GARDEN TILLAGE AND SOIL COMPACTION

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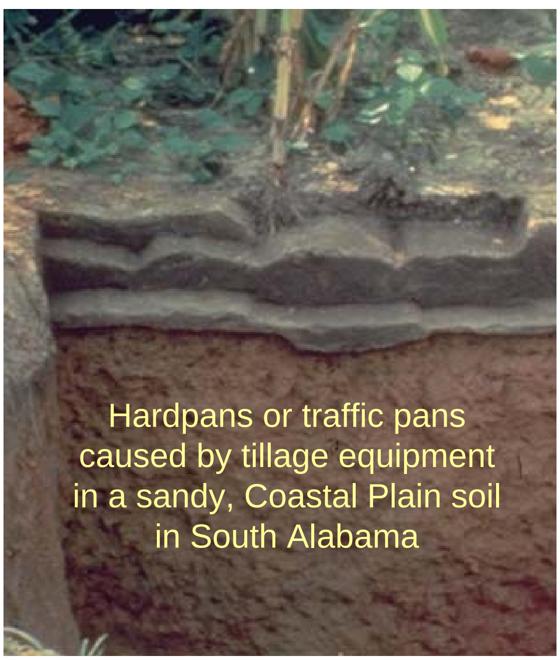
BACKGROUND

Soils have traditionally been tilled and cultivated to (1) prepare a seed bed and (2) control weeds. Heavy equipment used for tillage and other purposes may compact soil, increase soil bulk density, and reduce yields (Brady, 1990). Therefore, a third reason for tillage may be to breakup compacted soils that may have resulted from previous soil activities. Traffic pans or plow pans are a common problem in field crops on the sandy soils of the southeastern U.S. Coastal Plain region (Camp and Lund, 1964). Traffic pans are a thin layer (2 to 4 inches) of compacted soil resulting from the downward force of tillage equipment on the soil just beneath the plow layer. The problem is particularly serious on soils with a sandy topsoil (Ap horizon) just above a finer textured subsoil (Bt horizon). This compacted soil layer can restrict water and air movement through the soil and limit root growth.

Commercial farmers have employed several techniques to overcome or prevent the development of plow pans and soil compaction. These include no-till or reduced tillage farming, in-row subsoiling or paratilling to break hardpans, high residue management to protect surface soils and increase water use efficiency, and slit tillage. Slit tillage was proposed in the 1980s to accomplish the same thing as subsoiling but with less energy. Instead of disrupting a plow pan, a thin slit is cut through it for root growth (Elkins, 1980. Elkins and Hendrick, 1983, Allen, 1984).

Slit tillage uses a blade to cut a narrow slit through the traffic pan. Roots can follow the slit into the subsoil. Root channels through this slit persist from year to year if the soil is not drastically disturbed. Unfortunately, abrasion caused by coarse textured, sandy soils tend to rapidly wear away a blade. Therefore, slit tillage has not become a practice for large scale farmers.



Traffic pans or tillage pans may also be a problem for gardeners and small-scale vegetable producers. These growers probably don't have access to large equipment necessary for deep tillage and subsoiling. Often they depend on small tractors with disks and/or garden tillers that may create traffic pans as serious or worse than those created by field cropping practices. In fact, estimates of soil compaction by common activities rank tillers among the most serious. Values in Table 1 were calculated based upon the mass x acceleration and the surface area in contact with the soil.

Table 1. Estimates of forces of compaction from typical sources of soil activities.

Source of Compaction	Estimated compaction
	---------lb/inch^2--------
Man walking	6
Crawler-type tractor	12
Wheel-type tractor	20
Cattle	23
Horse	40
Garden rototiller	107-750

The faster the tines of a tiller rotate, the more energy is transferred into the soil just beneath the tines. This rapid rotation of a rear-tined tiller has the potential to create traffic pans more severe than a large tractor and disk. The fast spinning tines may also destroy soil structure by crushing soil aggregates. This can potentially result in soil crusting and increased soil bulk density.

OBJECTIVE

The objectives of these experiments and demonstrations are to apply what we have learned about tillage and soil compaction in field crops for small gardens and small-scale vegetable producers. We wanted to (1) demonstrate the effects of soil compaction and (2) determined the best techniques to overcome compactions negative effects of soil compaction. We were able to involve Master Gardener volunteers in conducting applied research thus providing Extension training through hands-on experience.

METHODS

Since the early 1990s, experiments and demonstrations with garden tillage techniques have been conducted with Master Gardeners at three Alabama sites. At all three sites, soil was tested and lime applied to the appropriate crop to maintain a soil pH 6.0 to 6.5. All sites tested high or very high in P and K according to the Auburn University Soil Testing Laboratory and no P or K was applied. Nitrogen was applied based upon standard recommendations for vegetable crops for Alabama (Adams et al., 1994). Insect and weed control were managed using IPM for that particular crop and site (http://www.aces.edu/pubs/docs/A/ANR-0500-B/).

Auburn Site. One of the first experiments was located on the campus of Auburn University on a Marvyn loamy sand (fine-loamy, siliceous, thermic Typic Kanhapludults), a typically sandy, Coastal Plain soil with a sandy clay loam subsoil (Bt horizon) approximately 10-12 inches deep. These soils are known to develop traffic pans about 8 inches deep.

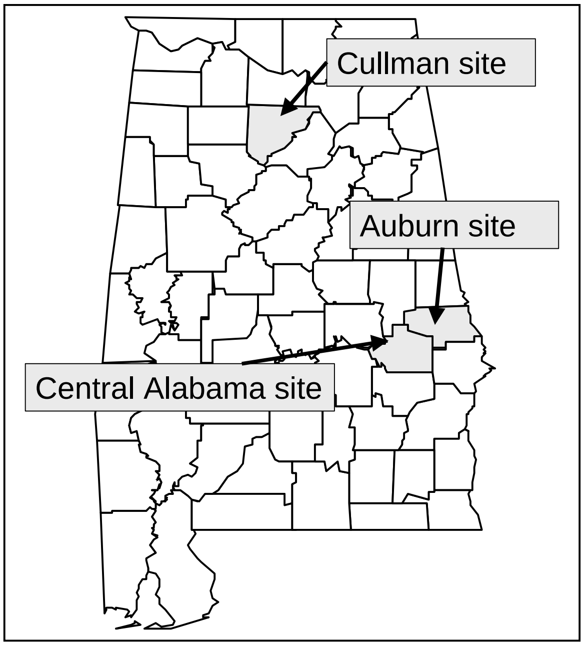
Soil was prepared just prior to spring planting using four tillage treatments (Fig. 1):

(1) Front-tine garden tiller. A 5 hp garden tiller; soil was prepared with multiple passes of tiller just prior to planting; tillage depth was approximately 6 inches.

(2) Slit tillage. Using the same 5 hp, front-tined, garden tiller adapted with a modified drag bar to cut a slit 12 inches beneath the row; soil was prepared as in the above treatment as the slit was being cut directly beneath the row.

(3) Rear-tine garden tiller. Using a 10-hp rear-tine, BCS garden tiller; soil was prepared to a depth of 6 inches with multiple passes of tiller just prior to planting.

(4) In-row subsoiled. Using a small tractor and a conventional subsoil shank to a depth of 14



inches directly beneath the row. Final seedbed preparation was made with the rear-tined tiller as in treatment 3 to a depth of 4 inches.

All tillage treatments were replicated 4 times in a RCB design. Plot size was 12-feet wide4, 36-inch rows) by 15 feet long. Crops planted during the 3-year experiment were:

- Sweet corn (*Zea mays L.* var. silver queen) -- every year
- Okra (*Abelmoschus esculentus (L.) Moench* var. Clemson spineless) -- 2 of 3 years
- Southern peas (*Vigna unguiculata (L.) Walp* var. Pinkeye Purplehull) -- 1 of 3 years

These crops were selected to represent crops with a fibrous root system (corn), a deeply rooted crop (okra), and a deeply rooted legume(peas).

Soil penetrometer measurements were taken in early fall of year 1 and year 3 to determine relative compaction of the soil. Penetrometer measurements were taken after a saturating rainfall when soil moisture was above field capacity. All measurements were taken in the treated row. Each year, the site of this experiment was moved to a different location within the same soil series. Crops were not irrigated.

Cullman Site. The Cullman County Master Gardeners assisted in conducting a similar experiment with additional tillage variables at the North Alabama Horticulture Research Center at Cullman, Alabama, in 2001 through 2003. The soil at this site is a Hartsells loam (fine-loamy, siliceous, thermic Typic Hapludults). There was only a slight increase in clay with depth. These soils generally do not respond to deep tillage as do the sandier soils of the Coastal Plain. Eight treatments were used with the first four treatments being the same as described in the previous experiment (Fig. 1, 2):

(1) Front-tine garden tiller.
2) Slit tillage with front-tine tiller.
(3) Rear-tine garden tiller. (An 8-hp Troy Bilt was used).
(4) In-row subsoiled with tractor.
(5) Hand tilled using the "double-digging" technique under the row.
(6) No tillage using a spade or blade to cut a slit into subsoil under the row..
(7) Conventional disking with a small tractor
(8) Rototilling using a 4-foot wide, tractor-mounted rototiller.

The "slit-tillage" treatment (no. 2) was replaced in 2003 with a completely no-tillage treatment because of difficulty cutting the slit in these soils. "Double-digging" is a popular garden tillage technique that is very labor intensive. It involves digging a trench the depth of a garden shovel along the length of the row. Another shovel depth is dug into the subsoil and this is inverted thus disrupting a tillage or traffic pan. The topsoil is then placed back over the trench and the crop is planted over the double-dug row (http://www.communitycrops.org/doubledig).

Sweet corn was planted on this site in mid April and harvested in late July each year. Plot size was 12 feet by 20 feet (4, 36-inch rows 20 feet long) and treatments were replicated four times in randomized blocks. The two center rows were harvested for yield. Following sweet corn harvest, the stalks were cut and cabbage and broccoli were hand planted as a fall crop with no additional tillage in 2001. In 2002, southern peas (cowpeas) were planted immediately following sweet corn harvest. In 2003, we had difficulty getting a stand of sweet corn (bird damage) so southern peas were the only crop grown. Tillage treatments were repeated each spring prior to planting. Crops were not irrigated.

Central Alabama Site. The same experiment conducted at Cullman was repeated as a non-replicated demonstration at E.V. Smith Research Center in Central Alabama on a Norfolk fine sandy loam (fine-loamy, siliceous, thermic Typic Kandiudults) in 2002.   This soil is known to develop pronounced traffic pans. This demonstration was conducted as part of the Southern Conservation Tillage Field Day held on 26 June 2002, and was viewed by several hundred participants from throughout the South. Two rows of sweet corn and two rows of wax beans were planted in each tillage treatment on 1 April and harvested 17 June. For the purposes of comparing yields, each row was harvested separately and handled as a replicate.

RESULTS

Auburn Site. Moisture stress showed dramatic, visual, growth responses to the 4 tillage practices. The degree of stress, of course was dependent on soil moisture. Total marketable yields reflect rainfall distribution as well as tillage practice. None of the crops were irrigated. There were significant and consistent yield differences due to tillage for every crop and every year of the test. Slit tillage increased total marketable yield of sweet corn, okra, and southern peas (Fig. 3, 4, 5). The rear-tined tiller resulted in lowest yield, presumably due to soil compaction resulting in moisture stress during short-term droughts. In general, yields were of the order: Subsoiled=Slit tilled > Front-tine tiller > Rear-tine tiller.

Recording soil penetrometer measurements made in the row by depth at the end of the cropping season. There was pronounced soil compaction following the rear-tine tiller and the front-tine tiller (Fig. 6). Subsoiling and in-row slit tillage effectively disrupted the plow sole at 20-30 cm.

Central Alabama Site (Table 2). Tillage treatments had the most dramatic effect on both corn and bean growth at this location compared to either the Auburn or Cullman sites. Because this was a demonstration, crops were harvested only once. Each row was treated as a replicate in order to run a Duncan's Multiple Range test (Table 2). In fact, surface compaction from rainfall following either disking with a tractor or tilling with a tractor-mounted rototiller resulted in very poor stands of both corn and beans. These plots were replanted but still failed to achieve an adequate stand. This is reflected in the yields.

While harvesting the plots, one of the Master Gardener volunteers made the statement, “Double dig, double yield.” Double digging resulted in the highest yield of both beans and corn. This technique apparently effectively disrupted any subsurface compaction yet did not destroy soil structure as the tractor-mounted rototiller and disking. The front-tine tiller with the slit and the no-till with the manual slit under the row were only marginally effective in improving yields.. We dug under plants and observed roots growing through the manual slit. Since this site had a history of cultivation, we assumed that the old plow layer had a rather high bulk density but this was not measured.

Cullman Site (Table 3). An extremely wet summer and severe summer thunderstorms damaged the corn crop in the first year of this study. We also believe that the very wet season reduced the expected responses to the tillage variables. Problems with weeds and insects masked any tillage variables we may have had in the fall crop. However, the second year of this experiment, 2002, was almost ideal with timely rainfall and excellent growing conditions. Yields of sweet corn followed by southern peas were very good. However, in contrast to the Auburn and Central Alabama experiments, no yield differences were observed due to tillage in this loamy, Sandstone Plateau soil (Table 3). We suspect that the lack of response to tillage is due to the soil texture and depth at his location in addition to ideal growing conditions. The soil series is a Hartsells loam with about 12 inches of loam over a clay loam subsoil. Repeated, qualitative measurements with a soil penetrometer failed to indicate the presence of traffic pans in these soils in contrast to the two Coastal Plain soils that developed pronounced traffic pans.

SUMMARY

The method used for garden tillage in sandy, Coastal Plain soils can have a dramatic effect on non-irrigated crop yields primarily due to .soil compaction both on the surface and in the formation of traffic pans or plow pans. Techniques resulting in major soil disruption such as roto-tilling and disking have the most damaging effects. Techniques that disrupt traffic pans without destroying soil structure such as double-digging, subsoiling, and slit tillage have the most positive effect on yields. .Slit tillage using a modified, 5-hp, garden tiller in a sandy, Coastal Plain soil significantly increased yields of sweet corn, okra, and southern peas over more conventional tillage practices such as using a standard, front-tined or rear-tined garden tiller. Slit tillage disrupted traffic pans, reduced in-row soil compaction, and resulted in yields as high or higher than traditional subsoiling. Slit tillage may offer the home gardener and small farmer a low-cost solution to a soil compaction problem created by conventional tillage practices. On a deeper, finer textured, loamy soil near Cullman with adequate rainfall, no tillage differences in crop yields were observed during a 3-yr experiment. Reduced tillage practices produced yields as high as conventional tillage. Reduced tillage may offers gardeners and small-scale vegetable producers opportunities to save on production costs while reducing erosion potential.

ACKNOWLEDGEMENTS

These tests were accomplished through the dedication and hard work of Master Gardener volunteers. Members of the Cullman Co. Master Gardener Association were responsible for all three years of the test in Cullman and members of the Lee County Master Gardener Association helped with the Central Alabama demonstration in 2002.

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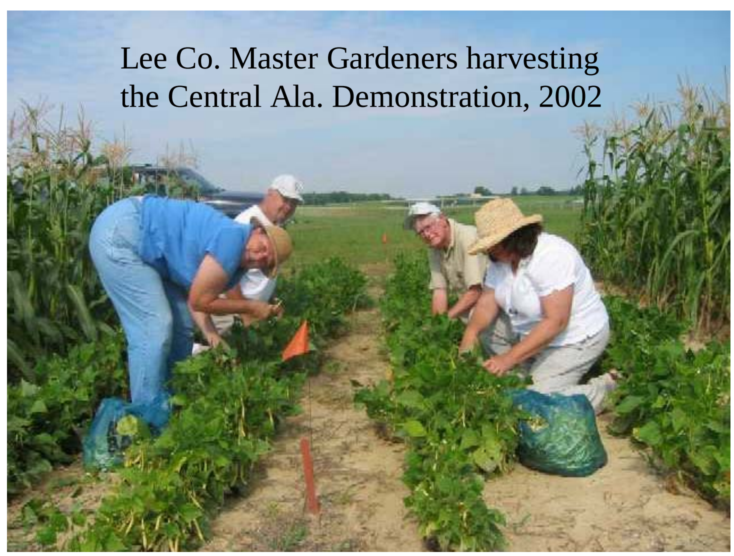
Table 2. Sweet corn and wax bean yield from Central Alabama demonstration on a Norfolk fine sandy loam in 2002.		
Tillage treatment	**Wax bean yield* (cwt/acre)**	**Sweet corn yield* (cwt/acre)**
Double-digging	76a	98a
Subsoiled with tractor	65 b	60 c
Front-tine tiller with slit	46 c	95a
No-till with manual slit under row	40 c	68 bc
Rear-tine tiller	28 d	84ab
No-tillage at all	25 de	36 d
Front-tine tiller	20 e	75 bc
Tractor-mounted rototiller	1 f	29 d
Disked with tractor	0 f	0 e

*Values followed by the same letter are not statistically different using Duncan's MRT at P< 0.05.

Table 3. Crop yields in Cullman tillage test, 2001-2003.*				
Tillage treatment	**2001 Sweet corn**	**2002 Sweet corn**	**2002 Southern peas**	**2003 Southern peas**
	------------------------------CWT/acre-----------------------------------			
Front-tine garden tiller	287	235	62.9	35.8
Front-tine tiller with slit	310	232	71.3	34.7
Rear-tine garden tiller	275	244	62.5	37.0
No-till with manual slit under row	277	229	68.2	35.2
Double Dug	289	210	66.5	39.6
Tractor mounted roto-tiller	266	249	71.6	34.8
Subsoiled under row	246	222	68.6	38.4
Disked with tractor	207	241	69.0	35.5
No tillage at all	--	--	--	34.7
*There were no significant differences in any of the treatments by year at P<0.10 level.				

Cullman Co. Planting Crew, 2002

Cullman Co. Planting Crew, 2003



Lee Co. Master Gardeners harvesting the Central Ala. Demonstration, 2002

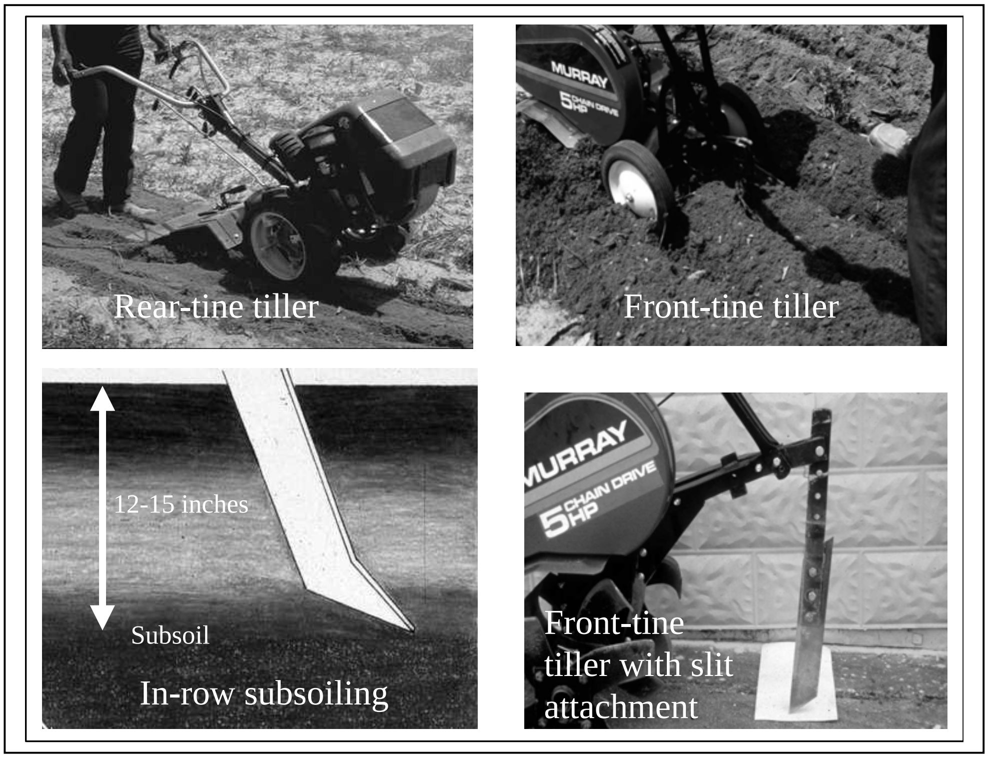


Figure 1. Treatments used in the Auburn experiment.

Figure 2. Additional treatments used in the Cullman experiment and in the Central Alabama demonstration.

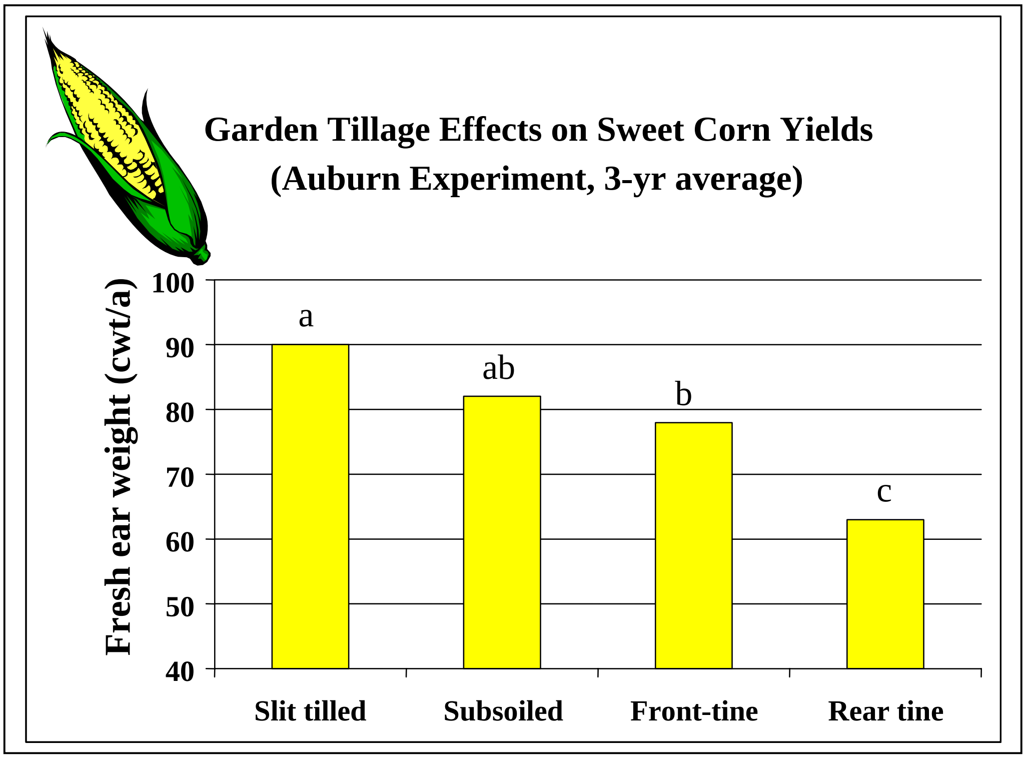


Figure 3. Three-yr average marketable yields of sweet corn as affected by the type of tillage system used in the Auburn experiment. Yields followed by the same letter are not significantly different (P<0.05).

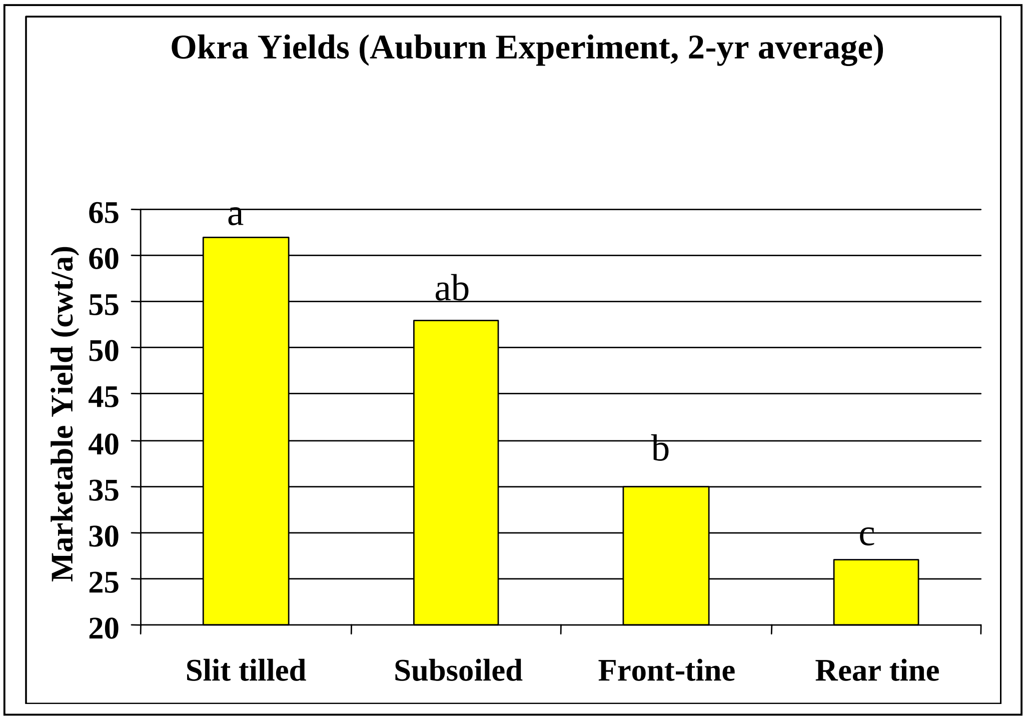


Figure 4. Two-yr average marketable yields of okra as affected by the type of tillage system used in the Auburn experiment. Yields followed by the same letter are not significantly different ($P<0.05$).

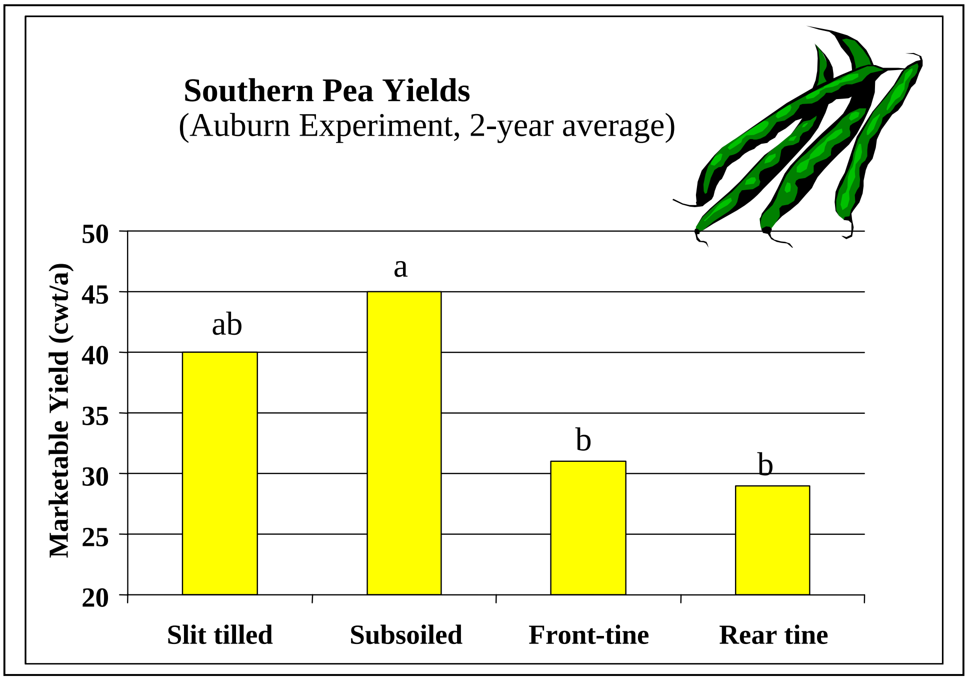


Figure 5. Average marketable yields of southern peas as affected by the type of tillage system used in the Auburn experiment. Yields followed by the same letter are not significantly different (P<0.05) from others.

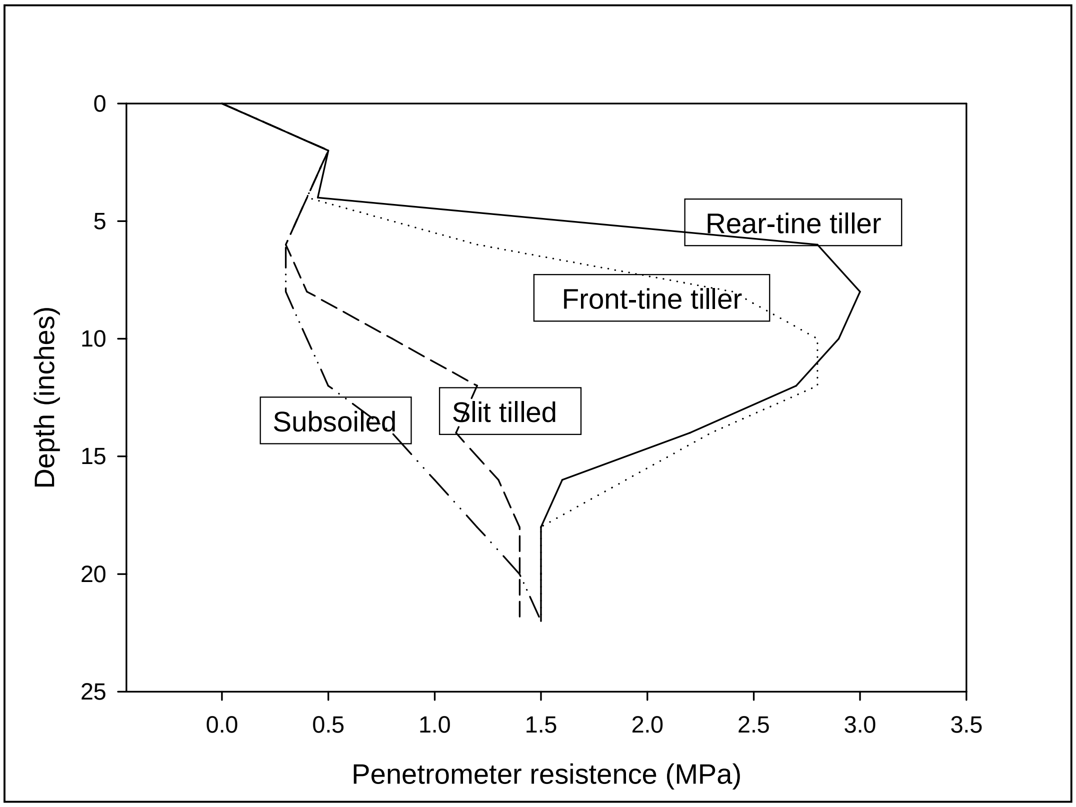


Figure 6. Mean penetrometer resistence (relative soil compaction) taken under the row after the first and third growing seasons following sweet corn and southern peas in the Auburn experiment.