

VARIATION IN COMPATIBILITY OF
PERENNIAL RYE GRASS CULTIVARS
WITH WHITE CLOVER

BY

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DECLARATION

I hereby declare that the work embodied in this dissertation for the degree of Magister In Scientia of the University of Wales is the result of my own investigation.

Candidate

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CERTIFICATE

I hereby certify that the work embodied in this dissertation has not already been submitted in substance for any degree, and is not being concurrently submitted in candidature for any degree.

Signed

Candidate

Date

DEDICATION

To my son Ssesanga-Sewaya, who was born
whilst I was away pursuing this study.

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SUMMARY

The growth of perennial rye grass (Lolium perenne) and white clover (Trifolium repens) in mixtures is the basis of pasture production in many temperate humid regions of the world. However, these two components have been traditionally bred separately without regard to their compatibility in a mixture.

Where more productive mixtures are sought, such compatibility should be considered in breeding programmes in order to develop a better ecological combining ability and the purpose of the present study was to identify differences in compatibility between a range of diploid and tetraploid rye grasses and white clover.

Agronomically it is required that both grass and clover maintain a substantial dry matter yield in mixtures. Variation in compatibility depends on the extent to which the yielding ability of both grass and clover is modified by interspecific competition. The late flowering grasses, Melle, Chieftain, Meltra and Ba 10764 produced the highest yields of white clover in addition to being highly productive both in monoculture and in mixtures. An agronomical implication of this is that grasses bred for high yields in pure stands may also be good companion grasses with white clover.

1.0 INTRODUCTION

Since agricultural scientists first became properly organised 100 years or so ago they have concentrated mainly on increasing yields (Vose, 1981). They have succeeded in this, especially in the 35 years since the Second World War, in which average yields have more than doubled. But the success has depended largely on breeding which has contributed a 30 - 60% increase (Sylvey, 1981).

Forage breeders working on perennial rye grass (Lolium perenne) have focussed their attention on high and stable herbage production, persistence, ease of management, high seed yield, resistance to biotic and abiotic factors and quality (van Dijk, 1984). Production of high yielding varieties has been achieved by hybridization between populations of diverse origin and inducing polyploidy (Humphreys, 1984).

Although Allard (1960) argued that simple polyploidy does not always confer superiority, a lot of research work has revealed that tetraploid rye grasses compete well with their diploid counterparts. Polyploidy has an effect on structural development. The nucleus is large resulting in large cells, thicker leaves and larger plant parts which may be fewer in number. Seed size is almost double compared to diploids and water content is 1 to 2% higher. Polyploids tend to have higher water soluble carbohydrate contents and are more palatable to stock. However, they

often have an open growth habit and total dry matter yield is similar to that of diploids (Breese et al., 1981). Because of their advantages in terms of quality and resistance to environmental stress, tetraploid usage as a percentage of total perennial rye grass usage has risen from 10 - 25% in the last 10 years.

The growth of perennial rye grass and white clover in mixture is the basis of pasture production in many temperate humid regions of the world. White clover, a legume, is of value because of its wide climatic range, the high nutritional quality and digestibility of its herbage, and the significant contribution it makes to the economy of grass/white clover pastures by fixing atmospheric nitrogen, especially in the absence of fertilizer nitrogen (Frame and Newbould, 1986). Practically speaking, these two components are generally bred separately, without regard to their compatibility in a mixture. However, where more productive mixtures are sought, such compatibility should be considered in breeding programmes in order to develop better "ecological combining ability".

The purpose of the present study was to identify differences in compatibility between a range of diploid and tetraploid perennial rye grasses and two white clovers. Also to identify characteristics of diploid and their genetically corresponding tetraploid grasses which affect their compatibility with white clover. The study focussed

on morphological features such as tiller angles, petiole length, leaf size and numbers. These characteristics may be used as selection criteria for breeding programmes to improve compatibility.

2.0 LITERATURE REVIEW

2.1 CROP MIXTURES

The practice of growing two (or more) crops simultaneously on one area of ground is as old as mankind and vegetation itself. It is very recent, however, that it has attracted scientific investigation (Willey, 1979). In the tropics, the number of crops involved ranges from 2 - 7 and in some cases higher (Sewaya, 1981). Natural vegetation normally occurs in a mixture of trees, shrubs, herbs and grasses of different species. In the temperate regions where agricultural research developed, sole cropping (monoculture) has been preferred because of the restriction imposed by the climate and shortage of agricultural labour (Ruthenberg, 1971).

Only in recent years, have reports become available on crop mixtures from different parts of the world and covering a number of crops. Research attention has been given to crop mixtures in different countries such as Colombia and other South American countries (Francis et al., 1975), the Carribean zone (Dalal, 1974), India (Aiyer, 1949), Nigeria (Andrews, 1972; Baker, 1974; Norman, 1974), the Philippines (IRRI, 1972; 1975), Tanzania (Finlay, 1974; Kayumbo, 1976), Uganda (Osiru and Willey, 1972) and United Kingdom (Lakhani, 1976; Rhodes, 1970).

A number of ecological reasons have been suggested why mixtures of genotypes (and species) should yield more, and

the yield be more stable, than that of genetically homogeneous stands (Trenbath, 1974). These include, on the one hand, more efficient use of environmental resources, through root and canopy stratification, both in time and space, and, on the other hand, the advantages of genetic diversity in combating pests and pathogens. The alleged advantages of genotypic heterogeneity have been reported to include lower variability of yield from season to season, a better spreading of production over the growing period and an improved quality of the crop product.

Although a yield and quality advantage has been firmly established for legume - grass mixtures grown for forage, there are a number of factors and cultural practices that would influence the relationship. These would include general compatibility (co-adaptation), competition, sward management, nitrogen fertilizer and moisture stress. I will discuss each in much more detail. It is worth emphasizing here that a further justification for more research in mixtures is that it is the small farmers of limited means who are most likely to benefit (Willey, 1979).

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2.2. CO-ADAPTATION IN CROP PLANTS

The choice of species for a mixture is the similarity of growth periods. Harper, (1983) argued that if a crop, which is slow to establish, is grown with one which has rapid early growth, the competitive balance will be strongly in favour of the latter. In natural ecosystems, stability is associated with diversity (Joy et al., 1980). For leys and sown pastures, unlike natural pastures, it is unreasonable to expect ecological combining ability between randomly chosen components, thus breeding programmes for co-adaptation or ecological combining ability should be adopted.

The growth of white clover (Trifolium repens. L.) and rye grass (Lolium spp) in mixtures is the basis of pasture production in many temperate humid regions of the world (Harris and Thomas, 1973). Natural populations of clover and rye grass which have co-existed in relatively stable equilibrium over a period of time may be expected to have become mutually adapted. Evans et al., (1985) found that clover populations which had a previous history of coexistence gave their highest yields when grown with their matching grasses.

2.3 PLANT COMPETITION

Plant competition can be defined as the struggle between individuals within a population for available resources, when the level of resources is below the combined need of the members of the population (Harper, 1983). Two plants, no matter how close to each other, do not compete as long as the common supply of a resource does not fall below their combined demands (Chirwa, 1985). The resources involved in crop growth are primarily light, water and nutrients. Two forms can be distinguished:- intra and inter-specific competition.

In populations of plants of similar genotype, in the absence of weeds, the competition is intra-specific, i.e. within a species. When different species of crops are grown in mixtures and when weeds are present, the competition is inter-specific i.e. between species. When competition occurs between parts of a single plant it is referred to as interplant (Beets, 1982).

The similarity of both intra and inter-specific competition is that the relationship between the final yield of a crop and plant population is either asymptotic or parabolic. Both in monocultures and mixed stands, total dry matter production usually increases asymptotically with increasing population density. On the contrary, Chirwa, (1985) strongly agreed with Rhodes and Stern, (1978) that competition effects within species and between species differ tremendously.

For example in mixtures of perennial rye grass and white clover dry matter production of both species and tiller numbers of rye grass, the inter-specific competition effects are significantly less than intra-specific competition effects (Chirwa, 1985). Rhodes and Mee, (1982) emphasized that the ranking of clover varieties varies with the companion grass variety implying that the degree of competition between associates may be specific to the individual mixture.

2.4 SWARD MANAGEMENT

The effects of management, environment factors and genotype on yield and composition of grass/clover mixtures are well documented (Rhodes, 1981). The most important effects of management is the method and frequency of defoliation. In the UK, the sward is either grazed or cut for conservation. To understand the way and magnitude defoliation affects yield and composition of grass/clover mixture, one has to understand the structure and pattern of growth of the components of sward canopy.

A lot of research work has been done towards the understanding of sward canopy structure at the Grassland Research Institute, Hurley, (Jones et al., 1982) and according to Woledge and Parsons (1986) one striking feature of similarity between grass and clover exists. In a grass sward, each shoot (tiller) typically bears three live fully expanded leaves or their equivalent; one expanding leaf, two fully expanded and one dying. The rate at which new leaves are produced depends on the environment, especially temperature; in the UK, each tiller expands a new leaf about every 9 - 10 days in mid summer and about every 35 days in winter (Davies, 1977). These leaves live for about 4 weeks in summer and up to 3 months in winter. Old leaves die as frequently as new leaves are produced, thus maintaining a more or less constant number per tiller. White clover, the most frequently used legume in grass mixtures in the UK,

has a similar turnover of leaves with similar rates of production and length of life (Davies and Evans, 1982; Korte, 1984). It is however, stoloniferous, unlike most of the agriculturally important temperate grasses, which are of the tussock type.

The clover stolons creep on the ground intermittently producing upright petioles at internodes that hold leaf laminae in the canopy. In mixed swards, the distribution of clover leaves is skewed towards the top of the canopy while that of grass is skewed towards the base (Woledge, Personal Communication). As a result, at 6 cm cutting height (NIAB, 1986/87) a higher proportion of clover lamina than of grass lamina is removed.

In mixed swards white clover requires flexible management with periods of rest interposed for recovery of leaf area; this may be achieved by using the sward for conservation (Frame and Newbould, 1984). However, the problem is that when conserved as hay, the wastage of leaf is excessive (Wright, 1984). But again, many studies have shown that total herbage from grass/clover swards increases as defoliation interval is lengthened (Frame, 1973). Experiments involving cutting, rotational grazing with sheep, or continuous sheep stocking have revealed marked variety x defoliation system interactions (Evans, 1979; Evans and Williams, 1982).

Increasing the interval between harvests from 3 or 4 to 8 - 12 weeks increased the yield of white clover and generally did not reduce the proportion of clover in total herbage (Wilman and Asiegbu, 1982). The effect of nitrogen will be discussed later in the review but it should be noted that increased Nitrogen application reduces the proportion of clover in total herbage although the total herbage increases. Wilman and Asiegbu's (1982) studies showed in detail that increased defoliation interval, reduced the number of grass tillers but increased grass yield and the size of grass leaves and increased grass height more than clover height; it also increased the proportion of petiole relative to leaflet in the clover. They went further to say that differences between varieties in response to interval between harvests were small but supported the view that medium large-leaved varieties can with advantage be defoliated rather less frequently than small-leaved ones. Moreover defoliation management can modify the varietal influence on composition of sward, with concomitant changes in the relative yields of the mixtures (Rhodes and Harris, 1978).

2.5 NITROGEN FERTILIZER

In intensively managed grassland, increased yields have been achieved by the widespread use of nitrogenous fertilizer. Woledge and Parsons (1986) showed that this increase is due to enhanced leaf growth and thus greater light interception, greater tiller density and the rate of leaf photosynthesis also increases with increased nitrogen supply. However, previously, Woledge this time working with Pearse (1985) on swards harvested by cutting or rotational grazing, had found out that nitrogen may have two conflicting effects. It may increase leaf photosynthetic capacity early in re-growth; but by stimulating leaf expansion, and thus mutual shading, it may depress it later, so that after a few weeks the photosynthesis capacity may be no greater than that of leaves in unfertilized swards.

In mixed swards of rye grass/white clover, it is widely believed that leguminous clover is capable of fixing nitrogen at rates equivalent to between 150 and 200 kg ha⁻¹ annum⁻¹ (Murphy, 1970; Ennik, 1970; Brock and Hoglund, 1974; Chirwa, 1985) and as stated earlier in the review, the smaller farmer of limited resources is in a position to obtain substantial yield increases from this association. White clover in swards derives its importance from its contribution to the nitrogen economy of the sward and in practice less competitive grasses than those commercially available may give better results where nitrogen

for the sward comes from clover (Murphy, 1970).

White clover varieties are commonly assessed in mown plots in mixtures with grass but without the application of fertilizer nitrogen. These plots often become clover dominant and are not typical of the type of sward that would be found in the field. Under field conditions the grass-clover association normally receives nitrogen both from animal returns and from moderate applications of fertilizer nitrogen, particularly in spring, and this results in higher grass/clover ratio (Aldrich, 1970).

Aldrich (1970) at Cambridge and Murphy (1970) in Wexford agreed with very many others that increased nitrogen levels virtually eliminates clover from the sward as well as reducing its yield. Indeed Murphy's results showed that nitrogen depressed clover stolons from 3203 to 613 cm per sq metre.

Purvis and Younger (1984) did not completely dispense with the idea of applying nitrogen to grass/clover swards. They found that substitution of clover by grass increased gradually as the amount of nitrogen applied increased. However, a certain initial quantity of nitrogen was absolutely essential to maintain a balance. Thus there is a threshold in the effect of nitrogen applied. Vallis (1978) discussed the use of "starter" doses of N as an aid to establishment of legumes that are slow to nodulate and also in the early weeks after germination, before nodulation becomes fully effective.

2.6 WATER-STRESS

For both dryland and irrigated pasture management, a greater understanding of the response of pasture plants to water deficits is required so that the information can be used to breed and select species with more desirable characteristics and to interpret and predict field performance, particularly in competitive situations. In the UK the annual potential transpiration is around 600 - 700 mm, with more than 1,000 mm of rainfall, in principle at least, sufficient water is available. Equally clearly, the excess of supply over requirement is small enough to tip the balance to excess of need over supply.

The water held in wet soil and available for removal by plants has often been defined as that held between the so called "soil constants", field capacity and permanent wilting point, (Stiles and Garwood, 1963) in the root zone of the plant. If the soil moisture content at field capacity and wilting point, and the depth of the rooting zone are known, the depth of available water can be calculated. In grass, the roots are strongly concentrated towards the surface, with over half the total root mass being in the top 5 cm of soil. Clearly this concentration of roots is not required for extraction of water, since the small fraction of roots present in the eighth centimetre of soil can remove nearly as much water as the plant requires. It is also reported (Andrew and Johansen, 1978) that the major plant

nutrients are concentrated close to the surface, like the roots. This suggests that the surface concentration of roots is required to extract nutrients, and that the cessation of growth when water is still readily available from the subsoil is due to the non-availability of nutrients from the dry top soil, since the nutrients must enter the plant in solution (Stiles and Garwood, 1963).

Water deficits, generally, cause marked reduction in leaf area and the resulting reduction in crop growth rate, particularly when there is incomplete light interception. Water stress has also been reported to affect leaf area by reducing tillering, for example in rye grass when soil water was reduced by 50% of field capacity (Luxmoore and Millington, 1971) and by hastening the death of leaves (Sheehy et al., 1975) and tillers. In general, soil water deficits of 5 cm or more slow the growth of temperate grasses (Stiles and Garwood, 1963).

Comparative studies on water stress show that differences in growth rate under stress do occur between species (Harris and Lazenby, 1974) and in mixtures of rye grass and clover this would affect their drought tolerance and thus competitive ability under dryland conditions. The factors determining these differences in growth rate under water stress are not clear from these studies.

In conclusion, Turner and Begg (1978) say that on the basis of the current knowledge of the responses of pasture species

to water deficit it is not possible to predict with any degree of confidence the effects of water deficits on mixed communities or the effects that a deficit will have on competition between species. Thus, research on the effects of water stress on the responses of both a range of monocultures and mixed communities is clearly warranted.

3.0 EXPERIMENT I

3.1 MATERIALS AND METHODS

3.1.1 EXPERIMENTAL SITE

The experiment was conducted at the Welsh Plant Breeding Station (50m above sea level) near Aberystwyth, Dyfed (52°26'N 4°1'W).

3.1.2 EXPERIMENTAL MATERIALS

This experiment was carried out with two white clover populations, Menna and Ac 3785, and eight Perennial rye grass populations, Aurora (Ba 9436), Ba 9954, Chieftain (Ba 9433), Ba 10764, Melle (Ba 10042), Meltra (Ba 10888), Ba 10431 and Ba 10428. See table 3.1.

Menna which has a good performance under a wide range of grazing, fertilizer managements and environments and able to sustain yields in mixture under high nitrogen was derived from plants collected from an intensively managed pasture in Surrey. This artificially sown pasture, established seven years prior to collection, had received 600 Kg of Nitrogen annum⁻¹ (Evans et al., 1985).

Ac 3785 which has a good early spring growth which should enhance its competitive ability with grass in mixtures, has an annual yield approximately 15 - 17 per cent higher than Menna. This population was collected from a natural pasture in the Jura mountains, Switzerland.

Ac 3785, like Menna belongs to the medium-leaved category but has short internodes, profuse flowering with long peduncles.

Basically, the eight perennial rye grass populations are made up of only four gene resources, Aurora, Melle, Chieftain and Ba 10431. The corresponding tetraploid grasses were obtained by doubling the chromosome numbers by use of Colchine. Aurora originated from the Zurich uplands, Melle from Belgium and Chieftain from the Ardennes plateau. Ba 10431 population is derived from a hybrid from Aurora and Melle (Humphreys, 1984). Both Chieftain and Melle are very late flowering varieties, Ba 10431 intermediate and Aurora very early.

TABLE 3.1

CHARACTERISTICS OF PERENNIAL RYE GRASSES USED

Populations	Place of Origin	Ploidy level	Heading Dates
Aurora (Ba 9436)	Zurich uplands	2n = 2x	4th May
Ba 9954		2n = 4x	8th May
Chieftain (Ba 9433)	Ardennes plateau	2n = 2x	19th June
Ba 10764		2n = 4x	15th June
Melle (Ba 10042)	Belgium	2n = 2x	17th June
Meltra (Ba 10888)		2n = 4x	5th June
Ba 10431	Hybrid	2n = 2x	20th May
Ba 10428		2n = 4x	27th May

3.1.3 EXPERIMENTAL DESIGN

The experimental design was a simple randomised block design with four replicates. The eight populations of perennial rye grass were grown (a) in monocultures and (b) with each of the two clovers, Menna and Ac 3785. The eight rye grass and two white clover monocultures together with the sixteen binary mixtures gave rise to 26 treatments. These were randomised within the four blocks with two levels of cutting frequency making a total of 52 treatment combinations.

3.1.4 ROUTINE PROCEDURES

The experiment was established in a glasshouse on 27th November, 1985 using deep boxes measuring 45.5 x 30.5 x 15.5cm. The boxes were filled with John Innes Compost (7 parts soil, 3 parts peat and 2 parts grit; which was steam sterilised at 80°C, and compound fertilizer vitax and hydrated lime added). Plants were sown on a square grid pattern, with 5.1cm interplant spacing. In mixtures, plants were sown alternatively such that each was surrounded by four of the other species. (Figure 3.1). Two seeds of perennial rye grass and three of white clover were sown per position to allow for inviable seeds.

FIGURE 3.1

The square grid pattern used in sowing perennial rye grass and white clover mixtures

G	C	G	C	G	C
C	G	C	G	C	G
G	C	G	C	G	C
C	G	C	G	C	G

G - Perennial rye grass; C - White clover

All varieties except Menna germinated successfully. Separate seedlings of Menna had to be raised on germination pads then later transplanted to the experimental boxes. Slug pellets were sprinkled around the clover seedlings to prevent slug damage. Water supply was not limiting. On 11th December, thinning was done leaving only one plant per position and 42 per box. Glasshouse temperatures were kept at a minimum of 15°C and as a result of warmth and moisture, a mildew developed on the rye grass and especially so on Aurora and Ba 9954. The glasshouse was smoke bombed.

From 11th February to 11th March, measurements were taken on grass leaf length, tiller numbers, tiller angles and clover leaf number, petiole length, leaf length and width. A clearing cut at 10cm height was taken for the whole experiment and from this point on, no further plants were replaced because weak or missing plants were then adjudged to have suffered from the effects of competition. Two weeks later another 5cm cut was carried out and the

glasshouse heating switched off.

The boxes were transferred to the field on the 9th April. Trenches were dug, boxes placed at approximately 15cm depth and covered with soil to ensure realistic soil temperatures. Two weeks later, the whole experiment was zero-timed by another clearing cut taken at 2cm height. No nitrogen fertilizer was applied on to the mixtures. However, grass monocultures included to establish yielding potential of grass, received $200\text{kg ha}^{-1} \text{ annum}^{-1}$ of nitrogen. The application was split into four doses, one after the last clearing cut and then after each infrequent cut.

Interception of Photosynthetically Active Radiation (P.A.R.) by the canopy was measured the day before every infrequent cutting. Dry matter harvests were taken at two frequencies, three weeks and six weeks. The final cut was on 8th September, the frequently-cut plots being harvested five times, and the infrequently-cut plots three times. At each harvest, one peripheral plant row around each box (22 plants) was discarded as a guard leaving a harvested area of 753.75cm^2 per box (20 plants). The experimental plants were cut to 2.5cm., separated into the rye grass and clover fractions where necessary and then oven dried at 80°C for 18 hours before dry matter weights were recorded.

3.1.5 MEASUREMENTS

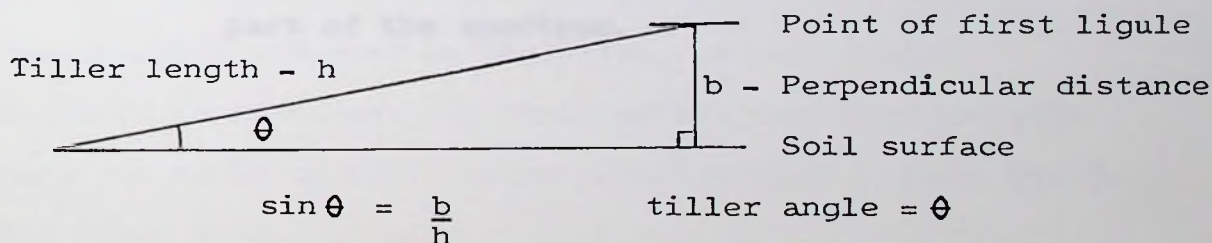
The following measurements were taken:-

- (i) Perennial rye grass leaf blade length (cm), on the last fully-extended leaf of the main tiller;
- (ii) Perennial rye grass tiller numbers/plant;
- (iii) Perennial rye grass tiller angles (degrees), from at least two peripheral tillers.

The angles were calculated from the sine of the perpendicular distance from the soil surface to the first ligule of the tiller and its length to that point; see figure 3.2.

FIGURE 3.2

DIAGRAMATIC REPRESENTATION OF THE METHOD USED IN MEASURING TILLER ANGLES



- (iv) White clover petiole length (cm), from a standard leaf, defined as the third leaf on a stolon counting backwards from the tip;
- (v) White clover middle leaflet length (cm),

from the central leaflet of the same standard leaf;

(vi) White clover middle leaflet width (cm), from the central leaflet of the same standard leaf;

(vii) White clover number of leaflets/plant.

All the above characters were measured from five randomly selected plants in the middle of each box.

(viii) Canopy photosynthetically active radiation (P.A.R.), in both mixtures and pure stands a day prior to harvest. This was assessed using a "T" meter (Williams and Austin, 1977) placed at 10cm height. Basically, the meter consists of silicon cells filtered to measure the photosynthetically useful part of the spectrum.

TABLE 3.3

MORPHOLOGICAL DIFFERENCES BETWEEN MIXTURE AND AC 3705 CLOVER POPULATIONS

Character	Mean	Ac 3705	L.S.D.	Exp. at sig.
Leaf number/plant	28.45	27.61	1.207	P = 0.18
Podicle length (mm)	7.45	7.12	0.276	P = 0.19
Leaf length (cm)	6.88	6.73	0.038	P = 0.18
Leaf width (cm)	4.02	3.95	0.005	P = 0.18

3.2 RESULTS

3.2.1 WHITE CLOVER MORPHOLOGICAL CHARACTERS

Despite the fact that Menna and Ac 3785 fall under the same medium-leaved category, their morphological characters showed significant differences. Menna was found to have overall superiority with a larger leaf number/plant, slightly longer petioles and a bigger leaf size as shown in table 3.2.

In mixtures with perennial rye grass, clover leaf numbers/plant were drastically reduced. The effect was greater in association with tetraploid than diploid grasses. There was a significant interaction between the clover populations and the effect of grass on leaf numbers/plant. The reduction in leaf numbers was greater in Menna than Ac 3785. Although leaf size (length and width) was not significantly affected by the grass, petiole length increased in mixtures. In other words, clover grown with grass was found to have longer petioles than in pure stands (see table 3.3).

TABLE 3.2

MORPHOLOGICAL DIFFERENCES BETWEEN MENNA AND AC 3785 CLOVER POPULATIONS

Characters	Menna	Ac 3785	S.E.D.	Lev. of sig.
Leaf numbers/plant	32.95	27.81	1.287	P < 0.1%
Petiole length (cm)	7.93	7.15	0.276	P = 0.5%
Leaf length (cm)	0.94	0.83	0.028	P < 0.1%
Leaf width (cm)	1.02	0.89	0.309	P < 0.1%

TABLE 3.3

EFFECT OF THE EIGHT PERENNIAL RYE GRASSES
ON CLOVER MORPHOLOGICAL CHARACTERS IN MIXTURES

Grass Companion	Leaf Numbers	Petiole Length (cm)	Leaf Length (cm)	Leaf Width (cm)
Ba 10431	25.9	7.98	0.93	0.95
Melle	30.1	6.96	0.82	0.88
Aurora	24.9	8.68	0.90	0.99
Chieftain	34.7	8.32	0.96	1.02
Mean effect of diploids	28.9	7.99	0.90	0.96
Ba 10428	30.4	8.09	0.94	1.01
Meltra	27.1	7.91	0.84	0.95
Ba 9954	23.0	7.81	0.84	0.91
Ba 10764	27.3	7.39	0.87	0.95
Mean effect of tetraploids	27.0	7.80	0.87	0.96
Clover monoculture	49.9	4.72	0.86	0.95
S.E.D.	2.73	0.586	0.059	0.066
Lev. of Sig.	P < 0.1%	P < 0.1%	P = 23%	P = 44.8%

3.2.2 PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS

Over all characters, diploid and tetraploid grasses showed significant differences. The diploids were found to have a larger number of tillers/plant, shorter leaves and more prostrate tillers than the tetraploids as shown in table 3.5. In table 3.5, out of the four grass gene resources, Aurora had the highest number of tillers/plant and Melle the least, Ba 10431 had the longest leaves and Chieftain the most erect tillers. The significant interaction between the gene resources and ploidy levels on tiller numbers/plant, leaf length and tiller angles is illustrated

in table 3.7.

There were highly significant differences in tiller numbers/plant and tiller angles of grasses compared to grass monocultures. As can be seen from table 3.8, the grass tiller numbers/plant were higher in association with Ac 3785 than Menna and pure stands. It is also shown that grass tended to have more erect tillers in pure stands than in mixtures with Menna and Ac 3785.

TABLE 3.5

THE EFFECT OF PLOIDY ON THE THREE PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS

Character	Diploid	Tetraploid	S.E.D.	Lev of Sig.
Tiller numbers/plant	4.8	4.4	0.125	$P < 0.1\%$
Leaf Length (cm)	16.49	21.07	0.464	$P < 0.1\%$
Tiller angles	12.5	18.0	1.255	$P < 0.1\%$

TABLE 3.6

PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS OF THE FOUR GENE RESOURCES

Gene resources	Tiller numbers/plant	Leaf length (cm)	Tiller angles
Ba 10431	4.4	20.47	16.39
Melle	3.8	18.25	14.30
Aurora	6.0	17.80	12.95
Chieftain	4.2	18.60	17.36
S.E.D.	0.176	0.656	1.775
Lev. of Sig.	$P < 0.1\%$	$P < 0.1\%$	$P < 0.1\%$

TABLE 3.7

PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS
OF THE FOUR GENE RESOURCES AT TWO PLOIDY LEVELS

Gene resources	Ploidy	Tiller no./ plant	Leaf length(cm)	Tiller angles
Ba 10431	diploid	4.3	19.71	17.00
	tetraploid	4.5	21.23	15.79
Melle	diploid	3.5	15.13	12.25
	tetraploid	4.1	21.38	16.35
Aurora	diploid	6.7	15.48	9.73
	tetraploid	5.3	20.12	16.17
Chieftain	diploid	4.8	15.66	11.02
	tetraploid	3.6	21.55	23.71
S.E.D. (diploid x tetraploid)		0.249	0.928	2.511
Lev. of Sig.		$P < 0.1\%$	$P = 0.2\%$	$P = 0.2\%$

TABLE 3.8

EFFECT OF THE TWO CLOVER POPULATIONS ON
PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS IN MIXTURES

Clover Companion	Tiller no./plant	Leaf length (cm)	Tiller angles
Menna	4.7	18.73	12.56
Ac 3785	5.1	18.13	13.41
Grass monoculture	4.0	19.48	19.78
S.E.D.	0.153	0.568	1.537
Lev. of Sig.	$P < 0.1\%$	$P = 6.3\%$	$P < 0.1\%$

3.2.3 INTERCEPTED PHOTOSYNTHETICALLY ACTIVE RADIATION

As described earlier, the "T" meter measures the amount of photosynthetically Active Radiation (P.A.R.) intercepted by the canopy relative to the total radiation falling onto the canopy. Canopies of pure stands of white clover intercepted more of this radiation than canopies of pure stands of rye grass. The interception was greater in infrequently-cut than frequently-cut regimes in both monocultures (Graph 3.1) and also the mixtures.

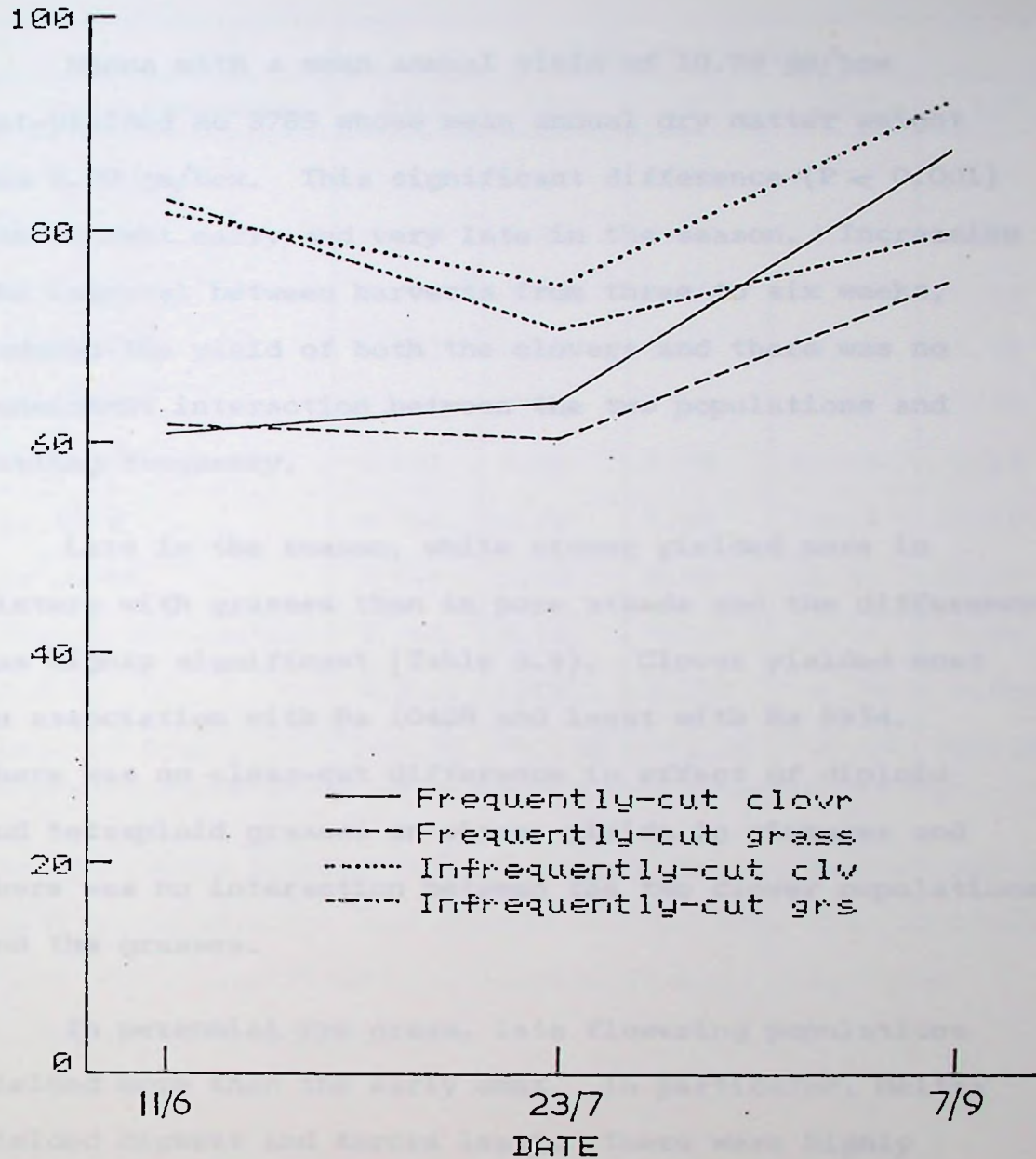
Differences in grass gene resources or even ploidy levels did not have a significant effect on light interception. Also the clover population did not differ at all. The only interaction was the effect of cutting frequency and mixtures and indeed the pattern of light interception in the mixtures broadly mirrored that of the clover monocultures.

Mixtures of perennial rye grass with Menna intercepted significantly larger amounts of radiation than with Ac 3785. The interception was steady initially but increased sharply later in the season for both of the clover mixtures. Generally clover and grass monocultures intercepted large amounts of radiation early in the season which dropped drastically in mid summer and slightly recovered to a much less extent later in the season.

3.2.4 DRY MATTER YIELD OF GRASS AND CLOVER COMPONENTS

For the five frequently-cut and three infrequently-cut

P.A.R. (%) INTERCEPTED



Graph 3.1 Photosynthetically Active Radiation (P.A.R.)
Intercepted by Perennial Rye Grass and White
Clover in Frequent and Infrequent Cutting
Systems.

regimes the dry matter weight fractions of white clover and rye grass were recorded and analysed separately as components of their mixtures.

Menna with a mean annual yield of 10.76 gm/box out-yielded Ac 3785 whose mean annual dry matter weight was 9.70 gm/box. This significant difference ($P < 0.001$) was evident early and very late in the season. Increasing the interval between harvests from three to six weeks, reduced the yield of both the clovers and there was no consistent interaction between the two populations and cutting frequency.

Late in the season, white clover yielded more in mixture with grasses than in pure stands and the difference was highly significant (Table 3.9). Clover yielded most in association with Ba 10428 and least with Ba 9954. There was no clear-cut difference in effect of diploid and tetraploid grasses on clover yields in mixtures and there was no interaction between the two clover populations and the grasses.

In perennial rye grass, late flowering populations yielded more than the early ones. In particular, Meltra yielded highest and Aurora least. There were highly significant differences between mean annual dry matter yields of the four gene resources and ranked from highest to lowest is Melle, Chieftain, Ba 10431 and Aurora (Table 3.10).

TABLE 3.9

WHITE CLOVER DRY MATTER WEIGHTS (GM/BOX)
IN MIXTURE WITH THE EIGHT RYE GRASSES

Grass Companion	Dates of Harvest					Mean
	20/5	12/6	3/7	24/7	8/9	
Ba 10431	1.209	6.22	4.34	22.77	11.27	9.16
Melle	1.606	6.84	5.17	24.77	11.20	9.92
Aurora	0.634	4.83	4.49	20.74	12.14	8.57
Chieftain	1.141	6.93	5.00	24.43	11.99	9.89
Ba 10428	1.431	7.90	7.10	26.99	12.50	11.18
Meltra	0.821	6.46	4.49	22.03	9.88	8.74
Ba 9954	0.799	4.66	3.99	19.55	11.02	8.00
Ba 10764	1.099	5.62	4.50	22.60	11.18	8.99
Clover Monoculture	4.105	9.94	7.03	15.49	7.49	8.81
S.E.D.	0.3131	0.897	2.039	2.334	0.832	
Lev. of Sig.	P<0.1%	P<0.1%	P<0.1%	P<0.1%	P<0.1%	

The difference between tetraploid and diploid grasses was not great but generally, tetraploids yielded more than diploids. There was a significant interaction between grass gene resources and ploidy levels.

TABLE 3.10

DIFFERENCES IN DRY MATTER WEIGHTS (GM/BOX)
OF GRASS GENE RESOURCES

Gene Resource	Dates of Harvest				
	20/5	12/6	3/7	24/7	8/9
Ba 10431	11.29	21.78	6.76	20.26	9.13
Melle	10.41	22.21	10.21	28.52	11.15
Aurora	10.48	18.35	6.35	17.24	8.33
Chieftain	9.33	19.48	9.32	26.41	10.85
S.E.D.	0.767	1.632	0.930	1.832	0.615
Lev. of Sig.	P = 0.096	P = 0.058	P < 0.001	P < 0.001	P < 0.001

The effect of cutting frequency on rye grass both in mixtures and monocultures was similar to that on white clover. Frequently-cut treatments yielded significantly more ($P < 0.001$) than infrequently-cut ones. There was no interaction between the effect of cutting frequency and ploidy levels, but there was a significant interaction between cutting frequency and grass gene resources in mid summer.

In mixtures with white clover, perennial rye grass yielded more than in pure stands (Table 3.11). The differences were highly significant ($P < 0.001$). There was no interaction between the effect of clover and the grass gene resources and/or ploidy levels. However, the interaction between the cutting frequency and the effect of white clover on dry

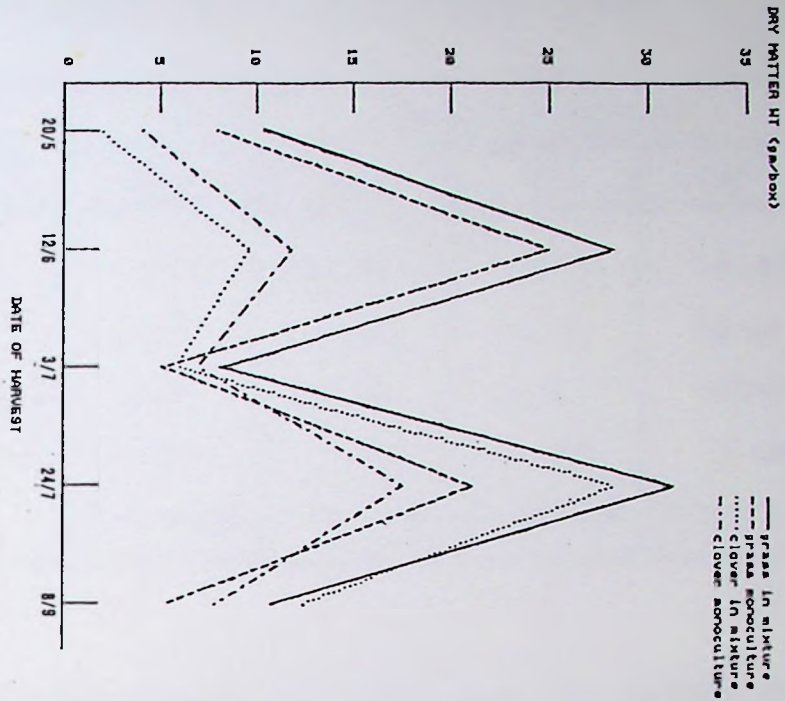
matter yield of grass was highly significant.

Generally, the dry matter yield of perennial rye grass/white clover mixtures and their component monocultures under the frequently-cut regime followed a bimodal pattern over the growing season and a monomodal increase under the infrequently-cut system (Graph 3.2.a). Frequently-cut white clover dry weight in monoculture increased early in the season but was higher than dry matter weight of white clover in mixture and lower than both grass dry matter weight in mixture and pure stand. It was, however, the lowest of the four later in summer; lower than dry matter weight of grass in mixture, clover in mixture and grass monoculture respectively. All dry matter weights dropped sharply in early July.

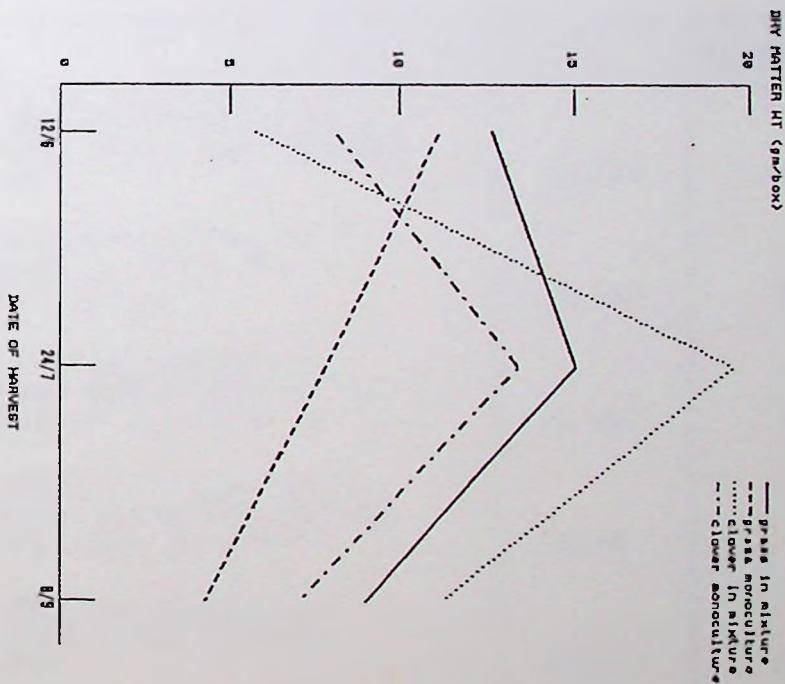
Increasing the harvest interval from three to six weeks reduced all the dry matter yields and changed the trend of increase of the four dry matter yields later in the season (Graph 3.2.b).

The correlation of mean dry matter weight (gm/box) of the perennial rye grass and white clover over the growing season is shown in table 3.12.

FREQUENT CUTTING (a)



INFREQUENT CUTTING (b)



Graph 3.2 Dry matter yield (gm/box) of grass and clover components.

TABLE 3.11

PERENNIAL RYE GRASS DRY MATTER WEIGHTS (GM/BOX)
IN MIXTURE WITH CLOVER POPULATIONS

Clover Companion	Dates of Harvest				
	20/5	12/6	3/7	24/7	8/9
Menna	7.13	12.79	7.01	19.36	9.95
Ac 3785	8.02	12.52	7.26	21.01	10.15
Grass monoculture	7.99	18.03	5.11	14.47	4.75
S.E.D.	0.664	1.414	0.805	1.586	0.532
Lev. of Sig.	P < 0.1%	P < 0.1%	P < 0.1%	P < 0.1%	P = 45.3%

TABLE 3.12

CORRELATION COEFFICIENTS FOR MEAN DRY MATTER YIELDS

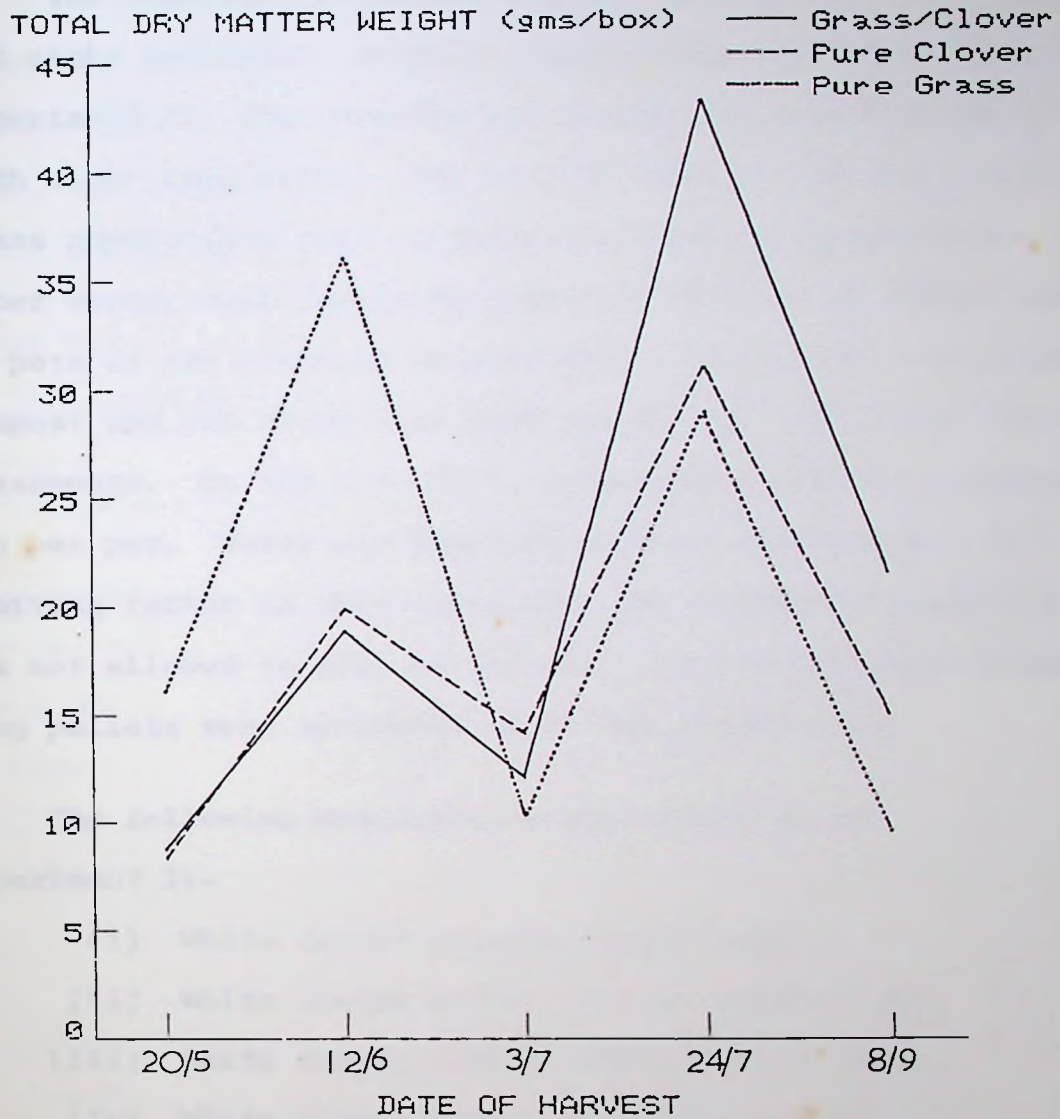
	"r"	Significance
Mean grass dry matter weight in monoculture x Mean Menna dry matter weight in mixture	0.084	N.S
Mean grass dry matter weight in monoculture x Mean Ac 3785 dry matter weight in mixture	-0.354	N.S
Mean grass dry matter weight in monoculture x Mean grass dry matter weight in mixture with Menna	0.96	***
Mean grass dry matter weight in monoculture x Mean grass dry matter weight in mixture with Ac 3785	0.90	**
Mean grass dry matter weight in mixture x Mean Menna dry matter weight in mixture	0.052	N.S
Mean grass dry matter weight in mixture x Mean Ac 3785 dry matter weight in mixture	-0.277	N.S
N.S. - Not Significant ** - P < 0.01 *** - P < 0.001		

3.2.5 TOTAL DRY MATTER YIELD OF MIXTURES

When dry matter weights of components of mixtures were added, mixtures yielded significantly higher ($P < 0.001$) than their pure stands (Graph 3.3). The pattern of the total dry matter yield over the growing season generally mirrored that of the components of mixtures with two peaks in mid June and late July.

There was no effect of the two clover populations and also no interaction between the populations and effect of grass on total dry matter yields. However, all mixtures that included Meltra and Ba 10764 out-yielded the rest of the grass combinations. All the highest recorded yields of mixtures were in association with late flowering grasses. There was no significant effect of grass ploidy levels on total dry matter yields of mixtures but significant differences between ($P < 0.05$) gene resources and no interaction between the two.

As for grass and clover yield, increasing the harvest interval reduced the total dry matter yields of the mixtures.



Graph 3.3 A comparison between total dry matter weights (gm/box) of white clover/rye grass mixtures and their pure stands.

4.0 EXPERIMENT II

4.1 MATERIALS AND METHODS

The experimental material comprised the two white clover and eight perennial rye grass populations that were used in Experiment I. The experimental design was a randomised block with eight replicates. Ten pots of each of the ten clover and grass populations were randomised within each replicate. In other words, each replicate comprised 20 pots of clover and 80 pots of rye grass. 20 cm pots were filled with John Innes Compost and two seeds were sown per pot on 17th July, 1986 in a glasshouse. On the 31st July, plants were thinned leaving one per pot. Water was supplied so that moisture was not a limiting factor in this experiment and minimum temperature was not allowed to fall below 15°C. To prevent slug damage, slug pellets were sprinkled on to the clover pots.

The following measurements were taken as in Experiment I:-

- (i) White clover petiole length (cm).
- (ii) White clover middle leaflet length (cm).
- (iii) White clover middle leaflet width (cm).
- (iv) White clover number of leaflets/plant.
- (v) Perennial rye grass leaf blade length (cm).
- (vi) Perennial rye grass tiller numbers/plant.
- (vii) Perennial rye grass tiller angles.

4.2 RESULTS

4.2.1 WHITE CLOVER

As shown in table 4.1 there were no significant differences in white clover petiole length, and leaf size (length and width) between the two populations. However, there was a significant difference in leaf numbers/plant. Menna was found to have more leaves/plant than Ac 3785.

TABLE 4.1

MORPHOLOGICAL CHARACTERS OF MENNA AND Ac 3785
WHITE CLOVER POPULATIONS

	Leaf numbers/ plant	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)
Menna	112.6	12.26	2.02	1.85
Ac 3785	97.3	11.67	2.08	1.87
S.E.D.	5.85	1.197	0.066	0.052
Lev. of Sig.	P = 0.010	P = 0.625	P = 0.341	P = 0.738

4.2.2 PERENNIAL RYE GRASS

Table 4.2 shows the significant differences ($P < 0.001$) in perennial rye grass tiller numbers and tiller angles. Diploid rye grasses were found to have more tillers/plant, but more prostrate tillers, than tetraploids. There was, however, no difference in leaf length.

The grass gene resources also showed significant differences (table 4.3) and there was an interaction between

grass gene resources and ploidy levels (table 4.4).

TABLE 4.2

THE EFFECT OF PLOIDY ON THE THREE PERENNIAL
RYE GRASS MORPHOLOGICAL CHARACTERS

Characters	Diploid	Tetraploid	S.E.D.	Lev. of Sig.
Tiller numbers/plant	21.2	15.4	0.401	$P < 0.001$
Leaf length (cm)	24.80	24.77	0.360	N.S
Tiller angles	17.4	24.2	0.754	$P < 0.001$

TABLE 4.3

PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS
OF THE FOUR GENE RESOURCES

Gene resources	Tiller numbers/plant	Leaf length (cm)	Tiller angles
Ba 10431	15.5	26.03	23.3
Melle	19.1	23.89	18.4
Aurora	20.8	25.92	18.8
Chieftain	17.7	23.31	22.6
S.E.D.	0.567	0.510	1.066
Lev. of Sig.	$P < 0.001$	$P < 0.001$	$P < 0.001$

TABLE 4.4

PERENNIAL RYE GRASS MORPHOLOGICAL CHARACTERS
OF THE EIGHT POPULATIONS

	Tiller numbers/plant	Leaf length (cm)	Tiller angles
Ba 10431	19.8	29.75	20.2
Melle	19.3	22.68	18.2
Aurora	24.7	25.31	14.7
Chieftain	21.1	21.58	16.3
Ba 10428	11.4	22.32	26.4
Meltra	18.9	25.09	18.6
Ba 9954	16.9	26.53	22.9
Ba 10764	14.3	25.03	28.8
S.E.D.	0.801	0.721	1.507
Lev. of Sig.	$P < 0.001$	$P < 0.001$	$P < 0.001$

5.0 GENERAL DISCUSSION

5.1 VARIATION IN COMPATIBILITY

Agronomically, a compatible grass/clover mixture is one which maintains a reliable and substantial clover contribution over a period of time so that the benefits of clover can be fully realised. Associated with this should be a high grass plus clover yield. It has been suggested that to realise the benefits of clover in terms of nitrogen fixation and nutritional quality, clover should contribute 30% of the annual yield of the mixture (Frame and Newbould, 1984) although this percentage will vary throughout the season, from 5% in April to 50% in July and August.

The aim of this study was to identify differences in compatibility between a range of diploid and tetraploid rye grasses and two white clover varieties. Most agronomical assessments of rye grass/white clover mixtures have not involved simultaneous comparisons of the performance of the component species in monoculture. The experimental design used in this study was augmented to compare the competitive performance of the grasses and clover varieties and investigate their intrinsic yielding abilities by including monocultures. Since a grass population's competitive performance and/or compatibility with a white clover variety depends on the extent to which both can maintain a substantial dry matter yield in a mixture,

variation in compatibility depends on yielding ability and the extent to which this is modified by interspecific competition.

Despite the fact that the total dry matter production of the mixtures followed a bimodal pattern over the growing season (graph 3.3) the clover contribution in terms of dry matter yield, as a percentage of the total dry matter production of the mixtures increased steadily in all combinations with the eight grass populations. Overall, white clover maintained a relatively higher percentage contribution (32%) of dry matter yield over the growing season in association with diploid than with tetraploid rye grass populations (30%). Assessed with the four grass gene sources was 29% with Melle, 30% with Chieftain, 32% with Aurora and 33% with Ba 10431. The early flowering grasses, Ba 9954 and Aurora produced the lowest yields of white clover (table 5.1) and the late flowering grasses (Melle, Chieftain, Meltra and Ba 10764) the highest clover yields apart from the tetraploid Ba 10428. Ba 10431 gave clover yields intermediate between Aurora and Melle.

TABLE 5.1

THE CLOVER ANNUAL DRY MATTER PRODUCTION (GM/BOX)
ANNUAL TOTAL YIELD OF MIXTURES (GM/BOX) AND
PERCENTAGE CLOVER CONTRIBUTION TO TOTAL YIELD IN MIXTURES
WITH THE EIGHT RYE GRASS POPULATIONS

Companion grass	Clover Yield	Total Yield	Percentage Clover Contribution
Ba 10431	45.81	101.27	31.14
Melle	49.59	107.67	31.71
Aurora	42.83	86.33	33.16
Chieftain	49.49	105.45	31.94
Ba 10428	55.92	105.27	34.69
Meltra	43.68	118.95	26.86
Ba 9954	40.02	90.12	30.75
Ba 10764	45.00	108.12	29.39

The fact that there was no significant effect of grass ploidy levels on the total yield (grass and clover) and no interaction between the grass gene sources and ploidy levels (Section 3.2.5) indicates that the tetraploids did not affect yields of mixtures more than diploids or vice versa. Late in the season, white clover yielded more in mixtures with grasses than in pure stands.

Increasing the harvest interval from three weeks to six weeks reduced dry matter yield but there were no interactions between defoliation frequency, grass and clover populations

on total yield. There was no interaction between the grass and clover varieties on total dry matter production of the mixtures implying that the two clover varieties did not have a differential enhancement of yield in mixture.

Menna yielded more than Ac 3785 in pure stands. This is an interesting feature of the results because Ac 3785 is known to have a good early spring growth (Glendining, 1987) which should enhance its competitive ability with grass in mixtures and an annual yield approximately 15 - 17 per cent higher than Menna. Because the experiment was established in a glasshouse, where temperatures were kept to a minimum of 15°C, Ac 3785's competitive advantage resulting from its superior low temperature growth was eliminated.

The highly significant differences between mean annual dry matter yields of the four rye grass gene sources in pure stands (table 3.10) showed that both Melle and Chieftain, the late flowering populations, yielded more than Ba 10431, and Aurora (the earliest flowering populations) least. Although there were no differences in the percentage light interception at harvest by the canopies of the four gene resources, differences in dry matter yield may have arisen from either size of the canopies or rate of dry matter accumulation. In both experiments, I and II, both Melle and Chieftain were found to have fewer tillers per plant than both Ba 10431 and Aurora respectively. Variation in the number of parts of a plant, in this case tillers, is of

great interest because it is this variation that can largely determine its potential contribution to yield. Harper (1977) suggested that the population - like structure of an individual plant fits it admirably to respond to stresses by varying the birth rate and the death rate of its parts, leaves and branches (tillers) see section 2.3. The mortality of tillers of Aurora, an early maturing cultivar may have become strongly density - dependent. This may have resulted in an early decline in total dry matter production explaining the reduction in yield which occurred by increasing the harvest interval from three to six weeks. Like Ac 3785, Aurora did not show its early season growth characters because the swards were established in warm glasshouse conditions.

In pure stands, tetraploids yielded more than their diploid counterparts. The tetraploid counterparts of the Melle and Chieftain cultivars, Meltra and Ba 10764 yielded more than any other grasses. The diploid hybrid derived selection Ba 10431, also performed well. Both the box and spaced plants experiments showed that the highest yielding cultivars had fewer tillers per plant and an interesting feature is their similarity in leaf length (table 3.7 and 4.4). Although the dry weight of a plant population tends to compensate more or less perfectly for variations in tiller density, the other parts such as leaf size are not all altered to the same extent. A tiller density stressed individual is not simply a miniature version of its

vigorous low-tiller density counterpart.

Rye grass in mixtures with white clover yielded more than in pure stands and generally mixtures intercepted larger amounts of radiation than monocultures. Even when grown with white clover, Meltra and Ba 10764 yielded more than any other combinations. There was no interaction between the effect of clover and the grass gene resources indicating that irrespective of the clover variety, grass dry matter yields were enhanced in mixtures.

Rye grass/white clover mixtures yielded more than pure stands (graph 3.3). A comparison between experiment I and II (table 3.3. and 4.1) showed that clover petiole length increased in mixtures resulting in a taller canopy and thus greater light penetration. Secondly, the increased yields in mixtures may have been due to nitrogen fixation by the white clover. In this experiment, nitrogen fixation and transfer appeared to have occurred very early possibly due to optimum conditions early in establishment of the clover in the glasshouse.

It is not always simple to relate the intrinsic yielding ability and competitive ability of a species with its growth characteristics. Just as the first two parameters are sometimes unrelated, morphological characters of a species may be negatively correlated with either of the two or both. Tetraploid grasses which generally yielded more than diploids were found to have (table 3.5 and 4.2) fewer

tillers per plant, longer leaves and tillers were more erect relative to the diploid counterparts. This is not surprising because the more erect the tillers are, the more light is intercepted by the canopy. Erect canopies are able to accumulate a larger canopy per unit of light interception. Both in experiemnt I and II, (table 3.6 and 4.3) the late flowering and indeed high yielding gene sources, Melle and Chieftain, compared to the early ones, had fewer but erect tillers per plant and longer leaves. Tiller angles, for example may be used as a selection criterion to improve yielding ability of a species in a breeding programme.

The variation in grass/clover compatibility may be associated with the effect of the grasses on the clover morphological characters in mixture. Tetraploid grasses suppressed both the clover leaf numbers and petiole length (table 3.3). As a result the average clover contribution to total yield was found to be lower in association with tetraploid grasses although this had no effect on the total yield of the mixtures. In mixtures with both clover varieties, grass populations had fewer but very erect tillers per plant and longer leaves (table 3.8). This may yet be another reason in addition to nitrogen fixation, why grasses yielded more in mixtures.

5.2 YIELDING ABILITY AND COMPETITIVE ABILITY

The contribution of grass and clover to mixture yield under any management or environment are basically dependent on their "yielding ability" (as measured in monoculture) and the degree of competitive enhancement or suppression of this yielding ability, resulting from differences in the competitive abilities of the components (Rhodes, 1981). The significant correlation coefficients between grass dry matter production in monoculture and in mixtures with clover (table 3.12) demonstrates that rye grass cultivars found to be productive in monoculture such as Meltra and Ba 10764, were also productive when grown with white clover. Grass dry matter production in monoculture was not at all related to clover yield in mixtures. This implies that high yielding grasses were not necessarily the most aggressive to clover. As a result of this relationship between grass yield in pure stands, in mixture and clover yield in mixture there was, as mentioned before, a variation in total yield (clover + grass) of the mixtures. Although the correlation coefficients here cannot be used as a decisive measure for the relationship between yielding ability and competitive ability it is fair enough to make an agronomical inference that grasses bred for high yields in pure stands may also be good companion grasses with clover.

5.3 PLANT BREEDING IMPLICATIONS

Since yielding ability and competitive ability may be unrelated, or even negatively related (Rhodes and Stern, 1978) it is important from breeding points of view that their effects are quantified and attempts made to define the characters associated with them. As mentioned above, grasses bred for high yields in pure stands may also be good companion grasses with clover.

Morphological features such as tiller angles, petiole length, leaf size and numbers may be used as selection criteria for breeding programmes to improve compatibility. White clover and rye grass have been traditionally bred separately without regard to their compatibility in a mixture. Where more productive mixtures are sought, such compatibility must be considered in a breeding programme in order to develop better "ecological combining ability".

The evidence from this study shows that the extent and magnitude of variation in compatibility of rye grass merits more detailed study in order to develop selection criteria to improve this feature and incorporate it into breeding programmes.

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