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FATE OF THE ^{15}N-LABELLED UREA APPLIED TO IRRIGATED WHEAT GROWN AFTER COTTON HARVEST UNDER SEMIARID SUBTROPICAL CONDITIONS

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Abstract

Fate of the fertilizer-N applied to irrigated wheat grown after cotton harvest was studied under field conditions using ^{15}N-balance method. Of the total urea-N applied (100 kg ha^{-1}), 47.7 kg N ha^{-1} was utilized by the wheat crop, the recovery being maximum in the grain component (30.0 kg N ha^{-1}), followed by straw (16.9 kg N ha^{-1}) and roots (0.9 kg N ha^{-1}). Of the 24.3 kg N ha^{-1} of the fertilizer-N remaining in the soil at the crop harvest, most (22.2 kg N ha^{-1}) was present in the organic form, whereas maximum (15.6 kg N ha^{-1}) was recovered in the upper 10 cm soil layer. Total fertilizer-N loss during the wheat-growing season amounted to 28 kg N ha^{-1}, which was 1.5 times the denitrification loss directly measured from the same field.

Introduction

In Pakistan, crop husbandry depends largely on irrigation and other inputs including fertilizer-N, the annual consumption of which stands at 2.01×10^6 t for 21.96×10^6 ha of the cropped area (Anon., 2000). Only limited information is available on the fate of fertilizer-N applied to irrigated croplands under semiarid subtropical climatic conditions such as those prevailing in Pakistan and the data are restricted to maize-wheat and cotton-cotton cropping systems (Mahmood *et al.*, 1998; 2000). Under irrigated maize-wheat cropping system, fertilizer-N recovery by maize and wheat crops was 37% and 39%, respectively whereas fertilizer-N loss during the growing period of maize and wheat amounted to 39% and 33%, respectively (Mahmood *et al.*, 1998). Under cotton-cotton rotation, recovery of the fertilizer-N by the cotton crop was 39%, whereas 42% of the applied N was lost (Mahmood *et al.*, 2000). Under wheat-maize cropping system, denitrification was of minor significance (Mahmood *et al.*, 1998), whereas under cotton-cotton rotation, it was found to be the major N loss process (Mahmood *et al.*, 2000). The very high denitrification loss under cotton-cotton rotation was attributed partly to the high soil temperatures, high water-filled porosity for extended period during the monsoon season, and high soil organic matter content due to regular input of cotton crop residues for the past twenty years, which is commonly practiced by the progressive cotton growers in Pakistan. A significant proportion of the cotton growing area in Pakistan is also brought under wheat cultivation after cotton harvest. However, information on the fate of fertilizer-N applied to wheat after cotton harvest has been lacking. In a previous study with wheat grown after cotton harvest, directly measured denitrification loss amounted 19 kg N ha^{-1} (Mahmood *et al.*, 1999), which was several-fold higher than the denitrification loss under wheat grown under maize-wheat cropping system. The present paper reports the fate of ^{15}N-labelled urea applied to wheat crop grown after cotton harvest.

Materials and Methods

The field plot (450 m^2) selected for the present study was located within a 5 ha area that has been under cotton receiving fertilizer-N at 150-170 kg ha^{-1} besides cotton crop residues, which have been regularly incorporated for the past 20 years. Some physicochemical characteristics of the (0-20 cm) soil were: total organic C, 2.3%; total N, 0.06%; pH (saturation paste), 7.9; EC (saturation extract), 0.06 S m^{-1}; water-holding capacity, 35.5%; bulk density, 1.5 g cm^{-3}; porosity, 44.5%; sand, 57.8%; silt, 22.7%; and clay, 19.5%. Before land preparation for sowing wheat, cotton plants were removed in November, which is a usual practice for the cotton-wheat rotation in this region. Wheat (*Triticum aestivum* L. cv Pak-81) was seeded on 13 December and the crop harvested on 8 April. The row-row and plant-plant distance was 20 cm and 10 cm, respectively. At land preparation, P_2O_5 at 60 kg ha^{-1} (as single superphosphate) and urea-N at 50 kg ha^{-1} were mixed in the upper 10 cm, whereas another 50 kg ha^{-1} of the urea-N was broadcast just before the second irrigation (14 February). A total of five canal irrigations were applied; all were equivalent to 75 mm of water except the pre-sowing and the second, which were 100 mm and 50 mm, respectively. Fate of the applied fertilizer-N was studied by ^{15}N-balance method. The ^{15}N micro-plots (four replicates) consisted of PVC irrigation pipes (28.8 cm × 120 cm; inner diameter × depth) pushed to a depth of 1 m within the main plot. These micro-plots were established a season before the actual ^{15}N-balance experiment and maintained under the same cropping/fertilizer regimes as the surrounding cotton field. Ten wheat seeds were sown in each micro-plot and the population reduced to three plants. Irrigation and fertilizer regimes were equivalent to those in the surrounding main plot, except that the micro-plots received ^{15}N-lebelled urea (25.06 atom % ^{15}N). Plants were harvested at maturity, different shoot components separated, dried at 60°C to a constant weight and ground (< 0.5 mm) before analysis of the total N. The soil from micro-plots was removed in 10 cm segments up to 1 m depth, air-dried, sieved (< 0.5 mm), and analyzed for the total and mineral N. For each micro-plot, the root material from all depths was pooled, washed, dried at 60°C and ground (<0.5 mm) before analyzing for the total N. Soil mineral N was determined by a micro-Kjeldahl method after extracting 20 g soil with 100 ml of 2N KCl (Keeney & Nelson, 1982). Total N of plant and soil was determined by a micro-Kjeldahl method (Bremner & Mulvaney, 1982) and samples prepared for ^{15}N analysis (Hauck, 1982). Rittenburg method was used to convert ammonium to N_2 and the ^{15}N content measured on a VG Isogas mass spectrometer fitted with a double inlet system.

Results and Discussion

Table 1 presents the fertilizer-N balance sheet for the wheat crop grown after cotton harvest. Of the total fertilizer-N applied, 47.7% was utilized by the wheat crop, which is in agreement with the generally reported figure of about 50% for the plant uptake of fertilizer-N during the year of application (Hauck, 1985; Stevenson, 1985). Most of the fertilizer-N used by the crop was recovered in the grain component (63%), followed by straw (35%) and roots (2%). At harvest, 24.3% of the applied N remained in the soil and most of the residual fertilizer-N (91%) was present in the organic form, with maximum (80%) recovered in the upper 30 cm. Recovery of the fertilizer-N by the wheat crop was higher than that (39.2%) reported in a previous study with wheat grown under maize-

Table 1. Fertilizer-nitrogen balance sheet for the wheat crop grown after cotton harvest.

Component		% of the applied N[a]
Recovery in plant		
Grain		30.02 ± 2.35[b]
Straw		16.85 ± 0.36
Root		0.87 ± 0.38
Total recovery in plant		47.74 ± 2.13
Recovery in soil		
Depth (cm)	0-10	15.56 ± 2.18 (0.90 ± 0.17)[c]
	10-20	2.45 ± 1.15 (0.34 ± 0.26)
	20-30	1.33 ± 1.00 (0.18 ± 0.08)
	30-40	0.79 ± 0.23 (0.13 ± 0.03)
	40-60	1.66 ± 0.14 (0.24 ± 0.11)
	60-80	1.30 ± 0.23 (0.19 ± 0.03)
	80-100	1.17 ± 0.11 (0.14 ± 0.05)
Total recovery in soil		*24.26 ± 2.89 (2.11 ± 0.18)*
Total recovery (plant + soil)		72.00 ± 4.54
Loss		28.00 ± 4.54

[a]The crop received urea-N at 100 kg ha^{-1} with 25.06 atom% ^{15}N.
[b]Mean of four replicates ± SD.
[c]Figures in parentheses represent the fertilizer-N present in the mineral form.

wheat cropping sequence receiving ^{15}N-labelled ammonium sulphate (Mahmood *et al.*, 1998). The difference in the fertilizer-N recovery by the wheat crop in the two studies was mainly due to difference in the recovery by the grain component, which was higher (30.0%) than that (17.5%) recorded under the maize-wheat cropping system. The difference in the fertilizer-N recovery by the wheat crop under two cropping systems can be explained by the difference in the level of soil fertility as evidenced from the soil organic C content. The soil organic C in the present study was 2.3% due to regular input of cotton crop residues for the past 20 years, compared to 1.1% in the field soil under maize-wheat cropping system that received relatively less organic matter input (only root material) for the past 10 years.

Total fertilizer-N loss during the wheat growing season was 28%, which is 1.5 times the denitrification loss measured concurrently using the acetylene-inhibition technique (Mahmood *et al.*, 1999). The observed higher N loss by ^{15}N-balance than acetylene inhibition technique may be attributed to losses other than denitrification viz., NH_3-volatilization (Hamid & Ahmad, 1987) and losses through vegetative plant parts (Farquhar *et al.*, 1979). Nevertheless two methods are not comparable because the ^{15}N-balance method measures total N loss only from the applied fertilizer-N (taking no account of the loss from the native soil N pool), whereas the acetylene-inhibition method measures only denitrification loss from the applied N as well as from the native soil N pool (taking no account of the N losses other than denitrification). Therefore, considering the N loss from the applied fertilizer and that from the native soil N pool, total N loss under wheat crop grown after cotton harvest may be higher than 28 kg N ha^{-1} recorded with ^{15}N-balance method in the present study. Comparing the ^{15}N-balance loss under wheat with that under maize (39%, Mahmood *et al.*, 1999) and under cotton (42%, Mahmood *et al.*, 2000), higher soil temperatures might have lead to higher N loss during the maize and cotton growing seasons. The soil temperature during the wheat-growing season ranged from 10.5-24.0°C, whereas it ranged from 20.3-33.0°C and 21.0-35.5°C during the maize and cotton growing seasons, respectively.

Results of the present study showed that a substantial proportion of the applied N fertilizer is lost from wheat crop grown after cotton harvest under semiarid subtropical climatic conditions prevailing in this region and appropriate measures need to be adopted to reduce this loss. Besides, fertilizer-N recovery in the grain component is substantially improved when wheat is planted in the soil having relatively higher organic matter level due to regular input of cotton crop residues.

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