Technical Bulletin No. 7

Rehabilitation of Mine reject Soils for Crop Production

गोआ में स्थित भा. कृ. अनु. प. अनुसंधान समूह

(भारतीय कृषि अनुसंधान परिषद)

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(Indian Council of Agricultural Research)

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Published by :

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ICAR Research Complex for Goa.

Ela, Old Goa - 403 402, India.

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Correct Citation :

Wasnik H. M. 2005. Rehabilitation of Mine reject soils for crop production. Technical Bulletin No. 7, ICAR Research Complex for Goa.

Technical Assistance :

Sidharth K. Marathe

Printed at :

Bandekar Offset, Curchorem - Goa.

Ph.: 2650034

CONTENTS

Importance of mining and its contribution to the economy of Goa

The total mineral production of Goa during the year 1996-97 was about 13,737 metric tonnes, out of which, iron ore contributed 13,643 metric tonnes followed by bauxite (73 metric tonnes), manganese (12 metric tonnes) and ferro-manganese ore (6 metric tonnes) (Anon.1999). Mining is contributing to earn valuable foreign exchange of about Rs.800 crores annually and provides direct and indirect employment to a sizeable population of Goa.

Nature and extent of damage to soils, environment and the need for rehabilitation programmes

It is widely recognized and accepted by industry and regulatory bodies that mining and mineral processing activities create damage to the surrounding land, air and water that cannot be reversed by nature, but requires the aggressive application of carefully planned restoration programmes. Further, experience and scientific research are continuously required to identify problems and develop new methods for avoiding and correcting both potential and historical environmental damage.

In Goa, mine rejects at the site and their transportation by road have proved detrimental to agriculture, desilted lakes and riverbeds in the low lying areas. The soils in the form of clay, flow along with monsoon run off water and spread in the surrounding agricultural fields, affecting the low lying paddy fields besides silting the lakes and riverbeds. Annually 40-50 million tonnes of mine rejects are being produced requiring about 80 ha of land for stock piling (Patil, 2002), thus one could understand magnitude of mine reject dumps.

The present status of rehabilitation programmes and the need for the study

Goa receives average annual rainfall of 3000 mm to 4500 mm causing serious problems of erosion of waste dumps. The threat caused is further more compounded as the mines lie in the crest of Western Ghat which is a catchment area for major rivers of Goa. It is noticed that mined

out waste consist mainly Mangiferrous, Phyllitic or Siliceous clays and hardly 8 to 10 per cent of laterite rejection. The management of clays becomes difficult as they are fine and loose and tend to erode and get deposited in water sources and cultivated lands with the slightest rain. Mining wastes are sterile with no organic matter and biological activity. To utilize the mine rejects for more productive purposes, determining the kind and quality of toxic or synergistic elements present in the mine reject soils, evolving suitable ameliorative measures using amendments to make the mine reject soils fit for crop production, forestry and horticultural plantations is essential.

Salient findings of the project

The Sirigao mines of M/s. Chowgule and Company was selected for the trial. The composite soil samples were analyzed for its metallic, mechanical and physico-chemical properties and presented in Table-1.

The mine rejected dump yard soils consisted of 214.5 g kg^{-1} Fe_2O_3, 2.1 g kg^{-1} FeO, 220 g kg^{-1} SiO_2, 102.4 g kg^{-1} Al_2O_3 and 2.0 g kg^{-1} MnO in the metallic form. The soil had 265 g kg^{-1} coarse sand, 304 g kg^{-1} fine sand, 220 g kg^{-1} silt and 181 g kg^{-1} clay . The soil was acidic in reaction pH (6.0), low in Organic carbon (4.2 g kg^{-1}), available P (6.0 kg ha^{-1}) , available K (15.0 kg ha^{-1}), available Ca (127 kg ha^{-1}), available Mg (269 kg ha^{-1}), available Na (53 kg ha^{-1}) DTPA extractable Fe (18 mg kg^{-1}), Mn (7.5 mg kg^{-1}), Zn (0.8 mg kg^{-1}), Cu (0.6 mg kg^{-1}) (Table-1). Thus, it was observed that the mine reject soils are low in available major nutrients while the DTPA extractable Fe and Mn contents are in higher proportions.

A field trial on cashew grafts (40 Nos.) and mango grafts (25 Nos.) ammended with 500 g N, 125 g P_2O_5 and 125 g K_2O to each graft planted in one block with another block having similar number of grafts maintained as control during *kharif* seasons of 1987-1990. The observations on different parameters viz. plant height, branching habit and inflorescence were recorded and presented on Table-2.

It was observed that there was an increase in average plant height of cashew (1.91 meters),

Table 1: Physico-chemical properties of mine reject soils.

1. Total elements (Metallic form)	
Fe_2O_3	214.5 g kg^{-1}
FeO	2.1 g kg^{-1}
SiO_2	220 g kg^{-1}
Al_2O_3	102.4 g kg^{-1}
MnO	2.0 g kg^{-1}
2. Physical properties	
Coarse sand	265 g kg^{-1}
Fine sand	304 g kg^{-1}
Silt	220 g kg^{-1}
Clay	181 g kg^{-1}
3. Chemical properties	
PH	6.0
E. C.	0.31 dSm^{-1}
Organic carbon	4.2 g kg^{-1}
Available P	6 $kgha^{-1}$
Available K	15 $kgha^{-1}$
Available Ca	127 $kgha^{-1}$
Available Mg	269 $kgha^{-1}$
Available Na	53 $kgha^{-1}$
DTPA Extractable Zn	0.8 mg kg^{-1}
DTPA Extractable Fe	18 mg kg^{-1}
DTPA Extractable Mn	7.5 mg kg^{-1}
DTPA Extractable Cu	0.6 mg kg^{-1}

number of branches (17), canopy development (6.27 sq.m) and cashew nuts ranging from 50-105 nuts per tree due to NPK treatment as compared to control which recorded average height of 1.30 meters, 11 number of branches, 2.27/m^2 canopy development and producing 2-3 nuts per tree (Table 2).

Table 2: Growth performance of cashew and mango in mine reject soils.

Parameters	NPK Treated	Control
1. Cashew		
Height (m)		
Mean	1.91	1.30
Range	1.60-2.30	1.20-1.60
Branches		
Mean	18	11
Range	12-34	9-13
Canopy (m^2)		
Mean	6.27	2.27
Range	4.0-8.99	1.75-3.42
2. Mango		
Height (m)	1.20	0.72
Branches	3	2
Canopy (m^2)	0.42	0.04

Similarly, in mango NPK treatment enhanced plant height (1.20 meters), number of branches(3) and canopy spread (0.42 sq m) as compared to control, which recorded the 0.72 meters plant height with only two branches and 0.04 square meter of canopy development after three years of plantation on mine reject soils.

Another experiment on cashew was laid out in Split plot design with four treatments i.e. (1) Control, (2) Poultry manure (5 kg plant^{-1}),(3) 250:125:125 g N:P_2O_5:K_2O and (4) poultry manure (5 kg plant $^{-1}$) + 250: 125: 125 g N: P_2O_5:K_2O per plant as main plot treatment and cashew grafts and cashew seedlings as subplot treatments with three replications during *kharif* 1990-91-1991-92. Observations on different growth parameters were recorded in cashew and presented in Table-3.

The results indicated that there were significant increase in the plant height, canopy spread, number

of branches, number of flowering shoots and panicles per plant due to the application of poultry manure and inorganic nutrients separately over the control in both cashew grafts and the seedlings. A higher percentage of the flowering was recorded in case of cashew grafts (39 %) and cashew seedlings (32 %). Further, with the application of poultry manure flowering per cent improved (Table-3).

An experiment was conducted in Split plot design with cashew grafts and cashew seedlings as main plot treatments and sub plot treatments included comparison of organic manure (Poultry manure 5 kg plant^{-1}), inorganic fertilizers (500 : 125 : 125 g N : P_2O_5 : K_2O per plant), poultry manure (5 kg plant^{-1}) + 500 : 125 : 125 : g N : P_2O_5 : K_2O per plant and control along with three replications during the *kharif* seasons 1991-92 to 1992-93. The observations on different growth parameters were recorded and presented in Table- 4. The soil samples on different plots were collected, dried, ground, analysed for nutrient content and presented in Table-5. The cashew leaf samples from different

Table 3 : Influence of organic and inorganic supply of nutrient on Performance of cashew cultivars in mine reject soils.

Treatments		Height (m)	Canopy (m^2)	Branches	Percentage flowering
A. Cashew grafts					
M_0	Control	1.43	3.78	10	10
M_1	Poultry manure (5 kg/plant)	2.53	7.28	23	25
M_2	250:125:125 g N.P.K/plant	3.33	8.70	25	53
M_3	Poultry manure (5 kg/plant) + 250:125:125 g N.P.K/plant	3.03	8.72	23	67
B. Cashew seedlings					
M_0	Control	1.60	3.04	13	10
M_1	Poultry manure (5 kg/plant)	3.03	8.10	21	40
M_2	250:125:125 g N.P.K/plant	2.30	6.50	16	---
M_3	Poultry manure (5 kg/plant) + 250:125:125 g N.P.K/plant	3.0	7.84	17	77

treatments were collected, washed, dried, analysed for nutrient content and presented in Table-6.

The results indicated that there was a significant increase in plant height, canopy spread, number of branches, trunk girth, number of flowering shoots and fruits per plant due to the application of poultry manure and NPK fertilizers over control in both cashew grafts and cashew seedlings (Table-4).

There was also a gradual increase in soil pH, organic carbon, available P and K content of the soils due to the application of poultry manure and NPK fertilizer as compared to control both in cashew grafts and cashew seedlings (Table-5).

Similarly, there was a gradual increase in nitrogen, phosphorus, potassium, zinc, iron, manganese and copper contents in cashew leaf due to application of organic and chemical fertilizers over the control (Table-6).

Table 4 : Growth and yield of cashew as influenced by different treatments under mine reject soils of Goa.

Treatments	Plant height (m)	Canopy spread (m)		No. of branches	Trunk Girth (cm)	No. of fruits per plant
		E-W	N-S			
Cashew grafts	2.83	3.61	3.35	4	45.60	7
Cashew seedlings	2.73	1.64	1.59	2	22.0	-
C.D. (P=0.05)	0.15	0.15	0.15	-	19.20	-
M_0	1.96	1.68	1.73	2	21.00	-
M_1	2.42	2.12	2.05	2	28.65	-
M_2	3.08	2.82	2.60	3	34.00	-
M_3	3.72	3.89	3.50	3	51.65	15.0
C.D. (P=0.05)	0.15	0.15	0.15	-	19.20	-

M_0- Control

M_1- 5 kg Poultry manure per plant

M_2- 500:125:125g NPK per plant

M_3- 500:125:125 NPK + 5 kg poultry manure per plant.

Table 5 : Nutrient status of mine reject soils as influenced by different treatments.

Treatments	pH	EC (dSm^{-1})	Organic C (%)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
Cashew grafts	6.2	0.01	0.23	12	64
Cashew seedlings	6.2	0.01	0.31	13	77
M_0	5.9	0.01	0.15	9	48
M_1	6.1	0.01	0.17	11	53
M_2	6.3	0.01	0.22	13	71
M_3	6.4	0.01	0.53	16	110

M_0- Control

M_1- 5 kg Poultry manure per plant

M_2- 500:125:125g NPK per plant

M_3- 500:125:125 NPK + 5 kg poultry manure per plant.

Table 6 : Nutrient content of cashew leaf as influenced by different treatments.

Treatments	N (%)	P (%)	K (%)	Zn	Fe	Cu	Mn
				(ppm)			
Cashew grafts	1.47	0.29	0.36	17	1510	16	546
Cashew seedlings	0.95	0.21	0.36	17	1293	11	970
M_0	1.10	0.18	0.30	11	898	8	393
M_1	1.16	0.21	0.34	15	1390	13	497
M_2	1.24	0.27	0.38	18	1500	15	788
M_3	1.35	0.33	0.42	23	1817	20	1353

Further, four hundred pits were dug at a spacing of 5x5 m. in one hectare area filled with 10 kg of Farm Yard Manure. About 200 cashew grafts (Vengurla-4) and 200 numbers of mango grafts (50 each of Amrapali, Hilario, Ball and Mussarat) were planted on the onset of monsoon 1996. The growth performance of different parameters in cashew and mango grafts were recorded. The cashew leaf, cashew kernel, cashew apple and mango leaf were collected, washed, dried and analysed by standard procedures for their macro and micro nutrients content and presented in Table-7. The soils under cashew, mango and mine pits were collected, dried, analysed for nutrients content and presented in Table-8. The water samples from the mine pits were collected and analysed for quality parameters and presented in Table-9.

It was observed that there was 80 per cent survival of cashew grafts on mine reject soils during 1996-99. However, the survival of mango grafts was 80 per cent, 40 per cent and 20 per cent during 1996-97, 1997-98 and 1998-99, respectively.

The cashew grafts were 1.40 to 1.80 m. in height having 12-31 branches with canopy spread of 0.48 to 2.72 m^2. and 25 leaves per twig on an average. The nutrient content of the cashew leaf was 15.9 gkg^{-1} N, 5.5 gkg^{-1} P, 8.0 gkg^{-1} K, 1.10 gkg^{-1} Ca, 1.0 gkg^{-1} Mg, 208 $mgkg^{-1}$ Fe, 96 $mgkg^{-1}$ Mn, 14 $mgkg^{-1}$ Zn, 12 $mgkg^{-1}$ Cu and 16 $mgkg^{-1}$ B . A well branched cashew graft, yielded 40 fruits per plant with a bold cashew kernel weighing 8.10 g and contained 12.5 gkg^{-1} N, 6.5 gkg^{-1} P, 11.5 gkg^{-1} K, 2.4 gkg^{-1} Ca, 3.7 gkg^{-1} Mg, 3 $mgkg^{-1}$ Fe, 1.7 $mgkg^{-1}$ Mn, 0.46 $mgkg^{-1}$ Zn, 0.3 $mgkg^{-1}$ Cu and 0.3 $mgkg^{-1}$ B. The cashew apple was containing 13.6 gkg^{-1} N, 9.8 gkg^{-1} P, 17.5 gkg^{-1} K, 9.5 gkg^{-1} Ca, 2.0 gkg^{-1} Mg, 2.5 $mgkg^{-1}$ Fe, 0.9 $mgkg^{-1}$ Mn, 0.2 $mgkg^{-1}$ Zn, 0.6 $mgkg^{-1}$ Cu and 0.3 $mgkg^{-1}$ B content respectively. The mango grafts were 60-90 cm in height with 6-12 branches having canopy spread of 0.12- to 0.56 sq.m. and 12 leaves per twig on an average. The nutrient content in mango leaf was 10.2 gkg^{-1} N, 7.7 gkg^{-1} P, 5.0 gkg^{-1} K, 1.0 gkg^{-1} Ca, 1.2 gkg^{-1} Mg, 211 $mgkg^{-1}$ Fe, 314 $mgkg^{-1}$ Mn, 20 $mgkg^{-1}$ Zn, 13 $mgkg^{-1}$

Cashew grown under poultry manure amendment to mine reject soil

Cu and 26 mgkg^{-1} B (Table-7). It was also observed that cultivation of cashew in mine reject soils is proved to be better over mango in conserving soil and there by protecting the ecosystem.

The soil under cashew plantation was having a soil pH of 6.5 with a electrical conductivity of 0.06 dSm^{-1}. The available N content of soil was 144 kg ha^{-1},while available P and available K were 8 kg ha^{-1} and 61 kg ha^{-1}, respectively. The soil had a Ca content of 704 kg ha^{-1}, Mg content of 418 kg ha^{-1}, DTPA extractable Fe content of 17 kg ha^{-1}, Mn content of 22 kg ha^{-1}, Zn content of 0.68 kg ha^{-1} and Cu content of 0.40 kg ha^{-1}.

The mango soil had pH 6.35, E.C. 0.04 dSm^{-1}, available N 47 kg ha^{-1}, P 8 kg ha^{-1}, K 114 kg ha^{-1}, Ca 575 kg ha^{-1}, Mg 535 kg ha^{-1}, DTPA extractable Fe 10 kg ha^{-1}, Mn 19 kg ha^{-1}, Zn 1.3 kg ha^{-1} and Cu 0.30 kg ha^{-1}.

Table 7 : Nutrient contents of cashew leaf, cashew kernel, cashew apple and mango leaf under mine spoiled environment.

Nutrient	Cashew leaf	Cashew kernel	Cashew apple	Mango leaf
Nitrogen (gkg^{-1})	15.9	12.5	13.6	10.2
Phosphorus (gkg^{-1})	5.5	6.5	9.8	7.7
Potassium (gkg^{-1})	8.0	11.5	17.5	5.0
Calcium (gkg^{-1})	1.1	2.4	9.5	1.0
Magnesium (gkg^{-1})	1.0	3.7	2.0	1.2
Iron ($mgkg^{-1}$)	208	3.0	2.5	211
Manganese ($mgkg^{-1}$)	96	1.7	0.9	314
Zinc ($mgkg^{-1}$)	14	0.46	0.2	20
Copper ($mgkg^{-1}$)	12	0.30	0.6	13
Boron ($mgkg^{-1}$)	16	0.30	0.3	26

A view of mango grown on mined soil

The mine pit soil was having pH 6.45, E.C. 0.03 dSm^{-1}, available N 84 kg ha^{-1}, P 8 kg ha^{-1}, K 59 kg ha^{-1}, Ca 1672 kg ha^{-1}, Mg 545 kg ha^{-1}, DTPA extractable Fe 21 kg ha^{-1}, Mn 9 kg ha^{-1}, Zn 1.3 kg ha^{-1} and Cu 0.30 kg ha^{-1} (Table-8).

Table 8 : Availability of nutrients under cashew, mango and mine pit soils in the mine spoiled environment.

Nutrient	Cashew soils	Mango soils	Mine pit soils
pH (1:2.5)	6.55	6.35	6.45
E. C. (dSm^{-1})	0.062	0.04	0.030
Available N ($kg\ ha^{-1}$)	144	47	84
Available P ($kg\ ha^{-1}$)	8	8	8
Available K ($kg\ ha^{-1}$)	61	114	59
Available Ca ($kg\ ha^{-1}$)	704	575	1672
Available Mg ($kg\ ha^{-1}$)	418	535	545
DTPA extractable Fe ($kg\ ha^{-1}$)	17	10	21
DTPA extractable Mn ($kg\ ha^{-1}$)	22	19	9
DTPA extractable Zn ($kg\ ha^{-1}$)	0.68	1.30	0.51
DTPA extractable Cu ($kg\ ha^{-1}$)	0.40	0.30	0.18

The mine pit water had 6.88 pH, 0.02 dS m^{-1} E.C. 0.50 me l^{-1} Ca, 0.10 me l^{-1} Mg, 1.80 me l^{-1} HCO_3, 2.40 me l^{-1} Chloride, 0.40 me l^{-1} Sulphate, 1.20 me l^{-1} RSC, 0.20 Mg : Ca and SAR 0.03 (Table 9).

Table 9 : Quality of water in mine pit under mine spoiled environment.

Nutrient	Quantity
PH	6.88
E. C. (dSm^{-1})	0.02
Ca (mel^{-1})	0.50
Mg (mel^{-1})	0.10
HCO_3 (mel^{-1})	1.80
Cl (mel^{-1})	2.40
SO_4 (mel^{-1})	0.41
RSC (mel^{-1})	1.20
SAR	0.031
Mg:Ca	0.20

To utilize the mine rejects for more productive purpose, the agri-horticultural approach was adopted and mine dump was stabilized by planting *Acacia auriculiformis* and *Casuarina* which were established satisfactorily. Forage grass hybrid napiers PBN-16 was satisfactory grown on mine reject soils with better tillering and yield (10.66 t/ha/harvest). This grass apart from acting as a barrier for water conservation, prevents soil erosion and encourages microbial activity. The efforts are being carry out to know the survival of lesser known fruits like Jamun, Jack fruit, Aonla, Tamarind and Kokum in mine reject soils. Pisciculture is one of the best ways of mine pit reclamation. An experiment was launched by M/s. Sesa Goa in which the worked out pits (Lisboa) was terraced with loose soil to facilitate afforestation and the pit is used for Pisciculture.

Expected economic and ecological benefits

1. The mine reject soils are gravelly sandy clay loam, slightly acidic in reaction, low in available N, P, K and high in DTPA extractable Fe, Mn content

2. More number of flowering shoots and fruits per plant of were recorded with amendment of poultry manure to cashew in mine reject soils.

3. There were 80 per cent survival of cashew grafts during the growth period for three years, where as mango grafts survival reduced by 50 per cent every year of growth in mine reject soils.

4. It was observed that the cultivation of cashew in mine reject soils proved to be an excellent conservation for ecosystem.

Recommendations

1. Rehabilitation with the suitable silvi-horti-pastoral systems keeping in view the biodiversity of the region, soil and climatic conditions and the adaptability of the species will pay rich dividends.

2. The mining activity being carried out in these fragile ecosystems, need to be scientifically planned, taking into consideration its impact in the natural resources. The piling of wastes need to be planned and suitable physical and biological measures of reclamation need to be attempted, for survival of vegetation.

3. Mitigation of environmental hazards causing water resources and air pollution need to be given priority and proper management of water resources through Pisciculture needs to be attempted.

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