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COUCH (*ELYTRIGIA REPENS* (L.) DESV.;  
SYN. *AGROPYRON REPENS* (L.) BEAUV.)  
IN MONOCULTURES AND IN MIXTURES  
WITH PERENNIAL RYEGRASS  
(*LOLIUM PERENNE* L.)

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INTRODUCTION

In the Netherlands, couch (*Elytrigia repens* (L.) Desv.) is one of the most serious weeds on cultivated soils. This is probably due to its ability to form rhizomes. The species is very variable and indications have also been found that couch populations of different fields can differ in the composition of genotypes (WILLIAMS, 1973; BULCKE et al., 1974; NEUTEBOOM, 1975, 1980). In an experiment with spaced plants (NEUTEBOOM, 1975) couch clones also clearly differed with regard to characteristics such as tillering, stem elongation and daughter plant production from rhizomes, but further information is needed about the significance of this variability in a crop situation and in competition with other species. Therefore, in a field experiment the performance of four very different clones was investigated in monocultures and in mixtures with perennial ryegrass. In the experiment, different mowing regimes were applied. This was done to simulate the couch problem in intensively used *Lolium perenne* grasslands, a problem that is assumed to be partly related to the harvesting regime; couch seems to increase after repeatedly late mowing or late grazing. In view of the considerable clonal differences in vegetative propagation and other developmental characteristics in couch, it also seemed worthwhile to study this increase of the species from the viewpoint of its variability.

LITERATURE

HOGERKAMP (1975a, b) in analysing data on the botanical composition of 1577 old grasslands studied by KRUIJNE, DE VRIES and MOOI (1967), concluded that some 30 years ago couch was not a great problem in Dutch grasslands. According to KLAPP (1956) and SCHÄFER (1971), the same held for the grasslands in Germany at that time.

In the last thirty years, however, cases have been frequently reported of a considerable spread of couch in intensively used grasslands where high dressings of nitrogen are applied (DE VRIES and KRUIJNE, 1960; 'T HART, 1963; KREIL et al., 1965; PÄTZOLD, 1967). This increase in couch was supposed by some to be directly related to the higher nitrogen applications, but on the other hand, couch does not increase in all cases of high nitrogen applications. Several authors (BOXEM, 1966; WETZEL, 1966; HOGERKAMP, 1975a, b) therefore point to the fact that in grassland other factors change as a result of the improved nitrogen

fertilization and these might facilitate the spread of couch; e.g. higher stocking rates and consequently more sward damage from trampling, dung and urine patches and an increased risk of harvesting late.

Indications that besides nitrogen the harvesting regime can also affect the amount of couch in grassland were reported by MULDER as early as 1949. In a grassland experiment on a peat soil and on clay, MULDER applied nitrogen dressings of 0 to 2520 kg/ha/year. On the clay field couch increased as nitrogen increased, but this increase was stronger the less frequently the grass was mown.

In England, CUSSANS (1973) compared the effect of two nitrogen levels (125 and 350 kg N/ha/year) and two mowing regimes (3 and 7 cuttings per year) on couch in a perennial ryegrass ley, in which couch rhizomes had been planted. In the second year, couch appeared to have increased only at the combination of high nitrogen and less frequent mowing.

Our experiment with mixtures as well as monocultures of couch and perennial ryegrass may possibly avoid some theoretical problems in the interpretation of the results of the experiments mentioned above. In most previous experiments the quantity of couch was determined in dry weight percentages, even though a proportional increase in couch does not always mean that other species are crowded out. In his experiment with different mowing intervals and nitrogen levels, CUSSANS (1973) determined the increase of couch in terms of dry weights and shoot numbers but he did not collect the same data on perennial ryegrass. According to DE WIT and VAN DEN BERG (1965) in an experiment with both monocultures and mixtures of the competing species, the increase or decrease of a species can also be calculated in terms of the relative yield. This is the quotient of the yield of a species in the mixture and its yield in a monoculture.

## MATERIALS AND METHODS

*Clones:* The clones were chosen from a trial with spaced plants. They had relatively minor differences in shoot size, but differed in productivity primarily as a consequence of differences in tillering and vegetative propagation by way of rhizomes. This is illustrated in Table 1 and Fig. 1. The clones in this experiment were reared from individual leafy shoots of equal size, which were planted in the last week of April 1967. The data refer to a first and a second clipping date on July 20 and August 31 of that year, respectively, and in all cases are average values of 4 replicates.

K1 and K4, owing to good tillering of the planted shoots, formed high yielding parent plants, K1 and K2 showed a relatively early and intensive production of daughter plants from rhizomes (Table 1). However, the latter clone differences have to be regarded in relation to the distribution patterns of daughter plants. As a consequence of an increasing rhizome length in the sequence of K1, K2, K3 and K4, the clones had formed their daughter plants increasingly further away from their parent plants, in the same sequence. This also resulted in interesting clone differences with regard to the density of shoots

TABLE 1. Characteristics of the clones in the experiment with spaced plants in 1967. Data from the parent plants at a first clipping date (July 20) and from the daughter plants from rhizomes at a second clipping date (August 31) at 6-weekly clipping.

	parent plants (20/7/67)			daughter plants (31/8/67)		
	shoot number	dry weight (g)	mean shoot dry weight (mg)	number	mean shoot number per daughter plant	dry weight per daughter plant (mg)
K1	110	50.5	460	169	4.0	515
K2	38	21.1	580	172	2.3	430
K3	56	24.4	440	101	3.0	356
K4	107	47.2	410	115	4.0	417

from daughter plants at successive distances from the parent plant (Fig. 1). At the second clipping date at the end of August, K1 and K2 had attained significantly higher shoot densities of daughter plants in the immediate vicinity of the parent plant (Fig. 1) and therefore in an open sward may be expected to form dense patches far earlier than K3 and K4. Even in K2, within a radius of 50 cm from the parent plant this shoot density was three times higher than in K4. Although the individual daughter plants of K4 and K1, like their parent plants, on average had higher tiller numbers, at the same second cut the daughter plants of K2 were equally developed in terms of dry weights (Table 1).

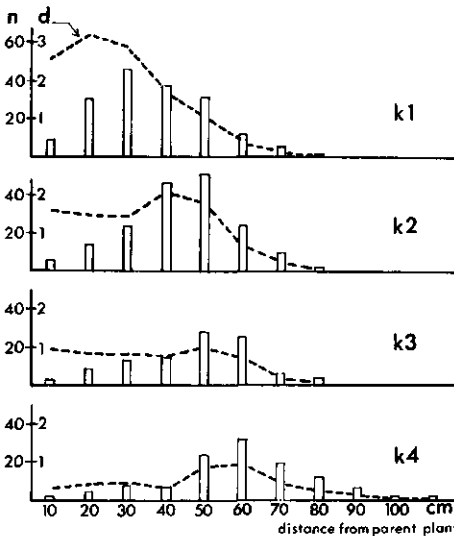


FIG. 1. Average numbers ( $n$ ) and density ( $d = n \cdot dm^{-2}$ ) of shoots from daughter plants from rhizomes within successive 10 cm-wide rings from the parent plant. Data from the four couch clones (K) in the experiment with spaced plants, second cut, August 31.

In K3 a combination is found of weak tillering and a relatively slow propagation at a moderate distance from rhizomes (Table 1, Fig. 1). In the second year of the experiment K1 had an early spring growth and early stem elongation, and in the later growing season it produced larger leaves. In early spring, K4 had larger leaves. K3 showed a pronounced prostrate growth habit in early spring. For *Lolium perenne* the early variety 'Cropper' was chosen, which has a median heading date of May 16 (ANONYMOUS, 1980).

*Treatments*; The mowing experiment with the clones and perennial ryegrass was located on a rather poor sandy soil of an experimental farm in Wageningen. The monocultures and mixtures were laid out in plots of 2.25 m<sup>2</sup>, which were separated by weekly mown strips of *Festuca rubra*. The mowing treatments were started in 1970.

The experiment was done according to a split plot scheme. Each of the four blocks (replicates, R) was subdivided into 6 smaller blocks, representing different mowing treatments. Within each of these smaller blocks there was one sub block with three crop situations (C) for each clone (K); one monoculture of couch, one monoculture of perennial ryegrass and one mixture of both species.

The six mowing treatments consisted of two dates for the first cut (May 12 and June 3, 1970; T1 and T2, respectively) and 3 mowing frequencies (3-, 6- and 9-weekly mowing; F1, F2 and F3). The total number of plots was 2 (T) × 3 (F) × 4 (K) × 3 (C) × 4 (R) = 288.

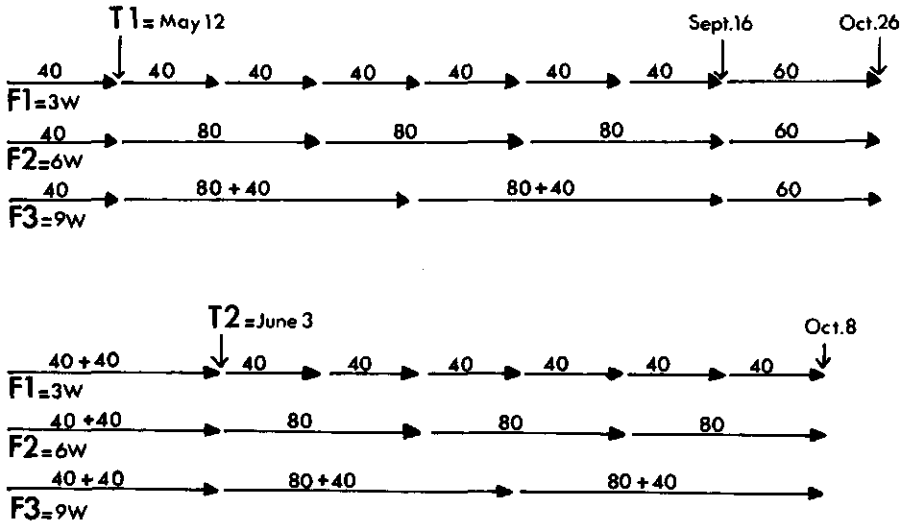
*Lay out*: The couch clones in the monocultures and the mixtures were vegetatively propagated from 12 equally sized individual plants per plot. These were planted in the first week of April 1968. After mowing in the second week of August, perennial ryegrass was sown.

At the end of the 1968 growing season, K1 and K2 had already formed almost closed monocultures, K3 and to a lesser extent K4 did so during the growing season of 1969. In 1968 and 1969 the plots had been moderately fertilized with NPK. In 1968 all plots had only been mown twice (in August and at the end of October), in 1969 three times (early June, third week of August and last week of October).

Because of the differences in the degree of vegetative propagation of the clones in August 1968 (when perennial ryegrass was sown) by the start of the mowing treatments in 1970 the clones had different shoot densities in the mixtures. This is illustrated in Table 2. The shoot densities of the clones showed roughly the same sequence as their daughter plant production and total shoot production (shoot-numbers) from rhizomes in the earlier experiment with spaced plants (Table 1, Fig. 1).

TABLE 2. Average shoot densities (n.dm<sup>-2</sup>) of the four clones in the mixtures at the late first cut in 1970.

K1	K2	K3	K4
10.6	7.1	3.2	3.2



Mowing and fertilizer scheme 1970 (nitrogen dressings in kg/ha indicated above the arrows).

**Mowing scheme and fertilizer applications:** In the scheme above further information is given about the harvesting dates and the nitrogen dressings in 1970. In 1970 the 3-, 6- and 9-weekly mowing treatments with the early first cut (May 12) were simultaneously harvested again on September 16 and October 26. This last cut followed a common regrowth period of 6 weeks. The 3-, 6- and 9-weekly treatments with the late first cut (June 3) were simultaneously mown again on October 8.

In 1971, all mowing treatments were harvested at a first cut on May 18. After that cut the mowing frequencies were continued, although not all treatments were harvested again.

The plots in 1970 and 1971 were dressed with 600 kg  $K_2O$  and 150 kg  $P_2O_5$  per ha.  $K_2O$  was applied in two gifts in March and mid-June, respectively.

For fear that the couch might lodge after longer growing periods, only moderate nitrogen dressings of 40 and  $2 \times 40$  kg per ha respectively were applied, for the early and the late first cuts. However, as no lodging occurred, the nitrogen dressings were subsequently based on 40 kg per ha for each three weeks of regrowth, i.e. for each of the following cuts of the 3-, 6- and 9-weekly mowing treatments, the nitrogen dressings were 40, 80 and 120 kg per ha, respectively. Of the gift of 120 kg, 80 kg was applied directly after mowing and 40 kg after 6 weeks. As follows from the scheme 60 kg nitrogen per ha was applied for the last cut on October 26 (T1 treatments) and 80 kg nitrogen per ha for the first cut in 1971. For the subsequent cuts in that year, nitrogen was again applied on the basis of 40 kg per ha per each 3 weeks of growth.

During some dry periods in 1970 the experimental field was irrigated; however, this was not enough to ensure optimum growth.

**Observations:** Yields were determined by harvesting permanent squares of  $\frac{1}{4}$

$m^2$  in the middle of the plots. The crop was cut off at a constant height of 3.5 cm, along a frame of metallic pins. The remaining part of the plots was mown afterwards at the same height. The harvested crop was sorted out into couch, perennial ryegrass and weed and after being dried, these components were weighed. Occasionally, shoots in the mixtures and in the monocultures were counted. In November 1970 samples were taken from all monocultures of couch to determine the amount of rhizome material. In September 1971 only the T1 mixtures and T1 monocultures were sampled. In each plot at each of the four edges of the harvested  $\frac{1}{4} m^2$  squares, a 20 cm-deep boring with a diameter of 7 cm was taken. Within this depth practically all the rhizome material occurred. The rhizome pieces in the borings were counted, dried and weighed. Before the weighing the roots had been removed and weighed.

### THEORETICAL CONSIDERATIONS

In replacement series with monocultures and mixtures of two species  $a$  and  $b$ , for each of the species the relative yield can be calculated as:

$$r = \frac{O}{M}$$

in which  $O$  is the yield of the species in the mixture and  $M$  the yield of the same species in the monoculture. Several experiments (DE WIT, 1960; DE WIT and VAN DEN BERGH, 1965; VAN DEN BERGH, 1968) have indicated that grass species in a mixture are often mutually exclusive and that the sum of the relative yields of both species (Relative Yield Total, RYT) mostly equals 1;

$$RYT = r_a + r_b = 1$$

The relation between the relative yields of species  $a$  at the  $n^{\text{th}}$  and at the  $m^{\text{th}}$  harvest can be calculated by a constant value  ${}^{nm}k_{ab}$ , thus:

$${}^n r_a = \frac{{}^{nm}k_{ab} \cdot {}^m r_a}{{}^{nm}k_{ab} \cdot {}^m r_a + {}^m r_b} \quad {}^n r_b = \frac{{}^{nm}k_{ba} \cdot {}^m r_b}{{}^{nm}k_{ba} \cdot {}^m r_b + {}^m r_a}$$

At  $RYT = 1$ ,  $k_{ab} \cdot k_{ba} = 1$

The  $k$  values are called the relative crowding coefficients (DE WIT, 1960). In the mixtures at the  $n^{\text{th}}$  with respect to the  $m^{\text{th}}$  harvest the relative reproductive rate ( $\alpha$ ) of species  $a$  with respect to species  $b$  can also be calculated (DE WIT, 1960):

$${}^{nm}\alpha_{ab} = \frac{{}^n O_a / {}^m O_a}{{}^n O_b / {}^m O_b}$$

It is said that at constant  $k$  values and  $RYT = 1$  the species in the mixture compete for the same space with regard to growth factors such as light, minerals and water, but also, in the course of time (DE WIT and VAN DEN BERGH, 1965). Cases of  $RYT > 1$  are interesting with regard to the question of whether mixtures can be higher yielding than the highest yielding monoculture (VAN DEN BERGH, 1968; VAN DEN BERGH and ELBERSE, 1970).

## RESULTS

### *Monocultures:*

During 1970 at more frequent mowing we ran up against the problem of a strong weed invasion, mainly of *Poa annua*, in the monocultures of couch. Later on this complicated the interpretation of the data on the interaction between couch and perennial ryegrass in the mixtures. On the other hand, weed invasion is a general phenomenon in couch monocultures and thus can be considered as a characteristic of the species. Therefore the yields of the clones can still be compared.

The reason that weeds can easily establish in couch monocultures is that couch cannot form a dense sward. This is primarily because of its weak tillering ability but partly also results from its stemmy growth habit (Fig. 2). Because of this, couch can lose a large percentage of its shoots at mowing, because their growing



FIG. 2. A stemmy couch crop.



TABLE 3. Mean shoot numbers per dm<sup>2</sup> in the monocultures of the couch clones at the late first cut and the second cuts in 1970 and at the first cut in 1971.

	1970 late first cut (June 3)	1970 second cut				1971 first cut (May 18)					
		T1F2	T1F3	T2F2	T2F3	T1F1	T1F2	T1F3	T2F1	T2F2	T2F3
		(24/6)	(15/7)	(15/7)	(5/8)	(3w)	(6w)	(9w)	(3w)	(6w)	(9w)
K1	27	40	43	27	21	29	36	33	23	35	32
K2	24	34	31	16	17	17	33	40	23	24	34
K3	31	43	36	20	16	29	32	41	34	33	34
K4	23	23	23	16	13	24	29	34	21	24	23
	26	35	33	20	17	25	33	37	25	29	31

points are cut off. This means that after mowing in the outmost case the species has to initiate totally new shoots from basal stem buds or from rhizomes and consequently in a crop situation couch cannot easily extend its shoot numbers. Thanks to its good tillering and leafy shoots, perennial ryegrass had formed much denser swards than couch, whilst more frequent mowing clearly seemed to have increased its tiller density.

Mass decapitation of the growing points of couch, especially at the late first cut in 1970 when all clones had greatly elongated, resulted in an open sward, because due to senescence of basal stem buds, almost all the new shoots had to be regenerated from rhizomes. This explains the low shoot densities that were found in the clones at the second cuts of the T2 monocultures; on average 19 shoots per dm<sup>2</sup> compared with 31 to 43 shoots (three clones; K1, K2 and K3) at the second cuts after the early first cut in the T1 treatment (Table 3). The latter shoot densities are representative for a well developed couch crop in May and June and in 1970 were also found in monoculture patches of this species in an intensively used grassland that did not form part of the set-up of this trial. At the second cut of the 6-weekly T1 treatment, 120 shoots per dm<sup>2</sup> had been counted in the monocultures of perennial ryegrass, which can be considered as a good tiller density.

*Dry matter yields, weed percentages and rhizomes:* In Fig. 3, the total dry matter yields for 1970 of the couch clones and perennial ryegrass in the T1 and T2 treatments are plotted against the mowing frequency. Table 4 presents the weed percentages of these yield totals and Table 5 the weed percentages of the dry matter yields at the first cut in 1971. Fig. 4 shows the dry matter yields themselves at the first cut in 1971 and Table 6 shows the quantities of rhizome found in November 1970 in the borings taken in the couch monocultures. All the dry matter yields include weed.

Fig. 3 shows that in couch as well as in perennial ryegrass, less frequent mowing generally resulted in higher total dry matter yields. In the T1 treatment for the highest yielding clone (K1), yields were equal or even higher than the perennial ryegrass (1000–1250 g.m<sup>-2</sup> compared with 900–1250 g.m<sup>-2</sup>). The less

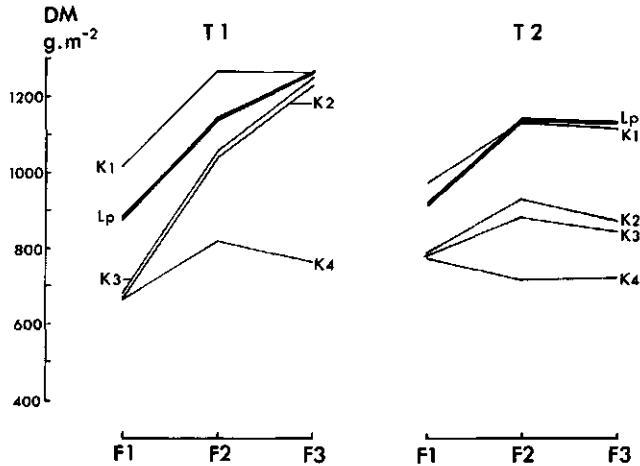


FIG. 3. Total dry matter yields- 1970 (DM) of the monocultures of the clones (K) and perennial ryegrass (Lp) in the different mowing treatments.

TABLE 4. Mean weed percentages in the yield totals - 1970 (DM) of the monocultures of the couch clones (K).

	T1F1 (3w)	T1F2 (6w)	T1F3 (9w)	T2F1 (3w)	T2F2 (6w)	T2F3 (9w)
K1	-	-	-	-	-	-
K2	11	-	-	5	-	3
K3	9	2	-	7	2	4
K4	16	11	-	15	6	11

TABLE 5. Mean weed percentages in the dry matter yields of the monocultures of the clones at the first cut in 1971.

	T1F1 (3w)	T1F2 (6w)	-T1F3 (9w)	-T2F1 (3w)	T2F2 (6w)	T2F3 (9w)
K1	6	1	1	38	5	-
K2	49	3	-	37	20	-
K3	27	12	-	17	15	5
K4	36	13	6	33	28	32

productive clone K4 yielded half of this, whilst in the same T1 treatment two clones (K2 and K3) were reasonably productive at the 6- and 9-weekly mowings. In both 3-weekly treatments K2 and K3 had had yields as low as K4. Their low yield totals in all T2 treatments may be attributed to the mentioned regrowth problems after the late first cut. The reason that yields in the T2 treatment of all genotypes at 6- and 9-weekly mowing were lower than the T1 treatment is the fact that in 1970 the T2 monocultures had been harvested one time less. Because the

crop height was reduced so frequently at 3-weekly mowing, the couch monocultures with this mowing regime had most weed (Tables 4, 5).

At the first cut in 1971, the yields of the couch clones showed a strong positive after-effect of less frequent mowing in the preceding year (analysis of variance,  $p < 0.001$ ) whilst those of perennial ryegrass only indicated a difference between the two T treatments ( $p < 0.01$ ). Perennial ryegrass had higher yields in the T2 monocultures (Fig. 4), which may be explained by the longer growth period after the last cut of these monocultures in the autumn.

The higher yields of the couch clones at the first cut in 1971 are not all related to higher shoot densities (see right-hand side of Table 3) but in all clones a clear relationship is found with the average shoot weight (Fig. 5). In both the early and late first cut treatments, all clones had formed taller elongated shoots and a taller

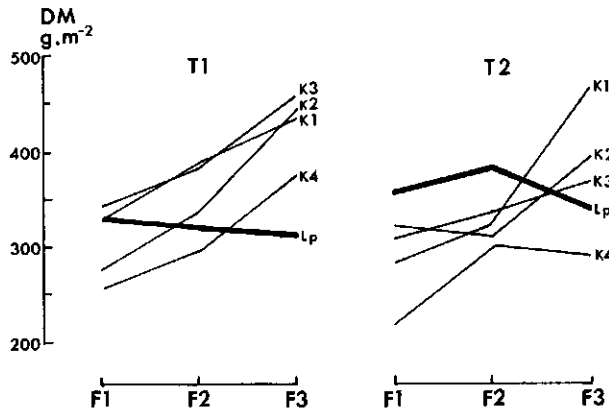


FIG. 4. Effect of the mowing frequency in 1970 on the dry matter yields of the monocultures of the four couch clones (K) and perennial ryegrass (Lp) at the first cut in 1971. Yields including weed.

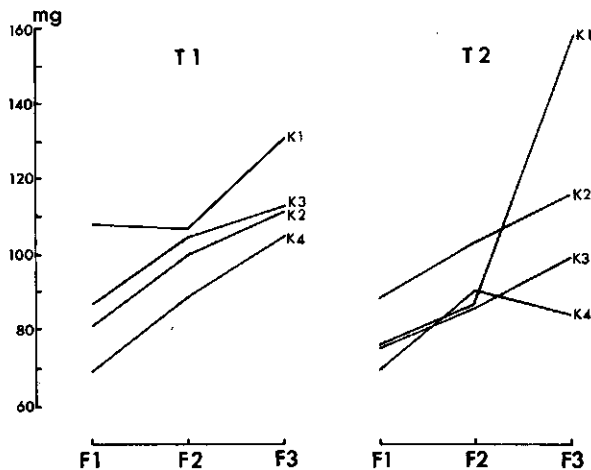


FIG. 5. Average shoot weights of the couch clones (K) in the monocultures at the first cut in 1971.

TABLE 6. Dry weight, number and mean weight of rhizome pieces in the couch monocultures, November 1970. Means per four borings per clone and per mowing frequency.

	K1	K2	K3	K4	F1 (3w)	F2 (6w)	F3 (9w)
dry weight (g)	5.8	14.3	11.3	7.7	8.2	9.2	11.7
number (n)	113	182	167	147	144	154	159
mean weight (mg)	49	75	68	51	55	58	69

crop the less frequently they had been mown. In the formerly 6- and 9-weekly mown treatment the clones had formed much taller crops than perennial ryegrass. The higher average shoot dry weight was possibly related to thicker rhizomes, for in all clones, less frequent mowing had also resulted in a higher mean weight of the rhizome pieces in the borings (Table 6, November 1970). An analysis of variance showed that this effect of the mowing frequency was very significant ( $p < 0.001$ ) whilst a similar significant effect was not shown by the number of rhizome pieces in the borings. The same borings in November had shown that the perennial ryegrass monocultures had formed three times more root material than the monocultures of the couch clones.

*Further information on the couch clones:* In the T2 treatments K1 recovered more easily from the low shoot densities after the late first cut, but the higher dry matter yields in 1970 and the lack of weed in almost all its monocultures (Fig. 3, Table 4) were possibly also related to the fact that after the first cuts this clone had formed larger leaves. Because of an earlier spring growth and early stem elongation, at the early and the late first cut K1 was already the highest yielding clone and in fact had deviated from the other clones in the whole seasonal pattern of dry matter production. This is further illustrated in Fig. 6 and 7. Fig. 6 shows the dry matter increase for all clones at the early and the late first cuts, with respect to April 10 when growth started; Fig. 7 gives the dry matter yields of the individual cuts of the 6-weekly T1 treatment for all clones and perennial ryegrass.

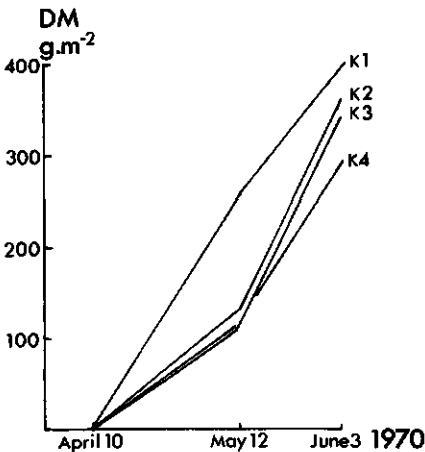


FIG. 6. Dry matter increase of the four clones (K) at the early and late first cuts in 1970, May 12 and June 3, respectively.

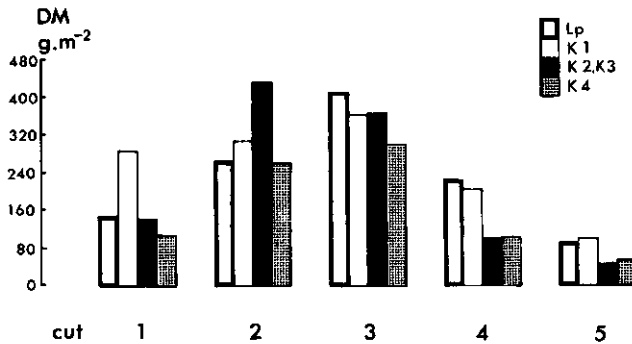


FIG. 7. Dry matter yields of the four couch clones (K1, K2, K3, K4) and perennial ryegrass (Lp) at the successive cuts of the 6-weekly mown monocultures with the early first cut in 1970.

grass. As two clones (K2 and K3) did not differ in yield, in the latter figure their data have been averaged.

The yields of the early first cut are particularly low (Fig. 6) compared with the yields of the first cut in 1971 (Fig. 4). This also holds for perennial ryegrass and can be attributed to the low first nitrogen dressing and to the late spring in that year. However, despite the fact that perennial ryegrass produced its first leaves earlier after the winter, at the early first cut the yields of K1 were twice as high as those of all remaining genotypes.

As K2 and K3 had started elongating later in spring, they were higher yielding at the second cut of the 6-weekly T1 treatment (Fig. 7). The main reason for the lower yield of K1 at this cut is that because of its early stem elongation, at the early first cut this clone had already lost almost all its shoots because the growing points had been cut off: this resulted in a very slow regrowth. Fig. 7 also illustrates that in the autumn, as well as K1, perennial ryegrass also yielded more than the other couch clones.

However, as Fig. 4 showed, K1 no longer produced higher yields in all the treatments at the first cut in 1971. This indicates that clonal differences in first cut yields are not constant and it is quite possible therefore, that the higher K1 yields at the first cuts in 1970 had resulted from the fact that in the previous year the monocultures had only been mown three times. For, as follows from Fig. 4 as well, the only indications of still higher yields of K1 are found in the least frequently mown 9-weekly T2 treatment. In this treatment K1 also had the highest shoot weight (Fig. 5).

The experiment shows that the degree of tillering and vegetative propagation from spaced plants is not always an appropriate measure of the shoot-forming ability of couch clones in a crop situation. This is clearly illustrated by K2 and K3. For, in spite of the much stronger vegetative propagation from spaced plants of K2 (Table 1, number of daughter plants; Table 2), in 1970 in their monocultures both clones did not systematically differ in shoot densities and in pattern of weed increase (Table 3, Tables 4 and 5). On the other hand, the faster recovery of K1 from low shoot densities agreed with its stronger tillering and more intensive

daughter plant production from rhizomes, whilst K4, because of its long rhizomes (Fig. 1) was the only clone that spread beyond the plots of the monocultures and mixtures and this may have been why in the T2 treatment it was finally unable to maintain a closed sward (Table 3). At the first cut in 1971 K4 had 32% weed even in the 9-weekly mown T2 monocultures (Table 5).

The clones differed considerably in rhizome production, mean rhizome weight and number of rhizome pieces in the borings (Table 6, November 1970), but their differences in productivity did not correlate with these characteristics. The production of many thick rhizomes might favour couch in arable land, where rhizomes are cut into pieces and easily spread over the field by cultivation (NEUTEBOOM, 1975, 1980), but apparently rhizome production per se is not an appropriate measure for predicting the performance of clones in grasslands.

### MIXTURES

Is perennial ryegrass crowded out by couch at continuously late mowing and how important are clonal differences in the couch in this respect? Conversely, can perennial ryegrass maintain or even increase with respect to couch at frequent mowing?

Taking the mean yield differences between the couch clones and perennial ryegrass in the monocultures in 1970 (Fig. 3), we would not expect that perennial ryegrass would be excluded by couch. This surely holds for the T2 treatment, where at all mowing frequencies at all cuts, on average couch had been lower yielding than perennial ryegrass. At the most, perennial ryegrass might have been excluded at the first cut in 1971, when in both 9-weekly treatments this species had been outyielded by almost all clones (Fig. 4).

However, as is illustrated in Fig. 8, the data on the relative yields of perennial ryegrass ( $r_{Lp}$ ) show a different picture; so, initially in 1970, perennial ryegrass was excluded by couch in all mowing treatments, whilst in the second part of the growing season or not until the first cut in 1971, the relative yield of perennial ryegrass had recovered again in all mowing treatments. Between the last autumn cut in 1970 and the first cut in 1971, in the 9-weekly treatments, perennial ryegrass had apparently recovered against an invigorated and more productive couch (compare Fig. 4).

It might be queried if the growing conditions in the monocultures had restricted production, but the relative yield totals (RYT) of the total dry matter yields in 1970 had equalled one (Table 7) and thus indicate that the monocultures of both species and their mixtures had, on average, yielded in one straight line. The conflicting recovery of perennial ryegrass at the first cut in 1971 was possibly due to a difference in growth rhythm between the two species in early spring, i.e. perennial ryegrass had an earlier spring growth and therefore had recovered before the couch came through later from rhizome reserves. This is supported by the fact that at the first cut in 1971 as well as at the early and late first cuts in the preceding year, in all treatments RYT had systematically tended to be greater

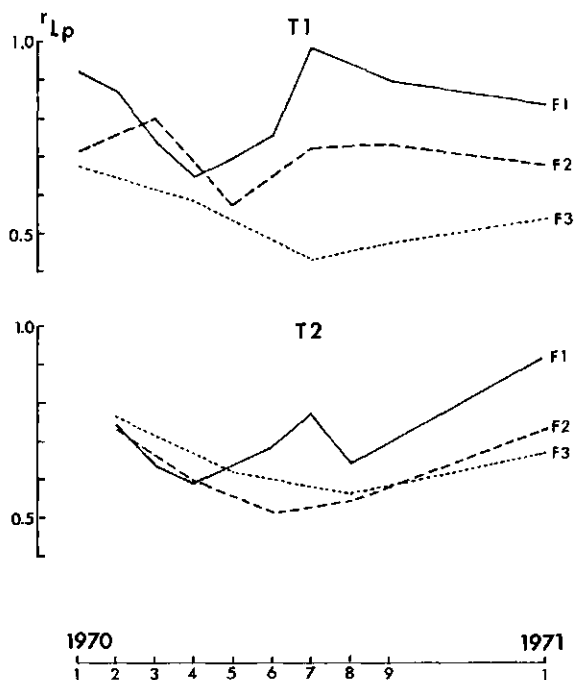


FIG. 8. Changes in the relative yields of perennial ryegrass in the mixtures at successive harvest dates in 1970 and 1971, different mowing treatments.

TABLE 7. Average RYT values of the yield totals of 1970 (DM). Only values of treatments with less than 5% weed.

	T1F1 (3w)	T1F2 (6w)	T1F3 (9w)	T2F1 (3w)	T2F2 (6w)	T2F3 (9w)
K1	1.05	0.98	0.98	1.02	1.09	1.03
K2		1.04	0.80		0.95	1.00
K3		0.97	0.95			1.03
K4			0.99			

TABLE 8. Average RYT values at the first cuts T1 (May 12) and T2 (June 3) in 1970 and at the first cut in 1971 (May 18). In the latter case only values of treatments with less than 5% weed (DM) are presented.

	1970		1971					
	T1	T2	T1F1 (3w)	T1F2 (6w)	T1F3 (9w)	T2F1 (3w)	T2F2 (6w)	T2F3 (9w)
K1	1.07	1.16	1.22	1.04	1.20		1.25	1.12
K2	1.01	1.00		1.14	1.02			1.26
K3	1.08	1.06			1.00			1.30
K4	1.05	1.03			1.17			

than one (Table 8). The RYT values in Tables 7 and 8 are all mean values, calculated from the individual replicates of each clone in each of the mowing treatments that on average contained less than 5% weed in their monocultures.

As at the first cut in 1971, in fact only the relative yield of perennial ryegrass increased significantly in the 3-weekly treatment with the late first cut (Fig. 8, T2F1); the ultimate effects of the mowing frequency on the exclusion of this species are not very clear. On the other hand, as will be illustrated in connection with Fig. 9, the mowing frequency had resulted in a strong effect on the relative reproductive rate of couch with respect to perennial ryegrass. As this was the same effect as found with the yields of the couch monocultures in 1971 (Fig. 4), it seems that also in the mixtures, less frequent mowing had invigorated the couch more than the perennial ryegrass.

Indications were found of a stronger exclusion of perennial ryegrass in the mixtures of the most productive clone K1, especially in the 9-weekly treatments: however, because of  $RYT > 1$  at the first cuts in spring, this might also have resulted from the higher initial densities of this clone in the mixtures (compare Table 2).

Because of the weed problem in the couch monocultures we cannot calculate relative yields of couch for all cuts of all clone- mowing treatments as we did for perennial ryegrass in Fig. 8. The latter relative yields are always mean values of four replicates as well, whilst the same holds for the relative reproductive rates ( $\alpha$ ) of couch with respect to perennial ryegrass at the first cut in 1971, shown in Fig. 9. These relative reproductive rates of couch were calculated with respect to the early and the late first cuts in 1970 and show that whereas the amounts of couch relative to perennial ryegrass in the 3- and 6-weekly mowed mixtures remained

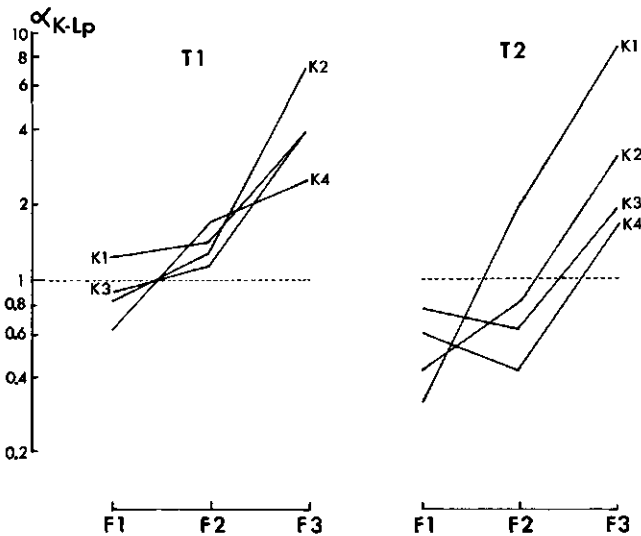


FIG. 9. The relative reproductive rates ( $\alpha$ ) of the clones (K) with respect to perennial ryegrass (Lp) at the first cut in 1971, compared with the early and late first cuts in 1970; effect of the mowing frequency (F).



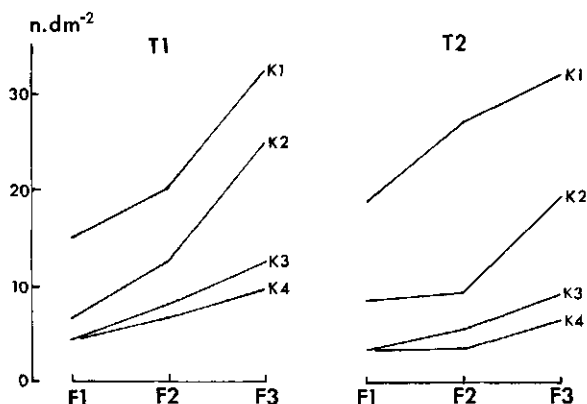


FIG. 10. Average shoot densities ( $n.dm^{-2}$ ) of the clones (K) in the mixtures at the first cut in 1971, and the effect of the mowing frequency (F).

constant or even decreased, couch strongly increased in the 9-weekly mixtures. The higher relative reproductive rates of couch were partly due to a higher shoot weight (compare Fig. 5, monocultures), partly, however, also the result of higher shoot numbers in the 9-weekly mowing regime (Fig. 10). Table 9 finally shows data on the amounts of rhizome found in the borings (which in the mixtures were taken in September 1971); less frequent mowing had also resulted in an increase in the number and the mean dry weight of the couch rhizomes.

*Clonal differences:* During the experiment, in all the mowing treatments the clones differed in the changes of their dry weight ratios with respect to perennial ryegrass, but as we saw in Fig. 9, where the different relative reproductive rates of the mowing treatments reflected the after-effects of these treatments on the productivity of couch, these changes partly have to be attributed to clonal differences in seasonal pattern of dry matter production. This is further illustrated in Fig. 11a and b. Fig. 11a graphs the relative reproductive rates of the couch clones with respect to perennial ryegrass for the 6-weekly mixtures with the early first cut; Fig. 11b shows changes in the relative yields of perennial ryegrass at the subsequent cuts.

The relative reproductive rates are calculated from the early first cut and clearly show that contradictory to an initial increase in the relative reproductive rates of K2, K3 and K4, at the second cut the relative reproductive rate of K1 had

TABLE 9. Dry weight, number and mean weight of rhizome pieces in the  $T_1$ -mixtures, September 1971. Means per four borings per clone and per mowing frequency.

	K <sub>1</sub>	K <sub>2</sub>	K <sub>3</sub>	K <sub>4</sub>	F <sub>1</sub> (3w)	F <sub>2</sub> (6w)	F <sub>3</sub> (9w)
dry weight (g)	2.4	5.8	2.8	1.5	1.4	3.5	4.5
number (n)	72	114	62	49	42	78	99
mean weight (mg)	34	46	40	31	31	40	43

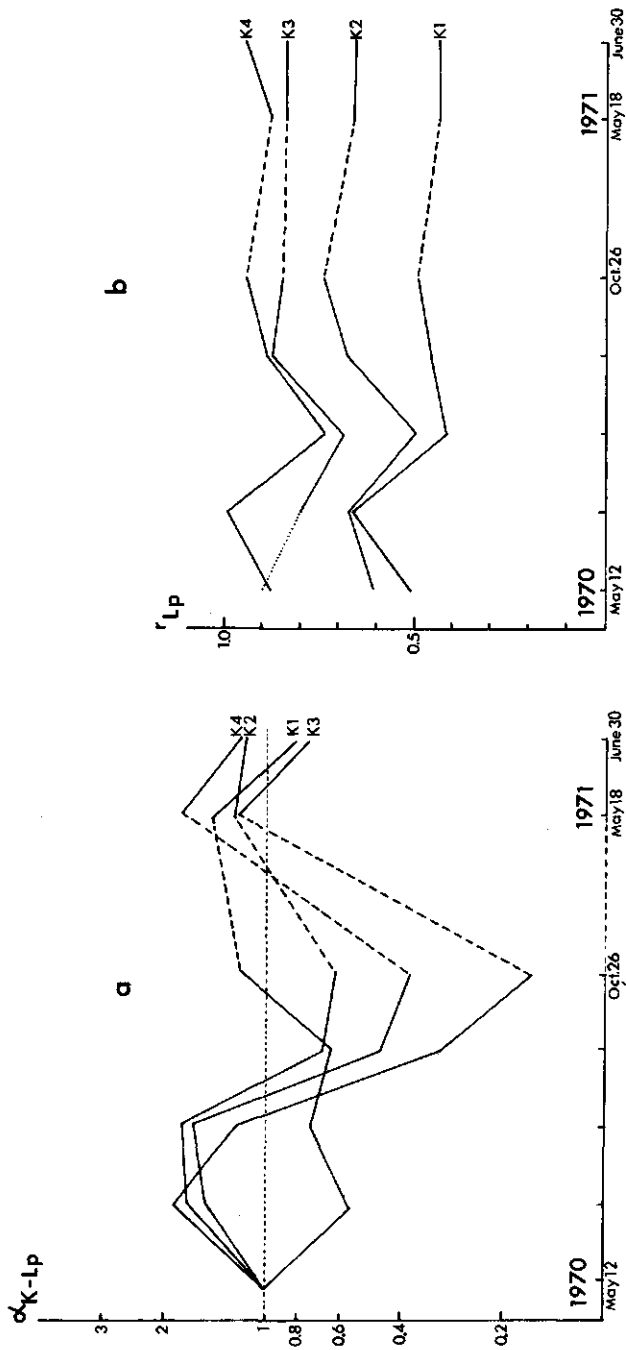


FIG 11a. Graphs of the relative reproductive rates of the clones with respect to perennial ryegrass ( $\alpha_{K-Lp}$ ) in the 6-weekly mixtures with the early first cut.  
 b. Changes in the relative yields of perennial ryegrass ( $r_{Lp}$ ) in the same mixtures.

sharply decreased. This decrease had occurred in each of the replicates of K1 and was caused by the fact that after significantly higher yields of K1 at the early first cut, equal yields for K1 and perennial ryegrass were found at the second cut (Fig. 7). Conversely, the other clones yielded more than the perennial ryegrass at the second cut, after they had yielded the same as the ryegrass at the early first cut. The decreases in the relative reproductive rates of K2, K3 and K4 after the third cut correspond with their relatively low productivity in the later part of the growing season (Fig. 7, monocultures). However, after the winter, the first cut of 1971 showed that the relative reproductive rates of these clones had recovered remarkably. Fig. 11*b* shows that although changes had occurred in the relative yields of perennial ryegrass, the mixtures with the respective clones had not systematically differed in these changes.

Fig. 12 further illustrates the stronger exclusion of perennial ryegrass in the 9-weekly treatments in the mixtures with K1. In this figure, the relative yields of the individual mixtures of some comparable cuts of both 9-weekly treatments (couch as well as perennial ryegrass) have been plotted against each other. The straight lines through the origin and the mean yield of the monocultures ( $r_{Ely}$  or  $r_{Lp} = 1$ ) represent the situation of  $k_{Lp-Ely}$  or  $k_{Ely-Lp} = 1$ , the curved lines are average  $k$  lines fitted to the points of the mixtures of all clones. In the figures 12*d*, *e*, *f*, four points of one clone (K4, 9-weekly treatment with the late first cut) are missing because of the already high weed percentages at the third cut in its monocultures.

The figure shows that the decrease in perennial ryegrass between the first and the third cuts (1970) was complemented by an increase in couch (Fig. 12*a*, *d*) whilst both species showed an increase in the following growth period until the first cut in 1971 (Fig. 12*b*, *e*). At the second cut after 9-weeks in 1971, indications of a new decrease of perennial ryegrass are found although the yield of couch seemed not to have increased towards the yield of its monoculture (Fig. 12*c*, *f*). However, at this cut, data had only been collected for two clones, K3 and K4. The relative yields of perennial ryegrass had not decreased at the second cut of the 6-weekly mixtures in 1971. This is illustrated in Fig. 11*b* for the 6-weekly T1 mixtures.

Figure 12 clearly indicates a lower  $k$  value for perennial ryegrass during the 1970 growing season in the mixtures of K1 (Fig. 12*a*), while in contrast to the other mixtures, perennial ryegrass had not clearly recovered in the K1 mixtures at the first cut in 1971 (Fig. 12*b*). At the third cuts in 1970 as well as at the first cut in 1971 in the same K1 mixtures, this corresponds with a stronger relative increase in couch (Fig. 12*d*, *e*). For, in both cases (both Figures 12*d*, *e*) the K1 mixtures seem to indicate a higher  $k$  value for couch than is suggested by the average curved lines. Conversely, perennial ryegrass had hardly changed during the 1970 growing season in the mixtures of K4 (Fig. 12*a*), whilst during the whole experiment until the first and the second cut in 1971, couch had hardly increased in the mixtures of K4 or of K3 (Fig. 12*d*, *e*, *f*).

Occasionally, perennial ryegrass in the mixtures was crowded out at a still higher or increasing productivity relative to the clones. This holds for the relative decrease in this species after the late first cut in the 9-weekly T2 mixtures of K2

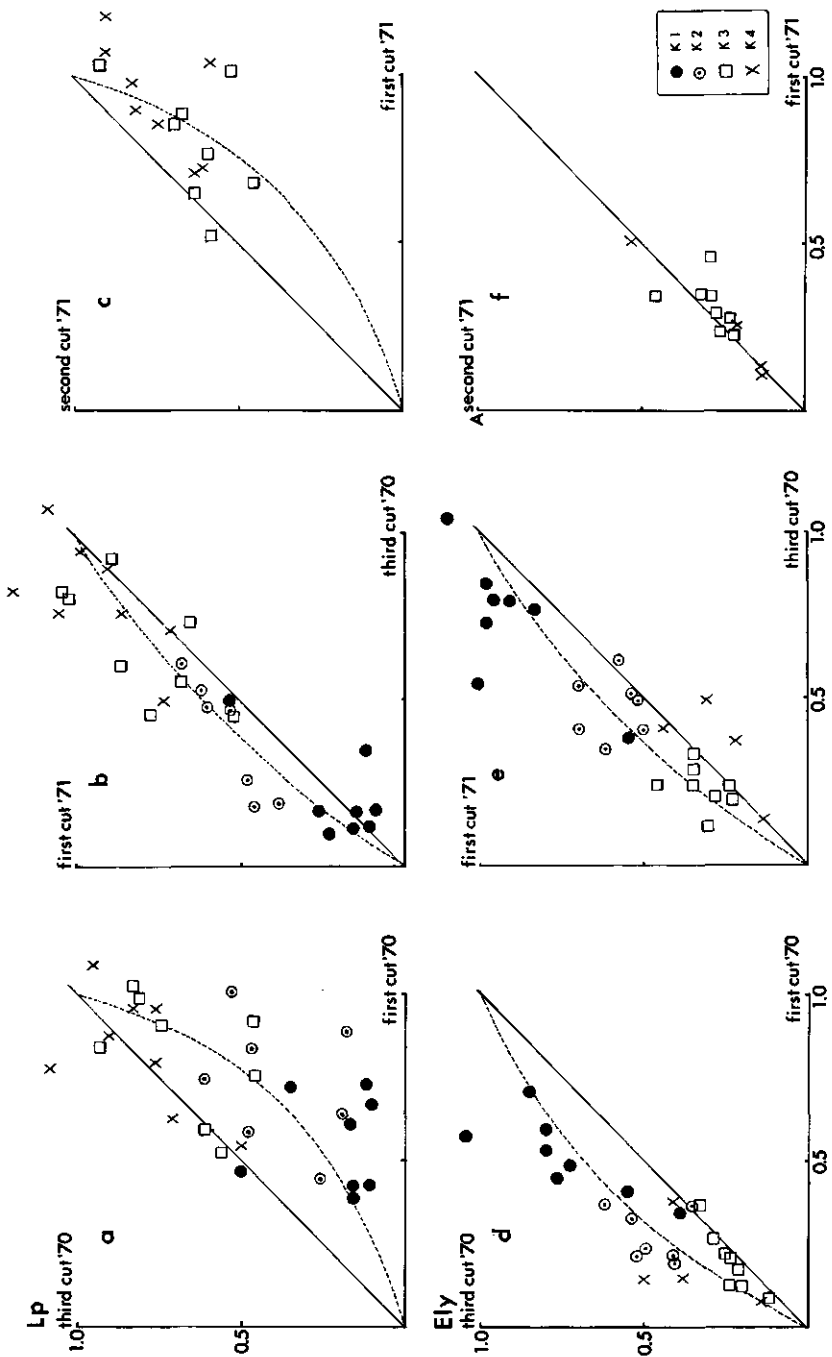


FIG. 12. Changes in the relative yields of perennial ryegrass (LP) and couch (Ely) in the individual mixtures of the four clones at some cuts of the 9-weekly mowing treatments.

and K3 (Fig. 12a, Fig. 3). This decrease therefore might also have been due to an after-effect of a stronger couch in the preceding growth period. In this period, couch might have formed more rhizomes or perennial ryegrass might have been weakened as a consequence of an enforced etiolation between a strongly elongated couch. The latter possibility is supported by the fact that in the 9-weekly treatment mentioned, the couch yield had not increased towards the yield of its monoculture in the K3 mixtures (Fig. 12d). Also between the first and the second cut in 1971 in the mixtures, the yield of perennial ryegrass appeared to have decreased relative to the yield of its monocultures at unchanged relative yields of couch (Fig. 12c, f).

## DISCUSSION

*Mowing treatments and main species differences:* That continuously late mowing can increase the dry weight of couch in perennial ryegrass mixtures has also been found in other experiments (MULDER, 1949; CUSSANS, 1973). Our experiment showed that perennial ryegrass can be crowded out by couch, particularly in the first part of the growing season, and that continuously late mowing has an invigorating effect on the growth of couch in the following spring. The latter contradicts the general experience that perennial ryegrass is more sensitive to late defoliation. To some extent this tendency in ryegrass also seemed to be indicated by our experiment, where as a result of strong tillering, perennial ryegrass had formed a much denser sward at 3-weekly mowing than at 9-weekly mowing. CUSSANS (1973) also reported that in his experiment at 3 cuttings a year the perennial ryegrass sward had started to deteriorate. And although in our experiment, even at 9-weekly mowing, the perennial ryegrass had greatly recovered from exclusion again by the autumn and in early spring, on a long term in grassland, continuously late mowing also for that reason might run the risk of a further exclusion or even simply a replacement of perennial ryegrass by couch. However, perennial ryegrass may also be especially crowded out at higher densities of couch (Fig. 12, K1).

Our experiment also indicates that although at frequent 3-weekly mowing couch could not maintain closed monocultures, this mowing frequency is still not always a suitable means of reducing couch in perennial ryegrass mixtures over the short term (Fig. 8, Fig. 9; T1 treatments). Even at 3-weekly mowing, couch can form new rhizomes. This was shown by a new sampling of the T1 monocultures in September 1971. The total rhizome dry weight had decreased compared with the samples taken in November 1970, but for each of the mowing frequencies the number of rhizome pieces in the borings appeared to have increased by 25%! The decrease in the rhizome dry weight was probably due to the death of old rhizomes. It is true that in a field experiment COURTNEY (1980) found that in a perennial ryegrass sward the rhizome levels of couch were contained by defoliation at less than four weekly intervals, but in a grassland open patches always occur and here couch can behave as if in a monoculture. However, the

formation of new rhizomes might also depend on the cutting height, which in our experiment was 3½ cm. Like CUSSANS (1973), we found that at an increasing age of the sward, new rhizomes were formed at increasingly shallow depths. For, whereas in the first year, rhizomes had even been formed at 10–20 cm below soil surface, when the monocultures developed from spaced plants, at the last sampling in September 1971, almost all new rhizomes were found in the topmost 3 cm of the soil.

Couch and perennial ryegrass not only differ in tillering ability and in the fact that couch forms rhizomes, but also in propensity to stem elongation, which is much stronger in couch. The higher yields from couch at longer growth periods primarily seemed to be due to an increased shoot weight resulting from continuous stem elongation; this strong stem elongation might also make couch more competitive for light. The reason that couch can continuously elongate was discussed in an earlier paper (NEUTEBOOM, 1975). In couch, generative as well as vegetative shoots can strongly elongate, whilst in perennial ryegrass, apart from short vegetative internode elongation (KRUIJNE, 1958, 1963, SIMONS et al., 1974; MINDERHOUD, 1977), only generative shoots can form real culms. Therefore, perennial ryegrass can only elongate some of its shoots during its main period of ear formation and before and after that period it mainly forms leafy shoots with their growing points near ground level. However, the T2 treatment clearly illustrated that in couch its strong and total stem elongation can also result in a poor regrowth and temporary low productivity when this species is defoliated at a senescent stage, (Fig. 3, Table 3). This might also explain why in the mixtures we did not also find that the late first cut invigorated the couch more than the early first cut. It is interesting that in a grazing experiment, BLATTMANN (1966) found that just a yearly early first grazing had resulted in a strong increase in couch, whilst in contrast, a yearly late first grazing at the end of May favoured the spread of *Dactylis glomerata*; in fact this seems to be more in the line of the picture of our monocultures that couch can be weakened when the first cut is late. BRANSON (1953) had already indicated that because of their elevated growing points, stemmy species are more sensitive to defoliation and he used this sensitivity to explain why, for example, a species like *Agropyron smithii* is less adapted to heavy grazing. The reason that we still believed that the low productivity and strong weed increase of the couch monocultures at 3-weekly mowing were primarily due to weak tillering, is that we had the strong impression that in couch this mowing frequency also inhibited further stem elongation. The same feature can be observed in *Agrostis tenuis*, a species that despite its pronounced vegetative stem formation can stand very intensive and short mowing in lawns (NEUTEBOOM, 1977).

*Clone differences:* Depending on the mowing frequency, clones can apparently differ in their seasonal pattern of dry matter production (Fig. 7) and thus in their changes in dry weight ratio with respect to perennial ryegrass at successive cuts in mixtures (Fig. 11a). These differences partly appeared to be related to clonal differences in growth vigor in the later part of the growing season, but also resulted from clonal differences with regard to the onset of stem elongation in

spring. Clones may differ particularly markedly in rapidity of vegetative propagation by rhizomes, in situations of spaced plants. For, despite their considerable differences in rapidity of vegetative propagation from spaced plants (Table 1, Fig. 1) and in rapidity in forming closed monocultures (compare also Table 2), at the first cut in 1971 three clones in the monocultures no longer systematically differed in shoot density (Table 3; K1, K2, K3); in the mixtures at rather late 6-weekly mowing these clones did not differ in the changes of their relative yields (Fig. 11b). This agrees with the results of an experiment done by LAWRENCE, (1965) in which no relationship was found between the degree of 'creeping rootedness' of spaced plants of twenty clonal lines of *Agropyron intermedium* (Host) Beauv. and their final basal ground cover in monocultures three years after sowing.

It is true that in the extremely late mown 9-weekly mixtures the clone with the strongest ability to produce daughter plants from rhizomes (K1) still had excluded perennial ryegrass the most (Fig. 12); however, because  $RYT > 1$  at the first cuts in spring (Table 8) this might also have been due to the higher densities of this clone in the mixtures (Table 2). The latter possibility is supported by the observation that perennial ryegrass had formed strongly etiolated shoots with long narrow leaves between the taller couch, especially in the K1 mixtures. In any case, it remains true that in grassland, clones like K1 and K2 can much more rapidly fill up open patches and consequently will be sooner able to form locally high shoot densities in which the remaining perennial ryegrass can be more easily crowded out. Typical clone characteristics such as the earlier spring growth and early stem elongation of K1 might accelerate this latter process, whilst in colonizing open patches a clone like K1 can also more successfully compete with other invading weed species of grasslands e.g. *Poa annua* (Tables 4, 5). In an intensive grassland management system, many factors can cause an open sward and because high nitrogen can strongly stimulate bud activity (MCINTYRE, 1965) and thus shoot production from rhizomes, clonal differences in vegetative propagation might become apparent in intensively used grasslands. Its explosive daughter plant production on open patches characterizes couch as a typical colonizing grassland species and for that reason typical cases of an explosive increase of couch in grassland may have to be primarily attributed to an open sward.

In an earlier paper (NEUTEBOOM, 1980) I reported that in a comparison of spaced plants, couch clones collected from grasslands on average showed stronger tillering and a more prostrate growth habit than couch clones collected from arable fields, which on average had thicker rhizomes. Stronger tillering clones might persist longer at frequent defoliation (NEUTEBOOM, 1975) and this might also apply to the clone K4, which in the spaced plant experiment had shown a relatively strong tillering of its parent plants and daughter plants from rhizomes (Table 1). In a crop situation, most of the above-ground plant units of couch have a short life span of less than one year, but at the first cut in 1971 even at the 3-weekly mowing, many of the plant units of K4 that originated from the spring of the previous year had continued tillering. In the second clone with

relatively strong tillering in the spaced plant experiment (K1, Table 1) tillering in early spring may have been inhibited because of its early stem elongation. This indicates that tillering is not always a constant characteristic. The rather dense monocultures of K3 might partly have been related to its prostrate growth habit which meant that many shoots of this clone escaped defoliation, especially at the early first cut in 1970.

#### SUMMARY

In a field experiment, the growth and development of four clones of couch were studied in monocultures and in perennial ryegrass mixtures at different mowing regimes. The experiment, in which monocultures of perennial ryegrass were also included, was done at a high fertilization level; the mowing height was  $3\frac{1}{2}$  cm.

Repeatedly late 9-weekly mowing invigorated the growth of couch and on a long term seems to weaken perennial ryegrass. In mixtures this invigoration of couch, especially in the first part of the growing season, can lead to the exclusion of perennial ryegrass, although in the later growing season and in early spring at sufficiently high tiller densities the latter species can reassert itself. Possibly perennial ryegrass can only be totally excluded by couch at high densities of couch. Perennial ryegrass can even be temporarily excluded by couch at 6- and 3-weekly mowing, if there was a late mowing in the preceding year.

Typical cases of an explosive increase of couch in intensively used perennial ryegrass grasslands may be primarily due to an open sward, which at a high nitrogen fertilization is easily colonized by clones with a strong ability to propagate vegetatively. The couch problem in these grasslands may therefore also be related to other factors, which together with late mowing, can seriously damage a perennial ryegrass sward; drought, low winter temperatures, heavy trampling and more dung and urine patches at high stocking rates, application of slurry, etc.

Couch not only differs from perennial ryegrass because it forms rhizomes but also because of its continuous strong stem elongation and weak tillering. The invigoration of couch through late mowing may be partly related to its stemmy growth habit, which enables this species to form a tall crop, in which especially at high densities of couch perennial ryegrass can be crowded out in the competition for light. Long growth periods will also favour the rhizome production of couch. However, mowing at an extremely late first cut can also temporarily weaken the growth of couch, because after its stems have been mown off at a senescent stage it can no longer regenerate from basal stem buds. The species can then only regenerate from rhizomes, which can lead to temporary low shoot densities and temporary low cut yields. Couch is relatively sensitive to frequent defoliation, possibly because of its poor tillering.

Couch clones can differ greatly in rapidity of vegetative propagation by rhizomes, but this variability becomes especially apparent in spaced plant situations, e.g. in an open sward. Because of differences in the onset of spring growth



and stem elongation and differences in growth vigour in the autumn, couch clones can differ in seasonal pattern of dry matter production and therefore also in their seasonal changes in dry weight ratio vis-à-vis perennial ryegrass in mixtures. Couch clones with a strong ability to tiller may better be able to stand intensive and short defoliation in grassland over the long term.

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