Harnessing Biological Nitrogen Fixation in African Agriculture

Challenges and Opportunities

edited by
Sheunesu M. Mpepereki
and
Fred T. Makonese

Harnessing Biological Nitrogen Fixation in African Agriculture

Challenges and Opportunities

Sixth International Conference of the African Association for Biological Nitrogen Fixation
12–17 September, 1994, Harare, Zimbabwe
Selected Papers

Edited by
Sheunesu M. Mpepereki
and
Fred T. Makonese

UNIVERSITY OF ZIMBABWE Publications

CTA

ISBN 0-908307-58-6

First published in 1998 by
University of Zimbabwe Publications
P.O. Box MP 203
Mount Pleasant
Harare
Zimbabwe

Typeset byUniversity of Zimbabwe Publications
Printed in Zimbabwe by Mazongororo Paper Converters (Pvt.) Ltd

6.6 Use of legumes in the revegetation of mine wastes

M. Piha

Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P. O. Box MP 167, Mt. Pleasant, Harare

Introduction

Mine waste heaps and overburden materials are usually barren, and not colonised by natural revegetation. These materials are thus susceptible to leaching, wind and water erosion, resulting in pollution of the environment. Vegetation establishment on these wastes is the most environmentally appropriate method of controlling all of the above pollution problems (Bradshaw and Chadwick, 1980). In addition to this, the establishment of a mixture of indigenous plant species on such wastes could be considered as being most appropriate. However, most mine wastes contain both nutrient deficiencies and mineral toxicities which inhibit the growth of plants.

A combination of addition of essential nutrients with selection of species tolerant to toxicities offers a logical approach to revegetation problems. Establishment of a self-sustaining permanent plant cover, which would require little aftercare is a practical necessity in such revegetation efforts. For nutrients which are adsorbed by the wastes (e.g. phosphorus), it is easy to envisage that a single large application would suffice for numerous years of continued plant growth. For nutrients which are easily leached (e.g. nitrogen), it will be necessary to make regular small applications for a number of years (i.e. until organic N recycling is adequate).

Because mine wastes contain no organic matter, they are often totally devoid of nitrogen (Bradshaw *et al.*, 1982). The continuous long-term addition of fertiliser N that would be required for sustained vegetative growth over numerous years is a serious management problem. The inclusion of leguminous nitrogen-fixing species in revegetation attempts offers a solution to this nitrogen problem (Jefferies *et al.*, 1981). Such legumes could survive without nitrogen fertilisation, and would eventually contribute N to the entire ecosystem. In fact, the inclusion of N fixing species is the only reliable way of ensuring the establishment of a self-sustaining ecosystem in a situation where organic and mineral N are non-existent.

Low input approaches to revegetation of mine wastes include: direct planting onto the waste substrate, the use of hardy, climatically adapted species having low nutritional requirements; the use of species tolerant of any toxic substances present; and the inclusion of nitrogen-fixing plants to provide a sustainable source of nitrogen.

Methods

General

An appropriate methodology aimed at low input establishment of self-sustaining vegetation was carried out for five waste materials in semi-arid Zimbabwe. The sites were: a tin slimes dam (Kamativi); a coal power station ash dam (Hwange); an asbestos tailings heap (Zvishavane); a coal overburden spoil (Hwange); a gold slimes dam (Arcturus). For each of the five sites the following methodology was used:

1. Site appraisal

2. Chemical analysis of the wastes to identify potential plant toxicities (e.g. heavy metals, extremes of pH, salinity) and nutrient deficiencies.
3. A missing-element greenhouse trial to identify or confirm nutrient deficiencies.
4. A preliminary greenhouse species selection trial in which a large range of mainly indigenous species is screened by observing their growth on optimally fertilised waste (including N). Species chosen included nine grasses, 16 herbaceous legumes and 27 trees (including 19 N-fixing species).
5. Relative-growth greenhouse trials in which the growth of promising species on soil is compared with that on fertilised waste, in order to identify those most tolerant of any toxic factors.
6. Small-scale field trials to test establishment techniques and the on-site response of selected plants to fertiliser amendments.
7. Large-scale field trials to test promising combinations of plant species and amendments.
8. Full-scale establishment of vegetation.

Legume inoculation

Legume species were first selected in the presence of nitrogen fertiliser (4 and 5 above). Promising legume species were then planted into 500 ml pots containing the individual wastes, together with all essential nutrients apart from nitrogen. To each of these pots was added 10 g of a rhizobia-rich soil. This soil comprised a mixture of a large number of soils which had been collected from beneath indigenous legumes throughout Zimbabwe. For each legume species, two nodules were selected and rhizobia isolated. For on-site revegetation, legumes used were usually inoculated with a broth containing the two isolates selected above. In other cases legume seeds were coated with glue and covered with finely sieved soil that was collected from beneath wild representatives of the host species.

Results

Tin tailings dam

Toxicities: High pH (8.7); aluminate (44 ppm)
Deficiencies: N, P, K
Species survival: (selection trial 4 above): grasses 100%, tree legumes 100%, herbaceous legumes 54%.
Relative growth (growth on waste/growth on soil): grasses 16–100%, tree legumes 28–89%, herbaceous legumes 0–47%.
Promising legumes: Herbaceous — *Macroptilium atropurpureum*
Trees — *Acacia* species

Coal ash dam

Toxicities: High pH (9.0); boron
Deficiencies: N
Species survival: (selection trial 4 above): grasses 100%, tree legumes 60%, herbaceous legumes 25%.
Relative growth (growth on waste/growth on soil): grasses 0–27%, tree legumes 0–54%, herbaceous legumes 0–8%.
Promising legumes: Herbaceous — None
Trees — *Acacia gerrardii; Acacia sieberana*

Asbestos tailings heap

Toxicities: High pH (9.5); bicarbonate; Mg > Ca.
Deficiencies: N, P, K

Species survival: (selection trial 4 above): grasses 70%, tree legumes 28%, herbaceous legumes 5%.
Relative growth (growth on waste/growth on soil): grasses 0–60%, tree legumes 0–12%, herbaceous legumes 0–10%.
Promising legumes: Herbaceous — *Sesbania brevipedunculata*
Trees — *Acacia karroo; Acacia erioloba; Acacia kirkii; Acacia tortilis; Acacia goetzii*

Coal overburden

Toxicities: Low pH (3.3)
Deficiencies: N, P
Species survival: Acid condition (i.e. N, P added): grasses 100%, tree legumes 100%, herbaceous legumes 75%.
Relative growth (growth on waste/growth on soil): grasses 2–69%, tree legumes 1–43%, herbaceous legumes 0–17%.
Promising acid tolerant legumes: Herbaceous — *Crotalaria sp.* Trees — *Acacia* species; *Lonchocarpus capassa*

Species survival: Low phosphorus condition (i.e. N, lime added) grasses 100%, tree legumes 100%, herbaceous legumes 100%
Relative growth (growth on waste/growth on soil): grasses 1–27%, tree legumes 3–60%, herbaceous legumes 1–15%.
Promising low P adapted legumes: Herbaceous — *Rynchosia minima; Indigofera; Crotalaria*
Trees — *Acacia* species; *Dichrostachys cinerea*

Gold tailings dam

Toxicities: Low pH (2.8); arsenic; cyanide
Deficiencies: N, P, K
Species survival: (selection trial 4 above; lime added) grasses 30%, tree legumes 3%, herbaceous legumes 0%.
Relative growth (growth on waste/growth on soil): grasses 6–21%, tree legumes 0–6%, herbaceous legumes 0%.
Promising legumes: Herbaceous — None
Trees — None

Discussion

For all waste materials, indigenous legumes were generally more sensitive to the adverse chemical conditions than were grasses. For all materials evaluated, indigenous legume tree species (especially *Acacia*) were more tolerant to the adverse conditions than were herbaceous legumes. Adapted indigenous legume tree species were found for all toxic sites, except for the gold tailings dams. Such perennial species are highly appropriate for revegetation. Inoculated trees should be able to sustain permanently on N deficient wastes without any aftercare. Such trees are, however, unlikely to contribute much N to associated non-fixing species. Herbaceous legumes would be more appropriate than tree legumes in this regard. Unfortunately, well adapted herbaceous legumes were only found for the relatively hospitable tin tailings dam.

Direct seeding of herbaceous and tree legume species was attempted on the tin tailings dam, and on the coal overburden material after addition of lime and phosphorus. Seed which was inoculated with rhizobia broth failed to produce plants which possessed nodules in both cases. On the other hand, seed which was coated with soil which was collected from beneath legumes produced well-nodulated plants. Given the wide range of waste material chemistry and the large number of potential species, on-site inoculation of indigenous legumes with rhizobia rich soil is preferred to inoculation with pure culture isolates.

References

BRADSHAW, A.D. AND CHADWICK, M.J. 1980. *The Restoration of Land*. Blackwell Scientific Publications, Oxford.

BRADSHAW, A.D., MARRS, R.H., ROBERTS, R.D. AND SKEFINGTON, R.A. 1982. The creation of nitrogen cycles in derelict land. *Philosophical Transactions of the Royal Society of London* 296:557–561.

JEFFERIES, R.A., BRADSHAW, A.D. AND PUTWAIN, P.D. 1981. Growth, nitrogen accumulation and nitrogen transfer by legume species established on mine spoils. *Journal of Applied Ecology* 18:945–956.