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Fertilizer Placement and Tillage Interaction in Corn and Soybean Production

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Abstract

Different tillage systems can affect the availability of phosphorus (P) by changing the soil environment. The objective of this study was to evaluate the effects and interaction of fertilizer placement, tillage, and varieties for soybean and corn. The experiment was established at two locations in Kansas in 2014. The experimental design was a factorial in a randomized complete block with four replications. Three fertilizer treatments were combined with two tillage systems and two varieties of soybean and corn selected based on contrasting root systems. Plant tissue samples were collected during the vegetative and reproductive stages to evaluate P concentration, P uptake, and dry matter. Significant differences were found in the parameters across locations for corn and soybean. Results suggest advantages for deep-band application for soybean and broadcast application for corn. Varieties responded differently in the parameters evaluated in this study.

Keywords

tillage, corn, soybean, phosphorus, fertilizer placement

Fertilizer Placement and Tillage Interaction in Corn and Soybean Production

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Summary
Different tillage systems can affect the availability of phosphorus (P) by changing the soil environment. The objective of this study was to evaluate the effects and interaction of fertilizer placement, tillage, and varieties for soybean and corn. The experiment was established at two locations in Kansas in 2014. The experimental design was a factorial in a randomized complete block with four replications. Three fertilizer treatments were combined with two tillage systems and two varieties of soybean and corn selected based on contrasting root systems. Plant tissue samples were collected during the vegetative and reproductive stages to evaluate P concentration, P uptake, and dry matter. Significant differences were found in the parameters across locations for corn and soybean. Results suggest advantages for deep-band application for soybean and broadcast application for corn. Varieties responded differently in the parameters evaluated in this study.

Introduction
Phosphorus is considered a non-mobile nutrient in the soil compared with other macronutrients. Different soil tillage systems can affect the availability of this nutrient in the soil. In Kansas, both no-till and strip-till are increasing in popularity, especially because of the water storage capacity that these systems provide to the soil. A no-till system consists of leaving the soil surface covered with residue to minimize erosion, conserve moisture, and improve nutrient cycling if associated with crop rotation. The residue that remains on the soil surface also can cause a reduction in yield in some regions because of wetter and cooler soils at planting time, which can reduce nutrient uptake and crop growth. No-till can restrict root growth because of compaction that can reduce the ability of roots to explore the soil and result in less contact with available P (Havlin et al., 2014). Even with sufficient P in the soil, some deficiency can occur under cool and wet soil conditions, hindering P diffusion. Strip-tillage consists of disturbing only the portion of the soil that is to contain the seed row. Strip-till helps increase soil temperature and expand root growth and therefore contact with the fertilizer or P in the soil.

The effects of tillage on crop yield, early growth, and nutrient stratification can be greatly influenced by fertilizer placement. It improves plant nutrient uptake efficiency and consequently can increase crop yields by enhancing the contact of the fertilizer with the plant roots.

Modern corn hybrids and soybean varieties are being developed to support dry conditions. These hybrids and varieties may differ in root growth habits and therefore in their ability to extract and use nutrients. Gordon et al. (1998) suggested that different root systems among corn hybrids may influence nutrient uptake, including P early in the season, often resulting in different responses to starter fertilizer application in corn. The objective of this study was to evaluate the effects of fertilizer placement, tillage, and varieties on P uptake, P concentration, dry matter accumulation, and grain yield in soybean and corn.

Procedures

The experiment was established at two locations in Kansas in 2014. The Scandia location is located west of Scandia, KS, on the North Central Kansas Experiment Field. This location used supplemental irrigation to maintain adequate soil moisture and limit water stress throughout the growing season. The Ottawa location is south of Ottawa, KS, on the East Central Kansas Experiment Field. The Ottawa location was under rainfed conditions. Soil samples were collected in blocks, and one composite sample of 20 cores was taken for each block, making four samples per location. Samples were analyzed for P by the Mehlich-3 method (Frank et al., 1998) and for K with the ammonium acetate method (Warncke and Brown, 1998). Soil pH was measured using a 1:1 soil:water ratio (Watson and Brown, 1998), and soil organic matter (OM) was determined by the Walkley–Black method (Combs and Nathan, 1998). Soil test results are in Table 1.

Plot size was 10 ft × 40 ft with four rows planted at 30-in. spacing. The experimental design was a factorial in a randomized complete block with four replications. The fertilizer treatments consisted of a control, deep-band application only, and broadcast application only. These three fertilizer treatments were combined with two tillage systems and two different varieties of soybean and corn selected based on contrasting root systems. The two varieties of soybean used were 94Y40 and P44T63R. The two hybrids of corn used were P1151 AM and P1105 AM. The two tillage operations were no-till and strip-till. Fertilizer was applied 2 to 3 weeks before planting. Deep-band treatment rate was 40 lb/a N as urea ammonium nitrate (UAN; 28-0-0, N-P_2O_5-K_2O, respectively) and 40 lb/a P_2O_5 as ammonium polyphosphate (10-34-0, N-P_2O_5-K_2O, respectively) for corn; 20 lb/a N as UAN (28-0-0, N-P_2O_5-K_2O, respectively), and 40 lb/a P_2O_5 as ammonium polyphosphate (10-34-0, N-P_2O_5-K_2O, respectively) for soybean. Broadcast treatment rates were the same as deep-band rates for both crops. Nitrogen for corn was applied at 120 lb/a for Ottawa and 180 lb/a for Scandia as anhydrous ammonia (82-0-0, N-P_2O_5-K_2O, respectively).

Plant tissue samples were taken during the vegetative and reproductive portion of the growing cycle of soybean and corn. For soybean, whole-plant samples were collected at growth stage V3, and trifoliate at the R3 growth stage. For corn, whole-plant samples were collected at stages V6, V10, and VT. Plants were weighed and dried in a forced-air oven at 155°F for a minimum of 6 days and weighed for dry biomass calculation, then the plants were ground and sent to the Kansas State University Soil Testing Lab for P analysis. The biomass weight and P concentration were used to calculate P uptake. The data were analyzed by location and across locations. The parameters were analyzed using PROC GLIMMIX (SAS 9.3, SAS Institute Inc., Cary, NC). Separation of means at a significance level of $P = 0.10$ were completed using the LINES option in PROC GLIMMIX.

Results

Soybean

Fertilizer placement showed a significant effect on P tissue concentration, P uptake, and biomass (Tables 2 and 3). Deep-band application resulted in the higher values for those parameters (Table 4). Deep-band was probably superior to broadcast and control treatments because this technique applies the fertilizer closer to the seed, which facilitates P uptake by the roots. Although these advantages fostered early growth and P uptake, they were not enough to contribute to better grain yields.

Preliminary results showed differences in varieties for both Scandia and Ottawa locations (Table 3). The variety 94Y40 was roughly 7 bu/a more productive than P44T63R in Ottawa (Figure 1). It can be explained by the poorly drained soil, where 94Y40 had better performance according to genetic characteristics. In Scandia, the opposite was found, where P44T63R was approximately 5 bu/a superior than 94Y40 (Figure 1). Also, no-till showed better results than strip-till in this location (Figure 1). Soils with good drainage, low compaction, and a pivot irrigation system contributed to those achievements.

Corn

P concentration, P uptake, and dry matter were affected by fertilizer placement across locations (Table 5). Even with soil P test high for Ottawa, both deep-band and broadcast application were superior to the control, although the responses are similar among them.

Hybrids behaved differently under these parameters (Table 6). In general, P1151AM was superior to P1105AM. P1151AM contains drought-tolerance traits that can contribute to deep root system development and more P absorption by the plant. Complementary studies will be done to test this hypothesis.

Corn yields were responsive to fertilizer placement (Table 7). According to results, in Ottawa, broadcast application had better yields than deep-band application (Figure 2). It can be explained by the higher levels of P in the soil test. Those values are close to the critical level in Kansas, which is 20 ppm (Leikam et al., 2003). Broadcast treatment probably helped the corn later in the growing season when the root system could reach the P available in the surface. The irrigation system in Scandia could have influenced deep-band and broadcast applications to attain similar yields.

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Table 1. Average soil test values on each location of study

		Soil test values			
Location	Crop	STP[1]	STK	pH	OM
		----------- mg/kg -----------			%
Ottawa	Soybean	25	175	6.5	3.1
	Corn	26	164	6.2	3.9
Scandia	Soybean	14	526	6.6	3.3
	Corn	13	527	6.5	3.0

[1] STP, soil test for phosphorus; STK, soil test for potassium; OM, organic matter.

Table 2. Levels of significance (*P*-values) for different variables across locations for soybean

	V3			R3
Variables	P[1]	UPP	DM	P
	-----------------	*P* > F	-----------------	
Till (T)	0.061	0.273	0.396	0.117
Hybrid (H)	0.907	0.007	0.001	0.490
T × H	0.680	0.399	0.168	0.908
Fertilizer (F)	0.002	0.001	0.001	0.001
T × F	0.333	0.863	0.278	0.551
H × F	0.920	0.605	0.433	0.997
T × F × H	0.743	0.977	0.537	0.191

[1] P, phosphorus concentration; UPP, phosphorus uptake; DM, dry matter; V3, trifoliate leaves at three nodes; R3, beginning pod.

Table 3. Levels of significance (*P*-values) for soybean yields by location and across locations

	Ottawa	Scandia	Across locations
		P > F	
Till (T)	0.203	0.035	0.209
Hybrid (H)	0.001	0.001	0.174
T × H	0.404	0.413	0.433
Fertilizer (F)	0.415	0.150	0.673
T × F	0.902	0.763	0.900
H × F	0.225	0.246	0.321
T × F × H	0.287	0.456	0.787

Table 4. Mean values for the parameters evaluated during the soybean growing season across locations

Variables				V3			R3
				P1	UPP	DM	P
				%	mg/plant	g/plant	%
Tillage (T)	No-till			0.31 a2	6.42	1.93 b	0.32
	Strip-till			0.30 b	6.66	2.12 a	0.32
Variety (V)	94Y40			0.30 b	6.24 b	1.99	0.33
	P44T63R			0.31 a	6.84 a	2.07	0.32
Fertilizer (F)	Check			0.28 c	5.87 c	1.96 b	0.3 b
	Broadcast			0.31 b	6.44 b	1.96 b	0.33 a
	Deep band			0.33 a	7.31 a	2.16 a	0.32 a
T x F x V	No-till	94Y40	Check	0.29	5.62	1.84	0.32
	No-till	94Y40	Broadcast	0.31	6.07	1.86	0.33
	No-till	94Y40	Deep band	0.33	6.17	1.82	0.33
	No-till	P44T63R	Check	0.28	5.91	1.93	0.3
	No-till	P44T63R	Broadcast	0.31	6.53	1.90	0.34
	No-till	P44T63R	Deep band	0.36	8.23	2.24	0.32
	Strip-till	94Y40	Check	0.28	5.60	1.93	0.3
	Strip-till	94Y40	Broadcast	0.30	7.01	2.23	0.34
	Strip-till	94Y40	Deep band	0.30	6.97	2.24	0.33
	Strip-till	P44T63R	Check	0.28	6.35	2.14	0.3
	Strip-till	P44T63R	Broadcast	0.32	6.15	1.86	0.32
	Strip-till	P44T63R	Deep band	0.32	7.87	2.36	0.32

[1] P, phosphorus concentration; UPP, phosphorus uptake; DM, dry matter; V3, trifoliate leaves at three nodes; R3, beginning pod.
[2] Letters indicate a significant difference at $\alpha < 0.10$ using PROC GLIMMIX (SAS 9.3).

Table 5. Levels of significance (*P*-values) for different corn variables across locations

	V6 growth stage			V10 growth stage			VT growth stage		
Variables	P[1]	UPP	DM	P	UPP	DM	P	UPP	DM
	----- *P* > F -----								
Till (T)	0.061	0.273	0.396	0.433	0.407	0.483	0.150	0.345	0.003
Hybrid (H)	0.907	0.007	0.000	0.057	0.011	0.052	0.034	0.956	0.020
T × H	0.680	0.399	0.168	0.670	0.070	0.016	0.140	0.153	0.296
Fertilizer (F)	0.002	0.001	0.001	0.001	0.001	0.002	0.024	0.001	0.001
T × F	0.333	0.863	0.278	0.617	0.356	0.307	0.789	0.189	0.005
H × F	0.920	0.605	0.433	0.548	0.529	0.394	0.469	0.757	0.461
T × F × H	0.743	0.977	0.537	0.334	0.040	0.049	0.858	0.806	0.641

[1] P, phosphorus concentration; UPP, phosphorus uptake; DM, dry matter.

Table 6. Mean values for the parameters evaluated during the corn growing season across locations

Variables				V6			V10			VT		
				P1	UPP	DM	P	UPP	DM	P	UPP	DM
				%	mg/plant	g/plant	%	mg/plant	g/plant	%	mg/plant	g/plant
Tillage (T)	No-till			0.42 a2	45.61	12.57	0.34	283.13	85.53	0.22	338.11	150.42 a
	Strip-till			0.41 b	43.21	12.21	0.35	295.30	87.67	0.23	326.6	140.14 b
Hybrid (H)	P1105 AM			0.41	41.38 b	11.47 b	0.33 b	270.24 b	83.61 b	0.24 a	332.02	141.35 b
	P1151 AM			0.41	47.45 a	13.31 a	0.35 a	308.19 a	89.59 a	0.22 b	332.69	149.21 a
Fertilizer (F)	Check			0.39 b	33.31 b	10.8 b	0.32 b	244.18 b	79 b	0.22 b	286.02 b	131.85 b
	Broadcast			0.43 a	49.05 a	12.84 a	0.35 a	317.97 a	91.6 a	0.24 a	356.65 a	151.90 a
	Deep band			0.42 a	50.88 a	13.53 a	0.36 a	305.49 a	89.22 a	0.23 a	354.39 a	152.10 a
T × F × V	No-till	P1105 AM	Check	0.39	32.47	10.55	0.30	210.78 e	72.63 e	0.22	273.50	125.79
	No-till	P1105 AM	Broadcast	0.43	48.81	12.74	0.34	290.52 bcd	88.03 bcd	0.23	345.70	150.41
	No-till	P1105 AM	Deep band	0.44	49.23	12.56	0.35	250.93 de	75.78 ed	0.23	367.87	158.05
	No-till	P1151 AM	Check	0.40	34.98	11.31	0.32	239.91 de	76.59 ed	0.21	283.26	135.68
	No-till	P1151 AM	Broadcast	0.43	51.98	14.21	0.35	332.54 ab	96.06 ab	0.23	377.95	161.54
	No-till	P1151 AM	Deep band	0.44	56.21	14.07	0.37	374.09 a	104.12 a	0.22	380.40	171.05
	Strip-till	P1105 AM	Check	0.39	29.45	9.57	0.32	262.46 cde	85.02 bcd	0.24	310.66	132.16
	Strip-till	P1105 AM	Broadcast	0.42	43.36	11.51	0.34	291.63 bcd	87.83 bcd	0.24	359.68	149.16
	Strip-till	P1105 AM	Deep band	0.41	44.93	11.86	0.36	315.10 abc	92.40 abc	0.25	334.70	132.50
	Strip-till	P1151 AM	Check	0.39	36.33	11.75	0.33	263.55 cde	81.72 cde	0.20	276.66	133.76
	Strip-till	P1151 AM	Broadcast	0.42	50.46	12.91	0.38	357.17 a	94.48 ab	0.23	343.28	146.47
	Strip-till	P1151 AM	Deep band	0.40	54.71	15.63	0.35	281.85 bcd	84.57 bcde	0.23	334.60	146.78

[1] P, phosphorus concentration; UPP, phosphorus uptake; DM, dry matter; V6, six-leaf collar present; V10, 20-leaf collar present; VT, tasseling stage.
[2] Letters indicate a significant difference at $\alpha < 0.10$ using PROC GLIMMIX (SAS 9.3).

Table 7. Levels of significance (*P*-values) for corn yields by location and across locations

	Ottawa	Scandia	Across locations
	------------	*P* > F	------------
Till (T)	0.363	0.636	0.486
Hybrid (H)	0.736	0.966	0.900
T × H	0.374	0.467	0.618
Fertilizer (F)	0.001	0.049	0.001
T × F	0.057	0.255	0.404
H × F	0.011	0.569	0.366
T × F × H	0.403	0.148	0.239

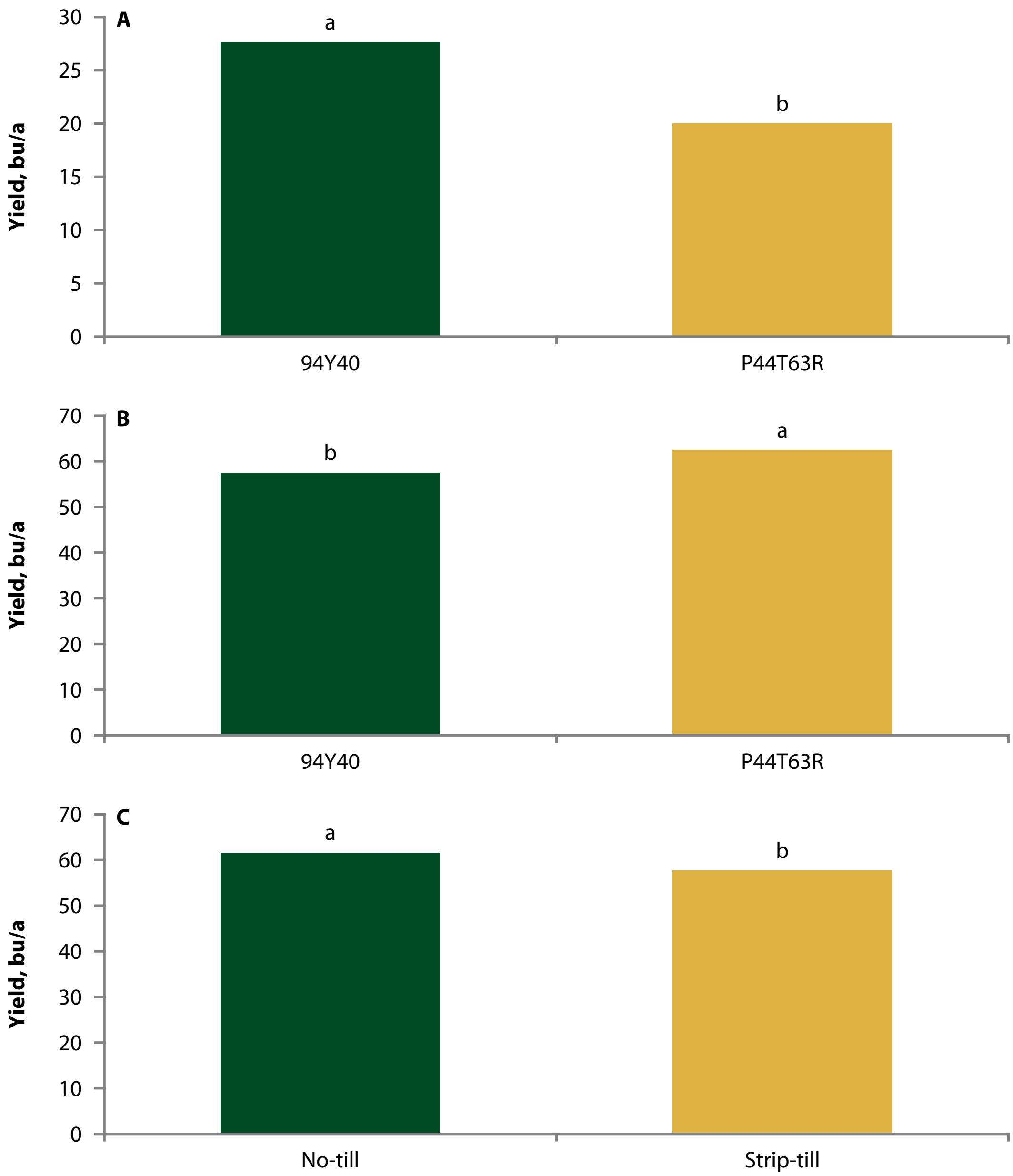

Figure 1. A and B: mean values for soybean yields according to varieties in Ottawa and Scandia, respectively; C: mean values for soybean yields according to tillage in Scandia.

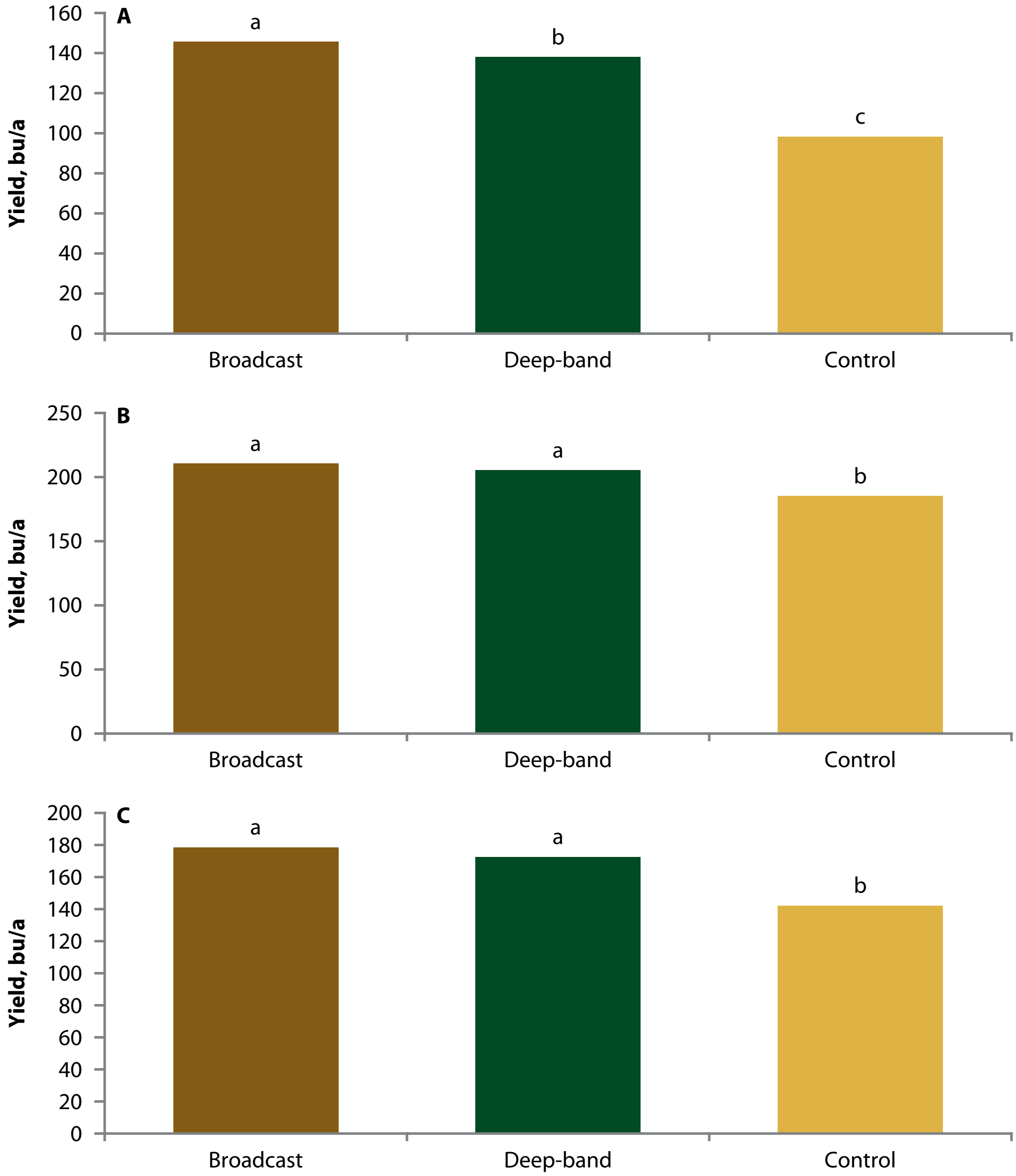

Figure 2. A, B, and C: Mean values for corn yields according to fertilizer placement in Ottawa, Scandia, and across locations, respectively.