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Cone Index and Root Growth in Surface and Subsurface Microirrigated Hardpan Soil

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Summary

Restricted root growth caused by subsurface hardpans and low water holding capacity reduces crop yields in many United States southeastern Coastal Plain soils. With intensive irrigation it is possible to obtain suitable yields without deep tillage. The objective of this study was to find differences of root growth and cone indices between surface and subsurface applied sources of irrigation water. We measured root growth and cone index in intensively managed irrigation plots of green beans (*Phaseolus vulgaris* L.) in 1988 and 1989. Microirrigation tubes were placed on the surface or in the subsurface — buried at a depth of approximately 0.25 m — and irrigated either continuously or with intermittent pulses of water. Mean profile cone indices for the surface tube placement were significantly lower than for the subsurface tube placement. Mean profile cone indices for the continuous irrigation treatment were significant lower than for the intermittent irrigation treatment. However, no one treatment significantly reduced the cone indices within the hardpan. Total root count was significantly greater for the subsurface tube placement with increased root growth below the 0.1-m depth. There was a high density of roots next to the subsurface tube that would have been effective in uptake of water from the microirrigation tube. However, yield was significantly greater for the surface tube placement. For all treatments, the largest concentration of root growth occurred in the top 0.2 m of the soil within the row. We expected this for the surface irrigation treatment. However, we also measured this for the subsurface treatment, probably because of high rainfall and upwelling of water from the subsurface micro-irrigation tube.

1 Introduction

Deep profile disruption, usually in the form of in-row subsoiling, is often necessary to provide a suitable medium for plant root growth in southeastern Coastal Plain hardpan soils of the United States (Doty et al. 1975, Trouse & Reaves 1980, Box & Langdale 1984). Cone indices above 2.5 MPa are commonly found in non-tilled subsoils even without wheel traffic (Campbell et al. 1974). Cone indices of this magni-

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tude are often considered root restricting (Blanchar et al. 1978, Busscher et al. 1986). The E horizon, just below the A_p, often registers the highest cone indices and can have root restricting cone indices at water contents as high as field capacity (Campbell et al. 1974).

There is abundant rainfall in the southeastern Coastal Plain (1100 mm annually: NOAA 1983). However, only a limited amount of this is available for plant growth since soils are generally sandy and low in water holding capacity. They can retain as little as 0.085 m of water per meter of soil (Beale et al. 1966). During short periods of low or no rainfall, plants experience yield reducing stress (Sadler & Camp 1086). Without deep tillage, intensive irrigation management would be needed to produce suitable crop yields (Camp et al. 1989a).

Because of its precise water placement, microirrigation can aid in the intensive soil water management needed to supplement rainfall. With intensive microirrigation management, high yields can be produced without deep tillage (Camp et al. 1989a). The objective of this study was to determine root growth and soil cone index in plots where microirrigation tubes were placed on the soil surface or buried near the top of the subsoil compacted layer.

2 Methods

This study was conducted during the summers of 1988 and 1989 in Florence, SC, on a Norfolk loamy sand (a structureless, fine loamy, siliceous, thermic, Typic Kandiudult). Green beans (*Phaseolus vulgaris* L. cv. Bush Blue Lake 274[1]) were planted on 1.5-m wide raised beds. There were two beds per plot with two rows on each bed, separated by 0.5 m (fig. 1). Plots were 12 m by 3 m.

The field design was randomized complete block with four replications. Treatments were irrigated with microirrigation tubing (Lake Drip-In). There were two treatments, placement of the microirrigation tube and frequency of irrigation, with two levels each. Tubes were placed either on the surface immediately next to each row or buried in the subsurface at approximately a 0.25 m depth below the beds at 0.75-m intervals (fig. 1). Irrigation was applied at two frequencies: high frequency where one third of the application was applied every four hours, and low frequency where the same amount of irrigation was applied without interruption.

Because of the buried tube, plots were not subsoiled annually, which is the recommended practice for this soil. All plots had been subsoiled in August 1984. In November 1984, tubes were plowed into the subsurface tube placement treatment using a steel tube attached to a subsoil shank as a guide. Hardpans reconsolidate in these soils by natural reconsolidation, traffic, and disking within a year after deep tillage (Busscher et al. 1986). Surface irrigation tubing was installed in the plots each year after planting and removed before harvest. The same tubing had been used for each of the plots since they were developed. Prior to this experi-

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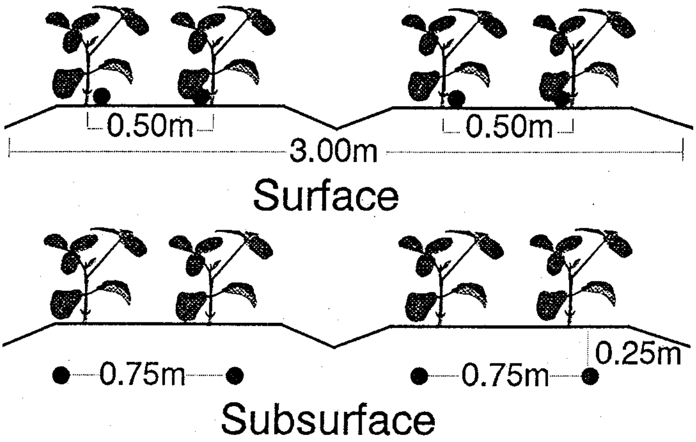

Fig. 1: *Schematic diagram of bedding and tube placements. Shaded circles indicate microirrigation tube locations.*

ment, plots had been in corn (*Zea mays* L.) and winter fallow from 1985 to 1987 (Camp et al. 1989a).

The same wheel tracks were maintained throughout the study. These wheel tracks separated each of the beds (fig. 1). Pesticide and fertilizer were applied as recommended by the South Carolina Cooperative Extension Service at 34-29-56 kg/ha of N-P-K for both 1988 and 1989 with a side-dressing of 22-0-0 kg/ha of N-P-K for 1988 and 34-34-0 kg/ha for N-P-K for 1989. The side-dressing was applied by fertigation. Spring land preparation included disking followed by levelling with a tined field cultivator to incorporate preplant fertilizer and herbicide and rototilling to prepare for shaping and compressing of the beds.

The plot area was fumigated with a methyl bromide-chloropicrin mixture and covered for three days prior to bed formation for weed control. Beds (0.15-m high) were formed using a Larchmont Bedder (Larchmont Engineering and Irrigation, Inc., Lexington, Massachusetts). The bedder consisted of two adjustable concave discs which ridged the soil to a bed center. Leveling boards smoothed the top surface. Two gangs of meeker harrows (small discs for clod pulverization) followed the leveling boards. The harrows slightly firmed the bed surface. Beans were planted on 28 April 1988 and 16 May 1989.

Tensiometers were installed at 0.3- and 0.45-m depths in the middle of the beds of two replicates and soil water potentials were recorded three times a week. When the 0.3-m deep tensiometer of any plot reached a tension of 30 kPa or more, 6 mm of irrigation was applied. Equal amounts of water were applied to all treatments. Yields were obtained from several hand pickings, and quality analysis was conducted as described in Camp et al. (1989b).

At the end of the harvest season, 15 July 1988 and 8 August 1989, cone in-

Frequency Tube placement	High	Low	Mean
	Yield Mg/ha		
Surface	8.67	8.06	8.36a[1]
Subsurface	5.48	6.88	6.18b
Mean	7.08a	7.47a	

[1] Means with the same letter are not significantly different at $P<0.01$

Tab. 1: *Green bean yields for plots with different tube placements and irrigation frequencies.*

Depth m	Surface	Subsurface	Mean
	Water contents kg/kg		
0.05	0.16a[1]	0.14b	0.15c[2]
0.15	0.13a	0.12a	0.13e
0.25	0.14a	0.14a	0.14d
0.35	0.17a	0.16a	0.16b
0.45	0.18a	0.18a	0.18a
0.55	0.17a	0.18b	0.17ab

[1] Means within the same column with the same letter are not significantly different at $P<0.10$.

[2] Means within the same column with the same letter are not significantly different at $P<0.05$

Tab. 2: *Gravimetric water contents accompaning cone index measurement by depth for surface and subsurface tube placement.*

Frequency Tube placement	High	Low	Mean
	Root count $m^{-3} \times 10^5$		
Surface	3.89	4.33	4.11b[1]
Subsurface	4.68	4.67	4.67a
Mean	4.28a	4.50a	

[1] Mean with the same letter are not significantly different at $P<0.10$.

Tab. 3: *Root count for the main treatments.*

Depth m	Surface	Subsurface	Mean
	Root count $m^3 \times 10^5$		
0.0–0.1	8.96a^1 a^2	8.58a a	8.77a^2
0.1–0.2	4.35a b	4.67a b	4.51b
0.2–0.3	1.28b c	2.69a c	2.30c
0.3–0.4	1.85b c	2.76a c	1.98c
Position			
E^3	5.10b^1	7.57a	6.34a^2
BE	4.90a	4.83a	4.86b
MB	4.40a^4	3.91b	4.16c
WT	2.05a	2.38a	2.21d

[1] Means within the same row with the same letter are not significantly different at $P<0.05$.

[2] Means within the same column with the same letter are not significantly different at $P<0.05$.

[3] E and BE are taken along the tube: at the emitter (E) and between emitters (BE); MB is taken at mid-bed; WT is taken in the wheel track.

[4] Means within the same row with the same letter are not significantly different at $P<0.10$.

Tab. 4: *Root count by depth and by position across the row.*

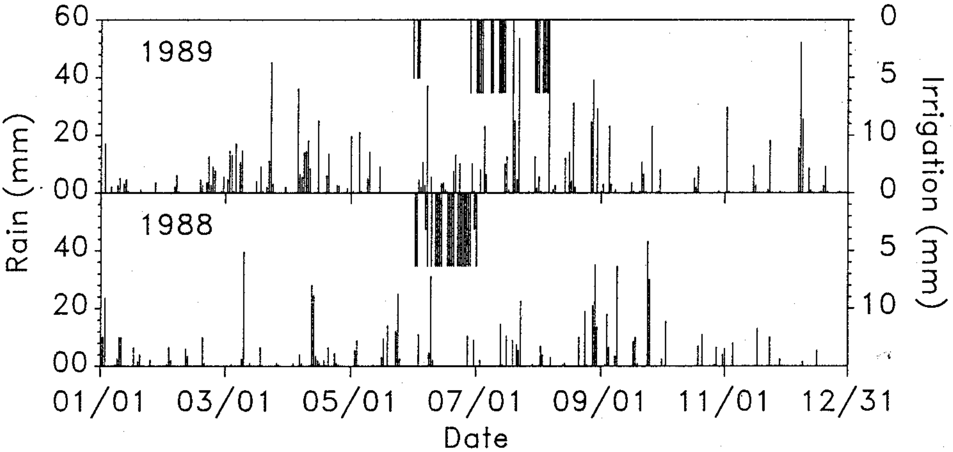

Fig. 2: *Rainfall and irrigation for 1988 and 1989.*

Frequency Tube placement	High	Low	Mean
	Cone index MPa		
Surface	2.31	2.19	2.25a[1]
Subsurface	2.46	2.22	2.34a
Mean	2.39a	2.21b	

[1] Means with the same letter are not significantly different at $P<0.10$.

Tab. 5: *Cone indices by frequency of irrigation and tube placement.*

to 30 minutes after the initiation of irrigation. Incorporation of the starter fertilizer would have also encouraged root growth near the surface, while fertilizer added later through fertigation would have encouraged root growth near the microirrigation tubes.

In a by-depth analysis of root count (tab. 4), the surface tube placement had a higher root count for the 0.0 to 0.1-m depth and the subsurface placement had a higher root count for the 0.1 to 0.4-m depths. While taking root samples, it was obvious that there were more roots at the depth of the subsurface microirrigation tube (0.25 m) than at the equivalent depth in the plots with the surface tube. Roots at this depth were difficult to sample because they were immediately adjacent to the tube. Samples were taken close to but not through the tube. These roots would be effective in water uptake for the plant because of their proximity to the source of irrigation.

Root counts for samples taken at each location within and across the row were significantly different ($P<0.05$) from the other locations with the ranking at the emitters > between emitters > mid-bed > wheel track (tab. 4). As expected, root counts were higher in the row (at and between emitters) and lower between the rows (mid-bed and wheel track) with the lowest count in the wheel track. The surface tube placement had a significant higher ($P<0.10$) root count in the mid-bed. The subsurface tube placement had a significantly higher ($P<0.05$) root count at the emitter. These differences could also be interpreted as a more uniform distribution of root count across the sampling locations for the surface tube placement than the subsurface tube placement. A more uniform root count could be a result of more uniform watering of the surface tube placement. Water from the microirrigation tubes on the surface was free to run across the surface before infiltrating and was often seen to do so.

Cone indices: Cone indices were significantly different for frequency of irrigation treatments (tab. 5, $P<0.10$). Cone index differences for positions across the row and for depths were also significant ($P<0.01$.)

Cone index differences with depth were expected in a hardpan soil. The higher cone indices were measured at the 0.15-m to 0.35-m depths where the hardpan is usually found (tab. 6 and fig. 3).

When gravimetric water content samples were added to the statistical design as a covariate, significant differences were maintained for depth and fre-

	Surface	Subsurface	Mean
Depth m	Cone index MPa		
0.05	0.75	0.83	0.79f[1]
0.15	3.26	3.38	3.32b
0.25	4.10	3.78	3.94a
0.35	2.41	2.55	2.48d
0.45	2.05	2.08	2.07e
0.55	2.63	2.88	2.75c

[1] Means within the same column with the same letter are not significantly different at $P<0.01$.

Tab. 6: *Cone indices by depth for surface and subsurface irrigation.*

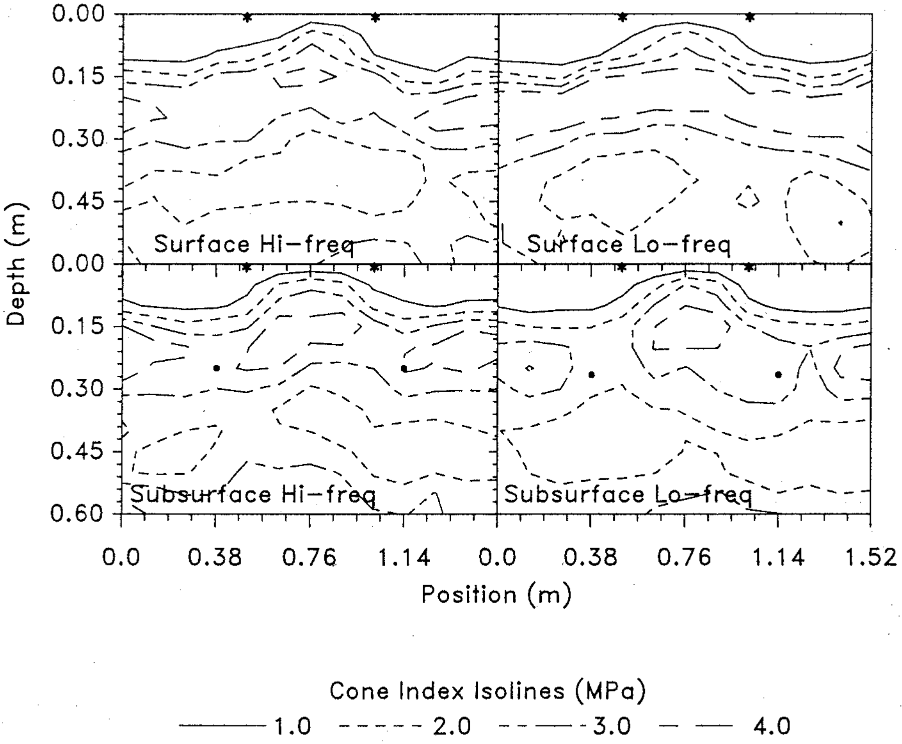

Fig. 3: *Cone index isolines as a function of depth and position for the surface and subsurface tube placement, high and low irrigation frequency treatments in 1988. * indicates the row location. • indicates the location of the buried tube.*

quency of irrigation but lost for position of measurement across the row and the interaction of frequency by position. This indicated that the differences with position were related to water content. However, it is difficult to say that water content is not responsible for the change in cone index for frequency since small changes in water content can cause large changes in strength (Camp & Lund 1968).

Water contents measured along with the cone indices were significantly different for depth and position of measurement within and between the rows. Differences were small (tab. 2) but significant. For example, for differences with location water contents were 0.16 kg/kg for the mid-row and 0.15 kg/kg for the row. It is interesting to note that significantly lower moisture contents with depth were measured for the 0.15-m and 0.25-m depths, which are within the zone of high cone index readings (fig. 3). This would have contributed to the high cone indices measured for the pan.

4 Conclusions

Green bean yields were greater for the surface tube placement than the subsurface tube placement probably because it was more effective in wetting the surface 0.2 m where the largest concentration of roots was located.

The largest concentration of roots grew in the row and near the surface for all the treatments, including the subsurface tube placement. This could have been a result of the high rainfall rate and upwelling of water from the subsurface tubes.

Root count was higher for the subsurface tube placement than for the surface tube placement. However, these increases were below the 0.10-m depth. Deeper roots were apparently not as effective in increasing yield as the roots nearer the surface. Dense root growth was observed immediately next to the subsurface tube. Root growth there would have been encouraged by the abundance of irrigation water and the mid-season fertigation. Also, these roots would have been effective in taking up subsurface irrigation water because of their proximity to its source.

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