Maize Yield Response to Sulphur and Phosphorus Applied Under Different Tillage Systems in the Dominican Republic

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In Luperon, Dominican Republic, maize grows on sloping hillsides without the use of conservation tillage practices. As a result, excessive soil erosion for this 10,000 hectare area threatens future productivity on these moderately shallow soils. Recent work has also documented the advantages of applying sulphur (S), especially where residues are commonly burned, as is the case in Luperon. Annual burning of previous year residues is a major cause of soil erosion and can volatilize up to 75% of the S present in the organic residue (13). Advantages associated with the use of zero tillage include soil moisture conservation (3), increased residual mineral nitrogen (N) (10), and increased surface soil organic matter (10). Zero tillage systems improve micronutrient uptake (10), microbial biomass (7), and phosphorus (P) availability (9). The use of zero or minimum tillage is not always recommended for neutral to acid soils because of the acidifying effect associated with these tillage systems (4,5).

Fertilizers and conservation tillage are not currently used on highly eroding slopes of the Northern Coast of the Dominican Republic. However, this region could benefit from these practices. Therefore, the objectives of this experiment were to evaluate the effects of N, S, and P fertilizer applications on maize grain yield under zero and conventional tillage.

Experimental Methods

In October 1988, four field trials were initiated in Luperon to evaluate the effects of zero and conventional tillage with varying rates of P and S. The soils of this region have calcareous parent material at a depth of 60 cm, receive 1270 mm of precipitation per year, and most commonly have a silty clay loam texture. Soil test analyses for the four locations are listed in Table 1. In general, slopes on these maize-seeded hillsides exceed 15% and have been subjected to excessive soil erosion. The experimental design at each site was a split-plot, randomized complete block with three replications. Main plots were zero and conventional tillage. Conventional tillage consisted of burning the previous year's residue followed by two diskings prior to planting. In the zero tillage plots, no burning or disking was employed. Weeds were controlled in the zero tillage plots through three methods: pre-plant hoeing, applications of pre-emergence herbicides, and applications of post-emergence herbicides. The open pollinated maize variety, "Frances Largo", was hand planted at all locations. Plots consisted of 4 rows, 5 m in length.

Fertilizers were all applied at planting in joint bands 7 cm to the side of the seed and 7 cm below the surface of the soil. In order to evaluate the potential response to S, ammonium sulphate (AS)

Table 1. Soil analysis by location, Luperon, Dominican Republic, 1989.

Location	*pH*	*OM, %*	*P* *µg g⁻¹*	*meq/100g* *K*	*Ca*	*Mg*	*µg/ml* *Fe*	*Zn*	*Cu*	*Mn*
Balbuena (1)	7.7	2.73	1.0	1.25	29	9.3	25	3.5	8.1	6.0
Echavarria (2)	7.9	2.79	5.6	1.20	30	4.3	34	9.3	11.4	17.0
Momin (3)	7.4	2.46	1.9	0.65	38	10.2	29	9.6	4.5	6.0
Valdez (4)	7.6	4.12	1.0	1.06	44	7.1	23	7.1	11.7	16.0

pH-1:2.5 H_2O, OM = organic matter, (15).
P, K (11).
Fe, Zn, Cu, Mn-Olsen

and urea were applied in the same manner to avoid ammonia volatilization losses which could potentially restrict the S comparison desired. Nitrogen and P as triple superphosphate (TSP) were applied at recommended rates.

Grain yield was obtained by hand harvesting the center rows of each plot. Stalk lodging was determined by counting the number of stalks broken below the ears. Root lodging was determined by counting the number of plants that were inclined 30° or more. Both lodging scores were taken at physiological maturity.

Grain Yield

Maize grain yields were lower under zero tillage compared to conventional tillage (2.76 and 3.15 Mg ha^{-1}, respectively) (Tables 2 and 3). This difference could be the consequence of increased N immobilization under reduced tillage (1). Although actual N immobilization was not measured in this study, increased N deficiencies in zero tillage plots compared to conventional tillage plots were observed. Other possible causes include increased nitrate N leaching and denitrification losses compared to conventional tillage (12). Despite lower yields, the advantages of zero tillage with respect to soil erosion control were considered invaluable for this region. In an attempt to use these trials as an extension mechanism, 40 kg N ha^{-1} was applied, reflecting an amount farmers could afford. Visual N deficiencies were still observed in zero tillage plots compared to conventional tillage, and the magnitude of S and P responses was undoubtedly affected by the limited N supply.

Yield response to applied S was greater in conventional tillage compared to zero tillage. This may be due to the residue burning in these plots. Sanchez (13) indicated that burning could volatilize up to 75% of the S in residues. Since more than 95% of the total S in soils from humid and semihumid regions is in organic forms (14), total available S would be expected to be low in conventional plots where residue is burned. In general, P applications increased yields, although yields tended to peak at the 20 kg ha^{-1} P rate. Response to applied P at the low P rate was much greater in conventional tillage while at the high P rate, grain yields responded better under zero tillage.

Although both independent responses to S and P were significant, responses to applications of both were synergistic and not antagonistic as others have shown (2,8). This previous work demonstrated induced sulphate leaching losses as a result of broadcasting P on soils having high anion exchange capacities. Band-applying the two fertilizers together apparently overcame this problem. In addition, S leaching was considered unimportant for these soils since anion exchange is negligible when soil pH is greater than 7 (6). However, whether this synergistic effect was due to the use of AS as the S source could not be determined.

Farming region outside Luperon, Dominican Republic.

Table 2. Combined analysis of variance of maize grain yield, root lodging and stalk lodging as affected by tillage and fertilizer treatments at four locations, Luperon, Dominican Republic, 1989.

		Mean Squares		
Source of variation	*df*	*Grain Yield*	*RL*	*SL*
TOTAL		119		
Location (L)	3	41.941**	8200**	1569*
Rep (L) ERROR A	8	0.724	228	394ns
Tillage	1	4.352*	3509**	4442**
Location*Tillage	3	0.764ns	1348**	1026 @
ERROR B	8	0.755	34	321
Treatment	4	3.556**	22ns	91ns
Location*Treatment	12	0.740 @	78ns	139ns
Tillage*Treatment	4	0.693ns	254 @	58ns
Location*Tillage*Treatment	12	0.578ns	109ns	106ns
ERROR C	64	0.394	109	231
Coefficient of Variation		21.25	80.78	83.54
CONTRAST				
1 vs 3	1	3.997**	6ns	11ns
P Rate Linear	1	5.424**	30ns	23ns
P Rate Quadratic	1	1.832*	7ns	144ns
2 vs 3	1	5.461**	1ns	164ns
5 vs 1, 2, 3, 4	1	4.744**	27ns	36ns
1 vs 3 * Tillage	1	2.669*	26ns	163ns
3 vs 4 * Tillage	1	1.406*	131ns	5ns
P Rate Quadratic * Tillage	1	2.145*	8ns	1ns

*@, *, **—significant at 0.10, 0.05, and 0.01 probability levels respectively*
ns—not significant
RL, SL—root lodging and stalk lodging, respectively

Table 3. Yield and lodging means over four locations as a function of tillage system and fertilization treatments.

Location			Grain Yield		Root Lodging		Stalk Lodging	
Treatment kg ha^{-1}			Conv. Tillage	Zero Tillage	Conv. Tillage	Zero Tillage	Conv. Tillage	Zero Tillage
N	*P*	*S*	*Mean*	*Mean*	*Mean*	*Mean*	*Mean*	*Mean*
40U	12	0	2.84	2.74	12.63	11.03	26.26	11.03
40AS	0	43	2.76	2.62	16.18	8.57	20.33	10.64
40AS	20	43	3.83	2.91	18.18	6.87	24.24	14.12
40AS	40	43	3.48	3.25	22.91	5.01	22.58	11.16
0	0	0	2.81	2.30	21.70	6.03	28.00	10.60
Mean by Tillage Practice			3.15	2.76	18.32	7.50	24.28	12.11

40U-40 kg N as Urea ha^{-1}.
40AS-40 kg N as Ammonium Sulphate ha^{-1}, 43 kg carrier S ha^{-1}.
P applied as 0-46-0.

Root and Stalk Lodging

Both root and stalk lodging were found to be greater under conventional tillage compared to zero tillage (Table 3). Root lodging was higher when fertility levels were higher (Treatments 3 and 4) under conventional tillage, but not under zero tillage. Yield and root lodging were positively correlated, suggesting that greater ear weights were a factor in causing plants to fall. Under conventional tillage, yields decreased as stalk lodging increased, but not with zero tillage. Although not reported in the tables, ear rot was also higher in conventional tillage compared to zero tillage.

Conclusions

Maize grain yields were lower under zero tillage than under conventional tillage in these first year trials, probably because N immobilization was higher in zero tillage as a result of increased carbon to nitrogen ratios in the soil. Further research may support Bandel's finding that this particular effect is temporary. Significant soil erosion control was observed in zero tillage. Phosphorus response was altered by tillage whereby zero tillage required increased rates of P compared with conventional tillage to obtain the same yield. Response to applied S was substantially greater in conventional tillage compared to zero tillage. Sulphur volatilization as a result of burning in conventional tillage plots was considered important since S response was minimal under zero tillage. Yields were found to increase synergistically when P as TSP, and S as AS were applied in a joint band. Root and stalk lodging were found to be greater in conventional tillage compared to zero tillage, but this did not lower conventional tillage yields to levels observed under zero tillage.

Yield levels were lower in the first year when zero tillage was employed. However, this practice may be advantageous in the long term for Luperon farmers and others in the Dominican Republic where the majority of the 50,000 hectares of maize are produced on marginal lands.

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