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Performance of Two Mono Cotyledon Species on Lead/Zinc Mine Spoil with Various Nitrogen Sources

Muhammad Anwer, [1]T. McNeily, [1]P. D. Putwain and [2]S. Sarwar Alam
Government College Satiana Road Faisalabad, Pakistan
[1]School of Biological Sciences Nicholson Building,
University of Liverpol, P.O. Box 147 L69 3BX, United Kingdom
[2]Nuclear Institute of Agriculture and Biology, Faisalabad, Pakistan

Abstract: The influence of five nitrogen sources on the growth of two monocotyledon species were investigated in the Trelogan mine spoil in a glasshouse experiment. A slow release nitrogen fertilizer was examined, in addition to the fast release sources, to assess its performance. Single and split doses of conventional nitrogen fertilizers were also used to compare their effects. There was no effect of single or split doses of urea an d NH_4NO_3 and the single application of slow release (Gold-N) on the growth characters of *Festuca rubra* and *Anthoxanhum odoratum* when compared to control treatment. Single application were less effective than split doses of conventional nitrogen sources

Key words: Monocotyledons species mine spoil, nitrogen sources, single or split doses

Introduction

The successful reclamation of abandoned metal mine wastes using metal tolerant material, has necessitated the removal of the physical and the chemical limitations to plant establishment and growth (Sutton and Dick, 1987; Jones *et al.*, 1975). This can be accomplished by combining several techniques such as mechanical mixing of the soil, fertilizer addition, mulch application and use of adaptive plant species (Roberts *et al.*, 1988; Joost *et al.*, 1987). Nitrogen deficiency results in reduced photosynthesis (Woledge and Pears, 1985; Bowman, 1991), reduced plant growth and chlorosis (Fernandes and Rossiello, 1995) and reduces cell size, volume and protein content and chloroplast number and size (Natr, 1992). In perennial grasses, reduced leaf elongation associated with nitrogen limitation (Volence and Nelson, 1983; Pilbeam, 1992) results from reduced cell division and not from cell elongation (MacAdam *et al.*, 1989). The primary effect on forage quality is reduced crude protein resulting from nitrogen deficiency.
In order to obtain plant growth on metal contaminated wastes, slow release chemical fertilizers has been advocated (e.g., sulphur coated urea, (Gold-N) and urea formaldehyde) and their value has been proven in several mine waste situations (Johnson and Bradshaw, 1979; McNeilly and Johnson, 1981). Such materials are nevertheless expensive and a single application at seeding, even at higher rate (100 kg N ha^{-1}) is rarely satisfactory by itself for sustainable growth (Gemmell, 1975). For the establishment of the vegetation on mine spoils, considerably more valuable slow acting sources of nitrogen are organic amendments such as sewage sludge, mushroom compost and farmyard manure.
An inadequate supply of nitrogen is the single most common factor in sward deterioration on all forms of mine spoils and derelict land (Bradshaw *et al.*, 1975).
Objective of this study was to examine the response of two monocotyledons to different nitrogen sources on the mine waste. The effect of slow release spore was assessed. Single and split doses of conventional fertilizers were also undertaken.

Materials and Methods

The experiment was conducted in the Department of Environment and Evolutionary Biology in the University of Liverpool, England (UK).

Seedlings: Seeds of two monocotyledon plant species, *F. rubra* and *A. odoratum* collected from their indigenous Trelogan mine populations were sown in growth room conditions (22 ± 2 ^{0}C, 16 hour photoperiod [45 μmoles m^{-2} s^{-1}] and 65% relative humidity). The seeds were sown in seed trays on moist paper towel.

Nitrogen fertilizer treatments: Three week old seedlings (as uniform in height and size as possible) were transplanted, five per pot into mine waste in 130 mm diameter plastic pots. The seedlings were thinned after two weeks to leave only three seedlings per pot.
P and K were added as superphosphate (18% P) and potassium sulphate (50% K) respectively. They were incorporated into the surface 10 mm of the mine spoil to provide uniform P and K nutrient contents. The superphosphate and potassium sulphate fertilizers were applied at rates equivalent to 44 kg ha^{-1} (7.92 kg P ha^{-1}) and 42 kg ha^{-1} (21 kg K ha^{-1}) respectively.
Four nitrogen fertilizers, urea, (04%N), sodium nitrate, (16% N), ammonium sulphate, (21 % N) and ammonium nitrate, (34.5 % N) and slow-release sulphur coated urea (Gold-N, 32%N), were incorporated 100Kg N ha^{-1}. They were added either as a single treatment prior to seedling transplantation for the conventional and slow release types, or as a split application for conventional types only, equivalent to 50 N ha^{-1} at the beginning of the experiment and 50 Kg N ha^{-1} 4 weeks after seedling transplantation. Only P and K were applied to the control (no nitrogen) treatment.
The experiment was laid out in randomized complete block design. The potted seedlings were grown in a glasshouse maintained at 22 ± 2 ^{0}C with an 18 hour photoperiod at 230 μmoles m^{-2} s^{-1}, photosynthetically active radiation are maintained at field capacity using tap water from above regularly every day.

Harvest and growth measurements: The two species, *F. rubra* and *A. odoratum* were harvested 3 months after transplanting. The plants with roots were removed from the pots and excess moisture on the plants were removed. Roots and shoots of each plant in each pot were separated and transferred into an oven at 60 ^{0}C to dry. Shoot and root dry weights were measured after drying for 5 days (McNeilly and Johnson, 1981).
The data for root and shoot dry weight of 3 species were transformed into $\log_{10}$ and two way analysis of variance was computed from PROC ANOVA by SAS package (SAS Institute Inc., 1989). LSD was also determined for treatment mean comparison (Steel and Torrie, 1980).

Results

Mean shoot dry weight per plant: There was a significant ($p < 0.001$) difference between species, reactions to different nitrogen fertilizer sources. There was no significant difference between replicates (Table 1).

Corresponding Author: Muhammad Anwer, Principal, Government College Satiana Road, Faisalabad, Pakistans

Festuca rubra: The shoot dry weight of *F. rubra* produced in the control treatment was significantly ($p < 0.05$) greater than any other single source application. The lowest shoot dry weight was in response to the single dose of urea treatment (Fig.1). It is clear that a single application of fertilizer from any of the compounds used depressed the growth of shoots of *F. rubra*.

In the split application treatments, sodium nitrate produced significantly ($p<0.05$) more shoot growth than any other treatment. Compared with the control, the split dose treatment of sodium nitrate was not significantly different in shoot dry matter production. The single dose treatment of sulphur coated urea produced significantly greater shoot growth than single doses of urea, ammonium sulphate, or ammonium nitrate.

Table 1: Mean squares and shoot dry weight of two monocotyledons growing in Trelogan mine spoil with various nitrogen sources

	F. rubra		*A. odoratum*
SOV	df	M.S.	M.S.
N.Sources	9	0.000371***	0.00006 ***
Replicates	3	0.00017 NS	0.000006 NS
Error	27	0.00012	0.000006
Total	39	-	-

Table 2: Mean squares and root dry weight of two monocotyledons growing in Trelogan mine spoil with various nitrogen sources

	F. rubra		*A. odoratum*
SOV	df	M.S.	M.S.
N.Sources	9	0.00227***	0.00006***
Replicates	3	0.00005 NS	0.0000007 NS
Error	27	0.00008	0.000002
Total	39	-	-

Table 3: Mean squares and root/shoot ratio of two monocotyledons growing in Trelogan mine spoil with various nitrogen sources

	F. rubra		*A. odoratum*
SOV	df	M.S.	M.S.
N.Sources	9	0.030118***	0.0563***
Replicates	3	0.00002 NS	0.00345 NS
Error	27	0.00014	0.00422
Total	39	-	-

*** =Significant at 0.001 NS = Non significant

A. odoratum: The results (Fig. 2) show that seedlings in the single doses the only survived in sodium nitrate. The shoot dry weight yield was significantly less than the control.

In contrast seedlings of *A. odoratum* survived in the split dose treatments of sodium nitrate and ammonium sulphate, but the shoot dry weight yield in the ammonium sulphate treatment was significantly less ($p < 0.05$) than the control treatment. Although the split dose treatment of sodium nitrate gave greater shoot growth than those of all other nitrogen sources, but the response was less than control, the difference being non-significant. There was no growth of seedlings in the Gold-N treatment indicating a probable excess availability of nitrogen.

Mean root dry weight per plant: The ANOVA of root dry weight calculated for two plant species and 10 nitrogen treatments, showed significant ($p<0.001$) effects (Table 2).

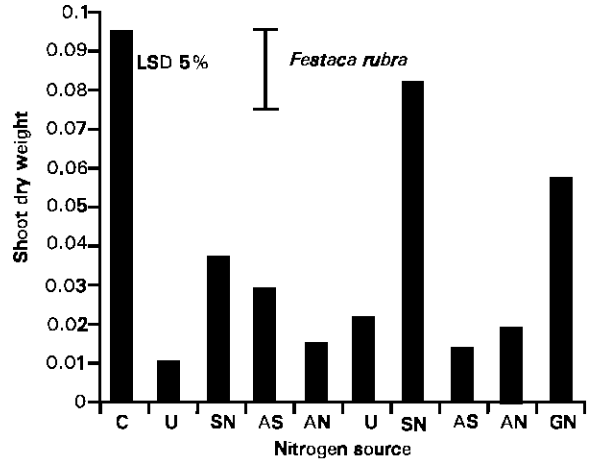

Fig. 1: Shoot dry weight of *F. rubra* in different nitrogen sources

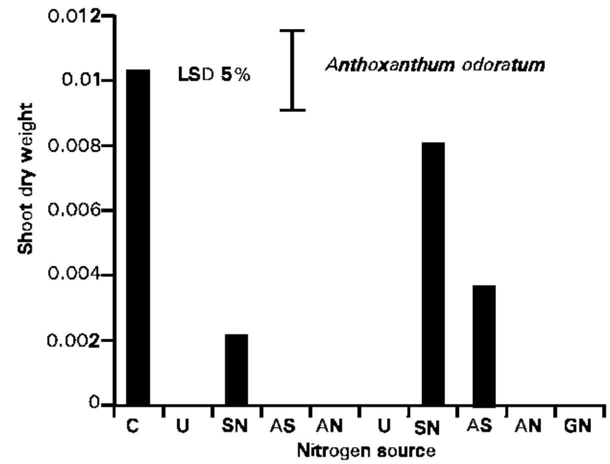

Fig. 2: Shoot dry weight of *A. odoratum* in different nitrogen sources

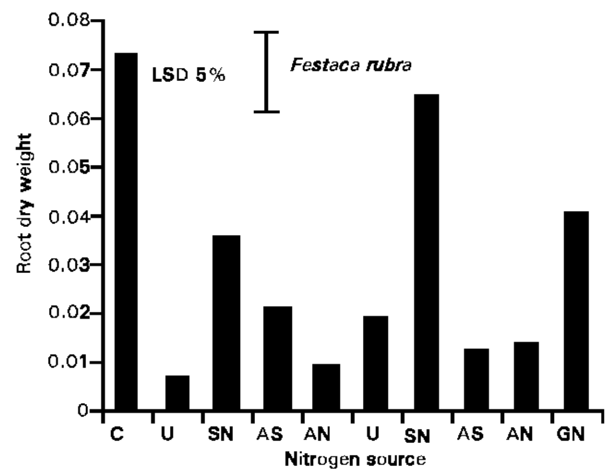

Fig.3: Root dry weight of *F. rubra* in different nitrogen sources.

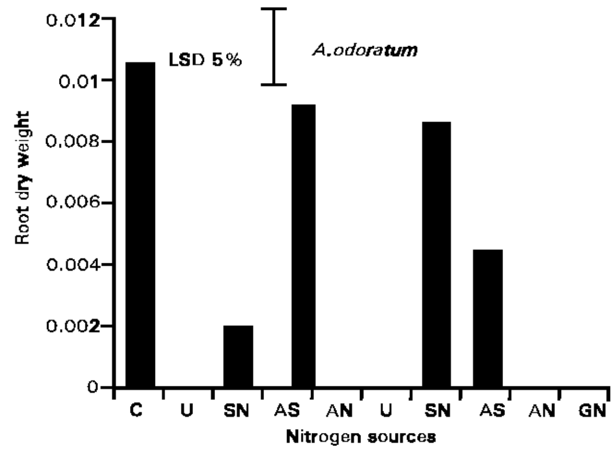

Fig. 4: Root dry weight of *A. odoratum* in different nitrogen sources

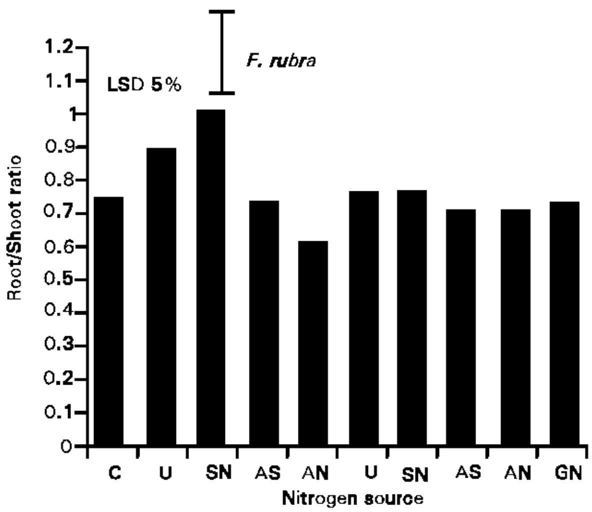

Fig. 5: Root/shoot ratio of *F. rubra* in different nitrogen sources.

Festuca rubra: *F. rubra* seedlings survived after addition of all nitrogen sources, unlike the other species examined. In all of the single application treatments of nitrogen the root dry weight of *F. rubra* was significantly less than the control treatment (Fig. 3). A single application of sodium nitrate resulted in significantly ($p<0.05$) greater root growth than urea, ammonium sulphate and ammonium nitrate.

All split doses of nitrogen also produced significantly less root growth than the control in all treatments except sodium nitrate where root weight equaled that of the control. Split sodium nitrate produced significantly greater root dry weight compared with the other nitrogen sources.

A single application of Gold-N produced significantly ($p<0.05$) more root growth than the other single applications except sodium nitrate but less root growth than the control. Overall the root growth of *F. rubra* was generally less suppressed than the other four species in the experiment. Again sodium nitrate suppressed root growth the least.

A. odoratum: A single application of nitrogen from all sources except sodium nitrate were toxic to seedlings of *A. odoratum* and the root dry weight of those seedlings that survived was less than the control (Fig 4).

Growth was successful in single and split application of sodium nitrate, but only with split ammonium sulphate application. Root dry weight in the sodium nitrate split treatment was significantly ($p<0.05$) greater than in the ammonium sulphate treatment and equal to the control root dry weight. For Gold-N and urea there were no survival of seedlings.

The overall comparison of means indicated that all nitrogen sources did not enhance the root growth beyond the control. Split addition of ammonium sulphate yielded significantly greater ($p<0.05$) root dry weight than the single application of sodium nitrate.

Mean root/shoot ratio: Results obtained from the analysis of variance of root/shoot data (Table 3) demonstrated a significant ($p<0.001$) response to the different sources of nitrogen. There was also a significant difference between the species. The significance ($p<0.001$) of the species x nitrogen interaction was also of interest.

F. rubra: *Festuca rubra* was different from the other species in that there was survival in all the nitrogen treatments (Fig. 5). In comparison with the control treatment and all but the single urea addition, root/shoot ratio values of only that of the single application of sodium nitrate was significantly greater ($p<0.05$).

A. odoratum: In the control treatment the root/shoot ratio was almost 1.0 (Fig. 6). No plants survived a single dose of urea, ammonium sulphate and ammonium nitrate. The sodium nitrate treatment was not significantly different from the control treatment, the root/shoot ratio of both being approximately 1. With split application of sodium nitrate, the root/shoot ratio was significantly and twice the value of the control and the single addition did not differ significantly from the control. The split application of ammonium sulphate gave a higher root/shoot ratio than the control but not a significant increase. No seedlings survived in the single application treatment of Gold-N. The split application of sodium nitrate significantly ($p < 0.05$) doubled the root/shoot ratio of the single application.

Discussion

Nitrates constitute a more common source of nitrogen than ammonium compounds on calcarious agricultural soils (Gardner, 1965) because of effective retention of nitrate ions which are less likely to be leached than ammonium compounds in very basic soils. Results showed when urea was added as single and split dose, only *F. rubra* survived. A similar effect was also found by Davies (1973), where urea application gave a total dry yield of grass, that was less than that from ammonium nitrate and sulphur coated urea. Johnson (1977) found that urea gave the lowest shoot dry yield response on fluorspar mine tailings from those of $NaNO_3$, NH_4NO_3, $(NH_4)_2SO_4$, sulphur coated urea, hoof and horn, and dried blood. This may have been due to the loss of ammonia from urea which is often more marked than from ammonium nitrate and ammonium sulphate (Volk, 1961; Hamid and Mahler, 1994).

The two monocotyledon species in the experiment responded differently to the single and split doses of $NaNO_3$ in terms of shoot and root dry weight. $NaNO_3$ was the least inhibitory source of nitrogen assessed and the split application usually gave greater dry weight response than the single dose. These results were in accordance in part with the results of McNeilly and Johnson (1981), who reported that shoot dry matter yield per pot of *F. rubra* from $NaNO_3$ was greater on acidic Y Fan mine spoil than on the calcareous Minera mine waste. *A. odoraum* only survived in single and split doses of $NaNO_3$ and split dose of ammonium sulphate. Comparatively *F. rubra* survived in all the tested nitrogen sources.

In all species these sources of nitrogen depressed yield whether applied as a single or split application. In case *A. odoratuma* single and split applications of ammonium nitrate and urea were lethal. In contrast McNeilly and Johnson (1981) found that ammonium nitrate and urea treatments had significantly greater overall plant

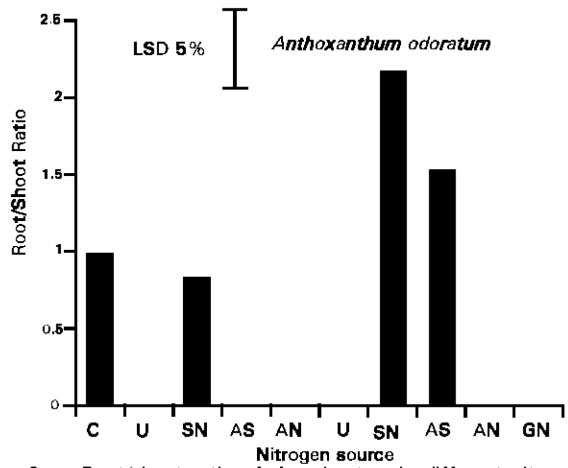

Fig. 6: Root/shoot ratio of *A. odoratum* in different nitrogen sources

dry matter yield than ammonium sulphate on calcareous Minera Pb/Zn mine spoil which was applied at the same rate as in this experiment. *Festuca rubra* showed poor growth in both the doses of urea than all other treatments. Similarly ammonium nitrate gave relatively better growth than urea, similar to the findings of Pollett *et al.* (1995). Lower production in urea may have been due to greater loss from urea than ammonium nitrate by volatilization in the normal soil (Hamid and Mahler, 1994).

Split doses generally appeared to be less damaging to the growth of two species examined in comparison with single applications. Similar results were reported by McNeilly and Johnson (1981), when split doses of urea and ammonium nitrate, gave significantly greater shoot dry matter yield than a single application. This is due to low cation exchange capacity of both wastes, and the consequent inability of the material to retain ammonium ions when leached due to lack of organic matter. Johnson (1977) also resulted the lower shoot dry yields from plots treated with single applications of $NaNO_3$ than 2 and 3 applications of $NaNO_3$ probably therefore reflect losses of the nutrient by volatilisation and leaching.

On the calcareous Trelogan mine spoil single and split applications of nitrogen fertilizers did not improve the dry weight yield production of any of these two species. This suggests that addition of nitrogen was in excessive amounts either causing depression of plant growth due to high conductivity, or toxic concentrations of ammonium ions. It is almost certain that nitrogen is not the critical limiting soil mineral in the Trelogan spoil. Similar results had been reported by Smith (1973) who showed that nitrogen was not an important limiting factor for plant growth on Trelogan mine spoil from the lower mine site because application of nitrogen in the form of slow release nitroform, did not result any increase in growth over the control. Smith argued that phosphorous was the limiting factor in that Trelogan mine waste. However this view did not agree with the findings of McNeilly and Johnson (1981) who found that nitrogen was indeed a limiting plant growth factor on both the calcareous Minera mine and acidic Y Fan mine spoils. The different results of the two investigators may be due to different types of mine spoil used and the species undertaken were originally from different mines. The importance of adequate nitrogen supply had been shown to be a major cause of sward regression in restored derelict land and many substrates by Bradshaw and Chadwick (1980), lack of nitrogen lead ultimately, to the deterioration of even the most successfully established ground cover vegetation.

From the results of this experiment it can be seen that all fertilizer additions did not bring about any significant yield increase over the control in both theses species. This also may have been due to the adaptation to low soil nitrogen in plants on sites very low in nitrogen (Bradshaw *et al.*, 1964). However the *F. rubra* survived in all the treatments and gave significantly higher root and shoot dry weight yield than *A. odoraum*. The growth of *F. rubra* on the Trelogan mine spoil is greater than the *A. odoratum*.

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