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Seed Balls Accelerate Succession of Plant Species in Degraded Coal Mined Land Restoration: a Case Study on Tikak Colliery, Margherita, Assam, India

A study was conducted to introduce seed ball technology in an opencast coal mined overburden dump (OBD) site of Tikak Colliery, Margherita, Assam, India with an objective to study the seed germination and survival of plant species. The other objective was to record the plant species that allowed to grow naturally on the OBD after 3 years of seed balls sowing. Seeds of nine native plant species were used for preparation in seed balls. PGPRs isolated from native soils were used @ one litter of PGPR with 10^{-6} concentration to treat 10 kg of seeds and made seed balls to enhance germination, amelioration and survival. About 12000 seed balls of all the nine plant species were sown at the on sets of monsoon in the year 2018. The study revealed that per cent seed germination of 4 leguminous species i.e. Crotolaria striata, Mimosa pudica, Indigofera tinctoria and Pongamia pinnata was 20-35%, whereas the survival was far batter 50-60% in comparison to two grass species except Thysanolaena latifolia. Soil physicochemical parameters were also found to improve with time. A total of 26 naturally colonizing plant species were also recorded from the site 3 years after sowing of seed balls. Of them 20 were herbs. Poaceae family with 8 species dominated the herbaceous flora. Other plant species includes 4 fern species, 4 shrubs and two tree species i.e. Callicarpa arborea and Schima wallichii. Among the natural invaders, 2 plant species Chromolaena odorata and Lantana camara were invasive species. The seed ball technology could accelerate succession of plant species in degraded coal mined OBD of Tikak Colliery, Margherita, Assam. The technology may be replicated for further confirmation in other mined land restoration programme.

Key words: Seed ball, PGPRs, Coal mined OBD, Seed, Native plant species, Succession

Sowing of seed balls could enhance colonization of plant species in degraded coal mined OBD basically dominated by herbaceous flora and could improve the soil quality with time.

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Introduction

Seed ball technology is an old age, ecofriendly and low-cost technique adopted for propagating plants throwing seeds balls without opening up soil with cultivation tools (Kannan *et al*., 2021; Shoo *et al.*, 2016) and can be used successfully in regeneration of trees, herbs and shrubs in degraded sites (Atkinson, 2003; Jakovac *et al*., 2016; Balkrishna *et al*., 2020). Seed ball (also called seed pellets and seed bombs) is one such integrated approach where seeds are sown putting inside the ball mixed with clay soil and organic manure such as cow dung, vermicompost and water in ball shape (Schreiber, 2014; Madsen *et al*., 2016). The first application of seed balls technology was known for ancient Egypt, where it was used to restore farmlands after the Nile's annual spring flood. The practice was incorporated into guerrilla gardening in the 1970s, and the movement sought to rehabilitate derelict or neglected urban land in the USA. The popularization of seed ball technique modern times happened due to a Japanese farmer and philosopher Masanobu Fukuoka, who introduced natural farming called "*the Fukuoka Method*". Fukuoka (1985) used volcanic red clay to make seed balls which he termed as “Clay Dumplings” and wrote a book -*The One-Straw Revolution* in 1975. Fukuoka's natural farming minimizes human labour and adopting the principle of no tillage, no fertilizer, no

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pesticides or herbicides, no weeding, no pruning, as closely as practical, nature's production of foods such as rice, barley, citrus in biodiverse agricultural ecosystems (Fukuoka 1985; Schreiber, 2014). This was successful even without plowing, seeds were germinated on the surface while appropriate site conditions meet the needs of the seeds placed there. Later, with time modification has been made on seed ball preparation incorporating various additives such as humus, compost, vermicompost, microbial inoculants (symbiotic mycorrhizal fungi and PGPRs), cotton-fibres or liquefied paper mash, Alginate etc. to further strengthening of the seed ball during sowing by throwing, or to adapt in harsh habitats (Niazy 2020; Tamilarasan *et al*., 2020; Hazarika *et al*., 2022; St. John *et al*., 1998).

Tamilarasan *et al.* (2020) recommended seed ball technique for forest regeneration and was found quite useful in establishment of plant species (*Leucaena leucocephala* (Subabul)) from seeds in three derelict sites in Krishnagiri district, Tamilnadu, India. A numbers of studies referred efficacy seed ball over direct seeding of seeds to difficult sites as the ball provided a protective layer to the inside seed from external stress and predation (Fukuoka, 1985; Harper *et al*., 1965; Rasmussen *et al*., 2003; Whisenant, 1999). Apart from them, seed balls sowing had more seedlings survival rate in comparison to normal seed sowing practices (Tamilarasn *et al*., 2020). This technology was particularly found useful in dry and arid areas (Atkinson, 2003). It helps people farming in rural areas have a more consistent supply of food. This technology was also reported as suitable to for ecological restoration or revegetation of large area within a short period of time (Gornish *et al*., 2019; Kannan *et al*., 2021)

In spite of having many prospects of seed ball technology no works have been carried out for restoration of degraded mined land so far. Coalmining operations destroy hilly terrains during excavation of coal underneath it and causes loss of forests and biodiversity (Hazarika *et al*., 2006; Malviya *et al*., 2010), habitat fragmentation and deterioration of ecosystem services, which inherently damage and pollute the environment (Bradshaw, 1997; Ghose, 2007). Ultimately creates deposition of thousands hectares of backfill area as overburden dumps (OBDs). These OBDs are completely barren, devoid of soil structure, lack of nutrients and moisture with unfavourable physico-chemical properties to grow plants (Hazarika, 2003; Hazarika *et al*., 2003; Uma Sankar *et al*., 1993). However, these area need to be reclaimed with suitable technology to return the native vegetation prior to mining. Many research efforts have been carried out in India and abroad for restoration of coalmine sites with integrated biological approach. Therefore, to reclaim such mined out lands of North Eastern Coal fields of Coal India Ltd., this study attempted to investigate potentials of seed ball technology in a field trial established in the year 2018 in Tikak Colliery, Margherita, Assam. About 12000 seed balls were sown in 5 ha of the coal mine overburden dumps with the objectives to restore herbaceous flora and improve soil parameters.

Material and Methods

Study area

The Tikak Colliery, Margherita is located in Tinsukia district of Assam, India in the border of Arunachal Pradesh. It comprises of Ledo, Boragolai, Tikak, Tirap and Tipong Collieries. The area lies between the

Fig 1: Map of experimental site (Overburden dump) for reclamation at Tikak Colliery

latitudes 27°15' and 27°25' N and longitudes 95°40' and 96°5' E (Fig. 1). The general elevation above MSL near the plains of the river Buri-Dihing is 140 m rising to elevation of 300 m to 500 m on the Patkai Naga Range. Overburden dump (OBD) namely Kargil site of Tikak Colliery was selected for the study and the topography and barrenness of the site is presented in Fig. 3 [C].

The climate is tropical monsoon. The annual temperature in winter falls up to 4° C and the maximum summer temperature is 36° C. The rainy season is confined mainly June to September with an average annual rainfall ranging from 3000 to 4250 mm. The average humidity ranges from 87-91% during wet months.

Preparation and sowing of Seed ball

The schematic representation of methods involve in preparation of seed balls is presented in Fig 2. Seed ball technology is one of such integrated approach where seeds are sown putting inside the ball mixed with soil and organic manure such as cow dung. This was done for establishment of herbaceous flora to stabilize mine sites and to trigger soil formation process. Plant growth promoting rhizobacteria (PGPRs) isolated from native soils were also incorporated in seed balls to induce plant growth in such extremely degraded sites. These microscopic organisms help the plant to thrive in hostile conditions providing nutrients in poor soil condition and extreme environment. Seeds of primary colonizing plant species such as *Arundo* spp, *Crotalaria striata*, *Dicranopteris linearis* (Syn*: Gleichenia linearis*)*, Mimosa pudica, Thysanolaena latifolia* and *Vetiveria zizanoides* were collected. Apart from these, seeds of other plant species *i.e. Abroma agusta*, *Indigofera tinctoria*, *Pongamia pinnata*, were also collected for preparation of seed balls. Application of neem leaf powder was done to protect seeds from decay and insect attack. Healthy and viable seeds of grass and herbaceous legume species were either treated with liquid form of PGPR or mixed with carrier based PGPRs in adequate quantities *i.e.* one litter of PGPR with 10^{-6} concentration to treat 10 kg of seeds. Before that a paste mixed with 1:1 (Clay soil: Cow dung) was prepared. A small part of the paste was taken and a few treated seeds (maximum 10) with PGPRs were put inside middle of the paste and hand rolled to make a ball of the size of areca nut fruit (25-35 mm dia) or seed bomb bigger than that and allowed to shade dry. Well dried seed balls were stored in humid free open room in gunny bags up till monsoon or for a year depending upon the viability of seeds. Seed balls were broadcasted during the rainy season. As precautionary measure PGPR treated seeds were not exposed to sun or rain and not sun dried. Precaution was taken not to mix seeds along with the paste of clay soil and cow dung to avoid induction of germination, particularly legume species as they are geminate easily if they are occurred on the seed ball surface. Approx. 12,000 seed balls were prepared for soil stabilization in plantation site in Tikak Colliery, Margherita.

Broadcasting of seed balls was done either throwing or dibbling depending upon approachability of the area (Fig. 3). This measure was taken to overcome other constraints to make favourable to germination of the seed in seed balls. The mulching was immediately after seed ball broadcasting in the slopes to reduce removal of seed balls by runoff.

Collection and analysis of soil samples

Three OBD composite spoil samples (OBD materials devoid of desired physic-chemical properties of soil was termed as spoils) amounting (500 gms) and also soils from adjacent natural forest up to the depth of 1-15 cm were collected. Physico-chemical properties of the required soil samples was done following standard methods such as (pH, EC by Electrode method, per cent Organic carbon (Walkely and Black, 1934; Brady, 1995); total Nitrogen (Bramner, 1965); available Phosphorous (Brays and Kurtz, 1945; Olsen *et al*., 1954); available potassium (Knudsen *et al.*, 1982) and available soil micro flora (Bhattacharya, 1986).

Record of plant species

After 3 years of seed ball sowing plant species which were come naturally in the OBD site was recorded for their occurrence only.

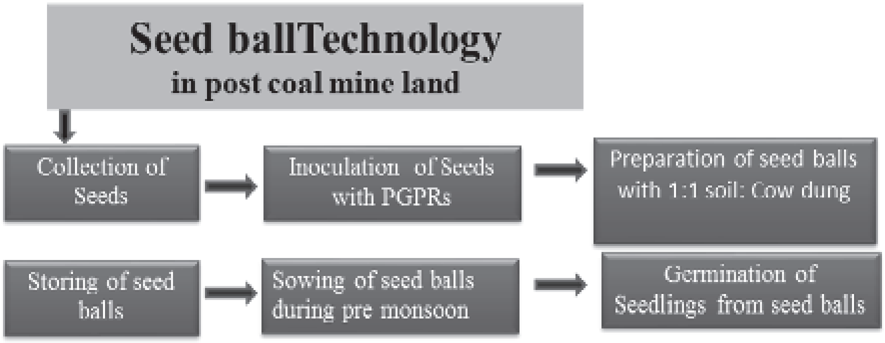

Fig. 2: Schematic representation of processes involve in preparation of seed balls

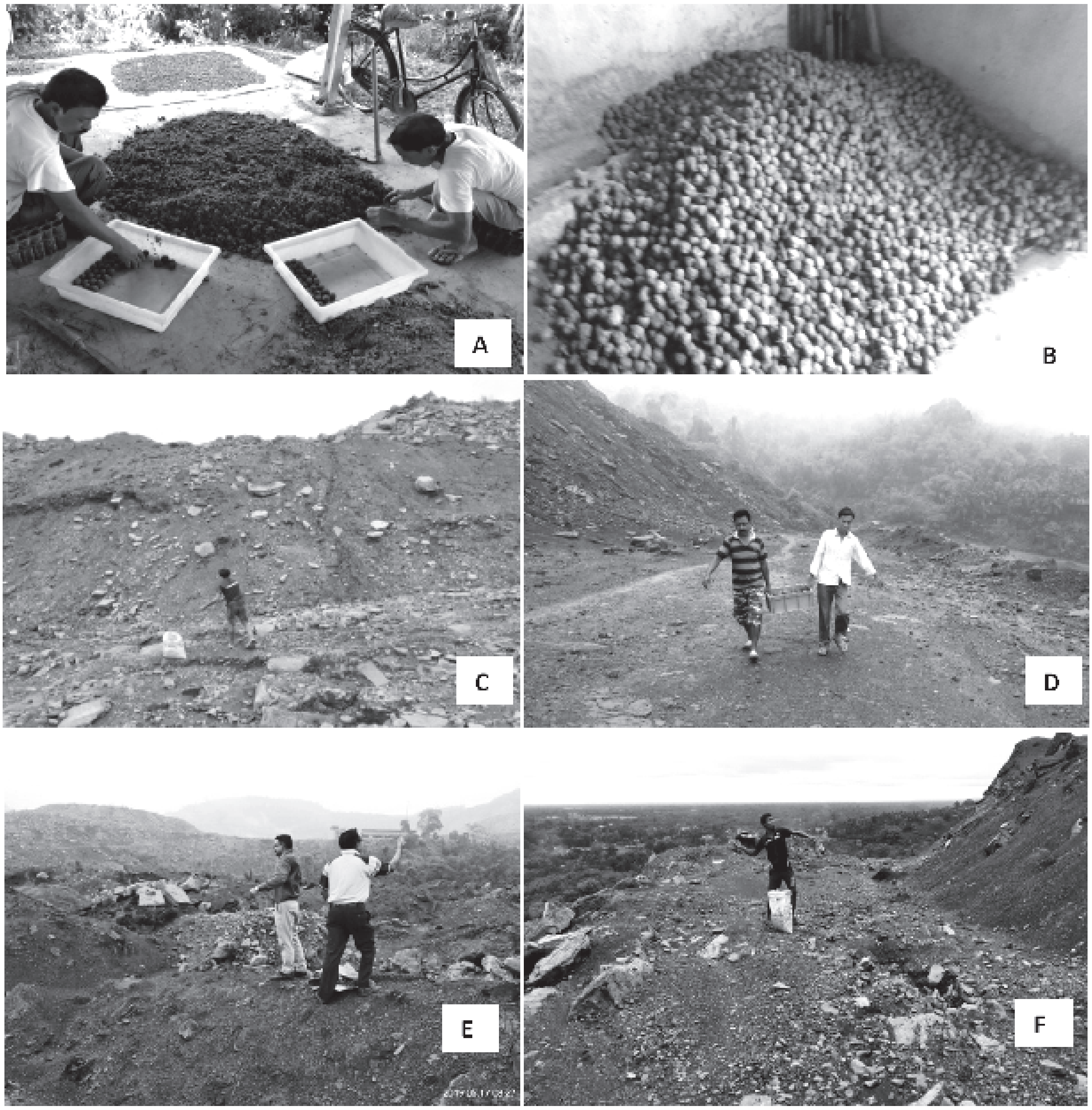

Fig. 3 : [A & B] Preparation of seed balls and [C to F] broadcasting in OBD site in Tikak Colliery, Margherita

Results

Broadcasting of seed balls of different plant species have different rate of germination and survival (Fig. 4). As seed balls of 9 native plant species were sown in pre-monsoon season during March to May, the germination also starts when the rains starts. The result revealed that seeds of different plant species had different germination rate, could grow from seed balls and survive in the OBD area. It was observed that the germination of *Crotolaria striata* seeds in seed balls were cent per cent but survival percentage was less than 10%. In contrary to the above the germination percentage of *Thysanolaena latifolia* was less than 10% but survival percentage was cent per cent. Grass species like *Vetiveria zizanoides*, *Cymbopogon nardus* and *Arundo* spp were recorded for 100 per cent germination and 30 per cent mortality after germination. The survival percentage of *Abroma agusta* was 50% but germination was very low (20%), for *Mimosa pudica* germination from seed ball was 30% however survival of germinated seedlings was 50%. Similarly, for *Indigofera tinctoria*

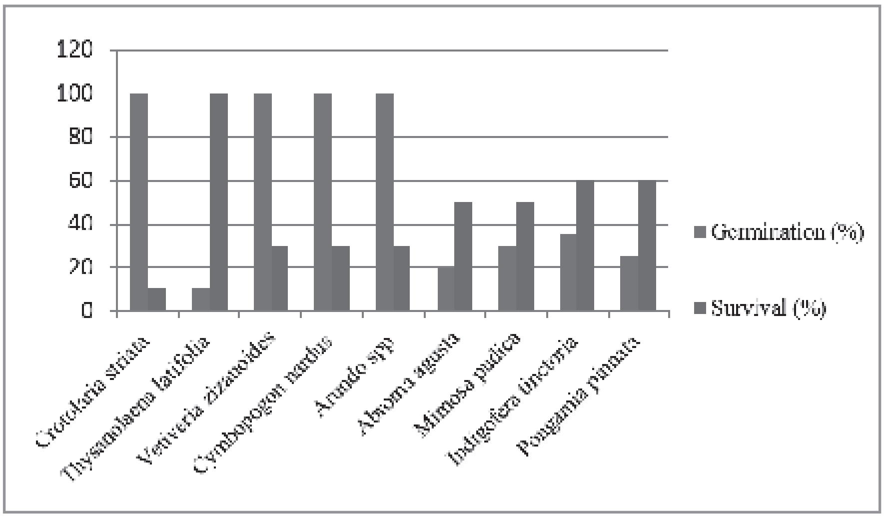

Fig. 4 : Percentage of germination and survival of plant species from seed ball sowing on the OBD site

seed ball germination rate was 35 per cent and seedling survival after germination was recorded for 60 per cent. Likewise, *Pongamia pinnata* grown from seed ball were recorded for 60 per cent. However germination was only 25%. Overall scenario of seed ball performance for plant species growth and survival is presented in Fig. 5.

The study revealed that per cent seed germination from seed balls of 4 leguminous species *i.e. Crotolaria striata*, *Mimosa pudica*, *Indigofera tinctoria* and *Pongamia pinnata* was 20-35%, whereas the survival performance was far better *i.e.* 50-60% in comparison to two grass species except *Thysanolaena latifolia*.

Soil physicochemical properties of overburden dump (OBD) before seed ball sowing and 2 years after sowing of seed balls were analysed for pH, EC, available nitrogen, available P and available K and also projected soil parameters of adjacent natural forest for comparison of status and values are presented in Table 1.

The mean pH value of the overburden dump spoils of before sowing seed balls was 3.37 and natural forest was 5.6. The mean pH value of OBD spoils 2 year after seed ball sowing was recorded for 4.9 and that was better before plantation.

EC of the OBD site was high with 597.53µs/cm, whereas natural forest soils was analyzed for 106 µs/ cm which was more than 5 fold high in OBD site. Likewise, available nitrogen (N) was analysed and found 75.32 kg ha^{-1} in OBD site and the same was found 238.51kg ha^{-1} in natural forest soils. Similarly, available phosphorus (P) was analysed for 63.75 kg ha^{-1} in natural forest soil and 6.75 kg ha^{-1} in OBD site before seed ball sowing.

Accordingly, after 2 years of seed ball sowing in OBD site physicochemical properties of spoils were analysed and the result reveals that pH of the OBD site was gradually improving from 3.37 to 4.9 during 2 years after vegetation growth. Likewise, ECµs/ cm were also decreased from 597.53 to 475 and were a good sign for soil health. Estimation of available N (kg ha^{-1}) was found to increase almost 2 folds *i.e.*168.55 kg ha^{-1} after two years of vegetation growth from seed balls.

There were 3 folds increased in available phosphorus (P) (19.62 kg ha^{-1}) which was 6.75 kg ha^{-1} before 2 years. Similar trend was also recorded for the data analysed for available K (94.49 kg ha^{-1}) which was near to double before seed ball sowing.

Table 1 : Mean (± standard error) physico chemical characteristics of OBD spoil before and after seed ball sowing and natural forest soil.

Site	**pH**	**ECµs/ cm**	**Available N** (kg ha^{-1})	**Available P** (kg ha^{-1})	**Available K** (kg ha^{-1})
Natural Forest	5.6±0.158	106±6.746	238.51±10.21	63.75±1.76	316±8.06
OBD before Seed ball sowing	3.37±0.138	597.53±68.42	75.32±7.38	6.75 ±0.595	56.41± 2.86
OBD 2 years after Seed ball sowing	4.9±0.195	475±46.77	168.55±11.79	19.62±0.77	94.49±6.70

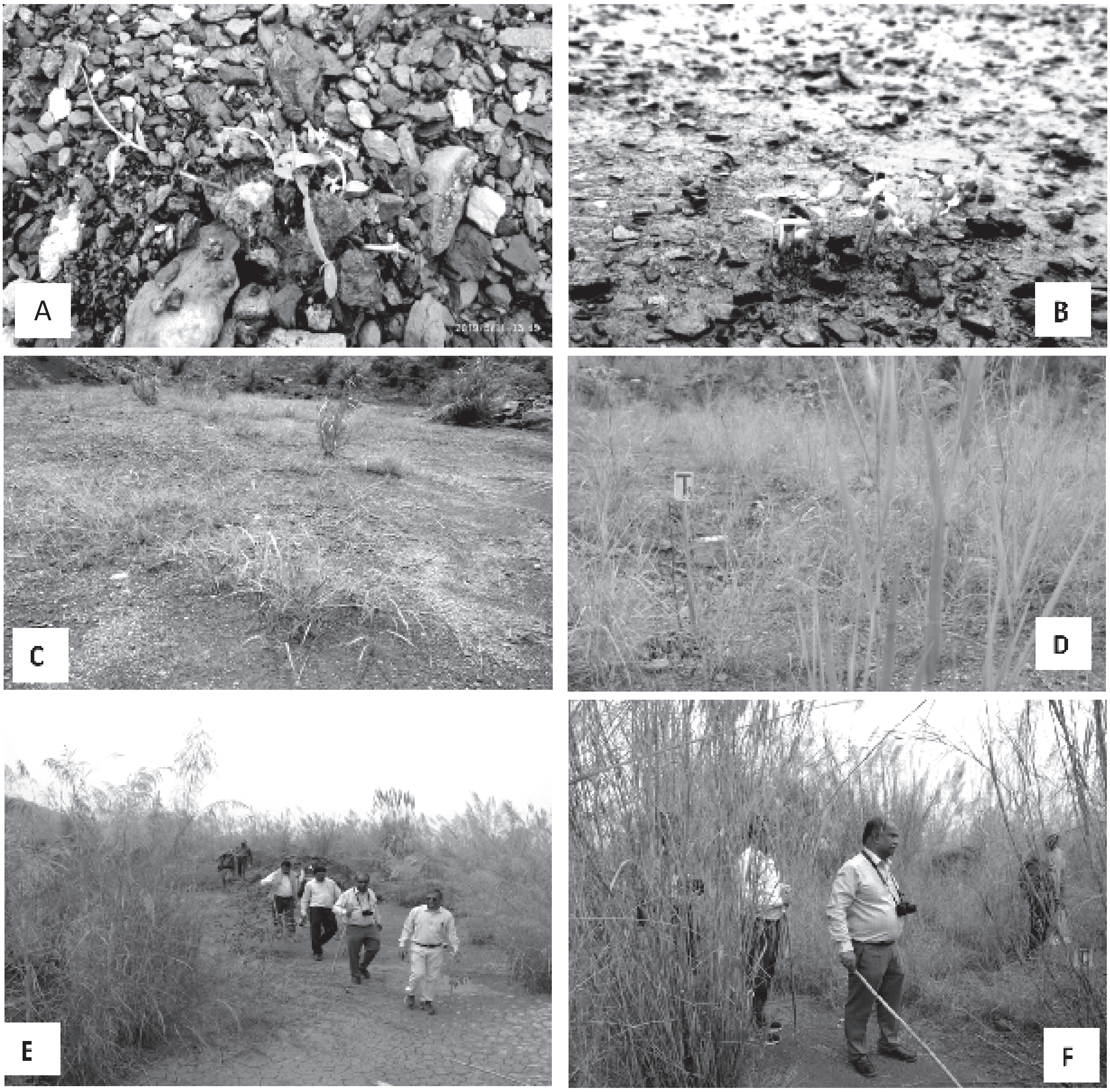

Fig. 5 : Performance of seed balls in Coal mine OBD, Tikak Colliery, Margherita [A&B]- germination of seed balls; [C]- A part of OBD 2 months after sowing seed ball;[D]- Same area 3 months after seed balls sowing; [E& F] – 1 year after sowing of seed balls.

Twenty six (26) plant species excluding the species broadcasted through seed balls were recorded from the OBD and are presented in the Table 2 and photograph of a few plants species presented in Fig. 6. Of 26 plants species belongs to 16 families which were found to come naturally on the OBD of Tikak Colliery, Margherita after sowing seed balls maximum of 8 plant species contributed by Poaceae; followed by 4 fern families, 3 were contrinuted by Fabaceae and 2 from Lamiaceae and other families *i.e.* Araceae, Asteraceae, Boraginaceae, Malvaceae, Melastomataceae, Rhamnaceae, Rubiaceae, Theaceae, Thelypterisdaceae, and Verbenaceae contributed only 1 species each (Table 2).

Majority 20 by number were herbaceous species that colonizing naturally in the OBD site after sowing of seed balls. Species like *Cassia sophera*, *Melastoma malabathricum*, *Lantana camara* and *Ziziphus jujuba* are shrubs. Two tree species *Schima wallichii* and *Callicarpa arborea* were also found to come naturally. Interestingly, the study also recorded succession of two invasive plant species namely *Chromolaena odorata* and *Lantana camara* and rest of 24 colonizers plant species were native (Table 2).

Table 2 : Natural invader plant species recorded 3 years after seed ball sowing on OBD of Tikak Colliery, Margherita

Sl. No.	Name of plant species	Local Name	Family	Habit
1.	*Axonopus compressus* (Sw.)P. Beauv.	Dolicha bon	Poaceae	Herb
2.	*Blechnum orientale* L.	Bih Dhekia	Blechnaceae	Herb
3.	*Callicarpa arborea* Roxb.	Bonmola/Gunmola	Lamiaceae	Tree
4.	*Cassia sophera* L.	Kasunda	Fabaceae	Shrub
5.	*Centotheca lappacea* (L.) Desv.	Banhpotia bon	Poaceae	Herb
6.	*Chromolaena odorata* (L.) R. M. King & H.Roxb.	Baghdhoka /Jarmani bon	Asteraceae	Herb
7.	*Colocasia esculenta* (L.) Schott	Kochu	Araceae	Herb
8.	*Cyathea dealbata* (G.Forst.) Sw	Silver fern	Cyathaceae	Herb
9.	*Cynodon dactylon* (L.) Pers.	Dubori bon	Poaceae	Hern
10.	*Desmodium triflorum* (L) D.C.	Sukula	Fabaceae	Herb
11.	*Dicranopteris linearis* (Burm. F.) Underw.	Dhekia loti	Gleicheniaceae	Herb
12.	*Erianthus elephantinus* Hooker f., Fl. Brit.	Eckora	Poaceae	Herb
13.	*Imperata cylindrica* (L.) Raeusch.	Ulukher	Poaceae	Herb
14.	*Lantana camara* (L.)	Gubon/Gu-phul	Verbenaceae	Shrub
15.	*Leucas aspera* Linn	Durun khak	Lamiaceae	Herb
16.	*Melastoma malabathricum* (L.)	Phutkala/Phutuki	Melastomataceae	Shrub
17.	*Mimosa pudica* (L.)	Nilajban	Fabaceae	Herb
18.	*Paspalum conjugatum* L.	Kodoa-dhan	Poaceae	Herb
19.	*Phragmites karka* (Retz.) Trin.ex Steud.	Khagori	Poaceae	Herb
20.	*Saccharum spontaneum* (L.)	Kohuwa /khagori	Poaceae	Herb
21.	*Schima wallichii* (DC.) Korth	Makrisal /Noga-bhe	Theaceae	Tree
22.	*Spermacoce articularis* L. f.	Gahori bon	Rubiaceae	Herb
23.	*Spherostephanos unitus* (L.) Holttum.	Bon Dhekia	Thelypterisdaceae	Herb
24.	*Stachytarpacta indica* (L.) Vahl.	Hati-huria bon	Boraginaceae	Herb
25.	*Urena Lobata (L.)*	Honborolua	Malvaceae	Herb
26.	*Ziziphus jujuba* Mill.	Bogori	Rhamnaceae.	Shrub

Discussion

The seeds of seed balls were shown differential germination and survival percentage while sowing in the backfill OBD area of Tikak Colliery, Margherita. These may be multiple factors seeds and seed balls such as variation in seed germination among the plants species such as seed type, seed dormancy, activation of enzymes and availability of essential nutrients and hormones apart from temperature, water, light, enzymes. Mueller *et al*. (2021) investigated the effect of nutrient components and design of seed ball and found higher seed germination with application of composite mixer of manure over single use of manure or soil alone. They also observed to have no relationship between seed size and germination and even no effect of seed density on germination. Tamilarasan *et al*. (2020) observed that seed balls making with vermicompost could improve growth of subabul (*Leucaena leucocephala*) seedlings under irrigated and non-irrigated (rain-fed) conditions in Krishnagiri district, Tamilnadu, India. Similar studies were also reported for improvement in seedling germination, root and shoot length and biomass accumulation while seed balls were made out of red earth and vermicompost (Chiranjeevi *et al.,* 2018; Sondarva *et al*., 2018).

The native plant growth promoting rhizobacteria (PGPR) isolates were applied in seed balls for sowing in Tikak Colliery. Because PGPRs were reported to beneficial for seed germination, seedling growth, enhance metabolic rate and other physiological activities of plants such as production of plant growth regulators, nitrogen fixation, solubilization of inorganic phosphate, mineralization of organic phosphate, siderophore production, exopolysaccharide secretion and their role in various ecosystem processes like nutrient cycling, seedling establishment and in soil structure formation and most importantly reduce heavy metal toxicity (Mushtaq *et al*., 2022) in coal mined area (Upadhyay and Raghuwanshi, 2018).

The herbaceous plant species were found to colonize more in number on the OBD site where seed balls were sown. This may happen because of the plant species that were sown with seed balls grown on the OBD along with the PGPRs and with time they provided a suitable environment and substrata for germination and survival of these natural invaders on the OBD. The soil seed bank that was used to make seed ball may be other possible source of all the species that colonized on the OBD site. Hazarika *et al.* (2006) in a different study reported 24 naturally colonizing plant species in a revegeted OBD from Tikak Colliery, Margherita. Komara *et al.* (2016) reported occurrence of higher diversity of herbaceous plants diversity after 16 years of revegetation activities in a coal mining reclamation site in East Kalimantan, Indonesia.

Conclusion

This preliminary investigation could explore potential of seed ball technology for reestablishment of herbaceous flora and other plant species in barren opencast coal mined out area of Tikak Colliery,

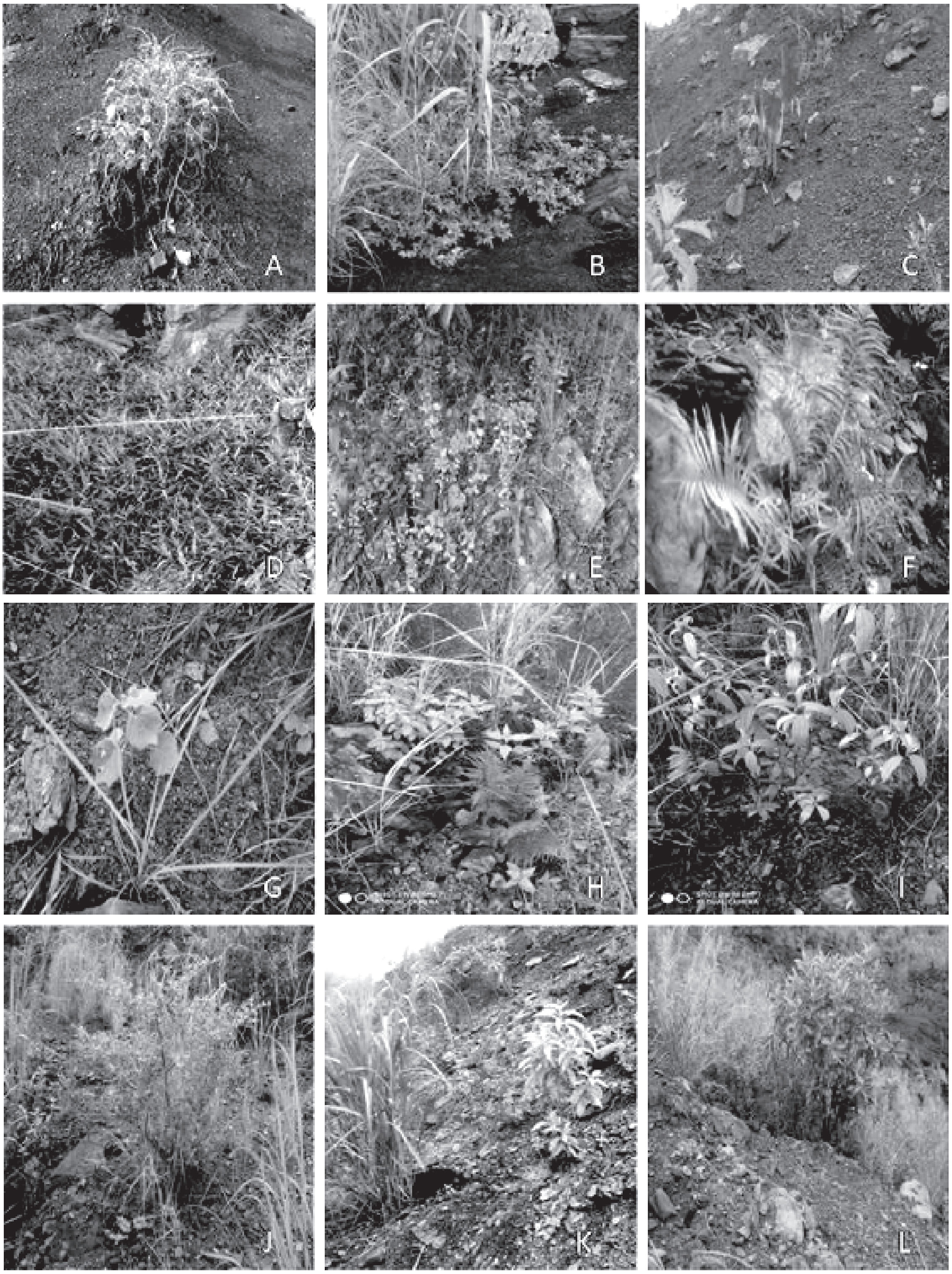

Fig. 6 : Naturally invading plant species on OBD site, Tikak Colliery after 3 years of Seed Ball Sowing [A] *Stachytarpacta indica* ; [B] *Desmodium triflorum* with *Arundo donux*.; [C] *Colocasia esculenta*; [D] *Paspalum conjugatum*; [E] *Spermacoce articularis* with *Imperata cylindrica* ; [F] *Spherostephanos unitus*; [G] *Urena Lobata* with *Vetiveria zizanoides*; [H] *Cyathea dealbata* with *Lantana camara* and *Chromolaena odorata*; [I] *Melastoma malabathricum*; [J] *Ziziphus jujuba* ; [K] *Schima wallichii* with *Phragmites karka* and [L] *Callicarpa arborea*

Margherita. The nine plant species which were sown through seed balls could colonized on the barren and futile OBD surface and soil qualities also improves with time. It is a sign of overall efficacy of seed ball technology. However, more holistic approach may be required to determine all possible factors that influence germination, growth and survival of plant species on the coal mined OBD. The authors are hopeful that this work could open up opportunity for design a replicable best management practices and deployment of seed balls as a techniques for restoration coal mined area to enhance plant species succession in a cost effective manner.

सीड बॉल्स; डिग्रैडेड कोयला खनन भूमि पुन:स्थापना में पौधों की प्रजातियों के अनुक्रमण (वंशक्रम) में त्वरितता लाते है: टिकाक कोलियरी, मार्घेरिटा, असम, भारत पर एक केस अध्ययन

पी. हजारिका, डी. दत्ता, प्रोतुल हजारिका, के. गिरि और एस.पी. दत्ता

सारांश

बीज अंकुरण और पौधों की प्रजातियों के उत्तरजीविता का अध्ययन करने के उद्देश्य से टिकाक कोलियरी, मार्घेरिटा, असम, भारत के एक ओपनकास्ट कोल माइन्ड ओवरबर्डन डंप (ओबीडी) स्थल में सीड बॉल तकनीक शुरू करने के लिए एक अध्ययन किया गया था। इसका दूसरा उद्देश्य उन पौधों की प्रजातियों का पता लगाना था जो सीड बॉल्स की बुवाई के 3 वर्ष बाद ओबीडी पर स्वाभाविक रूप से बढ़ते है। सीड बॉल्स में तैयार करने के लिए नौ देशी पौधों की प्रजातियों के बीजों का उपयोग किया गया था। देशी मिट्टी से अलग किए गए पीजीपीआर का उपयोग 10 किलो बीजों के उपचार के लिए 10-6 सांद्रता वाले पीजीपीआर के एक लीटर की दर से किया गया और अंकुरण, सुधार और उत्तरजीविता को बढ़ाने के लिए सीड बॉल्स बनाए गए। वर्ष 2018 में मॉनसून के सेट पर सभी नौ पौधों की प्रजातियों के लगभग 12000 सीड बॉल्स को बोया गया था। अध्ययन से पता चला कि 4 फलीदार प्रजातियों के बीज अंकुरण का प्रतिशत अर्थात् *क्रोटोलारिया स्ट्रिएटा, मिमोसा पुडिका, इंडिगोफेरा टिंक्टोरिया* और *पोंगामिया पिन्नाटा* 20-35% थे, जबकि *थिसानोलाएना लैटिफोलिया* को छोड़कर दो घास प्रजातियों की तुलना में जीवित रहने की दर 50-60% अधिक थी। समय के साथ, मिट्टी के भौतिक-रासायनिक मापदंडों में भी सुधार देखा गया। सीड बॉल्स की बुवाई के 3 वर्ष बाद स्थल से कुल 26 प्राकृतिक रूप से उपनिवेश बनाने वाली पौधों की प्रजातियाँ भी दर्ज की गईं। इनमें से 20 जड़ी-बूटियां थी। 8 प्रजातियों वाले पोएसी परिवार में जड़ी-बूटी वाले वनस्पतियों का वर्चस्व था। अन्य पौधों की प्रजातियों में 4 फ़र्न प्रजातियाँ, 4 झाड़ियाँ और दो पेड़ प्रजातियाँ (*कैलिकार्पा आर्बोरिया* और *शिमा वॉलिची*) शामिल हैं। प्राकृतिक आक्रमणकारियों में, 2 पौधों की प्रजातियाँ *क्रोमोलाएना ओडोरेटा* और *लैंटाना कैमारा* आक्रामक प्रजातियाँ थी। सीड बॉल तकनीक टिकाक कोलियरी, मार्गेरिटा, असम के डिग्रैडेड कोयला खनन वाले ओबीडी में पौधों की प्रजातियों के अनुक्रमण (वंशक्रम) में त्वरितता ला सकती है। इस प्रौद्योगिकी को अन्य खनन भूमि पुनः स्थापना कार्यक्रम में आगे की पुष्टि के लिए दोहराया जा सकता है।

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