Loss of nitrogen through leaching and runoff from two potato land-use systems on different soils

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Abstract Field experiments conducted for two years on three soils of different texture, planted with potatoes grown by two methods of cultivation—terraced and *bun* (traditional method on hillslopes)—revealed that nitrogen loss through leaching and runoff increased with increased application of nitrogen and was significantly influenced by the nature of the soil, the amount of rainfall received and the method of cultivation followed. The mean N loss was 14.2, 16.5 and 30.3 kg ha^{-1} through leaching, and 5.8, 5.5 and 4.0 kg ha^{-1} through runoff in terraced areas, and 7.1, 9.8 and 19.9 kg ha^{-1} in leaching and 19.5, 19.4 and 33.7 kg ha^{-1} in runoff in *bun* method, from soils S_1, S_2 and S_3, respectively. The NO_3-N content of the soil was observed to be higher near the surface (0–20 cm) compared to lower depths (20–40 cm and 40–60 cm) in both methods of potato cultivation, and it increased with increased application of nitrogen. Applied nitrogen increased the dry matter yield (tuber + shoots) of potato, and productivity was found to be higher in light textured soil.

INTRODUCTION

Loss of nitrogen occurs through leaching or runoff, either by precipitation or irrigation, and its magnitude depends on the nature of the soil, the amount and intensity of rainfall or irrigation water, and the nature of the crop plant or extent of soil surface covered by it. The efficient use of nitrogen depends in its judicious management. Potato (*Solanum tuberosum* L.) is one of the most important crops of the Northeastern Hills region of India. It is grown in the summer season (March–July) under long day conditions in the hills as a rainfed crop. The region receives about 2500 mm of rainfall annually; about half of which is received during the potato growing season. Precipitation causes heavy loss of N through leaching and runoff, resulting in poor crop productivity (Sharma, 1990, 1991). This is further aggravated by a faulty method of potato cultivation in the region. The potato is traditionally cultivated by the *bun* method, in which raised soil beds are prepared along the hill slopes for planting of potato or other vegetable crops. Soil for making the beds is taken from the land between two beds and, thus, about 25 to 40% space is lost in making the beds. Succulent twigs and leaves of bushy vegetation are burnt on these beds to enhance soil fertility. Currently, potato cultivation on terraces is being popularized for better crop and soil management for higher productivity.

The present investigation was conducted to quantify leaching and runoff losses of N from potato crops grown on three types of soils by two methods of cultivation, with different levels of applied nitrogen, as no specific information was available on these aspects. This will help in judicious management and efficient utilization of applied nitrogen for higher crop productivity.

MATERIALS AND METHODS

Field study was conducted to monitor the loss of N through leaching and runoff from potato (*Solanum tuberosum* L.) grown on three soils (S_1 S_2 and S_3) of different texture, by two methods of cultivation (terraced and *bun*) under rain-fed condition. The texture of the soils was silty clay loam (S_1), loam (S_2) and sandy loam (S_3). All the soils were low in available N and acidic in reaction. The four N treatments were (a) control (no N), (b) N at a rate of 100 kg ha^{-1} (c) N at 200 kg ha^{-1} and (d) N at 200 kg ha^{-1} + farmyard manure (FYM) at a rate of 10 t ha^{-1}. The physico-chemical characteristics of the soil are given in Table 1. Nitrogen was applied as ammonium sulphate. A basal dose of 63 kg P ha^{-1} as single superphosphate and 50 kg ha^{-1} K as potassium chloride was uniformly applied in all the plots. Fertilizers were incorporated into the upper 20-cm layer of the soil. Uniform potato tubers of variety *Kufri Jyoti*, weighing about 60 g, were planted at inter and intra-row spacing of 60 cm and 20 cm, respectively. The land slope in *bun* method was 46%. Rainfall during the crop period was 1134 mm in the first year and 879 mm in second year of investigation. The applied FYM contained 0.379% N, 0.151% P_2O_5 and 0.372% K_2O.

Twenty-seven lysimeters, 20 cm in diameter and 60 cm in depth were installed in the field. Leachate from the lysimeters was collected in plastic containers connected to the lysimeters with rubber tubing. Soil samples were collected during the crop period from 0–20 cm, 20–40 cm and 40–60 cm depths at 30, 45, 60, 75 and 90 days after planting. The soil samples were analysed for NO_3-N using the method suggested by Sim & Jackson (1971). The tuber and shoot samples were collected at maturity, washed in 0. 1N HCl followed by distilled water, and then dried in oven at 65 ± 5°C. Plant analysis for N was done as outlined by Jackson (1967), and that of water samples by Nesslers method (Jackson, 1967). Available N was determined by the method described by Subbiah & Asija (1956).

Table 1 Physico-chemical characteristics of the soil (surface sample to 20 cm depth).

Characteristics	Soil:		
	S_1	S_2	S_3
Sand	56.5	51.1	70.6
Silt	21.5	31.6	20.2
Clay	22.0	17.3	9.2
Texture	Scl	1	S1
Average N (kg ha^{-1})	182	202	232
pH	5.0	5.1	5.2
EC (dS m^{-1})	0.32	0.25	0.18

RESULTS

Nitrogen loss

Leaching The loss of nitrogen through leaching was significantly higher in the light textured soil and it increased with increase in applied N, both in terraced as well as *bun* methods of potato cultivation, and during both the years of investigation

(Tables 2 and 3). Mean loss of N through leaching in S_3 was 133.8% and 83.6% higher in terraced and 71.2% and 55.6% in bun method compared with S_1 and S_2. This may be attributed to the fact that S_3 has a higher sand content and, thus, more pore space for easy percolation of leachate N. In both the methods of potato cultivation, leaching of N increased significantly with increase in applied nitrogen and varied between 7.6 and 29.3 kg ha^{-1} in terraced and 3.9 kg and 20.2 kg ha^{-1} in *bun* method. Application of FYM along with nitrogen increased leaching of N by 9.9% and 6.9% in terraced and *bun* methods, respectively. The percentage increase in the leaching of N over the control (no N) was 201.5%, 304.6% and 376.9% higher in terraced, and 205.8%, 397.0% and 438.2% in the *bun* method with 100 kg N, 200 kg N and 200 kg N + 10 t FYM ha^{-1}, respectively. Nitrogen leaching during the first year (1134 mm rainfall) caused 54.7% more leaching in terraced and 36.5% more in the *bun* method, than during the second year of study (879 mm rainfall). The coefficient of correlation between the amount of rainfall and leaching of N was, $r = 0.912^{**}$, in the terraced and,

Table 2 Nitrogen loss through leaching and runoff for the terraced method of cultivation (kg ha^{-1}).

Treatment	First year: Leaching	Runoff	Total	% of applied N	Second year: Leaching	Runoff	Total	% of applied N
Soil:								
S_1	16.3	6.7	23.0	10.2	12.2	5.0	17.2	7.8
S_2	18.8	6.4	25.2	12.0	14.3	4.7	19.0	9.2
S_3	32.8	4.7	37.5	21.8	27.8	3.4	31.2	19.0
C.D. ($p = 0.05$)	2.5	0.4	2.7	–	2.2	0.4	2.3	–
N (kg ha^{-1}):								
0	7.6	2.6	10.2	–	5.4	2.0	7.4	–
100	21.0	5.0	26.0	15.8	18.3	3.8	22.1	14.7
200	29.3	7.8	37.1	13.4	23.4	5.8	29.2	10.9
200 + FYM (10 t ha^{-1})	32.2	8.2	40.4	15.1	26.0	6.0	32.0	12.3
C.D. ($p = 0.05$)	2.8	0.5	3.1	–	2.5	0.5	2.6	–

Table 3 Nitrogen loss through leaching and runoff for the *bun* method of cultivation (kg ha^{-1}).

Treatment	First year: Leaching	Runoff	Total	% of applied N	Second year: Leaching	Runoff	Total	% of applied N
Soil:								
S_1	8.7	22.0	30.7	16.0	5.6	17.1	22.7	11.9
S_2	11.6	23.1	34.7	19.2	8.0	16.8	24.8	13.9
S_3	22.9	30.3	53.2	34.0	16.9	22.9	39.8	25.6
C.D. ($p = 0.05$)	1.9	3.0	4.1	–	1.4	2.8	3.3	–
N (kg ha^{-1}):								
0	3.9	6.7	10.6	–	2.9	4.9	7.8	–
100	11.9	21.5	33.4	22.8	8.9	15.8	24.7	16.9
200	20.2	35.1	53.3	22.3	12.9	26.9	39.8	16.0
200 + FYM (10 t ha^{-1})	21.6	37.2	58.8	34.1	15.7	28.3	44.0	18.1
C.D. ($p = 0.05$)	1.7	2.6	3.6	–	1.2	2.5	2.9	–

$r = 0.861^{**}$, in the *bun* method, respectively. The result corroborate the findings of Sharma (1990) and Singh & Singh (1987).

Runoff For the terraced method of cultivation, the N loss through runoff was significantly lower in S_3 than in S_1 and S_2 soils but there was no significant difference between S_1 and S_2 (Table 2). The N loss through runoff increased significantly with increase in nitrogen dose and varied from 2.6 kg and 6.7 kg (no N) to 7.8 kg and 35.1 kg N ha^{-1}(200 kg N ha^{-1}) in terraced and the *bun* methods, respectively. For the *bun* method, the loss of N through runoff was higher in S_3 than S_1 and S_2 and there was no significant difference between the latter two soils (Table 3). Due to a steeper land gradient for the *bun* method, more water was lost in runoff and as the availability of N was greater in S_3, more N was lost from this soil. For the terraced method, due to the light soil texture, more water percolated through S_3 soil compared to runoff and N lost through runoff was less in this soil. The result confirm those reported by Singh & Singh (1987).

On average, the combined loss of N (terraced and *bun* methods) was 20.2% higher through leaching than runoff (Tables 1 and 2). However, leaching loss of N was higher by 295.4% than runoff for the terraced method and lower by 79.3% for the *bun* method. Average N loss in the two years of study in leaching and runoff was 9.0%, 10.6% and 20.4% of applied N in terraced and 13.9%, 16.4%, and 29.8% in *bun* method from S_1, S_2 and S_3 soils, respectively.

Nitrate-N content

The NO_3-N content of all the soils varied significantly at different depths, both in terraced as well as *bun* methods of cultivation. The soil N variation was linked to the nitrogen treatments (Table 4). Increase in N dose significantly enhanced the NO_3-N content at various soil depths and FYM applied at 10 t ha^{-1} further improved it significantly in both the methods. The results show that application of nitrogen and FYM enhanced the availability of N in the soil. The effect of FYM in enhancing the NO_3-N content of the soil might be attributed to the additional supply of N through this source as well as to improved soil physical conditions. It was observed that NO_3-N decreased significantly at lower depths. The mean soil NO_3-N content was found to be 33.4 kg, 28.8 kg and 23.3 kg ha^{-1} in the terraced and 27.3 kg, 21.7 kg and 17.7 kg ha^{-1} in the *bun* method at 0–20 cm, 20–40 cm and 40–60 cm soil depths, respectively. The results corroborate the earlier findings reported by Allison (1966) and Sharma (1991). Allison (1966) reported that the low content of NO_3-N at lower soil depths might be due to denitrification by facultative organisms in the absence of aerobic conditions and volatilization of N as nitrous oxide and elemental N. On average, the NO_3-N content of the soil was higher by 22.3%, 32.7% and 31.6% in the terraced than the *bun* method at 0–20 cm 20–40 cm and 40–60 cm soil depths.

The time of soil sampling after the planting of the potato crop had a significant effect on the NO_3-N content in all the soils and at all the depths because it decreased with successive sampling dates at various depths in both the methods of cultivation. This confirmed the earlier findings of Sharma (1991). A non-significant variation was

Table 4 NO_3-N content of soils at different depths under terraced and *bun* methods of potato cultivation.

Treatment	Terraced method: 0–20 cm	20–40 cm	40–60 cm	*Bun* method: 0–20 cm	20–40 cm	40–60 cm
Soil:						
S_1	32.1	26.6	20.0	25.8	19.7	16.1
S_2	33.1	28.8	24.3	27.1	22.2	18.2
S_3	35.2	31.2	25.6	29.1	23.2	19.0
C.D. ($p = 0.05$)	1.9	1.7	1.7	1.8	1.6	1.7
N (kg ha^{-1}):						
0	14.4	13.9	11.2	13.2	12.0	10.6
100	28.9	23.8	19.8	24.3	19.6	15.7
200	41.9	35.5	29.9	34.3	25.0	21.1
200 + FYM (10 t ha^{-1})	48.7	42.1	32.4	37.4	30.2	23.7
C.D. ($p = 0.05$)	2.1	1.9	1.9	2.0	1.8	1.9
Time of sampling (days after planting):						
30	40.6	35.7	29.4	33.8	28.1	23.3
45	40.5	33.7	27.0	31.2	25.3	20.3
60	33.1	28.6	23.9	27.3	22.6	18.4
75	28.1	24.8	20.0	23.3	18.5	14.8
90	25.1	21.3	16.4	20.9	14.0	11.9
C.D. ($p = 0.05$)	2.4	2.2	2.2	2.3	2.0	2.2

found in NO_3-N content in top soil (0–20 cm depth) at 30 and 45 days after planting thereby indicating that the surface soil maintained almost the same level of NO_3-N up to about 45 days after planting of potato. However, it declined at later sampling dates. The NO_3-N content within different soils varied significantly and S_3 maintained significantly higher levels than S_1 and S_2 at 0–20 cm depth.

Biomass production

Table 5 shows that for both the methods of cultivation, dry matter yield (tuber + shoots) was significantly higher in light textured soil (S_3) compared to S_1 and S_2, while no significant difference was observed between latter two soils. A similar trend in N uptake was observed among different soils. The increase in the dry matter yield and N uptake may be attributed to the high NO_3-N content of soil S_3 (Table 4) and thus maintenance of higher N availability to the potato crop. The results corroborate the. findings of Doll *et al.* (1971). Increase in applied N increased the dry matter yield of potato crop significantly over the control (no N) and the application of FYM at 10 t ha^{-1} further improved it by 10.1% in the terraced and 13.4% in the *bun* method of potato cultivation. Increase in applied N also significantly increased N uptake by the potato crop and the application of FYM had a positive and significant influence on N absorption. Similar results were reported by Lorenz *et al.* (1974) and Sharma & Arora (1987). The N removal by the potato crop was 21.4%, 21.2%, 36.8% and 32.8% higher in the terraced than the *bun* method with 0, 100 kg N, 200 kg N and 200 kg N + 10 t FYM ha^{-1}, respectively. Both the dry matter yield of potato and N uptake by the crop were significantly influenced by the amount of rainfall received (Table 5). The rainfall correlated significantly with the dry matter yield (r = 0.882**)and N uptake (r = 0.791**). The dry matter yield was higher by 7.6% and 21.8% and N uptake by 8.2% and 14.0% in the terraced and the *bun* methods, respectively, during the first year of study (rainfall 1134 mm) over the second year (rainfall 879 mm).

Table 5 Potato dry matter (DM) yield (tuber + shoots) and nitrogen uptake by the crop (mean of 2 years).

Treatment	Terraced method: DM (t ha^{-1})	N uptake (kg ha^{-1})	*Bun* method: DM (t ha^{-1})	N uptake (kg ha^{-1})
Soils:				
S_1	3.38	68.9	2.94	56.4
S_2	3.66	75.4	2.99	60.9
S_3	4.76	101.2	3.52	72.4
C.D. (p = 0.05)	0.39	8.8	0.31	6.0
N (kg ha^{-1}):				
0	2.62	50.4	2.22	41.5
100	3.63	72.0	2.95	59.4
200	4.52	96.5	3.49	70.5
200 + FYM (10 t ha^{-1})	4.98	108.4	3.96	81.6
C.D. (p = 0.05)	0.45	10.2	0.36	6.9
Rainfall:				
1179	4.08	85.1	3.46	67.4
879	3.79	78.6	2.84	59.1
C.D. (p = 0.05)	NS	NS	0.25	4.9

CONCLUSIONS

The area receives heavy rainfall during the year (average 2500 mm). Nitrogen is the most limiting nutrient in crop production because it is prone to leaching, particularly in light textured soils. Monitoring the loss of N through leaching and runoff may help in the management of nitrogen applications to potato crops and its efficient utilization. It is possible to adjust the N dose according to the nature of the soil, method of cultivation and rainfall for higher potato productivity.

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