Substituting Legumes for Fallow

in US Great Plains Wheat Production

the first five years of
research and demonstration
1988 - 1992

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Executive Summary 1988-1992

Substituting Legumes for Fallow in US Great Plains Wheat Production

A collaboration among three state universities, a non-profit farmer organization, and more than a dozen individual farmers, the goal of this project is to discover legumes and crop/legume systems which will effectively substitute for traditional fallow systems in the central and northern Great Plains. Of the 42 legume species evaluated to date, yellow-blossomed sweetclover, hairy vetch, foxtail dalea, and black lentil have shown the greatest immediate promise. While seedling establishment has been most reliable from those species with larger seed, under current markets, the cost of using these species is generally prohibitive. Alternative approaches to legume establishment, being conducted mostly in on-farm trials, have shown adapted broadleaf crops (such as the oilseeds sunflower, crambe, safflower, and rapeseed) as providing the best opportunity to establish the legume as a companion crop. Some of the reasons for legume success in these systems include compatibility with the growth habit of the oilseeds, tolerance of common herbicides used with the oilseeds, and the motivation of the farmers themselves to experiment with cover crop establishment within these crops which produce little residue for erosion protection. Another barrier to adoption of substituting legumes for fallow is the possibility of excessive soil moisture depletion. This project is demonstrating, through rotational small and large plot trials, that there are legumes and management approaches effective in transforming evaporative water loss (from black fallow) into transpirational water loss (through legume fallow). Systems which reduce evaporative demand from the vegetative cover, increase snow retention and capture, and various cultural practices including early legume termination, haying, or grazing, have all been successful in contributing towards water conservation during the legume fallow. Subsequent wheat yields have been equal to traditional fallow management.

Wheat Production in the Great Plains

Once a vast grassland, the US Great Plains now produces the majority of this country's wheat. Transforming this region from a perennial prairie to that of annually cropped fields has taken place through more than a century of adapting cultural practices to the most urgent production problems. History describes the first two eras of wheat production practices on the Plains; first mining the prairie sod, and second, practicing black fallow. Conservation mandates, which must be implemented by the mid-1990's, will probably foster broader adoption of residue management, and probably help better establish the third era of wheat production practices; brown fallow.

Mining the Prairie Sod

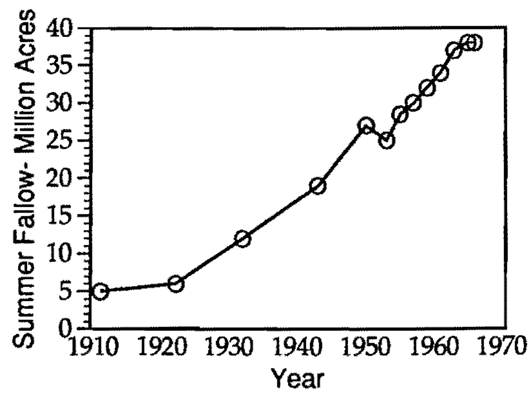
Wheat was among the first of the crops sown in the freshly plowed prairie sod. Being relatively drought tolerant and early maturing compared to other alternatives, wheat became the predominate crop of the Plains. Russian varieties of winter wheat were successful in Kansas and Nebraska, while spring-planted varieties were grown in the northern Plains. Soil fertility was of little concern during this era since nutrients stored in the grasses, forbs, and thatch of the sod were abundant. Experiment Station reports from south central North Dakota reported little need for fertilizer as late as 1924 (1). Soil organic matter content in the eastern Plains was probably 12-14%, with about half as much in the drier west. Reoccurring wheat diseases, grasshopper populations, and drought were no doubt the major factors limiting yield.

Black Fallow

Most historical accounts of fallow as a production practice trace their origin to Angus McKay from the area now known as Indian Head, Saskatchewan. Unable to plant his wheat crop in 1885 due to a shortage of labor, he plowed then repeatedly cultivated one field to keep it weed-free. Wheat seeding in this field the next year reportedly yielded 35 bu/a as compared to an adjacent field which was not fallowed at 2 bu/a. Whether this account is factual or not, the discovery of fallow in the late 1800's did set the stage for what later became the black fallow era (2, 3, 4).

Fallow, as used here, is the deliberate practice of not planting a crop during the usual growing season in anticipation of benefiting the following crop. Black fallow refers to the use of repeated tillage operations to maintain a weed-free fallow period. Black fallow increased dramatically in the dryland farming regions west of the Mississippi River, particularly between 1920 and 1970 (Fig. 1). Reported benefits of the practice include moisture conservation, additional time needed for nutrient mineralization, weed control, and wheat yield stability.

Figure 1. Acres of fallow in the US over time (5).



When comparing wheat yield from fallowed and continuously cropped sites, never has the fallow yield been 100% or more. A 100% yield increase would be necessary from fallow (fallow/wheat) to produce as much wheat as from annual cropping (wheat/wheat). However, in order to be economically profitable to the farmer, the fallow increase only has to be about 50% for an alternating wheat/fallow rotation (5). Further, if the increase from fallow is from 34 to 50%, it would be considered economically advantageous to fallow about one year in three. If the fallow increase is under 33%, it still is considered profitable to fallow one year in four or more years of cropping in most of the wheat growing regions of the northern and central Great Plains.

Actual yield comparisons made during the black fallow era demonstrate the geographic differences in the success of fallow in meeting the objectives of moisture conservation and yield enhancement. Generally, the efficiency of water storage during fallow decreases from north to south. Cooler temperatures in the north, however, also increase the effectiveness of precipitation that is received because of less evaporative demand. Thus, though more water is stored in the Dakotas during fallow, less is actually needed than in the winter wheat region of Nebraska and Kansas.

In the central Great Plains, the success of fallow in providing needed moisture can be tempered by high temperatures during critical stages of wheat development. From Kansas south, fallowing does not assure increased wheat yield. In this region air temperatures play a larger role in determining annual yield. The interaction among the type of wheat grown (spring or winter), the timing of precipitation, air temperatures, and hence, evaporative demand, all combine to influence the effectiveness of fallow to store water and enhance wheat yield.

Location	Yield Period	Wheat Yields After Wheat	Wheat Yields After Fallow	% Increase
		bu/a		
Mandan, ND	1915-1948	14.9	20.9	40
Highmore, SD	1909-1948	13.6	21.2	55
North Platte, NE	1912-1950	13.1	28.1	114
Colby, KS	1915-1950	9.6	18.0	89

taken from Haas et al. (5).

Black fallow has accounted for more than 12 million acres of cultivated land annually in the two leading wheat producing states of Kansas and North Dakota. While maximizing yield per acre, helping control pests, mineralizing nutrients, increasing soil moisture content, and helping distribute the workload, it has not been without problems. The potential for soil erosion from both wind and water increased from the use of black fallow. Over time, the practice of black fallow has also caused an overall decrease in soil organic matter and fertility and lead to other local problems, such as saline seeps in some areas of the northern Plains. The economics of summer fallow have never included these costs of soil loss and degradation. Beyond the eventual loss of productivity from the land, other costs include the removal of soil from fence lines and road ditches. Streams and rivers must be dredged and both water and air quality has been degraded from the increases amounts of soil erosion from black fallow (5).

Brown Fallow

Recognition of the problem of erosion from black fallow began only shortly after its adoption. One of the first accounts of altering black fallow again came from that of farmers in Canada (5). Leonard and Arie Koole of Alberta reportedly observed wind erosion from their black fallowed fields in 1917. The west edges of these fields, perpendicular to the wind direction, did not blow until some distance within the field. Why not narrow the fields and grow alternating strips of wheat and fallow? The strip cropping they began experimenting with in 1918 rapidly spread southward into the US Great Plains and was even supported by government payments after the dry years of the early 1930's. The concept of using wheat stubble, or residue, as a valuable deterrent to soil erosion in conjunction with fallow was born.

Though most of the early studies comparing the type of tillage used to maintain the fallow period showed little difference in fallow effectiveness, research began being published in the late 1950's about the effectiveness of stubble mulching. Lead by researchers such as Al Black in the northern Plains and C. Fenster in the central Plains, tillage tools such as the noble blade and rod weeder, which left more stubble on the surface than disks and other inversion tillage tools, became widely used (6, 7, 8, 9). The benefits of this early form of 'brown' fallow included reducing susceptibility to erosion, reducing evaporation through surface cover and soil cooling, and generally higher efficiencies of water storage as compared to black fallow. Stubble mulching generally requires three to four operations in the northern Plains and four to six operations in the central Plains.

Substituting Legumes for Fallow

Approx. Years	Emerging Fallow Practices	% Water Storage Efficiency[1]
1911-1930	plows, harrows	21
1931-1946	small one-way disk	24
1946-1958	rod weeder	27
1959-1966	sweeps, rod weeder	34
1967-1970	fall weed control + sweep	41
1975-1987	complete chemical control	49

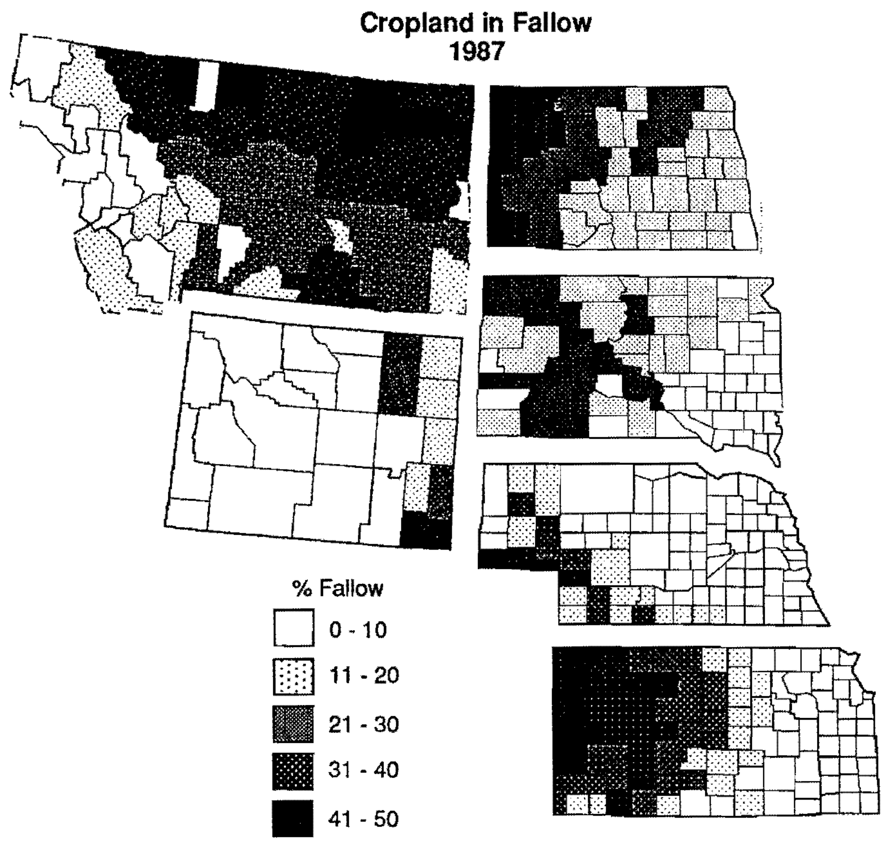
[1] data from North Platte, NE (5) except 1975-87 from Akron, CO (17).

Since chemical herbicides have been widely available, they too have been used in conjunction with tillage to manage brown fallow (7, 17). Early herbicides, such as 2,4-D, did not adequately control enough different weed species to be widely useful. Some soil-applied residual herbicides have been used in fallow management systems, such as the use of atrazine in Nebraska's ecofallow system (10). It was not until the registration of glyphosate (Roundup™) in the mid-1970's, however, that a post-emergence, broad spectrum herbicide was available. Though initially expensive when compared to the tillage operations it was replacing, chemical fallow and even whole crop production systems without tillage where now possible (11). The cost of these production systems were justified by their impact on reducing soil erosion.

Chemical fallow became more widely adopted towards the later part of the 1980's when availability of new herbicides and patents on old herbicides were nearing expiration. These forces combined to reduce the price of fallowing chemically to near that of tillage when figuring machinery and labor savings. This era of brown fallow is now also firmly established through legislation as well. By 1995, all recipients of farm program benefits who farm land which is considered 'highly erodible' must follow a conservation plan filed with the approval of the local Soil Conservation Service office. The chief criteria used in documenting success of these plans, and hence compliance with the law, is the presence of crop residue on the soil surface. The intolerance of the general public with soil erosion, long predicted by farmers and scientists alike, has finally resulted in a mandate to alter production practices.

Though not all land fallowed today is considered 'highly erodible', its management will change. Brown fallow, which here includes both chemical fallow or stubble mulch fallow which leaves more than 30% of the soil surface covered with crop residue, is now practiced on about one third of all fallow acres in the US (16). The majority of those fallow acres are in the central and northern Great Plains (Fig. 2).

Figure 2. Percentage of cropland in fallow during the 1987 crop year, by county in MT, WY, ND, SD, NE, and KS (32).



What Next?

Though just beginning the era of wide-spread adoption of brown fallow, if history is a guide, recognition of future new problems and possible solutions to those problems should already exist. Ample evidence from both farmers and science suggest several possible scenarios. Just as tillage practices needed refining to reduce impact on environmental degradation, so too must we fully expect our current use of chemical herbicides to need changing as we discover more about their behavior in the environment. Brown fallow may slow the decomposition of crop residue, but will it build soil organic matter and structure? And what about fertility; have we reached a point where increasing levels of fertilizers will be needed to replace the organic matter already mineralized?

While using chemical herbicides to fallow has aided in reducing soil erosion, several limitations have already been documented. First, continued use of the same herbicide have resulted in some weeds becoming resistant (12). Though the genetics for resistance to a particular herbicide may occur only rarely, the repeated use of the same product rapidly eliminates all susceptible types, allowing the resistant genotype to dominate. Herbicides with different modes of action are needed in rotation if weed control is expected to continue. The chemistry of herbicides are also changing. Though it may be desirable from a weed control standpoint to have a long-lived compound, it appears that short-lived chemicals have less overall environmental impact (13). Chemicals resistant to breakdown have ended up in ground and surface waters, raising questions about their long-term consequences. And lastly, using chemicals on fallow may have unique problems associated with it. Since no plants are growing on fallow, and the herbicides allow undisturbed residue cover, net movement of soil water is nearly always downward during the fallow period. Though fallow is limited to generally dry regions, the majority of precipitation in these areas usually falls in short, intense storms. Past experience, such as the development of saline seeps, has demonstrated the leaching potential of fallow. When coupled with the improved water capture ability of chemical fallowing, such problems can only be assumed but to increase. Chemicals may leach more when used on fallow than might be expected under normal crop use.

Brown fallow's effect on soil organic matter and general soil condition is usually attributed to the reduction of soil erosion. In North Dakota, comparisons of long-term sites managed in black fallow, stubble mulch brown fallow and native prairies have pointed this out (14). Despite these improvements, there has been a decline of approximately 46% in the organic carbon and 42% in the organic nitrogen in soils of the U.S. Great Plains (18). In some areas of the Northern Great Plains, organic matter levels have decreased as much as 75% in agricultural soils as compared to similar sites in native prairie.

One possibility to alleviate the problem of reduced organic matter and soil tilth is to redefine the concept of fallow to meet new needs. Instead of having it be time of no plant growth, it could be used as a period of growing plants with the specific purpose of soil-building. Research on legumes in rotation in the Great Plains took place in the early 1900's. Summaries of these studies clearly report legumes were of no benefit to succeeding wheat crops, '*The results of 20 years of experiments with green-manure crops show nothing to recommend them...*' (19). Twenty years later similar conclusions were offered, but qualifiers began to creep into the summaries, '*The crop weather data... suggest that with present cultural techniques green manures should not be used...*' (20). Army and Hide went on to acknowledge that the research reported was set up with ideas from a humid-region tradition and implied that these approaches wouldn't work in drier regions.

Others speculated that the value of using green manures in the Great Plains may not be realized until after the land had been farmed for a longer time, and further experiments determined the most effective cultural methods (21). Brown (22) recognized the changes which had occurred in Great Plains' soils due to erosion and cropping over time. He also emphasized that the full benefits of cropping systems which included perennial grasses and legumes would not be detected from research plots located on favorable, relatively protected sites atypical from the norm of the Great Plains.

More recent studies have found legumes in rotation to be equal or superior to nitrogen fertilizer within environments of ample rainfall (23,24). In drier regions, the benefit of legumes instead of fallow in rotation is bound to be a trade-off between water used by the legumes and their favorable rotation and nitrogen-fixing effects. Legumes have been used in the semi-arid wheat growing regions of the Mediterranean and southern Australia for several decades (25,26). Legume cover crops can also serve as temporary pasture (27). Used in southern Australia for several decades, legumes are regularly used to establish self-perpetuating pastures and are used in an integrated crop/livestock production system. Having a leguminous fallow serve as temporary pasture could add immediate and measurable economic value to these alternative systems.

Alternative legumes which are less competitive and use less water are now also being investigated in the U.S. Black medic has been demonstrated in the Palouse wheat country of Washington in a production system called 'PALS' or perpetuating alternative legume system (28). It is also being investigated in the northern intermountain region of the U.S. (29). Montana studies with black medic have shown wheat following black medic used water more efficiently than wheat following fallow, producing 91% more grain (30). Washington studies indicated that the effect of medic in rotations was not only due to nitrogen-fixation, but also control of soil-borne cereal diseases (31). This system, or one similar to it with a legume of low water use, thus seems to hold the potential to substitute for fallow, supply a portion of the nitrogen need, both conserve and improve soil tilth, and possibly contribute to the overall rotational benefit in ways yet unknown. Perhaps green fallow is the next step in crop management in the wheat growing regions of the central and northern Great Plains.

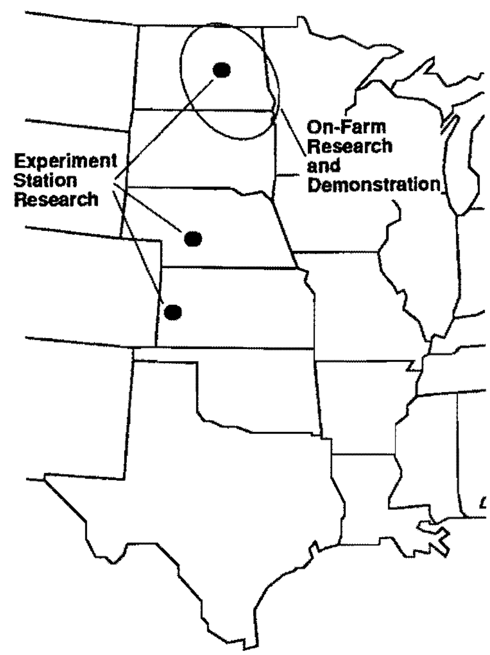
Developing a Project to Substitute Legumes for Fallow

With an overall objective of anticipating what was to lie beyond brown fallow, the idea of developing a combination of researchers, extension educators, and farmers to work together on the concept of green fallow emerged. The project began in search of farmers who were actually using green fallow. Just as the literature shows a greater historical interest in green fallow in the northern Plains, that too is where the largest group of farmers using these practices was found. A considerable number of farmers, concentrated most in central North Dakota, have practiced a crop rotation of cool season cereals/warm season cereals/sweetclover fallow for several decades. In recent years, the number of farms using these practices has increased in this region with the growth and development of markets for organically certified grains (15). It was the success of the green fallow production system that these farmers had refined which encouraged the development of a partnership among them, a non-profit research organization they were already involved with, and the land grant universities of the northern and central Great Plains.

In 1987, Walter Goldstein of the Michael Fields Agricultural Institute, a non-profit research institute from East Troy, Wisconsin, began working with a the green fallow farmers in North Dakota on legumes other than sweetclover. Black medic (*Medicago lupulina*) was among the first of the legumes they were trying in small, field-scale evaluations. Interested in the green fallow concept as an alternative to brown fallow, researchers at North Dakota State University's experiment station in east central North Dakota, near Carrington, inquired about the trials. Discovering mutual interests and complimentary skills and knowledge, the farmer/non-profit/university link began.

With the encouragement of the then emerging Low-Input Sustainable Agriculture (LISA) grants program as a possible source of financial support, the scope of the project grew geographically to better investigate the potential of green fallow in the wheat growing region of the Great Plains contained within the North Central states administering the LISA program. With the overall objective of identifying how and where legumes could be successfully substituted for fallow, the project initiated a geographic structure which represented a continuum of moisture stress (hence, legume adaptability) from the most humid (north and east) in North Dakota, to the most arid (south and west) in Kansas. In the most humid region, where sweetclover was already being successfully used, 10 farmers cooperated to test alternative legumes (primarily black medic) and alternative legume management systems in large, replicated plots. Small-plot and feasibility research on black medic and other alternative legumes and production systems were begun on experiment stations by North Dakota State University at Carrington, the University of Nebraska at North Platte, and by Kansas State University at Tribune (Fig. 3).

Figure 3. Experiment station and on-farm research sites for the project 'Substituting Legumes for Fallow', 1988-1992. Experiment station sites (and the fallow frequency which predominates) are near Carrington, ND (one fallow year in five), North Platte, NE (one fallow year in three), and Tribune, KS (one fallow year in two).



Using a common set of legumes and management systems, plus any additional site-specific treatments desired, the small-plot feasibility research has quickly progressed in identifying the adaptation zones of both legume species and management practices. Black medic, for example, did not prove reliably winter-hardy enough for the northern-most locations, but has performed relatively well in Nebraska trials. Hairy vetch, though a competitive water user if not properly managed, seems best adapted in southwest Kansas and Nebraska, but has also shown promise in North Dakota.

Applicability to farmers has also shown a similar evolution. In the Northern Plains, sweetclover is again gaining broad recognition for its value as a fallow substitute. The traditional manner of underseeding the biennial sweetclover in a small grain crop or buckwheat is now fairly well known, and commonly practiced by organic farmers and those with livestock who hay the companion crop. On-farm research is now expanding to include conventional cash grain farmers, who often find it difficult to interseed sweetclover in crops which are sprayed with broadleaf herbicides. These farmers, equally interested in seeking the benefits of nitrogen fixation, meeting compliance with surface cover requirements of the farm bill, and controlling winter wind erosion in low-residue crops, are now teaming with researchers in the project to develop reliable methods of interseeding row crops, such as sunflower, corn and soybeans. Likewise, farmer interest is growing in the winter wheat region. Though neither farmer use nor historic research on legume fallow is as common in this region, sufficient data and interest now exist to expand on-farm research and demonstration southward into Nebraska.

Results to Date

Legume Species

Evaluating the suitability of various legumes for green fallow has been on-going at the experiment stations sites since 1989. A total of approximately 42 legume species have been studied with 20 species being included in detailed experiments. Data from each legume being collected in the detailed experiments have generally included biomass yield, nitrogen content, water use, effect on soil nitrogen status, and effect on yield and quality of subsequent cash crops. Biomass, nitrogen content, and soil nitrogen measurements provide information on the legume's ability to add carbon and nitrogen to the cropping system.

Biomass and nitrogen mean yields from selected legumes grown as annual green manures at Carrington, ND, 1990-1991.

Legume	Legume Biomass	Termination Date[1]	Nitrogen Gain From Legume 40%	Nitrogen Gain From Legume 70%[2]
	lbs/a		lbs/a	
alfalfa	1796	Aug 3	19	33
sweetclover	2901	Aug 8	33	58
berseem clover	3284	Aug 5	34	59
hairy vetch	4702	Aug 5	71	124
black medic	1256	Oct 2	14	25
black lentil	3744	Jul 28	40	69
foxtail dalea	3652	Aug 27	42	74
partridge pea	3059	Sep 7	33	58
soybean	2514	Aug 14	26	46
dry bean	2895	Jul 29	27	48
field pea	3563	Jul 13	45	79
fababean	2582	Jul 13	36	64
lupin	3416	Jul 26	43	76
chickpea	3226	Jul 25	37	64

1 average date the legume was killed by tillage. All were spring planted.

2 nitrogen gain from above ground dry biomass assuming either 40% or 70% of the total nitrogen biologically fixed.

Legume biomass production at North Platte, NE.

Legume	Legume Biomass[1] 1989	Legume Biomass[1] 1990
	lbs/a	
black medic	616	2839
soybean	1143	1661
sweetclover	598	3223
hairy vetch	821	3527

1 spring planted legumes were terminated 10 weeks after planting in 1989 (Aug 10) and 23 weeks after planting in 1990 (Nov 2).

Legume biomass production at Tribune, KS.		
	Legume Biomass	
Legume	1990[1]	1991[2]
	lbs/a	
hairy vetch	2023	2650
sweetclover	2009	2360
partridge pea	1503	-
snail medic	-	1770
barrel medic	-	490

[1] legumes planted Apr 3, terminated Jul 13.

[2] legumes planted Mar 29, terminated Jun 25.

Water use by the various legume species has been a critical characteristic to measure since it the major barrier to greater adoption of green fallow management. Though most of the precipitation that is received during the fallow period is lost either through evaporation, runoff, or leaching, the small amount that is stored often makes a critical difference to subsequent wheat yields, especially in dry years. It is this yield stabilizing characteristic of fallow which has made it predominate in wheat rotations in the Plains.

Water-use efficiency of selected legumes grown as fallow substitutes at Carrington, ND (1991-1992) and Tribune, KS (1990).

	Water-Use Efficiency	
Legume	Carrington, ND	Tribune, KS
	lbs/a/inch	
sweetclover	239	203
hairy vetch	396	239
foxtail dalea	296	-
black lentil	365	-
field pea	410	-

Substituting legumes for fallow effectively transforms evaporative water loss (from black fallow) into transpirational water loss (through legume fallow). Transpirational water consumption through the legume fallow generally results in greater soil water deficits than black fallow, but this difference is dependent upon the species of legume grown. A means of measuring the cost and benefits of green fallow is to compare these soil water deficits on the basis of how much biomass is produced during the fallow period. The 'legume fallow efficiency' is a measure of the legume biomass produced per inch of water deficit greater than that of black fallow.

Comparative mean soil water use and legume fallow efficiency from selected legumes grown at Carrington, ND as annual green manures, 1990-1991.

Legume	Soil Water Deficit Greater Than Fallow	Legume Fallow Efficiency[1]
	in/4 ft soil profile	lbs/in
alfalfa	3.1	578
sweetclover	2.5	1170
berseem clover	2.4	1354
hairy vetch	2.9	1619
black medic	3.7	338
black lentil	1.4	2655
foxtail dalea	2.8	1284
partridge pea	3.7	832
soybean	1.7	1501
dry bean	1.4	2083
field pea	1.7	2127
fababean	1.3	2033
lupin	1.7	1963
chickpea	1.9	1721

[1] legume fallow efficiency calculated as biomass produced per inch of soil water deficit greater than black fallow.

Comparative mean soil water use and legume fallow efficiency from selected legumes grown at Tribune, KS as annual green manures, 1990.

Legume	Soil Water Deficit Greater Than Fallow	Legume Fallow Efficiency[1]
	in/5 ft soil profile	lbs/in
hairy vetch	2.9	693
sweetclover	2.6	782
partridge pea	1.2	1242 [2]

[1] legume fallow efficiency calculated as biomass produced per inch of soil water deficit greater than black fallow.
2 weed biomass nearly equaled legume biomass at 1030 lbs/a.

Of the 42 legume species evaluated to date, yellow-blossomed sweet clover, hairy vetch, foxtail dalea, and black lentil have shown the greatest immediate promise. As has been expected, the number of legume species that seem adapted for use as a green fallow increases the farther north they are evaluated. While seedling establishment has been most reliable from those species with larger seed, under current markets, the cost of using these species is generally prohibitive.

Wheat Performance After Green Fallow

Measuring yields and quality of wheat following the legume green fallow integrates all the characteristics necessary to compare the performance of the various legumes as well as any rotation effects. These yield measurements extend the time required to complete the trials but are necessary to determine the economic feasibility of using green fallow practices.

Spring wheat grain yields the first (1991-1992) and second year (1992) following various green manured fallow treatments at Carrington, ND.

Fallow Treatment	Successive Wheat Crops After Fallow First Year	Second Year
	bu/a	
dry bean	41.2	28.3
soybean	40.2	28.3
fababean	37.3	29.9
chickpea	41.3	32.1
field pea	38.6	30.3
lupin	35.7	33.1
foxtail dalea	35.2	26.2
black medic	34.3	19.6
partridge pea	34.7	24.8
hairy vetch	40.4	26.8
berseem clover	36.2	28.0
sweetclover	39.6	27.9
black lentil	39.6	28.6
alfalfa	37.6	26.6
spring wheat (continuous)	22.6	18.4
spring wheat (fertilized)	36.3	20.7
black fallow	39.2	31.2
LSD 0.05	7.3	5.6

Winter wheat grain yields the first year after green manured fallow treatments at North Platte, NE in 1991 and 1992.

Fallow Treatment	Wheat Yield After Fallow 1991	1992
	bu/a	
black medic	50	72
soybean	46	72
sweetclover	50	79
hairy vetch	49	78
fallow + N fertilizer	52	81
LSD 0.05	NS	5

While agronomic performance is critical, green fallow will not be widely adopted unless it also competes economically with brown or black fallow management. Small plot trials conducted in North Dakota have been used to evaluate the economic competitiveness of substituting legumes for black fallow. Comparisons among treatments were based on total costs and returns after two complete years of actual data collection. Land was assumed to be cash rented and nitrogen fertilizer was applied to continuous wheat as anhydrous ammonia in amounts based upon fertilizer tests. Potential impact of soil loss because of tillage or crop were not included in this economic analysis. Continuously cropped wheat had the greatest return over cash costs, followed by wheat after black lentil fallow and black fallow. During these two years of actual data collection, continuously cropped wheat had the greatest variable costs per acre, however, given favorable rainfall during the trial period, these greater variable costs were more than offset by the greater gross revenue.

Economic comparison of spring wheat production after various rotations from data collected at Carrington, ND in 1990-1992.

Previous Management	Gross Returns	Variable[1] Costs	Total[2] Cash Costs	Return Over Cash Costs
			$/a	
continuous wheat	169.07	93.45	153.45	15.62
black fallow	113.68	43.51	103.51	10.17
green manured				
black lentil	125.86	51.34	111.34	14.52
sweetclover	118.03	48.82	108.82	9.21
hairy vetch	122.96	62.25	122.25	0.71
foxtail dalea	91.06	51.19	111.19	(20.13)
field pea	113.10	52.85	112.85	0.25

[1] variable cost prices used included actual seed costs, nitrogen (.116 $/lb), diesel fuel (.90 $/gal), land rent (30 $/acre), interest rate (9.5%), and wheat market price at $2.90 bu.

[2] fixed costs were equal among alternatives at $60/acre.

In the northern spring wheat areas, already a considerable number of farmers have been practicing , or are considering the adopting some from of green fallow. Work is just beginning in the central Plains area in on-farm evaluation of substituting legumes for fallow. Beyond selection of the appropriate legume, discovery of new management systems that include green fallow will be necessary. As has been found in the past, broad adoption of new practices is often dependent upon farmer innovation to make the principles work in local situations.

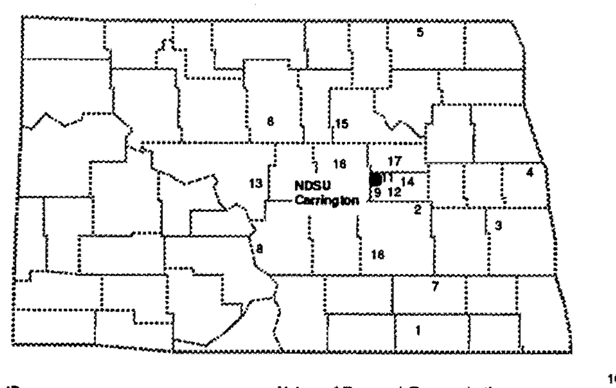
Alternative Methods of Making Green Fallow Work

Legume Establishment Legumes can be planted either as companion crops, or alone, prior to the fallow period. For example, traditional practices in the northern Plains require establishment of sweetclover in growing cereal grains. After small grain harvest, the sweetclover overwinters, greens early the next spring and is green manured at the onset of bloom early in the fallow period. Crops other than the cereal grains, however, may be better to establish the legume for fallow. Locally adapted broadleaf crops (such as the oilseeds sunflower, crambe, safflower, and rapeseed) are providing the best opportunity to establish the legume as a companion crop. Some of the reasons for legume success with these crops include compatibility with the growth habit of the oilseeds, legume tolerance to common herbicides used with the oilseeds, and the motivation of the farmers themselves to experiment with cover crop establishment within these crops which produce little residue for erosion protection.

Sunflower is the predominate oilseed in central North Dakota. Because of its deep root system and full-season growth habit, the land is often fallowed after sunflower production, especially during dry years. Farmers recognized the opportunity to establish sweetclover in sunflower at least ten years ago when the practice of aerially seeded sweetclover in sunflower at bloom was reported in the farm press. Since that time, numerous accounts of other establishment methods have been reported among farmers themselves. The presence of the sweetclover seems to have little impact on sunflower yield. Small-plot observations and on-farm demonstration of interseeding sweetclover during the last cultivation of sunflower over the past several years has shown it to be successful about half the time. Dry conditions or poor seed:soil contact seems to be the primary reason when the practice fails.

Recent on-farm trials have shown increasing the seeding rate or earlier legume seeding dates as improving establishment success. Studies conducted at North Platte, NE during the summer of 1992 included seeding the legume at the same time as the sunflower, using the insecticide box on the planter to distribute the legume seed in a band over the row. Not only did this practice prove successful in getting the legumes established, it also would be a practice which could allow later between-row cultivation, if necessary.

Figure 4. Location, cooperator, and subject of on-farm trials/demonstrations in North Dakota.



Map ID	Cooperator	Year(s)	Nature of Research/Demonstration
1	David Podoll	1988-91	Eval of b medic, foxtail dalea, hairy vetch as alternative legumes
2	Kent Ableidinger	1990-91	Eval of b medic, sweetclover and hairy vetch interseeding in sunflower
3	Charles Nelson	1989-90	Eval of b medic
4	Don Duffner	1988-90	Eval of b medic, sainfoin
5	Terry Jacobson	1988-91	Eval of b medic, sweetclover management and interseeding in sunflower
6	Dan Thomas	1988-91	Eval of b medic, sweetclover interseeding in sunflower
7	Bob Neevil	1988-91	Eval of b medic, sweetclover management
8	Eugene Haakenson	1989-90	Eval of b medic
9	Dennis Montgomery	1988-91	Eval of b medic, sweetclover interseeding in sunflower
10	Carmen Femholz	1989-91	Eval of various medics, hairy vetch, foxtail dalea, berseem clover
11	Mark Mullenberg	1991	Interseeding sweetclover in sunflower
12	Paul Straley	1991	Interseeding sweetclover in sunflower
13	Dave Presser	1991	Interseeding sweetclover in sunflower
14	Frank Davis	1991	Interseeding sweetclover in sunflower
15	Dale Pfeifer	1991	Interseeding sweetclover in sunflower
16	David Clough	1991	Interseeding sweetclover in sunflower
17	Gary & David Anderson	1991	Interseeding sweetclover in sunflower
18	Fred Kirschenmann	1988	Eval of b medic

Fall-sown winter wheat competes with legumes as companion crops at different times than does spring wheat. In trials at both North Platte, NE and Tribune, KS, over-wintering, forage-type legumes have generally been found unable to compete with winter wheat and establishment of legumes for growth after wheat harvest has been difficult. One exception has been hairy vetch, which has not only survived when seeded with winter wheat, its growth has been vigorous enough to consistently reduce wheat yield. The presence of other legumes has occasionally increased wheat yield, such as was found with red clover sown with wheat in Nebraska harvested in 1992.

Winter wheat grain yield when seeded with legume companion crops at North Platte, NE (1992) and Tribune, KS (1991).

Legume Companion Crop	Wheat Grain Yield North Platte	Tribune
	bu/a	
none	61	35
hairy vetch	53	27
alfalfa	62	-
red clover	73	-
sweetclover	60	-

Establishment of legumes is difficult for many farmers in the Great Plains because of the weed control practices currently used in rotations where grassy crops predominate. Soil-applied, long-residual broadleaf herbicides used in the central Plains are injurious to most legumes. Also, post-emergence herbicides used in cereal grains prevent using legumes as companion crops. Establishing the legumes by themselves is often the only option and most of the legumes used as green manures, particularly the forage type legumes, are poor competitors with weeds during early vegetative development. Small-plot research conducted by this project at North Platte, NE has shown some promise for use of a new herbicide as an establishment aid for the legumes. Pursuit™ herbicide applied as a post-emergence treatment to the seedling legumes has demonstrated fairly broad-spectrum residual weed control and seems safe to most legume species. Should this practice continue to have promise, product registration and subsequent labeling would be necessary before it could be practiced.

Managing Legume Water Use Once green fallow is successfully established, managing soil water consumption is critical to achieve adequate performance from the wheat crop which will follow. Deciding exactly when to cease legume growth during the fallow period is a trade-off between additional nitrogen and dry matter production versus the water required to do so. The has best been illustrated by the growth potential of hairy vetch, especially in western Kansas trials.

Water-use and effects of hairy vetch termination date in two separate legume fallow trials at Tribune, KS.

Legume Fallow for Grain Sorghum

Hairy Vetch[1] Termination Date	Soil Water 7/1/92	Vetch Biomass
	inches water/8ft	lbs/a
9/4/91	25.9	-
10/3/91	24.6	1260
3/16/92	20.0	4780
4/14/92	20.6	5920
5/12/92	18.9	9760

[1] hairy vetch seeded on 8/14/91. Precipitation from 9/4/91 to 7/1/92 was 13.15 inches.

Legume Fallow for Winter Wheat

Hairy Vetch[2] Termination Date	Wheat Grain Yield
	bu/a
5/13/91	24
6/5/91	19
6/29/91	14
7/16/91	11
7/28/91	4

[2] Hairy vetch seeded on 3/29/91. Wheat planted 9/16/91.

Usually, it is best to grow the legume as early as possible during the fallow period, which allows the greatest time for soil water recharge before wheat planting. Legume species differ in the time required to establish themselves, which can have lasting effects on the time left for soil water recharge. Lentils, peas, lupines, fababeans and other grain legumes generally produce dry matter, fix nitrogen, and use water earlier than the clovers, alfalfa, hairy vetch, or other forage-type legumes. It is probably for this reason that grain legumes have generally resulted in higher subsequent wheat yields, as compared to forage-type legumes, when substituted for fallow. Management of the legumes also influences wheat yield. Grain legumes harvested for beans or forage legumes harvested for hay, both result in lower wheat yields. Somewhat contradictory to the results from this project gathered in the short-term, are other data which indicate that dry matter from annuals (such as the grain legumes) turn over more quickly in the soil and do not have as a long-lasting effect as the forage-type legumes (33). Such findings would suggest that non-annual, forage-type legumes would be a better choice than annual legumes for soil building over the long-term.

Spring wheat yield after seven grain legumes and nine forage legumes, both harvested and green manured, at Carrington, ND.

Legume Fallow	Successive Wheat Crops After Fallow		
Treatment	First Year[1]	Second Year[2]	First Year[3]
		bu/a	
grain legumes, combine harvested	34.1	25.5	36.1
grain legumes, green manured	37.6	30.1	40.5
forage legumes, hayed	31.6	23.6	33.0
forage legumes, green manured	37.0	26.4	37.4

[1] legumes grown in 1990, wheat in 1991
[2] legumes grown in 1990, wheat in 1991, wheat in 1992
[3] legumes grown in 1991, wheat in 1992

The method used to terminate the legume is another important management consideration with green fallow. As an example, sweetclover in the northern spring wheat region is usually terminated just at the onset of bloom as a compromise between dry matter and nitrogen gain versus the water consumed. During this growth stage, which usually is in early June, sweetclover is near its peak in both rate of growth and water use. Trials have been ongoing, both in large and small plots, to establish the best means of rapidly ceasing growth while still achieving adequate soil surface cover to reduce evaporation and erosion potential. Chemically killing sweetclover at this stage of growth with 2,4-D, Banvel™, and/or, glyphosate, while killing the plant, has not stopped transpiration as rapidly as with tillage or haying.

Soil water content at two dates after various methods of terminating sweetclover growth at Carrington, ND in 1991.[1]

Date and Treatments	Total Soil Water Content 4 ft Depth	6 ft Depth
	inches	
June 10		
sweetclover fallow	8.1	13.0
black fallow	11.4	16.8
October 9		
sweetclover treatments		
not terminated	6.2	10.0
sprayed w/ herb.	8.6	13.6
plow	9.7	14.7
sweep	9.9	15.9
rotary mower	10.2	15.5
disk	10.6	15.9
hayed	11.2	16.5
black fallow	11.2	17.1
LSD 0.05	2.1	2.1

[1] sweetclover termination treatments imposed June 10. Rainfall between June 10 and October 9 was 12.3 inches.

Grazing is another management option for limiting legume fallow's water use. Regularly used in the wheat growing regions of southeast Australia, ruminants have the potential of economically utilizing the high quality forage of green fallow. Studies with beef cattle grazing sweetclover and black medic in North Dakota have demonstrated the potential and need for additional research in this area. With sweetclover, cattle must be turned out relatively early to keep ahead of the rapid growth. Rotationally grazing legume fallow at high stocking rates might offer the best performance from rapidly growing forage legumes. Conversely, the prostrate habit of black medic makes it a durable and long-lasting forage for season-long grazing.

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Legumes Observed to Date

Common Name	Genus and Species	Approx Seeding Rate (lbs/a)	Approx Seed Cost ($/a)
alfalfa	*Medicago sativa, M. falcata*	10	20.00
berseem clover	*Trifolium alexandrium*	10	
red clover	*Trifolium pratense*	10	
lupin, various	*Lupinus spp.*	100	10.80
sweetclover	*Melilotus officinalis, M. alba*	10	2.90
hairy vetch	*Vicia villosa*	25	
arrowleaf clover	*Trifolium vesiculosum*	8	
fababean	*Vicia faba*	110	14.30
black medic	*Medicago lupulina*	10	35.00
field pea	*Pisum sativum arvense*	90	8.50
chickpea, desi	*Cicer arietinum*	70	13.60
soybean	*Glycine max*	50	5.00
partridge pea	*Cassia fasciculata*	35	
subclover	*Trifolium subterraneum*	15	
foxtail dalea	*Dalea alopecuroides*	15	
black lentil	*Lens esculenta*	30	6.00
cicer milkvetch	*Astragalus cicer*		
sainfoin	*Onobrychis viciifolia*	25	
birdsfoot trefoil	*Lotus corniculatus*	10	
kura clover	*Trifolium ambiguum*		
IL bundleflower	*Desmanthus illinoensis*	40	
dry bean	*Phaseolus vulgaris*	70	10.50
fenugreek	*Trigonella foenum-graecum*	20	
kidney vetch	*Anthyllis vulneraria*	15	
barrel medic	*Medicago truncatula*	15	15.00
snail medic	*Medicago scutellata*	20	20.00
flatpea	*Lathyrus hirsutus*	20	

Seeding rates will vary with local use and climates. Seed costs are approximate for those species which are available in the Great Plains.

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