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DRY MATTER AND NITROGEN ACCUMULATIONS IN DETERMINATE SOYBEAN GROWN ON LOW-NITROGEN SOILS OF THE SOUTHEASTERN UNITED STATES

P. G. Hunt and T. A. Matheny

USDA-ARS, Coastal Plains Soil and Water Conservation Research Center, P. O. Box 3039, Florence, SC

ABSTRACT: Reliable assessments of erosion potential, N fertilization need, and nitrogen (N) non-point pollution potential for soybean [*Glycine max* (L.) Merr.] cropping systems require accurate estimates of soybean dry matter and N accumulations. The objective of this field study was to determine dry matter and N accumulation in soybean during the growing season and at harvest in samples large enough to reduce sample variation and increase the confidence in measured values. A split-plot design was used with cultivar (Braxton, Coker 338, and Davis) as the main plot treatment and sampling date as the split-plot treatment. Each split-plot contained eight rows 4.6 m in length on 0.75 m spacing. The seed were sown in a Norfolk loamy sand (fine-loamy, siliceous, thermic, Typic Paleudult) on May 18 at the rate of 33 seeds/m. Water was applied by use of an overhead irrigation gun. Plant samples were collected from 20 m^2 of the six center rows on 89, 115, and 138 days after planting as well as at seed harvest. Fallen plant material (crop litter) was collected from each plot at each sampling date. Intact plant samples, crop litter, and soil samples were analyzed for total Kjeldahl N. The mean seed yield was 2.01 Mg/ha; the mean maximum dry matter accumulation for intact shoots plus crop litter was 10.2 Mg/ha, and the coefficients of variation were <10%. The actual harvest index (seed yield/total dry matter accumulation) ranged from 0.19 to 0.28, and the mean maximum N accumulation was 293 kg/ha. These accumulations are greater than those reported for indeter-

minate soybean grown on high-N soils in the midwestern United States, and they clearly show that determinate soybean grown in the southeastern United States accumulate substantial amounts of dry matter and N.

INTRODUCTION

Accurate assessments of soybean dry matter accumulations are important for predicting residue levels for soil erosion control and estimating N fertilization credits. However, regional differences in soybean growth and seed yield can contribute to confusion and inaccurate estimates. In the southeastern United States, determinate soybean often accumulate >8 Mg/ha of intact shoot dry matter in normal rainfall seasons (Karlen et al., 1982; Scott and Batchelor, 1979; Scott et al., 1983; and Henderson and Kamprath, 1970). Furthermore, soybean plants generally obtain more than half of their accumulated N from dinitrogen (N_2) fixation because soils of this region are low in N (Hunt et al., 1985; Matheny and Hunt, 1983; Thurlow and Hiltbold, 1985). Accumulation of fixed N can result in net additions of >50 kg/ha N which can be used by subsequent crops or lost as a nonpoint pollutant of streams and groundwaters (Hunt et al., 1985; Hubbard and Sheridan, 1989). Conversely, large accumulations of soybean dry matter and fixed N are not common for soybean in the midwestern United States, where indeterminate soybean are grown on high-N soils. Those soybean generally accumulate lower amounts of dry matter and fix a smaller portion of their N than determinate soybean grown in the southeastern United States (Hammond et al., 1951; Hanway and Weber, 1971; Hanway and Thompson, 1971; Welch et al., 1973; Johnson et al., 1974; and Schapaugh and Wilcox, 1980).

The high levels of dry matter and N accumulated by determinate soybean grown in the southeastern United States are not always recognized, and clarity of supporting data is diminished by the fact that estimates of crop residue and N accumulation are generally confounded with large sampling variation. Coefficients of variation (CV's) are commonly greater than 20% (Carter et al., 1983). Such large sampling variation makes it difficult to have confidence in the dry matter estimates that are necessary for soybean residue management. However, Hunt et al. (1987) conducted a large-sample experiment in which CV's were less than 9%. They defined the sample variability and bias associated with various sampling techniques, and they reported the seasonal mean for dry matter accumulation. The objective of this manuscript is to better define the dry matter and N accumulation of southeastern-grown determinate soybean.

MATERIALS AND METHODS

A field study was conducted on a Norfolk loamy sand (fine-loamy, siliceous, thermic, Typic Paleudult). A split-plot design was used with soybean cultivar as the main plot treatment and sampling date as the split-plot treatment with four replications. Each split-plot contained eight rows 4.6 m in length on 0.75-m spacing. Fertilization consisted of 15, 100, and 1121 kg/ha of P, K, and dolomitic lime, respectively. 'Treflan' [trifluralin-ααα-Trifluro-2,6-dinitro-N,N-dipropyl-p-toludine] and 'Lexone' [(metribuzin-4-amino-6-(1,1 diemethethyl)-3-(methylthio) -1,2,4-Triazin-S (4H)-one] were applied prior to planting at the rate of 0.7 and 0.4 L/ha, respectively.

Soybean (Braxton, Coker 338, and Davis) were sown on May 18 at the rate of 33 seeds/m. Water was applied with an overhead irrigation gun as needed to prevent severe plant water stress. Plant samples for each cultivar were collected from 20m^2 of row at 89, 115, and 138 days after planting (DAP), as well as at seed harvest. Fallen plant material (crop litter) was collected from each plot on each sampling date. Plant samples and crop litter were dried at 70°C, weighed, ground to pass a 0. 4-mm screen, digested with 3mL 30% H_2O_2 and 7 mL H_2SO_4, and analyzed for N by Kjeldahl digestion and ammonium determination in the digest using a Technicon AutoAnalyzer II using Industrial Method 334-74 W/B (Technicon Industrial Systems, 1977). Soil samples were taken from the 0-5 cm, Ap, E, and B horizons at each sampling date. Soil samples were air-dried, ground, and analyzed for Kjeldahl N.

Data were analyzed by analysis of variance (ANOVA) and least significant difference (LSD) as outlined by Steel and Torrie (1960).

RESULTS AND DISCUSSION

Dry Matter Accumulation

The mean maximum intact shoot dry matter accumulation was 7.5 Mg/ha; and Braxton, Coker 338 (Coker), and Davis had maximum values of 8.3, 7.3, and 6.6

TABLE 1. Dry Matter Accumulation for Determinate Soybean Grown on a Norfolk Loamy Sand in South Carolina.

DAP[†]	Component	Cultivar			LSD
		Braxton	Coker	Davis	
		-------Mg ha^{-1}-------			
89	Intact shoots	5.95	6.22	5.67	NS
	Intact shoots	8.30	7.25	6.60	0.88
115	Crop residue	0.87	0.88	0.94	NS
	Total	9.17	8.13	7.54	0.88
	Intact shoots	8.27	5.91	6.30	1.13
138	Crop residue	3.43	2.70	3.98	0.62
	Total	11.70	8.61	10.28	1.82
	Intact shoots	2.79	3.23	3.30	NS
Harvest	Crop residue	3.44	2.71	2.55	0.62
	Seed	2.32	1.38	2.32	0.80
	Total	8.55	7.32	8.17	NS

[†]DAP = Days after planting

Mg/ha, respectively (Table 1). These values were measured at either 115 or 138 DAP. The mean maximum dry matter accumulation for intact shoots and crop litter was 10.2 Mg/ha. Yet, the mean seed yield of 2.01 Mg/ha would not represent an exceptional or even high level of production (Table 2). Much greater accumulations of dry matter occurred in the following season. Coker 368 had accumulated 8.9 Mg/ha of standing dry matter by 97 DAP (Hunt et al., 1987). The CV's for dry matter accumulation values were <9% in both years. These data clearly

TABLE 2. Indexes for Determinate Soybean Grown on a Norfolk Loamy Sand in South Carolina.

Cultivar	Actual harvest	Apparent harvest	Leaf
Braxton	0.27	0.45	0.40
Coker	0.18	0.30	0.37
Davis	0.28	0.41	0.31

Actual harvest index = (seed weight/total above ground dry matter weight)
Apparent harvest index = (seed weight/total standing dry matter weight)
Leaf index = (leaf weight/total dry above ground matter weight)

show that the dry matter accumulations are large for determinate soybean grown in the southeastern United States. A benchmark for midwestern soybean dry matter and N accumulations is Hanway and Thompson (1971). However, it does not accurately represent the development of determinate soybean grown in the southeastern USA. The difference is most notable in the late season where Hanway and Thompson (1971) predicted <5 Mg/ha for intact shoot dry matter accumulation about 138 DAP in Iowa, and our values in South Carolina ranged from 6.6 to 8.3 Mg/ha at 138 DAP.

The actual harvest index (seed weight/total above ground dry matter weight) in our study ranged from 0.19 to 0.28 (Table 2). These values reflect the high vegetative component of maturity group VI to VIII soybean that are grown in the southeastern USA, and the values are substantially lower than those reported for many midwestern cultivars. Schapaugh and Wilcox (1980) reported values of 0.28 to 0.53 for indeterminate soybean and values of 0.25 to 0.42 for determinate soybean grown in Indiana. Differences in vegetative components are also apparent for the leaf index (leaf weight/total dry matter weight), values ranged from 0.31 to 0.40 in our study (Table 2). Schapaugh and Wilcox (1980) reported much lower leaf index values, 0.16 to 0.30 and 0.18 to 0.38 for indeterminate and determinate soybean, respectively.

TABLE 3. Plant Nitrogen Accumulation for Determinate Soybean Grown on a Norfolk Loamy Sand in South Carolina.

DAP†	Component	Cultivar			LSD
		Braxton	Coker	Davis	
		-------Mg ha⁻¹-------			
89	Intact shoots	129	153	144	NS
115	Intact shoots	326	188	169	91
	Crop residue	8	8	9	NS
	Total	334	196	178	92
138	Intact shoots	303	237	243	52
	Crop residue	33	26	38	6
	Total	336	263	281	NS
Harvest	Intact shoots	27	31	31	7
	Crop residue	33	26	24	6
	Seed	151	90	150	52
	Total	210	146	206	58

† DAP = Days after planting

TABLE 4. Estimates of Net Nitrogen Returned to the Soil.

Nitrogen fixation	Braxton	Coker	Davis
%	-----------------	kg ha⁻¹	-----------------
50†	17	42	-10
90‡	151	147	103

† = [(Max. N Accumulation) (0.50) - seed N]
‡ = [(Max. N Accumulation) (0.90) - seed N]

TABLE 5. Soil Nitrogen Concentrations in the Ap Horizon at Various Sampling Dates and Harvest.

Cultivar	89 DAP	115 DAP	138 DAP	Harvest
	$\mu g\ g^{-1}$			
Braxton	476	491	463	440
Coker	431	433	518	504
Davis	406	443	398	397
LSD .05	NS	NS	NS	NS

DAP = Days After Planting

Apparent harvest index (seed weight/total standing dry weight) is a more commonly reported parameter, and apparent harvest index values were 0.30, 0.41, and 0.45 for Coker, Davis, and Braxton, respectively (Table 2). These values also reflect a higher vegetative component when compared to the apparent harvest index values reported by Schapaugh and Wilcox (1980), 0.49 to 0.65 and 0.38 to 0.54 for indeterminate and determinate soybean, respectively.

Since only 2.01 Mg/ha were removed as seed at harvest, over 8.0 Mg/ha of residue was returned to the soil surface during the soybean growing season, and 6.0 Mg/ha of crop residue remained after harvest. A seasonal contribution of 8.0 Mg/ha of crop residue is significant relative to the organic matter content of Coastal Plain soils which often contain less than 1% organic matter. Furthermore, this amount of crop residue can be a very important aspect of soil erosion control when combined with conservation tillage.

Nitrogen Accumulation

Southeastern soils are commonly low in N. Consequently, the addition of 8 Mg/ha of soybean residue is important to nutrient cycling as well as erosion control. Maximum N accumulations occurred 138 DAP, and values ranged from 263 to 336 kg/ha (Table 3). Dinitrogen fixation likely accounted for 50 to 90% of the N (Matheny and Hunt, 1983, Hunt and Matheny, 1985, Thurlow and

Hiltbold, 1985). If N_2 fixation accounted for 50 to 90% of the accumulated N, the net increase of N to the soil (fixed N-seed N) would have ranged from 10 to 42 kg/ha and 103 to 151 kg/ha, respectively (Table 4). These values are clearly different from estimates of negative N returned from indeterminate soybean grown in the Corn Belt (Johnson et al., 1974).

Soil N values during the growing season are presented in Table 5. The Ap total soil N values of 377 to 518 µg/g during the soybean growing season and at harvest document the low level of soil N in the Norfolk loamy sand. The mean soybean N accumulation of 293 kg/ha would have constituted a large portion (>30%) of the total N in the Ap horizon. However, N accumulated by soybean came from dinitrogen fixation and the deeper soil horizons as well as the Ap horizon. The soil N was not significantly different for cultivars at any depth at any sampling date, but the relatively higher Ap horizon N for Coker and the lower N for Davis at harvest are consistent with the projected net N values of Table 4. They may reflect the gain and redistribution of soil N associated with soybean growth on these low N soils.

CONCLUSIONS

1. Total dry matter accumulation values as measured in large samples with low CV's support the general conclusions from studies with smaller samples and larger CV's, *i.e.* dry matter production of determinate soybean grown in the southeastern USA will commonly be >10 Mg/ha.

2. Actual harvest indexes for determinate soybean measured in this study were lower than those reported for indeterminate soybean grown in the midwestern United States (<0.28 and >0.28, respectively).

3. Large dry matter accumulations, low harvest indexes, and high N_2 fixation levels associated with indeterminate cultivars grown on the low-N soils of the southeastern United States will generally produce net additions of N to the soil.

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