Injury (%)[y]		
Joseph's coat	Marigold	Tomato
68 a	58 ab	48 a
53 b	65 a	43 ab
53 b	35 b	50 a
50 b	35 b	48 a
50 b	38 b	38 b
0 c	0 c	0 c
0 c	0 c	0 c
68 a	83 a	83 a
47 b	67 b	71 b
0 d	35 c	57 c
15 c	0 d	0 d
0 d	1 d	3 d
0 d	1 d	2 d
0 d	1 d	1 d
0 d	0 d	0 d
69 a	68 a	72 a
29 b	47 b	44 b
2 c	27 c	21 c
5 c	19 c	17 c
1 c	20 c	19 c
0 c	0 d	0 d
0 c	0 d	0 d
0 c	0 d	0 d

Soil Depth and Tillage Effects on Dry Bean Production

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Additional index words. *Phaseolus vulgaris*, black bean, culture, pinto bean

Summary. The effects of soil depth on yields of dry bean (*Phaseolus vulgaris*) produced under different types of tillage is not well understood. Black and pinto bean yields were evaluated under conventional and reduced-tillage for 2 years in a 3.24-ha (8-acre) commercial field in southeastern Oklahoma. Before planting, a grid pattern was laid out on the field with points at every 13.7 m (45.0 ft) north to south and 6.1 m (20.0 ft) east to west. Samples were taken at each intersection of the grid lines (496 sites) to determine pH, and the amounts of nitrogen, phosphorus, and potassium present in soil. Depth to an impervious clay pan was determined at these sites, and were grouped as being one of the following: <25 cm (9.8 inches), >25 to 50 cm (19.7 inches), >50 to 75 cm (29.5 inches) and >75 cm. Irrigation was supplied, if needed, at 50% flowering and, in both years, at 50% pod set. There was no significant effect on yield due to year. Black bean yields from conventional tillage averaged 1166 kg·ha^{-1} (1040.4 lb/acre) across soil depths and were better than yields from reduced-tillage which averaged 136 kg·ha^{-1} (121.3 lb/acre). Pinto bean yields from conventional tillage were 611 kg·ha^{-1} (545.2 lb/acre) across soil depths and were better than for reduced tillage, which averaged 403 kg·ha^{-1} (359.6 lb/acre). Yields generally were reduced as soil depth increased regardless of tillage type. The reduction in input for reduced-tillage would not compensate for the reduced yields for plants grown on the most productive soil depths.

Dry beans, components of a balanced diet (Quebedeaux and Bliss, 1988), are grown wherever environmental conditions will allow (Gepts, 1998). World wide, beans are an important source of protein in diets, especially in developing countries (Pachico, 1989). In addition, black beans, and to a lesser extent pinto beans, contain phytoestrogens that may be important to women's health (Franke et al., 1994).

There is increased interest in the Southern Plains of the United States in alternative crops to be used to diversify current types of agriculture. Dry beans are under study for production in the region. Previous studies at Lane, Okla. indicated that there is a wide range of yields for beans, which is likely due to environmental conditions occurring during production (Russo, 1995; Russo and Perkins-Veazie, 1992). Soils in the region can be variable in depth and are underlaid with a clay hardpan. It is not clear how variability in depth affects bean production in the region.

Cultural methods can affect yield of a crop. Devising a system to produce beans that provides an acceptable return and reduces impact on the environment is important. Advantages of specific tillage systems depend on microclimate, soil characteristics, cropping systems, and management goals (Robertson et al., 1982).

Although there is little disease and insect pressure on beans in southeastern Oklahoma, it is important that weeds be controlled. Reduced-till management uses herbicides to control weeds. Xu and Pierce (1998) found that studies relating the tillage system to dry bean yield are limited, and they found that no-till management either had no effect on, or reduced, yields of dry beans. There have been few studies where effects of tillage and soil characteristics have been evaluated on commercial production-size fields. This project was undertaken to

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determine how tillage and soil depth affected yield of black and pinto beans grown under conditions of commercial production.

Material and methods

FIELD PREPARATION. The 3.24-ha field was 243 m (797.2 ft) long, north to south, by 132 m (433.0 ft) wide, east to west. Cultural activities including field preparation, field maintenance, pesticide applications, and irrigation are listed in Table 1. The soil was a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf (1% to 3% slope). Air temperatures and precipitation events were retrieved from the Oklahoma Mesonet system from a station at Lane, Okla., about 40.2 km (25.0 miles) from the production field. In September 1999, the entire area was cultivated and seeded with winter wheat (*Triticum vulgare*) which was uniformly grazed by cattle from December 1999 to February 2000. Wheat was about 5.1 cm (2 inches) tall when cattle were removed. The wheat was allowed to re-grow and the entire area was treated with glyphosate (Roundup, Monsanto, St. Louis, Mo.) in March 2000. Two types of tillage were used. Conventional tillage was defined as the soil being clean cultivated before planting, and reduced-tillage was defined as planting seed into standing plant residue.

DETERMINATION OF SOIL DEPTHS, PH AND RESIDUAL NUTRIENT LOAD. Before treatment with glyphosate a grid on 13.7 m (north to south) by 6.1 m (east to west) intervals was superimposed on the field. Depth to an impervious clay hard pan was measured using a soil probe at intersections of grid lines (496 sites). Based on frequency of occurrence soil depths were assigned to one of four groups: <25, >25 to 50, >50 to 75 and >75 cm. Soil samples were obtained according to recommendations (Johnson, 1985) from the top 25 cm (tillage depth) of the soil. Samples were analyzed for pH from solutions [1:4 w/v using an Omega 34 pH meter (Beckman, Fullerton, Calif.)]. Total nitrogen and total phosphorus were determined from a Kjeldahl digest with a model AE flow-injection analysis system, and potassium (as K_2O) was determined with a QuikSep-C3 ion-chromatography column, both from Zellweger Analytics (Milwaukee, Wis.) at the USDA South Central Agricultural Research Laboratory, at Lane, Okla., using manufacturer supplied methods.

FERTILIZATION, HERBICIDE APPLICATION, PLANTING, AND IRRIGATION. Fertilizer applications were based on recommendations for dry bean production for the area (Motes and Roberts, 1994). Before planting in both years levels of nitrogen and phosphorus were uniformly depleted to <10 kg·ha^{-1} (8.9 lb/acre) necessitating application of nitrogen and phosphorus to the full recommended values. Ammonium nitrate and phosphoric acid were applied over the soil surface in each area of the field to bring nitrogen and phosphorus levels to 84 and 56 kg·ha^{-1} (74.9 and 49.9 lb/acre), respectively. Residual potassium levels, 252 kg·ha^{-1} (224.8 lb/acre), were sufficient for bean production. Before planting in 2000 soil pH was 6.1, and dry lime at 2.24 Mg·ha^{-1} (1 ton/acre) was broadcast over the entire area.

In April 2000, the field was divided into four 0.8-ha (2-acre) strips running north to south. Two of the strips were randomly assigned to either conventional or reduced-tillage. Half of each strip (north-south) was assigned to a bean cultivar. Rows, oriented north to south, were on 0.9 m (36 inches) centers in unbedded soil in the conventional till area, and at the same distance in standing stubble in the reduced-tillage areas. The herbicide metolachlor (Dual II, Syngenta Crop Protection, Greensboro, N.C.) was applied preemergence to both areas. A rotary hoe (Brush Hog Corp., Selma, Ala.) was used to incorporate lime, fertilizer and herbicide in both tillage types.

On 18 Apr. 2000 seed of 'Midnight' black seeded, or 'Apache' pinto, beans were planted at a depth of about 2.54 cm (1 inch) with a tractor-mounted vacuum planter (John Deere, Moline, Ill.) equipped with double disk openers in front of each seed tube at an in-row spacing of 5.1 cm. Populations were 216,900 plants/ha (87,780 plants/acre) for each cultivar. The herbicide sethoxydim (Poast, BASF, Parsippany, N.J.) plus crop oil was applied to both areas post-emergence at the third true-leaf stage. All herbicides were applied according to label directions. A mechanical cultivation to reduce weed populations was performed with a rolling cultivator (Bush Hog Corp.) over the conventional tillage area before canopy spread. Pressure from disease and insects did not require application of chemicals for control. About 5.1 cm of water to assure pod fill were applied by wheel row irrigation at 50% flower and 50% pod set.

YIELD SAMPLING PROCEDURES. From the grid it was possible to identify areas comprising the various soil depths in tillage types. For each cultivar three, 3 m^2 (32.3 ft^2), sampling sites were randomly assigned within soil depths and tillage types. Sampling sites were never adjacent to each other and not located within 5 m (16.4 ft) of field borders. Based on maturity, pods of pinto and black bean seeds were manually harvested from plants on these sites on 2 and 14 July 2000, respectively. Seed were separated from pods and dried in a forced air oven at 33 °C (91.4 °F) until 13% to 15% seed moisture. Seed were weighed and yields extrapolated to a per hectare basis.

SECOND-YEAR PROCEDURES. Following harvest in 2000 the area was disked and seeded to winter wheat and grazed as before. Field design and preparation were the same as in 2000. Soil samples

Table 1. Cultural activities from field preparation to harvest in conventional and reduced tillage areas in which black seeded and pinto beans were established in 2000 and 2001 at Lane, Okla.

	Type of tillage	
Activity	Conventional	Reduced
Disking (twice)	X	---[z]
Preemergence herbicide[y]	X	X
Herbicide incorporation[x]	X	X
Postemergence cultivation	X	---
Postemergence herbicide[w]	X	X
Irrigation[v]	X	X

[z]Activity not done.
[y]Both: glyphosate 1.75 L·ha^{-1} (1.5 pt/acre) plus 3.51 L·ha^{-1} (1.5 qt/acre) crop oil preplant; metolachlor 1.75 L·ha^{-1} preemerge.
[x]for metolachlor with rotary hoe.
[w]Both: sethoxydim 1.75 L·ha^{-1} plus 3.51 L·ha^{-1} crop oil, at third true-leaf stage.
[v]Wheel-row overhead irrigation [5.1 cm (2 inches)]: twice in 2000 (at 50% flower and 50% pod set) and once in 2001 (50% pod set).

Table 2. Effects of year of production, tillage method (conventional or reduced tillage) and soil depth on black seeded ('Midnight') and pinto ('Apache') bean yields at Lane, Okla.

Source	Black bean	Pinto bean
Year of production	NS	NS
Tillage	**	**
Soil depth	*	*
Tillage by soil depth[z]	*	*

[z]Shown is the only significant interaction.
*,**Significant at $P < 0.05$ or 0.01, respectively, by analysis of variance.

were obtained in March 2001 at the same locations on the grid. The same methods to determine pH, nitrogen, phosphorus and potassium levels, the same source for recommendations, and the same materials to supply nitrogen and phosphorus were as previously described. Fertilizer applied for the 2001 planting season was comprised of: 67 $kg\cdot ha^{-1}$ (59.8 lb/acre) nitrogen, 56 $kg\cdot ha^{-1}$ (50.0 lb/acre) phosphorus, and 112 $kg\cdot ha^{-1}$ (99.9 lb/acre) potassium from muriate of potash. The potash level represented the full recommended rate. Seeds of both cultivars were sown on 24 Apr. 2001. Soil pH was 6.5 and no additional lime was added. Due to precipitation events irrigation by wheel row was required only at 50% pod set. Yield samples were obtained as in 2000 on 31 June and 9 July 2001 for pinto and black beans, respectively, and processed as before.

Analysis of yields from plants grown at various soil depths. Areas of each soil depth could be approximated from the grid, and yields for cultivars grown at each soil depth, in each tillage type, could be calculated from sampled areas. The cultivars have different growth habits and were not directly compared. Data were analyzed with analysis of variance, and where appropriate, means separation was with the Ryan-Einot-Gabriel-Welsch posthoc test or in interactions with least squares means analysis in SAS (SAS Institute, Cary, N.C.).

Results and discussion

Deposition of manure due to grazing by cattle can affect soil fertility. It does not appear that this was the case in this field. Soil tests were conducted after cattle were removed. The number of sampling sites provided a good indication of nutrient loads and amounts of fertilizers needed to bring soil loads to reasonably uniform levels across the field. Soil nitrogen and phosphorus levels in the 2 years were not very different across the field. About half of the potassium present in the soil at the beginning of the experiment had to be replaced in the second year indicating that not all was used. In the second year the yields were not changed from those in the first year. It may be possible to use less potassium than that recommended for dry bean production in the area. Seed germinated uniformly and stand did not appear to be affected by tillage or soil depth. Average maximum air temperatures during flower and pod set were about 29 °C (84.2 °F), while minimum air temperatures were about 22 °C (71.6 °F) in both years. Rainfall amounts from planting to last harvest were 23.4 cm (9.2 inches) and 19.8 cm (7.8 inches) in 2000 and 2001, respectively. Precipitation during the overwintering periods before planting were in excess of 60 cm (23.6 inches). Most of the precipitation occurred before flowering and plants were not suffering from drought. Irrigation applied at flower set and pod fill in 2000 and at pod fill in 2001 was to insure there was sufficient soil moisture to support fruit set and filling of seed.

The effect of year on yields was not significant and data were pooled. Tillage method, soil depth, and their interaction affected bean yields (Table 2). Since it was significant, only the results of the interaction are presented (Table 3). For 'Midnight' under conventional tillage, yields were similar as soil depth increased to 75 cm, and decreased for plants in soils that were >75 cm. Under reduced-tillage yields tended to increase as soil depth increased. Across soil depths, yield for 'Midnight' under conventional tillage was 8.5-fold greater than for plants under reduced-tillage. Across soil depths, yields for 'Apache' under conventional tillage were 1.5-fold greater than for plants under reduced-tillage. Under both tillage types pinto bean yields tended to decrease as soil depths increased. For black beans under conventional tillage yields decreased as soil depth increased, but under reduced-tillage yield increased slightly as soil depth increased.

Beans are considered to be a crop which produce best in deeper soils under ideal conditions (Smucker et al., 1991). In this study higher yields were not consistently produced on the

Table 3. Interaction of type of tillage and soil depth on black seeded ('Midnight') and pinto ('Apache') bean yields[z] at Lane, Okla.

		Black bean		Pinto bean	
Tillage	Soil depth (cm)	Area at depth (ha)	Yield ($kg\cdot ha^{-1}$)	Area at depth (ha)	Yield ($kg\cdot ha^{-1}$)
Conventional	<25	---[y]	---	0.38	1257
	>25–50	0.07	1583	0.14	473**
	>50–75	0.16	1670NS	0.13	430NS
	>75	0.65	243**	0.09	283*
Average			1166 a[x]		611a[x]
Reduced-tillage	<25	0.09	97	---	---
	>25–50	0.13	90NS	0.07	507
	>50–75	0.13	160*	0.25	367*
	>75	0.57	197*	0.27	337*
Average			136 b		403 b

[z]1 cm = 0.4 inch; 1.00 ha = 2.471 acres, 1 $kg\cdot ha^{-1}$ = 0.9 lb/acre.
[y]Soil depth was not present in this cultivar and tillage combination.
[x]Values for averages in a column followed by the same letter are not significantly different, $P < 0.05$ Ryan-Einot-Gabriel-Welsch posthoc test.
NS,*,**Nonsignificant or significant at $P < 0.05$ or $P < 0.01$, respectively, least squares means analysis, values rounded to nearest whole number. Data pooled over years.

deepest soils. This suggests that factors other than soil depth are involved. It may be that plants on well drained soils with depths >75 cm require more water than was supplied by precipitation or irrigation. It also may be that water and nutrients in shallower soils are closer to the roots and plants due to the presence of the hardpan. If this is the case plants may not have to expend as much energy in the production of roots to reach the pool of nutrients. In deeper soils the nutrients may have been leached lower in the soil profile. The optimum amount of water, and the distribution of nutrients and/or water in soils of various depths, required for optimum bean production needs further study.

Although conservation management can cause problems with dry bean germination on cool soils (Hardwick, 1988), and disease and moisture retention in soils in some parts of the United States (Webber et al., 1987), the soil types in southeastern Oklahoma tend to dry and warm quickly in the spring. It does not appear that the lower yields for beans with reduced-tillage were due to wet, cold soil.

Dry bean yields under conservation tillage are reported to be less than under plow and rotary-till systems (Smith and Yonts, 1988). This was the case for both bean cultivars in this study. Black bean yields approached United States yield averages only under conventional tillage, and in soils shallower than 75 cm. The input reduction due to the lack of disking in soil preparation and field maintenance under reduced-tillage would not provide sufficient financial incentive to use this tillage method for plants grown on the most productive soil depths. More work is necessary to clarify the optimum conditions for dry bean production in the Southern Plains. This is especially necessary to better understand effects that soil depths in the region have on plant development and yield.

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Peel Injury on ‘Marsh’ Grapefruit from Quaternary Ammonia

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ADDITIONAL INDEX WORDS. **phytotoxic chemical injury, chlorine, surfactant, Triton N-101, *Citrus paradisi***

SUMAMRY. Quaternary ammonia (QA) has been used on equipment and fruit bins in Florida to reduce the risk of spreading citrus canker. This study was initiated to understand the cause of a previously unknown peel injury believed to be associated with QA residues. Symptoms of QA injury on ‘Marsh’ grapefruit (*Citrus paradisi*) usually developed within 24 to 36 h of contact with QA and ranged in severity from very slight discoloration to severe, dark brown, necrotic peel tissue that collapsed to form large sunken areas. Placing fruit in 10 mL (0.34 fl oz) of ≥100 mg·L^{-1} (ppm) fresh QA solution caused moderate to severe peel injury. Drying the QA solutions on polystyrene petri dishes and then redissolving the residue with 10 mL deionized water before fruit contact resulted in essentially the same degree of peel injury as contact with fresh QA solutions. Peel injury on early (November) or late-season (April) grapefruit also occurred when fruit were placed on a thin film of QA solution left on polystyrene petri dishes after dipping the dishes in ≥300 mg·L^{-1} QA solutions or if fruit themselves were dipped in QA solutions ≥500 mg·L^{-1}. No significant peel injury occurred when dipping solutions contained only water with 200 mg·L^{-1} chlorine, 0.025% (v/v) Triton N-101, or a combination of both.

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