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THE USE OF LEGUMES AS ANNUAL DRY SEASON COVER CROPS IN SANTA CRUZ, BOLIVIA

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Of 66 selections of 21 temperate annual legume species sown in the dry season after the harvest of an annual crop, those which showed best adaptation to the environment were *Vicia atropurpurea*, *V. sativa* and *V. villosa*. These species showed resistance to drought, occasional near freezing temperatures and common local pests and diseases, nodulating without the use of inoculants and producing from 1 to 5 t/ha of DM with up to 20% CP without fertilizer application. The yield and quality appeared to be more dependent upon soil fertility and cropping history than upon rainfall, and while the nutrient recycling and N-fixation may be sufficient to prevent the rapid decline of crop yields in fertile soils, yields are not considered to be great enough to restore fertility to exhausted soils. At optimum sowing rates, the ability to produce a rapid soil cover should give protection against wind erosion, and act to suppress the build-up of weeds between main season crops. It was shown that animals unaccustomed to the *Vicia* spp. readily consumed them in the dry season, selecting a diet higher in CP than the general level of the material on offer, in quantities sufficient to complement poor quality grass pastures. They provided useful grazing, but this may be at the expense of their ability to control wind-erosion effectively.

Key Words: Legumes, dry season, cover crops, wind erosion

In the Santa Cruz region, strong winds in the dry period between June and August produce severe wind erosion (Derpsch, 1974) with the result that recommendations to destroy crop residues after harvest in April and May in order to prevent pest carry-over from one season to the next are often ignored. While rainfall in the dry season is often insufficient to justify the risk of sowing a dry season cash-crop, an annual legume sown after the harvest of the rain crop could serve some, or all of the following purposes:

- to provide a cover to prevent wind erosion
- to prevent rapid loss of soil fertility under the commonly employed technique of continuous cropping with a single annual crop
- to reduce build-up of annual weeds in the dry season
- to provide high quality green fodder in the second half of the dry season when most native pastures are dry and unproductive.

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Although mean temperatures for the drier months are not low, the cold south winds (surazos) at this time of year cause temperatures to fall close to, or below freezing point 3 or 4 occasions in most years, and this consideration, together with the shorter daylengths in these winter months suggested that a temperate legume would be more successful than a tropical species. In view of this, a series of trials were carried out in the period 1977-1982, the most important of which are reported here, and consisted of a species screening trial (Experiment 1), time of sowing trials (Experiment 2a and 2b) an investigation of sowing rate by distance (Experiment 3) and an animal acceptance trial (Experiment 4).

Materials and Methods

Experiments 1, 2 and 4 were sown at the Estación Experimental Agrícola de Saavedra (EEAS) situated 65 km north of the city of Santa Cruz de la Sierra (latitude 17°14' S, longitude 63°10' W, altitude 320 m above sea level), while Experiment 3 was sown on 2 private farms in the cotton-growing area of Warnes, about 50 km NE of the city. No general fertilizer application was made in any experiment due to its prohibitive expense, and seed was not inoculated, except as one of the treatments in Experiment 2b.

Experiment 1

On a sandy loam soil, rendered relatively infertile by successive cropping to cereals, and without application of fertilizer, 42 lines of temperate annual legume species introduced from 15 different (mainly Mediterranean) countries were sown as single spaced rows of each accession. They were sown in mid-April, and maintained weed-free by hand weeding. Species sown (number of accessions in parentheses) were *Lathyrus sativus* (3), *Medicago lupulina* (3), *M. orbicularis* (3), *Ornithopus compressus* (15), *O. purpusillus* (1), *O. pinnatus* (1), *O. sativus* (7), *Trifolium vesiculosum* (3), *Vicia sativa* (3) and *V. villosa* (3). Total rainfall from sowing to final evaluation (162 days) was 209 mm.

Evaluation was by visual estimation, although seed was collected from the 4 lines that completed their biological cycle.

Experiment 2

a) On a site adjacent to Experiment 1, with similar history, 24 lines were sown at each of 3 dates, at 15 day/intervals (mid-April, early May and mid-May). The species were *Medicago littoralis* (1), *M. tornata* (1), *M. truncatula* (1), *M. polymorpha* (1), *Melilotus alba* (1), *Onobrychis viciifolia* (2), *Trifolium alexandrinum* (1), *T. pratense* (1), *T. resupinatum* (2), *T. subterraneum* (4), *Vicia atropurpurea* (2), *V. sativa* (3) and *V. villosa* (4). Plots were 2 m x 5 m with 40 cm between rows, using sowing rates of 20 kg/ha for the *Vicia* spp. and *Onobrychis* spp., and 8 kg/ha for the other species. One hand weeding was done, about 30 days after sowing. Yield was measured from a sub-plot 1 m x 2 m, at the end of September, leaving the rest of the plot for the measurement of seed production in mid November. Total rainfall to the end of September was 209, 193 and 188 mm respectively for the 3 sowing dates.

b) In the following year, on a similar adjacent site a separate sowing date by seed treatment trial (treatments were: 1: control, 2: inoculation, 3: pellet with hyperphosphate and 4: inoculate and pellet) was sown with each of *V. atropurpurea*, *V. sativa* and *V. villosa* at 21 intervals (mid-April, early May and late May). Again, plots were 2 m x 5 m, with 20 kg/ha seeding rate, and a single hand weeding. Cuts were taken from all plots in late September for DM yield and analysis of protein content. Total rainfall was 280, 273 and 204 mm respectively for the 3 sowing dates.

Experiment 3

A factorial experiment employing the following rates:

Seed	10 kg/ha	Inter-row	15 cm
	20 kg/ha		30 cm
	30 kg/ha		45 cm
	40 kg/ha		

was sown at each of 2 sites. The soils were basically similar sandy loams, except that one had been cropped for 3 years, while the other had been in continuous cropping for 10 years. In both cases, cotton had been the only crop. The trial was sown in early June as 4 repetitions of all combinations of seeding rate by inter-row distances, using plots of 4 m x 5 m. One weeding was carried out 6 weeks after sowing, and samples cut for yield estimations at 12 weeks. *Vicia* cover was visually estimated on a scale from 1 (little cover, about 10%) to 5 (complete cover, 90-100%) at 22, 38, 54, 70 and 86 days. Total rainfall in the growing season was 230 mm at the newer site and 217 mm at the other.

Experiment 4

Four individual areas of 13 x 70 m were mechanically sown in early May to each of *V. atropurpurea*, *V. sativa* and *V. villosa* using 15 kg/ha of seed. The plots were cultivated mechanically 20 days after sowing to control inter-row weeds. One plot of each species was grazed by cattle, according to the following scheme:

1. Grazed once, October
2. Grazed twice, September, October
3. Grazed 3 times, August, September, October
4. Grazed 4 times, July, August, September, October

Animals were free to choose between the 3 available species at each grazing period. Total rainfall in the trial period was 275 mm.

Ten randomly selected areas of 1 m x 1 m were cut before and after each grazing in each area, in order to assess available material and fodder consumed. Sub-samples were taken for analysis of CP content.

Results

Average climatic data for the dry season are shown in Table 1. The results obtained in the respective experiments were as follows.

Table 1:
Climatic data at EEAS, 31 year means 1952-1982

Month	Precipitation	Monthly mean temperatures (°C)		
		Minimum	Mean	Maximum
April	81.8	18.4	23.8	29.3
May	71.6	16.7	21.8	25.9
June	62.0	15.3	20.4	25.5
July	37.3	14.4	20.3	26.2
August	40.0	15.2	22.0	28.7
September	66.5	18.8	24.4	30.9
Annual Total/Mean	1252.9	18.5	23.9	29.3

Experiment 1

Of the 42 lines sown, 33 exhibited some germination, but only 12 lines survived to 20 days after sowing. One accession died out subsequently, the survivors being *Ornithopus purpusillus* and *O. sativus* both of which showed little vegetative development, together with all 3 lines of each of *Vicia sativa, V. villosa* and *Lathyrus sativus*, all of which showed good growth. Only one *Vicia* flowered (4 g of seed from a 5 m row of *V. villosa*) while the *Lathyrus* accessions produced 89, 97 and 115 g of clean seed respectively from 5 m rows.

Experiment 2a

Both lines of *Onobrychis viciifolia* germinated, but did not survive beyond the first month. All other accessions were present at the end of the dry season. Four of the *Vicia* spp., all 4 *Medicago* spp. and the *Trifolium alexandrinum* accession flowered, and most of these produced small amounts of seed when sown at the earliest date. At the latest sowing date, only one *V. atropurpureum* produced flowers. The second and third sowings produced only traces of seed which were not sufficient to give reasonable estimates of yields per unit area due to small plot size. Yields of DM and seed together with protein content of the foliage are given in Table 2. Although there was considerable variation between selections within species, when averaged over all 3 sowings, the means ± standard errors for the different genera were as follows:

Vicia	2057 ± 106.1 kg/ha	(9 selections)
Trifolium	1035 ± 112.5 kg/ha	(8 selections)
Medicago	1034 ± 159.1 kg/ha	(4 selections)
Melilotus	901 ± 318.3 kg/ha	(1 selection)

Table 2:

DM yields (kg/ha), protein content (%) and seed yields (kg/ha) of species used in Experiment 2a

Species	Sowing 1, 22 April			Sowing 2, 7 May			Sowing 3, 23 May		
	DM	CP %	Seed	DM	CP %	Seed	DM	CP %	Seed
V. villosa (best)	1437	13.8	3	2837	16.0	*	3701	12.4	0
(Mean of 4 selections)	1439	15.0	1	1889	14.8	*	2435	13.8	0
V. sativa (best)	2995	12.1	0	1263	11.4	0	2319	13.0	0
(Mean of 3 selections)	2006	15.6	6	1212	12.7	0	2284	15.1	0
V. atropurpurea (Mean of 2 selections)	3034	14.6	40	2287	12.3	*	2556	14.2	*
M. littoralis (best medicago)	1505	12.0	20	1612	12.0	*	1749	13.0	0
Medicago spp. (Mean of 4 species)	755	11.6	20	985	9.4	*	1263	11.6	0
T. subterraneum cv Seaton Park (best)	1842	9.4	0	1940	12.1	0	1758	8.6	0
Trifolium spp. (Mean of 8 selections)	898	11.3	*	1182	11.9	0	1209	11.5	0
Melilotus alba	1469	16.4	0	772	12.6	0	463	15.1	0
Mean of 22 selections	1284	12.4	-	1361	12.1	-	1695	12.8	-

* Traces of seed produced, but not sufficient to measure yields per unit area.

Experiment 2b

Uneven germination resulted in a poor stand and this invalidated the results from the trial sown with *V. atropurpurea*. Results for *V. sativa* and *V. villosa* are shown in Table 3. No significant responses were noted to any treatments, and the data presented are means over 4 repetitions of each of 4 treatments.

Individual plants of *V. atropurpurea* sampled at the time of cutting of the other trials showed crude protein contents of 18.3, 19.7 and 16.2 % respectively for the 3 sowing dates.

All three species nodulated freely without inoculation.

Table 3:

DM yields (kg/ha) and crude protein content (%) of Vicia sativa and V. villosa. Experiment 2b. (Adapted from Paterson, 1979).

Sowing date	*V. sativa* DM (kg/ha	*V. sativa* CP (%)	*V. villosa* DM (kg/ha)	*V. villosa* CP (%)
14 April	3197	20.1	3164	18.9
5 May	2198	19.9	2669	20.1
26 May	1395	18.0	1695	16.8
S. E.(±)	262.0	0.60	213.9	0.50

Experiment 3

There were large differences in growth of *V. villosa* between the two sites, due to differences in soil fertility as a result of varying cropping histories. Soil analysis showed the main differences to occur in total N, organic matter, P and exchangeable cation capacity. Results of the best treatment mean ± standard error) together with the averages of all treatments are presented for each site in Table 4. Only average figures are presented for the quality components of the *Vicia* since no significant differences were seen between treatments.

Samples of weeds were cut from outside the trial areas to estimate the effect of the *Vicia*. Yields of fresh material of the weeds were reduced by 76% in the poor soil and 79% at the better site as a result of the growing of the cover crop.

Table 4:

Growth parameters for the best, and the average of 12 sowing rate treatments of Vicia villosa, sown at two sites (after Justiniano, 1982). Experiment 3.

Parameter	Poor soil: 20 kg/ha, 15 cm between rows	Poor soil: Average 12 treatments	Better soil: 40 kg/ha, 30 cm between rows	Better soil: Average 12 treatments
Vicia, Yield DM kg/ha	1091 ± 156.2	575 ± 45.1	5356 ± 430.2	3424 ± 124.2
Cover*, 22 days	3.0 ± 0.27	2.8 ± 0.08	4.3 ± 0.20	3.0 ± 0.04
Cover*, 54 days	4.0 ± 0.19	3.4 ± 0.05	4.5 ± 0.23	3.6 ± 0.07
Height, 86 days (cm)	43.1 ± 2.64	36.7 ± 0.76	69.2 ± 0.42	69.0 ± 0.12
CP, %		9.2 ± 0.19		12.6 ± 0.36
Ca, %		1.20 ± 0.073		0.93 ± 0.026
P, %		0.50 ± 0.010		0.45 ± 0.009
Weed yields DM kg/ha	359	297	381	748

* Based on a visual scale of 1 (little cover, 10%) to 5 (complete cover 90-100%).

Experiment 4

The grazing pressures corrected to grazing for a single day, the class of animal and the consumption of *Vicia* spp. at each of the 4 separate grazing periods were estimated as follows, considering 'Animal Unit' (AU) to be equivalent to 400 kg liveweight.

July:	Brown Swiss weaner at 26.1 AU/ha consumed 5.9 kg DM/AU
August:	Brangus yearling at 29.3 AU/ha consumed 3.2 kg DM/AU
September:	Brangus cows at 32.6 AU/ha consumed 14.6 kg DM/AU
October:	Brown Swiss cows at 25.3 AU/ha consumed 8.1 kg DM/AU

In Table 5 the consumed *Vicia* material is expressed as a percentage of the fodder available, both in terms of DM and CP. Total production of *Vicia* DM (CP % in parentheses) averaged over the 3 species was 953 kg/ha (17.3%), 1035 kg/ha (18.2%), 1142 kg/ha (20.4%) and 1490 kg/ha (21.9%) for 1 to 4 grazings respectively, indicating that frequent grazing increased both fodder and quality.

Table 5:

Relative Vicia consumption by cattle (quantity available before grazing = 100). Experiment 4.

Grazing period	*V. atropurpurea*		*V. sativa*		*V. villosa*	
	DM	CP	DM	CP	DM	CP
1. October	11.1	16.3	60.3	68.5	8.4	11.3
2. September and October	38.6	34.7	68.9	71.6	66.1	77.1
3. August, September and October	52.7	57.8	74.7	81.9	70.3	75.5
4. July, August, September and October	61.5	61.1	85.6	89.9	68.4	74.9
Mean	43.4	46.2	72.6	79.5	60.8	68.7

Discussion

Between Experiments 1 and 2, a total of 66 selections of 21 different temperate annual species were screened for their ability to grow in the dry season in a sub-tropical area. Those of best tolerance to the environment were *Lathyrus sativa*, *Medicago littoralis*, *Trifolium subterraneum* cv Seaton Park and several *Vicia* spp. The *Lathyrus* and *Medicago* lines were rejected on the grounds that while seed production was not promising enough to lead to an attractive commercial enterprise, seed was produced in sufficient quantities to make them potentially dangerous as weeds in the following wet season. The yield recorded from the subterranean clover was only some 60% of that measured from the best *Vicia* selection, and it was much slower in providing a soil cover. In view of these considerations, it was decided to carry out further work only with *Vicia* spp., a seed supply of which was already assured in the Cochabamba area of the country (2500 m altitude). *Vicia* spp. are known for their tolerance of dry conditions (Hadjichristodoulou, 1978) and of frost (Soffes and Prine, 1980).

Although a significant sowing date effect was noted in Experiment 2a where the later sowing out-yielded the earlier ones, these results could not be confirmed in Experiment 2b. In the first trial, May, June and July were much drier than normal, but good rains fell in August. The earlier sowings were becoming physiologically mature by this time, possibly initiating flowering as a response to water stress (Humphreys, 1976) while the later sown plants could take advantage of the rains to resume vegetative growth which resulted in higher yields when samples were cut at the end of September. The following year (Experiment 2b), rains in May and June provided a good start for all sowings, before the arrival of the very dry months of July and August. The earlier sowings benefited from a longer period of good growing conditions, probably developing a better root system in this period, and therefore being better able to tolerate the dry months in the middle of their growth cycle. If it is considered that the optimum sowing date is determined by subsequent climatic patterns, there would appear to be little practical advantage to be gained from further sowing date studies when the extremely erratic nature of the dry season rains is taken into account.

From the results of Experiment 3, it would appear that optimum sowing rates and spacings are highly dependent on soil fertility, since on the infertile site, intra-specific competition resulted in poorer yields at higher plant densities. On the better soil, although 40 kg/ha was the highest rate used, there was no evidence to suggest that the optimum rate was above that level. This would appear to be in contrast to commonly used rates in other parts of the world (for example Hadjichristodoulou, 1978, used 75 kg/ha in Cyprus), but fertilizer usage at sowing time would probably favour higher plant densities.

The use of inoculation had no effect on DM yields, and uninoculated plants nodulated freely (Experiment 2b). These observations lend weight to the contention of Paterson (1979) that the soils of the area harbour a range of *Rhizobium* strains that are capable of forming symbiotic relationships with many different cultivated legumes. Since Latin America is considered to be a centre of origin of many legumes, it is logical that it should also be a centre of origin and diversification for nodule-forming bacteria. The failure of the hyperphosphate pellet to stimulate growth in relatively low phosphate soils could be due to the low availability of the nutrient source in almost neutral soil conditions (pH 6.5).

At the best sowing rates, even on the poorer soil, the legume provided a reasonable plant cover within the first month, indicating that

Vicia spp. sown after the harvest of the wet season crop have the ability to form a protective cover over the soil before the strongest winds occur in the months of July and August.

The fresh weight yield of weeds growing in the *Vicia* plots was only a quarter of that measured outside the plots, this being the combined result of a single weeding together with the competitive effect of the legume. While no attempt was made to measure weed seed production, it seems likely that the practice of growing *Vicia* spp. in the dry season could have a positive effect in limiting the potential weed population in the following cropping cycle. Further work along these lines should seek to identify the weed species that continue to grow with the legume, and which could produce problems in the future, if they come to dominate the weed flora.

In general, the trials so far realized show that depending upon soil fertility and climatic conditions, *Vicia* spp. can produce from 1 to 5 t/ha of high quality pasture when sown after the wet season crop, and without the use of fertilizers. These results are comparable to the figures of Hadjichristodoulou (1978) who showed in Cyprus with annual rainfall of 159-480 mm that 7 varieties of *V. sativa* sown with fertilizer over 12 site years produced from 0.57 to 7.53 t/ha (overall average 3.69 t/ha with 19.8% CP). The foliar fraction of a well-grown *Vicia* stand contains something of the order of 100 kg/ha N, resulting from both N fixation and up-take by the roots, while on a poor soil the N yield is considerably less than this. It therefore seems likely that while the legume may be capable of helping to prevent the rapid deterioration of crop yields on a fertile site, its capacity to restore fertility to a run-down area is limited. In a situation such as the poor soil of Experiment 3, it seems that in the absence of chemical or organic fertilizers, the only way to restore fertility would be through the use of a leguminous ley of several years duration.

Experiment 4 showed that *Vicia* spp. were readily consumed in quantities sufficient to complement usefully poor-quality dry season pastures, both by young and adult cattle that had never before been exposed to the pasture. Adult animals consumed more *Vicia* relative to their body-weight than did weaners and yearlings, but this observation should be treated with caution, since the trial was not designed to evaluate acceptance by different classes of livestock. Consumption of fodder was poorer in *V. atropurpurea* than in the other species (Table 5), but in most casses the accepted feed was higher in protein content than the general level for the material on offer, indicating an active selection of the parts of the plants with higher nutritive capacity. Although no local animal production data are available for diet complementation with *Vicia* spp. the positive effect of limited quantities of legume forage on cattle growth (Paterson *et al.*, 1983) and milk production (Paterson *et al.*, 1981; Paterson and Samur, 1982) has been demonstrated in Santa Cruz for a range of pasture legumes of similar nutritive quality.

While much remains to be done to recommend management systems to maximize *Vicia* production, it must be noted that grazing on a monthly basis resulted in an average 56% increase in DM production and 27%

increase in protein content compared with a single grazing at the end of the dry season (Experiment 4). Defoliation during the course of the growing period stimulated the production of fresh new shoots, and this aspect should be considered in future grazing work, while bearing in mind that early grazing of the legume may slow sward closure, thus reducing the beneficial effects in terms of erosion reduction and weed control.

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