Root Characteristics and Seed Yields of Cowpeas Grown with and without Added Nitrogen Fertilizer

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Additional index words. *Vigna unguiculata*, adventitious root, basal root, lateral root, taproot, nodule, southernpea

Abstract. Field experiments were conducted in Oklahoma in 1993 and 1994. Cowpeas [*Vigna unguiculata* (L.) Walp.] were grown using either noninoculated seed and 23 kg·ha⁻¹ of preplant nitrogen (N) fertilizer (conventional) or *Rhizobium*-inoculated seed and no preplant N fertilizer (reduced input). Sample plants were excavated at first pod set and analyzed for nodulation and root morphology. Additional plants were harvested at the green-shell stage to determine seed yield and plant N concentration. Conventional and reduced input cowpeas did not differ in dry weight of root mass components, total root dry weight, shoot dry weight, shoot : root ratio, nodule distribution among root morphological components, total nodule fresh weight, plant N concentration, or green-shell seed yield. Most of the nodule fresh weight generally was associated with nodules on the basal and lateral roots. Results indicate that cowpea root characteristics are not necessarily altered by the presence or absence of added N fertilizer at a given location.

Cowpea is a valuable food grain legume that also has applications as a soil-improving crop. Concerns over nitrate levels in groundwater are stimulating the use of grain legumes such as cowpea in crop rotation systems because of their potential for producing crops without added N fertilizers (Buttery et al., 1992). Thus, cowpea is of interest for sustainable or reduced input agricultural systems.

The efficiency of effective nodulation in supplying the cowpea plant's N requirement is well documented (ElHassan and Focht, 1986; Summerfield et al., 1977). Despite this fact, the use of commercial N fertilizers in cowpea production remains a common recommendation (Fernandez and Miller, 1986; Halsey, 1960). Reports of cowpea response to N fertilization in the literature conflict. Some researchers have observed yield responses to N in the field, while others have observed none (reviewed by Beverly and Jarrell, 1984).

Dart (1975) stated that nodule formation often restricts lateral and secondary root production in the root zone where the nodules are borne. Fernandez and Miller (1986) investigated the interaction between inoculation and fertilizer N levels on N₂ fixation and seed and biomass yield of cowpea. However, they eliminated native *Rhizobium* sp. through fumigation, and they did not describe treatment effects on root morphology or on the distribution of nodules among root morphological components.

Such information could contribute to improved N₂ fixation through development of cowpea plants with appropriately modified root systems (Kahn and Stoffella, 1991).

Our objective was to compare root characteristics and seed yields of cowpeas grown with two commercial cultural systems (conventional, using preplant N fertilizer, and reduced input, using seed inoculation without preplant N fertilizer).

Materials and Methods

These experiments took place within a larger green manure study as described by Schroeder et al. (1998). The green manure experiments were arranged in randomized complete blocks with four replications. Since certain treatments were not applied in the green manure experiments until after cowpea harvest, extra sampling areas were available for the present studies.

The experiments were conducted at the Vegetable Research Station at Bixby, Okla., during 1993 and 1994. The soil was a Severn very fine sandy loam [coarse-silty, mixed (calcareous), thermic Typic Udifluvent]. Extractable soil nitrates at the 0- to 15-cm soil depth, measured before any experimental treatments were applied, averaged 4.6 µg·g⁻¹ soil in 1993 and 3.9 µg·g⁻¹ soil in 1994. Other soil characteristics were described by Schroeder et al. (1998). The two experiments occupied different fields at the station. The cowpea cultivar Pinkeye Purplehull BVR was used. Water was applied as needed by sprinkler irrigation to prevent drought stress. Weeds were controlled by a preplant-incorporated application of 2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine (trifluralin) at 560 g·ha⁻¹. Insect pests were chemically controlled as required.

Cowpeas were grown using either non-inoculated seed and 23 kg·ha⁻¹ of N from preplant-incorporated urea fertilizer (conventional) or inoculated seed and no preplant N fertilizer (reduced input). A slurry of 4.2 g of cowpea-type *Rhizobium* inoculant plus 8 mL water per kilogram of seed was used for inoculation. Control seeds were treated with plain water at the same rate, and were planted before the inoculated seeds. Seeds were machine-sown on 27 May 1993 and 20 May 1994 at one seed per 5 cm. Following thinning, stand counts averaged one plant per 10 cm in 1993 and one plant per 13 cm in 1994. Plots were 6 m long and eight rows wide, with 0.9 m between rows. Conventional and reduced input plots were separated by ≥4.5 m in all directions.

Twenty-four plants per treatment were sampled at the late anthesis/early pod set stage (14 July 1993 and 7 July 1994). Plants were excavated with a shovel at a 20-cm radius around each plant to a depth of ≈23 cm (Kahn and Stoffella, 1987). Root breakage was minimized by wet soil conditions. Roots were soaked in water, gently rinsed to remove adhering soil, and separated from the shoots. The recovered root mass of each plant was partitioned into adventitious, basal, lateral, and taproot components (Kahn and Stoffella, 1987). Nodules were dissected from each root mass component and weighed. Roots and shoots were dried at 50 °C for at least 4 d and then weighed.

Sixteen (1993) or twenty-four (1994) plants per treatment also were excavated at the green-shell stage (6 Aug. 1993 and 19 July 1994). Roots were washed and marketable pods were removed. Plants were dried as previously described, ground to pass a 20-mesh screen, and analyzed for N by the macro-Kjeldahl method without nitrate reduction (Method 3.1; Undersander et al., 1993) so that N concentrations could be calculated. Marketable (green-shell) pods also were picked by hand from 12 m of row per plot. Pods were shelled and seed yields (fresh weights) were recorded.

Data were evaluated by analysis of variance procedures. An F test was used to determine significance between conventional and reduced input treatments.

Results and Discussion

Conventional and reduced input cowpeas did not differ in dry weight of root mass components, total root dry weight, shoot dry weight, shoot : root ratio, nodule distribution among root morphological components, total nodule fresh weight, plant N concentration, or green-shell seed yield (Table 1). The taproot and its associated laterals accounted for most of the root mass, but most of the nodule fresh weight generally was associated with nodules on the basal and lateral roots (Table 1), in agreement with previous studies (Kahn and Stoffella, 1987, 1991).

Plants were smaller in 1994 than in 1993 (Table 1), perhaps because of climatic variations. However, plant N concentrations and seed yields were similar between years, a surprising observation, given that total nodule

Received for publication 1 Apr. 1999. Accepted for publication 4 June 1999. Approved for publication by the Director, Oklahoma Agr. Expt. Sta. This research was supported in part under project H-2026. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Effects of conventional (CONV.) and reduced input (R.I.) cultural systems on 'Pinkeye Purplehull BVR' cowpea grown at Bixby, Okla.²

Variable	1993		1994	
	CONV.	R.I.	CONV.	R.I.
Root dry wt. (mg/plant)				
Adventitious	26	18	17	13
Basal	210	163	222	187
Lateral	247	220	149	136
Tap	883	832	315	320
Total	1367	1233	702	656
Shoot dry wt. (g/plant)	27.1	25.6	20.2	21.2
Shoot : root ratio (w/w)	19.4	20.7	29.6	32.6
Nodule fresh weight (mg/plant) from given root mass components				
Adventitious	11	28	7	11
Basal	162	237	24	57
Lateral	334	426	20	55
Tap	94	238	14	21
Total	601	929	64	144
Plant N concn (%)	2.4	2.2	2.5	2.3
Seed yield (kg-ha ⁻¹)	798	703	724	867

²Conventional plants were grown using noninoculated seed and 23 kg-ha⁻¹ of preplant N fertilizer. Reduced input plants were grown using inoculated seed and no preplant N fertilizer. Within years and variables, means for the two cultural systems did not differ significantly, $P \leq 0.05$.

weights were much smaller in 1994 than in 1993 (Table 1). Elowad and Hall (1987) reported that an application of 60 kg-ha⁻¹ of N at sowing had little effect on cowpea grain yield or N fixation from 45 d after planting through the end of the growing season. Effectiveness of nodules was not examined in our studies, nor was source of assimilated N in the cowpea plants. We can only speculate that some nodules were ineffective in 1993, or N fixation was particularly efficient in 1994, or plants were able to meet their N requirements largely from N in the soil solution in 1994.

There was a consistent trend for plants in the reduced input system to have higher nodule weights than plants in the conventional system, but differences were not statistically significant at $P \leq 0.05$ (Table 1). Pate and Dart (1961) noted that, while inorganic combined N in the root medium usually inhibits nodule

formation, this may not hold for some associations at low levels of combined N. The more important finding is that, in our studies, inoculating cowpea seeds with *Rhizobium* produced a nodulation pattern among root morphological components similar to that obtained from natural infection in the soil. The two cultural systems also had no effect on partitioning of plant dry weight among the root morphological components (Table 1). Thus, cowpea root characteristics are not necessarily altered by the presence or absence of added N fertilizer at a given location. When combined with the lack of differences in seed yield, we can conclude that if conditions are favorable for nodule formation, cowpea producers may be able to reduce inputs by substituting seed inoculation with *Rhizobium* for application of preplant N fertilizer. A similar recommendation was made by Fernandez and Miller (1986).

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