Quantitative Difference Method for Estimation of Fertilizer Nitrogen Balance and Uptake by Zea mays on an Orthic Oxisol of North Central Nigeria

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Abstract

The percentic recovery and balance of fertilizer nitrogen can be determined by different methods. In this study, quantitative difference method in recovery of Nitrogen of above-ground dry matter was applied to investigate the uptake of field applied nitrogen by maize cultivated in an orthic oxisol soil. It was found that the maximum uptake of fertilizer N is about 75 % decreasing at the end of the growing period to about 65%. About 25% of the N remains in the upper part of the profile, while about 10% can not be localized and presumably lost by denitrification.

Keywords: Fertilizer, Soil, *Zea mays*, Uptake, Nigeria

Introduction

Soils contain mineral nutrients in varying quantities and proportions. The nutrient especially nitrogen is essential for crop production. Soil nitrogen and fertilizer nitrogen constitute the major sources of nitrogen and can easily be influenced by the following factors: plant uptake, leaching, denitrification, volatilization, run-off and erosion and mobilization into active and passive organic nitrogen pool. Consequently, fertilizer nitrogen is transformed into such a form or transported to such a place that it is no more accessible to plants.

The need, therefore, to increase food production may require an increased efficiency of fertilizer use. The addition of fertilizers results in an increase in plant growth and more exploitation of the soil volume by the roots. This induces an increasing uptake, but has also an influence on the air and water regime in the soil (Van Cleemput *et al*, 1977). When the plants have more food, they are healthier and can take up the fertilizer more efficiently. The efficient use of fertilizer nitrogen would minimize monetary and energy losses. The non-efficient part of the fertilizer should be in such a form that pollution of the environment is limited.

The study of the uptake of fertilizers especially nitrogen is of agronomic interest because of its biological importance and influence on the yield of crops. This is more evident after fertilization when the nitrogen of the fertilizer is taken up by plants.

Studies have shown that the balance of the field applied nitrogen can be recovered (Low and Piper, 1975; Westerman and Kurtz, 1974; Kissel and Smith, 1978; Hauck and Bremmer, 1976) by estimations. Several methods used include Dose-uptake linear regression (N-15), Dose-uptake linear regression (N-14), isotopic tracer, and the difference method. The first two are direct methods, while the last two are indirect methods. Van Cleemput and Baert (1980) noted that the direct methods permit to calculate the recovery and balance of field-applied nitrogen on an absolute basis, while on the part of indirect methods, Low and Piper (1975) observed that the difference method gives higher recovery results than the tracer methods. Low and Piper (1975) found an Ammonium (NH4+) recovery of 37.5% by the difference method and 28% with the tracer method. Kissel and Smith (1978) also found an uptake of 42% by the tracer method and 70% by the difference method using Ca (NO3)2 fertilizer, and Bermuda grass as test plant. All of these show that the difference method may be most effective in estimating nitrogen uptake by plants.

The present study, therefore, aims at estimating by quantitative difference method the field-applied fertilizer nitrogen balance and uptake by *Zea mays* cultivated on an Oxisol soil of North Central Nigeria.

Materials and Methods

The field of study is situated in the Teaching and Research Farm of Nasarawa State University, Lafia Campus. Lafia is located between 6^0 15'N and 9^0 30'N as well as 6^0 30'E and 11^0 00'E. The location has gentle, undulating topography. The vegetation type is dominated by grass savanna and small patches of woody shrubs. The mean temperature of the area ranges between 28.5 and 30.9^{0}C, while the annual rainfall ranges between 1270 and 1530mmm with 3-4 month dry season. Mean daily actual sunshine hours range from 3.71 and 7.20. The parent material is shales and basement complex (Obaje *et al.*, 2005).

Experimental design: A field plot of 3x3m^2 was marked out in a field of 1.30 hectare (ha) on which maize (*Zea mays*) was sown. The total number of maize stands on the experimental micro-plot (9m^2) was 64 or 72.220ha^{-1}. Prior to sowing of maize seeds, initial soil samples were collected from the experimental plots and analysed for soil nitrogen. The maize was harvested by three fractions-leaves, stalks and roots and subjected to analysis at three different harvest periods. The maize stands used for the nitrogen analyses were taken from the central part of the plots. After the final harvest, the soil of the field was sampled and analysed for residual N. The dates and operations carried out are shown in Table 1.

Table 1: Survey of different treatment

Date	Treatment
04-05-04	Sowing of the maize
19-05-04	Fertilization of $9m^2$ with 60kg N ha^{-1} as urea with 45% N
06-08-04	1st harvest
20-09-04	2nd harvest
22-10-04	3rd harvest

Laboratory determination: Total nitrogen in soil was determined according to Macro Kjeldal method of Bremmer and Mulvancy (1982), while total nitrogen in plant samples were obtained by mass spectrometry after distillation and concentration to about 1 mg nm 1^{-1} (Bremmer, 1982). Care was taken to avoid contamination and cross-contamination of the enriched samples.

Calculations by the difference method: The %N content of the three plant fractions was determined by the difference between the enrichment of treated and non-treated maize. In order words, the amount of nitrogen taken up from the fertilizer is obtained by finding the difference in nitrogen uptake by the maize crop growing on a fertilized and on a non-fertilized plot. The percentage recovery of the fertilizer nitrogen is, therefore, calculated by referring to a control treatment (no^{N-} fertilizer application) as follows: % recovery = NF - NC / R x 1000, where, NF = nitrogen in the plants grown on the fertilized plot, NC = nitrogen in the plants grown on a control (no^{N-} fertilizer) plot and R = rate of applied fertilizer.

Also, the percentage of nitrogen in the plant derived from the fertilizer (% N dff) is calculated as: % N dff = (c-b) / (a-b) x 100, where, a, c = % N in the fertilizer and non-fertilized plants, respectively, and b = % N in plants of non-treated with fertilizer (shows measure of the natural nitrogen abundance).

The percentage of N in the plant derived from the soil (% N dff) is made up by the difference: % N dff = 100 - % N dff. The choice of the difference method as used in this study is because of its high recovery results (Van Cleemput and Baert, 1980) relative to other methods.

Results and Discussion

The mean value of nitrogen from the soil samples collected and analysed from the experimental plots prior to planting is 0.073%. The yield, dry matter (dm) and nitrogen content (nc) as well as the distribution of proportion of dm and nc of the three plant fractions are shown in Table 2. The results show that roots gave higher fresh weight and dry matter during growing period and at final harvesting than at the young stage. The result further shows that the nitrogen concentration is much higher in plants at a young growing stage than at the end of the growing period. The distribution by proportion of dry matter and nitrogen content over the three plant fractions (Table 2) shows that at the first harvest, most of the N is located in the leaves, decreasing to the end of the growing period. Percentage distribution of dry matter was obtained more at the harvest time than at other periods.

Data on uptake and efficiency of fertilizer and soil nitrogen are given in Tables 3 and 4. Table 3 gives the percentage N excess and the total amount of the exported N (gN $9m^{-2}$), while Table 4 contains the percentage of nitrogen (N) in the plant derived from fertilizer (% N dff) and percentage of n in the plant derived from the soil (% Ndff) as well as the percentage recovery of the fertilizer nitrogen.

From Table 3, it can be seen that the distribution of N over the three plant fractions is very similar to the distribution of the total N, as given in Table 2, indicating a random uptake and distribution of nitrogen in the plants. Table 4 shows that about ¼ to 1/6 of nitrogen is supplied by the fertilizer (Ndfs) especially at the initial growth stage and about ¾ to 5/6 by the soil (% Ndfs). It can be observed that the difference between the fertilizer supplied by the soil at the middle and end of growing period is not substantial. It can also be seen (Table 4) that the total utilization by the crop (% efficiency) is most important at the second harvest which is about one month before the final harvest.

This clearly demonstrates that during this last month an important amount of nitrogen is consumed by the plants. The decrease of % efficiency (21 %) at the end of growing period (Table 4) may be due to the decrease of percent efficiency in the leaves. This corroborates an earlier observation that at the end of the growing period, nutrients are leached out of the leaves and returned to the soil (Cady and Bartholomew, 1976).

The result in Table 5 shows a total balance of the applied field nitrogen. The data refer to the plant analysis of the final (3rd) harvest and the analysis of the soil at that time. The table reveals that 63.7 % of the applied nitrogen (N) is recovered by the plants and that 36.3 % remains in the soil. The total recovery is 88.2 %, indicating a loss of almost 12%. This amount of loss during the growing period is minimal and may be associated to limited leaching. Van Cleemput and Baert (1980) similarly observed that leaching out of nitrogen from the soil profile is very limited during the growing period. They further observed that greater loss of N during this period is attributable to denitrification process than leaching. This view is further supported by the studies of Tiedje (1978) and Bremmer and Blackmer (1979), which show that even in aerobic, well-drained soils some nitrogen can disappear by denitrification.

The total N recovery by the maize plant is 65% and corresponds to reports by Jansson (1979) and Van Cleemput *et al*, (1980).

The reported values vary in most cases between 30 and 70% and the variation is often presumed to depend on the experimental condition.

Conclusion: The results of the field experiment conducted to estimate the balance and recovery of fertilizer nitrogen by maize plants grown on an oxisol soil show that the maximum recovery of the fertilizer nitrogen by the maize plants is about 75%.

Table 2: Plant analysis data at different harvesting times and percentage distribution of dry matter and nitrogen content over the three plant fractions

Harvest Intervals	Plant fraction	gN	N content			Dry matter			Maize yield
		$100g^{-1}$DM	gN $9m^{-2}$	kg Nha^{-1}	%N*	Kg $9m^{-2}$	$kgha^{-1}$	*%DM	$kgha^{-1}$
1	Leaves	3.22	111.27	124.40	81.8	2.36	3063	62.8	46612
	Stalk	1.73	4.52	4.91	3.4	0.22	379	4.9	3206
	Roots	1.34	22.68	22.34	14.9	1.47	1863	33.7	16107
2	Leaves	2.59	116.18	142.14	52.1	6.08	7200	26.1	67508
	Stalk	1.41	14.98	18.70	7.3	1.32	1394	5.3	7038
	Roots	0.66	98.80	110.98	41.8	16.21	15204	66.9	74510
3	Leaves	1.78	84.10	93.62	38.8	5.70	4183	23.7	46488
	Stalk	1.43	26.18	29.04	10.9	1.69	2018	8.8	7422
	Roots	0.78	103.64	118.64	47.8	12.89	14357	68.0	67927

* Percentage distribution of dry matter (DM) and nitrogen content (N).

Table 3: Total amount of exported N and the percentage nitrogen excess

Harvest	% N excess			Total export of N (g $9m^{-1}$)							
	Leaves	Stalk	Roots	Leaves		Stalk		Roots		total	
				g	%	g	%	g	%	g	%
1	1.2914	1.1970	1.3288	1.60	82.0	0.06	2.60	0.24	14.1	1.90	99.7
2	0.9218	0.8721	0.9261	1.02	51.3	0.14	6.40	0.88	42.1	2.04	99.8
3	0.8746	0.8941	0.8133	0.76	42.3	0.24	12.10	0.72	45.1	1.74	99.6

Table 4: Percentage of nitrogen in the plant from the fertilizer and soil, and fertilizer nitrogen efficiency (%)

Harvest	Leaves	Stalks	Roots	Total	Average
1	26.20	24.87	26.96	78.03	26.01
2	18.27	15.28	17.99	51.54	17.18
3	16.76	16.94	15.63	39.33	13.11
			%Ndfs		
1	72.59	74.09	73.91	210.49	70.16
2	80.72	83.16	81.12	245.00	81.66
3	81.43	82.20	81.54	244.17	81.39
			% efficiency		
1	53.78	1.92	10.54	66.26	22.08
2	37.66	4.88	32.04	74.58	24.86
3	24.71	8.09	30.07	62.87	20.95

Table 5: Total balance of the field applied nitrogen

Input 2.77g	Plant fraction	Output gN	% of input	Balance Recovery
	Stalks	0.22	7.9	
	Leaves	0.72	25.8	2.45g N
	Roots	0.83	30.0	88.2%
	Total	1.77	63.7	
	Soil profile			
	0 – 15 cm	0.41	14.8	Loss:
	15 – 30 cm	0.27	9.70	0.32g N
	> 30 cm	0	0	11.8%
	Total	0.68	24.50	

This recovery decreases during the ripening process. About 25% remains in the soil, while about 10% of the applied N is lost from the soil.

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