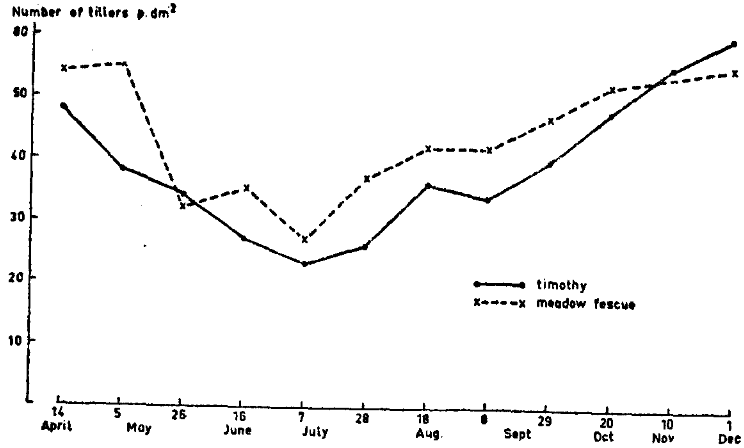
In an established sward the trend of the tiller formation per surface area is of more practical importance. This is shown by FIG. 16, the data of which have been taken from another research by LANGER (1958).

There is an obvious decrease in the number of tillers in late spring during the time that a small part of the tillers succeeds in forming a flowering culm. Dry matter is transported from stubble and roots to those parts which can be harvested easily, *viz.* the flowering culms, the leaves there on and the inflorescences. The tillers which have formed an inflorescence die afterwards even when the culm is removed before flowering or ripening of the seed. The decrease in the tiller number continues until July. During the flowering of the shooting tillers, the formation of new tillers already starts again and continues until the late autumn. As for the distribution of dry matter, this processus in autumn is the reverse of that in spring.

The new tillers have a relatively small size and the stubble which cannot be harvested forms a relatively large part, moreover, each new tiller forms its own roots and the dry matter accumulated therein can neither be harvested. As in the meantime also a period of the year has begun with decreased incoming radiation (shorter days, lower altitude of the sun), it is not surprising that in summer and early autumn less dry matter can be harvested than in spring.

FIG. 16 relates to a field which was not mown. When mowing or grazing does take place, the trend of the new tiller formation will be more irregular as, after each cut or grazing period, new tiller formation stops in order to enable the plant to form a new assimilation system and new reserves. It has already been mentioned before (FIG. 12) that, once the formation of new tillers has started, it proceeds at an accelerated rate.

FIG. 16. Number of tillers present per dm² in swards of timothy and meadow fescue (After LANGER, 1958)



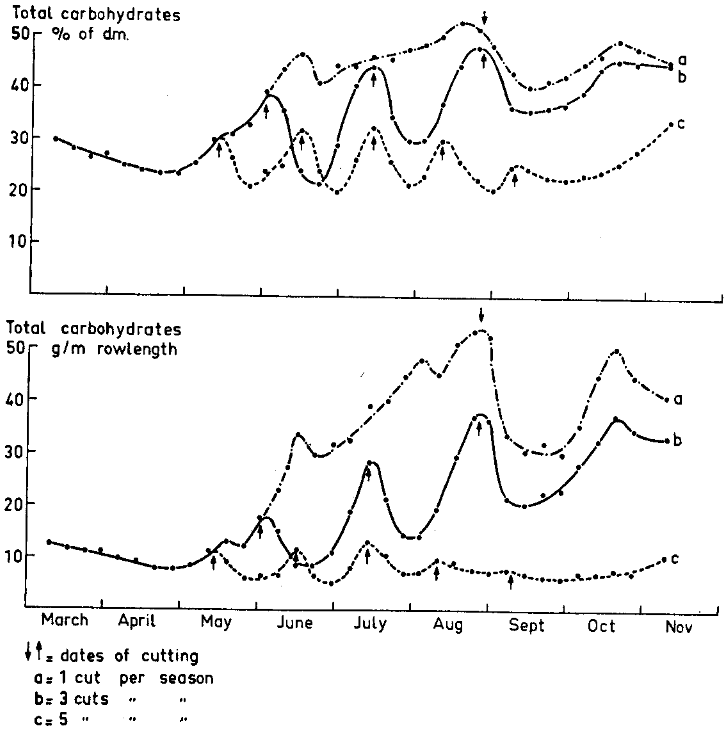
4.2. Lucerne

Also in this crop the reserves play an important part as has previously been mentioned. From FIG. 8 it appeared that after using the reserves for the formation of a new assimilation system in spring, these are restored as soon as the new system is present. The restoration is at its maximum when the crop is in full bloom. At that moment new crown buds start growing and the reserves in the roots are partly used again for that purpose. A second generation of sprouts is formed and as soon as these sprouts start flowering, the process is repeated. This makes it possible that, at the end of the season, sprouts of different generations may be found on plants that were not cut during that season. In such plants a considerable amount of reserves has been accumulated in the roots, despite temporary consumption. This is proved by FIG. 17, taken from a Danish research by NIELSEN and LYSGAARD (1956). The small fluctuations, in May and just before mowing, with the percentage as well as the amount of carbohydrates in plants mown only once are the result of a very favourable growing period; in June and August they are due to the development of a new generation of sprouts. The data of FIG. 17 relate to a young crop of lucerne, so that the amount of carbohydrates in late winter and spring is small. With one and three cuts in the course of the experimental year a considerable amount of carbohydrates was accumulated in the roots and the content of carbohydrates increased also. This was not the case with five cuts per season.

Most interesting in the trend of lines, however, is that the content as well as the amount of carbohydrates in the roots decrease at a very rapid rate after each cut and show an accelerated increase again three or four weeks later. This phenomenon is similar in grasses. After cutting the reserves are for a great deal used for the formation of a new assimilation system. As soon as this has grown to a reasonable size it contributes to the restoration of the heavily depleted reserves.

When five cuts a year are made this restoration cannot take place to a sufficient extent. The first cut is already harvested so early that the plant did not have time enough to restore its reserves depleted after the great effort of beginning growth. The subsequent cuts are also harvested too soon and after each cut the small

FIG. 17. Amount of total carbohydrates, absolutely and as percentage of dry matter in the roots of lucerne, cut once and three or five times per season respectively (After NIELSEN and LYSGAARD, 1956)

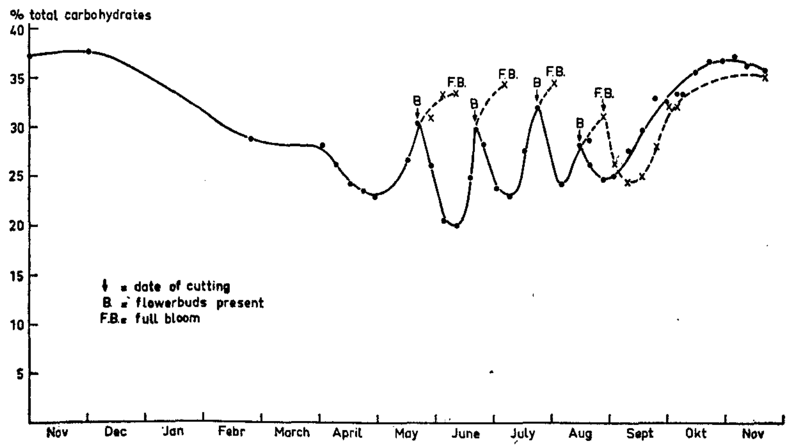


reserves are depleted even more with the result that the plants get exhausted and the crop remains low and weak; many plants even die.
In the Netherlands the conditions are about the same as those prevailing in Denmark. To keep the crop vigorous not more than three cuts are allowed and harvesting should take place when the reserves have reached a reasonable level, *i.e.* when the crop starts flowering. The reserves are so great then that the next generation of tillers begins sprouting and exhaustion will be prevented by cutting at that moment. When the crop is mown later the reserves have already been used partially for the formation of the next tiller generation which is simultaneously cut then. Besides the reserves used for the new assimilation system, also those used for affording the new tiller generation have more or less unnecessarily been withdrawn from the plant. As the young tillers have been removed, the formation of a new assimilation system will take more time, for new buds have to be mobilized first. It is unprofitable to the farmer too, because more energy is lost after mowing and he has to wait longer for another cut to be harvested. The last cut should be taken at such a moment that either the reserves can be restored or it is impossible to the crop to use them again before winter comes.
Similarly, too early harvesting each time is disadvantageous to the crop. This may be seen from FIG. 18, which is taken from an American investigation made by GRANDFIELD (1935) who harvested four cuts each time when the flower buds were

visible. In this way the content of carbohydrates in the roots did not increase in the course of the season. As appears from the figure, GRANDFIELD repeatedly harvested when the roots had a carbohydrate content considerably lower at that time than at the moment of full bloom.

The conditions under which GRANDFIELD worked are fairly well comparable to

FIG. 18. Total carbohydrates as percentage of dry matter in the roots of lucerne, cut too early (already when flowerbuds were present) (After GRANDFIELD, 1935)



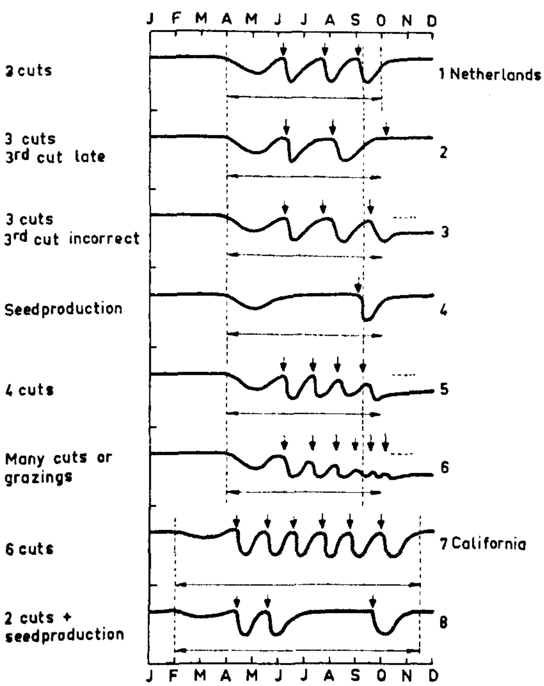


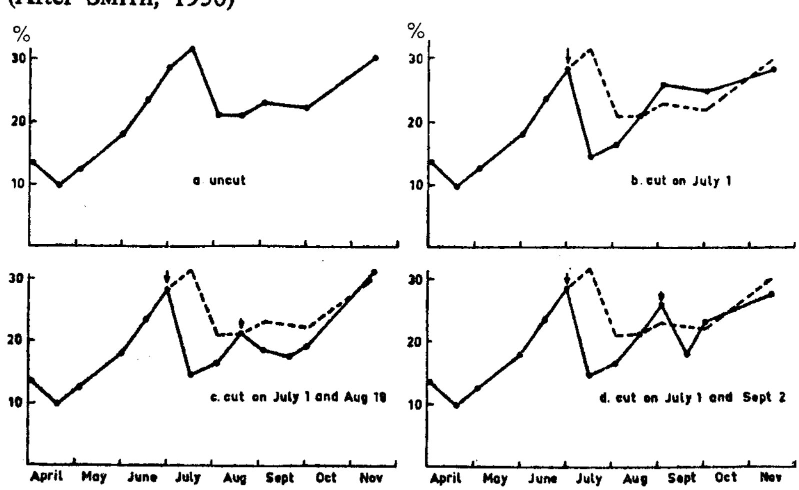
FIG. 19.
Schematic curves of food reserves in the roots of lucerne under different cutting practices in the Netherlands and in California (After MEYERS and BOUMAN, 1952)

those prevailing in western Europe. In other parts of the United States, however, they are more favourable. In the irrigated areas of California, for instance, the growing season is longer and five or six cuts can be taken more or less without causing harm to the crop. In that area the temperature is higher and, therefore, the crop will flower sooner. This does not lead to exhaustion as, due to the higher altitude of the sun, the continuously bright weather and the dry atmosphere, the radiation reaching the plant is so much stronger in comparison with that in the Netherlands that the reserves depleted after cutting are restored much sooner. The scheme reflected in FIG. 19 and taken from MEYERS and BOUMAN (1952) shows one and another.

4.3. Red clover

The trend in this species is mainly similar to that in lucerne. To demonstrate this several results of an investigation made by SMITH (1950) are summarized in FIG. 20. When the crop is not cut at all (a) the content of carbohydrates in the roots, after depletion by the formation of a new assimilation system in spring, increases sharply until half July. At that moment the crop is in full bloom and starts seed formation already. At the same moment new basal tillers are formed and the reserves are used for this purpose. Consequently, dry matter is transported to the overground parts and can be harvested. Afterwards, the reserves are restored to a slight extent only. The new generation of tillers is hampered in receiving the incoming radiation by the older generation which is going to die or has died already. Much energy is lost in this way. The same occurs in lucerne although in a less degree because of the structure of this crop, especially when the row distance is greater. When the crop is mown before the maximum reserves are accumulated (b) the reserves will be heavily depleted for the formation of a new assimilation system but will be restored to a much larger degree afterwards. The new green parts are not hampered in receiving the incoming radiation by the previous generation of tilllers which are going to die. When a second cut is taken the reserves, the restoration of which is

FIG. 20. Total carbohydrates available in percentages of dry matter in the roots of red clover, uncut or cut once or twice per season on different dates (After SMITH, 1950)



in progress, are depleted again for the formation of a new assimilation system (c and d). If this second cut is taken too late (d), the new green parts will not have time enough to re-accumulate reserves in such a degree as would have been possible by a more favourable execution of the cut (c) and, consequently, the crop enters winter in a much weaker condition than in the latter case.

5. Conclusions

It is a general phenomenon in perennial plant species that the photosynthetic products of the green leaf system are not only used in producing generative parts culminating in the formation of the seed which secures the survival and propagation of the species. These products are also used for the accumulation of reserves in those parts which do not die during winter. On the one side the reserves have to protect these parts against unfavourable conditions in winter, on the other side they are used again for the formation of the new assimilation system after the winter has passed. After the formation of the system the depleted reserves are more or less gradually restored before the next winter.

The growth cycle implies that growth is most vigorous in early spring. This tendency is strenghtened by the fact that later in spring the number of newly formed vegetative sprouts is suppressed by the formation of generative shoots.

The process of growth of fodder crops is complicated by harvesting, as in the course of the growing season the assimilation system is removed repeatedly. Thus, the plants are forced to deplete the reserves present at the moment of harvest to be able to form a new assimilation system as soon as possible in order to take profit of sun energy as much as possible. When the crop is harvested so frequently that the reserves cannot reach a certain level in the meantime, it will be exhausted which may ultimately lead to the death of many or all plants.

The consequence is that the farmer has to choose the right moment for harvesting with due care. Moreover, he has to bear in mind that the crop to be harvested should have such a chemical composition as to procure the greatest feeding value for cattle, for this feeding value decreases as the crop matures. He constantly has to aim at a certain compromise between the maintenance of a crop being as healthy as possible and obtaining a product possessing a feeding value as high as possible.

Furthermore, the trend in the distribution of the assimilates in the perennial fodder crops still has the following consequence for the farmer. In spring dry matter from the underground parts or parts near the soil is transported to higher situated parts that can be harvested. Later in the season and especially towards the end, however, an increasing part of the dry matter in those parts of the plant which can be harvested are transported downwards to those which cannot be harvested and remain alive on the field during the winter. The incoming radiation more and more decreasing after the longest day as well as the changed distribution of the assimilates make it impossible to harvest as much per time-unit later in the season than has been possible in the beginning of the growing season.

With the aid of various agricultural measures, *e.g.* supplying water, nitrogen fertilization and such-like, the course of matters may be favourably influenced to a certain extent from the farmers point of view. He will repeatedly have to consider, however, whether this influencing will not have an unfavourable effect on the crop, so that it will be in a weak condition when winter-time comes and he runs the risk of partly or completely losing his crop, in that way having killed the goose that lays the golden eggs.

LITERATURE

ALBERDA, TH. 1955 De veranderingen in de koolhydraatreserve bij Engels raaigras (*Lolium perenne* L.) in 1954. *Versl. C.I.L.O. 1954.* 70—78.

—— 1956 De verandering in de koolhydraatreserve bij Engels raaigras (*Lolium perenne* L.) van november 1954 tot november 1955. *Versl. C.I.L.O. 1955.* 48—56.

—— 1957 The effects of cutting, light intensity and night temperature on growth and soluble carbohydrate content of *Lolium perenne* L. *Plant and Soil. 8,* 199—230.

——, and C. T. DE WIT 1961 Dry matter production and light interception of crop surfaces. Uninterrupted growth of a grass sward. *Jaarb. I.B.S. 1961.* 37—44.

BROUWER, R. 1962 Nutritive influences on the distribution of dry matter in the plant. *Neth. J. agric. Sci. 10,* 5 Special Issue : 399—408.

GRABER, L. F. a.o. 1927 Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants. Univ. of Wisconsin. *Research Bull.* No. 80.

GRANDFIELD, C. O. 1935 The trend of organic food reserves in alfalfa roots as affected by cutting practices. *Journ. Agric. Res. 50,* 697—709.

—— 1943 Food reserves and their translocation to the crown buds as related to cold and drought resistance in alfalfa. *Journ. Agric. Res. 67,* 33—47.

GREATHOUSE, G. A., and N. W. STUART 1936 Hydration studies in fresh and dried red clover roots and shoots with reference to physical properties and chemical composition of tissue. *Plant Phys. 11,* 873—880.

JUNG, G. A., and D. SMITH 1961 Trends of cold resistance and chemical changes over winter in the roots and crowns of alfalfa and medium red clover. I Changes in certain nitrogen and carbohydrate fractions. *Agron. Journ. 53,* 359—364.

LANGER, R. H. M. 1956 Growth and nutrition of timothy (*Phleum pratense*). I The life history of individual tillers. *Ann. Appl. Biol. 44,* 166—187.

—— 1958 A study of growth in swards of timothy and meadow fescue. I Uninterrupted growth. *Journ. Agric. Sci. 51,* 347—352.

MEYERS, P. G. 1936 Verslag van een viertal veldproeven betreffende de cultuur van lucerne. *Versl. Landbouwk. Onderz.* No. 42 (4) A, 145—175.

——, and P. R. BOUMAN 1952 De lucernebouw in Amerika. Rapport Studiegroep Landbouw. Contactgroep Opvoering Productiviteit.

NIELSEN, H. M., and C. P. LYSGAARD 1956 Relationship between root and top growth and organic root reserves in lucerne. *Årsskrift Kong. Veter. og Landb.høgskole 1956.* 77—107.

SMITH, D. 1950 Seasonal fluctuations of root reserves in red clover, *Trifolium pratense* L. *Plant Phys. 25,* 702—710.

STEENBERGEN, T. VAN 1961 De grasopbrengsten in de jaren 1956 t/m 1960. *Landb. Voorl. 18,* 720—729.

WIT, C. T. DE 1959 Potential photosynthesis of crop surfaces. *Neth. J. agric. Sci. 7,* 141—149.