Variable Yield of Bell Pepper Established on Converted Perennial Pasture Fertilized According to Recommendations

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Summary. Soil conditions may not be adequate for uniform yields when perennial pasture is converted to vegetable production. This occurred with 'Pip' bell pepper (*Capsicum annuum* var. *annuum* L.) planted in a 0.17-acre field 3 years after conversion from perennial pasture. Depths of the A-horizon and pH levels, as well as concentrations of N, P, and K were variable throughout the field when sampled after the last harvest. Marketable yields from plots established in the field ranged from 4.1 to 14.5 tons/acre. The A-horizon depth, soil pH, and residual N, P, and K levels were correlated with yield at specific A-horizon depths and pH levels. An intensive soil-testing regime likely will be required so that nutrient levels can be maintained to support bell pepper production on soil converted from perennial pasture.

In the southern plains, cow-calf operations are one of the major agricultural enterprises. A typical farm contains perennial pasture that has received limited amounts of fertilizer, lime, or tillage. In regions of the country with established intensive farming programs, perennial pastures often are rel-

egated to land of low productivity and are not well-suited for row-crop production. Quality of the land for pasture usage is generally not a concern because field records have shown that the soils can support pasture. Historically, land in the southern plains has been converted from other uses to pasture,

In recent years there has been increased interest in alternative agriculture, which often means that land previously used for cow-calf operations is now being used for vegetable production. With this change in farm enterprises, there is a corresponding change in soil management techniques that brings with it certain problems. Perennial pasture soils tend to be heterogeneous. Factors contributing to this condition include soil genesis and the type and extent of component cover plants and root distribution through the various horizons (Jenny, 1980). In addition, native chemical and physical soil characteristics, fertilizer application (West et al., 1989), and the amount of plant (Jenny, 1980) and animal (Barrow, 1967) organic material deposited annually contribute to the condition of perennial pasture soils. Soils in perennial pasture are in equilibrium with the plant cover. Soils newly converted from perennial pasture, including those amended with nutrients or lime in response to soil test results, may not be adequate immediately for vegetable production, as are those that have been in row crops for extended periods. Conversion of perennial pasture to vegetable production changes the established equilibrium and produces an environment that could be disturbed several times a year. The objective of this study was to document the variability in bell pepper

yields in an area recently converted from perennial pasture, and to correlate the variations in crop yields with variations in soil physical and chemical characteristics. Understanding these processes can be of help to extension workers, field representatives, and consultants as they assist farmers attempting to convert their operations to include vegetables as cash crops.

The soil converted from pasture was a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf soil, which has a sandy loam A-horizon depth to 15 inches overlying a sandy clay loam layer that extends to 65 inches (Shingleton and Watterson, 1979). The 217 × 36-ft (0.17-acre) field was covered with common bermudagrass [*Cynodon dactylon* (L.) Pers.] and native prairie grasses prior to 1986, when it was placed into vegetable production. In 1986, soil samples were taken at random by collecting ≈ 20 subsamples, combining and mixing the subsamples, and analyzing a portion of the combined sample as described by Johnson (1985). Samples were analyzed by Oklahoma State Univ. (OSU) using routine procedures (McElreath and Johnson, 1990). Results produced by OSU and sent to producers report levels of N, P, K, pH, and soil buffering index and include recommendations for regulating pH with dolomitic or calcitic lime to assure the availability of other nutrients such as calcium or magnesium. Micronutrient availability for most crops grown in these soils is not a problem if pH is appropriately adjusted. The 1986 pH was 5.1 and lime at recommended rates (1.0 ton/acre) was incorporated by moldboard plowing (to 12 inches) and disking (to 8 inches) during Oct. 1986. Dry beans

Table 1. Means and standard deviations for postharvest soil levels of N, P, and K partitioned by A-horizon depth and pH.

Nutrient	A-horizon depth (inches)	pH		
		≤5.5	≥5.6 to <5.9	≥5.9
Soil nutrient level (lb/acre) by pH level				
N	≤10.25	21.4 ± 26.4	7.1 ± 4.0	6.2 ± 2.6
	≥10.25 to <13.25	13.4 ± 13.6	9.8 ± 5.5	7.1 ± 2.4
	≥13.25	6.2 ± 2.0	6.2 ± 2.0	15.2 ± 14.6
P	≤10.25	46.4 ± 34.4	42.8 ± 27.7	55.3 ± 59.0
	≥10.25 to <13.25	23.2 ± 8.5	32.1 ± 8.7	39.3 ± 34.4
	≥13.25	25.0 ± 15.3	21.4 ± 10.1	20.5 ± 7.5
K	≤10.25	188.2 ± 43.6	156.1 ± 24.9	156.1 ± 33.5
	≥10.25 to <13.25	161.5 ± 45.8	169.5 ± 44.7	135.6 ± 27.6
	≥13.25	169.5 ± 29.4	132.9 ± 24.1	143.6 ± 23.1

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Fig. 1. Yield for bell pepper in plots in rows 1–6. Numbers 1–12 on the x-axis represent tiers of plots in a row.

and snap beans were planted in 1987, followed by carrots in 1988. In Sept. 1988, soil pH was 5.7 and 62 lb N/acre, 44 lb P/acre, and 141 lb K/acre, respectively, were present. An additional 1.0 ton/acre of lime was applied and incorporated.

In Spring 1989, based on soil tests, 50 lb N/acre, 22 lb P/acre, and 83 lb K/acre were applied uniformly preplant. Raised beds on 6-ft centers were formed in Apr. 1989. The experimental area included 72 plots (12 tiers of plots in each of six rows; Fig. 1), in addition to a guard row to the north and south. Plots were 12 ft long and separated in length by a 6-ft alley. 'Pip' bell pepper plants were transplanted on 19 Apr. 1989 on 12 inches within rows and 6 ft between rows. Rainfall supplied 19.5 inches of water and an additional 3 inches of water was supplied evenly to all plots by drip irrigation.

Marketable yields (US#1 or better) from each plot were determined from nine weekly harvests between 6 July and 31 Aug. 1989. After the final harvest, soil samples were obtained from the top 4 inches of each plot and analyzed in routine soil tests for pH and N, P, and K levels by OSU. The A-horizon depth was determined by removing 0.75-inch-diameter soil cores on 18-inch intervals through the length of each plot. Within the plots, values of pH and A-horizon depth were found to be highly variable, and the plots were classified for partitioning according to soil pH and A-horizon depth. Soil pH was chosen for partitioning because it affects nutrient availability to the plant (Devlin, 1969),

and initial correlation analysis indicated that it affected yield significantly ($P = 0.0001$). The A-horizon depth was chosen for partitioning because it is a physical characteristic that is not easily manipulated. To establish the pH partitions, plots were grouped into three pH categories ($\leq \text{pH} 5.5$, $\geq \text{pH} 5.6$ to < 5.9 , and $\geq \text{pH} 5.9$) based on expected plant responses. Each pH category was further partitioned into three A-horizon depths (110.25 inches, > 10.25 to < 13.25 inches, and > 13.25 inches). Each A-horizon depth by pH partition had six to 11 observations, averaging nine, with 72 total observations. Yield information in the partitions was analyzed by backward stepwise regression. This is a computer-supported statistical method that examines all measured (independent) variables for effects and systematically removes variables until only those that best describe the observed effects re-

main. This procedure is a product of the Statistical Analysis System (SAS, Cary, N.C.). The soil tests, taken after the last harvest, affirmed the variable nutrient availability in the field. It was found that levels of soil N were 3.0 to 77.6 lb/acre (avg. 9.9), soil P was 6.25 to 155.0 lb/acre (avg. 30.4), and soil K was 80.3 to 241.7 lb/acre (avg. 142.4). The average soil pH was 5.6, ranging from 4.8 to 6.5; A-horizon depths averaged 7.9 inches and ranged from 3.8 to 19.7 inches. Means for pH and soil N, P, and K in the nine A-horizon depth $\times$ pH partition cells are presented in Table 1. The coefficients of variation for residual levels of both N and P, across A-horizon depth $\times$ pH partitions, ranged from $\approx 30\%$ to 115%. For residual levels of K, in the same partitions, coefficients of variation ranged from 16% to 28%. The average plot yield was 8.4 tons/acre, with yields ranging from 4.1 to 14.5 tons/acre (Fig. 1). There was no clear correlation between yield and N, P, or K levels in the field. Within partitions, no single factor was correlated consistently with yield. Depth of the A-horizon, pH, and residual K levels were correlated strongly with yield-specific combinations of A-horizon depth and pH in plots (Table 2).

The heterogeneity of soil and nutrient levels within this field was the most critical factor affecting yield. Uniform tillage, liming, and fertilization over a 3-year period did not reduce variation in yield for bell pepper in a 0.17-acre field. The addition of lime increased the average soil pH, but pH values were not uniform across the field. Soil pH was correlated positively with crop yield. Factors causing pH variability in soil can be physical or chemical. Availability of N, P, and K is reduced at pH values below 6.0 (Brady,

Table 2. Variable(s) positively (+) or negatively (–) correlated with yield and Prob > F in soils partitioned for A-horizon depth (inches) and pH. Removal of the variable from the backward stepwise regression model was at Prob > F = 0.1000.

A-horizon depth (inches)	pH		
	≤ 5.5	≥ 5.6 to < 5.9	≥ 5.9
	Variable, correlation, (Prob > F)	Variable, correlation, (Prob > F)	Variable, correlation, (Prob > F)
≤ 10.25	Depth*, (+), (0.0001)	Depth, (+), (0.0001)	K, (+), (0.0011)
≥ 10.25 to < 13.25	pH, (+), (0.0001) N, (–), (0.0171)	pH, (+), (0.0001)	Depth, (+), (0.0011)
≥ 13.25	pH, (+), (0.0040) P, (+), (0.0530) N, (–), (0.0570)	pH, (+), (0.0001)	K, (+), (0.0001)

*Depth = A horizon depth.

1984). Only about 25% of the plots were at or above this pH value. Although bell pepper is moderately tolerant to soil acidity (Lorenz and Maynard, 1988), the pH values from numerous individual plots were too low to support adequate bell pepper production. Routine soil sampling did not report accurately the low individual pH values.

The average yield for 'Pip' bell pepper at Lane, Okla., is 9.8 tons/acre (Oklahoma State Univ., 1989,1990), which is $\approx$ 13% more than the average of 8.5 tons/acre reported here. Based on figures reported by Lorenz and Maynard (1988), 8.5 tons/acre of pepper fruit would require 106 lb N/acre, 7 lb P/acre, and 106 lb K/acre. The average soil concentrations of 112 lb N/acre, 66 lb P/acre, and 224 lb K/acre (amount in soil preplant plus amount applied) should have supplied the nutrient needs of the pepper crop. Nutrient leaching is common on sandy soils (Earl and Jarry, 1977), but leaching does not explain the positive relationship between yield and A-horizon depth. Variation in levels of residual soil nutrients at different A-horizon depths can explain some, but not all, of the difference in yields. The combined effects of pH and A-horizon depth could affect rhizosphere nutrient availability and uptake. Nutrients exert specific effects on plant development; these effects can be modified by combinations of A-horizon depth and pH.

Standard deviations and coefficients of variation for residual levels of N, P, and K indicate that each plot had a unique nutrient level that was not estimated adequately by the soil test and that contributed to the variation in yield. Routine soil tests, as performed by OSU, assume that pH, N, P, and K, expressed as averages of those values, are the factors that are likely to limit crop production. These tests can mask large differences in available nutrients and pH within either large or small acreages. Three crop cycles passed between the initial liming and the final soil test, but there was still extreme variability in pH and nutrient concentrations within the small area of these plots. This project demonstrated that values obtained in a routine soil test were not sufficient to predict or prevent yield variability in nonuniform soils. If pH is at the proper level in southern plains soils, calcium and magnesium are not limiting, and soils reports from OSU do not include this information.

As farm profit margins are reduced, fertilizer efficiency will be a key to farm survival. Maximum profits will exist only when crops receive sufficient, but not excessive, levels of all nutrients. If lime and fertilizer had been added uniformly to this field at a rate required to raise the most infertile plots to an optimum level of fertility, then other plots fertilized at the same rate would have received rates that were above the point of maximum economic return. The transition from perennial pasture to other cropping systems likely will be made more efficient if soils are prepared far in advance of planting high-value crops. Extensive deep tillage is needed to homogenize the soil plow layer. When soils in perennial pasture are converted to vegetable production, soil sampling should be conducted with a pattern that requires more samples/unit area than is normally recommended, and fertilization techniques should reflect the soil nutrient variability. Soils should be monitored closely for variations in pH and nutrient levels in order to have uniform yields across fields and to maximize profits.

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