Macronutrient (N, P, K) Uptake in Maize H-149 in Conventional and Conservational Tillage Systems

G. A. BILBAO

Department of Plant Technology, University of Chapingo (Mexico)

Introduction

Low productivity in maize production in Mexico, intense soil degradation, a recent consciousness about manure and crop residue subutilization, and the increasing costs of fertilizers and fuel have given an impulse in Mexico in recent years to the evaluation and liberation of highly productive genotypes such as H-149, H-135, H-133 and H-311, and also to the promotion of conservational tillage.

Maize H-149 produced a mean of 9464 kg/ha of grain in more than 40 localities in the central part of Mexico (ALEJANDRO, 1990). This was 30% superior to the yields of local varieties and 26% above crops of H-32, a very popular commercial hybrid; it was also 9, 22 and 17% superior to the new materials H-135, H-133 and H-311, respectively (JOSÉ LUIS et al., 1990). Its forage production is higher than that of most grain-oriented genotypes. Estimations carried out in Chapingo showed 14 tons/ha yields, 280% superior to local varieties and H-32.

Some reasons for the compilation of this paper were: the higher yields in H-149 maize, both as regards grain and forage; the increase in nutrient demands; the fact that fertilization recommendations are the same for old and new genotypes and do not include K^+, despite the fact that recent works indicate how maize yields increase with potassium fertilization (LARA, 1990; SOLS & ASTEINZA, 1990); the small amount of data generated in relation to yield and nutrient extraction in different tillage systems.

Materials and Methods

The experimental area was established at the Autonomous University Chapingo in the Experimental Center of the Valley of Mexico (CEVAMEX) of the National Institute of Forestal, Agricultural and Pecuarian Investigations (INIFAP).

Parameters: altitude 2240 m. Climatic symbol C(w_o) (w)b(i')g; the driest of temperate subhumid climates (GARCIA, 1981), with fresh long summers and low temperature oscillation; average medium temperature registered during the cultivation cycle (June-October) 16.1 °C.

Soils: deep, franc texture, superficial strata with sand crumb, slightly alkaline, medium organic matter content.

In relation to the *tillage systems*, all the conservational variants had in common the elimination of subsoiling; one mechanical weeding was performed with a 120 hp tractor.

For each tillage system two fertilization conditions were established, one without fertilizer (00-00-00) and the other with the 150-50-00 formula recommended by INIFAP for irrigated areas.

Other characteristics of the *tillage variants* were:

Conventional tillage system: The conventional tillage system included subsoiling every three years, one year of fallow, one harrowing, one furrowing and two mechanical weedings. (Treatment No. 1. 00-00-00; No. 2. 150-50-00).

Conservational tillage with mulch: In addition to the reduction in machinery manouvres, 10 tons/ha of corn stubble were applied immediately after weeding. This corn mulching represented at least 50% coverture. In this system no herbicides nor insecticides were applied. In the following years only 5 t/ha of corn residue were added. (Treatment No. 3. 00-00-00; No. 4. 150-50-00).

Conservational tillage with dung: During furrowing, bovine dung was applied superficially in the lower part of the furrow. Dung levels were 0, 60 and 120 tons/ha. The moisture content at application was 50%; no pesticides were used. (Treatment No. 5. (60 t/ha dung) 0-00-00; No. 6. (60 t/ha dung) 150-50-00; No. 7. (120 t/ha dung) 00-00-00; No. 8. (120 t/ha dung) 150-50-00).

Integral conservational tillage: This treatment included a reduction in tillaging, the addition of corn stubble as described previously and the application of two levels of bovine dung, 60 or 120 t/ha (These manure levels correspond to observed dung applications by dairy farmers that produce corn for grain and forage.) (Treatment No. 9. (60 t/ha dung) 00-00-00; No. 10. (60 t/ha dung) 150-50-00; No. 11. (120 t/ha dung) 00-00-00; No. 12. (120 t/ha dung) 150-50-00).

The experimental plots, each measuring 24 m^2, were established at random and had 3 replications.

The evaluations included grain yield (kg/ha) at 13% humidity, forage production (air-dried), and macronutrient (N, P, K) uptake. Nutrients were evaluated when the grain reached physiological maturity; the determinations were made in roots, stalk, leaves, stamens and grain. Total nutrient extraction was determined by considering the separate concentrations of the listed parts, and

the proportion with which each component participated in the total weight. Root contents were not included in the forage uptake. Nitrogen was determined by the microkjeldahl method, phosphorus and potassium by atomic absorption. Soil humidity was read weekly at a depth of 20 cm.

Results and Discussion

Grain

The mean value of yields in the three years of evaluation for the conventional fertilized technical package recommended by INIFAP for maize production in the Valley of Mexico was 7749 kg/ha. When no fertilization was applied the treatment produced 6164 kg/ha. Maximum production, 9123 kg/ha was obtained under the integral conservational tillage system with 60 t/ha dung application and fertilization (Treatment No. 10), which represents a 17.7% increase with respect to the conventional fertilized tillage treatment, and is statistically significant at 0.05 level (Table 1). Other treatments with high yields:

- Conventional tillage with 60 t/ha manure: 8714 kg/ha;
- Conservational mulched with 120 t/ha and fertilization: 8340 kg/ha;
- Conservational, 60t/ha manured and fertilization: 8281 kg/ha yield.

Table 1

Effect of tillage system and fertilization on grain yields of maize H-149, Chapingo, Mexico

Treatment No.*	1988	1989	1990	Mean value	As a % of conventional	Tukey group
1.	7166	6470	4855	6164	-20.5	C
2.	8200	7405	7643	7749	-	BAC
3.	7733	7049	5115	6632	-14.5	BC
4.	8533	7705	8334	9191	+5.7	BAC
5.	9866	8985	7290	8714	+12.5	BA
6.	8833	8006	8003	8281	+6.9	BA
7.	8633	7795	8076	8168	+5.4	BAC
8.	7400	6746	8414	7520	-3.0	BAC
9.	9066	8265	6402	7911	+2.1	BAC
10.	10266	9271	7833	9123	+17.7	A
11.	9166	8277	7238	8227	+6.17	BAC
12.	9533	8608	6878	8340	+7.6	BA

For treatments: See Materials and Methods

Variance analysis shows that manure was a highly positive factor; the 60 t/ha application gave a mean yield value of 8507.2 kg/ha, with 8063.7 kg/ha for the 120 t/ha level, and 7184.0 kg/ha in the non-manured treatments (Table 2).

Another significant tukey group factor was fertilization, with a 7635.9 kg/ha yield in the non-fertilized treatments. Mulching did not affect yields at a significant level (Table 2).

Table 2
Analysis of variance for maize H-149 grain yields and forage production

Factor	Level	Grain yield, kg/ha	T.g.	Forage yield, kg/ha	T.g.	n
Mulch	0	7765.9	A	19028.4	A	18
	10	8070.7	A	19336.1	A	18
Manure	0	7184.0	B	17342.0	B	12
	60 t/ha	8507.2	A	21076.7	A	12
	120 t/ha	8063.7	A	19127.2	B	12
Fertilization	00-00-00	7635.9	B	18386.4	B	18
	150-50-00	8200.6	A	19978.1	A	18

T.g. = Tukey grouping

The only significant interactions were between manure and fertilization factors (Pr >F = 0.0144).

Higher grain yields in 1988 and 1989 were attributed to better meteorological conditions; the lower results in 1990 are due to intense cloudiness for more than three weeks and fifteen days of rain at the beginning of the reproductive phase.

Decrease in the yields of non-fertilized treatments, particularly in conventional tillage and conservational mulched plots, are explained by the depletion of the soil nutrients available in the first year due to fertilization carried out in previous agricultural cycles.

Fertilization in mulched treatments may have compensated for nutrient immobilization.

The lower crop values in the 120 t/ha manured treatments compared to the 60 t/ha manured areas, including conservational integral treatments, are due partly to an average 2% reduction in soil humidity, which in certain periods was as great as 6%. This is understandable if we consider that the manure was applied superficially.

Conservational tillage variants in general presented increases in production in relation to the conventional system.

Forage

The highest yields in forage production were obtained in the integral tillage system with mulch application and 60 t/ha of manure (22.20 kg/ha) and in the conservational system with 60 t/ha manure (Treatment No. 5), giving a 22.134 kg/ha yield (Table 3).

Table 3

Effect of tillage system and fertilization on maize H-149 forage yields, Chapingo, Mexico

Treatment No.	1988	1989	1990	Mean value	As a % of conventional
1.	14643	16375	14913	15310	-18.5
2.	16291	19803	20213	18769	-
3.	15563	16496	17108	16389	-12.7
4.	18170	18860	28683	22134	+0.7
5.	18860	18860	28683	22134	+17.9
6.	17710	18596	23564	19957	+6.3
7.	15755	16543	20921	17740	-5.5
8.	18400	19320	23061	20260	+7.9
9.	17901	18796	23347	20015	+6.6
10.	18860	19803	27940	22201	+18.3
11.	16866	17709	21616	18730	+0.2
12.	17250	17113	23972	19778	+5.4

The lowest significant values were for the mulched and non-fertilized treatments and for conventional tillage without fertilization, that produced 16.389 kg/ha and 15.310 kg/ha, respectively.

Variance analysis for mulching, manure addition and fertilization shows that the only factors that produced significant increases in forage production were the 60 t/ha manure application and fertilization (Table 2). None of the interactions proved to be significant.

Forage mean values in 1990 were 20% superior to those obtained in 1989, and 28% greater than the 1988 values. A factor that may explain this is a 43% increase in precipitation in 1990 in relation to previous years and the presence of many cloudy days during the vegetative stage of maize in 1988. The yearly progressive increase in yields in all the mulched and manured treatments, particularly the fertilized ones, may be due to nutrient liberation. The exceptions are the non-fertilized mulched plots (Table 3). Soil analysis in the plots showed a significant increase in extractable phosphorus and potassium in the third year. Manured conditions augmented these nutrients to an extent of 536 and 360%,

respectively; integral conservational tillage also promoted the liberation of these nutrients by 704% in the case of phosphorus and 384% for potassium release.

Macronutrient uptake

The highest *nitrogen* extraction in 1990 was registered in the conservational tillage system manured with 120 t/ha and fertilized (Treatment No. 8), where 356.3 kg/ha was extracted; the next highest value was obtained in treatment No. 10, with 347.9 kg/ha. The rest of the variants, except 1 and 3, were significantly higher than conservational fertilized plots (Table 4).

Table 4
Total extraction of N, P, K nutrients by maize H-149*

Treatment No.	N kg/ha	Tukey group	P kg/ha	Tukey group	K kg/ha	Tukey group
1.	139.8	H	33.3	E	133.3	E
2.	223.4	F	34.3	E	171.0	C
3.	178.4	G	39.3	CDE	173.5	C
4.	265.8	ED	53.7	B	172.4	C
5.	294.3	BCD	66.2	A	189.0	C
6.	326.1	AB	46.9	BC	149.0	D
7.	301.3	BC	43.1	CD	229.9	A
8.	356.3	A	46.6	BC	149.0	D
9.	260.9	E	69.6	A	209.2	B
10.	347.9	A	68.5	A	232.0	A
11.	262.3	ED	36.9	DE	202.9	B
12.	275.3	ECD	41.6	CDE	238.3	A

* 1990 extraction values

For *phosphorus* extraction the highest values were observed in the integral conservational tillage treatments No. 9 and 10, which accumulated 68.5 and 69.6 kg/ha, respectively. Most of the rest of the treatments were significantly superior in phosphorus uptake to the conventional fertilized plots.

For *potassium* uptake, again treatment No. 10 was the best, and treatments No. 5, 6, 7, 8 12 and 4 extracted significantly higher amounts of this nutrient than conventional fertilized tillage; only treatments No. 3, 11 and 1 registered smaller values than the conventional fertilized treatment No. 2 (Table 4).

The mean yields obtained for grain and forage during 1988, 1989 and 1990 changes the potassium extraction values. The highest uptakes of nitrogen and phosphorus were observed in treatment No. 10, where 360.1 and 67.4 kg/ha

were extracted, respectively. The highest potassium extraction was observed in treatment No. 4, where 221 kg/ha was removed by the crop (Table 5).

The analysis of mulching, manure and fertilization as single factors shows that maize residue application reduces nitrogen and potassium extraction and increases phosphorus uptake, all at significant levels (Table 6). Manure application at 60 t/ha level increases the N, P and K uptake significantly. Dung application at a 120 t/ha level increases N and K removal, but not P. Fertilization increased N extraction and did not affect P or K extractions.

Table 5

Total extraction of N, P and K nutrients by maize H-149*

Treatment No.	N kg/ha	P kg/ha	K kg/ha
1.	174.5	33.7	143.5
2.	220.3	42.6	162.1
3.	182.8	38.9	168.4
4.	251.1	41.0	221.0
5.	254.3	57.1	154.9
6.	245.7	41.5	132.3
7.	264.9	40.5	204.0
8.	281.1	38.5	191.3
9.	260.3	42.2	186.3
10.	360.1	67.4	192.3
11.	249.6	46.8	183.9
12.	288.9	51.3	207.5

*Mean values of 3 years

Table 6

Analysis of variance of total nutrient extraction

Factor	Level	N	T.g.	P	T.g.	K	T.g.
Mulch	0	273.5	A	45.07	B	178.4	B
	10	265.1	B	51.59	A	204.7	A
Manure	0	201.8	B	40.10	B	162.0	C
	60 t/ha	307.3	A	62.8	A	194.0	B
	120 t/ha	298.8	A	42.1	B	217.0	A
Fertilization	00-00-00	239.5	B	48.0	A	189.6	A
	150-50-00	299.1	A	48.6	A	193.5	A

T.g. = Tukey grouping

Several factor interactions are highly positive in macronutrient uptake; many such interactions are related with conservational tillage systems. Nitrogen extraction was increased by the mulch - manure (Pr>F 0.0001); manure - fertilization (Pr>F 0.0001); and mulch - manure - fertilization (Pr>F 0.0001) interactions.

Phosphorus uptake increased due to the mulch - manure (Pr>F 0.0001); mulch - fertilizer (Pr>F 0.0001); manure - fertilizer (Pr>F 0.0001); and mulch - manure - fertilizer (Pr>F 0.0055) interactions. For potassium the extraction values also increased due to the mulch - manure (Pr>F 0.0001); mulch - fertilization (Pr>F 0.0001); manure - fertilization (Pr>F 0.0001); and mulch - manure - fertilization (Pr>F 0.0001) interactions.

Final considerations

Soil analysis showed that three years of conservational tillage management, particularly in the manured and integral variants, increased phosphorus and potassium availability in the profile in the 253 to 1184% range in the first case, and by 293 to 485% in the second case. This fact may explain part of the forage yield increase.

The increase in forage yields may be very important, particularly in a highly productive genotype like H-149, because even if 5 tons of forage are used as mulch, the major part can be used as fodder for internal farm consumption or sold.

The grain yields in conservational tillage treatments only presented small increments but, due to the high productivity of the genotype, the additional crop represents major economic benefits. When the benefit/cost relation was analyzed, conservational variants proved to produce higher net benefits (PAT, 1992).

The removal of maize forage, no manure addition or no K fertilization, may represent a significant annual depletion of this element which could interfere with subsequent yields.

Conclusions

- Although the experiment was carried out under irrigated conditions, the atmospheric variations from one year to the other determined changes in the best grain treatments.
- The integral conservational tillage system that includes mulch, manure and fertilization was the best treatment, both for grain and forage production.
- Forage yields increase each year.
- Manure and fertilization increased grain and forage yields significantly.
- Mulching did not increase yields.

- Nutrient uptake was significantly incremented in all conservational tillage variants.
- Mulching increased phosphorus and potassium extraction.
- Manure elevated N, P and K extraction.
- Fertilization increased only N uptake.
- Interactions between double factors such as mulch - manure and manure - fertilization increased N, P and K extraction.
- The triple interaction mulch - manure - fertilization increased N, P and K uptake.
- H-149 forage production contributes in a great measure to the total nutrient uptake.

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