In-Row Subsoiling and Potassium Placement Effects on Root Growth and Potassium Content of Cotton

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ABSTRACT

One method of correcting K deficiencies in cotton (*Gossypium hirsutum* L.) is by in-row deep placement of K fertilizer. At present, the mechanisms involved in cotton yield response to deep placement of K have not been elucidated. A field study was conducted in 1990 and 1991 to evaluate root development and dry matter yield of cotton as affected by in-row subsoiling and placement of K fertilizer. The experiment was located in central Alabama on a Norfolk fine sandy loam (fine-loamy, siliceous, thermic Typic Kandiudult). Five treatments were compared: (i) check, without in-row subsoiling; (ii) check, with in-row subsoiling; (iii) 84 kg K ha^{-1} surface-applied, without in-row subsoiling; (iv) 84 kg K ha^{-1} surface-applied, with in-row subsoiling; and (v) 84 kg K ha^{-1} deep-placed, in-row. Penetrometer readings taken in 1991 demonstrated that the soil has a well-developed traffic pan at a depth of approximately 15 to 38 cm. In-row subsoiling disrupted the pan up to 25 cm away from the in-row position. Root density measurements taken in-row showed that root growth at depths > 20 cm was improved by in-row subsoiling and K fertilization. Cotton root growth at depths > 20 cm was generally better for the treatment receiving the deep applied K. However, broadcast K in combination with in-row subsoiling resulted in the highest productivity and K accumulation per plant. Results of this study suggest that, for cotton production in Alabama, deep placement of K is not superior to broadcast applications of K.

Crop response in relation to deep placement or deep incorporation of fertilizer has been the subject of numerous studies. Woodruff and Smith (1947) reported that, for a claypan soil, shattering of the subsoil in combination with subsoil mixing of limestone and an N–P–K fertilizer increased corn (*Zea mays* L.) yield and improved sweetclover (*Melilotus* sp.) root growth. More recently, Gonzalez-Erico et al. (1979) evaluated corn response to deep incorporation of limestone on an Oxisol. They reported that incorporation of limestone to a depth of 30 cm improved corn root growth, increased water utilization, and increased grain yield. Similar results with corn and cotton were obtained when limestone was incorporated to depths up to 45 cm (Doss et al., 1979). In contrast, Woodhouse (1956) did not observe any improvement in yield of a lespedeza (*Lespedeza* or *Kummerowia* sp.)–Dallisgrass (*Paspalum dilatatum* Poir.) mixture on a Cecil sandy loam (Typic Kanhapludult) as a result of lime, P, and K applications. Fehrenbacher et al. (1958) observed increased corn yield when a combination of limestone, P, and K was mixed to depths of 91 cm on a Weir silt loam (Typic Ochraqualf) soil in Illinois. Reeves et al. (1990) did not observe any benefit to grain sorghum (*Sorghum bicolor* L. Moench.) grown on two Ultisols in Alabama as a result of injecting a lime suspension into the subsoil.

Positive yield responses to deep placement of K fertilizer recently have been reported in Mississippi studies (Tupper et al., 1988, 1989; Tupper, 1992). Potassium fertilizer was banded into the subsoil behind a parabolic super-chisel shank. The applicator is designed to distribute the fertilizer in a 5 cm wide band that extends from a depth of 15 to 38 cm if the shank is run at a depth of 38 cm. Subsoiling and K fertilizer effects are confounded with this technique, since the soil is subsoiled when the K fertilizer is deep-placed. Increases in lint yield by as much as 112 kg ha^{-1} were reported on soils having low available K in the subsoil. Surveys have shown that many cotton soils in the southeast have medium or lower soil test ratings for K in the subsoil (Mitchell et al., 1992; Tupper et al., 1989).

At present, the mechanisms involved in cotton yield response to deep placement of K have not been elucidated. If a positive response does occur, it could be due to increased K availability in the subsoil. In addition, deep placement of K may influence cotton root growth within the zone of placement. Effects on root growth, either positive or negative, because of deep-placed K would affect the entire plant by altering water and nutrient uptake. Potassium has been shown to promote adventitious root growth on some vegetable crops (Zhao et al., 1991). Preliminary work with band application of K on Acala cotton (Cassman et al., 1991), however, suggests that cotton root length and root surface area are insensitive to K fertilization.

Our objective was to evaluate dry matter production, root growth, and aboveground K accumulation by cotton in response to in-row subsoiling and K fertilizer placement.

MATERIALS AND METHODS

A field study was initiated in 1989 on a Norfolk fine sandy loam in central Alabama. The soil had a medium soil test rating (Cope et al., 1981) for K in the top 0 to 15 cm of soil (Table 1) and a low soil test rating at greater depths.

Treatments consisted of K rates broadcast on the surface with and without in-row subsoiling, or deep-placed in the subsoil channel. Subsoiling and deep placement of fertilizer to a depth of 38 cm were accomplished with the two-row deep fertilizer applicator described by Tupper and Pringle (1986). The applicator has twin parabolic super-chisel shanks with rectangular steel tubes welded to the back of each shank. Each

Table 1. Initial chemical properties of the Norfolk soil.

Depth	CEC	pH	Mehlich I Extractable			
			P	K	Mg	Ca
cm	cmol$_c$ kg^{-1}		kg ha^{-1}			
0–15	4.77	7.0	103 (H)†	102 (M)	188 (H)	818
15–30	4.84	6.2	94 (H)	76 (L)	87 (H)	650
30–45	4.96	5.6	19 (L)	94 (L)	102 (H)	616

† Soil test ratings according to Cope et al. (1981): H, high; M, medium; L, low.

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tube has deflector plates that allow the fertilizer to be distributed in a 5-cm-wide band extending from 15 to 38 cm if the shanks are run at a depth of 38 cm. The experiment included four rates of K (0, 28, 56, and 84 kg ha^{-1}) broadcast on the surface with and without in-row subsoiling, or deep-placed, in-row. Two additional in-row, deep-placement treatments received either 1680 kg ha^{-1} limestone or 1680 kg ha^{-1} limestone + 84 kg K ha^{-1} (Mullins et al., 1991). Treatments (12 total) were established in the spring just prior to planting and arranged in a randomized complete block design with four replications. Data were collected from five selected treatments: (i) check, without in-row subsoiling; (ii) check, with in-row subsoiling; (iii) 84 kg K ha^{-1} surface broadcast, applied without in-row subsoiling; (iv) 84 kg K ha^{-1} surface broadcast, applied with in-row subsoiling; and (v) 84 kg K ha^{-1} deep-placed, in-row. After subsoiling and applying the surface K treatments, the experimental area was disked prior to planting. The variety used in this study was Deltapine 50. Experimental plots were 4.1 by 6.1 m (four rows).

Cotton was harvested by hand (1989) or mechanically (1990 and 1991), picking the two center rows from each plot. Immediately after cotton harvest in 1990 and 1991, two soil cores (3.2 cm in diameter) per plot were collected in-row to a depth of 80 cm. Cores were subdivided into increments of 0 to 20, 20 to 40, and 40 to 80 cm. Roots were quantitatively separated from the soil cores with a hydropneumatic elutriation system (Smucker et al., 1982; Gillison's Variety Fabrication, Benzonia, MI). Root length was determined by the line-intersect method (Tennant, 1975). The root length data were combined with the volume of the soil cores to calculate root length density. Soil cores were collected to avoid tap roots; thus, only branch roots were measured.

Soil penetrometer recordings were taken in the final year of the study (1991), at one month after planting, when the soil moisture content was near field capacity (shortly after a heavy rain). Five penetrations within each plot to a depth of 50 cm were made in nontrafficked rows at 0, 12.5, 25, 37.5, and 50 cm away from the in-row position. Measurements were made with a hand-held Bush recording soil penetrometer (Mark 1 Model 1979; Findlay, Irvine Ltd., Penicuik, Scotland).

During the second year of the test (1990), visual observations suggested that larger cotton plants were being produced with broadcast K in combination with in-row subsoiling as compared with other treatments. This difference was not fully realized in 1990 until the nonsubsoiled treatments had started to lose their leaves. To be able to better evaluate cotton response to the subsoiling and K fertilizer treatments, cotton plant dry matter production and K content was evaluated during the third and final year of the study. On 27 Aug. 1991 (just prior to leaf shed), four intact cotton plants were harvested from each plot. Harvested plants were separated into stems, leaves, and bolls. Each plant part was dried at 60 °C and weighed. The dried bolls were separated into burs, seed and lint prior to grinding and nutrient analysis. Subsamples of each respective plant part were ashed at 450 °C, and digested using 1 *M* HNO_3 and 1 *M* HCl (Hue and Evans, 1986). Potassium in the digests was determined by inductively coupled argon plasma (ICAP) spectrophotometry (ICAP 9000, Thermo Jarrell-Ash Corp., Franklin, MA).

All data were analyzed by analysis of variance with SAS procedures (SAS, 1985). Means were separated with Fisher's protected LSD. For seed cotton yield, dry matter production, and K uptake data, the probability level was preset at 0.10; for the root density data, it was set at 0.20.

RESULTS AND DISCUSSION

Soil penetrometer readings taken in 12.5 cm increments from the in-row position out to 50 cm show a well developed traffic pan beginning at ≈15 cm and extending to a depth of ≈38 cm (Fig. 1). The penetration re-

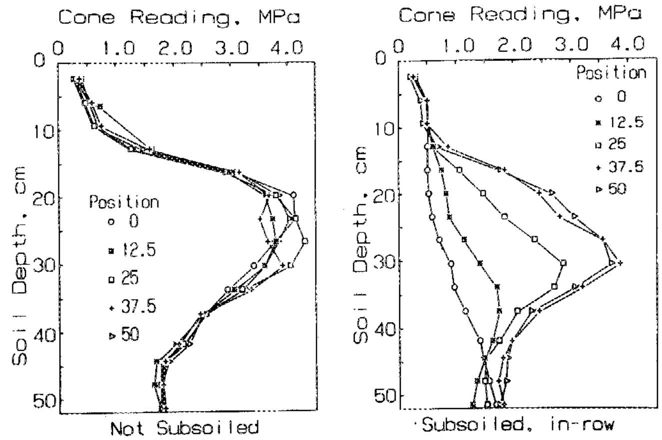

Fig. 1. Soil penetrometer readings for the nonsubsoiled and subsoiled check treatments. Penetration position refers to the number of centimeters from the in-row position.

sistance for the nonsubsoiled soil was relatively uniform with respect to distance from the in-row position. For the in-row subsoiled check treatment, resistance to penetration was greatly reduced in the in-row position. In-row subsoiling reduced the penetration resistance up to 25 cm out from the in-row position. These data suggest that the in-row subsoiled treatments would have less resistance for root penetration.

Cotton root density below the plow layer (20–80 cm) was increased by in-row subsoiling and K fertilization (Fig. 2). In the surface 20 cm of soil there were no treatment effects on root density in 1990. In 1991, the greatest root densities (0–20 cm) were observed with broadcast K and no subsoiling. In addition to the apparent stimulation by added K, compacted soil in the nonsubsoiled treatments probably forced a larger proportion of the root system to develop above the pan. A stimulation in root growth by K fertilization is in contrast to the findings of Cassman et al. (1991), who did not observe any response of Acala cotton roots to K fertilization. Tupper (1992), however, observed an increase in cotton taproot length when K fertilizer was band-applied in the subsoil of Mississippi soils having low soil test K.

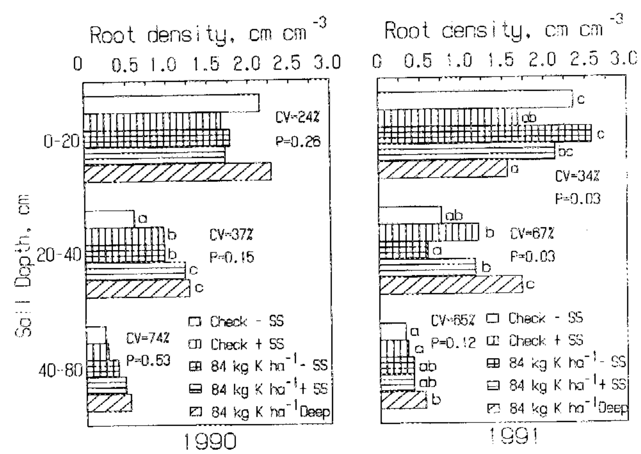

Fig. 2. Cotton root length density at three depths in a Norfolk soil as affected by the deep placement of K and in-row subsoiling. Columns followed by different letters are significantly different at the 0.20 level of probability. −SS, no subsoiling; +SS, in-row subsoiling prior to planting.

Table 2. Effect of in-row subsoiling and deep placement of K fertilizer on the number of bolls per plant, average boll weight, dry matter production, and K uptake per plant and seed cotton yields.

Treatment†	1991									Cotton yield		
	Bolls per plant	Boll weight	Dry matter yield per plant						Potassium accumulation	1989	1990	1991
			Stems	Leaves	Burs	Seed	Lint	Total				
	no.	g boll^{-1}	g plant^{-1}						g K plant^{-1}	Mg ha^{-1}		
Check, −SS	6.7b‡	5.7a	12.5b	5.9b	10.1b	16.8b	10.6b	56b	1.21b	1.99b	2.40b	2.90b
Check, +SS	7.9b	5.5a	17.3b	7.8b	11.7ab	19.9ab	12.4ab	69b	1.47b	2.50ab	3.12a	3.20ab
84 kg K ha^{-1}, −SS	6.5b	5.7a	13.6b	5.9b	9.1b	16.7b	11.3b	57b	1.36b	2.26ab	2.35b	3.45ab
84 kg K ha^{-1}, +SS	10.9a	6.0a	33.9a	11.5a	16.8a	29.1a	19.4a	111a	2.48a	2.24ab	3.17a	3.69a
84 kg K ha^{-1}, Deep	9.4ab	5.3a	17.4b	5.9a	13.6a	22.8a	14.4a	74b	1.76b	2.77a	3.06a	3.28ab
CV, %	28	30	33	37	31	29	30	29	30	23	15	15

† −SS, no subsoiling: +SS, in-row subsoiling prior to planting: Deep, placement of K at the 15- to 38-cm depth.
‡ Within columns, means followed by different letters are significantly different at the 0.10 level of probability.

In-row subsoiling resulted in a more uniform root distribution with depth, compared with the nonsubsoiled treatments. At a depth of 20 to 40 cm in 1990, the nonsubsoiled check treatment had the lowest root density compared with the other treatments. The highest root density (20–40 cm) was observed with deep band-applied K and broadcast K with in-row subsoiling. In 1991, at the 20- to 40-cm depth, treatments that were not in-row subsoiled had the lowest root density, while the highest root density was observed with deep band-applied K. At a depth of 40 to 80 cm there were no significant treatment effects in 1990, although slightly higher root densities were observed with K fertilization, especially in combination with in-row subsoiling. In 1991, at a depth of 40 to 80 cm, deep applied K resulted in a higher root density ($P \leq 0.20$) as compared with the two check treatments.

In 1991, leaf, stem, and total aboveground biomass just prior to maturity was highest for the broadcast application of 84 kg K ha^{-1} in combination with in-row subsoiling (Table 2). For this treatment stem and leaf weight per plant was increased by an average of 127 and 83%, respectively, as compared with the other treatments. Broadcast K in combination with in-row subsoiling and the deep banding of K produced the same number of bolls per plant. However, broadcast K in combination with in-row subsoiling produced a higher number bolls per plant as compared with the remaining treatments. Boll weight was not affected by any treatment. Weight of the various plant parts and whole-plant weights were lowest for those treatments that were not subsoiled and greatest for broadcast K in combination with in-row subsoiling. This shows that the aboveground growth was improved by in-row subsoiling and by the application of K fertilizer, especially when surface applied. The surface application of K in combination with in-row subsoiling also resulted in a higher aboveground accumulation of K per plant as compared with the remaining treatments ($P \leq 0.10$). There were no differences among the remaining treatments for K accumulation. Thus, K accumulation by cotton plants on the deep-placement treatment was the same as K accumulation on the in-row, subsoiled check treatment. Although the deep placement of K resulted in a stimulation of root development beneath the plow layer (Fig. 2), a higher aboveground accumulation of K per plant resulted from the surface broadcast treatment, possibly due to more roots being exposed to the applied K in 1991 (Fig. 2). Increased rooting in the subsoil could benefit the cotton plant if it were experiencing drought stress. Highest seed cotton yields for all years resulted from in-row subsoiling (Table 2). Although the results of studies conducted in Mississippi (Tupper, 1992) suggest that cotton yields will be improved by deep banding of K in soils with low soil test K, our results do not support this concept for Alabama.

SUMMARY

Results of this study show that on a soil with medium to low soil test K and a well developed traffic pan, broadcast K with in-row subsoiling was equivalent to deep K placement for cotton. In this test, the deep placement of K resulted in a higher root density below the plow layer as compared with the placement of K on the surface in combination with in-row subsoiling. However, this rooting pattern was not associated with increased dry matter production per plant, K accumulation per plant, or seed cotton yield. Deep placement of K increased in-row cotton root length density, but the aboveground plant obtained less K than broadcast K with in-row subsoiling. Higher aboveground K accumulation and dry matter production per plant for the surface application of K with in-row subsoiling probably resulted from a larger proportion of the cotton root system being exposed to the surface applied K as compared with the deep-placed K. The results of this and previous studies (Mullins et al., 1991) suggest that, for cotton growing on Alabama soils, deep placement of K is not superior to surface broadcast application of K.

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INTEGRATED PEST MANAGEMENT

FROM THE EDITOR. Early in 1993, responding to reader requests and after consideration of the role of *Agronomy Journal*, we issued a call for papers on integrated pest management (IPM). The intent was to provide a forum for basic and applied research on aspects of plant stress management that would be accessible both to crop and soil scientists and to researchers in the pest disciplines. Many scientists have responded to this call, and we are pleased now to begin publishing papers in a new **Integrated Pest Management** section.

This new section may represent a departure from our traditional studies, in that it brings together work in entomology, nematology, plant pathology, weed science, and interdisciplinary areas, particularly those describing biotic and abiotic stresses and their management. However, the multidisciplinary nature of agronomy itself makes *Agronomy Journal* an ideal place to publish papers of this nature. From the beginning, IPM has been linked with the effective management of both soils and crops, and for some time researchers in the crop and soil sciences have been working along those lines. It was time to provide a recognized place to present this work.

Authors are encouraged to continue to submitting papers for this section. It is our hope that this section will contribute a broad vision of stress management that considers the interaction of biotic stresses, such as weeds, insects, diseases, nematodes, and the like, with abiotic stresses, such as those caused by drought, heat or cold stress, and nutrient deficiencies.

The broadened scope of the journal will provide for a larger impact of our science upon the world. While IPM represents a new set of disciplines, it does not mean that we have run out of problems to study in traditional areas. Rather, this new integrated pest management section will provide another way of approaching those traditional studies, for effective management of our natural resources through proper soil and crop management is linked with how well we manage pests.

The *Agronomy Journal* is committed to adapting and changing as needed, in order to better serve its readers and members of the Society and to continue presenting you with a quality journal.

— *J. L. Hatfield, Editor*