Neth. J. agric. Sci. 30(1982)127-135

The influence of length of growing period, nitrogen fertilization and shading on tillering of perennial ryegrass (*Lolium perenne* L.)

Th. Alberda and L. Sibma

Centre for Agrobiological Research, Wageningen, Netherlands

Accepted: 8 december 1981

Key-words: growing period, nitrogen fertilization, shading, tillering, perennial ryegrass, *Lolium perenne*

Summary

The formation and death of tillers was studied in swards of perennial ryegrass. These swards differed in the length of the growing period and in the amount of nitrogen applied after each cut. Tillers died faster after a 6-weekly growing period than after a 4-weekly period. Usually some plants were far more affected than others, often resulting in the complete death of plants and thus in open spaces in sward.

Shading experiments suggested that plant deaths can result from mutual shading. Small plants are shaded by taller ones and have a lower reserve content and a higher death rate. High cutting frequencies or low nitrogen applications could prevent open spaces from appearing or could be used to rehabilitate an open sward, provided it was not yet infested with unwanted species.

Introduction

The increasing use of nitrogenous fertilizers on grassland has brought about an increased risk of sward deterioration. The high rates of growth which are the result of high levels of fertilizer application necessitate careful management. If the sward is allowed to grow for prolonged periods, little green material is left after cutting and regrowth is often slow. In such situations many tillers and even whole plants may die so that open spaces are formed and volunteer grasses like couch grass or weeds creep in. This usually leads to a reduction in the quality and quantity of the herbage produced, so that eventually reseeding may be necessary.

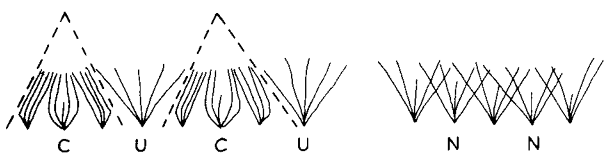
In order to gain a better understanding of the factors that influence tiller formation and tiller death some observations on tiller behaviour have been made during current experiments on the influence of nitrogen fertilization and cutting frequency on growth. Additionally, a collateral experiment has been conducted to investigate the effects of mutual shading.

Material and methods

The experimental swards were situated on a clay soil in the polder 'Oostelijk Flevoland' and tiller density was estimated in two ways. In the first individual plants, i.e. separate bunches of tillers, were marked and changes in the number of live tillers were followed during regrowth. Care was taken not to damage these plants nor those in the vicinity.

To compare the influence of different treatments such as cutting regime and nitrogen fertilization another method was used. A rod about 70 cm long was divided into 25 sections of 2.5 cm each. The rod was laid down on a sward that had just been cut and the number of sections that were touched by a tiller, or, in dense swards, that were not touched by a tiller was counted. On each plot the rod was laid down at 10 different places, chosen at random, thus giving a total of 250 counts per plot. As there were three replicates the total number of counts per treatment was 750.

A special experiment to study the effect of mutual shading on tiller behaviour was carried out in the following way. Rows of perennial ryegrass tillers were planted in the spring of 1978 at 20 cm distance. As soon as the plants which developed from these tillers had grown large enough to touch their neighbours in the next row, two wide-meshed metal wire screens were placed as a kind of roof over three rows, so that the inner row was intensively shaded by the leaves of the two outer rows (C = covered; U = uncovered; N = normal):



The row between two screen roofs was thus freed from shading by the rows adjacent to it. In untreated rows the distance was such that mutual shading occured during the experiment. In this way there were three different degrees of shading, viz uncovered (in which inter-row shading was prevented), normal (with natural mutual shading) and covered (with increased mutual shading).

All rows were cut on 25 July 1978 at a height of 6 cm, and herbage dry weight and number of tillers per 1 m row was determined. The herbage was retained and analysed for total soluble carbohydrates. Immediately after this a further 1 cm of plant tissue (consisting mainly of pseudostem) was cut from the remaining tillers. This fraction was similarly retained and analysed. The screens, which were removed just before cutting, were not replaced so that the after-effects of the shading treatments could be studied during the subsequent regrowth periods of 43 and 33 days respectively.

Results

To study tiller behaviour in an experiment in the polder 'Oostelijk Flevoland' a number of plants was marked in the 8-weekly and the 4-weekly cutting scheme and the tiller number of each plant was counted immediately after cutting and 3, 10 and 24 days later. The results are shown in Fig. 1 as the percentage of change. There was a distinct difference between the two cutting frequencies which showed at all counts. In the 8-weekly cutting treatment many tillers died within the first three days after cutting. In some plants few or no deaths were observed but in others all the tillers died. In this way the number of open spaces in the sward increased progressively as the season advanced. In the 4-weekly scheme there were also some tillers which died, but the percentage was much lower and no plants died off completely.

The initial decrease in tiller number which occurred during the first few days after cutting was usually followed by a period in which tiller numbers changed very little. New tillers started to appear about two weeks after cutting. When plots were cut every four weeks these new tillers appeared in the axils of the leaves, which is normal in a vegetative plant. At the last count the tiller number was re-established at or slightly above its original level (113 against 100). When the plots were cut every 8 weeks some of the new tillers developed in this way

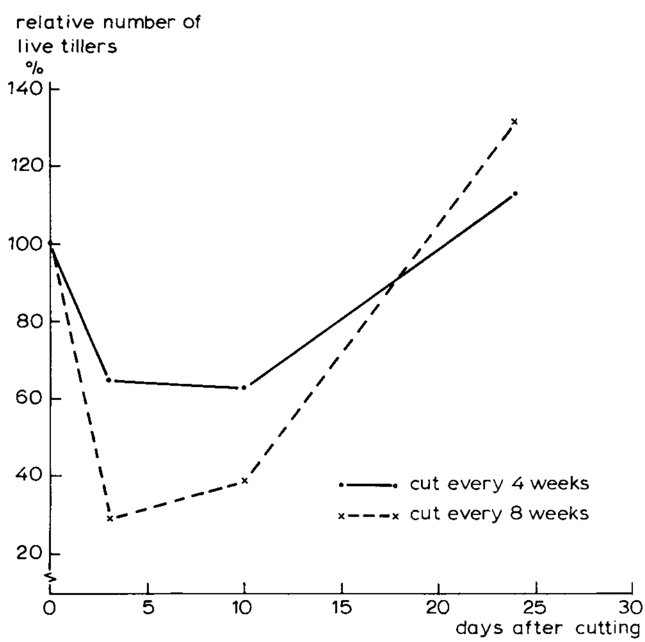


Fig. 1. Number of live tillers at different times after cutting, expressed as a percentage of the number immediately after cutting.

but many exhibited a different pattern of development. In these tillers the upper part, consisting of growing point, developing leaves and older leaf sheaths, died but the short stem below it remained alive. On the nodes of these short stems very small tillers were formed, often 4 or 5 per original tiller. In this way the relative tiller number increased rapidly to 132 at day 24, but the total weight of these tillers was far less than that of the new tillers in the 4-weekly cutting treatment. Counting later than 24 days after cutting was not possible as it would have damaged the surroundings of the marked plants too much.

It has been found previously (Alberda, 1966) that the death of tillers after cutting is enhanced when the total soluble carbohydrate (TSC) content in the stubble is low. In this experiment it was only possible to determine the TSC content in the herbage but as there is usually a good correlation between values from herbage and stubble this would be expected to give reasonable comparisons. Practically all TSC values, determined three times during the growing season, were distinctly higher in the 4-weekly cutting scheme than in the 8-weekly scheme, thus confirming previous results.

A reason for the irregular pattern of tiller deaths may be sought in the pattern of mutual shading in the sward, where some (usually smaller) plants are more heavily shaded than others. This hypothesis is difficult to verify in the field, because there is no visible difference between the plants directly after cutting and when plant parts are taken away to analyse their TSC content, this, of course, will have an impact on regrowth.

For this reason a separate experiment was designed in which differences in mutual shading were established artificially. Rows of perennial ryegrass plants were shaded or unshaded as indicated under 'Methods', whereas other rows were left as control. Forty days later the screens were removed and the rows were cut to a height of 6 cm. Immediately thereafter 1 cm was removed from the remaining stubble for TSC analysis and the number of live tillers per 1-m row was counted. There were three harvests, viz directly after the treatment and after two successive growing periods of 43 and 33 days respectively. The data are presented in Fig. 2A, B, C for herbage weight, number of tillers and percentage TSC respectively.

At the first harvest there were large differences in herbage weight, tiller number and TSC content of stubble and herbage. The uncovered rows had 33 % more herbage than the control rows and 39 % more tillers; the TSC content in the stubble increased by 17 % and that in the herbage by 28 %. For the covered plants the percentage reduction from the control was 16, 22, 42 and 24 respectively. These values indicate that shading had a very clear influence on tiller vigour. The after effects on regrowth are apparent from harvests 2 and 3. At the second harvest there was still a large difference in herbage weights from the three treatments, but the difference in number of tillers and in TSC concentration was already considerably less than at the first (the stubble was not analysed for TSC contents in the harvest 2 and 3). At the third harvest there were still some differences in yield and in tiller number, but no more differences in TSC content.

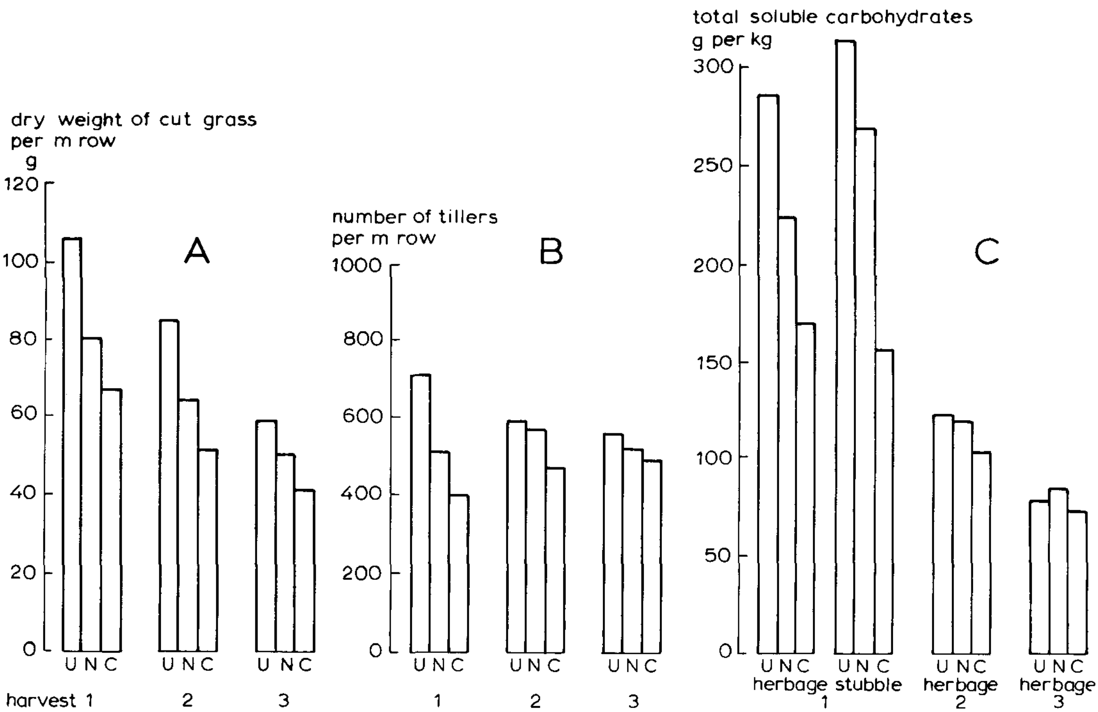


Fig. 2. A = dry weight of cut herbage per 1-m row; B = number of live tillers per 1-m row; C = percentage of soluble carbohydrates.
U = uncovered; N = normal; C = covered. 1, 2, 3: successive harvests.

Since the influence of mutual shading on tiller vigour is not only related to the length of the growing period but also to the growth rate during this period, the sward density was measured at the end of the growing season in an experiment in which both the cutting frequency and the amount of nitrogenous fertilizer were varied. The lay-out of this experiment is presented in the upper half of Table 1.

The treatments comprised a 2-weekly, a 4-weekly and a 6-weekly cutting scheme and four treatments in which cutting frequency varied. In two of these there was a shift from a 2-weekly to a 6-weekly scheme either approximately halfway through July or at the end of August. In the other two the change was from a 6-weekly scheme to a 2-weekly scheme. All these treatments were carried out at four levels of nitrogen fertilization: 200, 400, 600 and 800 kg per ha and per season, each amount applied in equal portions after each cut.

The yield data of this experiment have been published elsewhere (Sibma & Alberda, 1980); here only the effects on tiller density will be presented. This density was measured with a rod at the end of the growing season (3 October) as

Table 1. Upper part: cutting schemes for the various treatments. Lower part: degree of 'openness' of the sward, at the end of the experiment expressed as the percentage of 2.5-cm segments on a rod that were not touched by a tiller (25 segments on the rod × 10 measurements per plot × 3 replicates = 750 segments.

Treat-ment	Month → Week No →	18	May 20	22	June 24	26	28	July 30	32	Aug. 34	36	Sept. 38	Oct. 40
a		x	x	x	x	x	x	x	x	x	x	x	x
b			x		x		x		x		x		x
c				x			x			x			x
d		x	x	x	x	x	x			x			x
e		x	x	x	x	x	x	x	x	x			x
f				x			x	x	x	x	x	x	x
g				x			x			x	x	x	x

Treat-ment	N fertilization (kg year^{-1}) → 200	400	600	800
a	0.1	0.0	0.0	0.7
b	3.1	7.5	16.1	21.9
c	10.9	31.7	26.7	34.3
d	8.5	20.1	26.0	24.7
e	2.3	6.5	17.3	19.2
f	0.4	0.4	1.1	0.8
g	5.6	6.3	11.5	17.1

explained before. For the sake of convenience the data are presented as percentage openness, i.e. the percentage of the total of 750 segments of 2.5 cm that was not touched by one or more tillers. The data are presented in the lower half of Table 1. With a 2-weekly cutting scheme the sward was fully closed at all levels of fertilization. More or less the same can be said of the lowest level of nitrogen fertilization. With all cutting schemes the openness was only in one case slightly more than 10 %. Thus the openness increased with both the length of the growing period and the level of nitrogen fertilization, so that the most open sward was found with a 6-weekly cutting scheme and 800 kg N (34 %). When the 6-weekly scheme was started after a 2-weekly one the percentages on 3 October were still quite high (25 % and 19 % after changing the cutting frequencies on 11 July and 22 August). The reverse was also true; when the 6-weekly scheme was replaced by a 2-weekly one after 11 July, the then already rather open sward was completely closed again at the end of the season (less than 1 % openness). When the change was made as from 22 August, however, this effect was distinctly less marked (17 % openness).

These results show that a perennial ryegrass sward can be kept in good condition by either a low rate of nitrogen fertilization or a high cutting frequency. In addition an open sward can usually be restored to its former density by a temporary increase in the cutting frequency.

Discussion

Although cutting a grassy vegetation temporarily reduces the green leaf area, and with it the rate of photosynthesis, it is necessary for a continuation of growth. It has often been demonstrated that the growth of an undisturbed grass sward comes to a ceiling yield, after which there is no further increase in weight and often even a decrease (Brougham, 1959; Alberda & Sibma, 1968; Davies, 1971; Spiertz & Ellen, 1972; Kays & Harper, 1974). The level of this ceiling yield depends on the time of the year and on plant species. It is not only found with grasses but also with legumes (Versteeg et al., 1981). Usually, the heavier the cut the smaller the leaf area left after cutting. Consequently there is a negative correlation between the dry weight of a particular cut and that of the next cut (see e.g. Mulder, 1949). Nonetheless it has often been observed that the total herbage dry matter production increases with increasing length of the growing periods (Alberda, 1968, Sibma & Alberda, 1980). This means that the longer periods of undisturbed growth outweigh the more severe reduction in leaf area after cutting and, as the percentage countings have shown, the occurrence of open spaces, caused by the death of tillers or even whole plants. It has to be realized, however, that usually these results are obtained on swards that were completely closed at the start of the experiment. A continuation of a regime with long growing periods over a number of seasons might well have a cumulative effect on the openess of a sward and thus lead to progressively smaller yields. Moreover in agricultural practice the occurrence of open spaces after cutting usually leads to the penetration of weeds or unwanted grass species and, consequently, to a reduction in herbage quality.

Increases in productivity brought about by increases in the amount of nitrogenous fertilizer thus carry with them an increased risk of sward deterioration and demand careful management if this is to be avoided.

Exact rules as to the amount of nitrogen and the number of cuts per season cannot be given. Swards under a 4-weekly cutting scheme usually receive less than 400 kg N per ha per year, and even if they do, Table 1 suggests this does not lead to an open sward. Such a management, however, produces a dry herbage yield of 14.0 tonnes per ha, which is 80 % of the maximum of 17.3 tonnes per ha, obtained with a 6-weekly scheme and 800 kg N (Sibma & Alberda, 1980). The safest practical advice may be to say that whenever open spaces build up to an appreciable extent it is wise to deminish the N fertilization and shorten the growing period before weed species invade. Table 1 shows that a 2-weekly cutting scheme for 12 weeks removed open spaces completely whereas the decrease in herbage production being only 10 to 15 % (depending on the amount of nitrogen applied) when compared with the maximum obtainable.

The present study has shown that the death of tillers after a heavy cut is not regularly spread over all individual plants. Some plants are virtually unaffected, some lose many tillers and some may die. Evidence in the literature would suggest that these differences could be ascribed to differences in light regime, since light has a distinct influence on tillering (Langer et al., 1964; Spiertz & Ellen, 1972; King et al., 1979; Thomas & Davies, 1978), often through mutual shading (Kays & Harper, 1974; Ong, 1978; Ong et al., 1978). It is obvious that a longer growing period increases both the duration and the intensity of schading and, through this, reduces the level of reserve carbohydrates, which influences tiller survival (Alberda, 1966). The evidence presented in this paper shows that manipulating the level of mutual shading can greatly affect both carbohydrate reserve levels and tiller vigour. It was not, however, possible in this particular experiment to create a situation in which induced differences in plant vigour were enhanced in subsequent cuts and the least vigorous plants died away completely. Perhaps the plans rows in the experiment were spaced too widely.

At first sight the role of nitrogen fertilization on tillering is less clear than that of light intensity. Many authors claim a positive effect of nitrogen on tillering (Auda et al., 1966; Davies, 1971; Spiertz & Ellen, 1972; Robson & Deacon, 1978; Bartholomew & Chestnutt, 1978; Powell & Ryle, 1978), whereas the present results show that no open spaces are found at low levels of nigrogen fertilization and with cutting intervals of up to six weeks (Table 1). The explanation is that the experimental situation has a strong influence on the results. In practice many swards are strongly nitrogen deficient and relatively open and the application of nitrogenous fertilizer will have a positive influence on tillering. High levels of nitrogen applied to dense swards increase mutual shading and can have an adverse effect, a fact also observed by Ong (1978).

There is general agreement with the finding that a high cutting frequency promotes tillering (Kays & Harper, 1974; King et al., 1979). The results presented clearly illustrate the allround positive effect of a 'lawn treatment' on sward density and show that it can counteract the adverse effects of high nitrogen applications. Elsewhere (Sibma & Alberda, 1980) we have shown that a dense sward can be maintained with weekly cuts and 1000 kg N per ha per year. Finally it can be seen that frequent defoliation may close an open sward in a relatively short time.

Acknowledgement

The authors very much appreciate the help of Miss M. J. de Kock, Miss M. W. P. Geurtsen en Mr G. van de Sluis with the execution of the experiments and the numerous tiller countings. They also thank Miss Alison Davies for correcting the English text.

References

Alberda, Th., 1966. The influence of reserve substances on dry-matter production after defoliation. *Proc. 10th int. Grassld. Congr.*: 140-147.

Alberda, Th., 1968. Dry matter production and light interception of crop surfaces. IV. Maximum herbage production as compared with predicted values. *Neth. J. agric. Sci.* 16: 142-153.

Alberda, Th. & L. Sibma, 1968. Dry matter production and light interception of crop surfaces. III. Actual herbage production in different years as compared with potential values. *J. Brit. Grassld Soc.* 23: 206-215.

Auda, H., R. E. Blaser & R. H. Brown, 1966. Tillering and carbohydrate contents of orchardgrass as influenced by environmental factors. *Crop Sci.* 6: 139-143.
Bartholomew, P. W. & D. M. B. Chestnutt, 1978. The influence of vernalization on response to nitrogen of perennial ryegrass. *J. Brit. Grassld Soc.* 33: 145-150.
Brougham, R. W., 1959. The effect of season and weather on the growth rate of a ryegrass and clover pasture. *N.Z.Jl agric. Res.* 2: 283-296.
Davies, A., 1971. Changes in growth rate and morphology of perennial ryegrass swards as high and low nitrogen levels. *J. agric. Sci., Camb.* 77: 123-134.
Kays, S. & J. L. Harper, 1974. The regulation of plant and tiller density in a grass sward. *J. Ecol.* 62: 97-105.
King, J., W. I. C. Lamb & M. T. McGregor, 1979. Regrowth of ryegrass swards subject to different cutting regimes and stocking densities. *Grass Forage Sci.* 34: 107-118.
Langer, R. H. M., S. M. Ryle & O. R. Jewiss, 1964. The changing plant and tiller populations of timothy and meadow fescue swards. I. Plant survival and the pattern of tillering. *J. appl. Ecol.* 1: 197-208.
Mulder, E. G., 1949. Onderzoekingen over de stikstofvoeding van landbouwgewassen. I. Proeven met kalkammonsalpeter op grasland. *Versl. landbouwk. Onderz.* 55.7:95 pp.
Ong, C. K., 1978. The physiology of tiller death in grasses. 1. The influence of tiller age, size and position. *J. Brit. Grassld Soc.* 33: 197-203.
Ong, C. K., C. Marshall & G. R. Sagar, 1978. The physiology of tiller death in grasses. 2. Causes of tiller death in a grass sward. *J. Brit. Grassld Soc.* 33: 205-211.
Powell, C. E. & G. J. A. Ryle, 1978. Effect of nitrogen deficiency on photosynthesis and the partitioning of ^{14}C-labelled leaf assimilate in unshaded and partially shaded plants of *Lolium temulentum. Ann. appl. Biol.* 90: 241-248.
Robson, M. J. & M. J. Deacon, 1978. Nitrogen deficiency in small closed communities of S24 ryegrass. II. Changes in the weight and chemical composition of single leaves during their growth and death. *Ann. Bot., Lond.* 42: 1199-1213.
Sibma, L. & Th. Alberda, 1980. The effect of cutting frequency and nitrogen fertilizer rates on dry matter production, nitrogen uptake and herbage nitrogen content. *Neth. J. agric. Sci.* 28: 243-251.
Spiertz, J. H. J. & J. Ellen, 1972. The effect of light intensity om some morphological and physiological aspects of the crop perennial ryegrass (*Lolium perenne* L. var. 'Cropper') and its effect on seed production. *Neth. J. agric. Sci.* 20: 232-246.
Thomas, H. & A. Davies, 1978. Effect of shading on the regrowth of *Lolium perenne* sward in the field. *Ann. Bot.* 42: 705-715.
Versteeg, M. N., I. Zipori, J. Medina & H. Valdivia, 1981. Potential growth of alfalfa in the desert of Southern Peru and its response to high NPK fertilization. In press.