WHEAT INTERCROPPED WITH FORAGE LEGUMES IN SOUTHERN BRAZIL[1]

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ABSTRACT

The use of winter legumes in southern Brazil is hindered by the slow growth of these species in the year they are first established in a field. Faster growth occurs in the succeeding year. Introduction of these legumes as companion crops with wheat (Triticum aestivum) was studied. Reseeded legumes resulting from natural shattering are expected to serve as alternatives to winter fallow. Twelve legumes were tested (in pure stands and associated with wheat) in 1987-88 and five species were selected for further studies in 1988-89. Birdsfoot trefoil, red clover cv. Quiniquelli, white clover, and arrowleaf clover did not reduce wheat yields in either year. Wheat yield was reduced by intercropped red clover cv. Kenland and by subclover in the first year. No wheat grain yield differences due to intercropping with any legume were detected in 1988 when rainfall was below normal. An evaluation of intercrops during the year of seeding suggests that a minimum 62% ground cover can be expected when legumes are intercropped with wheat. Natural reseeding of white clover when intercropped with wheat was good in both years. White clover grown along with wheat is a promising species for intercropping purposes.

INTRODUCTION

The climate of Southern Brazil is humid and warm. Passo Fundo, located in the state of Rio Grande do Sul (RS) has a normal annual rainfall of 1763 mm with a June through November (wheat growing season) rainfall accumulation of 944 mm. Annual average temperature is 17.4° C (EMBRAPA, 1989). In most years conditions are ideal for the development of plant diseases. Average wheat yield losses in RS, due to Common root rot, primarily caused by Cochliobolus sativus, from 1979 through 1981, were estimated at 18.7% (Diehl et al., 1983). At present, rotating wheat and barley with crops resistant to root rot offers the best method of minimizing this disease (Chinn, 1976; Piening and Orr, 1988).

Alternative crops face market limitations which hinder their production in areas larger than those already

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cultivated. These factors have led farmers to leave the land in winter fallow. Rolling topography is predominant, and highly erosive rains are common in RS (Cogo et al.,1978). Without plant cover, soil losses can be as high as 13 t ha^{-1} over a 100 day period (Wünshe and Denardin, 1978b). The effectiveness of plant cover in decreasing erosion was studied in Zimbabwe. Mean annual soil losses on bare ground were 46.3 t ha^{-1} compared to only 0.4 t ha^{-1} on dense vegetation ground cover (Hudson, 1981). The use of ground cover by crop residues on an area basis is considered more advantageous than dry weight of residues, because the former has a direct relationship with raindrop interception regardless of residue type, while the later varies with type of crop residue. In addition, the visual estimation of ground cover is easier than of mulch rate (Wischmeier, 1973).

Legumes break the wheat and barley fungi cycle (Reis and Wünshe, 1984) and are the most desirable alternative crops to wheat. Forage legume production offers the potential to increase cattle ranching productivity while increasing the agriculture sustainability by protecting the soil surface against erosion (de Quadros and Maraschin, 1987; Maraschin, 1981). In addition, this practice should enhance soil fertility and aid to suppress weed growth when used as a cover crop. At present, the adoption of forage legumes by farmers, is restricted by the slow growth of these species in the year of establishment. During the year of legume establishment a large proportion of soil surface remains exposed and thus, susceptible to erosion. In addition, forage productivity is usually low. Faster growth occurs in the succeeding year.

The object of this study was to select potential legume species adapted to intercropping with wheat. Reseeded legumes resulting from natural shattering are expected to serve as an alternative to winter fallow in the year folowing intercrops seeding. Identification of species that do not reduce wheat grain yield and give complete ground cover, especially from May to September (soybean harvest to corn seeding time) of the succeeding year, are the relevant objects of this research.

MATERIALS AND METHODS

This study was carried out in Passo Fundo, southern Brazil, at the EMBRAPA-National Wheat Research Center (CNPT) which is located at latitude 28°15'S and longitude 52°24'W (EMBRAPA, 1988) during 1987-88 and 1988-89.

The experiments were seeded on June 25, 1987 and June 26, 1988. Precipitation deficit in relation to the evaporative demand (Class A pan evaporation) suggests that no moisture stress for plant growth occurred from June (seeding) up to the end of October, 1987 in the 1987-88 test. The 1988 growing season (June-November) was initially very dry. Higher (177 mm) evaporative demand than precipitation occurred during July and August. The low rainfall in July and August together with higher than normal air temperatures in August resulted in a major moisture deficit. These conditions made the 1988 early growing season very stressful for legume establishment. The weather conditions for plant growth during the wheat growing season (June through November) can be summarized as close to normal in 1987, and abnormally dry in 1988.

One serradella, two vetches, six clovers and three trefoils were evaluated in the 1987-88 experiment . Four clovers and one trefoil were selected from this group for further detailed study in the 1988-89 experiment (Table 1). Management practices were selected with the intention of maximizing wheat yield.

The experiments were laid out as a split-plot design with three replicates in 1987-88 and as a randomized complete block design with three replicates in 1988-89. During the 1987-88 experiment randomization was restricted within each replicate by placing wheat sole crop treatments together, in order to facilitate field operations. Legumes were used as main plots and cropping systems (sole legume or intercropped with wheat) as subplots (2 by 5 m). In the 1988-89 experiment plots measured 3 by 8 m.

In both experiments 200 kg ha^{-1} of a 1:1 blend of mono-ammonium phosphate and potash were broadcast and incorporated with a discer. A further 40 kg ha^{-1} of nitrogen in the form

Table 1 Species and cultivars evaluated for intercropping in the 1987-88, 1988-89 or both studies. Passo Fundo, RS, Brazil.

Scientific name	Cultivar	Common name	Studies
Triticum aestivum L.	BR-14[1]	Spring wheat	both
Ornithopus sativus Brot.	Common	Pink serradella	1^{st}
Vicia villosa Roth	[2]	Hairy vetch	1^{st}
Vicia sativa L.	Common	Common vetch	1^{st}
Trifolium incarnatum L.	[3]	Crimson clover	1^{st}
Trifolium repens L.	Jacui S-2	White clover	both
Trifolium pratense L.	Kenland	Red clover	1^{st}
Trifolium pratense L.	Quiniquelli	Red clover	both
Trifolium vesiculosum Savi	Yuchi	Arrowleaf clover	both
Trifolium subterraneum L.	Clare	Subclover	both
Lotus subflorum	Rincon		1^{st}
Lotus uliginosus	Maku	Big trefoil	1^{st}
Lotus corniculatus L.	Sao Gabriel	Birdsfoot trefoil	both

[1] Soft White Spring Wheat cultivar from EMBRAPA-Wheat National Research Center, 1984.

[2] Cultivar Ostsaat Dr. Baumanns, West Germany.

[3] Cultivar used by small scale farmers of the "Encosta Superior do Nordeste" and "Encosta Inferior do Nordeste" regions of the state of Rio Grande do Sul.

of urea (45-0-0) was broadcast on August 13, 1987 and July 21, 1988 on both sole crop wheat and the intercropped treatments. In 1988 a treatment was included with no topdressed nitrogen to create more favourable conditions for legume nitrogen fixation.

An "agronomically acceptable" number of legume seedlings per m^2 as defined in this study is obtained by taking the lower seeding rate recommended (number of kg ha^{-1}) for the state of Rio Grande do Sul, and dividing by the actual thousand seeds weight of the seed used. In this calculation the minimum germination required for seed trade in southern Brazil was considered as the actual seed germination occurring at the recommended seeding rates. The germination required for other species of the same genera was adopted when no standard was available. The definition "agronomically acceptable" was required as a guideline to determine the efficiency of legume natural reseeding.

Wheat seeding rates for the 1987-88 and 1988-89 experiments were 240 and 330 viable seeds m^{-2}, respectivelly. Legumes seeding rates were calculated to obtain the "agronomically acceptable" seedlings m^{-2} (Table 3). Legume seeds were inoculated with peat based inoculants and then broadcast. Wheat was seeded in rows spaced 20 cm apart. A commercial drill with double disc openers was used to plant wheat and incorporate legume seeds at the minimal possible depth (1-3 cm).

All field data were subjected to analysis of variance. Homogeneity of variances were checked by the F max procedure at the probability level of $P<0.05$ (David, 1952). Data transformations were done by $y=1/(X+1)$ on three variables from the first and one variable from the second experiment to fulfill the assumption of homogeneity of variances required for a valid ANOVA (Steel and Torrie, 1980). Legume data from the 1987-88 experiment on date of emergence, reseeding in plot harvested and in non harvested area were transformed. Data from the 1988-89 experiment on legume plant density was also transformed.

All mean comparisons were made at $P<0.05$. In order to detect minimal significant effects of intercropping on wheat, the Fisher's protected least significant difference test was used for wheat variables (whenever $P<0.05$). On all other mean comparisons the Student-Newman-Keuls' test was used. Information is provided whenever mean separation by both tests was equal.

The means, Pr>F (%), CV (%) and df values of the 1987-88 experiment presented in tables refer, not only to the treatments listed, but to the whole experiment. All analyses were run on SAS Version 5.18 (SAS, Institute Inc.)

All wheat variables (in both experiments) were tested as randomized complete block design with three replicates. Wheat grain yields were obtained from sample areas measuring at least 4 and 12 m^2 in 1987 and 1988, respectively.

Legumes, wheat intercropped with legumes, and ground cover variables were analyzed using a split plot design and a RCBD design, in the 1987-88 and 1988-89 experiments respectively. The time to legume emergence was determined when 80 % of seedlings had emerged. Legume plant density was counted on 1 m^2 square samples. In the 1987-88 experiment one evaluation was done on August 5, while the 1988-89 experiment had two evaluations dates (July 22 and August 18). Red clover, subclover, wheat + red clover and wheat + subclover treatments were evaluated on July 22, 1988. During 1988, when the first countings were done, certain legumes had still not reached complete emergence. For this reason white clover, arrowleaf clover, birdsfoot trefoil, wheat + white clover, wheat + arrowleaf clover and wheat + birdsfoot trefoil treatments were evaluated on August 18, 1988.

Ground cover throughout this study was visually evaluated on a percentage basis. This was done by visually separating the uncovered ground area from the plant ground covered portions of the plot. Ground cover provided by the seeded crops (wheat, legumes and intercropped treatments) was evaluated at 54 and 53 days after seeding in 1987 and 1988, respectively.

Legume reseeding by natural shattering in the 1987 seeded experiment was evaluated on June 16, 1988. Evaluations were done at both the center and border of the plots. The "plot center" measurements were done to provide an estimate of reseeding on previously (seed) harvested areas. Evaluations on "plot borders" were done to indicate the level of reseeding on none harvested areas.

In the 1988-89 experiment reseeding was evaluated on May 29, 1989. Square sample areas of 1 m^2 were used as in the previous year. The percentage ground cover from seedlings originating from natural shattering was evaluated instead of counting the number of seedlings. These evaluations were done only at the center of the plots (where seeds had been previously harvested) in the second experiment.

RESULTS AND DISCUSSION

Identification of suitable legume species to intercrop with wheat

The suitability of any specific legume for intercropping was determined according to various criteria related to economics of production or soil conservation parameters. Legumes suitable for intercropping should not reduce wheat grain yield or obstruct wheat grain harvest. To be successful, legumes intercropped with wheat, should display the ability of natural reseeding to avoid second seeding costs associated with continuing the rotation. In addition, any successful legume must produce adequate ground cover to prevent soil erosion.

Wheat harvesting and grain yield criteria

Wheat grain yield reduction was considered a primary reason to eliminate legumes for the purpose of intercropping. Yield reduction would make intercropping with legumes less attractive to southern Brazil farmers, because wheat provides their major winter crop income. Wheat production costs are already considered high. A yield reduction associated with intercropping legumes would not be tolerated.

An income from forage production may not occur because a large number of wheat growers do not raise grazing animals and may not harvest forage. Operational difficulties or additional costs associated with excessive legume green matter at wheat maturation, which may hinder wheat harvest are taken as negative characteristics. Adoption of intercropping with a legume species showing such a disadvantage may be minimal.

Forage natural reseeding criteria

Legume reseeding by natural shattering was also considered relevant in the selection of species for intercropping. Natural reseeding will eliminate secondary expenses associated with legume reseeding. In addition overland traffic of machinery and tillage is reduced if a second seeding operation is not required.

The selection of legumes for intercropping

The grain yield of wheat intercropped with serradella, red clover cv. Quiniquelli, arrowleaf clover, crimson clover, or white clover and any of the trefoils was not significantly different from single wheat in 1987 (Table 2). Subclover had a negative effect on wheat yield. However this legume was in the top species group concerning natural reseeding (Table 3) and total aerial biomass on intercropped treatments. Subclover has the advantage of burying its own seeds protecting them from being grazed. This habit enhances grazing management flexibility by protecting seeds for crop regeneration. This species was also considered the best associated crop for grain sorghum production at the latitude 32° S (Muldoon, 1984) (relatively similar to Passo Fundo's latitude).

During the 1987-88 experiment two red clover cultivars were studied, Kenland and Quiniquelli. The cultivar Kenland was eliminated because it had a slightly less favourable production pattern than the cultivar Quiniquelli. This was noted especially for yield of associated wheat (Table 2). Grain yield reduction by intercropping with red clover was also verified by Ngalla and Eckert (1987) on associated winter wheat. Kenland's reseeding stand (Table 3) and biomass yield were not superior to Quiniquelli's in the 1987 seeded experiment. No significant contribution to broaden the spectrum of the study was expected from the cultivar Kenland to justify its inclusion, along with Quiniquelli, in the 1988-89 experiment.

Intercropped hairy and common vetch grew taller than wheat plants. The large green biomass of the vetches attached to wheat plants hindered wheat harvest. Muldoon (1984) reports similar results with woolly pod vetch (Vicia dasycarpa) climbing sorghum stems by cereal harvesting

Table 2 Wheat grain yield of single and intercropped treatments. Passo Fundo, 1987.

Treatment	Wheat yield ($g\ m^{-2}$)
Wheat + 40 kg ha^{-1} of N	127 abc
Wheat + pink serradella	123 abcd
Wheat + hairy vetch	not harvested[1]
Wheat + common vetch	not harvested[1]
Wheat + crimson clover	122 abcd
Wheat + white clover	129 abc
Wheat + red clover cv. Kenland	97 de
Wheat + red clover cv. Quiniquelli	103 cde
Wheat + arrowleaf clover	110 cd
Wheat + subclover	82 e
Wheat + *Lotus subflorum*	137 ab
Wheat + big trefoil	142 a
Wheat + birdsfoot trefoil	112 bcd
Mean	117
Pr>F (%)	0.01
CV (%)	16

Means within a column followed by the same letter are not significantly different at P>0.05 level by Fisher's protected least significant difference test.

[1] Species grew up to the top of wheat plants hindering harvest of the cereal.

time . The height of some arrowleaf clover plants was similar to wheat plants in the 1987-88 experiment. During mechanized harvest some arrowleaf clover green matter would be harvested along with wheat increasing the amount of material at threshing and cleaning, which is undesirable. The use of a taller wheat cultivar, to intercrop with arrowleaf clover, could probably eliminate this inconvenience displayed by this legume.

The legume stand obtained by natural reseeding on previously harvested areas of pink serradella, common vetch, crimson clover, *Lotus subflorum* and the two trefoils were not statistically different (Table 3). Crimson clover, however, showed a small reseeding stand on previously harvested areas (5 seedlings m^{-2}) and a significantly superior stand on non harvested areas. On January 5, 1988 a high density of recently emerged seedlings was observed on both single and intercropped crimson clover treatments. The environmental conditions from that date to June (reseeding evaluation) probably were unfavorable and to a large extent jeopardized regeneration of the crimson clover. These results suggest a better adaptation of crimson clover relative to the other five species. On January 5 a small number of hairy vetch and subclover seedlings had already emerged. However, observations did not permit verification if the reseeding measured on 16 June referred to the same seedlings observed

Table 3 Legumes reseeding by natural shattering in a non harvested and previously seed harvested area from the 1987 seeded experiment in comparison to "agronomically acceptable" number of seedlings. Passo Fundo, June 16, 1988.

Treatment	"Acceptable" population	Natural reseeding[1] Non harvested	Harvested
	Number of seedlings m^{-2}		
Pink serradella	520	0 d	0 b
Hairy vetch	45	27 c	24 a
Common vetch	60	0 d	0 b
Crimson clover	430	79 b	5 b
White clover	270	4,000 a	2,417 a
Red clover cv. Kenland	1,250	50 b	29 a
Red clover cv. Quiniquelli	1,750	85 b	51 a
Arrowleaf clover	500	402 a	348 a
Subclover	300	345 a	29 a
Lotus subflorum	370	0 d	0 b
Big trefoil	370	0 d	0 b
Birdsfoot trefoil	370	0 d	0 b
Mean	520	416	242
Pr>F (%)		0	0.01
CV (%)		2	23

Means within a column followed by the same letter are not significantly different at P>0.05 level by Student-Newman-Keuls' test.

[1] Combined means due to lack of significant difference between single and intercropped treatments. Means separation on transformed data.

in early January or were later emerged plants.

A combined single crop and intercropped legume natural reseeding analysis showed difference on reseeding stands on non harvested and previously legume seed harvested areas. Mean separation of transformed data by the SNK test showed that only crimson clover reseeding stands were significantly different from non harvested and previously harvested areas.

Treatments including crimson clover, white clover, both red clovers and pink serradella displayed the lowest biomass increase in relation to single wheat. White clover and red clover cv. Quiniquelli intercropped with wheat were not eliminated from the 1988-89 experiment. *Lotus subflorum* and big trefoil produced negligible growth and did not flower until the end of January, 1988 on the intercropped treatments. These species therefore did not produce seed or showed any natural reseeding ability (Table 3) up to June 16, 1988. Weeding was required to maintain these two legumes stands. Without weeding the lack of competitive ability of these legumes would have resulted in a near complete suppression of growth.

Evaluation of selected legume species for intercropping with wheat

Based on the above information and the previously discussed selection criteria seven legumes were eliminated from the 1987-88 study (Table 4). This resulted in five species being further evaluated during the 1988-89 experiment .

Table 4 Summary of reasons for eliminating 7 legumes for the purpose of intercropping with wheat. Passo Fundo, 1988-89.

Legume species	Undesirable characteristics
Pink serradella	Reduced biomass, no stand by reseeding
Hairy vetch	Hinder wheat harvest
Common vetch	Hinder wheat harvest
Crimson clover	Reduced biomass
Red clover cv. Kenland	Similar to red clover cv. Quiniquelli
Lotus subflorum	Little biomass, did not produce seeds
Big trefoil	Little biomass, did not produce seeds

Wheat yield: single crop vs. intercropped

The grain yield of wheat intercropped with either white clover, birdsfoot trefoil, arrowleaf clover or red clover cv. Quiniquelli was not lower than single wheat topdressed with 40 kg ha^{-1} of N in 1987 (Table 5). Grain yield was however lower on wheat intercropped with subclover. Brandt et al., 1989 studied the effect of four subclover cultivars on intercropped winter wheat. Grain yield of wheat was decreased by intercropping with any of the four subclover cultivars in the first year the legumes were seeded together with this cereal. Wheat grain yield was, however, increased by at least 84% in the following season when both crops were repeated in the same area. This was attributed to the nitrogen contribution from residue of the previous subclover.

In 1988 no wheat yield differences due to intercropping with any legume were detected (Table 5). This was attributed to little growth of legumes in response to below normal rainfall which occurred during July and August (49 mm vs. a normal of 307 mm). Dry conditions continued up to 10 September. The overall mean wheat grain yield was 19.3% lower in 1987 than in 1988 (Table 5).

During September and October, 1987, symptoms of barley yellow dwarf virus (BYDV) were evenly distributed on wheat plants throughout the experiment. In the same period, symptoms of powdery mildew, caused by *Erysiphe graminis* f.sp. tritici were at economic damaging levels requiring a fungicide application. Wheat BR 14 is a cultivar moderately susceptible to BYDV and susceptible to powdery mildew (Banco Ativo de Germoplasma de Trigo, 1985). Wiese (1977) has recorded wheat yield losses of up to 40% due to powdery mildew, mainly caused by a reduction in head numbers and kernel weight. In this study the wheat thousand kernel weight on the single wheat + 40 kg ha^{-1} of N treatment was 17.3%

Table 5 Wheat grain yield of single and intercropped treatments. Passo Fundo, 1987 and 1988.

Treatment	year 1987	year 1988
	$g\ m^{-2}$	
Wheat + 40 kg ha^{-1} of N	127 abc	153 a
Wheat	--	151 a
Wheat + white clover	129 abc	144 a
Wheat + red clover	103 cde	142 a
Wheat + arrowleaf clover	110 cd	138 a
Wheat + subclover	82 e	143 a
Wheat + birdsfoot trefoil	112 bcd	144 a
Mean	117	145
Pr>F (%)	0.01	60
CV (%)	16	7

Means within a column followed by the same letter are not different at P<0.05 level by Fisher's protected least significant difference test.

(6.1 grams) lower in 1987 than in 1988. The number of spikes per tiller averaged over all treatments was 1.2% lower (0.504 vs. 0.510) in 1987 than in 1988. The number of spikes per plant was lower (21.6%) as well (0.913 vs. 1.164).

In the period under consideration the soil was wet showing signs of runoff flow around plants situated downslope to small uncovered ground areas (little soil enbankments). Under these conditions N losses by denitrification, leaching and erosion could be expected.

Those yield depressing factors evident in the 1987-88 experiment were not noticeable in the 1988 seeded experiment. The combination of damage by diseases (BYDV and powdery mildew) and insufficient N supply are suggested as causes for the chlorotic leaf appearance and the lower yield in the single wheat + 40 kg ha^{-1} of N treatment in 1987 than in 1988.

Ground cover in the seeding year

Ground cover evaluated 8 weeks after seeding was variable among single legume treatments (Table 6). More consistent ground cover was obtained on intercropped treatments. Ground cover was influenced by both, date of legume emergence and legume plant density. Legume emergence date (Table 7) had a more marked effect on ground cover than did the legume stand (Table 8). Later emerging species (white clover, birdsfoot trefoil and arrowleaf clover) on single legume treatments produced smaller ground cover than earlier emerging species (red clover and subclover).

The influence of legume emergence from time of seeding (Table 7) on ground cover was especially noticeable in the 1988 seeded experiment. Birdsfoot trefoil and white clover emerged respectively 5 and 7 weeks after seeding, while red

Table 6 Percentage ground cover occurring in wheat, legumes and intercropped treatments measured at 8 weeks following seeding. Passo Fundo, 1987 and 1988.

	Ground cover (%)			
	1987		1988	
Treatment	Single	Intercrop	Single	Intercrop
Wheat + 40 kg ha^{-1} of N	62 ef	--	56 c	--
Wheat	--	--	61 c	--
White clover	30 h	68 cde	2 f	62 c
Red clover	77 abcde	88 ab	55 c	72 ab
Arrowleaf clover	43 gh	76 abcde	34 d	62 c
Subclover	81 abcde	92 a	63 c	78 a
Birdsfoot trefoil	37 h	71 bcde	11 e	65 bc
Mean	61		52	
Pr>F (%)	0.01		0.01	
CV (%)	11		8	

Means followed by the same letter within or between cropping systems are not significantly different at P<0.05 level by the Student-Newman-Keuls' test.

Table 7 Legumes emergence, from date of seeding. Passo Fundo, 1987 and 1988.

	Year		
	1987	1988	
Legume species	Combined[1]	Single	Intercropped
	Weeks to emergence		
White clover	4.8 b	7.0 a	7.0 a
Red clover	2.0 d	1.0 d	1.0 d
Arrowleaf clover	3.2 c	3.7 c	4.7 b
Subclover	2.0 d	1.3 d	1.3 d
Birdsfoot trefoil	3.0 c	5.0 b	5.0 b
Mean	3.3	3.7	
Pr>F (%)	0.01	0.01	
CV (%)	3.5	10.0	

Means within a column (1987) and within or between cropping systems (1988) followed by the same letter are not different at P<0.05 level by both Fisher's Protected least significant difference and Student-Newman-Keuls' tests.

[1] Combined means due to lack of significant difference between single and intercropped treatments. Means separation on transformed data.

Table 8 Plant density of legumes in relation to the number of viable seeds planted. Passo Fundo, 1987 and 1988.

Legume species	Viable seeds planted m^{-2}	Plant density (plants m^{-2}) 1987[1]	1988[2] Single	Intercropped
White clover	270	83 ef	25 b	17 c
Red clover	1,750	489 a	1,444 a	1,526 a
Arrowleaf clover	500	92 ef	110 a	103 a
Subclover	300	259 c	219 a	246 a
Birdsfoot trefoil	370	188 d	258 a	87 a
Mean	638	164	403	
Pr>F (%)		0.01	0.01	
CV (%)		19	61	

[1] Measured on August 5. Combined means due to lack of significant difference between single and intercropped treatments. Means within a column followed by the same letter are not significantly different at P<0.05 by Student-Newman-Keuls' test.

[2] Measured on July 22 and August 18. Means followed by the same letter within or between cropping systems are not significantly different at P<0.05 level by both Fisher's Protected least significant difference and Student-Newman-Keuls' tests. Means separation on transformed data.

clover and subclover emerged two or fewer weeks after seeding. Red clover consistently was the first legume to emerge within the group of species studied, whereas white clover consistently was the last. The later emergence of white clover in both experiments reduced its ability to produce a high ground cover by the eighth week. Birdsfoot trefoil on single and intercropped treatments and intercropped arrowleaf clover in the 1988 seeded experiment showed a similar disadvantage.

Legume plant density in both experiments (Table 8) had a smaller influence on ground cover of intercropped treatments at 8 weeks (Table 6) than the influence of legume emergence date. For all single legumes, except white clover in 1988, there were at least 83 seedlings m^{-2}. In the 1987-88 experiment no difference was found in legume plant density between single and intercropped treatments. However, in 1988-89 a significant difference in plant densities was detected between single and intercropped white clover (Table 8). No differences in legume stand were detected in 1988-89 for red clover, arrowleaf clover, subclover and birdsfoot trefoil. For all species the plant density obtained was lower than expected, when compared to the number of viable seeds planted (Table 8).

Intercropping wheat with subclover or red clover, in the 1987 seeded experiment, did not increase ground cover when compared to swards of the same legumes as sole crop (Table 6). In the same experiment, however, intercropping with wheat significantly enhanced ground cover as compared to sole crops of white clover, arrowleaf clover and birdsfoot trefoil. In 1988 intercropping significantly increased ground cover, at 8 weeks after seeding, when compared to all single legume treatments (Table 6).

Intercropped treatments in both years provided a minimum 62% ground cover as measured eight weeks after seeding. In contrast, ground cover obtained by sole crops of these legumes was between 30 and 81% in the 1987-88 experiment and 2 to 63% in the 1988-89 experiment. Intercropping in both experiments increased ground cover to between 62 and 92% (Table 6). These results suggest that intercropping wheat with a certain legume can be used to reduce the risk of poor ground cover on a field in which legumes are seeded for the first time.

Legumes natural reseeding

In the 1987 seeded experiment legume reseeding by natural shattering was evaluated by measuring the number of seedlings per area (Table 3). In the 1988 seeded study the percentage ground area covered by seedlings (Table 9) was the parameter adopted to evaluate legume natural reseeding. Natural reseeding of legumes was evaluated at 357 and 337 days after seeding in 1987-88 and 1988-89, respectively (June 16, 1988 and May 29, 1989).

Table 9 Natural reseeding of legumes from the 1988 seeded experiment in areas previously harvested measured by ground covered area. Passo Fundo, 1989.

Legume species	Ground cover[1] (%)
White clover	67 a
Red clover	84 a
Arrowleaf clover	17 b
ubclover	5 b
Birdsfoot trefoil	96 a
Mean	54
Pr>F (%)	0.01
CV (%)	33

Means followed by the same letter are not significantly different at P<0.05 level by Student-Newman-Keuls' test.

[1] Combined means due to lack of significant difference between single and intercropped treatments.

Initiation of seedling emergence from natural shattered seeds was variable among the various legumes. This occurred as a function of different dormancy, growth and flowering patterns specific to the species studied. As a consequence, initiation of flowering also varied, ranging from October 18 and January 30 for the different species in both experiments. Flowering lasted from 1 to 16 weeks and from 3 to 13 weeks in the first and second experiments, respectively. Subclover seedlings began to establish as early as January 5,1988. In contrast, red clover, arrowleaf clover, white clover and birdsfoot trefoil were still flowering and required a second harvest of seeds on March 22, 1988.

The success or failure of establishment of the various legumes depended to a large extent on the environmental conditions during and immediately after their time of emergence (January to June). A similar situation occurred in Australia (Muldoon, 1984), where premature seed germination in summer jeopardized field pea regeneration. In the present study, less stressful conditions in February and March occurred in 1989 than in 1988 for early emerging seedlings such as those from subclover. In contrast, probably 1989 offered more stressful conditions than the previous year for seedlings of species such as red clover and birdsfoot trefoil which were still emerging in April and May.

Recommendations for intercropping

Of the twelve legumes studied, white clover is the most suitable species to intercrop with wheat under the environmental conditions and specific management practices of this study. Although arrowleaf clover performance was considered good, it showed low reseeding stand in 1988-89. Further, the use of a wheat cultivar taller than BR-14 may be required, if intercropping with arrowleaf clover, in order to avoid a high clover green matter volume during wheat harvest. Better arrowleaf clover performance could be possible using different crop management techniques. Grazing, (after wheat harvest), and/or more intense bee activity may result in higher seed yield and natural reseeding than was obtained in this study. Insect visitation is suggested to be especially important for big trefoil and birdsfoot trefoil seed set (Mckee, 1949). Grazing and the introduction of honeybee colonies have been shown to enhance seed set of species such arrowleaf clover, crimson clover, white clover and red clover (Knight and Hoveland, 1985; Carlson et al.,1985; Taylor, 1985). Adoption of one or both practices may improve the viability of these legumes in southern Brazil agricultural systems.

Future research required

Future research involving the use of summer crops such as corn and soybeans seeded on previously intercropped wheat fields is required. The emphasis of such studies should be directed towards evaluating the effects of these summer crops on natural legume reseeding.

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