NITROGEN DISTRIBUTION BETWEEN SHOOTS AND ROOTS OF FIVE COOL-SEASON ANNUAL LEGUMES

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ABSTRACT
Nitrogen contribution from legume green manure crops is becoming more important as the price of N fertilizer increases in order to maintain sustainable agricultural production systems. The quantity of N in the top growth and roots of 'Yuchi' arrowleaf clover (*Trifolium vesiculosum* Savi.), 'Tibbee' crimson clover (*Trifolium incarnatum* L.) 'Overton R18' rose clover (*Trifolium hirtum* All.), 'Mt. Barker' subterranean clover (*Trifolium subterraneum* L.) and hairy vetch (*Vicia villosa* Roth) was determined at monthly intervals throughout the growing season. Maximum N accumulation in all species occurred in May. Hairy vetch and crimson clover had some of the highest N levels from Oct. through Feb. From Apr. through June, arrowleaf clover contained the most N because of its later maturity. Percentage of total plant N in the roots ranged from 4 to 22% with the lower percentages in spring when a rapid increase in top growth occurs. Hairy vetch had a lower percentage of total plant N in the root than the other species from Oct. through Mar.

KEYWORDS
green manure, annual legumes, crimson clover, arrowleaf clover, rose clover, subterranean clover, hairy vetch

INTRODUCTION
The use of cool-season annual legumes in rotation with warm-season annual crops and in mixtures with warm-season perennial grasses have many benefits. A review of the value of winter clover crops for conservation tillage by Hargrove and Frye (1987) cited soil, water, and energy conservation; soil improvement in terms of higher organic matter, soil structure and water infiltration; reduced weed, disease and insect problems; and the addition of N to the cropping system through N_2-fixation. There are numerous reports in the literature on legume green manure crops as a N source (Carsky *et al*., 1990; Becker *et al*., 1995). As the cost of commercial N fertilizer increases, the N contribution of legumes becomes more important. The quantity of N contained in the legume plant is dependent on the N concentration and the quantity of biomass. In the southeastern US from 75 to 90% of cool-season annual legume production occurs in the spring (Evers and Gabrysch, 1993). The time in spring when a legume is plowed down or killed with chemicals for the planting of a summer crop affects the quantity of N in the legume plant. Nitrogen accumulation in the topgrowth and roots of five cool-season annual legumes was determined at monthly intervals during the growing season.

METHODS
Test site was a fine sandy loam (siliceous, thermic Glossic, Paleudalfs) at the Texas A&M University Agricultural Research and Extension Center at Overton, Texas (32° 17 N, 94° 58 W). Yuchi arrowleaf clover, Tibbee crimson clover, Overton R18 rose clover, Mt. Barker subterranean clover and Hairy vetch were planted in 7 18-cm rows, 30 m long on 20 Sept. 1990, at 9, 18, 16, 18 and 23 kg/ha, respectively. Fertilization was 90 kg P_2O_5, 90 kg K_2O and 1 kg B/ha at planting and additional 50 kg K_2O/ha in January. Plots were in a randomized complete block with four replications. Each 1.3 by 30 m plot was divided into 25 subplots (1.2 by 1.2 m). Approximately every two weeks, a subplot was selected at random and clover plants excavated from the center (30 by 36 cm) of the plot. After washing the soil from the roots, plants were separated into shoot and root and dried for 48 h at 60°C to determine yield. Nitrogen analysis was by Kjeldahl.

RESULTS
The ranking of legume species for N accumulation in the top growth varied during the growing season (Table 1). Crimson clover and hairy vetch were significantly higher than the other species from Oct. to Jan. because of their superior seedling vigor (Evers and Dorsett, 1986). In Feb., N accumulation of hairy vetch was 3 to 5 times greater than the other species. Because of its later maturity, arrowleaf clover top growth contained the most N from April through June. Rose clover always had the least amount of N except for May. Crimson clover roots had the highest accumulation of N from Oct. through Jan. For the remaining growing season arrowleaf clover, subterranean clover and hairy vetch roots contained the greatest amount of N. Except for Oct., rose clover always had the least amount of root N.

The general trend for all species was to have the highest percentage of total plant N in the roots during autumn and winter. Percent N in the roots decreased in the spring due to rapid increase in topgrowth during this period. Arrowleaf clover and subterranean clover had the greatest percent total plant N in the roots from Oct. through Dec. Subterranean clover continued to maintain a high proportion of N in the roots for the remaining growing season. Hairy vetch always had the lowest percent N in its roots until Apr. and May.

DISCUSSION
The optimum legume species for a cool-season green manure crop will depend on when growth of the legume is to be terminated and adaptability of the species to the specific soil and climatic conditions. Hairy vetch is the obvious choice if the legume is turned under or killed in Feb. Favorable attributes of hairy vetch are good seedling growth, early forage production and adaptability to a wide range of soil types and climates. If legume growth is not terminated until Mar. or Apr., arrowleaf and crimson clovers are options. If the cool-season legume is not followed by a summer crop and is allowed to reach maturity, the late maturing arrowleaf clover would contribute the most N. However, arrowleaf clover is limited in its adaptability. It grows poorly on wet soils and alkaline soils, and current cultivars are susceptible to viral and fungal diseases (Pemberton *et al*., 1994). If the top growth of the legume is to be utilized for grazing, subterranean clover may be an option since a high percentage of total plant N is in the roots. Under grazing N in the top growth is not lost from the farming system since 70 to 95% of the ingested N is excreted in the urine and feces (Russelle, 1996). Of the species tested, rose clover accumulated the least amount of N.

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Table 1
Nitrogen accumulation in topgrowth and roots of five cool-season annual legumes during the growing season.

Species	10 Oct	7 Nov	5 Dec	14 Jan	11 Feb	13 Mar	8 Apr	8 May	5 Jun
					Topgrowth N (kg/ha)				
Arrowleaf	11.1 c†	4.1 b	17.2 b	12.4 c	32.6 b	93.0 ab	200.3 a	358.0 a	349.9
Crimson	4.1 a	13.1 a	56.6 a	44.0 b	32.8 b	70.8 b	143.8 b	159.0 b	—
Rose	2.0 bc	2.0 b	7.7 b	8.5 c	18.8 b	28.4 c	83.9 d	138.4 b	—
Subterranean	2.4 b	3.7 b	11.4 b	10.9 c	29.8 b	71.8 b	109.4 c	131.3 b	—
Vetch	3.9 a	11.4 a	44.5 a	65.8 a	100.0 a	106.0 a	152.7 b	178.0 b	—
					Root N (kg/ha)				
Arrowleaf	0.21 c	1.13 b	2.76 b	2.93 c	6.39 ab	9.46 a	12.59 a	15.03 a	13.5
Crimson	0.51 a	1.86 a	6.51 a	6.26 a	4.84 b	6.72 b	6.77 c	7.15 cd	—
Rose	0.23 bc	0.45 c	1.09 c	1.65 d	2.88 c	3.46 c	4.27 d	5.82 d	—
Subterranean	0.43 a	1.03 b	2.56 bc	3.03 c	7.20 a	10.76 a	11.88 a	9.73 bc	—
Vetch	0.38 ab	1.37 b	3.47 b	4.94 b	7.83 a	6.37 b	9.79 b	9.97 b	—

† Values within a column followed by the same letter are not different, P <0.05.

Table 2
Percent of total plant n in the roots of five cool-season annual legumes during the growing season.

Species	10 Oct	7 Nov	5 Dec	14 Jan	11 Feb	13 Mar	8 Apr	8 May	5 Jun
Arrowleaf	16 a†	23 a	16 ab	19 b	17 b	9 bc	6 b	4 b	4
Crimson	11 b	13 c	10 cd	13 c	13 c	8 c	4 c	4 b	—
Rose	11 b	19 b	13 bc	16 c	13 c	11 b	5 bc	4 b	—
Subterranean	15 a	22 ab	18 a	22 a	20 a	14 a	10 a	7 a	—
Vetch	9 b	12 c	8 d	7 e	7 d	6 d	6 b	5 ab	—

† Values in a column followed by the same letter are not different, P < 0.05.