A Preliminary Study of Dual Use of Cover Crops: Sorghum Sudangrass as Both Hay and Summer Cover Crop for No-Till Organic Cabbage

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ABSTRACT

Sorghum sudangrass [*Sorghum bicolor* (L.) Moench X *S. sudanense* (Piper) Staph.] may be a suitable summer cover crop for no-till fall vegetable production, considering its potential to suppress weeds, produce high levels of biomass, and double as a hay crop. This study was conducted to identify management practices that lead to effective weed suppression by the sorghum sudangrass without negatively impacting subsequent cabbage cash crop yield and to assess the impact of residue removal on the overall production system. The experimental design was a split-plot, with main plot treatments consisting of drilled or broadcast planting of sorghum sudangrass. Subplot treatments represented four management regimes: no in-season mowing, 100 lb N/A applied prior to planting; no in-season mowing, no N applied; one in-season mowing event with residues removed from the field, 100 lb N/A applied; and one in-season mowing with residues left on the field, 100 lb N/A applied. Mowing reduced both biomass production and C:N ratio of the cover crop, and led to an increased rate of transplant survival. There was no evidence of a positive impact of N fertilization prior to cover crop planting. Cabbage yields were poor in all experimental plots in 2003. Experiments in 2004 will investigate causative factors of the poor cabbage yield and alternative cover crop management regimes to overcome negative impacts of sorghum sudangrass.

INTRODUCTION

There is a growing interest among southeastern vegetable growers, both organic and conventional, in no-till vegetable production. Conservation tillage systems offer advantages such as reduced erosion and runoff, enhanced soil moisture availability, improved crop yields, and improved efficiency in the use of fossil fuel based non-renewable resources (Coolman and Hoyt 1993). Cover crops are a common feature of no-till production systems. The benefits of cover crops are well documented and include management of runoff and soil erosion, enhanced soil fertility, weed suppression, and insect pest control (Lal *et al.* 1991). Though these features are advantageous within conventional production, cover crops are of increased importance for organic systems, and their application will increase with a rising interest in organic vegetable production.

The number of potential no-till vegetable systems appropriate to the Southeastern United States is diverse, as vegetables can be planted to benefit from a winter or summer cover crop, and many vegetable crop rotations are conducive to incorporating cover crops. Due to the economic significance of crops such as cabbage and broccoli in the region, along with prospects for increased organic production of these crops, no-till systems for fall vegetables are of particular interest. Previous research has demonstrated that no-till culture of these crops in winter cover crop residues results in yields comparable to conventional tillage systems (Knavel 1989; Morse and Seward 1986). Abdul-Baki *et al.* (1997) demonstrated that no-till fall broccoli production in summer cover crop residues also produces yields similar to conventional production systems. The use of a summer cover may allow growers to expand their production capability by producing both a spring and fall crop or an over wintered crop such as garlic or flowers, followed by a summer cover and fall crop.

Creamer and Baldwin (2000) assessed the performance of six legume, two broadleaved, and five grass species suitable for use as summer cover crops in North Carolina. Among the crops evaluated as summer cover crops in this study was sorghum sudangrass *Sorghum bicolor* (L.) Moench X *S. sudanense* (Piper) Staph. Sorghum sudangrass has the potential to produce abundant biomass, suppress weeds (Creamer and Baldwin 2000; Weston *et al.* 1989) and decrease soil compaction (Wolfe *et al.* 1998). Growers in North Carolina currently utilize sorghum sudangrass as a summer cover prior to the planting of a winter cover crop (Magdoff and van Es 2000).

Sorghum sudangrass is commonly cultivated as a forage crop for grazing, hay or silage (Chamblee *et al.* 1995). Because of its significance as a forage, there is a considerable body of literature regarding growth and management of sorghum sudangrass. The characteristics of biomass production, response to mowing frequency and stubble height, and re-growth potential are of greatest importance when determining management practices for sorghum sudangrass as a summer cover crop. Sorghum sudangrass is recognized for its high yield potential, though season biomass production is dependent on management. Increased cutting (mowing) frequency will lead to reduced seasonal biomass production (Beuerlein *et al.* 1968), though yield reductions are less severe than other grasses (Muldoon 1985). Generally, a stubble height of 6 to 8 inches is recommended to promote re-growth (Chamblee *et al.* 1995). Re-growth occurs from both terminal buds and basal and axillary tillers, a quality unique among common forage crops (Clapp and Chamblee 1970). Tillering capacity leads to an increased capacity to re-grow following cutting (Muldoon 1985) and allows re-growth from lower stubble heights (Clapp and Chamblee 1970). This is a potential drawback to the use of sorghum sudangrass in rotation with fall organic vegetables, as chemicals cannot be used to suppress re-growth if mowing is not completely effective. Study is needed to evaluate the biomass production, weed suppression, re-growth potential, and management of sorghum sudangrass within a no-till fall vegetable production system.

In addition to providing a base for no-tillage organic vegetable crop production, sorghum sudangrass may be harvested as a hay crop (Chamblee *et al.* 1995). Managing the summer cover crop to allow for a mid-season hay harvest may provide an additional income source for growers. Supplies of organic hay in North Carolina are limited and demand is expected to rise with the adoption of federal organic standards by dairy and livestock producers. The impact of cover crop removal as hay on cabbage yield and weed suppression, however, must be investigated as an initial step in the development of such a cover crop management system.

The objective of this study was to determine the best management practices, including N fertilization, planting method, cutting frequency, and residue management, for sorghum sudangrass grown as a summer cover crop preceding organic no-till production of fall cabbage. Optimal management and the impact of residue removal as hay were assessed based on cover crop biomass production, cover crop re-growth, cover crop C:N, weed biomass, and cabbage stand establishment and yield.

MATERIALS AND METHODS

This study was conducted at the Center for Environmental Farming Systems in Goldsboro, North Carolina in 2003 and will be repeated in 2004. The experimental design was a split-plot with four replications. There were two main plots per block, drilled and broadcast sorghum sudangrass. Drilled plots were planted on 9 June 2003 using a Sukup drill. Initial attempts to broadcast sorghum sudangrass using a Brillion seeder with cultipacker resulted in poor stands. In two attempts using this method, birds were observed eating seeds, indicating a need for improved incorporation. In addition, the hard seed coat and large size of sorghum sudangrass may have contributed to poor stand establishment. In order to improve seed incorporation, a field conditioner (a shallow tillage implement) was used to bury seed following planting with a hand seeder. As a result, broadcast stands were not established until 26 June 2003. Due to the number of growers that rely on broadcast planting of cover crops, the results of this trial are of interest. Sorghum sudangrass may not be well-suited to this planting method, though shallow tillage does appear to improve stand establishment following broadcasting.

Plots were planted at a rate of 43 lb/A of untreated sorghum sudangrass ‘Haychow’ seed. Following planting, each plot was divided into four sub-plots (10’ x 25’) representing the four cover management systems listed in Table 1. Prior to planting sorghum sudangrass, 2080 lb/A soybean meal was applied by hand to appropriate plots and all plots were lightly tilled to incorporate fertilizer and remove weeds. Additionally, 2 lb/A of Solubor were applied prior to planting.

Treatments which included in-season mowing were flail mowed to a 6¨stubble height when plants reached a height of 48”. Prior to mowing duplicate biomass samples were taken from each sub-plot using a 2’x 2’ frame. Aboveground biomass was sorted into crop and weed, dried at 120°F for at least 48 hours, and weighed. Sub-samples of cover crop biomass were analyzed for forage quality and C and N concentration.

On 18 August 2003 the sampling procedure above was repeated in all plots, excluding forage analysis. Sub-plots were flail mowed to a stubble height of 1” or lower on 26 August. Immediately following mowing, a sub-surface tiller transplanter was used to transplant ‘Bravo’ cabbage plugs. Cabbage was planted in 30” double rows, with an intra-row spacing of 12”. An Organic Materials Review Institute (OMRI)-certified 4-2-4 fertilizer was applied in the furrow at the time of planting at a rate of 2300 lb/A. Due to poor cabbage establishment, mowing and transplanting were repeated on 4 September. Stand establishment was recorded 7 days after planting, and cabbage was managed following federal organic standards throughout the growing season. Re-growth of sorghum sudangrass was monitored throughout the season, with a count taken 2 weeks after planting (WAP) and between row biomass sampled at 6 WAP. Prior to cabbage harvest on 25 November, in-row sorghum sudangrass re-growth and weed biomass were sampled using a 2’x 2’ frame. Samples were dried and weighed, and re-growth analyzed for C and N concentration. Cabbage was harvested from two ten foot rows per plot on 2 December dried at 120°F for at least 48 hours and weighed. Data were analyzed using analysis of variance procedures for a split-plot design ($P \leq 0.05$).

RESULTS AND DISCUSSION

Cover Crop Biomass Production

Biomass production was affected by both planting method and management treatment (Table 2). Cumulative biomass production was significantly higher in drilled (4.40 t/A) than in broadcast plots (2.87 t/A); however results are confounded by the later planting date of the broadcast treatment which likely reduced biomass production in those plots. The interaction between planting method and management system led to significant differences between management systems only in drilled plots. Again, this interaction may have been due to the truncated growth period of sorghum sudangrass in broadcast plots. Within drilled plots, mowing led to reductions in biomass production compared to the unmowed system with similar fertility. This is consistent with earlier findings that mowing decreases overall season production (Beuerlein *et al.* 1968).

Biomass production following cover crop kill did not vary with planting method or management treatment (data not shown). Mowing did, however, reduce the number of actively growing stems at two weeks after cabbage transplanting compared to the unmowed system with similar fertility (Table 3). As there was not a significant effect of planting method on re-growth at 2 WAP or an interaction of planting method and cover management, means presented represent averages across planting method. Variation between cover management systems may have been due to reduced plant vigor caused by mowing.

Cover Crop C:N

Both planting method and management system had a significant impact on the cover crop C:N ratio (Table 4). The C:N ratio of sorghum-sudangrass in drilled plots was higher (68) than in broadcast plots (53), though this variation was likely due to differences in planting date. Unmowed treatments had a higher C:N ratio than mowed treatments at the end of the cover crop growing season. By the end of the cabbage growing season, the C:N ratio of the sorghum sudangrass residues was no longer different between management systems and averaged 32 (data not shown).

Regardless of planting method, the C:N ratio of sorghum sudangrass prior to cash crop planting was significantly lower in mowed plots than in unmowed plots. Plants mowed at mid-season were in a vegetative growth stage at the time of final mowing (data not shown), leading to a lower C:N ratio. Considering the likelihood of net N immobilization at higher C:N ratios, mowing may lead to more rapid net N mineralization during the cash crop growing season.

Weed Suppression

Weed populations were negligible throughout the growing season (Table 2), indicating that sorghum sudangrass effectively suppressed weed populations. Though populations were minimal, weed biomass did vary with both planting method and management system. Weed biomass was greater in drilled (0.49 lb/A) than in broadcast plots (0.23 lb/A) at the end of the sorghum sudangrass growing season. Due to the interaction between planting method and management system, a significant effect of treatment was present only in drilled plots. Within drilled plots, weed biomass was higher in mowed than unmowed plots, perhaps due to canopy removal by mowing. Comparing residue management in mowed systems, plots from which residues were removed had a greater weed biomass than those in which residues remained on the field, an indication that residue removal as hay may lead to increased weed populations.

Cabbage Stand Establishment

Cabbage stand establishment was not influenced by planting method, though variation in percent transplant survival did exist between management systems across planting method.

There was a weak negative correlation ($R=-0.51304$, $p=0.0027$) between cover crop biomass and cabbage stand count, indicating that higher residue biomass may decrease transplant survival. Observations made during the transplant operation indicate that high levels of residue had a tendency to cause residues to build up on cutting implements and drag. This build up, in turn, was observed to cause poor closure of planting furrows and intercepted fertilizer delivery. Knavel and Herron (1985) reported a similar interference for fall cabbage transplants set with a no-till transplanter into sudangrass residues. Proper adjustment of transplanting equipment may mediate this problem.

Cabbage Growth

No marketable heads were produced in this trial. Though a number of factors not analyzed in this trial may have contributed to crop failure, it is likely that sorghum sudangrass re-growth interfered with crop growth. Statistical analysis did not detect a correlation between cabbage dry weight and re-growth density or biomass. However, Weaver (1984) demonstrated that cabbage must be free of weeds for three weeks following planting to avoid yield reduction, and re-growth of sorghum sudangrass was present at 2 weeks after planting. Other studies have shown that persistence and accumulation of re-growth biomass can contribute to cabbage yield loss (Lawson and Wiseman 1978, Brandsæster *et al*. 1998; Nicholson and Wein 1983, Bottenberg *et al*. 1997).

In addition to competing with cabbage for light, nutrients, and water, sorghum sudangrass re-growth may have inhibited cabbage growth through allelopathy. Actively growing sorghum sudangrass exudes sorgoleone (Rimando *et al.* 1998) and other organic acids that have been demonstrated to inhibit seed germination and seedling growth (Weston *et al*. 1989) and reduce growth of transplants (Geneve and Weston 1988). Sorghum sudangrass residues also have allelopathic potential, but may not be as suppressive as living plants. There are no studies of the response of cabbage to sorghum sudangrass allelochemicals, though cabbage is sensitive to other allelopathic species (Qasem 2001).

Forage Analysis

Forage analysis was performed on clippings from one mowed system in the drilled plots, as clippings represent a potential hay crop. The crude protein value of 14.3% and total digestible nutrient value of 64.9% were above the range for high quality forage for ruminants recommend by the North Carolina Cooperative Extension Service (Table 6), indicating that clippings were of saleable quality.

SUMMARY

Planting Method, Mowing, and Fertilization of Sorghum Sudangrass

Due to poor stand establishment using conventional broadcast planting methods, broadcast plots were planted more than two weeks later than drilled plots. Results concerning the significance of planting method are, therefore, confounded by the difference in age of sorghum sudangrass. Sorghum sudangrass may not be readily adaptable to broadcast seeding, though shallow tillage can help to improve stand establishment.

The results of this study indicate that mowing sorghum sudangrass during its summer growing season may be advantageous to no-till organic fall vegetable production. Mowing leads to a lower C:N ratio of residues at the time of transplanting, potentially limiting N immobilization. Sorghum sudangrass biomass reduction due to mowing may also promote transplant survival and did not appear to have a negative impact on weed suppressive qualities of the cover crop.

With regard to fertility management of the summer cover crop, results obtained in 2003 provide no evidence of an advantage to N fertilization of the cover crop prior to planting. As the application of soybean meal can provide additional nitrogen to the subsequent crop, continued studies of nutrient dynamics within the system with and without pre-cover crop N fertilization would be valuable.

Impact of Residue Removal as Hay

As weed pressure was inconsequential in all management systems, this study provided no evidence of a negative impact of residue removal following in-season mowing on weed suppressive qualities of sorghum sudangrass. Due to crop failure, no assessment of the impact of residue removal on crop yield can be made. Future study should include an economic analysis of cover crop harvest for hay.

Further Study

Repetition of this study in 2004 will provide more conclusive results regarding best management practices for sorghum sudangrass as a summer cover/hay crop. Results thus far suggest that sorghum sudangrass may not be a suitable summer cover crop for no-till organic fall vegetable production, largely due to crop persistence following mowing. Limiting sorghum sudangrass re-growth appears to be essential for the system to be successful. Two possible strategies to limit re-growth are increased mowing and effective mechanical kill. The effect of increased mowing on re-growth capacity should be investigated. Further study of alternative mechanical methods to provide a more consistent and effective means of killing the cover crop also merit investigation. Another concern with the use of sorghum sudangrass in a no-till system is its allelopathic potential. Investigations to elucidate the allelopathic interaction of both sorghum sudangrass re-growth and residues with transplants are needed to determine if sorghum sudangrass is detrimental to no-till fall vegetable culture.

REFERENCES

Abdul-Baki, A.A., R.D. Morse, T.E. Devine, and J.R. Teasdale. 1997. Broccoli production in forage soybean and foxtail millet cover crop mulches. HortScience 32(5):836-839.

Beuerlein, J.E., H.A. Fribourg, and F.F. Bell. 1968. Effects of environment and cutting on regrowth of a sorghum-sudangrass hybrid. Crop Science 8:152-155.

Bottenberg, H., J. Masiunas, C. Eastman, and D. Eastburn. 1997. Yield and quality constraints of cabbage planted in rye mulch. Biological Agriculture and Horticulture 14:323-342.

Brandsaester, L.O., J. Netland, and R. Meadow. 1998. Yields, weeds, pests and soil nitrogen in a white cabbage-living mulch system. Biological Agriculture and Horticulture 16(3)291-309.

Chamblee, D.S., J.T. Green, and J.C. Burns. 1995. Principle forages of North Carolina: adaptation, characteristics, management, and utilization, p. 25-47. In D.S. Chamblee and J.T. Green (eds.). Production and Utilization of Pastures and Forages in North Carolina. North Carolina Agricultural Research Service, Technical Bulletin No. 305.

Clapp, J.G. and D.S. Chamblee. 1970. Influence of different defoliation systems on the regrowth of pearl millet, hybrid sudangrass, and two sorghum-sudangrass hybrids from terminal, axillary, and basal buds. Crop Science 10:345-349.

Coolman, R.M. and G.D. Hoyt. 1993. The effects of reduced tillage on the soil environment. HortTechnology. 3(2):143-145.

Creamer, N.G. and K.R. Baldwin. 2000. An evaluation of summer cover crops for use in vegetable production systems in North Carolina. HortScience 35(4):600-603.

Geneve, R.L. and L.A. Weston. 1988. Growth reduction of eastern redbud (*Cercis canadensis* L.) seedlings caused by interaction with a sorghum-sudangrass hybrid (sudex). Journal of Environmental Horticulture 6(1):24-26.

Knavel, D.E. 1989. Double-cropping fall cabbage by no-tillage and conventional systems. Applied Agricultural Research 4(4):270-274.

Knavel, D.E. and J.W. Herron. 1985. Effect of sudan grass on yield and elemental content of cabbage. HortScience 20(4):680-681.

Lal, R., E. Regnier, D.J. Eckert, W.M. Edwards, and R. Hammond. 1991. Expectations of cover crops for sustainable agriculture. In W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conservation Society, Ankeny, IA. pp. 1-11.

Lawson, H.M., and J.S. Wiseman. 1978. Competition between weeds and transplanted spring cabbage: effects of selective weed removal. Horticultural Research 18:113-126.

Magdoff, F. and van Es H. 2000. Building soils for better crops, 2nd Ed. Sustainable Agriculture Network: Beltsville, MD.

Morse, R.D. and D.L. Seward. 1986. No-tillage production of broccoli and cabbage. Applied Agricultural Research 1(2):96-99.

Muldoon, D.K. 1985. Summer forages under irrigation 1. Growth and development. Australian Journal of Experimental Agriculture 25: 392-401.

Nicholson, A.G., and H.C. Wien. 1983. Screening of turfgrasses and clovers for use as living mulches in sweet corn and cabbage. Journal of the American Society of Horticultural Science 108(6)1071-1076.

Qasem, J.R. 2001. Allelopathic potential of white top and Syrian sage on vegetable crops. Agronomy Journal 93(1):64-71.

Rimando, A.M., F. E. Dayan, M.A. Czarnota, L.A. Weston, and S.O. Duke. 1998. A new photosystem II electron transfer inhibitor from *Sorghum bicolor.* Journal of Natural Products 61:927-930.

Weaver, S.E. 1984. Critical period of weed competition in three vegetable crops in relation to management practices. Weed Research 24:317-325.

Weston, L.A., R. Harmon, and S. Mueller. 1989. Allelopathic potential of sorghum-sudangrass hybrid (Sudex). Journal of Chemical Ecology 15(6):1855-1865.

Wolf, D.W., G. Abawi, L. Pederson, D. Riggs, L. Stivers-Young, and H. van Es. 1998. Management strategies for improved soil quality with emphasis on soil compaction. Cornell University Dept. of Fruit and Vegetable Sci. Report No. 72.

Table 1. Sorghum sudangrass management systems applied at Goldsboro, NC, in 2003.

#	Cut 1†	Cut 2	N applied‡
1	None	End of season, 1" stubble height residues left on field	100 lbs/acre
2	None	End of season, 1" stubble height residues left on field	None
3	At 48", 6" stubble height residues removed from field	End of season, 1" stubble height residues left on field	100 lbs/acre
4	At 48", 6" stubble height residues left on field	End of season, 1" stubble height residues left on field	100 lbs/acre

†In drilled plots, cut 1 occurred on 9 July 2003 (29 DAP). Cut 1 in broadcast plots occurred on 28 July 2003 (32 DAP). Cut 2 occurred in all plots on 18 August 2003.
‡N was applied on 5 June 2003.

Table 2. Aboveground biomass for sorghum sudangrass and weeds on 18 August 2003 in relation to planting method and cover crop management at Goldsboro, NC.

Planting method	Cover management	Cover biomass: (t/A) cut 1	cut 2	total	Weed biomass (lb/A)
Drilled	End of season cut w/ N		5.72	5.72a†	0.155c‡
	End of season cut w/o N		5.21	5.21ab	0.250c
	Mid & end of season cuts w/ N, residues removed	1.85	1.16	3.00c	0.995a
	Mid & end of season cuts w/ N, residues left	1.87	1.78	3.65bc	0.545b
Broadcast	End of season cut w/ N		3.31	3.31	0.177
	End of season cut w/o N		2.61	2.61	0.214
	Mid & end of season cuts w/ N, residues removed	2.68	0.51	3.19	0.085
	Mid & end of season cuts w/ N, residues left	1.75	0.61	2.37	0.442
Mean values:					
Drilled				4.40a	0.486a
Broadcast				2.87b	0.230b
Treatment effects:					
Planting method				**	*
Cover management				**	*
Planting method x cover management				**	*

†Mean values followed by the same letter are not significantly different (P = 0.05) according to pairwise comparisons using Fisher's LSD.
‡LSD applied to square root-transformed data

Table 3. Sorghum-sudangrass re-growth averaged over planting method at 2 weeks after cabbage transplanting on 18 September 2003 in Goldsboro, NC.

Cover management	stems/ft^2
End of season cut w/ N	6.6a†
End of season cut w/o N	6.5ab
Mid & end of season cuts w/ N, residues removed	4.1c
Mid & end of season cuts w/ N, residues left	4.4bc

†Mean values followed by the same letter are not significantly different (P = 0.05) according to pairwise comparisons using Fisher's LSD.

Table 4. C:N ratio of sorghum-sudangrass biomass at the end of summer growth season from samples collected on 18 August 2003 at Goldsboro, NC.

Planting method	Cover management	C:N
Drilled	End of season cut w/ N	81a†
	End of season cut w/o N	100a
	Mid & end of season cuts w/ N, residues removed	44b
	Mid & end of season cuts w/ N, residues left	45b
Broadcast	End of season cut w/ N	83a
	End of season cut w/o N	80a
	Mid & end of season cuts w/ N, residues removed	23b
	Mid & end of season cuts w/ N, residues left	28b
Mean values:		
Drilled		68a
Broadcast		53b
	End of season cut w/ N	82a
	End of season cut w/o N	90a
	Mid & end of season cuts w/ N, residues removed	33b
	Mid & end of season cuts w/ N, residues left	37b
Treatment effects:		
Planting method		**
Cover management		**
Planting method x cover management		NS

†Mean values followed by the same letter are not significantly different (P = 0.05) according to pairwise comparisons using Fisher's LSD.

Table 5. Percent cabbage transplant survival averaged over planting method at 1 week after planting on 11 September 2003 in Goldsboro, NC.

Management system	% transplant survival
End of season cut w/ N	63c†
End of season cut w/o N	71bc
Mid & end of season cuts w/ N, residues removed	86a
Mid & end of season cuts w/ N, residues left	80ab

†Mean values followed by the same letter are not significantly different (P = 0.05) according to pairwise comparisons using Fisher's LSD.

Table 6. Forage quality indicators for ruminants and experimental forage analysis for clippings from drilled plots on 9 July 2003 at Goldsboro, NC.

Forage type	High quality†	Average quality	Low quality	Experimental
Grass	CP 12-14% TDN 57-60%	CP 9-11% TDN 54-57%	CP below 7% TDN below 54%	CP 14% TDN 65%

†Indicators published by North Carolina Cooperative Extension