Partitioning of Dry Matter and Minerals in Sunn Hemp

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ABSTRACT

Sunn hemp (*Crotalaria juncea* L.) is a tropical legume commonly used as a cover crop or green manure, because of its soil improvement benefits. It has recently been introduced to the U.S. as a potentially valuable N source and nematode suppressor. The objective of this study was to determine the partitioning of dry matter, N, and other minerals in sunn hemp to better understand its efficiency as an organic N source. Ten replications of 'Tropic Sun' sunn hemp were grown in fall 2001 and harvested at the mid-flowering stage from 32 ft^2 plots, four inches above the soil surface. Some plants were separated into flower heads, leaves, and stems, and others were left as whole plants for comparison. Plant material from each plant part and whole plant were dried and mixed prior to sub-sampling. Two sub-samples were taken from each plant part and whole plant for N and mineral analysis. One set of sub-samples was re-dried prior to analysis to determine true mineral concentration, and the other set was analyzed "as is," such that some moisture would be present from natural accumulation after the first drying. Nitrogen and mineral concentrations were higher in dried whole plant and plant parts than those analyzed "as is." Stems had the greatest percent dry matter at 27.4%, and flower heads had the least at 21.8%. Stems had the largest accumulation of micronutrients. Leaves and flower heads combined contained 66.5% of the total P in the plant and 80.6 % of the total N.

KEYWORDS

Crotalaria juncea L., nitrogen content, plant parts, macronutrients, micronutrients

INTRODUCTION

Tropical Sunn hemp (*Crotalaria juncea* L.) is a relatively new leguminous crop to the United States. In recent studies it has proven to be a potentially valuable crop to U.S. organic farmers and to sustainable farmers in developing nations. Sunn hemp has the ability to suppress some plant-parasitic nematodes, mostly sedentary endoparasites, but is not effective against migratory nematodes (Wang *et al*., 2002). A study in Tanzania included 'Tropic Sun' sunn hemp in rotation with vegetables, ornamentals, and other crops to suppress weeds, control erosion, reduce root-knot nematodes, and to add N and organic matter to the soil. It was found that in 60 days after planting, at a broadcast-seeding rate of 40 to 60 lbs. acre^{-1}, sunn hemp produced 145 pounds of N and three tons of dry matter acre^{-1}. High plant densities were recommended to cause the stems to be more succulent and easier to be incorporated into the soil (Rupper, 2001). Another study found that sunn hemp could produce 98 to 125 lbs N acre^{-1} (Marshall *et al*., 2001).

Sunn hemp has been planted in the southern U.S. immediately after corn (*Zea mays* L.) harvest as a winter cover crop and as a speedy alternative to traditional covers like hairy vetch (*Vicia villosa* Roth) and crimson clover (*Trifolium incornatum* L.) (Comis,1997). In Alabama, a sunn hemp residue study found that approximately 66.8 lbs N acre^{-1} was released from the residue to the soil during the winter (Reeves *et al*., 1996). Sunn hemp bares large showy flowers that occur in inflorescence, each flower having 10 stamens: five with short filaments and long narrow anthers and five with long filaments and small round anthers (Howard *et al*., 1919). Sunn hemp stems are comprised of two fibers, the bast and woody core, that have similar fiber widths (Cunningham *et al*., 1978).

A recent study in north Florida found that sunn hemp has an impressive growth rate and accumulation of plant nutrients, making it potentially useful in cropping systems in the tropics and sub-tropics (Gallaher *et al*., 2001). Sunn hemp can be used as a mulch, green manure, or organic fertilizer. Therefore, it is important to know the partitioning of dry matter and nutrients within a plant to better understand how the plant functions and which parts contain the bulk of the nutrients. The objective of this study was to determine the partitioning of dry matter, N, and other minerals in sunn hemp.

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MATERIALS AND METHODS

Sunn hemp, c.v. 'Tropic Sun,' was planted in August of 2001 and harvested in November at the mid-flowering stage by cutting the stalks four inches above the soil surface. The entire planting was uniform and 10 replications of 180 plants per 32 ft^2 plots were harvested. Plants were separated into reproductive tissue (flower heads), leaves, and stems, and other plants were left whole and analyzed separately for comparison. All parts were weighed fresh, and then the parts and whole plant samples were dried for 48 hours in a 70 °C forced air oven. After drying, samples were re-weighed to determine dry matter. Then the individual parts and whole plant sample were chopped and thoroughly mixed in a small forage mixer for 60 minutes to ensure homogeneity. Two sub-samples were taken from each mixed plant part and whole plant for N and mineral analysis.

The reason for the two sub-samples was to run an analysis on the plant material in an "as is" state, where some moisture would be present from natural accumulation after the first drying. The other set of sub-samples were re-dried for 24 hours in a 70 °C convection oven prior to N and mineral analysis to determine true N and mineral concentrations. By allowing half of the sub-samples to contain moisture we would know the mineral content of the sunn hemp as it would most likely be applied as fertilizer in a practical situation. The plant material was analyzed for N using a modified micro-Kjeldahl procedure. A mixture of 0.100 g of each tissue sample, 3.2 g salt-catalyst (9:1 K_2SO_4:$CuSO_4$), 2 to 3 Pyrex beads, and 10 ml of H_2SO_4 were vortexed in a 100 ml Pyrex test tube under a hood. To reduce frothing, 2 ml 30% H_2O_2 was added in one-ml increments, and tubes were digested in an aluminum block digester at 370 °C for 3.5 hours (Gallaher *et al*., 1975). Tubes were capped with small Pyrex funnels that allowed for evolving gases to escape while preserving refluxing action. Cool digested solutions were vortexed with approximately 30 ml of de-ionized water, allowed to cool to room temperature, brought to 75 ml volume, transferred to square Nalgene storage bottles (glass beads were filtered out), sealed, mixed, and stored.

Nitrogen trapped as $(NH_4)_2SO_4$ was analyzed on an automatic Technicon Sampler IV (solution sampler) and an Alpkem Corporation Proportioning Pump III. A plant standard with a long history of recorded N concentration values was subjected to the same procedure and used as a check (Agronomy Lab, University of Florida).

For mineral analysis, 1.0 g from each of the 75 samples of sunn hemp tissue was weighed into 50-ml Pyrex beakers and ashed in a muffle furnace at 480 ∫C for 6 hours. The samples were then cooled to room temperature and moistened with de-ionized water. Under a hood, 20 ml de-ionized water and 2 ml concentrated HCl were added to the beakers, which were then placed on a hot plate, slowly boiled to dryness, and then removed.

Another 20 ml de-ionized water and 2 ml concentrated HCl were added and small Pyrex watch glasses were used to cover the beakers for reflux. They were brought to a vigorous boil and removed from the hot plate to cool to room temperature. The samples were then brought to volume in 100-ml flasks and mixed. They were set aside for a few hours to let the Si settle out. Twenty ml of solution was decanted into 20-ml scintillation vials for analysis. Phosphorous was analyzed by colorimetry; K and Na by flame emission, and Ca, Mg, Cu, Fe, Mn, and Zn by atomic adsorption spectrometry (AA).

Data was recorded in Quattro-Pro (1987) spreadsheets, transformed accordingly, made into ASCII files, and transferred to MSTAT 4.0 (1985) for analysis of variance for a completely randomized experiment design. Standard deviations are reported for mean separation.

RESULTS

Sunn hemp stems had the greatest fresh and dry weights and percent dry matter among the plant parts tested (Table 1). This was expected because of the large amount of fibrous material found in the stems. The majority of biomass is composed of stem material, comprising about 50% of whole plant weight. Leaf percent dry matter was very similar to that of whole plant. Leaf weights were 1682 lbs. and 588 lbs. greater than flower head fresh and dry weights, respectively (Table 1).

Mineral analysis was also determined by averaging plant mineral contents over 10 replicates (Table 2). All N and mineral concentrations were higher in the dried whole plant and plant parts than those analyzed "as is" (Table 3).

Table 1. Average values (n = 10) ± standard deviation for fresh weight, dry weight, and percent dry matter of tropical sunn hemp of plant parts and whole plants

Plant Part	Fresh Weight	Dry Weight	Dry Matter
	---------------- lbs $acre^{-1}$ -------------		----- % -----
Leaves	5954 ± 792.1	1522 ± 133	25.97 ± 4.31
Flower Head	4272 ± 703.1	934 ± 169	21.84 ± 2.15
Stem	8971 ± 827.7	2456 ± 365	27.37 ± 3.55
Whole Plant	19,197 ± 1975.8	4913 ± 596	25.67 ± 3.16
CV	12.5%	15.0%	13.4%

Table 2. Average mineral contents ± standard deviation (n = 10) of sunn hemp.

Minerals	Leaves	Flower Head	Stem	Whole Plant	CV
	------------------------------ lbs acre^{-1}			---------------------------------	%
Ca	45.0 ± 4.01	8.9 ± 1.60	9.2 ± 1.34	57.8 ± 7.12	13.91
Mg	6.8 ± 0.62	3.0 ± 0.53	5.2 ± 0.80	15.8 ± 1.96	14.61
K	18.7 ± 1.69	18.6 ± 3.38	32.4 ± 4.81	66.0 ± 8.10	14.94
P	7.4 ± 0.62	4.6 ± 0.80	5.9 ± 0.89	18.1 ± 2.23	14.56
N	60.3 ± 5.34	38.5 ± 7.03	21.5 ± 3.20	122.6 ± 15.04	14.59
Na	0.4 ± 0.09	0.8 ± 0.09	1.8 ± 0.27	8.6 ± 1.07	18.48
Cu	.0008 ± .0008	.0005 ± .0001	.0010 ± .0002	.0025 ± .0003	15.00
Fe	.0308 ± .0028	.0102 ± .0019	.0515 ± .0076	.0628 ± .0077	14.61
Mn	.0093 ± .0008	.0027 ± .0005	.0022 ± .0004	.0117 ± .0014	13.46
Zn	.0062 ± .0005	.0041 ± .0007	.0049 ± .0007	.0250 ± .0031	16.39

There was about a 3% increase in N concentration for dried leaves and whole plant, and a 13% increase in N concentration for dried flower heads and stems compared to the N concentrations of the samples that were analyzed with a higher moisture content (Table 3).

The highest N concentration was found in dry flowers and lowest in "as is" stems (Table 3). Leaves and flower heads contained comparable amounts of N, but flower heads had slightly higher dry N concentration. Leaves had the greatest N content for the whole plant, followed by flowers (Table 2).

A much smaller amount of flower head and leaf tissue is required to provide the same amount of N from stems alone or whole plant (Table 4).

For the other minerals examined, stems contained the highest amount of K among the plant parts, and leaves had the largest contents of Ca, Mg, P, N, Mn, and Zn. Stems had the largest accumulation of Cu and Fe. Leaves and flower heads combined contained 66.5% of the total P in the plant and 80.6 % of the total N (Table 2).

Table 3. Average N concentration (n = 10) in plant parts and whole plant.

Plant Part	Tissue N concentration "As Is"	Dry
	-------------%-----------	
Leaves	3.83	3.96
Flower heads	3.67	4.14
Stems	0.78	0.88
Whole Plant	2.42	2.50

Table 4. Amount of plant material required to be equivalent to one lb. of N.

Plant Part	Amount
	----- lbs -----
Leaves	57.44
Flower heads	59.95
Stems	282.06
Whole Plant	90.90

DISCUSSION AND CONCLUSIONS

The whole plant sunn hemp from our experiment contained N-P_2O_5-K_2O in amounts of 123-42-80 lb acre^{-1}, which gives a ratio of 3:1:2. According to this ratio, we can assume that sunn hemp could be an adequate fertilizer to meet most of the nutritional requirements of vegetable crops such as summer yellow squash (*Cucurbita pepo* L.), bush bean (*Phaseolus vulgaris* L.), and sweet corn (*Zea mays* L.) (Hochmut, *et al.*, 1998) (Table 5).

Since most of the N and macro-nutrients are found in leaves and flower heads, use of sunn hemp as a mulch or green manure would be most beneficial at the early to mid-flowering stage when the C:N ratio is presumed to be low and the nutrients are most available. Sunn hemp is a short day crop, which results in a restriction on its growth in the sub-tropics and its soil improvement abilities. In northern Florida and other parts of the sub-tropics, it can be grown in the fall when day length shortens. However, sunn hemp is

Table 5. Macronutrient requirements of vegetables (Hochmuth *et. al.*, 1998)

Species	N	P_2O_5	K_2O
	----------- lbs acre^{-1} ------------		
Summer Yellow Squash	120	80 – 120	80 – 120
Bush Bean	90	80 – 120	80 – 120
Sweet Corn	150	80 – 120	80 – 120

very susceptible to frost kill, so there is only about a 3 to 4 month window of opportunity during the fall to grow sunn hemp for its full benefits as a green manure in north Florida. Therefore, a winter crop would have to be grown to benefit from or preserve the nutrients released by the decaying sunn hemp. However, in our study we harvested sunn hemp as an organic fertilizer for spring vegetables. Since the hemp was harvested and dried, we were able to preserve nutrients at the early to mid-flowering stage for use as an organic fertilizer throughout the year, rather than risk losing them over the winter.

The greatest amount of dry matter was in the fibrous stems, which makes sunn hemp a good annually renewable fiber source, but not as good of a forage or immediate source of N. However, stems contain 17.6% of the total plant N, so they may still be incorporated as a useful and beneficial part of the fertilizer. Stems may prove to be a beneficial contributor to the organic fertilizer if they are shown to have a much slower rate of decay and release of N than leaves or flowers. If this is the case then the stems may allow for a better distribution of N over the growing season. However, if the stems have a very high C:N ratio, the leaves, flower heads, and soil may actually be robbed of N for the stems to be able to decay.

Net N mineralization can occur when C:N ratios are <20:1 (Foth et. al., 1988). Mansoer et al. (1997) conducted a decay rate study of sunn hemp residue for use as an alternative cover crop. They reported that sunn hemp leaf C:N ratios were <20:1, while stem C:N ratios were >20:1 after three weeks from the planting date. They also reported that stem tissue had high lignin concentration. A combination of high C:N ratio and high lignin concentration would reduce N mineralization. Further research on C:N ratio and decay rates of each plant part would help to better understand the potential of sunn hemp as an organic fertilizer, rather than a cover crop.

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