OnLine Journal of Biological Sciences 1 (4): 280-283, 2001

Amelioration of NPK on Metals Polluted Bare and Vegetated Sites of Trelogan Mine

M. Anwer[1], Irshad Hussain[2], T. McNeilly[3] and P.D. Putwain[3]
[1]Government Degree College, Satiana Road, Faisalabad, Pakistan
[2]Environmental Biotechnology Division, NIBGE, P.O. Box 577, Jhang Road, Faisalabad, Pakistan
[3]Department of Biological Sciences, Nicholson Building, University of Liverpool, UK

Abstract: A field experiment was carried out at Trelogan lead/zinc mine waste in North Wales, England with the amelioration of N, P, K. NP, NK, PK and NPK in bare and vegetated areas. In seven treated plots of bare mine area, the seedlings of three species, *Festuca rubra*, *Agrostis capillaris* and *Anthoxanthum odoratum* differed significantly ($p = 0.01$). Similarly dry weight of four species, *F. rubra*, *A. capillaris*, *A. odoratum* and *Cladonia sp.* (a lichen) in vegetated treated plots also differed significantly ($p = 0.001$). Fertilizers did not differed significantly in both bare and vegetated areas.

Keywords: Macronutrients, Trelogan mines, reclamation

Introduction

Abandoned mine workings and other industrial wastes associated with the exploitation of non-ferrous metal ores are ubiquitous in the United Kingdom. Derelict buildings and mineral spoil heaps are typical features of landscape in areas of Central/North Wales, south west England and Central North Pennines. Amelioration of abandoned mine lands often requires special attention because of the heterogeneity of the overburden material. This can be accompanied by combining several techniques, mulch application and use of adaptive plant species (Robert *et al.*, 1988; Joost *et al.*, 1987; Sutton and Dick, 1987). Soils are deficient in plant nutrients such as N, P, K, Ca and Mg and contain toxic levels of metals (Smith, 1973). Many un-reclaimed or unsuccessfully reclaimed mined areas contribute to water and soil pollution through acid and heavy metal drainage and sediment loading resulting from severe erosion. Many tips are therefore unstable and redistribution of spoil by flooding of contaminated watercourses (Davies, 1971) and by wind erosion (Smith, 1973) has caused extensive de-spoilation of agriculture land. Excessive nitrogen treatment at seeding should be avoided but applications in the range of 30-70 kg N/ha are usually acceptable and indeed necessary for initial sward development (Johnson and Bradshaw, 1979). In comparison with nitrogen, phosphorous is immobile in soils and less subject to leaching even in porous substrates. Thus in most situations phosphorous deficiency can be rectified simply by applying super-phosphate and basic slag or, where necessary, slow release forms e.g. magnesium ammonium phosphate, usually at rates corresponding to 100 - 300 kg P_2O_5/ha. In unfavorable materials, treatment rates must be compensated for fixation (Johnson and Bradshaw, 1979). Deficiencies of potassium are usually marginal and allowing leaching losses, applications rates greater than 75 kg ha^{-1} (as potassium sulphate) are rarely necessary. Initially major nutrient deficiency may be overcome by applying 400-700 kg ha^{-1} of a granular compound fertilizer (17N : 17 P_2O_5 : 17K_2O), but further maintenance treatments may be necessary to maintain substrate fertility in the event of leaching of nitrogen and complexing of phosphorous (Johnson and Bradshaw, 1979). Subsequent policies will vary with the final land use objective but annual treatment with 200 - 400 kg ha^{-1} of compound fertilizers will be necessary as a post-reclamation management practice (McNeilly and Johnson, 1978).

This study needs to examine the response of new colonization on bare area to NPK singly as well as with combinations. There is also a need to assess the population response to NPK singly and in combinations on vegetated site of Trelogan lead and zinc mine. The objective was to identify the nutritional requirements of Trelogan mine with respect to its use in schemes for the larger-scale permanent re-vegetation of such toxic sites. In the light of low level of N, P and K and regulatory effect on germination and growth by their addition in the mine spoil, a project was therefore initiated to determine the comparative ability of N, P and K singly and in different combinations on the bare and vegetated abandoned toxic mine spoil at Trelogan, North Wales, and to know the role of these macronutrients for the establishment of new seedlings of grass vegetation on the bare mine site.

Materials and Methods

Site Description and Plot Formation: Field sites were located on the abandoned lead zinc mine at Trelogan, Flintshire, North Wales, UK. The spoil heap was calcarious coarse material with toxic levels of lead and zinc and very low levels of macronutrients. The experimental area was fenced and there were vegetated and bare areas inside the fence.

Flora was composed only of species known to have evolved metal tolerant populations. The spoil heap was not only devoid of vegetation but mostly sparsely colonized by species characteristics of heavy metal contaminated substrates. The plant species mainly colonized there were *Festuca rubra, Agrostis tenuis, Plantago laceolata, Rumex acetosa, Minuaria verna, Anthoxanthum odoratum*, Bryophytes and Lichens.

Two sites were chosen adjacent to the permanent sample plots and the plots were made on the bare site, which was almost completely devoid of vegetation as well as on the vegetated site. The plots were made on 19.7.96. 21 randomly located metal quadrants (60 cm x 60 cm) were placed on the bare area without control. But 24 randomly located metal quadrants of the same size were placed on vegetated site with control. The boundaries of all the plots on the bare site were marked with iron nails of 6 cm length, but the vegetated plots were marked with wooden bars of 30 cm length.

Fertilizer Treatments: The specific NPK fertilizer singly as well as with various combinations received by each plot was provided on random basis. The seven treatments were replicated three times on the two sites i.e., bare and vegetated. The details of the treatments were presented in the Table1. The fertilizers were applied twice on the both sites. The first treatment of NPK fertilizers singly as well as with various combinations on bare area was added on 19.7.96 at the equivalent rate of 25 kg ha^{-1} and subsequent second treatment was given on 16.5.97 at the rate of 100 kg N ha^{-1}, 50 kg P ha^{-1} and 50 kg K ha^{-1}. The fertilizers on the bare site were added as chemicals dissolved in de-ionized water. Solutions were sprayed on to the bare mine soil inside the quadrants using a fine spray wash bottle.

On the other hand the first treatment of NPK fertilizers singly and with various combinations was added on vegetated site on 16.8.96 at the equivalent rate of 25 kg ha^{-1} and the second treatment was supplied on 17.6.97 at the rate of 100 kg N ha^{-1} and 50 kg P ha^{-1}. These fertilizers on to the vegetated site were added by mixing in the air dried silver sand in order to insure their supplies on the soil but not on the plant.

Harvest and Measurement of Growth Parameters

Bare Area: The numbers of seedlings of three species i.e., *A. capillaris, A. odoratum* and *F. rubra* germinated, after16 months of the first supply of the treatments were recorded.

Vegetated Area: On 22.12.97 about 16 months after the first supply of the fertilizers half of the treated plots of the vegetated area were harvested with shear above the ground level (shoot only). Yields were oven dried at 60° C for 5 days with the separation of the component species and dry weight was noted on the electric balance.

Statistical Analysis: Where appropriate data were subjected to analysis of variance (ANOVA) in order to check the significance of treatments on yield effect. Least significant differences (LSDs) were calculated for particular treatment term only if the F test of the variance ratio was significant at $p < 0.05$ (Steel and Torrie, 1980; SAS, 1989).

Results

Effect of Fertilizers on Seedling Establishment on Bare Mine Area: An analysis of variance of the number of seedlings established on each fertilizer plot/quadrant presented in Table 2 showed the non-significant ($p < 0.01$) effect of fertilizers. Only species seedlings differed significantly within themselves. The replications had also non-significant effect. Non-significant fertilizers x species interaction was also determined.

Nitrogen: Estimates of the number of seedlings germinated according to fertilizer treatments in each plot were shown in Fig. 1. Three species of grass, *A. odoratum, A. stlonifera* and *F. rubra* differed non-significantly (p, 0.05) under nitrogen treatment. But numbers of seedlings of *F. rubra* were more than other two grass species. *A. odoratum* germinated more seeds than that of *A. stolonifera*.

Phosphorous: Non-significant difference was also observed for phosphorous treatment among the 3 grass species assessed. Similar response pattern was indicated as was illustrated for nitrogen.

Potassium: Addition of Potassium alone did not cause any significant difference. Almost equal number of seedlings of the species of *F. rubra* and *A. odoratum* were established with slight difference. *A. stolonifera* seed germination was lesser than those of the other two grass species.

Nitrogen, +Phosphorous: The combined effect of nitrogen and phosphorous indicated the significant ($p < 0.05$) higher value for *F. rubra* than those of other two grass species. But seedling number of *A. odoratum* remained non-significantly higher over the *A. stolonifera*.

Nitrogen, + Potassium: The effect of this treatment had non-significant difference among the 3 species of grass investigated in this field experiment. Similar response pattern was noted as was shown by the addition of alone treatment of nitrogen and phosphorous.

Phosphorous, + Potassium: Perhaps the most dramatic effect on seedling germination was shown by this treatment. Significant ($p < 0.05$) more seedling number was observed for *A. odoratum* and *F. rubra* over the *A. stolonifera* In turn *A. odoratum* produced non-significant higher number than the *F. rubra*.

Nitrogen, + Phosphorous, + Potassium: The addition of three nutrients together produced significant ($p < 0.05$) higher number of seedlings of *F. rubra* over the other two grass species. *A. stolonifera* produced non significant lesser number of seedlings than that of *A. odoratum*.

As for as comparison of 7 nutrient/fertilizer plots was concerned the application of nitrogen, phosphorous and potassium alone indicated non-significant difference with maximum values of *F. rubra* and minimum of *A. stolonifera*. *A. odoratum* fell in between these two values. Over maximum numbers of seedlings of *F. rubra* germinated under combined NPK supply and of *A. odoratum* under PK treatment. Under the application of NP, NK and NPK F. rubra indicated non-significant difference with maximum number of seedlings over the other two grass species. Least number of *A. stolonifera* seedlings established under the NP, NK and NPK treatment and intermediate values were determined for A. odoratum on these 3 treatments. Overall *F. rubra* could only show significant higher number of seedlings under

NPK than those of NK and K, but NPK gave non-significant higher value than of P, NP and PK for this species and it gave overall poorest response under nitrogen treatment. *A. odoratum* produced significant higher number of seedlings under PK treatment over other 6 plots, but with minimum values under nitrogen treatment.

Among all the 7 fertilizer/nutrient plots A. stolinifera produced non significant difference with highest response under the alone supply of K and lowest response under NP treatment.

Effect of Fertilizers on Dry Weight Yield of Vegetated Plots: Statistical examination of the dry weight yield data by analysis of variance (Table 3) indicated a significant ($p < 0.001$) effect on species and replicates. treatments. The treated plots with nutrient did not show any significant difference, Similarly non significant The effect of each nutrition addition along with control on the dry weight of the each of the 4 mine species recovered was shown in Fig. 2 and described as follows-:

Control In the controlled conditions both species *A. stlonifera* and *F. rubra* produced significant ($p < 0.05$) greater dry weight yield than the other two mine species. *A. odoratum* and lichen, *Cladonia sp*. *F. rubra* yielded non significant more dry weight over *A. stolonifera*. Similarly *Cladonia sp*. gave

Table 1: Summary of the fertilizers treatments

Fertilizer Treatments	First Supply kg ha^{-1}	Second Supply kg ha^{-1}	Fertilizers added as
N	25	100	$NaNO_3$
P	25	50	Na_2HPO_4
K	25	50	K_2SO_4
NP	25 + 25	100 + 50	$NaNO_3 + Na_2HPO_4$
PK	25 + 25	50 + 50	$Na_2HPO_4 + K_2SO_4$
NK	25 + 25	100 + 50	$NaNO_3 + K_2SO_4$
NPK	25 + 25 + 25	100 + 50 + 50	$NaNO_3 + Na_2HPO_4 + K_2SO_4$

Table 2: Analysis of variance of effect of fertilizers on the number of seedlings of 3 grass mine species

Item	DF	SS	MS	F. ratio
Replicates	2	39.714	19.857	0.15^{NS}
Species	2	1779.809	889.904	6.54^{**}
Fertilizers	6	1255.047	209.174	1.54^{NS}
Sp X Fert	12	2116.190	176.390	1.30^{NS}
Error	40	5442.952	136.073	-
Total	62	10633.714	-	-

NS = Non significant
** = Significant at $p < 0.01$.

Table 3: Analysis of variance of effect of fertilizers on the dry weight of 4 mine species recovered from vegetated mine plots

Item	DF	SS	MS	F. ratio
Replicates	2	841.909	420.954	5.07^{**}
Species	3	25398.779	8466.259	101.98^{***}
Fertilizers	7	636.832	90.976	1.10^{NS}
Sp x fert	21	955.239	45.487	0.55^{NS}
Error	62	5147.286	83.020	-
Total	95	32980.046	-	-

NS = Non significant
** Significant at $p < 0.01$ and *** significant at $p < 0.001$

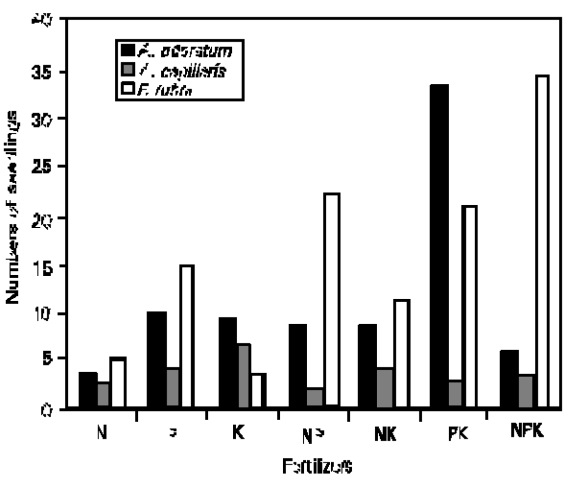

Fig. 1: Numbers of seedlings germinated in treated plots

non-significant higher yield over the minimum yield producer, *A. odoratum*.

Nitrogen: Under the alone treatment of nitrogen A. stolonifera and F. rubra again produced significant greater dry weight yield over *Cladonia sp.* and *A. odoratum*. Productivity of *A. stolonifera* remained non significantly greater over F. rubra. Similar response pattern was established for *A. odoratum* and

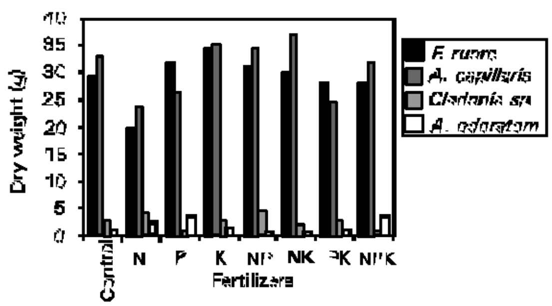

Fig. 2: Dry weight of four species in treated plots

Cladonia sp. to that of nitrogen treatment.

Phosphorous: In the P treatment there was again the reversal of the pattern established in the plot of nitrogen supply.
Potassium: This treatment produced more or less similar data to that of control.

Nitrogen, + Phosphorous: Addition of nitrogen and phosphorous together tend to show the significant higher yield of the two grass species, *A. stolonifera* and *F. rubra* than those of *Cladonia sp.* (lichen) and *A. odoratum*. The former and latter species could not produce significant difference for their dry weight yield between each other.

Nitrogen, + Potassium: When nitrogen and potassium were added together again A. stolonifera and F. rubra produced significant ($p < 0.05$) greater dry weight over the *Cladonia sp.* and *A. odoratum*. But *A. stolonifera* productivity was non-significantly higher to that of F. rubra. Similar response pattern was established between *Cladonia sp.* and *A. odoratum*.

Phosphorous, + Potassium: This treatment produced significant greater yield of the *F. rubra* and *A. stolonifera* than those of the dry weight yield of *Cladonia sp.* and *A. odoratum*. But *F. rubra* gave non-significant more yield over the *A. stolonifera*. Again *Cladonia sp.* gave greater but non-significant dry weight over *A. odoratum*.

Nitrogen, + Phosphorous, + Potassium: When these three fertilizers were applied together both grass species, *A. stolonifera* and *F. rubra* gave significant as well as higher productivity in terms of dry weight than those of *Cladonia sp.* and *A. odoratum*. Only under this treatment *A. odoratum* produced non-significant greater dry weight than that of *Cladonia sp.*

It was evident from the results that the addition of N, P and K singly or together as well as under controlled plots both species, *A. stolonifera* and *F. rubra* produced significant greater dry weight than those of *Cladonia sp.* and *A. odor atum*. In all plots except NPK *Cladonia sp.* yielded non-significant higher dry weight than that of *A. odoratum*. But under control, K and PK treatments *F. rubra* gave higher but non-significant yield over A. stolonifera. In contrast under N, P, NP, NK and NPK treatments *A. stolonifera* produced non-significant greater dry weight from that of *F. Rubra*.

Discussion

The reclamation of derelict and degraded land involves in overcoming many economic, social, technical and biological problems. The biological problem is to restore a functional and self-sustaining soil/plant ecosystem. It became clear from the results of spoil analysis of Terlogan mine (Anwer, 1999) that in addition to high metal content, spoil are known to have a very low plant nutrient status i.e., N, P and K. Antonovics *et al.* (1971) suggested that mine soils have very low content of N, P and K. McNeilly and Johnson (1978) commented that the Parys Mountain mine spoil was very low in N and P, but that the K level was within the range of normal soils. Similarly Bradshaw and McNeilly (1981) analyzed seven mine spoils which presented that all the spoils were deficient in N and P but their K status was very close to the range of uncontaminated soils.

Dead patches on the leaves, yellowing of the leaves and stunted growth were seen by the visual observation of the field vegetation. Metal tolerant populations also possess physiological and morphological characters, which reflect environmental stress apart from metal toxicity.

Figure 1 indicated that maximum number of seedlings were of *F. Rubra* and *A. capillaris* but *A. odoratum* produced the minimum. This difference was not due to the supply of nutrients, but it was due to the number of seeds dispersed and their availability for germination. Table 2 indicated non-significant effect of fertilizers which might be due to the adaptation of mine vegetation to low nutrient status (Bradshaw *et al.*, 1964). The results differed with the results of Johnson, 1977, who reported the increase in germination and survival of seedlings on the waste tips.

Table 2 showed the non significant effect of fertilizers on the dry weight yield of the plots which might be due to the adaptation of mine vegetation to low nutrient status but results were opposite to the results of McNeilly and Johnson (1978), who showed the significant increase into dry yield productivity of *Agrostis tenuis* grown in Parys Mountain spoil. Figure 2 showed the greater dry matter yield of A. capillaries and *F. rubra* than the *Cladonia sp.* and *A. odoratum*, and this difference might not due to the fertilizers but might be due to the difference of population already present in the Trelogan mine spoil.

Overall, results of this study indicate that generally phosphorous in both bare and vegetated area comparatively performed better than other fertilizers either used as single or in combinations. Many waste materials are however, infertile and may be toxic, phosphorous is often cited as macronutrient deficiency in metallic-ferrous spoils (Antonovics *et al.*, 1971; Baker, 1978). Nutrient deficiency in wastes can be overcomed by use of fertilizers (Jeffery *et al.*, 1974; Johnson *et al.*, 1976) but heavy metal toxicity cannot be so readily overcomed. It has been suggested that heavy phosphate application would complex heavy metals and reduce their toxicity (Newton, 1944; Jeffery *et al.*, 1974).

References

Antonovics, J., A.D. Bradshaw and R.G. Turner, 1971. Heavy metal tolerance in plants. Advances in Ecological Research, 7, 1-85.

Anwer, M., 1999. Ecology of abandoned metal mine waste. Ph. D. Thesis, University of Liverpool, U.K.

Baker, A.J.M., 1978. Zinc-phosphorous interactions in a zinc tolerant and non tolerant population of *Silene maritima* With. New Phytologist, 81, 331-339.

Bradshaw, A.D., M.J. Chadwick, D. Jowett and R.W. Snaydon, 1964. Experimental investigations into the mineral nutrition of several grass species. IV. Nitrogen level. J. Ecol., 52, 665-676.

Bradshaw, A.D. and T. McNeilly, 1981. "Evolution and Pollution" Edward Arnold, London.

Davies, B.E., 1971. Trace metal content of soils affected by base metal mining in the west of England. Oikos, 22, 366-373.

Jeffrey, D.W., M. Mabury and D. Levinge, 1974. Ecological approach to mining waste re-vegetation. *In*: Minerals and the Environment (Ed. Jones, M.T.). Institute of mining and metallurgy, London, pp: 371-385.

Joost, R.E., F.J. Olsen and J.H. Jones, 1987. Re-vegetation and mine soil development of coal refuse amended with sewage sludge and limestone. J. Environ. Qual., 16, 65-68.

Johnson, M.S., 1977. The establishment of vegetation on metalliferous fluorspar mine tailings. Ph.D. thesis, University of Liverpool.

Johnson, M.S. and A.D. Bradshaw, 1979. Ecological principles for restoration of disturbed and degraded land. Appl. Biology, 4, 141-200.

Johnson, M.S., A.D. Bradshaw and J.F. Handley, 1976. Re-vegetation of metalliferous fluorspar mine tailings. Transactions of the Institute of Mining and Metallurgy, Sect. A, 85, 31-37.

McNeilly, T. and M.S. Johnson, 1978. Mineral Nutrition of Copper tolerant Browntop on metal contaminated mine spoil. J. Environmental Quality, 7, 483- 486.

Newton, L., 1944. Pollution of the rivers of West Wales by lead and zinc mine effluent. Annals of Applied Biology, 31, 1-11.

Roberts, J.A., W.L. Daniels, J.C Bell and D.C. Martens, 1988. Tall fescue production and nutrient status on South West Virginia mine soils. J. Environ. Qual., 17, 55-62.

SAS Institute Inc., 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 1, Cary, N.C: SAS Institute Inc.

Smith, R.A.H., 1973. The reclamation of old metallic-ferrous mine workings using tolerant plant populations. Ph.D. thesis, University of Liverpool.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. A Biometrical Approach. Second Edition.

Sutton, P. and W.A. Dick, 1987. Reclamation of acidic mined lands in humid areas. Adv. Agron., 41, 377-405.