Suitability of Sunn Hemp as an Alternative Late-Summer Legume Cover Crop

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ABSTRACT

The tropical legume 'Tropic Sun' sunn hemp (*Crotalaria juncea* L.) may have potential as an alternative legume cover crop or as forage for cattle in southern temperate regions. This study determined dry-matter production, chemical composition, and N release from sunn hemp residue under conventional and no-tillage systems as might be used in corn (*Zea mays* L.) production. Sunn hemp was sown in mid-August and mowed in early December on a Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Kandiudult) and a Lucedale fine sandy loam (fine-loamy, siliceous, thermic Rhodic Paleudult) in Alabama (1991-1992). Mesh bags were used to determine residue decomposition and N release. Average dry-matter production was 5.9 Mg ha^{-1} 9 to 12 wk after planting. At mowing, residue N content averaged 126 kg ha^{-1}. Residue overwintered on the soil surface until early April. During the first 4 wk following mowing, N release from residue was 50%. In April, N remaining in overwintered residue was only 38% of that after mowing in December (45 kg N ha^{-1}). Nitrogen release from residue during the subsequent corn growing season was 13% in no-tillage and 43% in conventional tillage. Sunn hemp produced sufficient dry matter to cover and protect the soil from erosion and provided sufficient N to benefit a succeeding summer crop. In addition, forage quality of leaves was suitable to provide late summer and fall grazing. Sunn hemp has potential to be managed as an alternative to winter legume cover crops in warm temperate regions.

BESIDES FURNISHING N, winter legume cover crops can improve soil physical properties, reduce soil erosion, conserve soil water, and recycle plant nutrients, increasing crop yield potential and soil productivity (Smith et al., 1987; Frye and Blevins, 1989; Reeves, 1994). The practical use of winter legume cover crops, however, is often limited by asynchronization of cover crop planting windows and biomass accumulation with planting windows for summer cash crops. For example, to allow winter legume cover crops adequate growing time before cold temperatures occur, summer crops may need to be harvested prior to optimum conditions. Delayed planting date of summer cash crops is also often necessary to allow winter legume cover crops adequate time to produce biomass and accumulate N. Early harvest and late planting may reduce yields of summer cash crops.

Biomass production, chemical composition, and N accumulation of legume cover crops varies widely depending on legume species, stage of growth, environmental conditions, edaphic conditions, and crop management (Wagger, 1989; Yadvinder et al., 1992; Reeves, 1994). Adapted tropical legumes may produce more biomass than winter legume cover crops in a temperate climate. Yadvinder et al. (1992) reported that tropical legumes produced 2.9 to 8.9 Mg dry matter ha^{-1} by 50 to 60 d after planting, compared with winter legumes that produced 1.7 to 6.7 Mg dry matter ha^{-1} when grown during November to May. Thus, an alternative to winter annual legume cover crops may be adapted tropical legumes that quickly produce biomass to provide soil cover and accumulate N. Such legumes might also be used as forage for cattle during late summer and fall.

One tropical legume that may be adapted to residue management systems in the Southeast is sunn hemp. Sunn hemp has been used extensively for soil improvement or green manuring in the tropics (Lales and Mabbayad, 1983). This *Crotalaria* species is nontoxic and can be used as a forage as well as a green manure (Rotar and Joy, 1983, p. 1-7). Although not winter hardy, sunn hemp may produce sufficient biomass during the fall (until frost) to provide ground cover and N to a following summer cash crop in southern temperate regions. The sunn hemp cultivar Tropic Sun was jointly released by the U.S. Department of Agriculture, Natural Resources Conservation Service, and the University of Hawaii, Hawaii Institute of Tropical Agricultural and Human Resources, Department of Agronomy and Soil Science (Rotar and Joy, 1983, p. 1-7).

Nitrogen release from crop residues is not only dependent on environmental and edaphic factors, e.g., temperature, water, and aeration, but is influenced by residue type, quality, placement, and degree of incorporation in soil (Huntington et al., 1985; Muller et al., 1988; Wagger, 1989; Aulakh et al., 1991; Yadvinder et al., 1992; Varco et al., 1993). Some studies in no-tillage systems have shown poor synchronization between N release via cover crop mineralization and crop N uptake. In Georgia, Wilson and Hargrove (1986) found that N release from crimson clover (*Trifolium incarnatum* L.) was more rapid under conventional tillage than no-tillage. In another study, Huntington et al. (1985) reported that N mineralized from a hairy vetch (*Vicia villosa* Roth.) cover crop became available to no-tillage corn only after silking.

This study was conducted to determine the suitability of late-summer-planted Tropic Sun sunn hemp as a green manure and cover crop for summer grain production systems in warm temperate zones, as in the southeastern USA. Specific objectives were to: (i) determine total biomass production, N and C accumulation, and chemical composition of sunn hemp during a period extending from corn harvest until the first killing freeze (September-November); (ii) determine soil coverage by the overwintering residue; and (iii) determine N release from overwintered (December–March) sunn hemp residue under

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Abbreviations: WAP, weeks after planting; ADF, acid-detergent fiber; NDF, neutral-detergent fiber; PL, permanganate lignin; EVS, E.V. Smith Research Center; MEF, Monroeville Experiment Field.

no-tillage and conventional tillage during the period when a subsequent summer grain crop would be grown.

MATERIALS AND METHODS

This research consisted of two studies. The first study determined biomass, N accumulation, and chemical composition of Tropic Sun sunn hemp used as a cover crop. That study was conducted at the EVS of the Alabama Agricultural Experiment Station, Shorter, AL, on a Norfolk sandy loam in fall of 1991 and at both EVS and the MEF, Monroeville, AL, on a Lucedale fine sandy loam in fall of 1992.

The second study was conducted at EVS to determine decomposition of overwintered sunn hemp residue under no-tillage and conventional tillage during spring and summer 1992, corresponding to the period when corn would normally be grown. Our objectives were focused on decomposition and N release from overwintered residue, as this residue would be what a grower would "start with" in a summer grain production system. However, after observing the rapid decomposition of leaf tissue during the winter of 1991-1992, we wanted to determine residue decomposition and N release of the mowed residue during the winter, prior to the period when a summer grain crop would be planted. Therefore, decomposition of sunn hemp residue was also examined at both EVS and MEF during the winter season of 1992-1993. In addition, soil coverage by overwintering sunn hemp residue was determined during the period from fall of 1992 into spring of 1993.

Sunn Hemp Biomass and Nitrogen Accumulation

On 16 Aug. 1991, sunn hemp was sown following conventional tillage (moldboard plowing, disking, and leveling) at EVS. In 1992, sunn hemp was sown using conventional tillage at EVS on 2 September and at MEF on 18 August. These dates corresponded to a feasible sowing time for cover crops following summer corn harvest.

Sunn hemp seed was inoculated with cowpea [*Vigna unguiculata* (L.) Walp.] type rhizobium and drilled at 56 kg ha^{-1}, 2 to 4 cm deep. The experimental design was a randomized complete block with eight replications. Aboveground sunn hemp herbage was harvested at 3, 6, 9, and 12 WAP or until fall freeze killed the plants. Dry matter production was determined by collecting two samples from each plot within a 0.25-m^2 area at each sampling date. Whole plants were separated into a fraction containing leaves and flowers (leaves) and a fraction containing stems and petioles (stems). Leaf and stem fractions were oven dried at 55°C for 72 h. After weighing, the plant fractions were ground to pass a 1-mm screen.

Biomass production, N and C concentration, C/N ratio, cellulose, hemicellulose, and lignin of each fraction were determined. Plant samples were analyzed for total N and C using a Leco CHN-600 C-H-N analyzer[1] (Leco Corporation, St. Joseph, MI). Lignin, hemicellulose, and cellulose were determined using NDF, ADF, and PL procedures described by Goering and van Soest (1970, p. 1-20). The NDF fraction contains cellulose, hemicellulose, and lignin. Hemicellulose was calculated as the difference between NDF and ADF values. Lignin was calculated as weight loss from the PL procedure and cellulose was determined as weight loss upon ashing following the PL procedure.

Sunn Hemp Residue Decomposition

On 24 Mar. 1992, at EVS, sunn hemp residue that had been mowed in early December 1991and left in place in the field during winter was collected, cleaned of loose soil particles, and air dried in a greenhouse. Twenty-gram subsamples of residue were placed in 15 by 30 cm nylon mesh bags, having 1-mm openings and 57% open area. The 20-g residue subsample size was based on the average residue weight for a 15 by 30 cm area, corresponding to the bag size. Mesh bags were placed in the field on 17 Apr. 1992, which is within the normal planting window for corn grown in the Southeast. Although the litter bag technique has limitations, i.e., influence of mesh size on nutrient losses, exclusion of certain macroinvertebrates from feeding on bag contents, and creation of a somewhat artificial microclimate, it is still widely used and provides useful relative comparisons for residue decomposition and nutrient cycling (St. John, 1980; Wieder and Lang, 1982).

The experimental design was a split plot with four replications. Main plots were no-tillage and conventional-tillage residue management systems that would have been used for a corn crop following sunn hemp. Overwintered residue that had been mowed and left on the soil surface from December until April was left in place in no-tillage plots. In conventional-tillage plots, the residue was disked into the soil (15-cm depth).

Subplots were sampling dates of 0, 1, 2, 4, 8, and 16 wk for bag retrieval. Bags were placed on the surface of no-tillage plots or buried to the plow layer depth (10-15 cm) in conventional-tillage plots. Glyphosate [*N*-(phosphonomethyl) glycine] was used to keep the area weed-free during the study.

Collected bags were carefully cleaned to remove soil. Residue material inside each bag was oven dried at 55°C for 72 h, and then weighed. Samples were ground to pass a 1-mm screen with a Wiley mill. Total N and C content were determined using a Leco CHN-600 analyzer. To minimize the effects of soil contamination, residue weights were calculated on an ash-free basis after determining ash contents of 1-g subsamples from each bag ashed at 550°C for 4 h in a muffle furnace.

Soil samples (15-cm depth) were collected from each plot each time mesh bags were taken from the field. Ammonium-N and NO_3-N from each sample was determined using standard colorimetric techniques on an autoanalyzer (Keeney and Nelson, 1982).

Decomposition of sunn hemp residue during winter 1992-1993 was also examined at both EVS and MEF. Plant samples were harvested from the field 9 WAP. Based on data from 1991, N content and biomass in plant parts was near maximum at this time. Plant samples were air dried and weighed. On 15 Dec. 1992 at EVS and 8 Dec. 1992 at MEF, sunn hemp was mowed and the residue was left on the soil surface. Twenty-gram subsamples of residue containing 30% leaves and 70% stems by mass (actual ratio of plant parts sampled at 9 wk) were placed in nylon mesh bags (15 by 30 cm) and placed within the mowed residue on the soil surface.

The experimental design was a randomized complete block with eight replications. Bags were collected at 0, 1, 2, 4, 8, and 16 wk after placement. Upon collection, bagged samples were cleaned, dried, weighed, and ground to pass a 1-mm screen. Residue weights were corrected to an ash-free basis and total N and C were determined as previously described. Soil samples were taken to a 15-cm depth from each plot every time mesh bags were collected. Ammonium-N and NO_3-N were determined as described above.

[1]Reference to a trade or company name is for specific information only and does not imply approval or recommendation of the company by the USDA or Auburn University to the exclusion of others that may be suitable.

Soil Coverage

Percentage ground cover provided by sunn hemp residue was determined on 15 Dec. 1992, 9 Feb. and 6 Apr. 1993 at EVS, and on 8 Dec. 1992, 2 Feb. and 30 Apr. 1993 at MEF. Ground cover measurements corresponded to 0, 8, and 16 wk after mowing the sunn hemp. Ten slide photographs were randomly taken from the experimental area. A tripod was set at the same spot and at the same height each time pictures were taken. Percentage of ground covered by residue was determined by projecting slides on the wall at a fixed distance, and noncovered areas traced on acetate with a permanent marker. The cut-out acetate was then processed through a leaf area meter (Model LI-3100, LI-COR, Ft. Worth, TX).

Statistical Analyses

Data were subjected to analysis of variance and regression analyses using the Statistical Analysis System (SAS Institute, 1988; Littell et al., 1991). Nonlinear models were fitted using TableCurve (Jandel Scientific, San Rafael, CA 94901). Models were selected based on F statistics ($P \leq 0.05$). In all cases the simplest model that best fit the data was used.

RESULTS AND DISCUSSION

Dry Matter Production

Dry matter production varied by site-year and sample date (Fig. 1, $P \leq 0.01$). Sunn hemp biomass 12 WAP averaged 7.3 and 4.8 Mg ha^{-1} at EVS in 1991 and 1992, respectively, and 5.7 Mg ha^{-1} at MEF in 1992. Average sunn hemp biomass production for the three site-years (5.9 Mg ha^{-1}) was comparable to reported values for the two most common cover crops in the southeastern USA, i.e., hairy vetch (4.9 Mg ha^{-1}; Touchton et al., 1984) and crimson clover (5.0 Mg ha^{-1}; Reeves et al., 1993). Sunn hemp growth was reduced at MEF in 1992 (92 kg ha^{-1}) 3 WAP compared with EVS both in 1991 (485 kg ha^{-1}) and 1992 (405 kg ha^{-1}). This was probably due to less rainfall at MEF during the 2-wk period immediately following planting. For all site-years, after 3 wk, sunn hemp grew rapidly until 9 WAP (late October) and then slowed as temperatures declined.

During the first 3 wk, sunn hemp produced more leaf than stem dry matter. In contrast, stem dry matter increased faster than leaves following 6 WAP. Total dry matter at 6 WAP ranged between 1.2 and 3.5 Mg ha^{-1}. These values agree with those reported by Yadvinder et al. (1992) for dry matter production by tropical legumes (ranging from 1.3–4.9 Mg ha^{-1} 6–7 WAP).

Sunn hemp began blooming 5 to 6 WAP at EVS in 1991, 6 WAP at EVS in 1992, and 6 to 7 WAP at Monroeville in 1992. However, no seed pods were produced before plants were killed by frost. Average plant height of sunn hemp was 1.2 and 1.7 m at 9 and 12 WAP, respectively. Rotar and Joy (1983, p. 1–7) reported that Tropic Sun sunn hemp grew rapidly in Hawaii and achieved a height of 1.2 m 60 d after planting and 1.8 m 90 d after planting.

Nitrogen Accumulation

Nitrogen concentration was higher in leaf than stem fractions (Table 1). Nitrogen concentration is typically

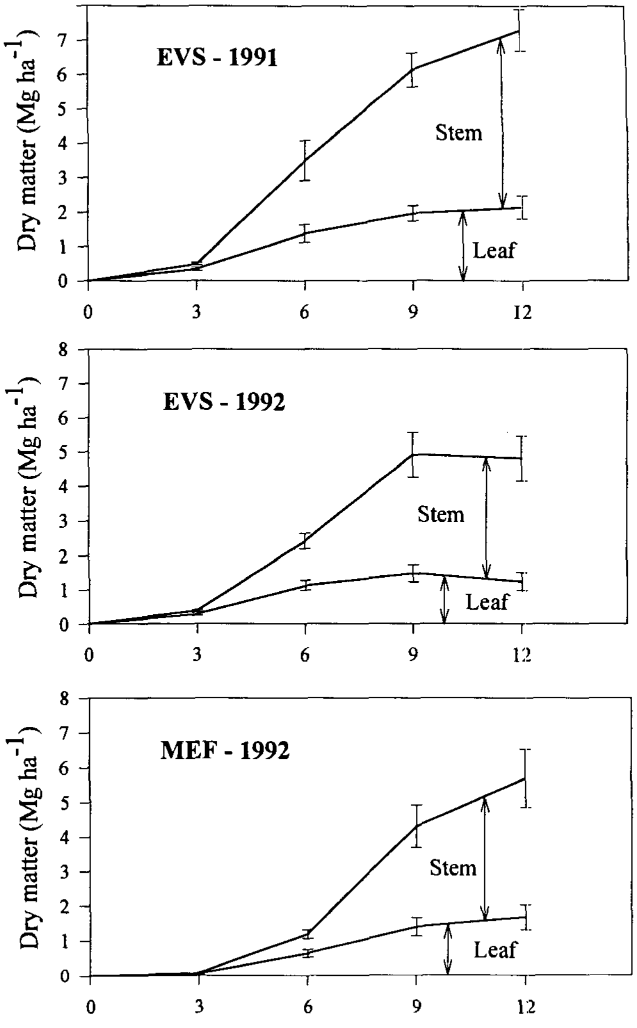

Fig. 1. Dry matter accumulation of sunn hemp at E.V. Smith Research Center in 1991 and 1992 and Monroeville Experimental Field in 1992. Vertical bars are standard errors.

higher in leaves of legumes than in stems or roots (Frankenberger and Abdelmagid, 1985; Muller et al., 1988). At Monroeville in 1992, N concentration in both leaf and stem fractions 3 WAP was lower than values for EVS. This may have been caused by the slower growth at this location or to retarded nodulation. Nitrogen concentration peaked at 3 WAP (ranging from 33.5 to 57.6 g kg^{-1} in leaves and from 18.1 to 34.3 g kg^{-1} in stems) and decreased with plant age. Tissue N concentration generally decreases as legumes mature (Akin and Robinson, 1982; Wagger, 1989). With the exception of stem tissue at MEF in 1992, there was little decrease in tissue N from 9 WAP until 12 WAP. Nitrogen concentrations ranged from 39.6 to 46.8 g kg^{-1} in leaves and from 11.3 to 15.7 g kg^{-1} in stems at 9 WAP. These results are comparable to those reported by Tamai et al. (1989), who reported that sunn hemp whole-plant tissue had a concentration of 23.9 g N kg^{-1} 60 d after planting.

Nitrogen accumulation was higher in leaves than stems (Fig. 2). Nitrogen accumulation ranged from 46 to 50 kg ha^{-1} in stems and from 61 to 78 kg ha^{-1} in leaves

Table 1. Constituent analysis and forage quality of sunn hemp stem and leaf tissue by plant age at E.V. Smith Research Center (1991 and 1992) and Monroeville Experimental Field (1992).

Site-year	Plant part	WAP†	C	N	C/N ratio	Lignin	Cellulose	Hemicellulose	NDF	ADF
			g kg^{-1}			g kg^{-1}				
EVS-1991	Stems	3	397	34.3	11.8	–‡	–	–	–	–
		6	440	13	34.4	163	432	114	709	595
		9	449	11.3	40.2	153	450	124	727	603
		12	452	11.1	40.8	184	434	125	744	618
		LSD (0.05)	2.1	1.6	2.2	6§	ns	7§	18§	16§
	Leaves	3	430	50.3	8.6	24	133	20	177	157
		6	444	41.6	10.7	50	161	33	244	211
		9	445	39.6	11.3	44	172	31	247	216
		12	452	36.3	12.3	51	139	57	246	189
		LSD (0.05)	2.3	2.2	0.6	4.3§	13§	10§	ns	11§
EVS-1992	Stems	3	383	34.3	11.4	–‡	–	–	–	–
		6	411	18.3	22.6	130	440	90	660	570
		9	434	14.6	29.9	159	477	113	749	637
		12	445	13.6	33.0	178	471	119	768	649
		LSD (0.05)	3.4	1.3	1.7	7§	8§	8§	12§	10§
	Leaves	3	416	57.6	7.2	37	170	12	219	207
		6	428	48.3	8.9	41	174	53	268	215
		9	433	46.8	9.3	66	219	88	373	285
		12	442	47	9.4	78	201	93	372	279
		LSD (0.05)	3.9	1.2	0.2	4§	7§	12§	14§	8§
MEF-1992	Stems	3	398	18.1	11.2	–‡	–	–	–	–
		6	419	19.9	21.2	124	410	83	626	543
		9	454	15.7	29	169	467	113	749	636
		12	442	12.6	35.4	174	480	130	783	653
		LSD (0.05)	2.2	0.6	1.4	8§	9§	6§	8§	7§
	Leaves	3	393	33.5	7.8	–	–	–	–	–
		6	425	46.9	9.1	42	197	34	274	240
		9	430	43	10	61	228	51	340	289
		12	426	42.3	10.1	63	214	107	384	277
		LSD (0.05)	4.2	1.3	0.4	5§	13§	13§	10§	14§

† WAP = weeks after planting.
‡ Insufficient sample for analysis.
§ LSD for comparing 6 to 12 WAP only; insufficient sample or replicate samples combined for analysis at 3 WAP.

9 WAP. Total N accumulation was 136 kg ha^{-1} 12 WAP at EVS in 1991, 120 kg ha^{-1} 9 WAP at EVS in 1992, and 123 kg ha^{-1} 12 WAP at MEF in 1992. Rotar and Joy (1983, p. 1-7) reported that 165 kg N ha^{-1} accumulated in sunn hemp grown under tropical conditions in Hawaii. Nitrogen accumulation from sunn hemp in our study was similar to the range reported for hairy vetch and crimson clover cover crops (Reeves, 1994).

Leaves had lower C/N ratios than stems for all site-years (Table 1). Carbon/nitrogen ratios in leaves with time ranged from 8.6 to 12.3, 7.2 to 9.4, and 7.8 to 10.1 at EVS in 1991 and 1992 and Monroeville in 1992, respectively. Stem C/N ratios with time ranged from 11.8 to 40.8, 11.4 to 33.0, and 21.2 to 35.4 at EVS in 1991 and 1992 and Monroeville in 1992, respectively. Foliage typically has lower C/N ratios than stems (Frankenberger and Abdelmagid, 1985; Muller et al., 1988) and at C/N ratios <20:1 N net mineralization usually occurs (Foth and Ellis, 1988). Overall, sunn hemp leaf C/N ratios were <20:1. However, for stems this C/N ratio was met only at 3 WAP, and was >20:1 for subsequent times (Table 1).

Constituent Analysis and Forage Quality

Because there were significant site-year × harvest date (WAP) interactions on forage quality variables, data are presented by site-year (Table 1). Lignin, cellulose, and hemicellulose in leaves were lower than in stems for each harvest at all site-years (Table 1). Lignin in leaves with time ranged from 24 to 78 g kg^{-1} and in stems ranged from 125 to 184 g kg^{-1}. Leaf cellulose ranged from 133 to 228 g kg^{-1} and stem cellulose ranged from 410 to 480 g kg^{-1}. Hemicellulose in leaves ranged from 12 to 107 g kg^{-1} with time and in stems ranged from 83 to 130 g kg^{-1}. In a study on chemical characteristics of winter legume cover crops, Muller et al. (1988) reported a similar range for lignin, cellulose, and hemicellulose values in leaves of subterranean clover (*Trifolium subterranean* L.), red clover (*Trifolium pratense* L.), and white clover (*Trifolium repens* L.). Sunn hemp leaf tissue lignin, cellulose, and hemicellulose concentrations were similar to reported values for a crimson clover cover crop (leaf and stem tissue); however, lignin and cellulose concentrations in sunn hemp stem tissue were much greater than in whole-plant crimson clover (Ranells and Wagger, 1992).

Neutral-detergent fiber and ADF are accurate measures of fiber in dairy cattle feeds. Recommended values for lactating cow total ration diets are 280 g NDF kg^{-1} and 210 g ADF kg^{-1} (National Research Council, 1988). Sunn hemp biomass production was sufficient to consider its suitability as a forage beginning about 6 WAP (Fig. 1). Mean NDF values in leaves 6 to 12 WAP ranged from 244 to 373 g kg^{-1} and ADF ranged from 189 to 289 g kg^{-1} (Table 1). By comparison, values for alfalfa (*Medicago sativa* L.) forage in the early vegetative stage are around 380 g NDF kg^{-1} and 280 g ADF kg^{-1} (National Research Council, 1988). Neutral-detergent fiber of stems ranged from 660 to 783 g kg^{-1} and ADF

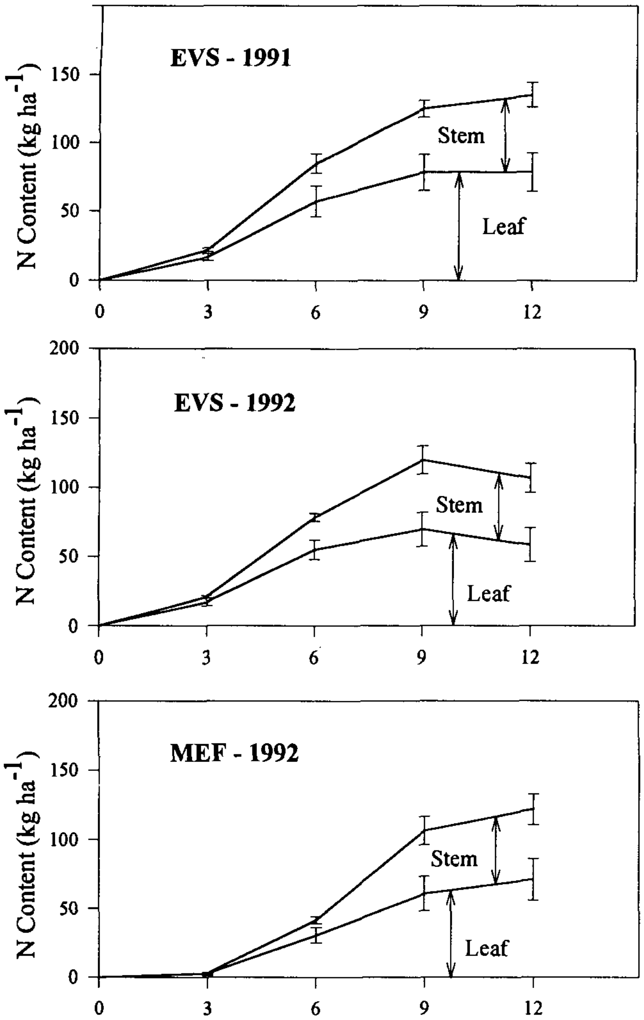

Fig. 2. Nitrogen acumulation in sunn hemp at E.V. Smith Research Center in 1991 and 1992 and Monroeville Experimental Field in 1992. Vertical bars are standard errors.

ranged from 543 to 653 g kg^{-1}. Sunn hemp leaves could serve as high-quality forage to meet nutritional demands for cattle but NDF and ADF values for stems were too high to serve as good-quality forage.

Table 2. Dry weight, N content, C concentration, N concentration, and C/N ratio of overwintered sunn hemp residue as influenced by tillage at E.V. Smith Research Center during corn growing season in 1992.

Tillage system	Time†	Dry weight	N content	C	N	C/N ratio
	wk	g	g	g kg^{-1}	g kg^{-1}	
Conventional	0	19.72	0.23	498	11.6	43.6
	1	17.87	0.25	443	14.1	31.7
	2	16.43	0.25	455	15.0	30.5
	4	14.43	0.22	452	14.9	30.7
	8	10.17	0.14	316	13.5	24.2
	16	6.5	0.13	402	19.8	20.3
	LSD (0.05)	0.97	0.05	53	3.4	4.9
No-tillage	0	19.73	0.23	497	11.9	42.0
	1	18.99	0.24	490	12.9	38.2
	2	18.63	0.26	486	14.0	35.2
	4	17.92	0.24	490	13.3	37.2
	8	16.5	0.22	470	13.2	35.9
	16	13.51	0.20	427	15.1	28.5
	LSD (0.05)	0.65	0.03	24	2	5

† Weeks after bags placed in field; week 0 corresponds to 17 Apr. 1992.

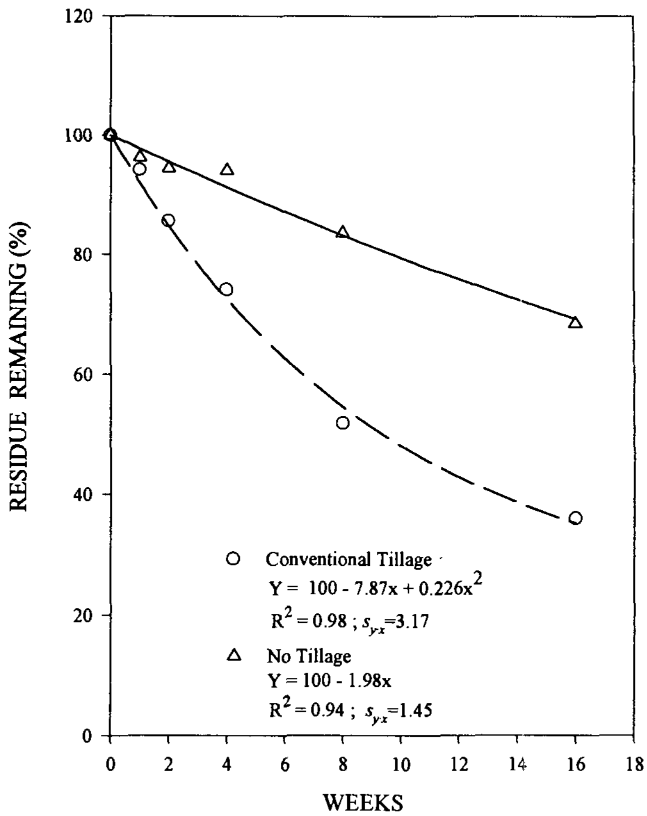

Fig. 3. Decomposition of overwintered sunn hemp residue from 17 Apr. to 7 Aug. 1992 (normal corn growing season) at E.V. Smith Research Center as affected by tillage system.

Soil Coverage

Ground cover from sunn hemp residue at MEF averaged 99 ± 0.4% (standard error) after mowing on 15 Dec. 1992 and at EVS averaged 94 ± 2.6% after mowing on 8 Dec. 1992. Eight weeks after mowing, residue coverage decreased 12 and 14% at EVS and MEF, respectively. Sixteen weeks after mowing (early April, the time a succeeding summer crop would be planted), soil coverage was 65 ± 10.3% and 76 ± 2.1% at EVS and MEF, respectively. This would meet conservation compliance guidelines of having 30% residue at planting on highly erodible land.

Decomposition of Overwintered Residue

Residue decomposition of overwintered residue at EVS during spring and summer 1992 (corresponding to corn growing season) depended on the tillage system employed (Fig. 3). In conventional tillage, residue decomposition was best described by a quadratic function. For no-tillage, however, a linear function provided a superior fit. Dry weights of residue decreased to 36 and 69% of initial values at 16 wk in conventional and no-tillage systems, respectively.

Loss of C in residue followed the same pattern as dry weight of residue remaining (Table 2). In contrast, N content in residue tended to increase for the first 2 wk in conventional tillage and up to 4 wk under no-tillage (Table 2). This is an indication of microbial N demand for residue decomposition and the high C/N ratio of the residue. Loss of N from overwintered residue in both

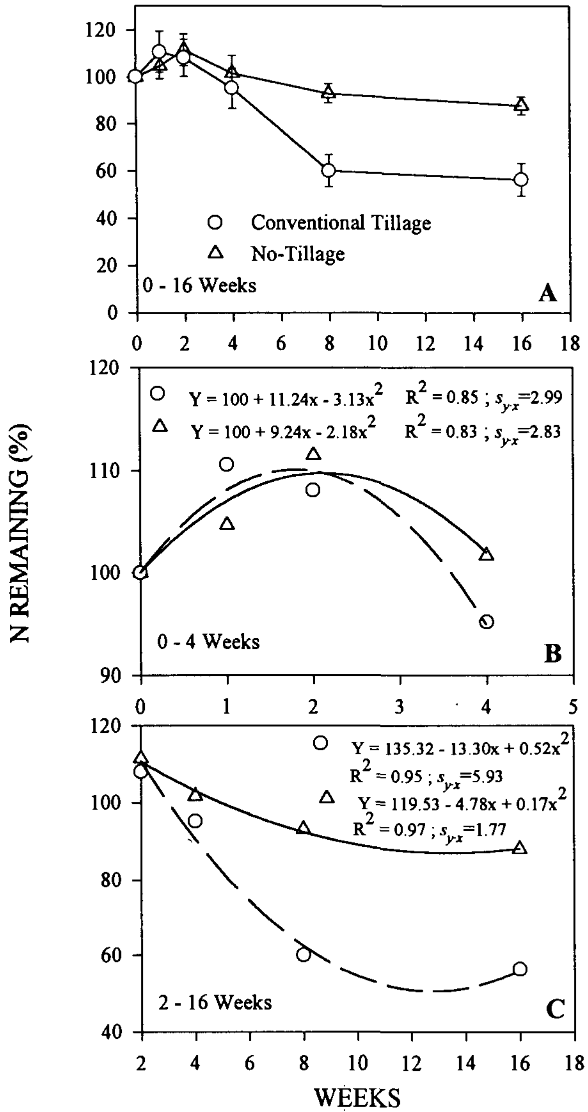

Fig. 4. Percentage of initial N remaining in overwintered sunn hemp residue from 17 Apr. to 7 Aug. 1992 at E.V. Smith Research Center as affected by tillage system: (A) during entire 16-wk period, (B) during 0- to 4-wk period, and (C) during 2- to 16-wk period. Vertical bars in (A) are standard errors.

conventional-tillage and no-tillage systems was described by two quadratic models, dependent on the time period (Fig. 4). Net immobilization was shown during 0 to 4 wk (Fig. 4B), and mineralization occurred from 2 to 16 wk (Fig. 4C). Little mineralization occurred in the no-tillage system. As explained above, most plant N was in leaves but the overwintered material was primarily stems. Stem tissue had a high lignin content and C/N ratio (Table 1), which would reduce N mineralization. Decomposition rate corresponded to the C/N ratio of each plant residue for both tillage management systems (Table 2). In conventional tillage, the C/N ratio was >30 until after 4 WAP. However, in the no-tillage system, the C/N ratio remained >30 almost the entire 16-wk period. Nitrogen remaining in residue at 16 WAP was 57 and 87% in conventional tillage and no-tillage, respectively (Fig. 4).

Changes in soil mineral N (data not shown) reflected the pattern of N immobilization and mineralization from residue, as shown in Fig. 4. Soil mineral N decreased from 13.2 to 4.6 mg N kg^{-1} (LSD[0.05] = 4.4 mg kg^{-1}) during the first 2 wk in conventional tillage, and from 15.7 to 7.9 mg N kg^{-1} (LSD[0.05] = 3.5 mg kg^{-1}) during the first 4 wk in no-tillage, corresponding to increases in residue N shown in Fig. 4A during the first 4 wk.

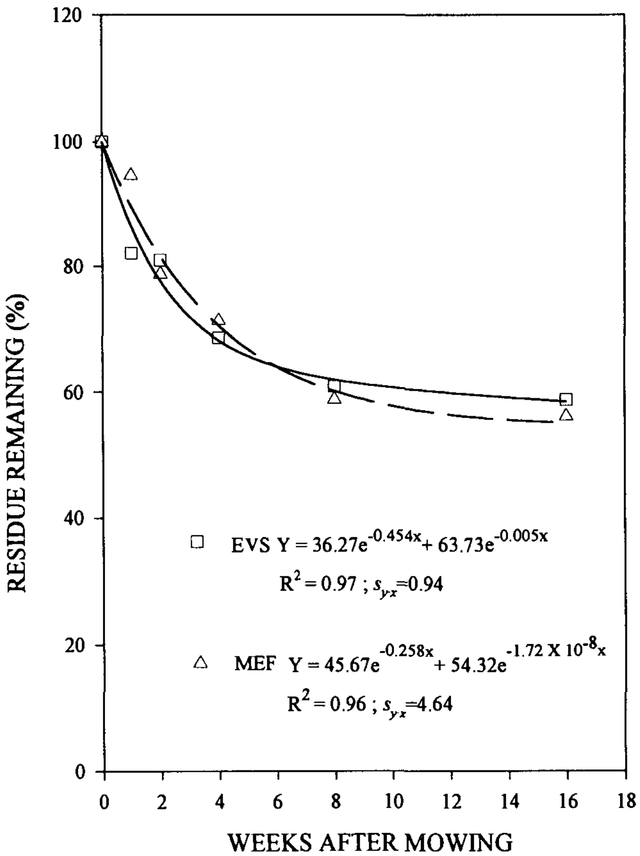

Fig. 5. Decomposition of mowed sunn hemp residue from 15 Dec. 1992 to 6 Apr. 1993 (during fall-winter) at E.V. Smith Research Center and from 8 Dec. 1992 to 30 Mar. 1993 at Monroeville Experimental Field.

Decomposition of Residue during Winter

Decomposition of residue during winter was similar at both sites (Fig. 5). Decomposition at both sites could be described by two-pool exponential functions. During 0 to 4 wk after mowing, 31 and 29% of the residue was lost at EVS and MEF, respectively. This increased to 49 and 44%, respectively, 16 wk after mowing, the time that corn would be planted into the overwintered residue. The decomposition rate during the first 4 wk was high due to decomposition of the leaf fraction of the residue. The low C/N ratio of this fraction increased the residue decomposition rate.

Percentage N remaining in residue also showed similar release patterns at both locations (Fig. 6). A two-pool exponential model best described N release from sunn hemp residue during fall and winter. The superiority of the two-pool model suggests that sunn hemp residue contains constituents that vary in resistance to decomposition; a readily decomposable fraction disappears more rapidly than resistant fractions (Somda et al., 1991;

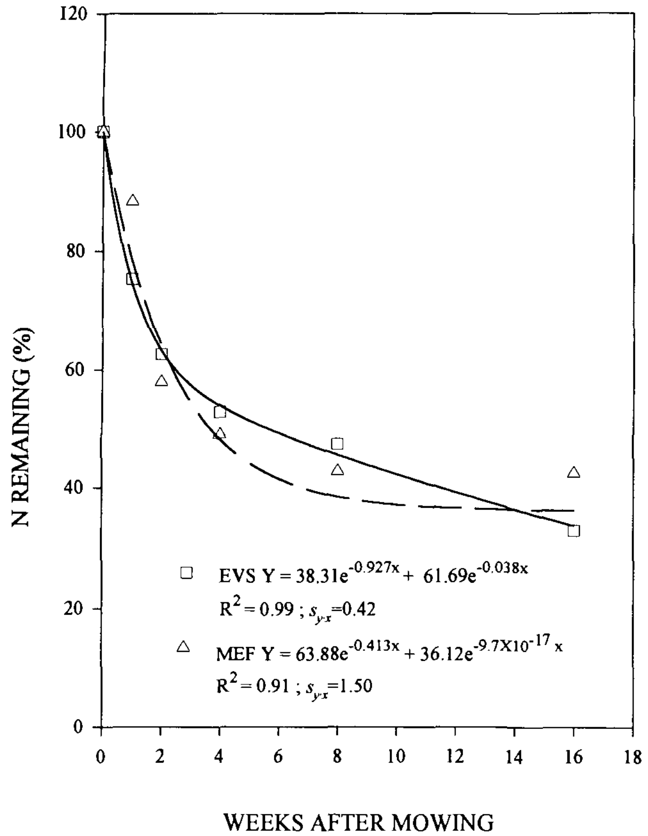

Fig. 6. Percentage of initial N remaining in mowed sunn hemp from 15 Dec. 1992 to 6 Apr. 1993 (during fall-winter) at E.V. Smith Research Center and from 8 Dec. 1992 to 30 Mar. 1993 at Monroeville Experimental Field.

Yadvinder et al., 1992). In this study, leaves decomposed quickly. As mentioned above, leaves had C/N ratios <20:1, and contained less lignin but more N than stems. Rapid decomposition and N release occurred from 0 to 4 wk after mowing at both locations. The percentage of N released from the residue was approximately 50% 4 wk after mowing at both locations. Nitrogen release rate declined after 8 wk. Sixteen weeks after mowing, corresponding to the time corn would be planted into the overwintered residue, 67% of the N was released at EVS and 57% was released at MEF. Surprisingly, these values agree with those of Wilson and Hargrove (1986), who found that 37% of the initial N in crimson clover was released 4 wk into the summer growing season and 64% had been released by 16 wk. It is interesting that the N release pattern from sunn hemp residue during the winter was similar to that reported for crimson clover during the summer. Winter temperatures during 1992–1993 averaged 1.1°C below the 30-yr norm at MEF and only 0.3°C above the 30-yr norm at EVS. This suggests that winter temperatures in this geographic region are not cold enough to retard microbial transformations of N to any great extent. At mowing in fall 1992, sunn hemp residue contained approximately 120 kg N ha^{-1} at both locations (Fig. 2). During the 16-wk overwintering period, 75 kg ha^{-1} of this N was released. At corn planting the next spring, approximately 45 kg N ha^{-1} was left in the residue. Net N mineralization occurred during the entire 16-wk fall and winter period. The C/N ratio in residue remained <30:1 (Table 3). Changes in soil mineral N (data not shown) concurred with the N-release pattern from residue during the fall and winter period, decreasing from 12.8 to 5.2 mg N kg^{-1} (LSD[0.05] = 2.4 mg N kg^{-1}) at EVS and from 12.5 to 5.0 mg N kg^{-1} (LSD[0.05] = 1.7 mg N kg^{-1}) at MEF during the 16-wk period. This suggests that N released from residue during the winter may be subject to losses from denitrification and leaching below the 15-cm sampling depth.

Table 3. Dry weight, N content, C concentration, N concentration, and C/N ratio of mowed sunn hemp residue during winter 1992-1993 at E.V. Smith Research Center and Monroeville Experimental Field.

Location	Time (wk)†	Dry weight	N content	C	N	C/N ratio
		g		g kg^{-1}		
EVS	0	18.8	0.44	462	23.7	19.8
	1	15.44	0.33	480	21.1	23.4
	2	15.23	0.28	453	18.3	25.1
	4	12.90	0.22	471	16.9	28.2
	8	11.28	0.2	455	18.0	25.9
	16	9.66	0.15	375	15.2	25.0
	LSD (0.05)	0.81	0.04	20	2.7	3.6
MEF	0	18.80	0.44	462	23.8	19.8
	1	17.79	0.39	478	22.1	22.0
	2	14.75	0.25	480	16.9	29.2
	4	13.38	0.21	472	15.8	30.0
	8	11.12	0.18	478	16.7	29.4
	16	10.55	0.19	463	18.0	26.0
	LSD (0.05)	0.56	0.04	11	2.6	4

† Weeks after bags placed in field; week 0 corresponds to 15 Dec. 1992 at EVS and 8 Dec. 1992 at MEF.

CONCLUSIONS

As an alternative to winter cover crops, Tropic Sun sunn hemp produced a large quantity of dry matter during the fall season (average 5.9 Mg ha^{-1} in 9–12 wk), covered the soil surface rapidly to protect it from erosion, and accumulated approximately 120 kg N ha^{-1}. Rapid mineralization in mowed residue occurred during the winter, due to release of N from leaves. Approximately 75 kg N ha^{-1} was released from residue to the soil during the winter. This rapid N release is probably conducive to consequent leaching and denitrification losses. Winter cereals like wheat (*Triticum aestivum* L.) are normally planted in the Southeast during mid-November to early December. We speculate that winter cereals grown following sunn hemp would have a synchronous N use pattern with the N release pattern from sunn hemp, reducing or eliminating this loss of N. Initially, N immobilization occurred in overwintered residue, followed by slow mineralization after 2 to 4 wk. Nitrogen release from the 45 kg N ha^{-1} in the overwintered residue during a subsequent corn growing season averaged 13% under no-tillage and 43% under conventional tillage. For late summer to early fall grazing, sunn hemp leaves were suitable for dairy cattle forage but NDF and ADF values in stems were high enough to limit their value as forage, especially after 6 WAP. Sunn hemp has potential to be managed as an alternative to winter legume cover crops in warm temperate regions.

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