SPECIES SELECTION

Development and evaluation of germplasm and cultivars of cover crops

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Most North American cover crops are winter annual legumes that evolved under a Mediterranean-type climate. Winter annual legumes have several advantages over perennial legumes in that they produce vigorous, rapidly developing, short-duration plants used as winter annuals in the southern United States *(17, 32)* or spring annuals in the northern United States *(27)*. Legumes also have several advantages over nonlegumes in that they can supply much of their nitrogen (N) requirement through symbiotic dinitrogen (N_2) fixation if properly inoculated with *Rhizobium*, and they produce readily decomposable organic material, resulting in rapid mineralization of the N in the legume crop. We can divide winter annual legumes into forage legumes, such as, crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth), or grain legumes, such as peas (*Pisum sativum* L.) and lentils (*Lens culinaris* Medik.). Hairy vetch and Austrian winter peas have the best winterhardiness of these winter annual legumes, but they still winterkill in the colder winters or colder areas.

Plant germplasm development (plant breeding) evolves through three successive stages: introduction, selection, and hybridization. Introduction involves screening and evaluation of plant introductions, foreign cultivars, and advanced breeding lines from other areas. The second stage is selection of superior-appearing plants from these introductions, increasing them, and evaluating them in local tests. The final stage is hybridization of selected parent lines, followed by selection for the best combination of traits from the two parents in each cross. The time and effort we devote to breeding a particular crop is largely a function of the acreage of the crop and whether the crop is a cash crop or not. Cover crops traditionally have been small acreage crops, except in the southeastern United States. Furthermore, cover crops are not cash crops, except in areas that specialize in seed production of these cover crops. Consequently, researchers have concentrated intensive plant breeding efforts primarily in the southeastern United States on crimson clover because it is the most widely adapted and highest yielding of the winter annual legumes *(20)*.

Breeding of most cover crops in North America is still in the introduction and selection-from-introduction stages. The low-acreage devoted to cover crops has inhibited private plant breeding efforts in the past, and current budgetary restrictions will further restrict public plant breeding efforts. However, the increased interest in erosion control and a green environment may stimulate increased plant breeding efforts on cover crops.

In this chapter, we discuss methods of accessing germplasm and present case histories of the development and evaluation of cover crops in the Northern Great Plains of North America.

Germplasm availability

A wide range of germplasm of most winter annual legumes is available from the National Plant Germplasm System of U.S. Department of Agriculture (USDA). A centralized computer data base, known as Germplasm Resources Information Network (GRIN), contains information about these plant genetic resources. Any North American scientist can access GRIN by writing to the GRIN Database Management

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Unit, BARC-West, Beltsville, Maryland 20705, and requesting a log-in identification, access code, and detailed instructions for use. In this way, researchers can readily obtain available information on the location and characteristics of the available germplasm for the species of interest.

Additional sources of germplasm are available from contemporary researchers here or abroad *(19, 23)*. Various Soil Conservation Service Plant Material Centers also are evaluating different winter annual legumes and other species for cover crops. A valuable source of information on current research and results of germplasm evaluation of winter annual legumes is published in the annual Progress Report on Clovers and Special Purpose Legumes Research, coordinated by R. R. Smith, U.S. Dairy Forage Research Center, USDA, University of Wisconsin, Madison, Wisconsin 53706.

Problems in evaluating annual legumes

Many early evaluations of annual legumes failed for various reasons. Investigators conducted many trials without the benefit of the proper strain of *Rhizobium* or even without *Rhizobium*. The resulting legume seedlings were often weak and noncompetitive, particularly on low-N soils. However, J. C. Burton and, subsequently, R. S. Smith of Liphatech Inc. (formerly, The Nitragin Co.) graciously supplied specialty inoculants for a small fee when advance orders were made. Subsequently, the performance of many annual legumes improved, particularly when properly inoculated in low-N soils.

Most legumes are poor weed competitors because of a lag period between emergence and formation of a competetive ground cover. Weed competition at this time is critical and often results in stand failure. However, development of effective grass herbicides and selective broadleaf herbicides has increased the frequency of successful stands in preliminary evaluation trials. However, chemical weed control may not be economically feasible on field-scale plantings.

Many annual forage legumes have a high hard-seed content and poor stands often result. However, this can be largely overcome by mechanical scarification. Alternatively, plant breeders have successfully selected for high hard-seed content in crimson clover and developed some reseeding cultivars. These reseeding cultivars, if properly managed for seed production over the cool season, will reestablish themselves with the advent of cool weather in the early fall.

One other problem is that many reports on evaluation of various annual legumes mention the species, but do not provide any further identification of the line(s) being tested. A single line, even if identified and repeatable, certainly does not represent the range of variability within a species. Thus, preliminary evaluations should include at least 10 distinctly different lines, if available. Researchers should perform subsequent detailed testing on a specific line, and adequate seed should be available to maintain that line and supply seed to other interested researchers.

These problems and their solutions are simple and straightforward. Nevertheless, one or more of them occur repeatedly in preliminary evaluations of annual legumes, rendering the results meaningless--a rather inefficient use of scarce research resources.

The Northern Great Plains agroecosystem

Agriculture in the Canadian Prairies/Northern Great Plains-Intermountain region faces a challenge to modify conventional cropping systems or develop new cropping systems involving green manure/cover crops that will allow for a more sustainable agriculture. Although several important irrigation projects have been developed in the region, producers conduct the majority of the cultivated agriculture in the region without benefit of supplemental irrigation--dryland farming or dry farming as it is. One way to describe dryland farming is a system that allows crop production in a hostile semiarid environment which, in this region, includes the following stresses and/or negative factors: low, erratic precipitation (drought); hot, dry July and August (drought); short growing season; unseasonable frosts; harsh winters; significant winter precipitation (positive and negative); Chinook winds (positive and negative); cool, wet spring weather (positive and negative); insect pests, diseases, weeds; nutrient deficiencies; few crop species (monoculture); saline-seep hazard; erosion hazard; isolation (positive and negative); and others.

The agroenvironments of cultivated agriculture in the region are numerous and varied. For example, farming is carried out in areas where average annual precipitation ranges from 10 to more than 30 inches, elevation varies from less than 2,000 to almost 7,000 feet above sea level, growing seasons range from 90 to as much as 140 days, and soil types vary from loamy sands to heavy clays. Over 700 recognized soil series occur in Montana alone. The primary crops grown in the Northern Great Plains region are winter, spring, or durum wheat (*Triticum aestivum* L.); spring barley (*Hordeum vulgare* L.); and, on occasion, canola (*Brassica* spp.) and safflower (*Carthamus tinctorius* L.), with several variations of an alternate crop-fallow rotation in a strip-cropping configuration. All are based on large quantities of purchased inputs. Rye (*Secale cereale* L.), oats (*Avena sativa* L.), and flax (*Linum usitatissimum* L.) are also grown on the Canadian prairies. In recent years, Saskatchewan producers have also included lentils, peas, mustard (*Brassica* spp.), and annual canarygrass (*Phalaris careniensis* L.) in their rotations. Two cropping systems, continuous cropping and flexible cropping *(7, 24)*, introduced in Montana during the 1970s as a means to reduce the saline-seep hazard, have achieved only limited acceptance, primarily due to conflicts with the rigid requirements of the federal farm programs. Our present systems, perhaps in a narrow context, have been successful but are obviously fraught with shortcomings when we consider profitability, erosion, saline seep, and other environmentally damaging effects *(13)*.

Certainly, when water is the most limiting factor, numerous important relationships will develop between water quantity and quality and the cropping systems employed. Dryland farming, as conducted in the region, has some potential to pollute surface water via runoff containing sediments and various agricultural chemicals and nutrients, including nitrates (NO_3). However, probably the greatest hazard to water quality from conventional dryland farming is groundwater pollution with soluble salts in general, and nitrate-N (NO_3-N) in particular. One common manifestation of this problem is the phenomenon of saline-seep, which involves shallow groundwater systems *(12)*. Saline-seep results when the alternate crop-fallow system is employed on landscapes underlain by an impermeable layer, commonly Colorado shale or lignite. On the section of land being fallowed, crop water is not used. This allows excess water to move through the soil profile, beyond the root zone, where it picks up soluble salts including NO_3. When this water encounters the impermeable layer, it eventually resurfaces, forming a seep spot that is subject to water loss by evaporation. As the process continues through time, the seep spot becomes salinized. In some areas, artesian pressure and a high water table also cause salinization.

Another and, perhaps, the most common manifestation of groundwater pollution is the leaching of NO_3-N into groundwater beneath land cultivated with the alternate crop-fallow system. The process is similar to that involved in saline-seep formation except, in the absence of an impermeable layer, the deep-percolating water transports NO_3 and other soluble salts to groundwater aquifers. Summer fallowing is quite conducive to mineralization of N from the soil organic matter; it also encompasses the periods of highest precipitation. Thus, with no crop on the land, this cropping system promotes deep percolation of NO_3-laden water, resulting in groundwater pollution. Researchers have reported as much as 55 parts per million (ppm) NO_3 in groundwater beneath crop-fallow cultivated land *(8)*. They found as much as 969 pounds/acre NO_3 below the root zone in the same fields, representing almost four times the amount of fertilizer N applied in the entire cultivated history of the fields. Thus, in both cases, mineralized N from the soil organic matter, rather than fertilizer N, is the source of the NO_3-N polluting the groundwater. Hence, the cropping system is faulty and should be replaced with a more sustainable system. Fertilizer N contributes to the problem indirectly. Farmers replace the leached N mineralized from soil organic matter with fertilizer N and achieve economic yields that allow the continued use of this faulty cropping system.

The solution to this problem lies in the more efficient and complete use of the dryland water resource and the N mineralized from soil organic matter. Also, the decline in soil organic matter caused by the faulty crop-fallow systems requires that a supplemental-N source be supplied for the small grain crops. The most logical modified cropping system to achieve the above is a legume-cereal rotation. The legume phase of the rotation can be a cash seed, forage, or green manure (cover) crop.

Development and evaluation of legume cover crops in the Northern Great Plains. In this chapter, we will focus on the evaluation and adaptation of green manure and cover crops for dryland cropping systems, with only occasional mention of irrigated systems. Prior to the experiments discussed in this chapter, little research had been done on dryland legume-cereal rotations in Montana since the early 1950s. Researchers summarized and published the results of a 38-year study (1914-1951) *(1)*. The results indicated that winter rye, field peas, and sweetclover (*Melilotus* spp.) green manures had no effect or a depressing effect on small grain yields the following year as compared with ordinary fallow (Table 1). The results of this study, inexpensive N fertilizer, increased use of herbicides, and federal farm program requirements are the most likely reasons that research on dryland legume-cereal rotations essentially ceased in Montana until 1978. Recent results indicate that early incorporation of the sweetclover crop will prevent depletion of soil moisture reserves and increase yield of the succeeding cereal crop *(14)*.

Table 1. Average wheat yields following green manure and fallow at Moccasin, Montana, 1914-1951, and Huntley, Montana, 1915-1951 (*1*).

	*Moccasin**		*Huntley†*	
Previous Crop	*Yield (pounds/acre)*	*Percent of Fallow*	*Yield (pounds/acre)*	*Percent of Fallow*
Fallow	910	100	1,300	100
Field pea	949	104	900	70
Sweetclover	870	96	659	51
Rye	945	104	895	70

*Average annual precipitation, 15.0 inches.
†Average annual precipitation, 12.6 inches.

After studying dryland legume-cereal rotations in Australia and North Africa, J. R. Sims began a series of field experiments to evaluate the performance and adaptability of several annual legumes to dryland farming in our region. In the first experiments in this series, he attempted to adapt Australian ley farming to Montana. Ley farming is a system in which crops and pasture are alternated on the same field *(9)*. It may be considered a fallow system that alternates small grains with a short-season annual legume grown for pasture during the fallow year *(22)*. The key to successful ley farming lies in the pasture phase of the rotation. A legume is needed that increases soil fertility, improves soil structure, and regenerates naturally after a crop. Some legumes can do this.

In South Australia, the main medics used are barrel medic (*Medicago truncatula* Gaertn.), strand medic (*M. littorali* L.), cultivar 'Harbinger'; gama medic (*M. rugosa* L.), cultivar 'Paragosa'; snail medic (*M. scutellata* Mill.); and disc medic (*M. tornata* L.).

The main subterranean clovers (*Trifolium subterraneum* L.) included the following cultivars: 'Clare', 'Geralton', 'Woogenelup', and 'Daliak'. The reason for the success of the legumes in Australia is that they produce many hard seeds. Hard seeds are seeds with seed coats resistant to the entry of water, thus retarding germination *(9)*. Medics have a high percent of hard seed when grown in areas where they are well adapted. This means that in the following summer they can resist germination after rains. During summer, extreme heat and microbial activity crack the seed coats of some seeds so that by autumn they have become soft, which allows imbibition to occur and results in germination.

Adaption of ley farming to Montana. Researchers imported small quantities of seed of most of the species mentioned above from South Australia in 1978 and collected seed of black medic (*M. lupulina* L.), a legume widely adapted to Montana, from areas and bulked them for use in the experiment *(21, 26)*. Replicated tests were established with these legumes in 1979, with the spring wheat phase of an alternate crop-bare-fallow rotation as the control treatment. The legumes were grown to maturity to build up seed supplies in the soil. Although yields were small, the medics all produced seed; however, none of the subterranean clovers did. Consequently, in 1980, the medic plots were allowed to reestablish the legume stands from residual seed in hopes of further building up seed supplies in the soil, and the subterranean clover plots were reestablished with a new seeding. The control treatment plots were managed as bare fallow. Again, the legumes were allowed to mature to establish seed production, after which the total biomass was incorporated as green manure in August. The plots were uniformily seeded to 'Pondera' spring wheat in 1981, after sampling individual plots to a 4-foot depth for stored soil water and NO_3-N (Table 2). Wheat grain yields and protein content were measured.

During 1982, the plots were allowed to reestablish from residual buried seed produced in 1979 and 1980. Again, none of the subterranean clovers reestablished stands and the Australian medics that did reestablish had rather sparse stands compared with black medic, which reestablished a near-solid stand. The control plots were, of course, managed as bare fallow. Once again, all plots were uniformily seeded to spring wheat in 1983. The 1981 water resource for wheat following the legume treatments was not significantly different from the fallow treatment (Table 2). In addition, all legume treatments increased the NO_3-N level of the soil above that of fallow with the black medic, increasing it to a level over 2.5 times that of fallow.

In 1981 wheat yields were greater from all medic treatments than from fallow, with yields from the black medic treatment being almost double those from fallow (Table 3). In 1983 only the black medic treatment produced wheat yields greater than the fallow control treatment. However, considering the average yields for two cycles of the rotation, all medic treatments outyielded the fallow control. An additional consideration is that the soils under the medic treatments were protected from soil erosion more of the time during the 4 years than were the fallow plots. Also, more water was evapotranspired by the medic-wheat rotations than by the fallow-wheat rotation, suggesting that the ley farming system could be effective in reducing saline-seep hazard.

The above results suggest that it may be possible to adapt the ley farming system to Montana and the northern Great Plains. Also, it appears that black medic, which has already adapted itself to the local environment, may be the best choice for extending this cropping system into other parts of the Northern Great Plains. Clearly, we need to conduct further experimentation in drier parts of the region.

Table 2. Mean soil water and NO_3 contents on April 17, 1981, to a depth of 4 feet in soils green manured with various annual medic species in 1980, Bozeman, Montana.

Green Manure Crop	*Soil Water (inches)*	*Nitrate-N (pounds/acre)*
Fallow (control)	10.4	46
Barrel medic, Ghor	10.1	98
Barrel medic, Jemalong	10.0	60
Barrel medic, Cyprus	9.6	80
Strand medic, Harbinger	9.8	93
Snail medic, Robinson	9.7	100
Black medic, MT BM-1	9.8	117
LSD (0.05)	NS*	30

*NS = No significant difference.

Table 3. Pondera spring wheat yields for 1981 and 1983 following various annual medic species grown as green manure in 1980 and 1982 in a ley farming rotation at Bozeman, Montana.

Green Manure Crop	*Pondera Spring Wheat Yields*		
	1981	*1983*	*Two-Cycle Average*
	pounds/acre		
Fallow (control)	1,627	2,185	1,906
Barrel medic, Ghor	2,135	1,834	1,985
Barrel medic, Jemalong	2,115	1,868	1,992
Barrel medic, Cyprus	2,030	1,869	1,950
Strand medic, Harbinger	2,302	1,988	2,145
Snail medic, Robinson	1,895	1,944	1,920
Black medic, MT BM-1	3,123	2,406	2,764
LSD (0.05)	607	331	

Classical legume-cereal rotations. The value of legumes as nutritious food and forage crops and for soil rehabilitation has been recognized for thousands of years. Both grain legumes and forage legumes have long been included in humid-area crop rotations as cash crops, pasture components, or cover and green-manure crops. However, such conventional legume-nonlegume rotations have not been widely adapted to dryland farming in the Northern Great Plains--Intermountain region. The exceptions have been some sporadic use of yellow sweetclover over the years in rotation with dryland wheat or barley and an occasional substitution of a grain legume, such as lentils or dry peas, for wheat or barley in an alternate crop-fallow system.

The declining fertility of the soils in this region and the deteriorating cereal-based agricultural economy induced regional agronomists in the mid 1970s to evaluate the potential of numerous alternate crops, including several grain legumes.

These studies have shown that several grain legumes can be successfully grown in Montana. The degree of success, i.e., yield level, varied from place-to-place and year-to-year, depending mostly on environmental conditions. With cool-season legumes, the success also depended on how early the crops were seeded. Faba beans (*Vicia faba* L.), chickpeas (*Cicer arietinum* L.), lentils, dry peas (spring), and Austrian winter peas (black peas) *(30)* showed the most promise. The most promising warm-season legumes were dry beans (*Phaseolus vulgaris* L.) and soybeans [*Glycine max* Merr. (L.)]. Several classes of dry beans have shown promise, including pinto, pink, great northern (white), red kidney, and black turtle.

Results suggest that several cultivars of a wide variety of grain legumes species can be inserted into the principal cropping systems of the region, alternate crop-fallow and flexible cropping. In the higher-rainfall areas, i.e., greater than 18 inches annual precipitation, these crops should be successful when inserted into a continuous cropping system in rota-

Table 4. Annual grain legume and cereal grain yields at Kalispell, Bozeman, Huntley, Conrad, Moccasin, and Sidney, Montana.

	Yields						
Crop	*Kalispell Cycle 1 1982 (18.3)**	*Kalispell Cycle 2 1983 (21.0)*	*Bozeman 1982 (18.6)*	*Huntley 1982 (20.4)*	*Conrad 1982 (11.6)*	*Moccasin 1982 (18.5)*	*Sidney 1982 (13.4)*
	pounds/acre						
Chickpeas	911	1,534	1,556	1,943	764	581	934
Lentils	1,906	1,624	797	1,412	1,689	942	1,235
Spring peas	2,812	1,391	1,701	2,613	2,321	1,281	1,918
Faba beans	1,115	2,113	1,150	2,381	1,630	639	633
Black peas-hay†	4,396	4,436	3,768	4,715	2,278	-	4,351
Soybeans	-	-	-	2,354	-	-	1,876
Pinto beans	-	-	-	1,057	-	-	-
Pink beans	-	-	1,092	-	-	-	956
Barley	3,280	3,654	861	4,162	1,904	2,139	2,639
Wheat	2,559	3,355	836	-	1,882	1,714	1,366

*Annual precipitation in inches September to August of the crop year, except that 6 inches of irrigation was included at Huntley.
†Forage yield.

tion with cereals and other nonlegume crops. In 1982, the Montana Agricultural Experiment Station initiated a legume-cereal rotation study involving most of the above-mentioned legumes, followed by 'Clark' barley *(35)*. All sites were dryland farmed, except for the irrigated site at Huntley.

The control treatments in this study included continuous grain, wheat-barley, or barley-barley on all sites plus alternate crop fallow on the dryland sites. All grain legumes, including faba beans, performed well on at least one site and quite acceptably at most sites (Table 4). Acceptable yields of the grain legumes are critical to this type of legume-cereal rotation in that harvesting the legume as a cash crop is an important part of the economics of the cropping system. Also, if the legume is used as a green manure in lieu of a fallow period, its biomass production must be sufficient to benefit the ensuing cereal crop in excess of the cost of producing the legume. This is, of course, above the erosion protection afforded the soil by the legume; the interruption of disease, insect, and weed cycles; and the long-term soil building effects of the legume.

Table 5 shows the benefits afforded by the various grain legumes to the following barley crop. Barley data for the second year at the Conrad site were precluded by a hailstorm and data for the Moccasin site were lost due to human error. With the remaining sites, yield of barley following the legumes, without use of N, was quite competitive with the yield of barley following fallow and, in general, much superior to the yield of barley following either wheat or barley, i.e., continuous grain.

Barley grown on the plots during the second year of the rotation was fertilized differentially with 0 to 150 pounds N/acre as ammonium nitrate (NH_4NO_3). Data from these treatments allowed calculation of the quantity of additional N fertilizer required to achieve maximum yield of barley the year following the various legume, continuous grain, or fallow treatments. These legumes reduced the N fertilizer requirement for maximum barley yields by 38 to 60 pounds N/acre compared with continuous barley and by 7 to 27 pounds N/acre compared with fallow at two sites *(10)*.

Barley yields following black (Austrian winter) peas plowed for green manure were 109% to 400% of barley yields following small grains when no fertilizer N was applied (Table 5). When we removed annual legume biomass as hay or grain in year 1 of the rotation, barley yields (as percent of second year barley) without fertilizer N varied from 94% to 311%, depending upon location.

The N contribution of annual legumes to barley production can be substantial under varying environments. The degree of contribution will depend upon environmental conditions the year annual legumes and recrops are grown. Timely precipitation at dryland sites and timely irrigation at irrigated sites are required for optimum legume growth and nodulation. Also, timely precipitation is necessary the second year of the rotation to recover N accumulated during the first year.

In cases where soil moisture levels are replenished by winter pre-cipitation, annual legumes may be substituted for fallow with-out significantly reducing yield of the succeeding barley crop. When the annual legume is harvested for grain or hay, savings in N fertilizer costs in the recrop year may exceed $15/acre.

Table 5. Effect of previous crop on barley grain yield without fertilizer N at five Montana locations.

	Barley Grain Yield				
Previous Crop	*Kalispell Cycle 1 1983*	*Kalispell Cycle 2 1984*	*Kalispell Cycle 2 1985*	*Bozeman 1983*	*Huntley 1983*
	pounds/acre				
Fallow	5,678	2,028	1,506	2,035	-
Black peas (green manure)	5,879	2,628	2,130	2,425	5,227
Black peas (hay)	5,227	2,363	1,832	1,825	4,829
Lentils	5,199	2,631	2,131	1,892	5,026
Spring peas	5,150	2,622	2,150	1,654	4,992
Faba beans	4,463	2,833	2,268	1,343	4,484
Chickpeas	4,001	2,405	1,930	1,465	4,589
Barley	3,314	1,810	1,953	607	3,505
Wheat	3,195	1,831	1,935	874	-
Pinto beans	-	-	-	-	4,558
Soybeans	-	-	-	-	4,844
Pink beans	-	-	-	1,451	-
LSD (0.10)	354	392	435	483	896

Table 6. Berseem clover forage yield as a function of seeding date at Bozeman, Montana, 1987.

	Berseem Clover Forage Yield	
Seeding Date	*Irrigated*	*Dryland*
	tons/acre	
May 9	5.6	2.4
May 15	5.5	2.6
June 3	1.7	0.5
June 9	0.4	0.1
June 16	0.2	0
CV%	26	35
LSD (.05)	1.1	0.6

Table 7. Forage yield of small-seeded annual legumes in 1986 and spring wheat yield in 1987 at Bozeman, Montana.

	Forage Yield		
Cultivar and Species	*1986 Forage (tons/acre)*	*1987 Spring Wheat* (pounds/acre)*	*1987 Spring Wheat† (pounds/acre)*
Ghor medic	1.31	3,120	2,130
Cyprus barrel medic	1.54	2,946	2,184
Medicago rugosa medic	1.80	2,820	2,232
Serena polymorpha medic	1.65	2,754	2,430
Ridawn barley	1.35	3,060	2,250
Mt. Barker sub clover	1.55	3,492	2,124
Shaftal clover	1.02	3,300	2,256
Clare sub clover	1.46	3,498	1,800
Paragosa gamma medic	1.98	3,534	1,926
Nungarian sub clover	1.14	3,618	2,652
Geraldton sub clover	0.99	3,552	2,592
Black pea	1.02	3,624	2,376
Daliak sub clover	1.24	3,678	1,542
Indianhead lentil	2.34	2,808	2,130
Horsford barley	1.56	2,646	1,866
Jemalong barrel medic	2.38	2,190	2,202
Robinson snail medic	1.48	3,552	2,424
Tornafield disc medic	1.89	3,132	1,908
Harbinger strand medic	2.88	2,268	1,896
Arrowleaf clover	0.74	3,516	2,118
Yellow sweetclover	1.14	2,382	1,884
Paraponto gamma medic	2.52	3,258	2,106
Fallow	-	2,664	-
LSD (0.05)	0.8	558	846
CV	35.1	12.6	28.0

*Weed control conducted in 1986.
†Weed control not conducted in 1986.

Clearly, our ability to manage the resources at hand in dryland farming areas in the region are such that many annual legumes can be successfully grown under dryland conditions. This new information, along with the declining soil organic matter and available N levels in our soils, suggests that legume-cereal rotations will play an increasingly important role in our dryland cropping systems in the future.

Current annual legume evaluation trials in Montana. Present research priorities focus on (a) further evaluation of various legume species for adaptation to Montana conditions, (b) expanding the range of environments for dryland experiments, (c) controlling water use by the legume green-manure crop to a predetermined allocation, and (d) developing inoculation techniques for more successful nodulation and N_2 fixation under dryland conditions.

Tables 6 and 7 present the species and cultivars under evaluation, their adaptation, and effects on spring wheat yield. Results indicate that early seeding and weed control are essential to high yield of legumes and the wheat. However, high legume-green-manure yields resulted in low wheat yields, undoubtedly related to higher water use that reduced the water available to the succeeding spring wheat crop.

These results support the use of CREST Farming strategy, and the concept of controlling water use and/or the amount of N_2 fixed by the green-manure crop by terminating the green manure crop once it has used its allocation of water or fixed a prescribed amount of N *(25)*. Results of these preliminary trials indicate that berseem clover (*T. alexandrinum* L.), several Australian medics, and Indianhead lentil are promising legume components in dryland legume-cereal rotations.

Yellow sweetclover and black medic in legume-cereal rotations were evaluated further at four dryland locations in Montana during 1988-1989. Table 8 presents results from the Bozeman location.

Black medic seed production trials in were initiated 1986 (Tables 9 and 10), and these trials will be continued. An adequate and inexpensive seed supply is essential for the successful establishment of this, or any other, species, as the legume component in dryland legume-cereal rotations. Additional uses for black medic under investigation by other agencies include reclamation of disturbed forest land and biomass production to aid farmers in complying with requirements of the U.S. farm bill.

Experiments were established to determine the feasibility

Table 8. Results of 1988-1989 legume-cereal rotation study, Bozeman, Montana.

	1988 Water Use (inches)				*1989 Winter Wheat*	
Species	*Soil*	*Precipitation*	*Total*	*1988 Yield*	*Spring Soil Water (inches)*	*Yield (pounds/acre)*
Black medic	2.90	1.71	4.61	0.78 t/a	9.36A*	1,470C
Yellow sweetclover	4.09	1.71	5.80	0.84 t/a	8.67A	1,566C
Barley + 0 pounds N on winter wheat	3.29	1.71	5.00	11.1 bu/a	10.52B	750AB
Barley + 100 pounds N on winter wheat	3.29	1.71	5.00	7.9 bu/a	10.81B	972BC
Fallow				11.1 bu/a	10.96BC	216†C
Fallow + 50 pounds N				9.5 bu/a	11.64C	522†AB

*Means followed by the same letter are not significantly different at the level of significance indicated.
†Late seeded spring wheat to put fallow-cereal plots in proper sequence.

of controlling the amount of water used by a green manure crop to a predetermined allocation at three locations in Montana. Indianhead lentils were planted in early May 1988 and growth terminated by cultivation (conventional tillage) or by herbicide spray (no-till) after three different levels of evapo-transpiration had occurred (Table 11). Water use was reasonably well controlled within allocated amounts at the Post Farm and Valley Center locations. Control of water use at the Moccasin location was not as good and was made more difficult due to the rainfall pattern. The plots were seeded to winter wheat in September 1988. At the Moccasin location, the winter wheat crop was lost to hail. The data for one complete cycle of the rotation at the Bozeman and Valley Center locations are shown in table 12. The intermediate moisture-use treatments, 5 inches at Bozeman and 4 inches at Valley Center, resulted in the greatest winter wheat yields. These data indicate that allocation of a specified amount of water for green manure use in dryland farming is a promising management practice. These plots are being maintained for one additional cycle of the rotation.

As presented in CREST Farming strategy *(25)*, fall seeding of the crop allows progress toward earlier maturity that helps evade the main period of drought hazard. Fall seeding also distributes the farmer's workload more evenly and helps solve the delayed seeding problem caused by wet spring weather. Thus, many of the annual legume species evaluated for adaptation to the area as spring-seeded crops are also evaluated as possible sources of fall seeded types. The species showing greatest promise to date include Austrian winter peas, lentils, berseem clover, and some *Medicago* species. At the same time, we are looking at all species for species characteristics important for grain legume, green manure or cover crops, and forage crops in our environments.

Grain legumes as cover crops in the Canadian Prairies. Annual forage legumes are small-seeded and must be planted at a shallow depth (<1 inch) for maximum emergence. Unfortunately, in semiarid Canadian Prairies the surface inch of soil often dries out during seedbed preparation and small-seeded annual forage legumes often fail unless timely rains occur. Grain legumes are large-seeded and can be planted deeper to moisture (3 to 4 inches deep, if required), greatly

Table 9. Effect of row spacing on 'George' black medic plant height, forage, and seed yield in 1986.

Plant Spacing (inches)	Plant Height (inches)	Yield (pounds/acre) Forage	Seed
6	8A*	2,666A	459
12	9B	2,442AB	451
18	10C	2,542B	440

*Means followed by the same letter are not significantly different at the level of significance indicated.

Table 10. Effect of seeding rate on 'George' black medic plan height, forage, and seed yield in 1986.

Seeding Rate (pounds/acre)	Plant Height (inches)	Yield (pounds/acre) Forage	Seed
4.5	7A*	2,354A	448
9.0	9B	2,634AB	454
13.5	10C	2,528AB	446
18.0	11D	2,684B	453

*Means followed by the same letter are not significantly different at the 0.05 level.

Table 11. Yield and water use control by Indianhead lentil for dryland green manure at three Montana locations in 1988.

Site	Water Allocated (inches)	Forage Yield (tons/acre)	Water Used (inches)
Moccasin	5	0.76	5.54
	6	0.98	5.63
	7	1.12	5.91
LSD (0.05)		0.16	0.83
Post Farm	4	0.54	4.37
	5	1.28	4.76
	6	1.07	6.31
LSD (0.05)		0.17	0.22
Valley Center	3	0.68	3.68
	4	1.28	4.18
	5	0.95	5.12
LSD (0.05)		0.14	0.41

Table 12. Indianhead lentil green manure water use, dry matter yield, and N content in 1988 and spring soil water content and winter wheat yield in 1989, Post Farm near Bozeman, Montana, and Valley Center, Montana.

	1988 Green Manure						1989 Spring		1989 Winter Wheat	
	Water Used (inches)		Yield (tons/acre)		N (pounds/acre)		Soil Water (inches)		Yield (pounds/acre)	
1988 Treatment*	Post Farm	Valley Center	Post Farm	Valley Center	Post Farm	Valley Center	Post Farm	Valley Center	Post Farm	Valley Center
3 Conventional tillage		3.88AB†		0.71AB		59.0A		8.9AB		2,244A
3 No-till		3.49A		0.66A		54.9A		8.7AB		1,974A
4 Conventional tillage	4.44AB†	4.23B	0.57A	1.28D	37.9A	97.3B	8.6B	8.6A	2,202C	2,412A
4 No-till	4.25A	4.14B	0.51A	1.30D	36.3A	98.1B	9.1B	9.4AB	1,932BC	2,436A
5 Conventional tillage	4.74BC	5.23C	1.24C	0.86BC	83.8C	57.6A	7.9A	9.2AB	2,070C	2,370A
5 No-till	4.78C	5.01C	1.41C	1.00C	95.5C	66.6A	8.7B	9.6AB	2,028C	2,364A
6 Conventional tillage	6.35D		1.20BC		58.7B		7.8A		1,248AB	
6 No-till	6.27D		0.94B		48.5AB		8.6B		1,554ABC	
C-C	6.02D	5.96D	918‡	306‡	-	-	9.3B	10.1B	930A	1,962A
F-C	-	-	-	-	-	-	9.0B	8.6A	1,074A	2,130A
C.V. (%)	2.21	4.46	8.77	6.62	9.41	8.46	2.85	10.8	16.3	6.5
LSD (.05)	0.34	0.58	0.26	0.19	17.1	18.4	0.7	1.4	768	426

*The green manure crop was incorporated as soon as it had used 4, 5, or 6 inches of water under conventional tillage and no-till systems.
†Numbers within a column followed by the same letter are not significantly different.
‡Barley yield in pounds/acre.

increasing the probability of successful stand establishment.

In 1984, a regional project was established in cooperation with Agriculture Canada to evaluate several annual legumes for use as cover and green manure crops in the Canadian Prairies. Plots were established at Swift Current, Saskatchewan (Brown soil zone); Saskatoon, Saskatchewan (Dark Brown soil zone); Melfort, Saskatchewan and Morden, Manitoba (Black soil zone); and Beaverlodge, Alberta (Gray soil zone). Three annual legumes were evaluated [Trapper peas, Indianhead lentils, and Tangier flatpeas (*Lathyrus tingitanus* L.)] at all locations for 3 to 4 years; several other annual legumes [Outlook faba beans, Sirius peas, and grass peas (*Lathyrus sativus* L.)] were evaluated at one or two sites.

Reports from these studies *(2, 3, 4, 5, 15, 18, 29, 33, 34)* indicate that the presence of any legume green manure cover crop has a marked effect on yield and quality of the succeeding cereal crop. The best results occurred if the legume crop was incorporated at the bloom stage before soil moisture was depleted. Undercutting with a wide-blade cultivator provided the best protection against wind and water erosion. Desiccation with diquat reduced yield of the succeeding cereal crop, possibly because of accelerated volatilization losses of N from the chemically damaged tissues. Trap strips of lentils or other crop-trapped snow replenished soil moisture and increased yield of the succeeding cereal crop *(6)*.

In 1986, 2-acre plots of Indianhead lentil were established in fallow fields on 11 farms in the Brown and Dark Brown soil zones of Saskatchewan. These plots averaged 1,332 pounds dry matter/acre, containing 17 pounds N/acre. In 1987 (a drought year), the farmers planted most of the fields to spring wheat. Paired and replicated yield samples were taken from the fallow and the green-manure parts of each field. Wheat yield on the Indianhead lentil green-manure plots averaged 70% of the wheat on the adjacent fallow portion of the field, ranging from 52% of fallow in the driest area to 89% in the area with the most favorable moisture. In this study, Indianhead lentils were allowed to continue growth all summer, seriously depleting the soil moisture and preventing any moisture storage. Under these severe drought conditions, the factor that limited production was moisture, not N. These results reemphasize the importance of seeding the annual legume early and incorporating it by July 10 before it depletes the soil moisture reserves, permitting storage of some of the precipitation during the rest of the fallow season. This system is gradually being adopted by farmers who are not already receiving the benefits of a legume in the rotation by growing lentils as a grain legume. Indianhead lentil has a place in the drier areas of the Northern Great Plains as an annual legume green manure/cover crop for the early portion of the fallow season, provided weed competition is not so severe as to virtually smother the lentil plants.

Soil moisture is not so limiting in the Black soil zone and barley crops respond to additional N fertilizer. The effect of the legume green-manure crop on yield of the succeeding barley crop was nearly additive to the effect of N rates up to at least 150 pounds/acre *(36, 37)*.

Use of legume green-manure/cover crops is most critical in the Gray soils because they are low in organic matter, N is nearly always limiting for crop production, and high rates of N fertilizer are often used. Under these conditions, long-term rotations, including 3 to 6 years of alfalfa, are most beneficial because the benefits often persist for up to 8 years *(18)*.

The annual grain legumes have more vigorous seedlings and are more readily established in droughty soils than the annual forage legumes. But, the annual grain legumes also have a larger seed and a higher seeding rate than the annual forage legumes. This results in a higher seed cost/acre than for the annual forage legumes, with the exception of Indianhead lentils. The small-seed size of Indianhead lentils means that a successful stand can be established with 35 pounds seed/acre; at $0.20 pound this comes to $7.00/acre. Cover crops are not a cash crop and farmers are reluctant to pay much to grow a noncash crop, no matter how beneficial it is for the soil.

Cover crops in the 21st century

Increased use of legume cover crops for soil protection, N_2 fixation, increased rates of nutrient cycling, and maintenance of soil organic matter levels will occur in the 21st century. This will occur as a result of higher prices for N fertilizer, greater emphasis on conservation of our edaphic resources, development and adoption of improved soil management practices, increased efficiency of N_2 fixation, and more and better cultivars of various cover crops.

Plant breeders will concentrate on the most promising winter/spring annual legumes, including vetch (hairy and common) *(16)*, crimson clover, subterranean clover *(11)*, berseem clover, arrowleaf clover (*Trifolium vesiculosum* L.), Persian clover (*T. resupinatum* L.), peas, lentils, and grass peas. Breeding objectives will include yield; N_2-fixation efficiency; stress tolerance (winterhardiness, heat, salt, acid soils, alkali soils, and drought); resistance to insects and diseases; competitive ability with weeds; and high seed yield. Genetic variability for most of these traits is available within most species, and the day is coming when plant biotechnologists will be able to transfer a desired gene from one species to a second species lacking that gene *(31)*. The primary drawback will be lack of research efforts expended on these noncash and thus, low-priority crop species. The potential is great, but progress will be slow, centered primarily on the public sector.

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Adaptation of legume species as cover crops in no-till systems

B. N. Duck and D. D. Tyler

Legumes have long been used as cover crops, and during the last decade numerous researchers have investigated their utility in conservation tillage. Hargrove and Frye *(5)* suggested important roles for legumes in modern systems: soil, water, and energy conservation; soil improvement; and enhanced productivity.

Legumes can contribute to agricultural sustainability by substituting biologically fixed dinitrogen (N_2) for energy-intensive N fertilizers. In recent studies involving no-till methods, investigators estimated fertilizer nitrogen (N) equivalency of legume N for subsequent grain crops in the range 67 to 152 pounds/acre for hairy and bigflower vetches and more than 80 pounds/acre for crimson clover *(1, 4, 6, 7, 8, 9)*. Legume cover crops often stimulate yields of following grain crops more than can be accounted for by legume N alone *(4, 7, 9)*.

Several legumes are potentially useful as cover crops, and comparisons of five species in Tennessee found differential adaptation to soil internal drainage and pH levels *(3)*. Holderbaum et al. *(6)* concluded that hairy vetch, crimson clover, and winter pea were superior to 11 other legumes as cover crops in Maryland. Brar et al. *(2)* reported wide differences in root development response of 12 legumes to temperature. Other research *(7, 10, 11)* has emphasized the influence of management upon effectiveness of cover crops in production systems.

We conducted studies reported herein to evaluate adaptation of several legume species for use as cover crops in no-till production systems for corn and grain sorghum in western Tennessee. We used results to estimate fertilizer N equivalency of legume N supplied to subsequent grain crops.

Methods

We conducted experiments on the Martin and Milan Experiment Stations during 1981-1986. We planted legumes (Table 1) and wheat September 22 to October 4 (early date) and October 17 to 30 (late date) each year. We arranged planting dates as main plots and species as subplots in a split-plot randomized complete block design. We planted cover crops into crop residues with a no-till drill and returned them to the same plots in repeated cycles of the experiments, but we did not repeat experiments on each site every year.

We sampled cover crops for biomass production April 17 to 27 (when corn was the primary crop) or April 29 to May 16 (when grain sorghum was the primary crop). Immediately after sampling, we killed the cover crops with paraquat at 0.5 pound active ingredient/acre plus surfactant at 0.25% volume/volume or glyphosate at 1.0 pound active ingredient/acre plus surfactant at 0.5% volume/volume. We applied the burndown chemicals as tank mixtures with herbicides recommended for residual preemergence weed control in corn or grain sorghum.

We planted grain crops into cover crop residues with a no-till planter; we planted corn April 24 to May 10 and grain sorghum May 16 to 30. We broadcast annual applications of phosphorus and potassium over all plots at planting of the grain crops. About 3 weeks after grain crop emergence, we applied ammonium nitrate to wheat cover plots at rates of 0, 60, 90, 120, or 150 pounds N/acre for corn or 0, 30, 60, 90, or 120 pounds N/acre for grain sorghum. We applied no fertilizer N to grain crops following legumes. We harvested grain crops September 4 to 30 each year and repeated the cycle.

Results

In 9 of 10 location-year trials, cover crops produced significantly more ($P < 0.05$) dry matter when planted in late September than in late October. Biomass production of cover crops averaged across all location-years for the early planting date are shown in table 1. We noted significant differences among species for dry matter yields in each experiment. Seedling vigor, tolerance to low temperatures, and disease resistance appeared to be key factors affecting legume adaptation. Based upon these criteria, we considered hairy and bigflower vetches, crimson clover, and caley peas to be adapted for use as cover crops under the management imposed.

Table 2 shows yields of corn and grain sorghum following the adapted legumes; it also shows yields following wheat and receiving 90 or 120 pounds fertilizer N/acre for comparison. We observed significant differences among cover species in 9 of 12 experiments.

Viewed over all location-years, grain yields were more consistent following hairy vetch, but were somewhat erratic following crimson clover due to winter injury and/or diseases, primarily crown rot. Corn production following hairy vetch and caley pea did not differ significantly in seven of eight experiments from that following wheat and fertilized with 90 pounds N/acre. Grain sorghum yields following each of the four legumes did not differ significantly in any of the four trials from those following wheat and receiving 90 pounds fertilizer N/acre.

Yield responses of corn and grain sorghum to fertilizer N rates when following wheat as a cover crop were subjected to regression analyses, and response curves were quadratic for 10 of 11 field experiments. We used these regression equations to estimate the fertilizer N equivalency of legume N for subsequent grain crops (Table 2). We substituted yields of grain crops grown after legumes and receiving no fertilizer N for Y (the dependent variable) and solved the equations for X (fertilizer N rate, the independent variable). Estimates for each legume species were greater when grain sorghum was the following crop. This probably was due to increased growth and N accumulation with the delayed killing of covers for grain sorghum planting; the effect was more pronounced for hairy

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Table 1. Location-years of evaluation, mean dry matter production, and rating of adaptation of cover crops.

Cover Crop	*Species*	*Cultivar*	*Location Years*	*Dry Matter (tons/acre)*	*Adaptation**
Arrowleaf clover	*Trifolium vesiculosum*	Yuchi	11	0.81	2
Ball clover	*T. nigrescens*	Segrest	2	0.28	3
Berseem clover	*T. alexandrinum*	Bigbee	6	0.03	3
Bigflower vetch	*Vicia grandiflora*	Woodford	11	0.87	1
Buttonclover	*Medicago orbicularis*	VNS†	3	0.00	3
Caley pea	*Lathyrus hirsutus*	VNS†	9	1.13	1
Common vetch	*V. sativa*	Cahaba	3	0.39	3
Crimson clover	*T. incarnatum*	Tibbee	11	1.09	1
Hairy vetch	*V. villosa*	VNS†	11	0.93	1
Red clover	*T. pratense*	Kenland	9	0.36	3
Sub clover	*T. subterraneum*	Mt. Barker	10	0.62	2
Winter pea	*Pisum sativum arvense*	Austrian	11	0.36	2
Wheat	*Triticum aestivum*	Caldwell	11	0.67	1

*Ratings of adaptation for use as cover crops for corn and grain sorghum in no-till: 1 = adapted, 2 = marginally adapted, 3 = unadapted. Ratings based upon dry matter production, seedling vigor, and tolerance to winter injury and diseases.
†Cultivar not stated; commercial seed sources, but not a named variety.

Table 2. Yields and estimated fertilizer N equivalency of legume N for corn and grain sorghum following selected covers.

Cover Crop	*Corn**		*Grain Sorghum†*	
	Grain (bushels/acre)	*N Equivalent (pounds/acre)*	*Grain (bushels/acre)*	*N Equivalent (pounds/acre)*
Bigflower vetch	91	81	82	95
Caleypea	94	113	88	130
Crimson clover	80	57	69	65
Hairy vetch	98	95	88	121
Wheat + 90 lb N	100		82	
Wheat + 120 lb N	113		92	

*Means of 8 location-years for grain yields and 7 location-years for N equivalency except for caleypea, for which means are based upon 6 location-years.
†Means of 4 location-years.

vetch and caleypea, which matured later.

These results demonstrate diversity among legume species for suitability as cover crops in no-till production systems. Hairy vetch appears to be the legume of choice for this purpose in the mid-South region. In these studies, yields of corn and grain sorghum following hairy vetch were not significantly different from yields of these crops grown after wheat and fertilized with 90 pounds N/acre.

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Legumes in rotation with corn in southeastern Nebraska

P. T. Koerner and J. F. Power

Legumes in rotation or as winter cover have historically provided benefit to grain crops. This is mainly done in short-term rotation, such as corn-soybeans [*Zea mays* L.-*Glycine max* (L.) Merr.], or for continuous corn with a legume winter cover crop such as hairy vetch *(3)*.

Hairy vetch (*Vicia villosa* Roth) has been shown to provide from 80 to 110 pounds nitrogen (N)/acre to the following grain crop in the eastern and southeastern United States *(5)*. Researchers have shown that benefit to be only about 55 pounds/acre in southeastern Nebraska under dryland conditions *(4)*. A disadvantage of vetch as a winter cover crop is its use of soil moisture in the spring when the newly planted grain crop needs moisture for establishment *(2)*. We conducted an experiment to determine effects of several legume winter cover crops on selected soil measurements and corn production.

Methods

We conducted two experiments on adjacent sites. The soil on the two sites is the same, a Crete-Butler silty clay loam (fine, montmorillonitic, mesic Pachic Argiustolls-Abruptic Argiaquolls). Site 1 has a slope of 3% to 5%, while site 2 is 1% to 3%.

We drilled legumes into a clean, tilled seedbed in plots 10 feet by 30 feet, with 10-inch rows. We inoculated all the legumes and applied 45 pounds/acre of phosphorous to help with establishment. We hand-weeded the legumes. During 1985 and 1986, legumes were grown, followed by corn in 1986 and 1987, respectively, for the two experiments. We planted legume plots on three dates: mid-May, early July, and mid-August, with three replications for each species on each planting date using a split-plot design. We double-disked the plots the following spring and planted corn with no addition of commercial fertilizer. We applied alachlor (Lasso) and atrazine at corn planting at 2.5 and 1.6 quarts/acre, respectively.

In both experiments, we evaluated a total of 23 legume species. Six species common to both experiments showed the most promise and will be discussed here: alfalfa (*Medicago sativa* L., 'Mesilla' at location 1, 'Nitro' at location 2); hairy vetch (*Vicia villosa* L., 'Madison'); rose clover (*Trifolium hirtum* All., 'Hycon'); winter rye (*Secale cereale* L., 'Cougar'); soybeans ('Century'); and flatpeas (*Lathyrus tingitanus* L., 'Tinga'). We monitored soil moisture using a neutron probe. We collected plant dry matter samples on three dates during the legume growing season, and we also measured surface cover of legumes using a photographic grid procedure at location 2 in 1986 *(6)*.

Results and discussion

Dry matter production of legumes differed between location-years. Hairy vetch, tinga pea, and rose clover accumulated significantly more N in dry matter in experiment 1 in 1985 than in experiment 2 in 1986 for the October sampling date. Alfalfa, soybeans, and rye accumulated similar amounts of N in dry matter for the two experiments.

Figure 1 shows the differences in the ability of the legume species to accumulate N in their biomass as affected by planting day. Soybeans produced the most dry matter. But because of its greater N percentage, hairy vetch was close in total amount of N accumulated, especially for experiment 1. All species except rye showed greatest dry matter production and N accumulation for earlier planting dates. Rye was adversely affected by the warm conditions experienced after the earlier planting dates.

All species planted in May achieved 93% to 100% surface

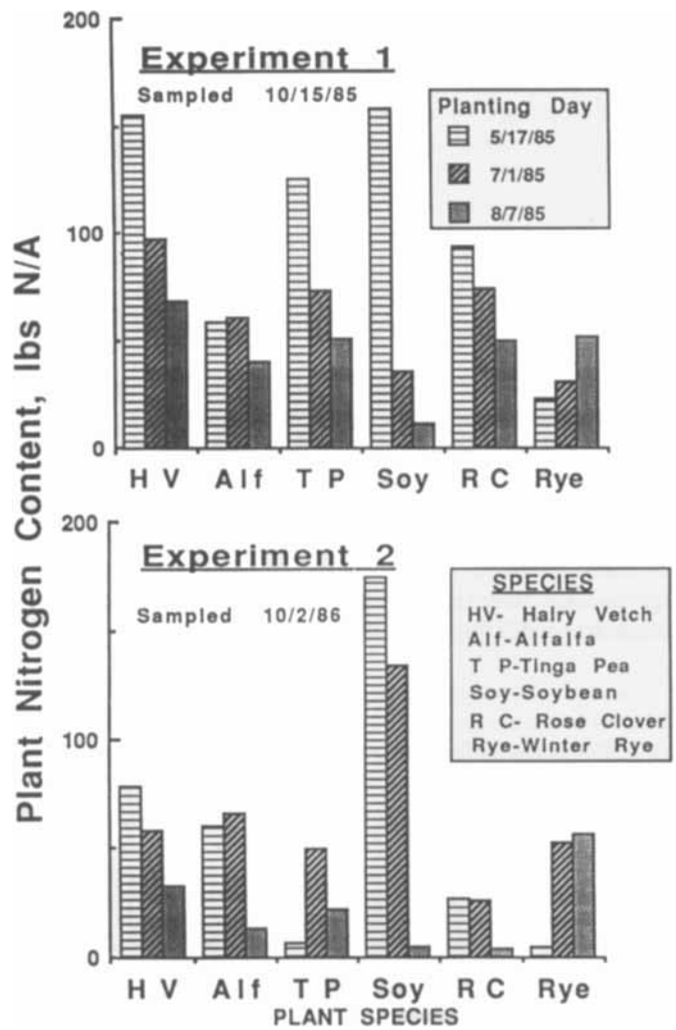

Figure 1. Differences in N content of various legumes by planting day.

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Table 1. Maximum surface cover achieved and days of growth to reach maximum cover for selected legume species in experiment two.

	Legume Planting Date					
	May 7, 1986		July 14, 1986		August 26, 1986	
Species	MC*	Days†	MC	Days	MC	Days
Alfalfa	99	117	98	78	73	66
Tinga pea	100	90	100	72	96	57
Hairy vetch	100	51	100	63	100	42
Rose clover	100	112	65	93	50	85
Soybean	100	69	80	73	5	29
Winter Rye	93	47	92	64	100	34

*Maximum cover observed (percentage of soil surface covered).
†Days to reach maximum cover.

cover by fall *(1)*. Hairy vetch provided complete surface cover in the shortest time: 51, 63, and 42 days when planted in May, July, and August, respectively (Table 1). The August planting showed that hairy vetch, tinga pea, and winter rye all provided good fall cover, while planting soybeans this late provided almost no winter surface cover.

Soil samples taken in the spring following legume production show that tinga pea, alfalfa, and vetch planted the preceding May resulted in the most inorganic N in the surface foot of soil: 20, 16, and 14 parts per million (ppm), respectively. Soil mineral N levels for soybeans, rose clover, and rye were lower, and averaged 11, 10, and 8 ppm, respectively. Soil mineral N levels for the later planting dates were 12.5 ppm or lower, and relative differences among species remained the same as the May planting date.

Corn yields following legume growth were very inconsistent. Spring precipitation was sufficient for good corn stand establishment both years. The early legume planting dates did not seem to affect yield in any consistent manner. Corn yields in 1986 on experiment 1 varied from 120 to 155 bushels/acre, while those for experiment 2 ranged from only 60 to 90 bushels/acre.

One reason for this difference may have been that experiment 1 was uniformly cropped to soybeans during 1984, while experiment 2 was a fallowed field prior to legume establishment. Another reason for the difference in yield may have been rainfall. During July, the main period for flowering and seed set, rainfall was 3.07 and 1.45 inches for experiments 1 and 2, respectively. Unfortunately, in this study growth of the winter cover crops showed no influence on yield of corn the following year.

It appears that all species performed well during the years 1985 and 1986 at this southeastern Nebraska location. The legumes provided near total surface cover and accumulated from about 27 to over 150 pounds/acre of N in aboveground plant parts. Hairy vetch and rye might perform best as winter crops in the subhumid continental climate of eastern Nebraska because of their ability to accumulate dry matter and provide surface cover quickly during cooler times of the year.

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Native winter cover shows potential in no-till cotton

J. S. Parkman and L. H. Bloodworth

Cotton (*Gossypium hirsutum* L.) is the most erosive row crop grown in Mississippi. Murphree and Mutchler *(5)* calculated C-values for conventionally tilled cotton in the Mississippi Delta that ranged from 0.10 for full canopy to over 1.00 for winter bedding, with an average of 0.58. Planted on about 1.2 million acres, cotton is the Mississippi's number one cash crop *(4)*. In order to reduce soil erosion and maintain crop productivity, farmers are using conservation tillage and cover crops.

Corn (*Zea mays* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] have been shown to have higher grain yields following hairy vetch (*Vicia villosa* Roth) compared with fallow *(2, 7)*. Double-cropping wheat (*Triticum aestivum* L.) with soybeans [*Glycine max* (L.) Merr.] reduced soil erosion while increasing net returns *(1)*. Touchton et al. *(6)* reported that crimson clover (*Trifolium incarnatum* L.) could supply enough nitrogen (N) to cotton when N requirements were low (30 pounds N/acre).

Disadvantages of using a planted cover crop are seeding and planting expenses. Presently, legume seed costs range from $0.82 to $1.00/pound while wheat seed averages $0.13/pound. Equipment, labor, and fuel expenses increase the total cost. An alternative to a planted cover crop is native cool season weeds. Volunteering naturally eliminates seed and planting expenses, and the burndown chemical rates can be reduced because the native cover can be eliminated more easily. We conducted a project from 1987-1990 to evaluate the potential of native winter weeds to reduce soil erosion in no-till cotton.

Methodology

We used an on-farm demonstration site that consisted of about 5 acres to evaluate native winter weeds as a cover crop for no-till cotton production. The soil type was Brooksville silty clay (fine, montmorillonitic, thermic Aquic Chromuderts). The demonstration site had been in conventionally tilled cotton for several years. Weed species at the site included annual bluegrass (*Poa annua* L.), buttercup (*Ranunculus spp.*), chickweed [*Stellaria media* (L.) Cyrillo], and henbit (*Lamium amplexicaule* L.).

We determined percent canopy cover using the line-transect method by averaging the cover of four random sites from February through April. We determined dry matter yield by hand harvesting four 9.62-square-foot plots and averaging the resulting weights. We eliminated weeds using glyphosate in mid-April. We planted the cotton in early May. We used normal cultural practices excluding cultivation.

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Results and discussion

Table 1 shows percent canopy cover and dry matter yield. In 1988 and 1989, native weeds produced 22% to 83% canopy cover during February and March. Almost complete cover was obtained in April. Dry matter yield was 900 and 679 pounds/acre for 1988 and 1989, respectively. In 1990, canopy cover and dry matter yield were significantly less than they were in the previous 2 years. We attributed these declines in cover and yields to the lack of cultivation that brings previously buried weed seeds to the surface and the use of norflurazon. Keeling et al. *(3)* reported that repeated applications of norflurazon increased norflurazon residues and crop injury to susceptible plants up to 3 years after final application. Norflurazon is used to control warm-season annual grasses and broadleaf weeds in cotton, but also controls some cool-season native weeds *(8)*.

We developed cover management factors using the U.S. Department of Agriculture's Agricultural Handbook No. 537 *(9)* and data published by Murphree and Mutchler *(5)*. We also used canopy cover and dry matter yield evaluations during the demonstration period to determine the soil-saving value of winter weeds.

Calculations indicated that no-till cotton with a cover of native winter weeds reduced soil loss by 64% when compared with conventional-tilled cotton. If no native winter weeds existed, we calculated the soil savings of no-till cotton versus conventionally tilled cotton to be 48%.

Lint yields were comparable in all years (Table 2). In 1989 and 1990, we planted the conventionally tilled cotton in another field that received less rain than the no-till cotton field. Crop emergence was uniform with little insect pressure during the seedling stage in all 3 years. Plant populations and plant heights (data not shown) were comparable.

Results show that native winter weeds are effective in reducing soil erosion. Almost complete canopy cover can be achieved from early November to June; expenses normally associated with a planted cover crop are either eliminated or

Table 1. Percent canopy cover and dry matter yield of native winter weeds.

	Canopy Cover (Percent)			*Dry Matter*
Year	*February*	*March*	*April*	*Yield (pounds/acre)*
1988	22	66	93	900
1989	83	71	97	679
1990	9	16	16	112

Table 2. Cotton lint yield.

	Lint Yield (pounds/acre)	
Year	*Conventional Tillage*	*No-till*
1988	1,078	946
1989	882	1,100
1990	875	1,125

reduced. However, consideration should be given to reduced use of residual herbicides.

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Development of caley pea for cover crop use

J. A. Mosjidis, Charles M. Owsley, and Malcome Kirkland

Farmers have used legumes in crop rotations for many decades to improve soil fertility in the southeastern United States. Availability of relatively inexpensive chemical fertilizers contributed to a decline in their use as a nitrogen (N) source. More recently, producers have recognized legumes as valuable crops in water and soil conservation programs. Hence, there has been a renewed interest in these plants because of the benefits observed in systems that use conservation tillage for grain production *(1, 2)*.

Caley pea (*Lathyrus hirsutus* L.) is an introduced cool-season legume from the Mediterranean region. In the southeastern United States, producers have utilized caley pea as a cattle forage as well as a cool-season cover crop. Caley pea is mostly grown on wet clays of the lower Mississippi Delta area and on calcareous clays of the Alabama and Mississippi Black Belt *(3)*. Currently, there are no caley pea cultivars available and most commercial seed is a mixture of caley pea and hairy vetch.

The objective of our work was to make an initial evaluation of the variability within a selected group of caley pea entries for several agronomic traits so we could determine the type(s) of cultivar(s) that may be developed.

Methodology

In 1983, at the Soil Conservation Service's Plant Materials Center at Americus, Georgia, researchers planted caley pea seeds from 150 ecotypes collected from fields and roadsides in central and northern Alabama and four foreign entries. This collection was grown in Americus, Georgia, where it was screened for adaptation, growth, winterhardiness, reseeding ability, and seed production.

In 1989, we conducted tests of 19 selected caley pea ecotypes in Georgia (Americus Plant Material Center) and Alabama (Winfield, Belle Mina, Marion Junction, Tallassee, and Brewton). We did not evaluate all entries at all locations because of limitations in the amount of available seed. The experimental design was a randomized complete block with four replications in each location. We applied fertilizers acccording to soil test recommendations.

We harvested the plots individually when 75% of the plants were blooming. At that time, we measured flowering date, canopy height measured at three places in the plot, and biomass fresh and dry yields. We calculated percentage of dry matter and performed analyses of variance to measure the response of the entries at each location. We measured matu-

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rity as number of days to flowering date starting from April 1. We obtained mean separations among entries by using the least significant difference test (LSD).

Results and discussion

We found differences for all traits studied in the entries in all locations. Entry T48912 was consistently the earliest flowering in all locations. Entry T52658 was one of the latest to flower in most locations (Table 1). The entries flowered within a range of 10 days at Marion Junction, Tallassee, and Brewton (19 to 29 days after April 1). The plants at Winfield and Belle Mina flowered later than the other locations (35 and 42 days, respectively). We expected this because these locations are in northern Alabama where the mean temperature is much lower than at the other locations.

Table 1. Maturity of several caley pea entries grown at six locations measured as days to 75% flowering starting from April 1, 1990.

	Maturity of Caley Pea Entries (days)					
Entry	*Tallassee*	*Americus*	*Marion J.*	*Brewton*	*Belle Mina*	*Winfield*
T52658	38	24	33	30	47	38
T52970	22	13	27	23	42	34
T48912	14	9	20	8	26	26
T52969	23	24	30	28	39	36
T52088	23	24	29	21	42	34
T53011	28	24	32	27	47	36
T52660	28	24	33	30	47	39
T54241	23	20	31	30	42	38
T52099	23	13	29	22	45	34
T54223	23	13	29	23	39	
T52085	23	24	31	30		
T53012	23	13	26			
T54235	23	24	26			
T54214	23	13	25			
T54213	22	20	30			
T52101	23	20	27			
T52086	22		29			
T54221	24		34			
T52097	22					
$LSD_{(0.05)}$	4	1	5	2.4	8	4.3
Mean	23.6	18.9	28.7	24.6	41.5	34.9

Table 2. Biomass dry matter production of several caley pea entries grown at six locations.

	Biomass Dry Matter Production of Caley Pea Entries					
Entry	*Tallassee*	*Americus*	*Marion J.*	*Brewton*	*Belle Mina*	*Winfield*
	pounds/acre					
T52658	3,018	5,295	3,108	1,268	3,501	1,491
T52970	1,982	3,277	1,947	1,206	1,625	750
T48912	2,483	3,501	2,447	750	1,482	500
T52969	2,483	4,581	2,206	1,491	1,715	768
T52088	2,983	5,983	2,759	1,929	1,741	1,072
T53011	2,107	3,777	2,483	1,250	2,429	964
T52660	2,527	4,054	2,947	1,768	2,670	1,411
T54241	2,599	4,260	2,349	1,670	1,527	670
T52099	2,447	4,510	3,000	1,581	1,581	688
T54223	2,750	4,072	2,295	1,536	1,456	
T52085	2,608	4,456	2,554	1,723		
T53012	2,849	3,947	2,447			
T54235	2,983	4,617	2,893			
T54214	2,554	5,001	2,536			
T54213	3,063	4,438	3,134			
T52101	2,304	3,840	2,750			
T52086	2,063		2,563			
T54221	3,117		3,259			
T52097	2,197					
$LSD_{(0.05)}$	982	1,280	777	482	1,134	482
Mean	2,584	4,350	2,648	1,470	1,974	924

If we selected the entries with the highest dry weight per acre (22% to 30% depending on the location), entry T52658 was consistently among the best at Americus, Winfield, Belle Mina, Marion Junction, and Tallassee. Entry T52088 was among the best in Americus, Tallassee, and Brewton. Entries T54213 and T54221 had high yields at the two locations where they were tested (Tallassee and Marion Junction) (Table 2). Americus was the location where the highest biomass dry weight was obtained, whereas the lowest mean yield occurred at Winfield.

These results suggest that two cultivars of caley pea might be developed. One would be made up of late-flowering lines and would have a high biomass yield, the other would be made up of an early line with a moderate yield. Seed production of this germplasm collection, as well as some additional lines, is being increased in Americus. We will conduct further testing of this plant material at several locations of the Southeast in 1991 and 1992.

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New cool-season legumes for use in conservation tillage

C. M. Owsley and W. L. Hargrove

Agricultural scientists have again begun to do extensive work with cool-season legumes for use on southern farms in conservation tillage systems. The results of a study conducted in the Piedmont of Georgia suggest that a double-cropping system of reseeding crimson clover (*Trifolium incarnatum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] provided sufficient nitrogen (N) for maximum sorghum grain yield *(2)*. Another study in Georgia used crimson clover, subterranean clover (*T. subterraneum* L.), hairy vetch (*Vicia villosa* Roth), and common vetch (*Vicia sativa* L.) in a grain sorghum no-till system *(1)*.

Investigators at the Soil Conservation Service's (SCS) Plant Materials Center at Americus, Georgia have assembled and evaluated collections of cool-season annual legumes for use as cover crops. They used the initial evaluation block located on Orangeburg sandy loam (fine, loamy, siliceous, thermic, Typic Paleudults) to screen about 1,000 cool-season annual legume accessions. These legumes have included germplasm from several genera, including *Lathyrus*, *Trifolium*, *Vicia*, and *Medicago*. They were assembled from foreign, as well as naturalized populations. All foreign accessions came through the plant introduction system. The naturalized legumes were collected and processed by SCS personnel in the southeastern United States. Each accession (a documented and numbered legume) was evaluated for adaptability, growth, vigor, winterhardiness, stand, reseeding ability, flowering date, seed production, disease resistance, and insect resistance. These evaluations produced several selections for further testing.

We conducted the present study to compare two selected button clover [*Medicago orbicularis* (L.) Bartal.] germplasm accessions and one selected hairy vetch germplasm accession to standards in conservation tillage systems. Herein, we will compare legume dry matter and N production and subsequent grain sorghum yield.

Materials and methods

We conducted the study at University of Georgia Experiment Stations at Griffin and Plains.

On October 19, 1988, we planted the seed of 'Coker 9766' wheat (*Triticum aestivum* L.), 'Tibbee' crimson clover (*Trifolium incarnatum* L.), 'Lana' vetch (*Vicia dasycarpa* Ten.), commercial hairy vetch (*V. villosa* Roth), PI-199258 button clover [*Medicaso orbicularis* (L.) Bartal.], and PI-383803 hairy vetch (*V. villosa* Roth) to test plots on Greenville sandy clay loam (clayey, kaolintic, thermic, Rhodic Paleudults) at the Southwest Georgia Experiment Station, Plains.

We hand-broadcast all seed to disked and cultipacked soil. After planting, we again cultipacked the plots. We seeded vetch, button and crimson clovers, and wheat at the rate of 30, 20, and 90 pounds of pure live seed/acre, respectively. We arranged each ground cover entry of 10-foot by 20-foot plots in a randomized complete block design with four replications. All plots received a fall application of 0 pounds N/acre, 43 pounds phosphorus/acre, and 81 pounds potassium/acre.

On March 20, 1989, we clipped each plot for dry matter and N determination using two 18-inch by 18-inch quadrants. We determined N content using a microkjeldahl procedure. On May 15, 1989, after we had applied paraquat (Gramoxone), Attrex (Atrazine), and metolachlor (Dual) herbicides, we planted grain sorghum to the cover crop plots with a no-till planter. The planter was set on 30-inch rows at a 3/4-inch depth. We harvested grain sorghum by hand on September 27, 1989 to determine yield. A similar planting and harvesting procedure was repeated during the following year.

At the Griffin site, we planted the legumes on October 27, 1988, similar to the Plains site. The soil was an Appling sandy loam (clayey, kaolintic, thermic, Typic Hapludults). There were two harvest dates for the cover crops corresponding about to a corn planting date (April 14, 1989) and a sorghum planting date (May 10, 1989) but no crops were actually planted.

Results and discussion

Button clover PI-289311 produced more dry weight per acre than any other legume at the Plains test site in 1989. Commercial hairy vetch and PI-383803 hairy vetch produced the highest N concentration of any cover crop in both years. Button clover PI-289311 and hairy vetch PI-383803 were the highest producers of N/acre in 1989. The only cover crop in 1989 to show a significant difference in sorghum yield compared with wheat was the PI-383803 hairy vetch (Table 1). The two crimson clover cultivars produced more dry weight per acre than any other cover crop at the Griffin test site on April 14, 1989. Hairy vetch PI-383803 produced the highest N concentration of any entry tested. Hairy vetch PI-383803 and button clover PI-199258 were the highest producers of N per acre (Table 2).

Sorghum-leaf N concentration at blooming was not significantly different among the legume cover crop treatments, but was greater for a legume cover crop versus the nonleguminous wheat cover crop. The same was true for grain concentration and grain N content. With respect to the legumes, no legume appeared to result in superior sorghum N uptake compared with another legume, but all resulted in greater N uptake when compared with wheat.

Conclusion

At both test sites, PI-383803 hairy vetch produced some of the highest N concentrations of any cover crop tested. Results from Plains and Griffin test sites indicate that PI-289311 and

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Table 1. Mean dry weight, N concentration, N content of cover crops, and subsequent sorghum yield at Southwest Georgia Experiment Station, Plains, Georgia.

	Cover Crop			Sorghum Crop			
Cover Crop and Year	Dry Weight (pounds/acre)	N Concentration (%)	N Content (pounds/acre)	Sorghum Leaf N Concentration (%)	Sorghum Yield (pound/acre)	Sorghum Grain N Concentration (%)	Sorghum Grain N Content (pounds/acre)
March 20, 1989							
PI-199258 Button Clover	2,379	3.05	72	2.62	3,048	1.65	49.2
PI-289311 Button Clover	3,591	2.84	104	2.64	2,843	1.59	44.8
Commercial Hairy Vetch	2,398	4.11	97	2.77	2,973	1.73	51.6
PI-383803 Hairy Vetch	2,580	4.07	105	2.78	3,375	1.77	58.3
'Lana' Vetch	2,630	3.75	99	2.80	3,202	1.63	52.5
'Tibbee' Crimson Clover	2,704	3.46	92	2.65	3,069	1.68	51.6
'Coker 9766' Wheat	3,839	2.68	102	2.12	1,484	1.50	22.1
LSD (p = 0.05)	712	0.59	18	0.33	1,867	0.21	16.5
March 15, 1990							
PI-199258 Button Clover	2,929	4.24	122	2.89	2,794		
PI-289311 Button Clover	3,050	3.71	115	2.68	2,873		
Commercial Hairy Vetch	1,946	5.18	101	2.71	3,012		
PI-383803 Hairy Vetch	2,618	5.05	132	2.72	2,733		
'Lana' Vetch	2,594	4.35	112	2.74	2,962		
'Tibbee' Crimson Clover	3,650	3.26	119	2.72	2,806		
'Coker 9766' Wheat	1,104	1.61	17	2.58	2,352		
LSD (p = 0.05)	1,023	0.63	45	NS	396		

Table 2. Mean dry weight, N concentration, and N content of cover crops at the Georgia Experiment Station, Griffin, Georgia.

	April 14, 1989			May 10, 1989		
Cover Crop	Dry Weight (pounds/acre)	N Concentration (%)	N Content (pounds/acre)	Dry Weight (pounds/acre)	N Concentration (%)	N Content (pounds/acre)
PI-199258 Button Clover	3,450	2.84	98	5,559	2.32	129
PI-289311 Button Clover	3,395	3.03	102	4,479	2.53	114
Commercial Hairy Vetch	2,829	3.57	101	3,478	3.55	125
PI-383803 Hairy Vetch	3,122	4.28	132	3,078	3.83	116
'Lana' Vetch	2,749	3.17	89	3,061	2.37	72
'Tibbee' Crimson Clover	3,723	2.45	91	4,991	1.71	85
'Chief' Crimson Clover	3,678	2.67	97	4,870	1.76	86
Rye	3,141	1.20	37	3,660	0.82	31
LSD (p = 0.05)	680	0.76	25	1,131	0.62	45

PI-199258 button clovers and PI-383803 hairy vetch produced large amounts of N per acre. The test at Plains in 1989 indicated that the only cover crop to express a significant difference in sorghum yield compared with wheat was the PI-383803 hairy vetch.

These results seem to indicate that PI-383803 hairy vetch and PI-289311 and PI-199258 button clovers have potential for use in conservation tillage systems. We repeated the test conducted at Plains in 1990-1991. We will compare results from this test to the previous tests.

REFERENCES

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Cooperative efforts of the Soil Conservation Service in developing and evaluating cover crops

David G. Lorenz and Jerry Lemunyon

Scientists with the Soil Conservation Service, U.S. Department of Agriculture (SCS, USDA) are developing cooperative agreements with agricultural and natural resource agencies for evaluation and research on the application of cover crops throughout the United States. There are 26 SCS Plant Material Centers located in the United States, including Hawaii and Alaska. All major land resource areas are represented. Plant Material Centers consist of land area, storage buildings, equipment, and staff strategically located in many of the climatic and geographic regions of the United States. The mission of these plant material centers is to assemble, test, and release plants for conservation uses; develop techniques for their successful use; provide avenues for their commercial increase; and promote the use of plant materials needed to meet the objectives and priorities of the nation's conservation program.

SCS is committed to the President Bush's Clean Water Initiative, assisting landownwers to adapt soil and water conservation practices that will protect both surface and groundwater. A new endeavor is underway for the use of crop rotations and cover crops in management systems as a means for cycling crop nutrients. This is an addition to the traditional soil erosion control programs of the agency.

Plants used to protect the soil and conserve water can also have positive impacts on water quality. Cover crops can be incorporated into the cropping sequence to protect the soil surface against erosion, as well as cycle nutrients from the previous harvested crops.

SCS is presently cooperating with the Agricultural Research Service (ARS), the National Park Service, and the Rodale Institute, along with a number of state universities, in studies on establishing vegetation for purposes ranging from erosion control on critical erosion sites to vegetated filter strips. The cooperative relation is becoming more essential with consideration of limited resources currently available to conduct field studies. The SCS Plant Material Centers are ideally suited to do field data collections because of their full-time staff, dedicated land area, and long-term project commitments. Field staff are experienced in field and plot data collection, equipment operation, and tending of vegetation plots. Research institutions, such as universities, are equipped to do precision laboratory analysis, data manipulation, and statistical analysis. They also can draw on a cadre of expertise from the research network that can offer advice on research techniques and draw conclusions from data collected. These cooperative agreements have been designed to use the strengths of all agencies.

Investigators at the Plant Material Center, Cape May, New Jersey, have made a collection of 1,200 plants, both species and cultivars, selected for their potential cover crop use in the northeastern and mid-Atlantic states. Researchers at the ARS at Beltsville, Maryland, in cooperation with the University of Maryland Agronomy Department, have concurrently been evaluating cover crops for winterhardiness and the ability to recycle nitrogen (N) to corn in rotation. The ARS researchers became interested in the Plant Material Center collection at Cape May and developed a joint project to evaluate the ability of several species and cultivars of winter cover crops to take up nutrients, particularly N, previously applied to the corn crop, and to evaluate the effects of various cover crop management practices, such as grass-legume mixtures versus monocultures, on the recycling of residual corn fertilizer by the cover crop system (see pages 57-68).

Investigators at the University of Rhode Island are cooperating with two Plant Material Centers in evaluating plants for vegetated filter strips. This effort evolved from initial research at the university that showed that plant species differ in the ability to entrap and transform N into filter strips. Besides the phenotypic differences in plant growth, such as height and stem density that functions to retard flow velocities during storm runoff events, there also exists a specific ability of the plant to absorb N and transform the nitrates (NO_3) either by uptake, immobilization, or denitrification, such that leaching losses beneath these species varied by more than 20-fold. The research has been expanded to two Plant Material Centers in the northeastern United States, Cape May, New Jersey, and Big Flats, New York, where additional species and cultivars are being tested. The species are mostly cool-season, C3 grasses, including *Poa, Festuca, Bromus, Lolium,* and *Phalaris.* For the cooperative agreement, the Plant Material Center investigators have established research plots instrumented with tension-plate lysimeters to collect percolate below the root zone of the grasses. Researchers collected percolate water samples after every rainfall event that was sufficient to produce leaching. They sent these samples to the university for NO_3 analysis and kept a data log for statistical analysis. Investigators harvested plant tissue samples as forage samples three times per year. Total N analysis will indicate plant N uptake. Researchers can calculate a mass balance with the leaching, uptake, and soil N. Plant Material Center officials provided field labor for establishing crops, installing instruments, and collecting samples. Investigators at the university performed the chemical analysis, data formatting, and statistical analysis.

A similar cooperative agreement is now underway with the Plant Material Center at Knox City, Texas, and the ARS Water Quality/Watershed Research Laboratory at Durant, Oklahoma. The laboratory officials share the cost of instruments, including the lysimeter plates, and assist in the installation of plots at the Plant Material Center. Researchers are evaluating a much different selection of grass species at the northern Texas site. The northeastern sites were testing cool-season species, whereas Texas researchers are studying warm-

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season, C4 grasses, such as *Panicum, Sorghastrum, Andropogon, Cynodon,* and *Tripsacum,* as well as two cool-season grasses, *Agropyron* and *Festuca.* Besides the percolate water and tissue testing, the ARS team is interested in using the minirhizotron to follow root turnover (thus N release from the root biomass) and a neutron gauge to measure moisture status in the root zone. The water flux recorded by capturing soil-water percolate will aid in the development and validation of the root zone model, an ARS model for tracking water and agrichemical fluxes through the root zone.

Currently, seven Plant Material Centers are actively evaluating the role of cover crops to reduce soil erosion. They are: Coffeeville, Mississippi; Cape May, New Jersey; Americus, Georgia; Big Flats, New York; Rose Lake, Michigan; Lockeford, California; and Elsberry, Missouri. At the Lockeford, California, Plant Material Center, researchers have developed cover crop systems for erosion control and soil structure improvement in orchards and vineyards. These projects need to be expanded to evaluate the existing selected species and systems for their water quality-enhancing potentials. This would include sediment entrapment, nutrient absorption, and biomass conversion. The ultimate cover crop would then be one that provides maximum erosion control and runoff protection as well as nutrient reclamation. Some research needs for the SCS plant materials program on cover crops include the following:

1. Periodic field harvest to determine timing and uptake rates of nutrient by cover crops.
2. Mineralization rates of cover crop residue and amounts of absorbed nutrients for release to subsequent crops.
3. Establishment techniques in late-harvested crops (corn, potatoes, and sugar beets).
4. Methods to establish interseeded and relay cover crops.
5. Benefits of weed suppression and allelopathy.
6. Suppression and control management techniques for cover crops.

From these cooperative research endeavors will come valuable information that the SCS team can use in its farm conservation planning. First, an expanded list of cover crop species and cultivars will be available for use in the cropping rotation. With this expanded list will be establishment techniques that consider the crop rotation, harvest dates, and tillage and seeding methods. There will be a better understanding of the nutrient-supplying potential of the cover crop to the subsequent crop and the leaching or runoff potential based on seasonal water budgets.

New cooperative efforts are continually pursued. If there are research proposals that can be jointly studied and funded, the SCS would be interested in reviewing and offering in-kind service of monitoring, instrument installation, calibration, maintenance, and field data gathering.