Evaluation of Alternative Cover Crops for Cotton on the Southern High Plains of Texas

Dick L. Auld*
Norman W. Hopper
Richard E Zartman
Fernando Gaitan-Gaitan
Trent G. Long
Department of Plant and Soil Science, Texas Tech University, Lubbock TX 79409-2122

ABSTRACT

Cotton (*Gossypium hirsutum* L.) is typically grown as a monoculture on the Southern High Plains of Texas, which results in reduced soil organic matter and increased soil erosion. Wheat historically has been used as a cover crop in this region, but other species may protect the soil while using less soil moisture. During 1991 and 1993, establishment, biomass production, moisture utilization and nutrient accumulation were measured on four cultivars of *Brassica* spp., one cultivar of Crambe (*Crambe abyssinica* Hochst. Ex. R. E. Fries), three cultivars of *Pisum* spp. and winter wheat (*Triticum aestivum* L). These evaluations were conducted on either a Pullman clay loam (fine, mixed, thermic Torreretic Paleustolls) or on an Amarillo fine sandy loam (fine-loamy, mixed, thermic Aridic Paleustalfs) near Lubbock, TX. Increased use of cover crops across this region could significantly reduce wind erosion. Late August or early September planting was essential for establishment and survival of *Brassica* species. With early seeding and optimum moisture conditions, interseeded cover crops produced biomass yields in excess of 1 Mg ha^{-1}. The larger-seeded legumes and winter cereals successfully established even when emergence was delayed until late fall, but delayed establishment (October to January) failed to provide total biomass production greater than 1 Mg ha^{-1}. Winter wheat planted in early February produced only 0.6 Mg ha^{-1} of total biomass even when fertilized with up to 33 kg ha^{-1} of nitrogen (N) while peas produced only 0.3 Mg ha^{-1} of biomass. These studies indicated that cover crops should be established in September to provide optimum soil protection. Neither spring- nor fall-planted cover crops significantly increased yield of the subsequent cotton crop. Soil moisture utilized by cover crops usually was not significantly higher than losses measured in the noncultivated control.

KEY WORDS: moisture utilization, nutrient accumulation, biomass production, interseeding

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Accepted 1 May 1996. This study was made possible by funding provided by the High Plains Underground Water District #1 and the College of Agricultural Sciences and Natural Resources at Texas Tech University. Special thanks are given to Mr. Harold Roberts, Mr. Kip Elms and Mr. Tom Hlavaty of Texas Tech University for their assistance in conducting these studies. *Corresponding author.

Over 250,000 ha of winter wheat are planted as cover crops following cotton to prevent wind erosion on the Southern High Plains of Texas. Use of a winter wheat cover crop under irrigated conditions has been shown to increase lint yields and profitability of a subsequent cotton crop (Bordovsky et al., 1994; Keeling et al., 1989; Segarra et al., 1991). Since wheat in this region often is seeded in late November after cotton harvest, lack of soil moisture and lower than optimum temperatures often limit cover crop growth which results in increased wind erosion. Even when fall temperatures are suitable for adequate wheat establishment and growth, precious soil moisture is depleted. Subsequent crop establishment often is limited because of inadequate soil moisture under both dryland and irrigated conditions. Wheat is also difficult and expensive to terminate. However, winter wheat cover crops have allowed cotton growers to use conservation tillage practices to reduce cotton production costs and soil erosion. Winter wheat cover crops have also been utilized in other cotton producing regions (Baker, 1987; Harmon et al., 1989; and Stevens et al., 1992).

Historically, cotton has responded well to legume cover crops capable of fixing the N needed for lint development (Bauer et al., 1993; Bloodworth and Johnson, 1995; Stevens et al., 1992). However, Keeling et al. (1996) showed that small-seeded legumes were difficult to establish on the Southern High Plains of Texas. Inadequate moisture at the soil surface combined with shallow seed placement made establishment difficult for these species. Larger-seeded legumes and cereals, which are seeded deeper, had more consistent establishment. Bilbro (1989) found that seeding in September was critical for successful establishment and growth of sixteen cultivars of spring and winter crops.

Recent work has shown that *Brassica* species may play a unique role as cover crops since they accumulate glucosinolates that produce allelopathic chemicals when degraded in soils (Brown et al., 1991). Incorporating *Brassica* plant amendments reduced some soil-borne pathogens (Adamsen et al., 1992). In 1992, the University of Idaho released a cultivar of winter rapeseed (*Brassica napus L.*), 'Humus', which produces high levels of glucosinolates for use as a green manure crop (Auld et al., 1992). Because *Brassica* species could potentially reduce soil-borne pathogens, disease pressure could be significantly reduced compared to the monoculture cotton produced in this region.

Much of the earlier research in this region used yield of a subsequent cotton crop as the primary index in measuring effectiveness of a cover crop (Bordovsky et al., 1994; Keeling et al., 1989; Segarra et al., 1991). Bilbro (1989) used percentage ground cover as an index of cover crop effectiveness in reducing soil erosion. Keeling et al. (1996) used plant height and total biomass accumulation of cover crops both in monoculture and when interseeded into cotton crops as indices of cover crop effectiveness.

Our studies were designed to measure biomass production, nutrient accumulation and soil moisture utilization of selected cover crops in greater detail than previous work. During the 1991-92 and 1992-93 growing seasons, five trials were conducted to evaluate alternative cover crops either interseeded or grown under monoculture conditions on the Southern High Plains of Texas. The objectives of these studies were to identify cover crops that would 1) establish under a wide range of conditions to ensure protection from wind erosion; 2) accumulate soil nutrients needed for subsequent crops; and 3) use less soil moisture than current wheat cover crops.

MATERIALS AND METHODS

Individual Species Evaluation

Three potential cover crops were planted at the Texas Tech University Plant Stress Field Laboratory at New Deal, TX on 27 Aug 1992. 'Pioneer 2157' hard red winter wheat, 'Cathy' winter canola (*Brassica napus* L.) (Auld et al., 1991) and 'Common' Austrian winter peas (*Pisum sativum* spp. *arvense* L. Poir) were planted at the rates of 69, 11 and 101 kg ha^{-1}, respectively. The soil was a Pullman clay loam (fine, mixed, thermic Torreritic Paleustolls) that had been fallowed during May, June and July after the previous crop of winter wheat pasture had been terminated with cultivation. Plots were seeded with a commercial grain drill equipped with double disc openers spaced 25 cm apart. Seeds were placed approximately 2.5 cm below the soil surface. Each species was seeded in adjacent 61 x 61 m blocks. Timely rains in late August and through the winter of 1991-92 provided adequate moisture so irrigation was not required (Table 1).

On 3-4 Apr 1992 and again on 16-17 Apr 1992, plots were harvested to determine total above-ground biomass production, and soil samples were taken to determine residual soil moisture content. Four 3.7 m^2 samples were harvested to estimate above-ground biomass in each replication of the study. Vegetation was cut approximately 5 cm above the soil surface and samples were dried at 51°C for 7 d to determine total dry weight. Samples were ground and analyzed for total N and P at the Texas Agricultural Experiment Station Soils Laboratory at Lubbock. Soil samples from each plot were taken with a 7.6 cm diameter soil auger to depths of 30, 60 and 90 cm. Approximately 1 kg of each soil sample were placed in plastic sacks, weighed and oven-dried at 51°C for 10 d to determine residual soil moisture. Each of the three studies utilized a randomized complete block design with four replications.

Immediately following harvest, the cover crops were terminated using a 1.5 m rototiller which incorporated crop residue to approximately a 5 cm depth. In late April, the soil was cultivated and shaped into beds 1 m apart. Cotton was seeded on 4 May, but cold temperatures and wet conditions in May and June 1992 prevented establishment and estimation of the impact of the cover crop treatments on a subsequent cotton crop.

Cotton Interseeding Study 1991-92

Four cultivars of *Brassica* species and 'Weather Master' hard red winter wheat were interseeded into standing 'HS 26' cotton at New Deal, TX on 4 Sep 1992 (Table 1). Seeds were dispersed with insecticide application boxes which dropped the seed on cultivator sweeps that incorporated the seeds between the 1 m cotton rows to a depth of 2 cm. Each species was seeded in plots that were 20 m long. Dry weight of cover crops and standing cotton stalks were determined from two 10 m^2 sections of each plot after the cotton crop had been harvested in early November.

Table 1. Cultivar, scientific name and seeding rate of ten potential cover crops evaluated during the 1991-92 and 1992-93 growing seasons.

Crop	Cultivar	Scientific Name	Seed Rate
			kg/ha
Spring White Mustard	Tilney	*Brassica hirta* Moench.	7.0
Spring Brown Mustard	Forge	*Brassica juncea* (L.) Czern & Coss.	3.5
Winter Rapeseed	Humus	*Brassica napus* L.	5.0
Winter Canola	Cathy	*Brassica napus L.*	6.0
Crambe	Meyers	*Crambe abyssinica* Hochst. Ex. R. E. Fries.	8.6
Winter Pea	Melrose	*Pisum sativum* spp. *arvense* (L.) Poir.	86.0
Winter Pea	Glacier	*Pisum sativum* spp. *arvense* (L.) Poir.	86.0
Spring Pea	Tracer	*Pisum sativum* L.	86.0
Winter Wheat	Weather Master	*Triticum aestivum* L.	46.0
Winter Wheat	TAM 109	*Triticum aestivum* L.	46.0

Cotton Interseeding Study 1992-93

On 18 Sep 1992, a second interseeding study was established at the Texas Tech University Plant Stress Field Laboratory at Lubbock. The soil at this site was an Amarillo fine sandy loam (fine-loamy, mixed, thermic Aridic Paleustalfs). This study included four cultivars of *Brassica* species, one cultivar of crambe, two cultivars of winter wheat, two cultivars of winter peas (Auld et al., 1978; Auld et al., 1983) and one cultivar of spring peas (Table 1). Seeding rates of all cultivars were adjusted to approximately 200 seeds m^{-2}. Plots consisted of four rows 13.7 m long of 'HS 200' cotton. Seeds were broadcast by hand and incorporated to a depth of approximately 5 cm between rows using a 56 cm-wide rototiller.

Nitrogen Applications to Spring-Planted Winter Wheat

On 11 Feb 1993, 'TAM 109' winter wheat was interseeded between standing cotton stalks immediately adjacent to the 1992 planted experiment. All procedures and seeding rates were the same as described earlier. Immediately after planting, ammonium sulfate was applied to the plots at rates of 0, 11, 22 and 33 kg N ha^{-1}. On 13 Apr, plots were harvested to determine total biomass yield and soil was sampled to a depth of 1 m to determine N content, P content and residual soil moisture. In early May 1993, HS 26 cotton was seeded over the plots using conventional production procedures. In late October, the plots were harvested to determine both lint and seed yield.

Spring-Planted Cover Crop Study

The same cultivars planted in the 1992-93 cotton interseeding study were seeded 11 Feb 1993 immediately adjacent to the previous experiment, with the exception that TAM 109 winter wheat was substituted for Weather Master winter wheat. These plots were harvested 15 Apr (63 d after planting) to determine total biomass yield, soil N and P levels, residual soil moisture and yield of a subsequent cotton crop using the procedure described earlier.

Statistical Analyses

Data taken on all indices in these five studies were subjected to analyses of variance. Where F Tests indicated significant differences, either a Duncan's New Multiple Range Test or a Fisher's Protected Least Significant Differences (LSD) were used for mean separation (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Individual Species Evaluation

The very wet conditions of the fall of 1991 provided sufficient moisture for the establishment and growth of all three cover crops evaluated in this study (Table 2). However, very cold conditions in late October 1991 killed > 80% of the Cathy winter canola plants and caused minimal damage to the Pioneer 2157-hard red winter wheat and the Common-Austrian winter peas (data not shown).

Some of the canola plants produced new growing points from underground meristems and established a partial stand of approximately five to nine plants m^{-2}. In early April, these plants had produced 2.1 Mg ha^{-1} of dry matter. Delaying termination of the canola until mid-April increased dry matter production to 3.7 Mg ha^{-1} (Table 3). The canola accumulated an average of 54.5 kg N ha^{-1} and 5.4 kg P ha^{-1}. Both total N and P content of the canola cover crop increased with delayed termination, but residual soil nutrient levels declined. Moisture depletion by the cover crop was uniform to a depth of 90 cm. Residual gravimetric soil moisture was 122 and 113 g kg^{-1} for the early- and mid-April harvest dates. No other studies have evaluated *Brassica* species as cover crops in this region.

Table 2. Precipitation at Lubbock, TX, from September to August 1991-92, September to August 1992-93 and the long-term 1911-1991 average (Texas Dept. of Agriculture and High Plains Underground Water Conservation District No. 1).

	Cropping Season		1911-1991
Month	1991-92	1992-93	Average
	mm		
Sep	172	25	65
Oct	15	0	53
Nov	28	37	16
Dec	57	28	16
Jan	29	36	13
Feb	44	20	17
Mar	43	5	21
Apr	23	41	30
May	166	64	66
Jun	78	6	68
Jul	43	109	55
Aug	32	30	53
Total	731	401	474

Common Austrian winter pea plants developed disease symptoms by the late-April harvest date indicative of root-rotting organisms such as *Fusarium* that are common pathogens in soils where cotton has been grown. No differences were found between harvest dates in total dry matter production (5.5 Mg ha^{-1}), N accumulation (108.9 kg N ha^{-1}), P accumulation (9 kg P ha^{-1}) or residual soil moisture (104 g kg^{-1}) (Table 3). Root samples indicated that some nodulation of the pea roots occurred from residual levels of *Rhizobium* bacterium in the soil at this site. Dry matter yield and accumulated N was lower than levels observed when winter peas were grown under a cooler, wetter environment in Northern Idaho (Auld et al., 1982 and Mahler and Auld, 1989). These total dry matter yields were within the range of yields reported for the Southern High Plains (Keeling et al., 1996).

The winter wheat had begun to head by the 17 Apr harvest date. Older leaves senesced at heading and were not recovered in the second harvest date. This resulted in slightly lower dry matter yield, accumulated N and accumulated P in the second harvest date (Table 3). The winter wheat produced an average of 4.9 Mg ha^{-1} of dry biomass that contained 65 kg N ha^{-1}. These yields closely approximated yields reported for winter wheat cover crops in this region (Keeling et al., 1996). Residual gravimetric soil moisture in the top 90 cm of the soil was similar for the first and second harvest dates (95 and 99 g kg^{-1}).

Table 3. Dry weight, nitrogen and phosphorous content, and residual soil moisture of winter canola, Austrian winter peas and hard red winter wheat grown at the Texas Tech Plant Stress Field Laboratory at New Deal, as winter cover crops during 1991-92.

Crop/Harvest Date	Dry Weight	Nitrogen			Phosphorus			Gravimetric Soil Moisture			
		Content	Total	Residual Soil	Content	Total	Residual Soil	30cm	60cm	90cm	Average
	$Mg\ ha^{-1}$	$g\ kg^{-1}$	$kg\ ha^{-1}$	ppm	$g\ kg^{-1}$	$kg\ ha^{-1}$	ppm	$g\ kg^{-1}$			
Cathy Winter Canola											
3 Apr	2.1 a†	24 a†	49.8	4.8	1.8 a†	3.8	12.0	121	124	121	122
17 Apr	3.7 b	16 b	59.2	2.0	1.9 a	7.0	10.3	108	122	109	113
Average	2.9	20	54.5	3.4	1.9	5.4	11.2	115	123	115	118
Common Austrian Winter Peas											
3 Apr	5.5 a†	19 a†	103.4	2.3	1.6 a†	8.8	11.8	96	103	102	101
17 Apr	5.4 a	21 a	114.5	3.3	1.7 a	9.2	15.0	102	112	108	107
Average	5.5	20	108.9	2.0	1.7	9.0	13.4	99	108	105	104
Pioneer 2157 Hard Red Winter Wheat											
4 Apr	5.6 a†	14 a†	75.6	1.5	1.3 a†	7.3	12.8	87	95	101	95
17 Apr	4.1 a	13 a	54.5	1.5	1.6 a	6.6	10.3	88	109	101	99
Average	4.9	13	65.1	1.5	1.5	6.9	11.5	88	102	101	97

† Within a column means a single crop followed by the same letter did not differ at the 0.05 level of probability by F tests.

Cotton Interseeding Study 1991-92

When interseeded into standing cotton in early September, an excellent stand was obtained on the four *Brassica* cultivars. The wheat stand was reduced due to the inability of the insecticide boxes to handle the larger volumes of seed needed for equivalent stand establishment of the large-seeded species. The fall crops (Cathy, Humus and Pioneer 2157) had a prostrate growth habit that would not have stained the cotton lint during harvest. Both spring mustard cultivars produced plants as tall as the cotton and may have discolored the lint when the cotton was stripped. The 'Forage' mustard produced the highest biomass yield (1.4 Mg ha^{-1}), while the 'Tilney' mustard and the two cultivars of winter rapeseed/canola produced only 1.0 to 0.7 Mg ha^{-1} (Table 4). The interseeded wheat produced only 0.6 Mg ha^{-1} of biomass by early November. These entries were grown under near optimum conditions due to the very wet conditions in the fall of 1991 (Table 2). No differences in cotton stalk biomass yields were detected in the interseeded cover crops indicating that competition of cover crops interseeded in late August probably had a minimum competitive impact on the cotton crop. Under wet conditions, such as the fall of 1991, interseeded cover crops could provide excellent ground cover. Earlier work done by Keeling et al. (1996) showed that winter wheat, winter rye (*Secale cereale* L.), Austrian winter peas and hairy vetch (*Vicia villosa* Roth) responded well to interseeding in cotton. Small-seeded forage legumes were more variable in their success when interseeded in this production area.

Table 4. Dry matter production of five cover crops and cotton stalks at the Texas Tech University Plant Stress Field Laboratory at New Deal, on 20 Nov 1991.

Cover Crop	Dry Weight Cover Crop	Dry Weight Cotton Stalk
	—Mg ha^{-1}—	
<u>Spring Mustards</u>		
Forage	1.4 a†	0.9 a†
Tilney	1.0 ab	1.1 a
<u>Winter Rapeseed Canola</u>		
Cathy	0.8 b	1.1 a
Humus	0.7 b	1.0 a
<u>Winter Wheat</u>		
Pioneer 2157	0.6 b	1.0 a
Fallow	0.0 c	1.0 a

† Within a column means in the same column not followed by the same letter differ at the 0.05 level of probability by Duncan's New Multiple Range test.

Cotton Interseeding Study 1992-93

September and October 1992 were extremely dry and all of the cover crops failed to emerge until late December or early January of 1993, even though they were planted in mid-September (Table 2). Dry conditions can be expected during the fall in nearly three out of five years in this production region based on long-term precipitation averages. Because of the late emergence, both spring mustard cultivars, the two cultivars of rapeseed/canola and the spring crambe failed to survive. Earlier work had shown that for optimum winter survival, winter rapeseed and canola must emerge and form a rosette before exposure to freezing temperatures (Auld et al., 1984). Late planting previously had been reported to limit establishment of small-seeded legumes and biomass production of larger-seeded cover crops on the Southern High Plains (Keeling et al., 1996). Data taken only on the winter wheat and winter peas from the end of March until mid-April indicated these species significantly increased biomass yields as well as accumulated more N and P with delayed harvest (Table 5). By mid-April, the winter wheat had produced 0.9 Mg ha^{-1} more biomass than the Melrose winter peas. The semi-dwarf Glacier winter peas produced slightly less biomass than the long-vined Austrian winter peas. The Austrian winter peas and winter wheat accumulated similar levels of P and N. Root samples indicated that the winter peas had minimal nodulation when grown without Rhizobium inoculum at the Lubbock site.

Soil moisture utilization of the three species did not differ (Table 6). However, at both the 60-cm and 90-cm depth of the soil profile, delaying harvest by 16 days until mid-April resulted in depletion of valuable soil moisture. The depletion was nearly as great in the fallow control, indicating that soil water loss was similar among standing cotton stalks, exposed soil surface and growing cover crops. This emphasizes the need for timely cultivation to preserve valuable soil moisture even when no cover crop is grown. No differences were detected in the lint or seed yield of the subsequent cotton crop. This could be expected since the cotton was furrow irrigated to replace the soil moisture utilized by the cover crops.

Nitrogen Fertilization of Spring-Planted Winter Wheat

The spring-planted winter wheat was harvested only 61 days after planting and produced an average biomass of only 0.7 Mg ha^{-1} (Table 7). No differences were detected among the four rates of N fertilization (0, 11, 22 and 33 kg N ha^{-1}) for any index except soil moisture depletion in the 30-60 cm zone of the soil profile. The application of 22 and 33 kg N ha^{-1} increased soil moisture utilization. Since no yield differences were detected in the subsequent cotton crop, N fertilizer should not be used on spring-planted cereal cover crops.

Spring-Planted Interseeding Study

The spring-seeded cover crops emerged within 2 wk of planting. Frosts in March and April killed the spring crambe and the four cultivars of *Brassica*. Only the TAM 109 winter wheat, the Melrose Austrian winter peas and the Tracer spring peas survived the frosts and produced enough growth to warrant harvesting (Table 8). The TAM 109 produced nearly 0.7 Mg ha^{-1} of biomass compared to only 0.3 kg ha^{-1} for the Melrose and Tracer peas. There were no differences in N and

Table 5. Dry matter yield and nitrogen and phosphorus content of Weather Master winter wheat and Melrose and Glacier Austrian winter pea cover crops at the Texas Tech University Plant Stress Field Laboratory at Lubbock, during the 1992-93 season.

Cover Crop	Harvest Date	Dry Matter Yield	Nitrogen Content	Nitrogen Total	Phosphorus Content	Phosphorus Total
		Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	g kg^{-1}	kg ha^{-1}
Weather Master	31 Mar	0.7 d†	21 ab†	15	3.9 a†	30
Weather Master	16 Apr	2.5 a	14 c	35	3.2 ab	80
Melrose	31 Mar	0.9 d	19 b	16	2.9 b	26
Melrose	16 Apr	1.6 b	19 b	30	2.7 b	41
Glacier	31 Mar	0.8 d	22 a	16	3.0 b	22
Glacier	16 Apr	1.4 c	19 b	26	3.0 b	40
F Values						
Cover Crop (CC)		98.4**‡	72.0**	--	42.2**	--
Harvest Date		90.4**	9.0*	--	1.9 ns	--
CC x Date		21.3**	3.8*	--	1.9 ns	--
CV		23.4%	18.0%	--	17.3%	--

† Within a column means followed by the same letter did not differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Tests.

‡ ns,*,** indicate F Test values that were not significant, or significant at the 0.05 and 0.01 levels of probability.

Table 6. Residual gravimetric soil moisture content and subsequent yield of cotton following 'TAM 109' winter wheat, Melrose and Glacier Austrian winter pea cover crops at the Texas Tech University Plant Stress Field Laboratory at Lubbock, during the 1992-93 season.

Cover Crop	Harvest Date	Gravimetric Soil Moisture			Yield of Subsequent Cotton Crop		
		30 cm	60 cm	90 cm	Seed Cotton	Lint	Seed
		g kg^{-1}			Mg ha^{-1}		
Fallow	31 Mar	102 a†	106 a	105 a	1.9	0.8	1.2
Fallow	4 Mar	82 a	77 b	75 b	1.9	0.8	1.1
TAM 109 Wheat	31 Mar	82 a	100 a	96 a	2.4	1.0	1.4
TAM 109 Wheat	4 Mar	98 a	78 b	88 b	2.0	0.8	1.2
Melrose Pea	31 Mar	71 a	89 a	79 a	1.7	0.7	1.0
Melrose Pea	4 Mar	102 a	72 b	72 b	1.7	0.7	1.1
Glacier Pea	31 Mar	70 a	81 a	93 a	1.7	0.7	1.0
Glacier Pea	4 Mar	67 a	58 b	63 b	1.5	0.6	0.9
F Values							
Cover Crop		ns‡	ns	ns	ns	ns	ns
Harvest Date		ns	**	*	ns	ns	ns
CC x Date		ns	ns	ns	ns	ns	ns
CV		31.4%	14.1%	21.3%	17.6%	18.3%	17.9%

† Within a column means followed by the same letter did not differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Tests.

‡ ns, *,** indicate F Test values that were non-significant and significant at the 0.05 and 0.01 levels of probability.

Table 7. Yield, nitrogen and phosphorus content, residual gravimetric soil moisture and subsequent cotton yield at TAM 109 wheat grown as a spring-planted cover crop with four rates of nitrogen fertilization at the Texas Tech University Plant Stress Field Laboratory at Lubbock, in 1993.

Nitrogen Rate	Dry Weight	Nitrogen		Phosphorus	
		Content	Total	Content	Total
kg ha^{-1}	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	g kg^{-1}	kg ha^{-1}
0	0.6 a†	17.8 a	11.2	4.0 a	2.5
11	0.7 a	15.0 a	10.4	3.7 a	2.5
22	0.7 a	17.0 a	11.6	3.7 a	2.5
33	0.6 a	17.2 a	9.8	3.6 a	2.1
CV	31.9%	13.8%	--	13.3%	--

Nitrogen Rate	Gravimetric Soil Moisture				Yield of a Subsequent Cotton Crop		
	30 cm	60 cm	90 cm	Avg.	Seed Cotton	Lint	Seed
kg ha^{-1}	g kg^{-1}				Mg ha^{-1}		
0	51 a	81 ab	90 a	74	2.2 a	0.9 a	1.3 a
11	65 a	99 a	82 a	82	2.3 a	0.9 a	1.4 a
22	54 a	63 b	63a	60	2.2 a	0.9 a	1.3 a
33	62 a	51 b	57 a	57	1.9 a	0.8 a	1.1 a
CV	32.9%	26.8%	25.6%	--	22.3%	22.0%	22.7%

† Within a column means followed by the same letter did not differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Test.

Table 8. Dry matter accumulation, nitrogen and phosphorus content, residual gravimetric soil moisture and subsequent cotton yield of winter fallow and three spring-planted cover crops at the Texas Tech University Plant Stress Field Laboratory at Lubbock, in 1993.

Cover Crop	Dry Matter	Nitrogen		Phosphorus	
		Content	Total	Content	Total
	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}	g kg^{-1}	kg ha^{-1}
TAM 109 Wheat	0.7 a†	21	14.0	4.7	3.3
Melrose Pea	0.3 b	21	7.0	3.8	1.3
Tracer Pea	0.3 b	21	6.5	4.0	1.3
CV	37.9%	--	--	--	--

Cover Crop	Gravimetric Soil Moisture				Yield of a Subsequent Cotton Crop		
	30 cm	60 cm	90 cm	Avg.	Seed Cotton	Lint	Seed
	g kg^{-1}				Mg ha^{-1}		
Fallow	91 a†	86 a	49 a	75	2.5 a	1.1 a	1.5 a
TAM 109 Wheat	65 a	53 a	45 a	54	2.4 a	1.0 a	1.4 a
Melrose Pea	63 a	60 a	44 a	56	2.5 a	1.1 a	1.4 a
Tracer Pea	71 a	44 a	38 a	51	1.9 a	0.8 a	1.1 a
CV	31.2%	39.7%	36.0%	--	19.1%	20.8%	18.1%

† Within a column means followed by the same letter did not differ at the 0.05 level of probability by Fisher's Protected Least Significant Difference Test.

P, soil moisture utilization or yield of a subsequent cotton crop. Based on our data, spring seeding of cover crops has very limited potential on the Southern High Plains of Texas. Cool spring temperatures and the need to terminate cover crops by mid-April do not allow sufficient cover crop growth to justify the expense of establishing spring-planted cover crops.

CONCLUSIONS

Five trials were conducted over the 1991-92 and 1992-93 growing seasons to compare alternative cover crops with winter wheat after cotton on the Southern High Plains of Texas. In these studies, the very cold air temperatures in the fall of 1991-92 limited the production of the winter *Brassica* cultivar. However, wet conditions allowed winter wheat and Austrian winter peas to produce excellent biomass yields. In 1992-93, dry fall conditions prevented establishment of nonirrigated cover crops in the fall. The harsh climatic conditions common on the Southern High Plains will require cover crop establishment in August or early September. Winter rye, winter triticale (*Triticale hexaploide* Lart.), winter wheat, winter peas and hairy vetch should be used when cover crops are planted after mid-September (Keeling et al., 1996). *Brassica* species and small-seeded legumes will survive consistently only when interseeded into standing cotton in August.

Soil moisture utilization of the cover crops evaluated in this study were similar to the noncultivated control. However, the loss of even minimal amounts of soil moisture could reduce yield of subsequent cotton crops under dryland conditions. Growth of all cover crops would be enhanced if the subsequent cotton crop were planted into standing residue of a terminated cover crop. This would allow the cover crop to grow into late April when much of the biomass is produced. Much additional research is needed to develop effective alternative cover crops for the Southern High Plains of Texas.

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