Snap Bean Production in Conventional Tillage and in No-till Hairy Vetch Mulch

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Abstract. A 3-year study was conducted at the Beltsville Agricultural Research Center, Beltsville, Md., to evaluate plant stand, growth, and yield of snap bean (*Phaseolus vulgaris* L.) cultivars Carlo and Matador grown with conventional tillage (CT) or with no-tillage hairy vetch (*Vicia villosa* Roth) (HV) mulch. Plant stand and dry mass of both cultivars in CT were similar to those in no-till HV. However, leaf area and yield with no-till HV were significantly higher than those with CT.

Snap bean is an important crop in the intensive, diversified, multicropped production farming in the mid-Atlantic (Skarphol et al., 1987) and southeastern (Stansell and Smittle, 1980) states. It is a high-value crop, fully mechanized, and has a short growing season. Its adaptability to a broad range of environmental conditions allows production as a spring, summer, or fall crop (Bellinder et al., 1987). Reported yields range from 2.8 t·ha⁻¹ (Nwaja et al., 1996) to more than 24 t·ha⁻¹ (Mack, 1983), and maximum yields were achieved at N rates of 56 to 84 kg·ha⁻¹ (Patterson et al., 1996) and high plant densities of 43 to 65 plants/m² (Mack, 1983).

Snap bean has generally been grown in conventional tillage (CT). The introduction of no-tillage (NT) into vegetable crops offered many advantages over CT, including reductions in soil erosion (Jent et al., 1967), increase in land use, and improved soil water relations (Blevins et al., 1971; Phillips, 1984). Data comparing snap bean yields in CT and NT are inconsistent. Grenoble et al. (1989) and Mullins et al. (1988) reported higher yields in CT than in NT, whereas Mascianica et al. (1986) and Skarphol et al. (1987) concluded yields with NT were equal to or greater than those with CT. NeSmith and McCracken (1994) and Mullins et al. (1980) found no yield differences between CT and NT. In these NT experiments, use was often made of mulch from residues of small grains, and N fertilizer was required to maximize yields.

In a few experiments, snap bean was grown in a NT system using a mulch from hairy vetch (HV) that had been killed with glyphosate (Knavel and Herron, 1986) or plowed under (Nwaja et al., 1996). Plants in HV mulch yielded ≈50% less than those in CT. In contrast, Skarphol et al. (1987) evaluated snap bean production in a NT system using hairy vetch, Austrian winter pea (*Pisum sativum* spp. *arvense* L. Poir), and crimson clover (*Trifolium incarnatum* L.), alone or combined with wheat (*Triticum aestivum* L.). Snap bean yields in mulches from these annual winter legumes without supplemental N were comparable to those obtained when 90 kg·ha⁻¹ additional N was applied.

The objective of this study was to evaluate plant stand, growth, and yield of snap bean grown in CT and in NT HV mulch.

Materials and Methods

Experimental plots. Field experiments were conducted on the North Farm of the Beltsville Agricultural Research Center, Beltsville, Md., from 1994 through 1996. The field has a Keyport fine sandy loam, Acquic Hapludult,

clayey, mixed, mesic soil, pH 6.7. The experimental design was a randomized complete block with cultural practices as the only factor in 1994 and a split-plot design with cultural practices as whole plots and snap bean cultivars as subplots in 1995 and 1996. Cultural practices were conventional tillage (CT) and hairy vetch mulch with no-tillage (HV). The same cultural practices were applied to the same 120 × 15 m whole plots each year. Four vegetable crops (tomatoes, muskmelons, sweet corn, and snap beans) were rotated within whole plots each year. The snap bean portion of each whole plot consisted of a 60 × 6-m section consisting of eight rows. These rows were divided into four contiguous rows each of 'Matador' and 'Carlo' snap bean in 1995 and 1996. There were two blocks and three subplots per block.

Major cultural operations and dates appear in Table 1. The HV mulch plots were spaded (Imants Sapder, Rusal Faimanto, Holland) to a depth of 15 cm during the second week of September each year. Hairy vetch seed (50 kg·ha⁻¹), treated with the proper *Rhizobium* spp., was seeded using a Brillion seeder (Brillion Iron Work, Brillion, Wis.) as described elsewhere (Abdul-Baki et al., 1996). The cover crops received no water, herbicide, fertilizer, or any other treatment until they were mowed. The vetch emerged within 1 week and some growth took place in the fall. However, most of the growth occurred in April and May of the following year. The vetch was mown with a high-speed flail mower (Alamo Group Corp., Seguin, Texas) to ≈6 cm above the soil surface to form a layer of mulch 5 to 6 cm thick. Before mowing, representative samples of aboveground growth were taken from 1-m² randomly selected locations outside the experimental area and dried overnight at 70 °C in a forced-air oven to determine dry matter yield and total Kjeldahl N concentration (Baker et al., 1964). Total N content was calculated by multiplying N concentration by dry matter yield.

The CT plots received the cultural practices generally performed when growing snap bean in CT. Based on soil test results, 50N–0P–0K (in kg·ha⁻¹) was surface broadcast as granular NH₄NO₃, disked twice to 20-cm depth, and cultipacked 1 d before planting.

Planting. 'Matador' snap bean was used in 1994 and 'Matador' and 'Carlo' were used in 1995 and 1996. 'Carlo' has a short, compact,

Table 1. Dates of main operations for snap bean production systems.

Operation	Growing season		
	1994	1995	1996
Seeding hairy vetch ²	9 Sept.	14 Sept.	16 Sept.
Sampling hairy vetch biomass	29 May	21 May	1 June
Mowing hairy vetch	31 May	23 May	2 June
Planting snap bean	31 May	25 May	3 June
Applying preemergence herbicide	31 May	26 May	4 June
Stand determination	17 June	14 June	17 June
Postemergence herbicide	None	29 June	None
Snap bean plant mass	3 Aug.	None	24 July
Snap bean leaf area	3 Aug.	None	24 July
First harvest	5 Aug.	2 Aug.	26 July
Second harvest	16 Aug.	12 Aug.	6 Aug.

²Dates are for year preceding the growing season.

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and upright plant habit, while 'Matador' is a large, vigorous plant with more foliage. 'Matador' is both a fresh-market and a processing bean, but is used for direct marketing rather than for shipping due to its low fiber content. In contrast, 'Carlo' is strictly used for fresh-market due to its high fiber content. They were seeded using an IH-800 two-row planter. Spacing was 75 cm between rows and 12 seeds/m within the row, resulting in 160,000 seeds/ha. Fertilizer (in kg·ha⁻¹) 17N-34P-15K was banded in both CT and HV plots with the planter. Weeds were controlled in the CT plots with a preemergence application of metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide] at 1.68 kg·ha⁻¹ in all years. No preemergence herbicide was applied to the HV plots, but emergence of grass weeds in 1995 required a postemergence application of sethoxydim [2-[1-(ethoxymino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] at 0.32 kg·ha⁻¹ plus 2.3 L·ha⁻¹ of crop oil concentrate. Isolated patches of emerged weeds in both treatments were removed by hand weeding.

Plant stand, leaf area, and plant mass. Plant stand determinations were made on six designated 23-m row sections per block for each treatment. Leaf area and mass of aboveground parts were determined 2 d before the first harvest in 1994 and 1996. For each determination, eight plants were randomly selected from each subplot outside the areas designated for yield determinations. Individual plants were cut at ground level, shaken to remove any soil particles, and taken to the laboratory. Leaves were detached and the leaf area of individual plants was determined using a leaf area meter (model LI-3100; LI-COR, Lincoln, Nebr.). The leaves from each plant were then combined with the stem and dried at 70 °C in a forced-air oven for plant mass determination.

Leaf nutrient analysis. Leaf samples of the 1996 crop were collected 2 d before first harvest, using one of the two lateral leaflets of young mature fully expanded leaves. Seventy lateral leaflets per treatment, one from each plant, were detached from the petiole at the point of contact, placed in plastic bags and taken immediately to the laboratory. They were washed in a 0.1% solution of sodium lauryl sulfate, rinsed 3 times in deionized water, dried for 2 d in a forced-air oven at 102 °C, and ground to pass through a 0.6-mm sieve opening. All material from a treatment was bulked before analysis. Analysis of total N was performed by Kjeldahl (Baker et al., 1964) and other macro- and microelements by plasma emission spectroscopy.

Yield. Yield was determined on plants from 9.5-m sections selected from the inner two rows of each subplot. Two hand harvests were made, the first when 90% or more of the harvested pods in each treatment were at prime maturity stage, the second 8 to 10 d later. Overmature, diseased, and mechanically damaged pods were discarded before weighing.

Statistical analysis. Data were analyzed as a one-factor model for 1994 and two-factor

models for 1995 and 1996, using PROC MIXED (SAS Institute, 1996). The factors were treatment and cultivar. There were no significant interactions between treatment and cultivar, so only main effects are presented. To correct for variance heterogeneity, data for the variables leaf area and plant mass were transformed to natural logs.

Results and Discussion

Adequate plant stands were achieved in both CT and HV cultural systems in all 3 years, and differences in plant stands between the CT and the no-till HV cultural systems were non-significant (Table 2). These results support those reported by Mullins et al. (1980) who showed no differences in plant stands of snap beans in CT vs. no-tillage. Our results disagree with those reported by Knavel and Herron (1986), who showed a reduced plant stand of snap beans in no-till hairy vetch mulch as compared to CT. These authors attributed reduction in plant stand in the HV plots to poor soil coverage of seeds by the seeder in the vetch plots. Differences in plant stands between 'Carlo' and 'Matador' were significant in both years and could be attributed to seed quality differences between the cultivars rather than to cultural methods.

Yields of snap beans were significantly higher in HV than in CT in all 3 years (Table 2). Since there were no differences in plant stands between the two treatments in any year, yield differences may be attributed to factors associated with the cultural systems used. Cover crops have been shown to reduce soil erosion, increase infiltration, provide

supplemental nutrients, reduce soil compaction, and improve soil tilth (Abdul-Baki et al., 1996; Langdale et al., 1979; McVay et al., 1989; Phatak, 1992). Our HV plots have been planted with HV every fall for the past 4 years. They have been receiving ≈5.2 to 5.4 t·ha⁻¹ of dry mass from HV each year, whereas the CT plots have been kept fallow (Table 3). In addition, N supplement by HV in the vetch plots ranged from 161 to 173 kg·ha⁻¹ per year—much higher than the recommended 44 to 88 kg·ha⁻¹ for snap beans in the mid-Atlantic states (Rutgers Cooperative Extension, 1997). In contrast, N applied to the CT plots was in the lower range of the recommended rate, although leaf tissue analysis showed that N was sufficient. Our results disagree with those of Knavel and Herron (1986) who reported lower yields of snap beans in cover crops as compared to CT. They attributed the low yield to competition from weeds and regrowth of HV, as well as to drought.

In our experiments, we did not measure vehicular compaction and its effect on nodulation in the CT and HV systems. However, Tu and Buttery (1988) and Voohree et al. (1976) reported a reduction in nodulation and nodule efficiency by legumes in soils compacted by vehicular traffic. The greater vehicular traffic in CT than in no-till HV may have contributed to the yield differences between the two systems. We observed no differences between systems in disease incidence, which was minimal.

Yields in the CT plots in 1996 were further affected by a 3-day storm (6–8 June). Strong winds, accompanied by 10.2 cm of heavy rain, caused severe runoff and soil erosion. No

Table 2. Plant stand and marketable yield from two harvests of snap bean in conventional tillage vs. no-till hairy vetch mulch.

Treatment	Plant stand (1000 plants/ha)			Yield (t·ha ⁻¹)		
	1994	1995	1996	1994	1995	1996
Mulch						
Conventional tillage	103.4 a	94.8 a	86.8 a	11.8 b ²	20.0 b	8.2 b
Hairy vetch	103.5 a	106.8 a	93.1 a	18.6 a	24.3 a	16.4 a
Cultivar						
Carlo	---	110.0 a	95.4 a	---	19.6 b	10.9 b
Matador	---	92.1 b	84.4 b	---	24.7 a	13.6 a

²Mean separation within columns and treatments (mulch, cultivar) by F test and $P \leq 0.05$.

Table 3. Hairy vetch biomass and N content (dry mass basis) at the time of mowing.

Year	Dry biomass	N content	
	(kg·ha ⁻¹)	Nitrogen (%)	Total (kg·ha ⁻¹)
1994	5.2	3.1	161
1995	5.4	3.2	173
1996	5.4	3.0	162

Table 4. Plant mass and leaf area of snap bean 2 d before first harvest.

Treatment	Year	
	1994	1996
Leaf area (cm ² /plant)		
Conventional tillage	3000 b ²	984 b
Hairy vetch	5218 a	1721 a
Plant mass (g)		
Conventional tillage	38.9 a	16.1 a
Hairy vetch	34.9 a	20.6 a

²Mean separation within columns and parameters by $P \leq 0.05$.

Table 5. Concentration of macro- and micronutrients in most recent fully expanded leaves of snap bean growth with conventional tillage vs. no till hairy vetch mulch in 1996.

		Macronutrients (% dry mass)					Micronutrients (μg·g ⁻¹ dry mass)							
Cultivar	Treatment	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Zn	Na	Sr
Matador	CT	4.26	0.27	1.44	3.68	0.71	54	117	7	15	50	16	20	58
	HV	4.10	0.40	2.88	1.58	0.38	36	96	9	24	13	23	14	24
Carlo	CT	3.68	0.25	1.55	3.68	0.64	49	183	7	17	119	16	13	52
	HV	4.19	0.32	2.12	2.78	0.39	32	75	10	20	20	20	14	41

runoff or soil erosion was observed in the HV plots. The CT plots may have lost some of their nutrients with the eroded soil and runoff, as reported by Langdale and Leonard (1983). This loss may have contributed to the vast yield differences between CT and HV in 1996.

Plant mass and leaf area. Cultural method did not affect plant mass (Table 4), although leaf area was significantly larger in HV than in CT in both years. We observed a similar increase in leaf area of fresh-market tomatoes grown with hairy vetch as compared to black polyethylene (Teasdale and Abdul-Baki, 1997). The increase in leaf area may have increased photosynthetic capacity and production, which could account for increased yield. Liebman et al. (1995) showed that yield of dry beans was positively correlated with late-season leaf area index.

Leaf nutrient analysis. Data on leaf nutritional analysis of a 70-leaflet bulked sample per treatment show that both cultivars responded in the same way to each cultural practice (Table 5). The N concentration of leaflets of plants grown in CT and HV was adequate for plant growth (Piggott, 1986). Both P and K were lower in CT than in HV and fell into the deficient range. In contrast, Ca and Mg were higher in CT than in HV. These results agree with data reported by Grenoble et al. (1986), who showed that snap bean petiole P concentration was lower in CT than in reduced tillage or NT. The lower Al concentration in snap bean leaflets grown with HV as compared with CT also agree with the observations made by Grenoble et al. (1986).

Since nearly all snap beans are harvested mechanically, heavy residues of mulch on the surface of the soil at the time of harvest could create a problem. This would not be a problem when HV is used because most of the residue decomposes within 5 weeks. By the time of harvest, there is hardly any residue that would interfere with mechanical harvesting. However, vetch residues could persist until harvest in a dry season or climate.

In conclusion, the HV no-till system improves soil tilth and protects soil from erosion and loss of nutrients by runoff. Plant stands are equal to, and yields are higher than, those in the CT system.

Literature Cited

- Abdul-Baki, A., J.R. Teasdale, R. Korcak, D.J. Chitwood, and R.N. Huettel. 1996. Fresh-market tomato production in a low-input alternative system using cover crop mulch. *J. Amer. Soc. Hort. Sci.* 31:65-69.
- Baker, D.E., G.W. Gorsline, C.B. Smith, W.J. Thomas, W.E. Brunde, and J.L. Ragland. 1964. Technique for rapid analysis of corn leaves for eleven elements. *Agron. J.* 56:133-136.
- Bellinder, R.R., H.P. Wilson, and T.E. Hines. 1987. Comparative studies of conventional and no-tillage systems for snap bean production. *HortScience* 22:159.
- Blevins, R.L., D. Cook, S.H. Phillips, and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. *Agron. J.* 63:593-596.
- Grenoble, D.W., E.L. Bergman, and M.D. Orzolek. 1989. Effects of tillage methods and soil cover crops on yield and leaf elemental concentrations of snap bean. *Appl. Agr. Res.* 4:81-85.
- Jent, C., F. Bell, and M. Springer. 1967. Predicting soil losses in Tennessee under different management systems. *Tennessee Agr. Expt. Sta. Bul.* 418.
- Knavel, D.E. and J.W. Herron. 1986. Response of vegetable crops to nitrogen rates in tillage systems with and without vetch and rye grass. *J. Amer. Soc. Hort. Sci.* 111:502-507.
- Langdale, G.W., A.P. Barnett, R.A. Leonard, and W.G. Fleming. 1979. Reduction of soil erosion by the no-till system in the Southern Piedmont. *Trans. Amer. Soc. Agr. Eng.* 22:82-92.
- Langdale, G.W. and R.A. Leonard. 1983. Nutrient and sediment losses associated with conventional and reduced tillage agricultural practices, p. 457-467. In: R.R. Laurence (ed.). *Nutrient cycling in agricultural ecosystems*. Univ. Georgia College Agr. Spec. Publ. No. 23.
- Liebman, M., S. Corson, R.J. Rowe, and W.A. Halteman. 1995. Dry bean responses to nitrogen fertilizer in two tillage and residue management systems. *Agron. J.* 87:538-546.
- Mack, H.J. 1983. Fertilizer and plant density effects on yield performance and leaf nutrient concentration of bush snap beans. *J. Amer. Soc. Hort. Sci.* 108:574-578.
- Mascianica, M.P., H.P. Wilson, R.F. Walden, T.E. Hines, and R.R. Bellinder. 1986. No-tillage snap bean growth in wheat stubble of varied height. *J. Amer. Soc. Hort. Sci.* 111:853-857.
- McVay, K.A., D.E. Radcliffe, and W.L. Hargrove. 1989. Winter legume effects on soil properties and N fertilizer requirements. *Soil Sci. Soc. Amer. J.* 53:1856-1862.
- Mullins, C.A., R.A. Straw, and D.L. Coffey. 1988. Production of snap beans as affected by soil tillage method and row spacing. *J. Amer. Soc. Hort. Sci.* 113:667-669.
- Mullins, C.A., F.D. Tompkins, and W.L. Parks. 1980. Effects of tillage methods on soil nutrient distribution, plant nutrient absorption, stand, and yields of snap beans and lima beans. *J. Amer. Soc. Hort. Sci.* 105:591-593.
- NeSmith, D.S. and D.V. McCracken. 1994. Snap bean response to soil tillage management and cover crop. *Commun. Soil. Sci. Plant Anal.* 25:2501-2512.
- Nwaja, V.N., J.B. Masiunas, and C.E. Eastman. 1996. Rye (*Secale cereale* L.) and hairy vetch (*Vicia villosa* Roth) intercrop management in fresh market vegetables. *J. Amer. Soc. Hort. Sci.* 121:586-591.
- Patterson, D.R., J.D. Downes, N.H. Peck, H. Ozaki, K.B. Tyler, and S.C. Wiggans. 1966. Effects of nitrogen on yield, quality, and mineral uptake of Harvester snap beans. *Texas Agr. Expt. Sta. Bul.* MP-808.
- Phatak, S.C. 1992. An integrated sustainable vegetable production system. *HortScience* 27:738-741.
- Phillips, S.H. 1984. Introduction, p. 1-10. In: R.E. Phillips, and S.H. Phillips (eds.). *No-tillage agriculture, principles and practices*. Van Nostrand Reinhold, New York.
- Piggott, T.J. 1986. Vegetable crops, p. 132-185. In: D.J. Reuter and J.B. Robinson (eds.). *Plant analysis: An interpretation manual*. Inkata Press, Melbourne, Australia.
- Rutgers Cooperative Extension. 1997. Commercial vegetable production recommendations. New Brunswick, N.J.
- SAS Institute. 1996. SAS/STAT software changes and enhancements through release 6.11. SAS Inst., Cary, N.C.
- Skarphol, B.J., K.A. Corey, and J.J. Meisinger. 1987. Response of snap beans to tillage and cover crop combinations. *J. Amer. Soc. Hort. Sci.* 112:936-941.
- Stansell, J.R. and D.A. Smittle. 1980. Effects of irrigation regimes on yield and water use of snap bean (*Phaseolus vulgaris* L.). *J. Amer. Soc. Hort. Sci.* 105:869-873.
- Teasdale, J.R. and A. Abdul-Baki. 1997. Growth analysis of tomatoes in black polyethylene and hairy vetch production systems. *HortScience* 32:659-663.
- Tu, J.C. and B.R. Buttery. 1988. Soil compaction reduces nodulation, nodule efficiency, and growth of soybean and white bean. *HortScience* 23:722-724.
- Voorhees, W.B., V.A. Carlson, and C.G. Senst. 1976. Soybean nodulation as affected by wheel traffic. *Agron. J.* 68:976-979.