SIMULTANEOUS MULTI-SITE RAILWAY EMBANKMENT STEEP SLOPES (BATTERS) EROSION CONTROL FOR A NEW SPUR LINE

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ABSTRACT
The Bauhinia Regional Rail Project (BRRP) is the construction of a 110 km spur line linking the Rolleston Coal Mine to the Blackwater rail network in Central Queensland, Australia. It will generate rail traffic of 8Mt/year of coal from Rolleston mine by 2008. BRRP is currently under construction and is expected to be completed by the end of 2005. The new spur line includes several embankments that need to be protected against erosion. Erosion of unprotected railway embankments causes serious maintenance and environmental problems within the project region. Earlier research has demonstrated that revegetation of the batters minimises the erosion risks considerably. Therefore the cost-effective erosion control strategies of the ongoing HEFRAIL Research Project are integrated with the earthworks construction. In order to reduce the treatment costs, the embankment batters are categorised with different levels of treatment. The top 3 m of batters of all embankment sections exceeding 4 m in height and embankment batters on the downstream side of the two major flood plains are receiving the full HEFRAIL erosion control treatment. The full HEFRAIL treatment involves topsoiling, grass seeding and drip irrigation system set up to aid in the grass establishment. The remaining embankment batters are receiving the full treatment except for the drip irrigation. Water from existing dams and creek water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor is being used to supply the irrigation water. The slow germination process and low germination rate of the preferred drought resistance buffel grass impose a serious bottleneck for the rapid grass establishment required for erosion control. Therefore an attempt has been made to increase the germination rate and accelerate the germination process by soaking seeds for 5 mins in water and pre-germinating in potting mix before spreading on the batter surface. Sulphuric acid treatment in the laboratory produced excellent results but has limitations for mass treatment, and it is being further investigated for improvement. Good emergence of buffel and Rhodes grass on the railway batters within a week of seeding with pre-germinated seeds has been observed where the irrigation water is secured. In general very good grass coverage is being achieved within 8 weeks after seeding with irrigation.

INTRODUCTION
Xstrata's Bauhinia Regional Rail Project (BRRP) is the construction of a 110 km spur line linking the new Rolleston Coal Mine to the Blackwater rail network at Kinrola in Central Queensland, Australia (Figure 1). Big cuttings and embankments, and bridges and culverts, are major construction activities as a result of the route crossing various terrains from rocky mountainous country in the north to expansive black soil river plains in the south. With a total cost of AU$240M, BBRP will generate rail traffic of 8Mt/year of coal from Rolleston mine by 2008 (http://www.networkaccess.qr.com.au/customer/Bauhinia/Bauhinia.asp). BRRP is currently under construction and is expected to be completed by the end of 2005.

Erosion of railway embankments batters within the region increases maintenance costs, risks of outages and derailments, interruptions of normal train operations and environmental degradation. Therefore railway embankment erosion control treatments have been incorporated in the BRRP earthworks construction. The QR (Queensland Rail) funded HEFRAIL Research Project with Central Queensland University has demonstrated that 60% grass cover on railway embankment batters reduces erosion by over 90% compared with the bare scenario. Further increase in grass cover increases the erosion reduction up to 99% (Gyasi-Agyei et al, 2001; Gyasi-Agyei, 2004a; Gyasi-Agyei, 2005). HEFRAIL processes involve amelioration of the surface soil with lime or gypsum where it is established that the surface soil is dispersive, sodic, saline and/or has extreme pH. In addition, fertilisers are spread to provide a conducive growth medium for grasses. Where cheap mulch (waste ballast or erosion control blanket) is available it is spread or laid to protect grass seeds/ seedlings and ameliorants from washout by high intensity and short duration rainfall events that characterise the semi-arid environment. A cost-effective drip irrigation system to aid grass establishment is an integral part of HEFRAIL processes. Water may be sourced from existing water mains, existing or temporary excavated ponds/ dams/ creek water holes, or temporary tanks filled periodically by water trucks. The choice of water source depends on availability and costs (Gyasi-Agyei et al, 2001, 2003; Gyasi-Agyei, 2003, 2004a, 2004b; Gyasi-Agyei & Nissen, 2003).

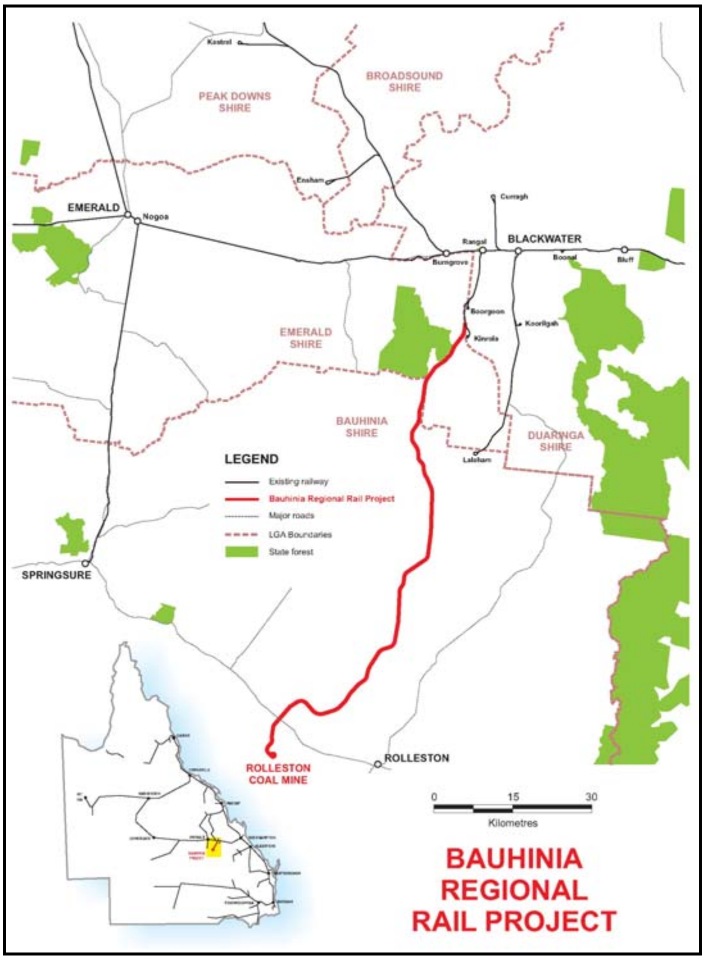

Figure 1: Location of Bauhinia Regional Rail Project (courtesy QR Network Access)

Since BRRP is a new construction, topsoil within the corridor was stripped and stockpiled for later spreading on the embankment batters. Hence all embankment batters of BRRP are topsoiled so there is no need for lime or gypsum application. Also, mulch application was not considered since no waste ballast is available for the new railway line construction. Hence the HEFRAIL processes have been limited to seeding with fertiliser and drip irrigation from cheap water sources to aid grass establishment. Hereafter these processes are referred to as HEFRAIL BRRP full erosion control treatment. Given the large scale nature of the project, the slow germination process and low germination rate of the preferred drought resistance buffel grass in the dry subtropical environment, and time constraints, acceleration of the seed germination process was very imperative.

In order to reduce the treatment costs the embankment batters were categorised with different levels of treatment. The top 3 m of batters of all embankment sections exceeding 4 m in height and the downstream side embankment batters of the two major flood plains (Comet River and Humboldt Creek) are receiving the HEFRAIL BRRP full erosion control treatment. Batter sections falling outside these criteria are topsoiled and seeded with fertiliser but without irrigation. Table 1 shows the location of the 37 sites receiving the HEFRAIL BRRP full erosion control treatment.

WATER SOURCES

Due to cultural heritage issues, new ponds could not be constructed for HEFRAIL BRRP erosion control treatment. Water from existing dams and water holes, from earthworks construction water tanks, and from road delivery to temporary tanks located within the rail corridor is being used to supply the irrigation water. The water sourcing process involved consultation with adjoining property owners for water availability on their property for HEFRAIL use. The cheapest water sources selected are presented in Table 1 with the quantity of water required per site. Water from existing dams, and water holes, accounts for 44% while only 17% of the water requirement is drawn from construction tanks. The remaining water (39%) is drawn from temporary tanks filled periodically by water trucks. The estimated water demand is for scenarios where the treatment is implemented during the wet season, and irrigation is used to supplement natural rainfall. Since the project is spanning through the dry season the water demand may be higher, and for some sites the grasses may rely only on irrigation water. The cost of water varied between AU$1 to AU$17 per kL. BMA did not charge for pumping water from their dam to supply sites 1 through 4.

Table 1: Embankment locations receiving HEFRAIL BRRP full erosion control treatment

Site No.	Chainage		Quantity (kL)	Source	Site No.	Chainage		Quantity (kL)	Source
	from (m)	to (m)				from (m)	to (m)		
1	1920	2240	355	dam	20	67940	68120	200	cons. tank
2	3240	3460	244	dam	21	69360	69480	133	cons. tank
3	4070	4120	55	dam	22	71300	73200	1405	temp. tank
4	4520	4620	111	dam	23	74530	74850	355	temp. tank
5	6120	6260	155	water hole	24	75320	75600	310	temp. tank
6	10860	11200	377	temp. tank	25	76560	76860	333	temp. tank
7	12880	13480	665	temp. tank	26	77950	78300	388	temp. tank
8	15920	17340	1574	cons. tank	27	81940	82480	599	cons. tank
9	19260	19360	111	temp. tank	28	86920	87040	133	dam
10	28540	28660	133	water hole	29	87520	87720	222	dam
11	29040	29620	643	water hole	30	88230	88520	322	dam
12	31100	31320	244	temp. tank	31	89280	89750	521	dam
13	35240	35400	177	dam	32	92430	92530	111	water hole
14	40340	40420	89	dam	33	95000	95140	155	temp. tank
15	44480	44580	111	temp. tank	34	96600	96780	200	temp. tank
16	50300	52870	1900	dam	35	101820	102400	643	temp. tank
17	53400	53700	222	dam	36	103400	103580	200	temp. tank
18	54200	55300	813	dam	37	105300	105830	588	temp. tank
19	61570	61640	78	dam					

IRRIGATION SYSTEM

Three rolls of driplines at 1 m spacing are set up at the top batter sections of the embankments receiving HEFRAIL BRRP full treatment, thus treating only the top 3 m batter length. For the flood scour protection areas (i.e. Comet River and Humboldt Creek) 4 rolls of driplines are set up on the downstream side of the embankment treating 4 m batter length. This strategy is for further reduction of the erosion control treatment cost of BRRP. It is hoped that grasses established at the top sections will spread runoff generated at the top of the embankment thereby minimising the erosion impact on the batters. Moreover, the grasses being runners are expected to gradually spread and cover the whole batter sections within the next two or three wet seasons.

The mains taking water from the sources to the embankment bottom are 40 mm poly pipe. Filters are installed to filter the water before entering the irrigation controller valves, or the driplines where controllers are not installed. Single and four-station battery operated controller valves are used at different sites to schedule irrigation. The submains taking water from the mains to the driplines are 25 mm poly pipe. Different 20 mm diameter driplines with emitter discharge of 1.5 L/h, 2.5 L/h or 3.8 L/h and emitter spacing of 0.3 m, 0.4 m or 0.5 m are being tested. The total area to be irrigated at each site is divided into bays. Bailing twine anchored to 25mm square cross section and 900mm long wooden stakes installed at the top of the batters are used to support the driplines at 5 m spacing. Fire fighting pumps (5.5 and 6.5HP) are used to pump water through the irrigation system. Apart from the dripline layout on the batters, the irrigation system differed from site to site. The first four sites, sourcing water from the same dam, are used to demonstrate the intricacies of the irrigation design.

SITES 1, 2, 3 AND 4 IRRIGATION SYSTEM SET-UP

Figure 2 shows the location of the first four sites. BMA South Blackwater Mine dam, about 400 m from the railway corridor, is the water source for these sites. Solar pump (Figure 3) is used to pump water from the dam to a temporary tank (Figure 4) located within the rail corridor. The average flow rate of the solar pump to the temporary tank is only 30 L/min. A float valve at the end of the inlet pipe to the temporary tank cuts off flow when the tank is full. The pressure in the delivery pipe is then increased and the pressure switch connected to the solar pump shuts down the solar pump automatically. This arrangement prevents temporary tank overflow minimising water wastage. A higher flow rate (60 L/min) can be achieved with fire fighting pump but, due to dam access restrictions, a maintenance free solar pump was the preferred option. Since the water demand for irrigation is more than the capacity of the solar pump, once a week a petrol fire fighting pump (6.5HP) is run for a few hours to pump water from the dam to fill the temporary tank. This measure ensures adequate water supply for irrigation during the week.

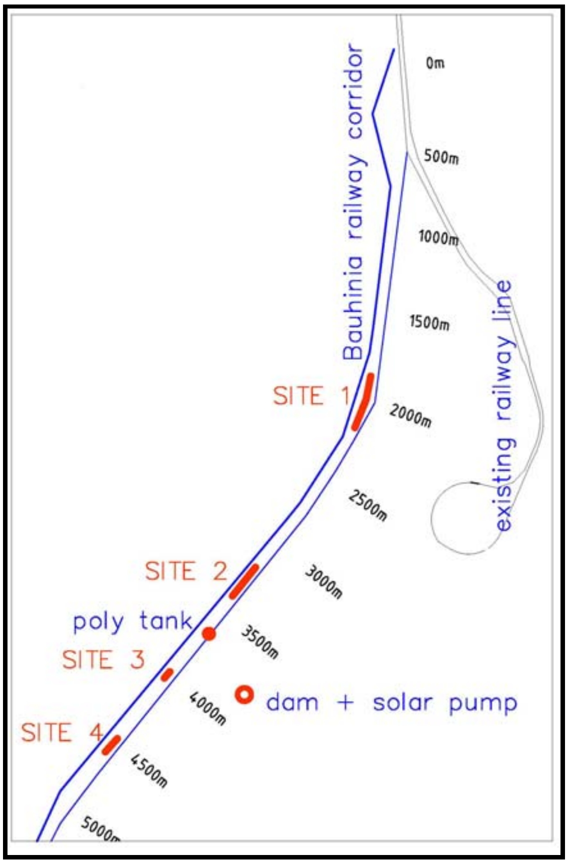

Figure 2: Location of the first four sites receiving HEFRAIL BRRP full erosion control treatment

The irrigation design of the four sites is shown in Figure 5. Culverts provide access to transfer water to the other side of the embankment. A 1.5 L/h discharge and 0.3 m emitter spacing driplines were used at this site. Six single-station controller valves were installed to schedule irrigation of the combined 22 bays of these sites. Table 2 presents the initial daily irrigation schedule which is subject to change after some time. This was based on the results of previous studies (Gyasi-Agyei, 2003, 2004a, 2004b).

Figure 3: Solar pump and panel at BMA dam

Figure 4: Temporary tank and petrol pump for irrigation of Sites 1 through 4

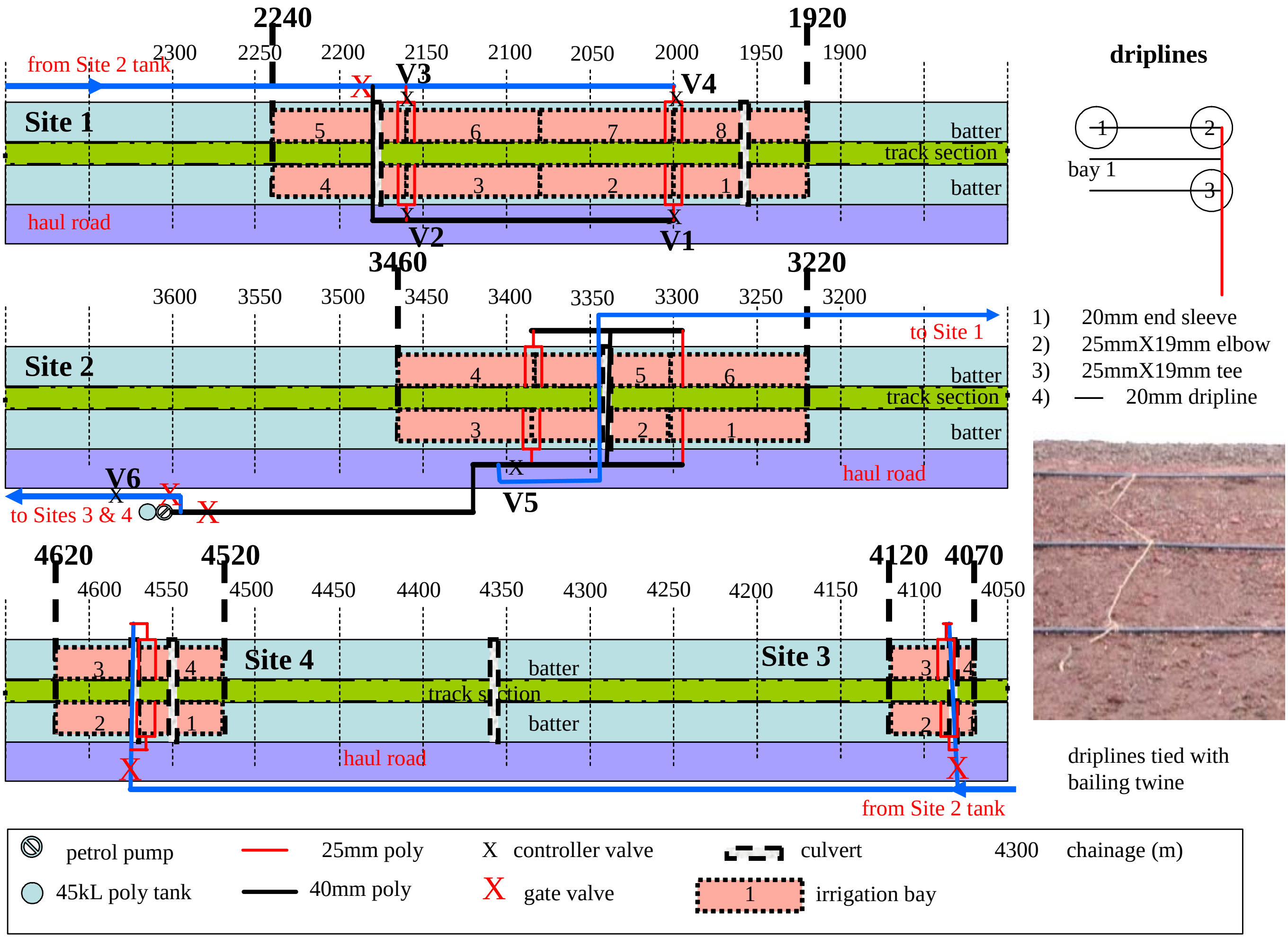

Figure 5. Irrigation system set up at the first 4 sites

Except for Site 2, all batters are irrigated for 45 mins allowing 2 mins for valve change over. Site 2 batters are irrigated for 15 mins since, being closest to the pump, this site experiences the highest pressures and the wetting pattern is satisfactory within this set time. Each bay is irrigated once a day but the four-cycle setting allows irrigation to commence anytime after 8.30am. An irrigation cycle for these sites lasts for 4 hours. Since it takes a little over 2 hours to empty a full original fuel tank when pump is running continuously, an improvised 20 L fuel tank (white tank in Figure 4) had to be put in place. Before leaving the site, the operator puts 6 L of unleaded petrol into the improvised fuel tank for the pump to run for at least 5 hours. This allows a repetition of irrigation of the first section which might have started in the middle of its cycle.

Table 2: Irrigation schedule of sites 1 through 4

Valve	1	2	3	4	5	6
start 1	8:30am	9:15am	10:00am	10:45am	11:30am	11:45am
start 2	12:30pm	1:15pm	2:00pm	2:45pm	3:30pm	3:45pm
start 3	4:30pm	5:15pm	6:00pm	6:45pm	7:30pm	7:45pm
start 4	8:30pm	9:15pm	10:00pm	10:45pm	11:30pm	11:45pm

SEED GERMINATION IMPROVEMENT

Buffel grass (*Cenchrus ciliaris L.*) is one of the preferred pasture grasses in Central Queensland, Australia, due to its perennial growth habit, drought tolerance and stable productivity with respect to soil and climatic variability. Cattle stations along the Bauhinia railway corridor are predominately under buffel grass supporting a sizable beef industry of the central highlands. The erosion control strategy of HEFRAIL Project focuses on the revegetation of the batters employing different grasses such as Red Natal, buffel, sabi, Indian blue and Rhodes. However, growers concern of potential invasion by other grasses in the buffel paddocks has prompted HEFRAIL Project to choose buffel as the priority species in the revegetation program. As forage, buffel grass is sown on soils of reasonable fertility in regions with between 300 mm and 1000 mm annual rainfall. The degree of success of establishment of surface-sown seeds largely depends on the availability of soil water for seed germination. Cook (1975) revealed that germination of buffel grass seeds in the soil surface is restricted by their ability to imbibe water, a consequence of a low soil-seed contact. Soil disturbance is generally essential for initial establishment. Thin topsoil, exposure to sun, low soil moisture content, heterogeneous soil bed, and unstable soil structure compounded by steep slopes are some of the challenges for an effective revegetation of the batters with buffel.

Inherently low germination of buffel seed is a major bottleneck for an early establishment and development of immediate grass cover of soil under the batters environment. The commercial buffel seed lot are marketed generally with the maximum seed germination of 20%. This rate is further reduced by the unfavourable batter environment. The need for rapid grass cover of the batters to minimise the risk of erosion of the loose soil calls for acceleration of the seed germination process, and an increase in the germination rate. Options for improving buffel grass germination consists of different seed treatment methods such as smoking the seeds, mixing seeds in ash, soaking, hammer milling of the seeds and treatment with sulphuric acid (Dowling et al, 1971). Experiments to enhance germination of Gayndah buffel seeds with concentrated and a low strength sulphuric acid were conducted. The results suggested that soaking of seed in the concentrated sulphuric acid up to two minutes followed by mixing in potting-mix as germination media increase the seed germination significantly. Any further detention of seeds in the acid reduced the germination rate. Germination was as high as 95% with concentrated sulphuric acid treatment for 2 minutes as opposed to 5% germination in the control (Figure 6). The control treatment consisted of sowing untreated seeds in the soil with initial soil water content close to field capacity. Since there is no addition of water the soil moisture declines with time, resembling seeding after rainfall in the field conditions. Such practices are common for buffel production in dry sub-tropical and tropical environments similar to that of Central Queensland. Therefore inherently low germination of buffel in the batter environment is further compounded by the unpredictable low soil moisture, which has severe consequences on rapid cover development. Hence, seed treatment and maintenance of soil moisture until the germination process is completed are considered mandatory for producing effective and rapid buffel grass cover for erosion control. The seedling emergence occurred at 3 days after seeding when placed in a controlled environment chamber at 28 ºC, 16 hours light and 8 hours dark. It was observed that germination percentage declined with dilution of the sulphuric acid. Dipping duration up to 5 minutes did not have any significant effect when sulphuric acid was diluted (Figure 6). Therefore the use of diluted sulphuric acid for the buffel seed treatment is of very limited use. The results of the sulphuric acid treatment under controlled environment are very encouraging. However, bulk seed treatment with concentrated sulphuric acid has some problems such as fume development, potential health hazards and safe disposal after treatment.

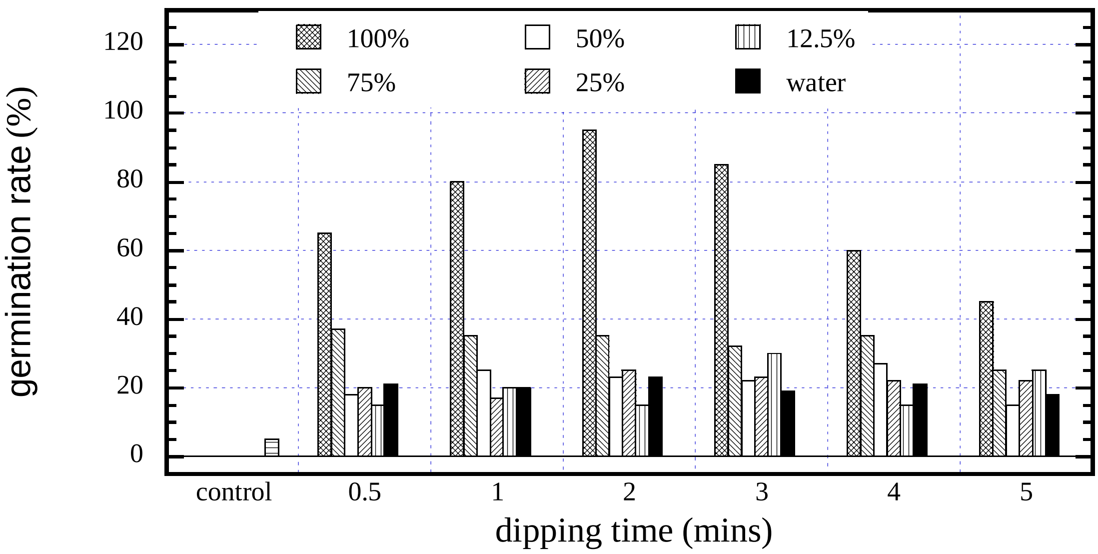

Figure 6: Effects of soaking Gayndah buffel seeds in sulphuric acid (SA) at different concentration and pure water for different dipping duration on germination rate (seeds embedded in potting mix after designated dipping time).

Table 3: Effect of soaking (in water) and media (potting mix and soil) on germination percentage of Gayndah buffel seed in growth cabinet (28 ºC and 16 hours light and 8 hours dark period)

Dipping time (mins)	0	5	15	30	60	120	240	720	1440
Potting mix	26	33	27	23	18	12	10	5	4
Soil	15	20	16	13	8	5	4	3	1

An alternative simpler and large-scale practical approach for improving the buffel seed germination is by soaking the seeds in water and pre-germinating in potting mix or soil media maintained at a constant soil moisture close to field capacity. Maintenance of constant soil/media moisture helped improve germination of soaked buffel seeds in the experiment. This suggests that batters should be kept close to field capacity after seeding until acceptable germination rate is achieved. Continued irrigation after germination will ensure rapid grass cover. However, results presented in Table 3 show that prolonged period of soaking in deep water reduced the seed germination rate. It was observed that soaking the seeds between 5 and 15 minutes before pre-germinating in potting mix yields about 30% germination rate. Also pre-germinating in potting mix produced better results than the soil medium. Extended soaking impairs seed aerobic respiration and leads to fermentation damaging the germinability of the seeds. Optimum soaking helps seed imbibe and initiate the germination process of otherwise dormant seeds. Soaking possibly also helps to remove germination inhibitors associated with the buffel seeds. Further research is required to elucidate the mechanism of seed dormancy in buffel and methods to enhance the seed germination to expedite the germination process and, thereby, the rapid grass cover on the railway batters.

RESULTS OF THE FIELD TRIALS

The embankments are progressively released for HEFRAIL treatment as the earthworks construction progresses. As at 30 June 2005, 21 out of the 37 HEFRAIL BRRP full treatment sites have been released. Sixteen released sites have been treated but at different times (Table 4) and, therefore, are at different levels of grass growth. Bare Gayndah buffel are soaked in water for 5 minutes before pre-germinating in potting mix, a process taking between 3 and 4 days. It takes less than 2 days to pre-germinate coated Katembora Rhodes seeds in potting mix. The pre-germinated buffel and Rhodes are spread on the irrigated batter sections together with coated Gayndah buffel and coated Katembora Rhodes. Before spreading the seeds it is ensured that the irrigation system is working very well. In this way, the germination process is continued and rapid grass growth is achieved within a short period. Some sites require a second round of seeding as a result of massive washout by rainfall. Poor germination rate, or grass growth, can result from a combination of factors including irrigation system malfunction, interruption in irrigation water supply, or just poor germination rate. Spreading seeds sparingly at poor germination sections is imperative to ensure the desired percentage grass cover. It takes some time before the wetting fronts of the driplines join, and patching in between the driplines may be necessary. For the non-irrigated batter sections a seed mixture of coated Gayndah buffel, coated Katembora Rhodes and bare Japanese millet is being spread.

Apart from initial problems at some sites, the irrigation systems (including the pumps) have been functioning effectively and reliably. Figure 7 shows some sites at different levels of grass growth. It needs to be underlined that the sites have been treated at different dates as indicated in Table 4. Despite above average rainfall during summer months (December to February), the non-irrigated batter sections of earlier sites established (Sites 11, 12 and 13) show poor grass growth. The initial grasses established at these sections have died back after a few weeks of dry spell. As observed at all treated sites (eg in Figure 7), grass growth at the irrigated batter sections is very encouraging. As a matter of fact, where irrigation is secured, over 80% grass coverage is achieved within 8 weeks after seeding.

Table 4: Dates of seeding

Site No.	First Seeding	Second Seeding	Site No.	First Seeding	Second Seeding
1	15/03/05	23/04/05	13	02/02/05	-
2	19/03/05	-	14	02/04/05	-
3	08/04/05	-	29	24/04/05	-
4	08/04/05	-	30	24/04/05	-
5	02/04/05	-	31	15/04/05	24/04/05
10	20/03/05	-	32	07/04/05	24/04/05
11	15/12/04	20/03/05	33	02/04/05	22/04/05
12	15/11/04	-	34	09/03/05	-

Site 30 was seeded on 24/04/05

Site 12 was seeded on 15/11/04

Site 10 was seeded on 20/03/05

Site 13 was seeded on 02/02/05

Site 13 was seeded on 02/02/05

Site 34 was seeded on 09/03/05

Figure 7: Different stages of grass growth on the batters at various sites

CONCLUSIONS

This paper has demonstrated the large-scale applicability of HEFRAIL erosion control processes at multi-sites at the same time. Where irrigation is secured, over 80% grass cover is achievable within 8 weeks greatly minimising the risk of railway batter erosion. Poor grass growth has been observed at all non-irrigated batter sections. Hence further development and integration of the irrigation system is paramount. Pre-germination of seeds in potting mix before spreading on the batters is very promising. However, further research is required to improve the sulphuric acid treatment which yielded over 95% germination rate in the laboratory.

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