Broccoli Production in Cowpea, Soybean, and Velvetbean Cover Crop Mulches

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SUMMARY. Fall transplanted 'Commander' broccoli (*Brassica oleracea* Botrytis group) yield in mulches formed from the residues of killed cowpea (*Vigna unguiculata*), soybean (*Glycine max*), and velvetbean (*Mucuna pruriens*) cover crops was compared to yield in conventional production on bare soil. Average aboveground biomass production was 6.9, 7.7, and 5.9 t·ha⁻¹ (3.08, 3.43, and 2.63 tons/acre) and total nitrogen content of the aboveground tissues was 2.9%, 2.8%, and 2.7% of the dry weight for cowpea, soybean, and velvetbean, respectively. Within each cover crop mulch main plot, subplots received different nitrogen rates, [0, 84.1, or 168.1 kg·ha⁻¹ (0, 75, or 150 lb/acre)]. For several nitrogen level × year comparisons, broccoli grown in mulched plots yielded higher than broccoli grown on bare soil plots. Cowpea and soybean mulches promoted broccoli growth more than velvetbean mulch. The mulches of all three species persisted through the growing season and suppressed annual weeds.

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In recent years, there has been considerable interest in developing alternative farming practices that are sustainable and require fewer external inputs (Allen et al., 1991). Cover crops have been used widely in agriculture for soil improvement and stabilization. Traditionally, cover crops are incorporated into the soil prior to planting subsequent crops (Teasdale, 1998). Advances in no-tillage crop production have allowed the adoption of cropping practices in which cover crop residues are left on the soil surface to serve as mulch for subsequent crops. Cover crop mulches positively affect pest management by suppressing weeds and other pests and reducing runoff or groundwater infiltration of pesticides and nutrients. Mulches alone usually do not adequately suppress weeds, and other forms of weed control may be required; however, mulches in combination with non-persistent postemergence herbicides may provide adequate control, so that the use of potentially water polluting, persistent preemergence herbicides is not necessary (Teasdale and Shirley, 1998).

There are several reports of the use of cover crop mulches in cole crop production. Abdul-Baki et al. (1997a, 1997b) found that yields of fall planted broccoli grown in mulches made of the residues of soybean, foxtail millet (*Setaria italica*), or a mix of the two crops were equal to yields of the conventionally grown control. Bottenburg et al (1997) reported that yields of cabbage grown in rye (*Secale cereale*) mulch were lower than yields of conventionally produced cabbage, but the rye mulch suppressed weed growth and pest insect populations were lower in rye mulch plots than in conventional tillage plots. Schroeder et al. (1998) were unable to demonstrate a consistent benefit in broccoli yield when cowpea residue incorporated into the soil was used as a substitute for nitrogen fertilization.

The objective of this study was to evaluate under coastal South Carolina environmental conditions, cowpea, soybean and velvetbean as cover crop mulches in a production system for broccoli designed after that reported by Abdul-Baki et al. (1997a, 1997 b).

Materials and methods

A field experiment was conducted in 1997 and 1998 at the U.S. Vegetable Laboratory Research Farm at

Charleston, S.C. The soil in the fields was a Yonges loamy sand (fine-loamy mixed, Thermic Albaqualfs) with less than 1% organic matter and pHs of 6.5 in 1997 and 6.8 in 1998. Both fields were fallowed during the winter prior to planting the cover crops.

The experiment was arranged in a split-plot design with five replicates in 1997 and four replicates in 1998. Main plot treatments were cover crop species and included 'Iron Clay' cowpea (Cross Seed Co., Charleston, S.C.), soybean, velvetbean (Adams-Briscoe Seed Co., Jackson, Ga.), and a control that was maintained free of vegetation during the summer growing season. The soybean was an experimental cultivar developed by Thomas Devine at Beltsville, Md., for use as a cover crop. Prior to planting the cover crops, the soil was shaped into 1.0-m (40 inches) beds with centers spaced 2.0 m (80 inches) apart. Main plots were two beds wide and 27.4 m (90 ft) long. Subplots were one bed by 9.1 m (30 ft). One bed of each main plot was not planted in broccoli; it was used for residue biomass measurement and weed sampling. Cover crops were planted in early June of each year in two rows spaced 50.8 cm (20 inches) apart and centered on top of the beds. Seeding rates were 60, 60, and 120 kg·ha⁻¹ (53.5, 53.5, and 107.1 lb/acre) for cowpea, soybean, and velvetbean, respectively, and the seeds of each species were inoculated with the appropriate *Bradyrhizobium* strain to ensure nodulation. Metolachlor was applied preemergence to the cover crop at 1.1 kg·ha⁻¹ (1 lb/acre) over the entire area of the experiment. The cover crops were not fertilized. Two weeks prior to transplanting broccoli, the shoot biomass for the cover crops were measured on 1-m² (10.8 ft²) quadrats, and the cover crops were flattened with a stalk chopper. A tissue sample was taken from each main plot for total nitrogen determination by the Clemson University Agricultural Service Laboratory. Napropamide, oxyfluorfen, and paraquat were applied at 1.12, 0.280, and 0.56 kg·ha⁻¹ (1.0, 0.25, and 0.5 lb/acre), respectively, to kill the cover crops and provide weed control for broccoli. Prior to herbicide application a 4 × 1 m (13.1 × 3.3 ft) quadrat on the unplanted row of each main plot was covered with polyethylene film that was removed after herbicide application. The untreated quadrats were used to determine the ef-

fect of the mulches without herbicides on weed growth. Hand-weeding was used to minimize the impact of weed interference on broccoli.

'Commodore' broccoli seeds were planted into 120-cell seedling trays filled with Metro-Mix 360 (Grace Sierra, Milpitas, Calif.). The individual cells had a root volume of 40 mL (1.4 fl oz). Two or three seeds were planted per cell, and seedlings were thinned to one per cell shortly after emergence. Approximately 6 weeks after planting, broccoli seedlings were transplanted to the field manually, using forestry dibbles to make planting holes through the cover crop mulch. Transplanting dates were 28 Sept. 1997 and 22 Sept. 1998. Seedlings were planted in double rows 45.7 cm (18 inches) apart on beds and 30.5 cm (12 inches) apart within rows. Main plots were fertilized with 47.1 kg·ha⁻¹ (42 lb/acre) phosphorous and 90.8 kg·ha⁻¹ (81 lb/acre) potassium prior to transplanting, and subplots received either 0, 84.1, or 168.1 kg·ha⁻¹ nitrogen as ammonium nitrate which was applied in three equal applications at transplanting and at 3 and 6 weeks after transplanting. The 168.1 kg·ha⁻¹ nitrogen rate is the recommended rate for several southeastern states.

Aboveground cover crop residue biomass was determined on 1.0-m² quadrats at 0, 4, and 8 weeks after transplanting broccoli and aboveground weed biomasses were determined in 1.0-m² quadrats at 8 weeks after transplanting. The predominant species were corn spurry (*Spergula arvensis*), redstem filaree (*Erodium cicutarium*), and wild radish (*Raphanus raphanistrum*); however, several other species were present in the fields.

All data were subjected to analysis of variance and means were separated using the protected least significant difference (LSD) test at $P \geq 0.05$. Broccoli yield data for the 2 years were analyzed separately due to a treatment $\times$ year interaction. Cover crop and weed biomass and cover crop nitrogen contents from 2 years were combined for analysis. Linear regression analysis was used to estimate the time required for loss of 30% of the original cover crop residue biomass and to determine the effect of nitrogen rate on broccoli yield.

Results and discussion

Preemergence metolachlor in combination with the high seeding rates resulted in excellent weed control,

Table 1. Biomass and total nitrogen (N) content of the aboveground tissues of three legume cover crops.

Cover crop	Cover crop biomass (t·ha ⁻¹ dry wt) ^z	N content of biomass (% dry wt)	Total N in biomass (kg·ha ⁻¹) ^y
Cowpea	6.93	2.96	205
Soybean	7.74	2.82	218
Velvetbean	5.89	2.66	157
LSD _{0.05} ^x	1.30	NS	

^z1.00 t·ha⁻¹ = 0.446 tons/acre.

^y1.0 kg·ha⁻¹ = 0.89 lb/acre.

^xProtected least significant difference at $P \leq 0.05$ for comparing means within a column.

Table 2. Residue biomass for three legumes used as cover crop mulches in a broccoli production system at 0, 4, and 8 weeks after transplanting broccoli.

Cover crop	Residue biomass (kg·m ⁻² dry wt) ^z			Weed biomass (g·m ⁻² dry wt) ^y	
	0 weeks	4 weeks	8 weeks	Without herbicides	With herbicides
Cowpea	0.40 a ^x	0.39 a	0.22 b	23	30
Soybean	0.64 b	0.60 a	0.29 b	45	17
Velvetbean	0.51 b	0.49 ab	0.35 b	10	1
Bare soil	---	---	---	192	73
LSD _{0.05} ^w	0.12	0.15	NS	25	30

^z1.00 kg·m⁻² = 4.461 tons/acre.

^y1 g·m⁻² = 8.9 lb/acre.

^xMeans within cover crop species and year followed by the same letter are not different according to the protected least significant difference test at $P \leq 0.05$.

^w Protected least significant difference at $P \leq 0.05$ for comparing means within a column.

and few weeds were present in the cover crops when they were killed (data not presented). Soybean produced higher biomass at 7.74 t·ha⁻¹ (3.453 tons/acre) than velvetbean at 5.89 t·ha⁻¹ (2.628 tons/acre) (Table 1). Cowpea biomass at 6.93 t·ha⁻¹ (3.091 tons/acre) was intermediate and not different from soybean or velvetbean. The biomass produced by soybean was somewhat higher than the 4.7 t·ha⁻¹ (2.10 tons/acre) reported by Abdul-Baki et al. (1997a) for the same soybean cultivar. This difference may have been due to less weed interference in our experiments and to the longer growing season in South Carolina. Percent nitrogen contents of the aboveground tissues of cover crop species were not different.

Although velvetbean produced less aboveground biomass than did soybean, velvetbean residue remaining on the soil surface was not lower than that for soybean at the 4 and 8-week sampling dates (Table 2). This indicates a less rapid decay for velvetbean residue than for the other two species. To illustrate this, interpolation from linear regression lines generated using the cover crop biomass data in Tables 1 and 2 indicated that the time required for loss of 30% of the initial biomass present at the time the cover crops were killed was about 4, 6, and 9 weeks for cowpea,

soybean, and velvetbean, respectively. Velvetbean residue covered the soil surface more completely due to its trailing growth habit. Cowpea and soybean residue mulches had more patches of bare soil, which allowed annual weed growth. All three species suppressed weeds effectively to the extent that weed biomasses were lower in either mulch than in the bare soil plots in both herbicide-treated and untreated quadrats at 8 weeks after transplanting broccoli (Table 2).

Since broccoli heads were harvested soon after they reached marketable size based on diameter, head numbers, and total head weight data corresponded closely, and average head weights were not different between treatments. Therefore, head numbers and average head weights are not presented. Early yield, obtained during the first 2 weeks of the harvest, is presented separately from total yield, because the effects of the treatments on early yield are greater than their effects on total yields (Tables 3 and 4). Less vigorous appearing broccoli plants often eventually produced a marketable head, but head production was delayed in comparison plants with more vigorous appearance. Considerable variability in the yield data is reflected by the relatively large LSD ($P \geq 0.05$) values. The variability in yields observed was largely

Table 3. Early yield of broccoli grown on cowpea, soybean, and velvetbean cover crop mulches at three nitrogen (N) fertilization rates.

Cover crop	Broccoli head wt (t·ha ⁻¹) ^z					
	1997			1998		
	N fertilization rate (kg·ha ⁻¹)					
	0	84.1	168.1	0	84.1	168.1
Cowpea	0.2 b ^x	5.3 a	7.0 a	1.9 b	6.0 a	6.6 a
Soybean	1.2 b	5.7 a	6.6 a	2.3 b	4.9 a	5.5 a
Velvetbean	0.3 b	2.5 a	3.7 a	1.1 b	4.5 a	5.2 a
Bare soil	0 b	3.6 a	4.0 a	0.6 c	2.9 b	4.1 a
LSD _{0.05} ^w	0.7	2.2	1.4	1.3	1.2	NS

^z1.0 t·ha⁻¹ = 0.45 tons/acre.^w1 kg·ha⁻¹ = 0.9 lb/acre.^xMeans within cover crop species and year followed by the same letter are not different according to the protected least significant difference test at $P \leq 0.05$.^wProtected least significant difference at $P \leq 0.05$ for comparing means within a column.**Table 4. Total yield of broccoli grown on cowpea, soybean, and velvetbean cover crop mulches at three nitrogen (N) fertilization rates.**

Cover crop	Broccoli head wt (t·ha ⁻¹) ^z					
	1997			1998		
	N fertilization rate (kg·ha ⁻¹)					
	0	84.1	168.1	0	84.1	168.1
Cowpea	2.3 b ^x	6.0 a	7.6 a	4.0 b	7.2 a	7.6 a
Soybean	3.2 b	5.9 a	6.9 a	4.3 b	6.2 a	7.0 a
Velvetbean	1.7 b	4.5 a	4.6 a	2.8 b	6.6 a	7.3 a
Bare soil	0.3 b	4.6 a	5.2 a	1.5 c	4.9 b	6.2 a
LSD _{0.05} ^w	0.7	NS	1.6	1.3	1.1	NS

^z1.0 t·ha⁻¹ = 0.45 tons/acre.^w1 kg·ha⁻¹ = 0.9 lb/acre.^xMeans within cover crop species and year followed by the same letter are not different according to the protected least significant difference test at $P \leq 0.05$.^wProtected least significant difference at $P \leq 0.05$ for comparing means within a column.

due to stand losses caused by insects present in the cover crops when they were killed. Stand loss appeared to be randomly distributed, and stands were not different between main plot treatments (data not included). Although broccoli yield data were variable, some conclusions can be drawn. Overall, the legume cover crop mulches benefited broccoli by providing nitrogen needed for broccoli growth (Tables 3 and 4). Broccoli plants grown in subplots receiving no nitrogen appeared markedly less vigorous and broccoli yields were consistently lower than those receiving nitrogen fertilization. With no nitrogen fertilization, early yields for the soybean mulch plots were higher than the bare soil control in both years (Table 3). At the 84.1 kg·ha⁻¹ nitrogen rate, early yields for all three mulch treatments were higher than the control in 1998, but none were different from the control in 1997. At 168.1 kg·ha⁻¹ nitrogen, early yields in cowpea and soybeans mulches were higher than the control in 1997, but in 1998 means were not different at the high nitrogen rate.

In 1997 total yields in all cover crop mulch treatments were higher than the bare soil control, and in 1998 cowpea and soybean mulch yields were higher than the control when no nitrogen fertilizer was added (Table 4). At the 84.1 kg·ha⁻¹ nitrogen rate, total yields in all cover crop mulches were higher than the bare soil control in 1998, but were not different in 1997. At the 168.1 kg·ha⁻¹ nitrogen rate, total yield in cowpea mulch in 1997 was higher than the control. Correlation coefficients for nitrogen rate versus broccoli yield ranged from 0.91 to 0.98 ($P > 0.1$) for early yields and 0.84 to 0.98 ($P > 0.1$) for total yields (data not presented).

Conclusions

Velvetbean is a tropical legume species with a vigorous growth habit and high rates of nitrogen fixation that when used as a cover crop suppresses nematodes and weeds through allelopathy and reduces their impact on subsequent vegetables crops (Caamal-Maldonado et al., 2001; Coultas et al., 1996; Crow et al., 1996; McSorley et

al., 1994; Sipes and Arakaki, 1997). We included it in this experiment to determine if it has superior weed suppressing capability as a cover crop mulch. Although the means were not always different, the general trend indicated that broccoli did not grow as well in velvetbean mulch as in cowpea and soybean mulches. For example, yields in velvetbean mulch at the high nitrogen rate were lower than yields in cowpea or soybean mulches in 1997 (Tables 3 and 4). Velvetbean aboveground tissues contained less total nitrogen than the other two species, but this difference does not appear to be large enough to account for the difference in broccoli growth. We suspect that velvetbean may have a suppressive effect on broccoli growth due to its allelopathic properties that were demonstrated in previous reports (Caamal-Maldonado et al., 2001; Crow et al., 1996; McSorley et al., 1994). We previously reported (Keinath et al., 2003) that the incidence of wirestem disease incited by *Rhizoctonia solani* in collard (*Brassica oleracea* Acephala group) transplants was higher on velvetbean mulch than on bare soil. The occurrence of elevated disease may be due to promotion of fungal growth by the cover crop residue. However, in some instances root damage by phytotoxic chemicals released by decaying plant residues may increase infection by soilborne pathogens by weakening plants and causing lesions in the root system that allow their entry (Conklin et al., 2002). Based on these observations, cowpea and soybean may be preferable to velvetbean for use as cover crop mulch for broccoli production.

In summary, cropping systems using cowpea and soybean mulches appear to be promising for use in broccoli production in the southeastern U.S. The problem encountered with insect damage to seedlings after transplanting has been reduced in subsequent experiments by application of insecticides to the killed cover crop prior to transplanting broccoli. However, other control measures are needed in organic production systems where use of synthetic pesticides is prohibited. Two benefits provided by cowpea and soybean mulches are weed suppression and residual nitrogen so that the requirement for nitrogen fertilization is reduced. Other benefits of organic mulches that may have enhanced broccoli growth include nematode and

disease suppression, enhanced water retention and improved soil structure (Lu et al., 2000).

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