Ecorestoration Of Waste Dump By The Establishment Of Grass-Legume Cover

Deblina Maiti, Subodh Kumar Maiti

Abstract: This study investigated the usefulness of grass-legume mixture as an initial cover species to initiate ecorestoration process on a hazardous waste dump, produced by the wastes from an integrated sponge iron plant. During production of sponge iron huge amount of solid wastes are generated, which is considered as hazardous material, with alkaline pH; composed of dolochar, coal fines, slag and fly ash; posing serious threat to the surroundings. The area occupied by waste dump was approximately 5 ha and surface area; 3.4 ha was located inside forests. The average dump height varied between 40-50m with a steep slope greater than 70°. Before ecorestoration work, dump was blanketed with a thick layer of topsoil (1-1.2 m) and slope was covered by coir-mat followed by sowing of grass-legume seed mixture before monsoon onset. Dominant grass species was *Pennisetum pedicellatum;* drought tolerant and quick growing; while legume seeds consisted of *Stylosanthes hamata, Sesbania sesban,* and *Crotalaria juncea. S. hamata* is perennial, whereas *C. juncea, S. sesban* completes their life cycle within 5-6 months and their dead aerial parts contributed nitrogen rich litter to the soil. Dry subterranean parts of the annual grass *P. pedicellatum* acts as mulch. In a whole, it has been observed that grass-legume growth initiated nutrient cycling in hostile conditions, which was corroborated by analyzing rhizospheric soil samples of grass-legume cover at an interval of six-seven months. Study concluded that hazardous waste dump with steep slopes can be restored by application of grass-legume mixture, topsoiling and coir matting that leads to a sustainable plant soil interaction.

Index Terms: Ecorestoration, grass-legume mixture, waste dump, topsoil, coir-mat

1 Introduction

India is the world's largest producer of sponge iron and contributes 13% of global production. Huge quantity of solid waste generated by these industries contains char, dust, sludge and fly ash and some of them are categorized as hazardous waste. Dumping of these solid wastes onto land causes its degradation, reduces productivity and aesthetic value. Gradual rise in sponge iron production, subsequent solid waste generation and degradation of lands can only be remedied by ecological restoration which will render back their self sustaining capacity and functional properties. One of the easiest alternatives is to ecologically restore these wastes by blanketing with topsoil and revegetate with grass-legume mixture. Grasses are quick growing, provide biomass, have the ability to survive on toxic waste material and tolerant to adverse pH, extremely low nutrient conditions and toxic metals. Extensive root system of these species holds loose soil particles and prevents soil erosion while enhancing productivity to a sustainable level [1]. On the other hand, legumes are drought tolerant, perennial, fast growing and enrich nitrogen in derelict sites. Some common species like, *Stylosanthes humilis, Stylosanthes hamata, Sesbania sesban, Crotalaria* sp., *Desmodium* sp. etc. are proven to be excellent nitrogen fixing legumes [2], [3]. At the end of growing season, grasses eventually dry to form mulches which conserve moisture. Moreover dry mulch decomposes to form humus and organic matter which initiate nutrient cycling on the derelict sites [4]. Legumes, being perennial, also conserve moisture, accretes organic matter and create a nitrogen rich substrate for the soil by decomposition of their subterranean parts [5], [6], [7].

- *Deblina Maiti is currently pursuing PhD in environment science in Indian school of mines, Dhanbad-826004,Jharkhand, India, PH-8987414586.
  E-mail: dmhellodeblina@gmail.com*
- *Subodh Kumar Maiti is professor in environment science in Indian school of mines, Dhanbad-826004,Jharkhand, India.*

Grass-legume mixture application has now become a widely used technique to restore soil fertility than conventional fertilisers. They are mainly propagated through seeds and create a nitrogen pool in soil by reducing its loss through leaching. Nitrogen fixation by a grass-legume plantation is influenced by legume persistence, soil N status and competition with associated grasses [9]. Some N fixed by legumes is transferred to grasses by below ground decomposition of roots and nodules, which may be in the range of 3 to 102 kg N $ha^{-1}yr^{-1}$ or 2 to 26% of biological nitrogen fixation [8]. In several studies, Dinanath grass (*Penissetum pedicellatum*) and a forage legume, *Stylosanthes humilis* has been successfully used for ecorestoration [9], [10]. *Stylosanthes humilis* can uptake P very efficiently from low-P soils required for their growth [11]. In this present study, *Stylosanthes hamata* and *Pennisetum pedicellatum* has been used to enhance the soil nitrogen level.this present study, *Stylosanthes hamata* and *Pennisetum pedicellatum* has been used to enhance the soil nitrogen level.

2 Materials and Methods

2.1 Study Area

The present study was carried out on a solid waste dump of an integrated sponge iron unit located in Chhattisgarh, India. Wastes were dumped at the outskirts of the plant surrounded by natural forests which mainly consisted of dolochar, coal fines, slag and ash. Waste materials were posing serious threat to the surroundings. Moreover, height of the dump exceeded 30m which was greater than surrounding canopy height (actually it was between 50-60m); with steep slope (between 60°-70°) causing continuous source of pollution and deterioration of aesthetics. Top soiling blanketing, coir matting and seeding with grass legume mixtures were done to stabilise the slope. Topsoil, being of slightly acidic nature, it will buffer the pH of loose alkaline solid wastes below; which will attain a neutral pH desirable for legume growth. Coir-mat, a tough organic fibre having high tensile strength, rich in lignin (46%), about 1.5-2cm thick, inter-weaved with coconut-coir, fixed by nylon net; available in a roll of about 1 m width and 50 m length was used. The mat is laid loosely from the top of the slope (berm) and unrolled downwards without stretching and stapled in each 1 m distance all along the slope with a "U-shaped" iron nail. This was followed by sowing of grass-legume seeds, consisting *Penissetum pedicellatum, Stylosanthes hamata, Crotalaria juncea* and *Sesbania sesban, Hibiscus sabdariffa* (high biomass yielding non leguminous under shrub) on the surface (**Fig 1**). Loose topsoil was then spread above it to create a substratum for their germination and growth. Two to three rows of tillers of *Cymbopogon citratus* were planted along the berm (edge) of dump. All these activities were carried out before the onset of monsoon to protect the soil and seed mixture from erosion. Some other herbaceous plants were sown as cover species; *Sorghum vulgare* as given in **Table 1**. Watering of the dump was done early morning by two synchronised pumps.

2.2 Sampling and Analysis

Monitoring of plant growth was carried out by laying random quadrates (1mx1m) all along the slope and soil samples were also collected from each sampling quadrate at an interval of 6 months. Approximately, 6 to 7 nos of quadrates were laid along the slope length, which was varied from 30-40m. Grasses and legumes grown over the coir mat was uprooted along with coir-mat, and underneath soil samples were collected, packed in pre-cleaned air-tight plastic bags. At the same time, root and shoot portion of legumes were also collected. All the samples were transported to the laboratory in field-moist condition for moisture content measurement, then air dried, for further physicochemical analysis. Soil samples (0-15cm) from nearby forests were also collected for reference. Standard methods were followed to measure soil physicochemical parameters; field moisture by gravimetric method; soil pH, electrical conductivity (EC) (soil: water ratio (w/v; 1:1)) by glass electrode and conductivity meter respectively [12]; organic carbon by Walkley and Black's method; nitrogen by Macro-Kjeldalh method [13] and available phosphorous by Olsen's [14] as well as Bray's method [15]. Available potassium and sodium was extracted by using (1N) ammonium acetate solution (1:10; soil: solution) and measured by flame photometer [14]. Shoot length, root length and fresh biomass of each plant were measured followed by drying them in oven at 80˚C for 48h, to determine dry weight. XLSTAT compatible with Microsoft Excel was used for all statistical analyses.

Table 1. List of plant species used for revegetation of waste dump.

Botanical Name (family) (Common name)	Plant characteristics
Crotalaria juncea L. (syn: *Crotalaria benghalensis* Lam.) (Fabaceae) (Shon)	Herb, annual, nitrogen fixing, stems yield a valuable fibre
Cymbopogon citratus (DC.) Stapf. (Syn: *Andropogon citratus* DC.) (Poaceae) (Lemon grass)	Aromatic grass, perennial, propagated through tillers, oil extracted is used as an insect repellent
Hibiscus sabdariffa (L.) Roselle. (syn: Hibiscus sabbariffa L.) (Malvaceae) (Rosemallow)	Under shrub, annual
Pennisetum pedicellatum Trin. (syn: *Cenchrus pedicellatus* (Trin.) Mor.) (Poaceae) (Dinanath grass)	Grass, annual, soil stabilizer
Sesbania sesban (L.) Merr. (syn: *Aeschynomene aegyptiaca* (Pers.) Steud.) (Fabaceae) (Egyptian pea)	Shrub, annual, nitrogen fixing, green manure
Stylosanthes hamata (L.) Taub. (syn: *Hedysarum hamatum* L.) (Fabaceae) (Caribbean stylo)	Creeping herb, perennial, nitrogen fixing

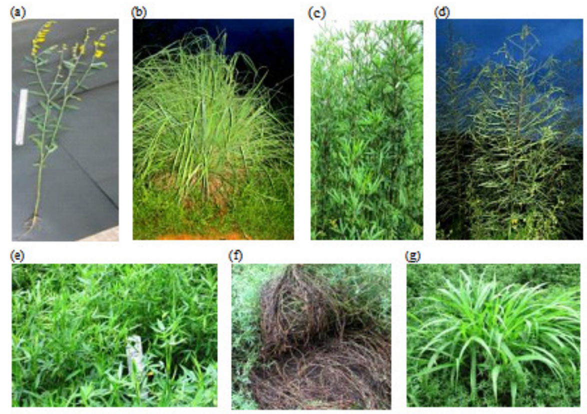

Fig. 1. (a) Whole plant of *C. junosa*, (3 months old), **(b)** *C. citratus*, **(c)** *H. sabdariffa*, **(d)** *S. sesban*, **(e)** *S. hamata*; close view of dense growth forming >30cm vegetation cover, **(f)** vegetation cover of *S. hamata* lifted up to show decomposition of belowground leaves on prostrate stems, **(g)** *P. pedicellatum* patch among *S. hamata* vegetation cover.

Stylosanthes hamata a branched legume with deep taproot system and numerous nodules (**Fig. 2a, 2b**) has prostrate stems with adventitious roots. Their extensive entangling root system and prostrate stems forms a dense vegetation mat of nearly 50-80cm. It covers steep slopes (**Fig. 2c**) and barren lands on presence of adequate moisture; becoming dominant over other species; binds soil particles to prevent erosion. It is an excellent nitrogen fixer and can be used on degraded soils for soil nitrogen enrichment. Close view of *Stylosanthes* legume with trifoliate leaflets and yellow flowers is shown in **Fig 2d**. *Sesbania sesban* with pubescent stems; pinnately compound leaves; straw-coloured sub-cylindrical, pods has slightly curved seeds with a hard seed coat. It can tolerate stress conditions of degraded soils and forms a nitrogen rich litter after drying. *Crotalaria juncea* has cylindrical, ribbed stems and a long taproot system possessing numerous nitrogen fixing nodules. It is a pioneer species for nitrogen fixation and used for restoration of degraded lands. Fruits are cylindrical pods having 5-6 nearly heart-shaped light brown seeds which burst open at maturity to germinate within 2-3 days in presence of adequate soil moisture (6.4%). Drying of plant parts occur after 8 months to form nitrogen rich litter for soil. Average number of nodules per plant was found as 20-30. Maximum germination of seeds was observed within 2 days, and within 7 days all seeds germinated (**Fig 3a**). Shoot and root growth of *C. juncea* is shown in **Fig 3b**.

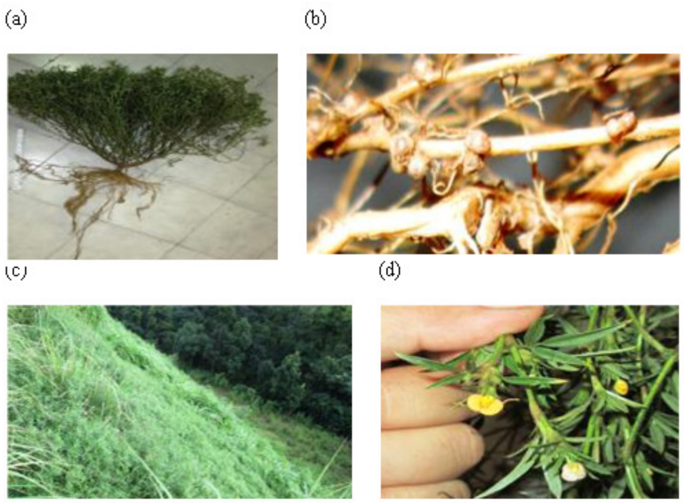

Fig. 2. (a) Bushy appearance of *S. hamata* collected from Dump top, with adventitious branches and long tap root system, **(b)** Nodules, **(c)** Dense cover of *S. hamata* on steep slope of waste dump along with patches of P. pedicellatum, beginning of forest area near foot. and **(d)** Close view of *S. hamata*.

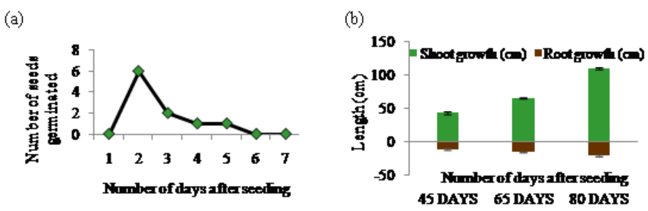

Fig. 3. (a) Seed germination of *C. juncea*, **(b)** Growth characteristics of *C. juncea*.

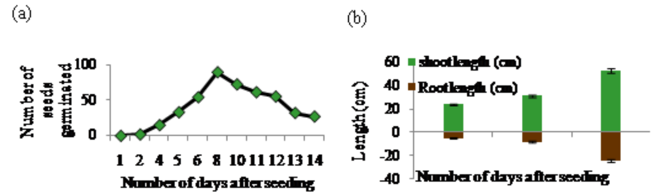

Fig. 4. (a) Seed germination of *P. pedicellatum*, **(b)** Growth characteristics of *P. pedicellatum*.

Table 2: Growth characteristics of grasses and legumes obtained from slopes six months after establishment (Mean ± SD; Min - Max).

Growth parameters	*C. juncea* #	*S. hamata* #	*C. citratus* *	*P. pedicellatum* *
Shoot length (cm)	238.7 ± 25.5^a (198 - 270)	35.1 ± 3.5^c (29 - 39)	75.3 ± 7^b (66 - 86)	75 ± 6.4^b (66 - 86)
Root length (cm)	34.1 ± 3.6^a (29 - 39)	28.9 ± 2.9^b (25 - 33)	16.5 ± 1.4^d (14.1 - 18.6)	23.3 ± 2.4^c (19.5 - 26.4)
Fresh weight (g)	241.43 ± 25^a (205 - 269)	6.67 ± 0.62^c (6 - 7.64)	43.46 ± 4.7^b (38.26 - 49.56)	29.38 ± 2.98^c (26.22 - 33.25)
Dry weight (g)	55.73 ± 6.09^a (47.15 - 62.16)	5.03 ± 0.54^c (4.33 - 5.78)	13.26 ± 1.39^b (11.07 - 15.11)	7.56 ± 0.79^c (6.26 - 8.52)

*# Legume, * Grass*

Values in a row suffixed with different letters are significantly different from each other at $p < 0.05$

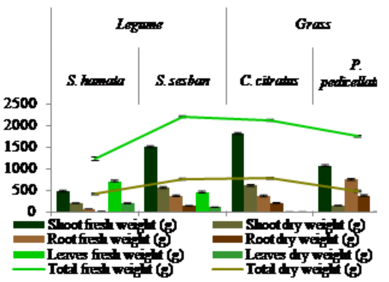

Fig. 5. Total average fresh, dry biomass of legumes and grasses per plant along with biomass of shoot, root and leaves, one year after growth on waste dump. Bars represent standard errors [data for 30 plants of *S. hamata* has been taken to show equivalence with biomass of other species in graph.]

Cymbopogon citratus forms dense clumps and grow up to a height of 1.5 m. Loose panicle containing numerous seeds is the inflorescence. It is propagated by planting tillers. It produces more biomass than Vetiver and has been recommended for bioremediation of Cu-tailings [16]. *Pennisetum pedicellatum,* a bunch grass and growing up to a height of 60 - 100 cm is branched from the base containing tillers and is leafy above. It propagates rapidly through seeds (**Fig. 4a**) and germinates within 7-8 days. Initial shoot and root growth is shown in **Fig. 4b**. Long dense roots of *P. pedicellatum* stabilize soil by binding small particles into large aggregates [17]. Later in its life cycle aboveground parts dry to act as mulches which conserve moisture as well as provide nutrients. **Table 2** depicts comparative evaluation of growth of grass-legumes species; six months after establishment. Highest shoot length was found in *C. juncea* and lowest in *S. hamata* due to its creeping nature. Highest root length was observed in *C. juncea* and lowest in *C. citratus.* Highest biomass was contributed by *C. juncea* among legumes due to its vigorous growth and *C. citratus* in case of grasses. Increase in biomass of legumes (*S. hamata* and *S. Sesban*) and grasses (*C. citratus* and *P. pedicellatum*) after one year is shown in **Fig 5**. Out of two legumes highest shoot biomass was found in *S. sesban* due to profuse growth of aerial parts and maximum leaf biomass was observed in *S. hamata*. In case of grasses maximum shoot biomass was found in *C. citratus* and root biomass in *P. pedicellatum.*

3.2. Soil physicochemical properties

Establishment of grass legume mixture and coir matting showed improvement in soil properties when compared to nearby forest soil.

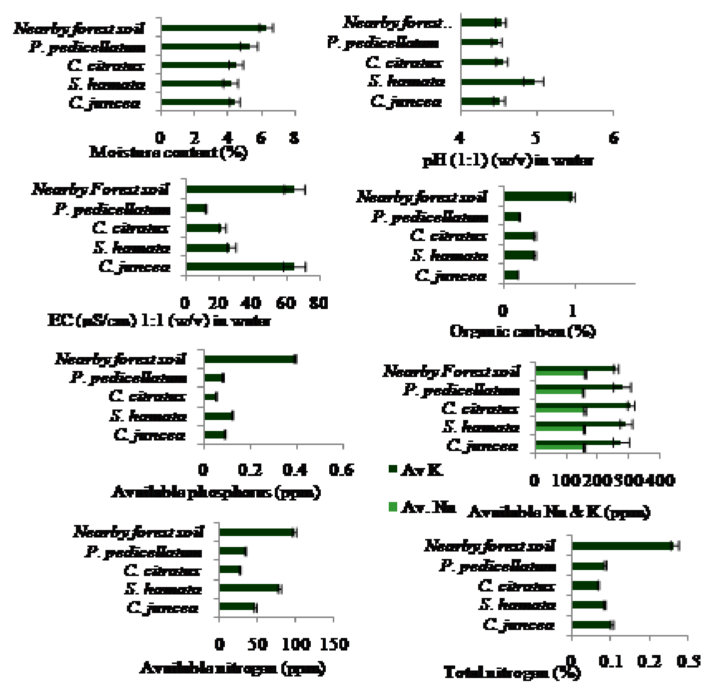

Fig. 6. Mean values of soil physicochemical parameters with error bars from grass legume vegetation area and nearby forest soil.

Soil nitrogen and carbon are the most important parameters and was found to increase due to growth of legumes. Moisture content in rhizospheric soil under grass-legume was found in the range of 4.0-5.0% which was less than forest soil (6.2%). Soil pH was found to vary between 4.5-5.0. Soil pH of rhizosphere of the grasses, *C. juncea* and forests was found nearly similar (4.5), while in case of *S. hamata* improvement in pH was found (pH 5.0). In forest soil, EC value (60µS/cm) was found higher than the grass-legume cover (15-20µS/cm), while in case of *C. juncea,* it was found close to forest soil. Presence of organic carbon (OC) in the soil is essential for sustainability of vegetation [18]. The level of OC under grass-legume cover was 0.50% which was still less than forest soil (0.97%). Nitrogen is the key element required for ecorestoration of degraded lands [19] and plants need a substantial nitrogen pool for their growth [20]. Legumes (*S. hamata)* have increased the nitrogen content of soil which is still less than that of forest soil (98 ppm) (**Fig. 6**). Total nitrogen in rhizospheric soil of individual plantation was found nearly similar (around 0.10%), which was less than forest soil (0.26%). Available phosphorus was found highest in forest soil (0.39ppm) than the grass-legume cover (0.05 – 0.12ppm). Available Na (152.70-159.70 ppm) and K (257.80-305.80ppm) of grass-legume cover was found close to forest soil. Distant views of the ecologically restored dump during dry and wet season are shown in **Fig 7a and 7b**.

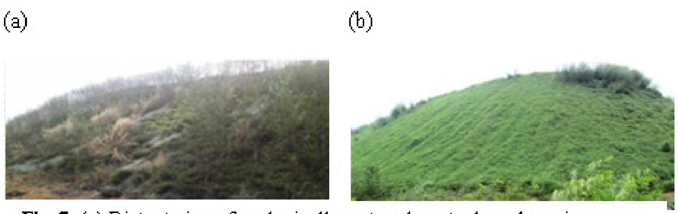

Fig. 7. (a) Distant view of ecologically restored waste dump by using grass-legume mixture in dry season showing patches of coir mat due to absence of vegetation, **(b)** vigorous growth of *S. hamata* after monsoon in restored dump.

4 Conclusion

Revegetation with grass-legume mixtures has a significant effect on protection of soil and nutrient cycling therefore can be used for ecorestoration of waste dumps. These plant species grow vigorously in nutrient deficient conditions and get established within a very short time period. Dry, aboveground parts of grasses (*P. pedicellatum),* rapidly growing legumes (*C. juncea, S. sesban*) are main source for influx of soil OC, N and other nutrients. Dry parts of these legumes and grasses also act as mulches to conserve moisture. Massive fibrous roots of the grasses also form soil aggregates and prevent erosion. The study is continuing and recovery of nutrient cycling, final colonisation and improvement of microbial population as well as enzymatic activity is being monitored.

5 References

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