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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 4 (2): 184-187, 2001

Uptake and Recovery of Mineral N Fertilizers in Herbage of an Established Grass Sward under Different Moisture Regimes

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Abstract: The herbage production and apparent recovery of fertilizer N in grassland ecosystem is generally low especially under wet soil conditions. This has been attributed to poor response to fertilizer N. The aim of the present investigation was to examine the response of grass to fertilizer N with respect to herbage yield, uptake and % recovery of applied N in order to provide a better basis for improving the efficient use of fertilizer N in grassland ecosystem. Both NO^{-}_{3} and NH_4^+ source of N were applied to an established grass sward with three moisture levels: natural conditions, near field capacity conditions and slightly wetter than field capacity. The results showed that applied N was not utilized efficiently by grass. The total herbage yield obtained was equivalent to 1800-3700 kg ha^{-1} while the apparent recovery of applied N ranging from 24-48%. The maximum herbage yield and recovery of N was obtained in soil near or below field capacity. The grass sward with added NH_4^+-N showed larger yield and recovery of N relative to sward with NO^{-}_{3}-N. Results confirm that a decrease in percent recovery and uptake of N are the key factors responsible for poor herbage productivity often observed in pastoral agriculture.

Key words: Grassland N, N recovery, NH_4^+-N, $N0^{-}_{3}$-N, water-filled pore space

Introduction

Application of mineral N fertilizers has been the key factor which has allowed the development of modern grassland management practices and at least half the productivity of temperate grassland systems is due to fertilizerp input (Jarvis *et al*., 1995). It has been reported that supply of fertilizer N not only increases primary plant and subsequent animal production, but also allows farmers a good deal of flexibility in the management of their enterprises. Because of its impact on dry matter and animal production, fertilizer N is the most effective management input for manipulating grassland yield within the limitations imposed by the local environment (White, 1985).

Most field studies of the response of grass to fertilizer N have relied on the uptake of N in the herbage. Van der Meer and Van Uumvan-Lohuyzen (1986) indicated that the response of herbage yield to fertilizer N depends mainly on the uptake of soil N, the apparent recovery of fertilizer N and dry matter production per kg of N taken up by the crop. Growing conditions and pasture management generally affects one or more of these three aspects of N utilization. Morrison *et al*. (1980) reported that the mean apparent recovery of N by cut perennial ryegrass swards ranged from 62-72% for annual applications up to 450 kg N ha^{-1} but decreased to between 50 and 60% at higher rates. White (1985) stated that the apparent recovery of fertilizer N is generally greatest at application rates of 250-350 kg N ha^{-1} year^{-1} and below this limit there are chances of significant amounts of N to remain in the roots and stubble. A recovery of less than 45% of applied N from a single application of N fertilizer over a growth period of between 3 and 6 weeks was reported by White (1985) because of abnormal weather conditions causing a large leaching or gaseous loss of N. Under wet soil conditions, very low recoveries of less than 40% of applied N were reported by Van der Meer (1982) and an improvement in the N recovery after lowering the water table on a heavy clay soil was found by Van der Meer and Van Uumvan-Lohuyzen (1986).

Studies with ^{15}N have often shown a considerable amount of fertilizer N to be retained in the grass roots (Triboi, 1987). In addition, there is often a rapid and substantial immobilization of fertilizer N into soil organic matter, more so with ammonium and urea than with nitrate (Stevens and Laughlin, 1989). Much of the immobilization appears to be due to incorporation into the microbial biomass. Some of the immobilized N may be reconverted into inorganic forms within a few weeks (Bristow *et al*., 1987) but some remains in organic forms for several years. In west Britain, soils become compacted at a depth of 4-10 cm because of mild, wet weather together with intensive grazing system. A fall in herbage production and unexpectedly small responses to nitrogen fertilizer application has been observed on these soils. A decrease in nitrogen uptake and utilization seemed to be a key factor responsible for poor herbage productivity (Yulun, 1987). Previous studies suggest denitrification as a major cause of N losses from these wet grassland soils. The primary aim of the present investigation was to study the response of grass to fertilizer N with respect to dry matter production, uptake and recovery at three different moisture regimes in order to quantify the flow and turnover of N in the herbage which will be helpful to obtain reliable estimates of N losses in the future research.

Materials and Method

Field operations: The investigation was conducted at Blaendolau near Aberystwyth, Wales UK on a pasture dominant by perennial ryegrass (*Lolium perenne*) and common bent (*Agrostis capillaris*). The soil had developed from silty alluvium and the surface soil (0-8 cm) had clay loam particle size class and was stone free as described in detail in Abbasi and Adams (1998). Briefly, the land had been in pasture till 1988 and then sward was maintained by mowing weekly at a height about 5 cm. The soil (0-7.5 cm depth) had a pH of 5.1 (1:1 water), total organic C of 57.0 g kg^{-1}, total N 3.43 g kg^{-1} and bulk density of 1.17 g cm^{-3}.

An area of 10 m $\times$ 10 m was selected from an actively growing grassland field. Broad-leaved weeds present in the field were eradicated by spraying Supertox (active ingredients mecaprop and 2, 4-D) at the rate of 50 ml L^{-1} water. The main plot was divided into two parts, one for the nitrate and one for the ammonium treatment. Three moisture levels were established: (A) plots with no extra water i.e., natural conditions, (B) plots saturated completely and allowed to drain for 2 days i.e., field capacity conditions and (C) plots saturated completely then drained for 1 day, saturated again and drained for 1 day i.e., slightly wetter than field capacity. A randomized complete block design with split treatments was used for the experiment.

Experiment 1: Experiment 1 was conducted on a 3 m × 6 m area with three moisture levels, one applied N and a control treatment with three replicates of each. A total of 18 sub-plots (1 m × 1 m) were established. KNO_3 was applied once at a rate equal to 100 kg N ha^{-1}. The fertilizer was applied in solution to the surface of the micro-plot using watering can to ensure even distribution. The resultant gravimetric moisture content at the start of the experiment was 30, 34 and 40% with a water-filled pore space (WFPS) of 63, 71 and 84%, respectively for the A, B and C plots. This moisture content was maintained throughout the experiment by applying tap water twice weekly.

Experiment 2: In this experiment $(NH_4)_2\ HPO_4$ was applied as source at a rate of 250 kg N ha^{-1}. This experiment was conducted on a 3 m × 6 m plot in the selected area. Experimental layout, soil conditions and treatments were the same as described for Experiment 1.

Soil Analysis: The physical and chemical characteristics of the soil used in the Experiment were determined by the methods described in Abbasi and Adams (1998). Soil temperature at 7.5 cm depth was measured in the field on every sampling day and varied around 17 ± 2°C during both the experiments.

Dry matter yield and Herbage analysis: The herbage was cut to the soil surface and collected from each of the control and fertilized plots from an area of 20 cm × 20 cm at the start of experiment and after 7 days in Experiment-1. In Experiment-2 the sampling was done 0, 7, 14, 21 and 28 days after fertilizer application. After taking fresh weight, these plant fractions were dried at 70°C for 48 hours to obtain oven dry weight. The plant material was milled and the Kjeldahl method used to determine total nitrogen.

Apparent N recovery: The apparent N recovery of herbage was determined by the proportion of added N removed in the herbage (Mannetje and Jarvis, 1990). It was calculated as:

N_{rec} = N_{tr}-N_o/N_{ap} × 100 Where
N_{rec} = percent of applied N recovered
N_{tr} = N yield of N added plot
N_o = N yield of control plot
N_{ap} = N applied

Results

Experiment 1-Herbage Yield and N uptake: After 7 days harvest, above ground dry matter (DM) production of grass sward with added NO^-_3-N showed relatively more yield over control where no inorganic N was applied (Table 1). By contrast, the uptake of N was substantially increased in plots where fertilizer was applied relative to control one. The difference in herbage production within plots of different moisture level was very small but the uptake of N showed a substantial difference. The maximum N uptake was observed at 71% water-filled pore space while the minimum at 84% WFPS. The apparent recovery of applied N varies widely and relatively low. The % recovery of applied N in the herbage was 36, 43 and 24% from plots with 63, 71 and 84% WFPS, respectively.

Experiment 2-Dry matter yield and N uptake and recovery: The dry matter yield of herbage harvested to above ground level was recorded on 5 occasions at 7 day intervals over 28 days period (Table 2). Addition of fertilizer N increased the dry matter yield of grass sward substantially over the control treatment especially in the early stages. The mean overall dry matter yield in the three moisture level was increased by 33% relative to control sward without NH_4^+-N over 7 to 28 day harvesting period. The response of herbage production to different moistures was not consistent. However, results indicated a fall in herbage production in plots with highest moisture level (84% WFPS).

The earliest harvested herbage had a very high total N concentration ranging from 133 to 213 kg ha^{-1} being highest in plots with 71% WFPS. This is nearly 4 times the concentration of N in herbage harvested from control plots. The total N uptake from fertilizer treated plots declined over time but remained higher than the control one throughout the study. The amount of N recovered in the herbage of plots with 63% WFPS from the four successive harvest was 121 kg ha^{-1} which amounted to 48% of applied N. The corresponding values for other two plots were 46 and 39%, respectively. Comparisons of herbage yield, N uptake and % recovery of applied N among three moisture levels and two N sources are presented in Fig. 1. All three parameters were remarkably affected by N source. The herbage yield from NH_4^+ added plots was almost double relative to the plots with NO^-_3-N. Similarly, the uptake and % recovery of applied N in NH_4^+ added herbage was 2-4 times as compared to NO3 sward. On the other hand, in both the N sources plots with 63 and 71% WFPS showed almost similar trend in herbage production and uptake but these parameter gave poor response at 84% WFPS (Table 3).

Discussion

Grassland soils receive a substantial inputs of N in the form of fertilizers, excretal N returned to the swards by animals and through mineralization of organic matter. In addition, biological fixed N_2 forms the basis of many improved pasture systems in temperate regions. Grassland soils are more frequently subject to excessive wetness in relatively mild climatic conditions throughout the world. Grazing by animals increases the risk of losses because both C and N are cycled in relatively labile forms in their excreta. Soil compaction through grazing also play an important role because it destroys soil macroporespace and influences many physical, chemical and biological soil properties and most importantly water retention and gaseous diffusion. These factors are important contributor to the low herbage production and inefficient use of N fertilizers in grassland.

Following the application of both NO^-_3 and NH_4^+ fertilizers, the dry matter yield of grass swards increased substantially. in case of NH_4^+ added plots, the overall dry matter yield at three moistures increased by 33% relative to grass swards from control plots. Similarly, the uptake and % N recovery in fertilizer added sward increased substantially over control sward. White (1985) reported that as the rate of fertilizer N increased there is often an almost linear increase in herbage yield. Dry matter production and % N in pasture both decreased over time. In the early period of fertilizer application was available at higher concentration but as plant uptake and other N transformations occur there is continuous depletion of inorganic N from mineral pool resulting less N

Table 1: Uptake and recovery of N following the application of nitrate N at a rate equivalent to 100 kg N ha^{-1} in grassland soil at three moisture levels during 7 days study

Treat.	WFPS# (%)	Above ground dry matter yield (g m^{-2})	Total N uptake (mg m^{-2}) Days after fertilizer application		(mg m^{-2})	N uptake at end (mg m^{-2})	Fertilizer N uptake (%)	Applied N recovery
		0	7	0	7			
Control	63	95 (3.8)	155 (12.6)	1961(89.1)	3138(176.7)	1176 (222.9)	-	-
KNO_3 added	63	95 (3.8)	178 (9.8)	1961 (89.1)	8852 (207.3)	4791 (282.4)	3815 (109.1)	36
	71	95 (3.8)	187 (7.5)	1961 (89.1)	7406 (312.3)	5445 (223.9)	4268 (419.7)	43
	84	95 (3.8)	178 (10.2)	1981 (89.1)	5533 (84.3)	3571 (173.3)	2395 (170.8)	24

*Bracketed values represent standard errors of the means (n=3) #WFPS = water-filled pore space

Table 2: Nitrogen uptake and recovery from grassland soil following the application of diammonium hydrogen orthoposphate [$(NH_4)_2$ H_2 PO_4] at the rate of 250 kg N ha^{-1} during 28 day study under field condition

Treatment	WFPS (%)	Days after fertilizer application 0	7	14	21	28
(a) Above ground dry matter yield (g m^{-2})						
Control	63	95 (3.92)	158 (15.2)	223 (28.1)	273 (3.12)	288 (2.25)
NH_4^+ added	63	-	311 125.0)	413 (47.5)	421 (49.3)	331 (82.5)
	71	-	340 (89.8)	435 (83.9)	354 (35.0)	282 (41.6)
	84	-	235 (22.9)	277 (39.2)	402 (40.8)	382 (47.8)
(b) Total N in herbage(mg g^{-1})						
Control	83	20.4 (1.43)	20.2 (0.98)	20.1 (1.23)	18.2 (0.17)	18.0 (0.14)
NH_4^+ added	83	-	48.5 (0.45)	47.4 (1.05)	42.4 (3.88)	38.7 (2.38)
	71	-	43.6 (0.86)	48.9 (1.64)	43.8 (1.06)	40.1 (1.99)
	84	-	54.2 (5.09)	48.0 (0.94)	42.3 (1.89)	34.2 (1.88)
(c) Total N uptake by herbage(kg ha^{-1})						
Control	63	19.4	31.9	45.0	44.1	42.9
NH_4^+ added	63	-	144.5	195.8	178.7	127.0
	71	-	148.4	212.9	155.1	113.2
	84	-	127.4	133.0	170.0	124.0

(d) Uptake and recovery of N at final harvest (28-day)

Treatment	WFPS# (%)	Above ground herbage yield (kg ha^{-1})	Total-N uptake (kg ha^{-1})	Fertilizer-N uptake (kg ha^{-1})	recovery of applied N (%)	mean recovery (7-28 days) (%)
Control	63	2680	23.5	-	-	-
NH_4^+ added	63	3308	108.8	85.0	34	48
	71	2818	93.7	70.0	28	46
	84	3617	104.3	81.0	32	39

*Bracketed values represent standard errors of the means (n= 3) #WFPS = Water-filled pore space

Table 3: Herbage yield and N uptake as affected by fertilizer source and moisture levels in a grassland field during 7-28 study

N-source	WFPS (%)	Herbage yield (kg ha^{-1})	N uptake (Kg ha^{-1})	Applied N recovery (%)
NO^-_3-N	63	1780 *(96)	36(2)	36
	71	1870 (75)	43 (4)	43
	84	1760 (102)	24 (2)	24
NH_4^+-N	63	3690 (625)	121 (17)	48
	71	3527 (416)	116 (11)	48
	84	3190 (718)	98 (13)	39

*Bracketed values represent standard errors of the means (n = 3)

available for subsequent uptake. The overall recovery of N in NO^-_3 added herbage ranges from 24-38% as compare to 39-48% recovery in NH_4^+ added sward. The apparent recovery of N applied to grass grown in the United Kingdom varies widely, but a value in the range 50-70% are frequently observed (Morrison *et al.*, 1980). The values reported in the present studies were relatively low probably due to the nature and conditions of the soil i.e. fine texture of the soil and its compactness. However, these values are within the range of N recovery in pasture under wet conditions reported by others (Van der Meer, 1982; Van der Meer and Van Uumvan-Lohuyzen, 1986; White, 1985). The dry matter yield and N uptake at 63 and 71% WFPS were higher compared with 84% WFPS probably because of chances of less loss of N through denitrification/leaching resulted more N available to the plants. The larger yield and recovery of N from NH_4^+ added plots compared with NO_3' plots may have been attributed to more loss of N from NO3 source through denitrification or lower rate of N being applied. The other possibility was the grass sward with NH_4^+ fertilizer grown for longer period till 28 days as compared to 7 days harvest in NO^-_3 added sward. White (1985) discussed that the difference in yield response to various forms of fertilizer N are due mainly to differences in the loss of N from the soil rather than to differences due to the form of uptake. The author further reported that in some grassland experiments particularly that on calcareous soils

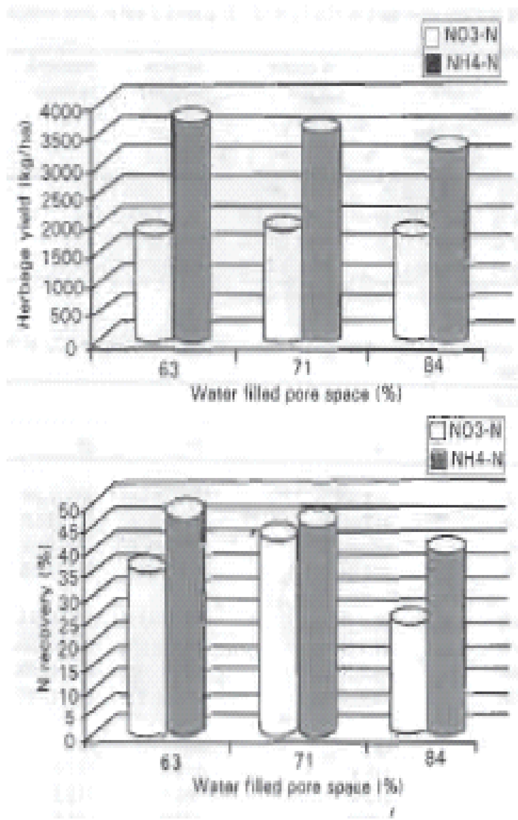

Fig. 1: Herbage yield and % recovery of applied N as affected by fertilizer source and moisture levels in a grassland field during 7-28 study

nitrate produced larger yield than ammonium. On the other hand, under cool wet conditions, yield is sometimes larger from ammonium than from nitrate. Similarly, Franco and Muns (1982) stated that plants differ markedly in their N uptake strategies, the majority of plants utilize both nitrate and ammonium, but some plants lack the ability to absorb or reduce nitrate.

In the period following the application of fertilizer, mineral N may have been taken up by the roots and translocated to the herbage, it may have entered the soil microbial biomass or been lost through leaching and denitrification. In our laboratory experiments it was concluded that chances of both leaching and immobilization are minimal in the present experimental conditions (Abbasi and Adams, 2000). However, in the early stage of fertilizer application if some amount of N immobilized, it could be remineralized in the later stages of application.

A substantial amount of added N was unaccounted for at the end of study. In addition to mat remained in the soil or lost, it is possible that some of unaccounted for N may retained in grass roots. Studies with ^{15}N have often shown a considerable amount of fertilizer N to be retained in the grass roots (White, 1985) Alternatively as reported by Clough *et al*. (1998) unaccounted for N could have been entrapped in the soil in gaseous forms and been released during soil destructive sampling, escaping detection, or diffused from the soil after gas measurement periods ceased.

References

Abbasi, M.K. and W.A. Adams, 1998. Loss of nitrogen in compacted grassland soil by simultaneous nitrification and denitrification. Plant Soil, 200: 265-277.

Abbasi, M.K. and W.A. Adams, 2000. Estimation of simultaneous nitrification and denitrification in grassland soil associated with urea-N using ^{15}N and nitrification inhibitor. Biol. Fert. Soil, 31: 38-44.

Bristow, A.W., J.C. Ryden and D.C. Whitehead, 1987. The fate at several time intervals of ^{15}N-labelled ammonium nitrate applied to an established grass sward. J. Soil Sci., 38: 245-254.

Clough, T.J., S.F. Ledgard, M.S. Sprosen and M.J. Kear, 1998. Fate of ^{15}N labelled urine on four soil types. Plant Soil, 199: 195-203.

Franco, A.A. and D.N. Muns, 1982. Plant assimilation and nitrogen cycling. Plant Soil, 67: 1-13.

Jarvis, S., D. Scholefield and B. Pain, 1995. Nitrogen Cycling in Grazing System. In: Nitrogen Fertilization in the Environment, Baccon, P.E. (Ed.). Marcel Dekker Inc., New York, USA., pp: 381-419.

Mannetje, L.T. and S.C. Jarvis, 1990. Nitrogen flows and losses in grasslands. Proceedings of 13th General Meeting of the European Grassland Federation, Soil-Grassland-Animal Relationships, June 25-29, 1990, Banska Bystrica, Czechoslovakia, pp: 114-131.

Morrison, J., M.V. Jackson and P.E. Sparrow, 1980. The response of perennial ryegrass to fertilizer nitrogen in relation to climate and soil. Report of the Joint ADAS/GRI Grassland manuring trial GM20. The Grassland research Institute Technical Report No. 27.

Stevens, R.J. and R.J. Laughlin, 1989. A microplot study of the fate of ^{15}N-labelled ammonium nitrate and urea applied at two rates to ryegrass in spring. Fertil. Res., 20: 33-39.

Triboi, E., 1987. Recovery of mineral N fertilizer in herbage and soil organic matter in grasslands of the Massif Central, France. Nutr. Cycl. Agroecosyst., 13: 99-116.

Van der Meer, H.G. and M.G. van Uumvan-Lohuyzen, 1986. The Relationship between Inputs and Outputs of Nitrogen in Intensive Grassland Systems. In: Nitrogen Fluxes in Intensive Grassland Systems, Van der Meer, H.G., J.C. Ryden and G.C. Ennik (Eds.). Martinus Nijhoff, The Netherlands, pp: 1-18.

Van der Meer, H.G., 1982. Effective use of Nitrogen on Grassland Farms. In: Efficient Grassland Farming, Corrall, A.J. (Ed.). British Grassland Society, Hurley, UK., pp: 61-68.

White, D.C., 1985. Grassland Nitrogen. CAB International, Wallingford, UK.

Yulun, Z., 1987. Some aspect of nitrogen transformation in soils. M.Sc. Thesis, University of Wales, Aberystwyth, UK.