Tropical Ecology **52**(3): 337-343, 2011
ISSN 0564-3295

www.tropecol.com

Species composition and diversity of vegetation developing on an age series of coal mine spoil in an open cast coal field in Orissa, India

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Abstract: Composition of herbaceous and woody vegetation, which developed as a result of natural succession on mine spoil dumps of different ages in an open cast coal field in Orissa, India, was analyzed. Species richness and diversity showed increasing trends for non-grass species with increasing age of spoil. The results indicated greater contribution of grass species during initial stages of vegetation development. Four native woody forest species were recorded in addition to five planted and one weed species, namely *Lantana camara*. Increasing Importance Value Index (IVI) of this weed with the age of the mine spoil reflects its invasiveness and is considered to be the reason for the poor performance of most of the planted woody species.

Resumen: Se analizó la composición de la vegetación herbácea y leñosa que se desarrolla como resultado de la sucesión natural sobre depósitos de dragado de diferentes edades en una mina de carbón a cielo abierto en Orissa, India. La riqueza de especies y la diversidad mostraron tendencias crecientes para las especies que no eran pastos conforme aumentaba la edad del depósito de dragado. Los resultados indican que hay una contribución mayor de especies de pastos durante las etapas iniciales de desarrollo de la vegetación. Se registraron cuatro especies leñosas nativas de bosque, además de cinco plantadas y una maleza, *Lantana camara*. Los valores crecientes del Valor de Importancia Relativa (IVI, siglas en inglés) de esta maleza conforme aumenta la edad del depósito de dragado de la mina refleja su capacidad de invasión y se considera como la razón del desempeño más bien pobre de la mayoría de las especies leñosas plantadas.

Resumo: Analisou-se a composição da vegetação herbácea e lenhosa que se desenvolveu como resultado de sucessão natural nos depósitos de escória em diferentes idades numa mina de carvão a céu aberto em Orissa, Índia. A riqueza específica e a diversidade mostraram um tendência crescente para as espécies não herbáceas com a idade crescente da escória. Os resultados indicaram uma maior contribuição das espécies herbáceas durante os estágios iniciais do desenvolvimento da vegetação. Registaram-se quatro espécies lenhosas nativas além das cinco plantadas e uma daninha a *Lantana camara*. O aumento do valor do Índice de Importância (IVI, sigla em inglês) desta espécie com a idade da escória da mina reflecte a sua capacidade invasiva e isto considera-se ser uma razão para a baixa prestação da maior parte das plantas lenhosas.

Key words: Coal mine, *Lantana*, restoration, revegetation, succession, weed.

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Open cast mining of coal deposits involves removal of overlying soil and rock debris. This debris is heaped in the form of dumps and is called mine spoil. These dumps change the natural land topography and affect the drainage system of the mining area (Chaulya *et al*. 2000). Due to the adverse physico-chemical and biological properties of mine spoil (Juwarkar *et al.* 2004), natural succession of plant species on these dumps is often prevented (Singh & Jha 1992; Singh *et al*.1996). Lack of vegetation cover on such dumps often leads to acute problem of soil erosion and environmental pollution (Singh *et al.* 1996).Therefore, development of vegetation on the dumps is essential for the conservation of biodiversity and stable environment in the coalfield area (Singh *et al*. 2002). There have been several studies on different innovative approaches for vegetation development on coal mine spoil dumps (Dugaya *et al*. 1996; Prasad & Mohammad 1990; Sonkar *et al*. 1998). Besides, specific use of native and indigenous species for revegetation of mine spoil has also been suggested (Banerjee *et al.* 1996; Jha & Singh 1993). There have been reports on the natural succession of different plant species on the barren dumps after certain interval of time (Borpujari 2008; Hazarika *et al.* 2006). But usually such natural succession proceeds at a conspicually slow rate (Singh & Jha 1992). Nevertheless, knowledge about natural succession of plant species on mine spoil is quite essential to initiate successful re-vegetation programme on dumps. In the present study, we attempted to document vegetation cover developed as a result of natural succession on an age series of coal mine spoil dumps of Basundhara coal mine area located in the western part of Orissa, India.

Basundhara Coal Mine of Mahanadi Coalfields Limited lies in the IB valley of Gopalpur block, which is 40 km northwest to the headquarters township of Sundargarh district in the state of Orissa, India. The study area is located between 22º 3′ 32″ - 22º 04′ 11″ latitude and 83º 42′ 18″ - 83º 44′ 08″ longitude. The altitude of the area varies from 262 to 288 m above mean sea level. The area experiences a seasonal tropical dry climate with three distinct seasons, viz. summer (March to June), rainy (July to October) and winter (November to February). Annual average rainfall (average of last 5 years) of the area is 1515 mm, of which 80 % falls during the rainy season. The mean air temperature varies from 10 (during December) to 45 ºC (during May). The river Basundhara, which flows from the northeast to southwest direction, acts as the main drainage system of the area. Tropical dry deciduous sal (*Shorea robusta*, Gaertn.) dominated forest forms the natural vegetation of the area. The total mining area (approximately 460 ha) of the coal field, which is under operation since 1990 was under the cover of the natural forest prior to open cast coal mining activities. In this area, land occupied by different mine spoil overburden dumps is approximately 40 ha. For the present study, six dumps of different ages i.e. fresh (0 yr), 3 yr, 6 yr, 9 yr, 12 yr and 15 yr were chosen. Existing planted species on different dumps are: *Cassia siamea* planted on 3 yr dump since 2006 with stocking density of 120 plants ha^{-1}; *Acacia nilotica, Acacia leucophloea* and *Cassia siamea* planted since 2003 on 6 yr dump with stocking density of 180 plants ha^{-1}; *Acacia nilotica, Cassia siamea* and *Eucalyptus citriodora* planted since 2000 on 9 yr dump with stocking density of 173 plants ha^{-1}; *Acacia nilotica*, *Cassia siamea* and *Gmelina arborea* planted since 1997 on 12 yr dump with stocking density of 138 plants ha^{-1} and, plants like *Acacia nilotica*, *Cassia siamea*, *Eucalyptus citriodora* and *Gmelina arborea* are planted since 1994 on 15 yr dump with stocking density of 193 plants ha^{-1} respectively.

Composition of vegetation on mine spoil dumps of different ages was studied by laying randomly placed quadrats during October-November 2009. The size of the quadrats for grasses was 1 m^2, herbaceous nongrasses 5 m^2 and for woody species 10 m^2. Ten quadrats were laid on different aspects of each dump for the analysis of herbaceous vegetation and an equal number for woody vegetation. Plant species were identified following the taxonomic manual of Saxena & Brahamam (1996) and by comparing with the herbarium sheets present in the Herbaria of School of Life Sciences, Sambalpur University and Institute of Minerals and Materials Technology, Bhubaneswar, India. Nomenclature of all the recorded species follows Panigrahi & Murti (1989). The data collected through quadrats were analyzed for frequency, density and abundance (Misra 1968) and their relative values were calculated. The relative values

Table 1. Herbaceous species with their Importance Value Indices (IVI) on spoil dumps of different ages.

Species	Family	Age of spoil dumps (yr)					
		0	3	6	9	12	15
		Grasses					
Aristida setacea Retz.	Poaceae	–	23	9	14	11	10
Cynodon dactylon (Linn.) Pers.	Poaceae	–	17	16	9	8	8
Cyperus metzii (Hochst. ex Steud.) Mattf.	Cyperaceae	–	9	6	–	–	–
Dichanthium annulatum (Forsk.) Stapf.	Poaceae	–	21	10	11	9	7
Eragrostis coarctata Stapf.	Poaceae	–	22	12	8	8	7
Eragrostis tenella (Linn.) (P. Beauv. ex Roem. & Schult.	Poaceae	–	25	6	10	9	7
Eragrostis tremula (Lamk.) Hochst.ex Steud.	Poaceae	–	18	4	10	8	7
Heteropogon contortus (Linn.) P.Beauv. ex Roemer & JA Schultes	Poaceae	–	14	7	9	8	6
Pennisetum pedicellatum Trin.	Poaceae	–	17	5	6	7	5
		Non-Grass Species					
Alysicarpus monilifer (Linn.) D.C.	Fabaceae	–	13	6	5	4	4
Abutilon indicum (Linn.) Sweet	Malvaceae	–	–	–	5	3	3
Achyranthes aspera Linn.	Amaranthaceae	–	10	10	8	7	4
Alternenthera sessilis (Linn.) R.Br.ex DC.	Amaranthaceae	–	17	18	9	7	6
Andrographis paniculata (Burm.f.) Wall.ex Nees.	Amaranthaceae	–	8	4	3	3	3
Argemone mexicana Linn.	Papaveraceae	–	–	–	5	3	4
Acalypha indica Linn.	Euphorbiaceae	–	–	–	–	–	9
Borreria hispida (L.)K.Schum	Rubiaceae	–	–	–	10	5	4
Boerhaavia diffusa Linn.	Amaranthaceae	–	–	–	–	–	10
Blumea lacera (Burm.f.) D.C.	Asteraceae	–	–	23	14	12	10
Celosia argentea Linn.	Amaranthaceae	–	–	10	11	9	7
Croton sparsiflorus Morung.	Euphorbiaceae	–	–	–	14	12	9
Cleome viscosa Linn.	Capparidaceae	–	–	–	8	6	4
Cassia tora Linn.	Caesalpiniaceae	–	–	–	10	7	4
Clitoria ternatea Linn.	Fabaceae	–	–	–	–	–	4
Cuscuta reflexa (L.) Roxb.	Convolvulaceae	–	–	–	–	–	3
Calotropis procera (Ait.)R. Br.	Asclepiadaceae	–	–	–	9	6	4
Chromolaena odorata (L.) R.M.King & H.Robinson	Asteraceae	–	–	–	13	10	8
Evolvulus alsinoides Linn.	Convolvulaceae	–	9	7	4	6	5
Evolvulus numularis Linn.	Convolvulaceae	–	10	7	5	5	4
Euphorbia hirta Linn.	Euphorbiaceae	–	13	14	8	8	7
Hemidesmus indicus (L.) R. Br.	Asclepiadaceae	–	6	6	4	4	4

Contd...

Table 1. Continued.

Species	Family	Age of spoil dumps (yr)					
		0	3	6	9	12	15
Heliotropium indicum Linn.	Boraginaceae	–	–	–	–	8	7
Lantana camara Linn.	Verbenaceae	–	–	–	–	–	3
Mimosa pudica Linn.	Mimosaceae	–	–	–	7	7	7
Merremia emerginata (Burm. f).Hall.f.	Convolvulaceae	–	–	–	–	–	4
Oldenlandia corymbosa Linn.	Rubiaceae	–	–	–	–	10	9
Ocimum basilicum Linn.	Lamiaceae	–	5	10	7	7	7
Ocimum canum (L.) Sims.	Lamiaceae	–	11	9	10	9	8
Oxalis corniculata Linn.	Oxalidaceae	–	–	–	–	–	9
Phyllanthus fraternus Webster.	Asteraceae	–	–	14	10	10	8
Portulaca oleracea Linn.	Portulacaceae	–	–	–	4	–	3
Rungia parviflora (Retz.) Nees	Acanthaceae	–	–	5	9	9	7
Sonchus wightianus D.C.	Asteraceae	–	–	–	–	6	6
Solanum surattene Burm.f.	Solanaceae	–	7	5	4	5	4
Solanum nigrum Linn.	Solanaceae	–	–	–	–	4	4
Scoparia dulcis Linn.	Scrophulariaceae	–	–	–	–	10	8
Sida rhombifolia Linn.	Malvaceae	–	–	–	–	–	10
Tridax procumbens Linn.	Asteraceae	–	8	9	7	7	5
Tephrosia purperia (L.) Pers.	Fabaceae	–	–	15	10	8	6
Tephrosia villosa (L.)Pers.	Fabaceae	–	–	16	5	5	4
Vernonia cinera (L.) Less	Asteraceae	–	–	–	6	6	4

Table 2. Woody species with their Importance Value Indices (IVI) on spoil dumps of different ages.

Species	Family	Age of spoil dumps (yr)					
		0	3	6	9	12	15
Acacia nilotica (L.) Delile	Mimosaceae	–	–	79	76	59	46
Acacia leucophloea (Roxb.) Willd.	Mimosaceae	–	–	70	–	–	–
Butea monosperma (Lamk.) Taub.	Fabaceae	–	–	22	32	–	–
Cassia siamea Lamk.	Caesalpiniaceae	–	300	103	67	63	43
Eucalyptus citriodora Hook.	Myrtaceae	–	–	–	–	75	43
Gmelina arborea Roxb.	Verbenaceae	–	–	–	–	49	37
Lantana camara L.	Verbenaceae	–	–	26	32	37	48
Phoenix acaulis Roxb. ex Buch.- Ham	Arecaceae	–	–	–	–	–	16
Woodfordia fructicosa Kurz.	Lythraceae	–	–	–	9	8	37
Zizyphus oenoplea (L.) Mill.	Rhamnaceae	–	–	–	–	19	30

of frequency, density and abundance of each species were summed up to yield the Importance Value Index (IVI) for each species. The species diversity (H′) was determined following Shannon & Wiener Index (Krebs 1989).

$$H' = -\sum_{i=1}^{S} (p_i \ln p_i)$$

where, H′= Observed species diversity, and S = Total number of species; $pi = ni/N$, where, ni = IVI of species i and N = Total IVI of all the species.

Analysis of vegetation of coal mine spoil dumps of different ages indicated absence of plants on fresh coal mine spoil. Absence of vegetation on such fresh coal mine spoils can be due to their hostile environment (Jha & Singh 1991). Often, presence of pyrite and its auto-oxidation in the spoil leads to fire and consequently rise in temperature & acidity (Chadwick 1973; Jha & Singh 1991; Machulla *et al*. 2005), and this may adversely affect germination and colonization of plant species on the fresh spoil (Ames 1980).

Importance value indices of herbaceous and woody species on the dumps of different ages are presented in Tables 1 and 2. Nine graminaceous species were recorded from 3 to 9 yr old dumps, of which 8 species belonged to Poaceae and 1 species to Cyperaceae (*Cyperus metzii*). In the rest of the dumps, all the recorded eight species belonged to Poaceae only. On the basis of IVI, *Eragrostis tremula* and *Cynodon dactylon* were the dominant species on 3 and 6 yr old dumps, respectively. However, *Aristida setaceae* was the dominant grass species on the rest of the dumps.

The number of non-grass species varied from 12 to 42, with the minimum number on the 3 yr old and the maximum on 15 yr old dump. The 12 non-grass species recorded from the 3 yr old dump belonged to 10 families. The number of families represented by non-grass species on 6, 9, 12 and 15 yr old dumps were 11, 17, 18 and 20, respectively. Species like *Blumea lacera*, *Phyllanthus fraternus*, *Celosia argentea*, *Rungia parviflora*, *Tephrosia purperia* and *Tephrosia villosa*, which were not noticed on 3 yr old dump, were recorded from 6 yr old dump. Similarly, *Abutilon indicum*, *Argemone mexicana*, *Borreria hispida*, *Croton sparsiflorus*, *Cleome viscosa*, *Cassia tora*, *Calotropis procera*, *Chromolaena odorata*, *Vernonia cineria* and *Mimosa pudica*, which were not recorded from 3 yr or 6 yr old dumps, were present in the rest of the dumps. Some of the species exclusively recorded from the 15 yr old dump were *Acalypha indica*, *Boerhaavia diffusa*, *Clitora ternatea*, *Cuscuta reflexa*, *Meremia emerginata*, *Lantana camara*, *Oxalis corniculata* and *Sida rhombifolia*. *Alternanthera sessilis* was the dominant species on 3 yr old, *Blumea lacera* on 6 to 12 yr old and *Sida rhombifolia* on 15 yr old dump.

In general, the family Poaceae contributed maximum species in different dumps (from age 3 to 15 yrs), which reflects the colonizing ability of the members of this family in hostile coal mine spoil habitat. Capacity of grass species to tolerate drought, low soil nutrients and climatic stresses (Helm 1995; Skeel & Gibson 1996) may contribute to their success in colonizing the mines spoil. Further comparative analysis of the contribution of grass and non-grass species to the importance value indices of herbaceous cover indicated that during the initial phase of succession, contribution of grass species was relatively more, and during the later stage, the contribution of non-grass species surpassed that of the grass species. This clearly demonstrates the strategic importance of grass and non-grass species with respect to the stages of successional colonization on the adverse habitats of coal mine spoil. Role of grasses as the initial colonizers during restoration of mined land has been highlighted by many workers (Helm 1995; Skeel & Gibson 1996). Due to their fibrous root systems, grasses are reported to slow down the pace of erosion and help to stabilize soil and conserve the level of moisture (Helm 1995). Besides, positive role of grass species cover as nurse crops for subsequent colonizers has been well documented (Ashby *et al*. 1989; Helm 1995).

Of the 10 woody species recorded from the sites (Table 2), 5 species were planted by the coal mine authority. The rest of the recorded species grew spontaneously in different sites. Out of this *Lantana camara* is exotic; whereas the remaining 4 species are native species of the local forest (Devi & Behera 2003). The only woody species recorded from 3 yr old dump was *Cassia siamea* which was a planted species. *Cassia siamea* dominated the woody vegetation on 6 yr old, and *Acacia nilotica* on 9 yr old dump. *Woodfordia fruticosa*, the species which was not noted on earlier dumps was recorded from the 9 yr old dump. Number of species recorded from 12 and 15 yr old dumps was 7 and 8, respectively. The species composition of woody vegetation in these two dumps was almost identical, except for the presence of *Phoenix acaulis* in the 15 yr old dump. The dominant woody species in 12 and 15 year old sites were *Eucalyptus citriodora* and *Lantana camara*, respectively. *E. citriodora* was a planted species and *L. camara* invaded from out side. The presence of *Lantana camara*, the exotic and highly invasive species (Aravind *et al*. 2010; Sharma & Raghubanshi 2010; Sharma *et al*. 2005), noticed from 6 yr onwards, showed an increasing trend in its importance value and this reflects its highly propagative nature on the mine spoil. *Lantana camara*, one of the ten worst weeds (Sharma *et al*. 2005), which suppresses/alters growth and regeneration of most of the plant species due to its allelopathic properties is of a concern and is expected to exert adverse effects on plant colonization on coal mine spoil dumps. Unless such weed invasion is checked, hindrance of growth and development of plants

Table 3. Species richness (S) and diversity (H′) of the vegetation on spoil dumps of different ages.

Age of spoil dump (yr)	Species richness (S)			Species diversity (H′)		
	Grasses	Non-grasses	Woody spp	Grasses	Non-grasses	Woody spp
3	9	12	1	2	2	0
6	9	18	5	2	3	1
9	8	29	5	2	3	1
12	8	33	7	2	3	2
15	8	42	8	2	4	1

particularly shrubs and trees, is going to have a bearing on the pace and progress of restoration of perturbed coal mine spoil dumps.

Species richness and diversity (Table 3) of grass species did not vary with the age of the dump. On the other hand, species richness and diversity of non-grass herbaceous and woody species showed a gradual improvement with the increase in the age of the dumps, and this finding is in conformity with the observation of Iverson & Wali (1982) and Borpujari (2008). Diversity did not show any trend with respect to the woody species. Such differential trends of species richness and diversity between grass and non-grass herbaceous vegetation implies that a successful stable colonization of the former favours the gradual successional recruitment of the latter on the perturbed mine spoil.

Acknowledgements

Authors thank Head, School of Life Sciences for providing facilities for the work. Financial assistance from UGC, New Delhi, to one of the authors (NJE) in the form of Rajiv Gandhi National Fellowship is gratefully acknowledged.

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(Received on 04.02.2010 and accepted after revisions, on 23.09.2010)