Interseeding Legumes into Chile: Legume Benefits to a Following Crop of Forage Sorghum

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SUMMARY. Hairy vetch (*Vicia villosa* Roth.), barrel medic (Medicago truncatula Gaerth.), and black lentil (*Lens culinaris* Medik.) were interseeded into 'New Mexico 6-4' chile pepper (*Capsicum annuum* L.) when plants were 8 to 12 inches tall or 12 to 16 inches tall in 1993 and 1994. Hairy vetch overwintered well both years, whereas barrel medic and black lentil did not. Spring aboveground dry mass yields of hairy vetch averaged 2.11 and 2.57 tons per acre in 1994 and 1995, respectively, while N accumulation averaged 138 and 145 pounds per acre in 1994 and 1995, respectively. Forage sorghum [*Sorghum bicolor* (L.) Moench] dry mass yield and N accumulation were significantly higher following hairy vetch than following the other legumes or no-legume control. There was no significant difference between forage sorghum yields following barrel medic, black lentil, or the no-legume control. Fertilizer replacement values (FRV) for the legumes were calculated from regression equations for forage sorghum dry mass yield as a function of N fertilizer rate. FRV for hairy vetch were at least 7-times higher than for either barrel medic or black lentil. Hairy vetch interseeded into chile pepper and managed as a winter annual can significantly increase the yield of a following crop compared to a nonfertilized control.

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Relay intercropping has been defined as a form of multiple cropping in which a second crop is planted into the first crop when the first crop has reached its reproductive stage but before it is harvested (Andrews and Kassam, 1976). With the use of relay intercropping, two crops can be produced in 1 year in areas where the growing season is too short for sequential or double cropping.

Relay intercropping may be a way to insert legume cover crops into rotations that include chile. Guldan et al. (1996) reported that chile yields were unaffected by interseeding legumes in either early or mid-August. This result is important because most chile growers would consider chile to be the primary crop and a relay-intercropped legume to be of secondary value. November dry mass yields of the legumes, however, were significantly greater when the legumes were planted in early August compared to mid-August (Guldan et al., 1996).

The green-manure value of hairy vetch to subsequent crops is well documented in the eastern United States (Abdul-Baki et al., 1996; Schonbeck et al., 1993; Smith et al., 1987). Studies by Schonbeck et al. (1993) indicated hairy vetch cover crops could potentially reduce N fertilizer inputs while maintaining production levels of *Brassica* vegetable crops in the northeastern United States. Little information is available, however, on the green-manure value of hairy vetch as a winter cover crop in the high-desert region of the southwestern United States.

Although overwintering legumes, such as hairy vetch, can, in many cases, provide additional spring growth, overwintering may not always be desired—for example, when the following year's crop is direct-seeded early in the spring. In this case, there may be little or no spring growth of an over-wintering legume by the time the following crop is seeded. However, special tillage or herbicides would likely be required to control the legume to prevent it from becoming a competitive weed in the following crop. In addition, hairy vetch escapes can develop into a serious weed problem in cereals (Duke, 1981).

The degree to which summer annual legumes, interseeded into chile, can contribute to the yield of a subsequent crop compared to the winter-annual hairy vetch is not clear. Recently, 'Indianhead' black lentil has been developed for use as a green manure. It is frost hardy, and the seed is relatively inexpensive compared to other grain legumes (Slinkard et al., 1987). Barrel medic and other annual Medicago species have been used extensively in southern Australia as pasture legumes in rotation with cereals to improve and maintain soil fertility (Puckridge and French, 1983). Many annual Medicago species are characterized as fast growers that produce large amounts of biomass (Diwan et al., 1994).

Developing relay intercropping methods for chile cropping systems would be particularly beneficial where a goal is to use land, sunlight, and other on-farm resources as efficiently as possible. Many of the soils of the high-desert region of the southwestern United States are coarse textured, low in organic matter, and relatively infertile. Legumes, because of their ability to fix N, may be particularly useful as cover crops on these soils. Our objectives were to determine 1) the effects of three legumes interseeded into chile on two dates on dry mass yield and N accumulation of a subsequent crop of forage sorghum and 2) fertilizer replacement values (FRV) of the three legumes.

Materials and methods

This study was conducted at Alcalde, N.M., on a Fruitland sandy loam [coarse-loamy, mixed (calcareous), mesic Typic Torriorthent] from 1993 to 1995. Soil organic matter content in the 0-6-inch depth was ≈0.37%. 'New Mexico 6-4' chile was planted on listed beds in rows 36 inches apart on 14 May 1993 and 9 May 1994 with a two-row planter. When plants were ≈4 to 5 inches tall (≈8.5 weeks after planting), they were thinned to two plants per hill and 1 foot between hills. Chile was fertilized with 30, 28, and 26 pounds of N, P, and S per acre, respectively. Details of methods of chile fertilization are reported elsewhere (Guldan et al., 1996). Weeds were controlled mechanically and by hand. All plots were furrow irrigated as needed throughout the study. The average date of the first fall temperature of 30 °F from 1985 to 1994 at the study site is 9 Oct. The first fall temperature of 30 °F or lower occurred on 20 Oct. 1993 and 9 Oct. 1994.

On 3 Aug. (early interseeding) when the chile was 8 to 12 inches tall and on 16 Aug. 1993 and 17 Aug. 1994 (late interseeding) when the chile was 12 to 16 inches tall, 'Parabinga' barrel medic, 'Indianhead' black lentil, and 'Madison' hairy vetch were hand-broadcast into the standing chile. The chile was in the pod development stage during all interseedings. Seeding rates on a pure live seed basis were 20, 50, and 40 pounds per acre for barrel medic, black lentil, and hairy vetch, respectively. Seed broadcast at the early date was incorporated with a row crop cultivator. Seed broadcast at the late date was incorporated with hand rakes because the width of the alleys between blocks was insufficient to maneuver the row crop cultivator around early interseeded plots. All legume seed was inoculated with appropriate Rhizobium before sowing.

All legumes were sampled on 8 Nov. 1993 and 15 Nov. 1994. In the spring following the interseeding year, hairy vetch was sampled on 28 Apr. and 24 May in 1994 and 1995. Aboveground biomass was measured by harvesting a 2.25-square-foot area from each subplot. Placement of square quadrats was such that a representative cross-section of the furrow-bed continuum was obtained in each sample. Samples were oven-dried at 149 °F for 48 h and weighed. Samples were ground to pass a 0.04-inch screen, digested, and analyzed colorimetrically (sodium salicylate-sodium hypochlorite) for total Kjeldahl N using an autoanalyzer (Technicon Instruments Corp., 1974). Nitrogen accumulation was obtained by multiplying the aboveground biomass by the N concentration for each legume.

Plots were disked and then moldboard plowed on 26 May 1994 and 1995. On 31 May 1994 and 1995, forage sorghum (Scotchman Brand) was seeded at 27 pounds per acre and fertilized with 46 pounds of P per acre as 0N–45P–0K. On 8 June 1994 and 2 June 1995, no-legume plots were fertilized with 0, 50, 100, and 150 pounds of N per acre as urea. Fertilizer was broadcast and incorporated with a hand rake.

Forage sorghum was harvested twice each season. In 1994, the first harvest occurred on 29 July and the second on 9 Sept. In 1995, the first harvest occurred on 3 Aug. and the second on 19 Sept. Forage sorghum plants were generally in the boot stage at the first harvests and varied from vegetative to boot stage at the second harvests. Dry mass yields were measured by harvesting and then weighing a 3 × 13-foot area in 1994 and 3 × 15-foot area in 1995 from each plot. Harvested plants were cut to a 3-inch stubble height. Dry mass yields were determined by adjusting fresh mass to dry mass by drying moisture subsamples at 149 °F for 48 h. After the first harvests, all nonsampled areas were harvested and removed from the plots. Moisture subsamples were ground to pass a 0.04-inch screen and processed to determine total Kjeldahl N using the same procedure as that used for determining N of the legumes. Nitrogen accumulation was calculated by multiplying the dry mass yield of the forage sorghum by the N concentration.

The experimental design was a randomized complete block with a split-plot treatment structure and four replications. Main-plot treatments were time of legume interseeding plus a no-legume main plot. Subplot treatments in the interseeded main plots included legume species and a no-legume control. Subplots were three rows wide and 20 feet long. The main-plot treatment that was not interseeded with legumes consisted of subplots that were

Table 1. Aboveground dry mass and N accumulation of legumes following interseeding into chile pepper; data averaged across two interseeding dates.

	Legume harvest					
	1993–94			1994–95		
Legume	8 Nov.	28 Apr.	24 May	15 Nov.	28 Apr.	24 May
	Dry mass (pounds per acre)					
Madison hairy vetch	2160 a[z]	4570	3880	1240 a	3800	6490
Parabinga barrel medic	1940 a	---	---	705 b	---	---
Indianhead black lentil	1450 a	---	---	875 b	---	---
	N accumulation in aboveground biomass (pounds per acre)					
Madison hairy vetch	87 a	155	121	38 a	121	168
Parabinga barrel medic	71 a	---	---	22 b	---	---
Indianhead black lentil	54 a	---	---	26 b	---	---

[z]Mean separation within columns of November harvests by Duncan's multiple range test at $P < 0.05$.

Table 2. Forage sorghum aboveground biomass yield and N accumulation following legume cover crops. Legumes had been interseeded into chile pepper the previous year. Sorghum data are averaged across two legume interseeding dates.

	Forage sorghum harvest					
	1994			1995		
	Harvest			Harvest		
Legume	1	2	Cumulative	1	2	Cumulative
	Dry mass (pounds per acre)					
Madison hairy vetch	4130 a[z]	2680 a	6800 a	4100 a	2030 a	6130 a
Parabinga barrel medic	2950 b	1260 b	4210 b	2540 b	804 b	3340 b
Indianhead black lentil	2500 b	1150 b	3650 b	2290 b	714 b	3000 b
Control	2570 b	947 b	3520 b	1820 b	527 b	2360 b
	N accumulation in aboveground biomass (pounds per acre)					
Madison hairy vetch	59 a	29 a	88 a	55 a	16 a	71 a
Parabinga barrel medic	27 b	11 b	37 b	21 b	7 b	27 b
Indianhead black lentil	22 b	10 b	32 b	20 b	6 b	25 b
Control	21 b	8 b	29 b	14 b	4 b	19 b

[z]Mean separation within columns by Duncan's multiple range test at $P < 0.05$.

fertilized with soluble N fertilizer at the time of forage sorghum seeding in year 2 of the study. Data from these N-fertilizer subplots were not included in the analysis of variance performed on the interseeded plots. Rather, data from these N-fertilizer subplots were used to obtain regression equations for seasonal forage sorghum dry mass yield (y) as a function of fertilizer N rate (x). The regression equations were used to calculate FRV of the legumes (Hesterman, 1988; Stute and Posner, 1995).

Analysis of variance was performed using the general linear models procedure (SAS Institute, 1992). Legume and forage sorghum yield data were analyzed separately for each year because variance estimates indicated heterogeneous variances for several of the yield parameters. An F test was used to verify this conclusion.

Results

Legume yield. In Fall 1993, there were no significant differences in yield between legumes. In Fall 1994, hairy vetch accumulated more ($P < 0.05$) biomass and N than either barrel medic or black lentil (Table 1). Fall legume yields are discussed in more detail by Guldan et al. (1996).

Hairy vetch overwintered, whereas barrel medic and black lentil did not, except when a few plants of barrel medic survived Winter 1994–95. Legume interseeding time did not affect ($P > 0.05$) any yield characteristics for spring hairy vetch or forage sorghum. Therefore, spring hairy vetch and forage sorghum data were pooled across interseeding dates.

Although plots were not tilled until late May, hairy vetch was sampled in late April and late May to better characterize its spring growth (Table 1). No significant differences ($P > 0.05$) were detected between spring harvest dates for dry mass or N accumulation in either year. In 1995, hairy vetch plants in some parts of the trial appeared to be stunted by a disease that we were not able to conclusively identify. The resulting uneven stand in the trial led to increased variability in our 1995 biomass samples. Spring dry mass yields were generally within the range of spring hairy vetch yields reported by Blevins et al. (1990) and Decker et al. (1994).

FORAGE SORGHUM. Forage sorghum dry mass yield and N accumulation were higher ($P < 0.05$) following hairy vetch than following the other legumes or no-legume control (Table 2). In terms of cumulative forage sorghum dry mass, barrel medic yielded 38% less dry mass than the hairy vetch treatment in 1994 and 45% less in 1995. Forage sorghum N accumulation following barrel medic was 58% less than following hairy vetch in 1994 and 63% less in 1995 (Table 2). Although mean forage sorghum dry-mass yields were 15% to 53% higher after barrel medic compared to the no-legume control, the differences were not significant (Table 2).

Regression equations that best described the data from the fertilizer N plots were chosen to calculate the FRV (Fig. 1). Estimated FRV are given in Table 3. In both years, the sorghum yields following hairy vetch were higher than the maximum estimated yield possible as a function of fertilizer N using the regression equations. To give an indication of the FRV for hairy vetch, the mean cumulative dry mass yields of sorghum at the 150-pound N rate were 6640 and 5440 pounds per acre in 1994 and 1995, respectively. This result compares with cumulative sorghum yields following hairy vetch of 6800 and 6130 pounds per acre in 1994 and 1995, respectively. FRV for barrel medic and black lentil were relatively low. Neither legume resulted in

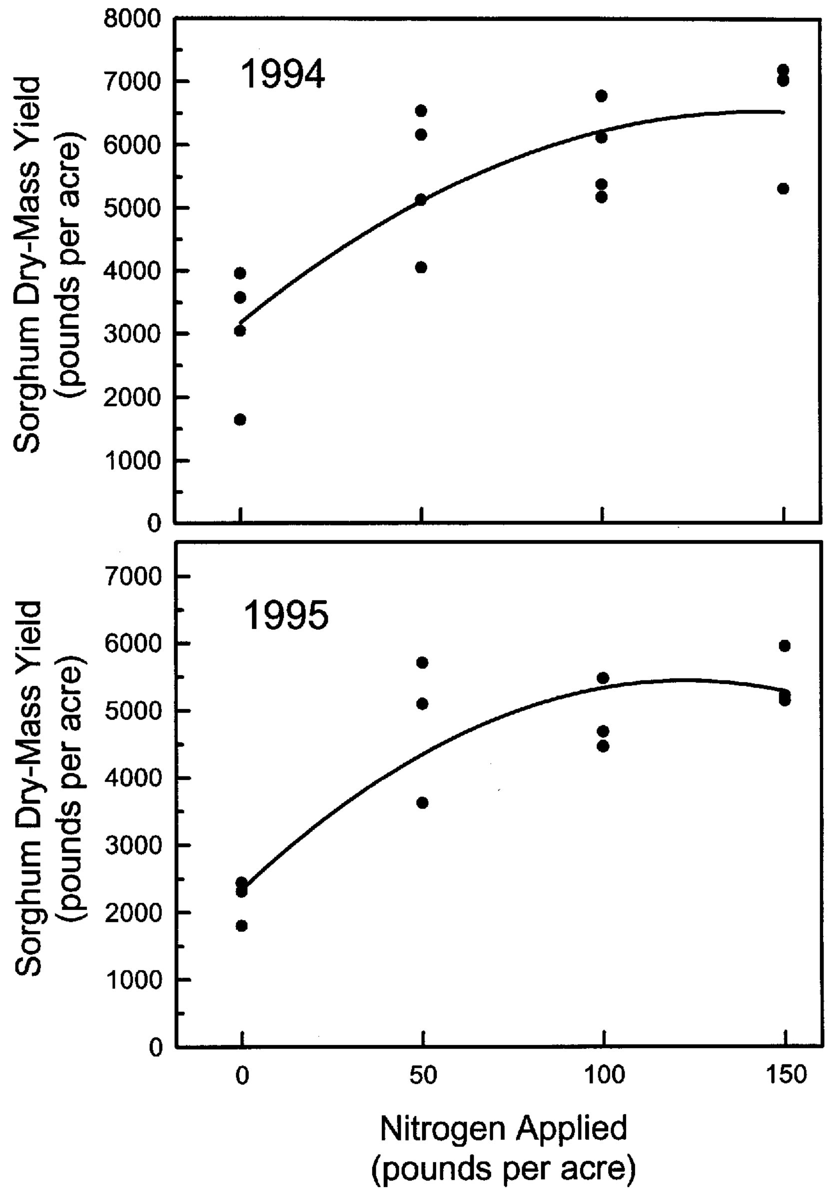

Fig. 1. Regressions of sorghum cumulative aboveground dry mass yield (y) as a function of fertilizer nitrogen rate (x). In 1994 (n = 4), y = 3180 + 46.7x – 0.16x², r² = 0.70. In 1995 (n = 3), y = 2341 + 50.5x - 0.21x², r² = 0.78.

Table 3. Estimated fertilizer replacement values (FRV) of legumes for forage sorghum; values based on cumulative seasonal sorghum yield. Legumes had been interseeded into chile pepper the previous year.

Legume	Fertilizer N replacement value (pounds/acre) 1994	1995
Madison hairy vetch	+[z]	+[z]
Parabinga barrel medic	24	22
Indianhead black lentil	10	14

[z]Forage sorghum dry-mass yields were higher following hairy vetch than the maximum estimated yield possible as a function of fertilizer N rate with the regression equations used.

FRV greater than 25 pounds of N per acre (Table 3). Clearly, hairy vetch was superior in terms of its capability to substitute for N fertilizer under the conditions of this study.

Conclusions

Fall growth of legumes interseeded into chile pepper could potentially be used as a winter cover crop. However, fall yield levels of the summer annuals barrel medic and black lentil appeared to be too low to add significant benefits to a second crop of forage sorghum. In contrast, hairy vetch managed as a winter annual significantly increased yield of a following forage sorghum crop compared to a nonfertilized control. Hairy vetch thus appears to have potential for relay intercropping into chile in similar environments. It can be established late enough in the season to not detract from chile yield (Guldan et al., 1996) yet early enough to over-winter and provide significant green-manure benefits to a following crop.

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In-row Spacing Affects Machine-harvested Jalapeno Pepper

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Additional index words. ***Capsicum annuum*, mechanical fruit removal, yield, plant characteristics**

Summary. Field studies were conducted in 1991 and 1992 to evaluate the effect of in-row spacing on machine-harvested jalapeno pepper (*Capsicum annuum* L.) yield and plant characteristics. In 1991, 'TAM Mild Jalapeno-1' (TAMJ1) and 'Jalapeno-M' (JM) were planted at 4-, 8-, 12-, and 16-inch (10-, 20-, 30-, 40-cm) in-row spacings and, in 1992, TAMJ1 was planted at 3-, 6-, 9-, and 12-inch (7.5-, 15-, 22.5-, 30-cm) spacings. Total marketable yield increased linearly for JM (in 1991), while the yield response was quadratic for TAMJ1 in 1992 with narrower in-row spacing. Total marketable yield for JM (1991) and TAMJ1 (1992) was highest for the narrowest spacing, 4 and 3 inches, respectively. Red fruit yield of both cultivars in 1991 increased linearly with narrower spacing. In 1992 there were no differences in red fruit yield among in-row spacings. Plants lodged more at wider spacings. In-row spacings as narrow as 4 inches may increase marketable yield of machine-harvested jalapeno pepper.

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