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Executive Summary

The project activity aimed at reclamation and rehabilitation of backfilled bauxite mine areas of Pakhar and Bagru plateaus at Lohardaga were pursued by The Energy and Resources Institute (TERI) in lieu of fulfilling its commitment of afforesting 25 ha of mine spoil area in a period of three years starting from April, 2010 to March, 2013. Having vast experience of TERI in the field of restoration and rehabilitation work, TERI initiated its project activity from April, 2010 started with preliminary surveys, stakeholder consultation, and provided technical & scientific consultation of afforestation activities to HINDALCO staff. This project was envisaged to develop a green cover in mine spoil areas while simultaneously addressing the livelihood issues of socio-economically marginal communities of surrounding villages through afforestation activity. Thus, accordingly vegetative measures were taken to address short, medium and long term benefits of the under privileged communities as well as cost benefit activities were achieved to yield maximum output (i.e. green cover and productive land) in a limited use of resources. Further soil and moisture conservation activities were also undertaken right from the inception of project to ensure efficient and effective reclamation of severely degraded areas.

First phase of the project activities were started in 2010, wherein 3 ha of backfilled mine area at Pakhar plateau was treated and afforested with near about 2,635 plants. These plants were chosen on the basis of their wider adaptability to eco physiological conditions, rapid growth, their capacity to endure water stress & absorbance to climatic extremes after initial establishments, their atmospheric nitrogen fixation abilities and to the most their ability to boost local economy via fruits, timber, fodder, biomass and medicinal enriched produces. Thus 12 tree species i.e. Anola, Bel, Harar, Jamun, Neem, Bakain, Bahera, Imlee, Arjun, Bamboo, Kanji and Ber and two grass species i.e. *Sesbania sesban* and *Stylo hamata* were introduced during the first phase of afforestation activity in 2010. Further, field visits by TERI experts during first year assessed average growth rate of all the tree species, which was due to less irrigation and ineffective protection while decent growth was observed next year due to effective fencing and irrigation facilities at the plantation site.

During second phase of project in 2011, around 12.58 ha of land was treated and afforested, of which 8.10 ha was covered from Pakhar plateau and 4.00 ha was covered from Bagru plateau and rest 0.48 ha area was from railway track near Lohardaga. Overall, 15,157 tree saplings of various species such as Mango, Guava, Aonla, Arjun, Bahera, Bel, Ber, Bamboo, Babul, Bakain, Gulmohar, Harar, Imlee, Jamun, Jack fruit, Khair, Karanj, Mahuwa, Neem, Citrus fruit, Pear, Shisham, Acacia, Sagwan, Cassia, Ashok, Jakranda and Gamhar were planted at both the sites in this phase. Apart from plantation activity, soil and moisture conservation activity were also constructed during first and second phase of project site. Approximately 15 percolation tanks of size 2m X 2m X 2m were constructed during first phase of the project, while contour trenches and contour terraces were excavated and demonstrated at the sloping areas to the field staff of HINDALCO during the second phase of the project.

During the third phase of the project in 2012, around 11.60 ha area of the backfilled mines area from Pakhar and Bagru plateaus were treated and afforested. Of which approximately 7.92 ha area was afforested in Pakhar plateau and rest 3.68 ha area from Bagru plateau. Further during this phase in-house production of healthy saplings was raised in the Hutap nursery wherein total 22,700 saplings were produced. Of which approximately 11,497 saplings were transported to Pakhar plateau and approximately 4,330 saplings to Bagru

plateau for afforestation activities and rest of the saplings were utilized by HINDALCO Ltd for plantation in other sites. Of the total transported saplings, around 8,695 and 3,580 saplings were planted at Pakhar and Bagru plateaus respectively thus amounting to a total of 12,275 saplings of around 30 species.

A toe wall and few diversion channels were also constructed in addition to contour trenches and contour terraces to capture the problem of soil erosion at the sloping area during this phase. Additional activities of bio fencing through *Vitex negundo* species was also carried out at the boundaries of the plantation area of Pakhar mines during this phase.

Besides, restoration through agriculture activity was also done in an endeavour to demonstrate the capability of land to yield agricultural crops at the project site. Therefore, a part of back filled area of bauxite mines at Bagru plateau (i.e. 0.75 ha) was reclaimed through cultivating agriculture crop such as pigeon pea (*Cajanus cajan*).

Capacity building and stakeholder consultation was part and parcel of project activity. Right from project planning till its implementation, all the stakeholders were involved and their concerns were properly addressed. HINDALCO's field staffs were trained in scientific and systematic manner of nursery establishment, raising saplings, maintenance, shifting and grading of the saplings etc. Under the capacity building program, various aspects of soil and moisture conservation activities were also demonstrated to the HINDALCO staff at the plantation sites.

Needs of socio-economically marginal communities of surrounding villages were identified through consultation with them and according to ecological condition of project sites various species of horticulture value, medicinal value, timber value and biomass were raised at project sites.

Moreover, systematic data collection and robust monitoring framework was followed regularly to measure the growth parameters such as height, collar diameter, number of leaves, branches, crown diameter and shoot length of each tree species from time to time throughout the project duration. Three research plots for first phase plantation site and six research plots for second phase plantation site, were maintained to evaluate the growth status of each tree species under the six different growth parameters (i.e. Height, Collar diameter, Crown diameter, Number of branches, Shoot length and Number of leaves) while performance of grass species were measured under two parameters i.e. Number of tufts and Shoot length. Both the graphical and tabular analysis was done in detail under each parameter for all the research plots of both the phases of plantations and their growth pattern was evaluated.

The findings revealed that the plantation activities in both the phases have shown impressive growth rate despite some mortality. In the first phase of plantation site, height of Harrar, Bakain and Anola species showed an impressive average increment of 481%, highest among all the planted species. While, Jamun and Imlee showed an average increment of 87%, which is lowest among all the planted species. Similarly, average collar diameter for all species was found 486%, wherein Harrar, Imlee and Bahera species showed an average increment of 723% (highest) as these species has natural tendency to grow faster at initial stage, while species of Jamun and Kanji showed an average increment of 239% (lowest) as they are slow growing species as compared to the other planted species.

In the second phase of plantation site at Pakhar, species of Ber, Bakain, Arjun and Neem have shown maximum average height growth of 138%, 111%, 99% and 98% respectively and species of Shisham and Mango has shown lowest increment rate. Similarly, collar diameter

of 15 species out of 17 species has shown an average growth rate of 109% at Pakhar plateau. This clearly indicates the robust growth trajectory of all the species at the project site. Moreover, some species of Guava at Pakhar site has sprouted fruits which are a true indicator of restoration of nutrients at project sites. Further, the entire hybrid Anola and Naspati which were purchased from outside nurseries during first phase of plantation died while Anola raised in the Hutap nursery has shown notable growth rate. Hence, it seconds the importance of in-house capacity building at Hutap nursery, which had provided quality saplings for afforestation activity in the third phase of plantation activity. Consultation and discussion with local dwellers revealed that the local people were satisfied with the plantation activity as it has converted their dump and degraded land to a productive land while it will also cater to their local economy through horticultural and medicinal plants.

Thus, overall 27.18 hectare of mine spoil area got rehabilitated and reclaimed through an afforestation activity of approximately 30,067 plant species of various types. Site specific techniques were adopted to restore the region and make the project site admiringly green and producible to local surroundings. But the project site needs to be continuously monitored and protected against uncontrolled grazing and any leakages. Facility of irrigation and market development is highly recommended for effective production at project site as well as for economic empowerment of under privileged communities of surrounding villages.

Progress Report on "Reclamation of back filled Bauxite mine areas through afforestation activities at Lohardaga, Jharkhand"

Introduction

Hindustan Aluminum Company Ltd (HINDALCO, Ltd.), one of the largest aluminium producing company of the country and The Energy and Resources Institute (TERI), one of the renowned research organization of country mutually agreed on the afforestation activities and restoring the plateaus of Pakhar and Bagru of Lohardaga, Jharkhand covering 25 ha of land during the three years duration starting from April, 2010 to March, 2013. TERI has initiated the project activities in April, 2010 and treated 3 ha area against the target of 5 ha from Pakhar plateau during the first phase. While in the second phase, 12.58 ha of backfilled mine areas against the target of 12 ha was afforested of which 8.10 ha was covered from Pakhar plateau and 4 ha was covered from Bagru Plateau and rest 0.48 ha area was from railway track near Lohardaga. This progress report is in continuation with the earlier two reports submitted to HINDALCO Ltd on the afforestation and treatment of the backfilled bauxite mine areas of Pakhar and Bagru plateaus.

During the third phase of the project in 2012, around 11.60 ha area against the target of 10 hectare area of the backfilled Bauxite mines area from Pakhar and Bagru plateaus were treated through afforestation activities. Major plantation activity was done in Pakhar plateau, which is around 7.92 hectare while rest was from Bagru plateau, which is around 3.69 hectare. Of the total area from Bagru plateau, around 0.75 ha was covered under the agricultural crops.

Further production of healthy saplings were also carried out at in-house Hutap nursery, wherein total 22,700 saplings were raised of which approximately 11,497 saplings were transported to Pakhra plateau and approximately 4,330 saplings to the Bagru plateau. Thus total 15,827 saplings of various species were transported to both the project sites for afforestation activities. While, remaining saplings in the nursery will be utilized by HINDALCO for plantation at other sites. Of the total transported saplings, around 8,695 and 3,580 saplings were planted at Pakhar and Bagru plateaus respectively. Thus total 12,275 saplings of various tree species were planted at both the project sites in 2012.

Major tree species planted during the third phase of the project at both the mining areas were Anola (*Emblica officinalis*), Bahera (*Terminalia belerica)*, Harar (*Terminalia chebula)*, Guava (*Psidium guyava*), Neem (*Azadirachta indica)*, Jamun *(Syzygium cumini)*, Imlee *(Tamarindus indica)*, Arjun (*Terminalia arjuna)*, Bamboo *(Bambuseae),* Karanj *(Pongamia piñata)*, Shisham (*Dalbergia sissoo)*, Khair (*Acacia catechu*) and Sagwan *(Tectona grandis)* etc. Among the grass species, seed of *Stylosanthes hamata, Indo pogon, Sesbania sesban,* were sown in backfilled area through broadcasting while in the sloppy areas the same grass species along with Vilayti Mehdi *(Dodonaea vescosa)* and Khair (*Acacia catechu)* were sown at the contour terraces through seed sowing in palm size pit.

Generally, average pit size for the tree species was kept at 0.45 m x 0.45 m x 0.45 m and plant to plant distance was kept 3 m x 3 m in the plain of the back filled area. While in the sloppy areas plant to plant distance and line to line distance was kept at 2 m whereas in some places this distance had varied because of the difficult topological conditions and gradient of slope.

Thus, variation of plant to plant and line to line distance of up to 4 m was also set aside during the plantation activity. At sites where distance between plant to plant was 4 m, then the seed sowing (of *Dodonia vescosa or* Acacia *catechu*) activity was done in the pit size of 0.30 m x 0.30 m x 0.30 m between such two plants to utilize the space between the plants as well as to capture soil erosion. Simultaneously for lease boundary identification via green cover, afforestation activity was done mainly in Pakhar Bauxite mine areas in a triangular fencing keeping a space of 3 m x 2.5 m. Additionally, a part of back filled area of bauxite mines at Bagru plateau (i.e. 0.75 ha) reclaimed through cultivating agriculture crop pigeon pea (*Cajanus cajan*). Restoration through agriculture activity was done in an endeavour to demonstrate the capability of land to yield agricultural crops at the project site.

Apart from the plantation activities, various soil and moisture conservation activities were also achieved through contour terracing, contour trenches, construction of toe walls & distribution channels at the project site. In the slopes of the dump areas where there was sharp steepness & abundant loose soil, at such sites soil conservation measures were adopted by excavating contour terraces of 0.60 m wide before plantation activity. These measures had created space for pit digging, planting of saplings and seed sowing of grasses & bushes in an undulating terrain. Furthermore, various diversion channels were also constructed along the sloppy areas of project site and railway site. The formation of these diversion channels helped in reducing the rate of the soil erosion, gully formation and water runoff from the top of the slopes at the mine spoil areas.

Soil erosion in the slopes of railway track siding for loading of bauxite at Lohardaga was also one of the major problems at the project site. As per the suggestion of TERI, this year HINDALCO started construction of toe walls made up from stone masonry mortar with cement and coarse sand to capture the problem of soil erosion. Diversion channels were also made at the bottom of the slope to divert the flow of run-off water from railway tracks. Besides seed sowing of grasses and bushes, 1200 tufts of lemon grass (*Cymbopogon citratus*) were also planted in the slope of railway siding to increase the green cover in this phase.

One of the additional activities that were initiated in the third phase of the project was bio-fencing of the plantation area at Pakhar mine. Since the barbed fencing with wooden poles in Pakhar mines had been seriously objected by the forest department because of use of wooden poles. Henceforth, TERI recommended a cost effective and easily implementable solution of bio-fencing through Chaste tree (*Vitex negundo*) species. This would help in increasing the green shield of the project site as well as delineating the project boundaries.

Project activities during the third phase of the project (April 2012 - March 2013)

Raising saplings in the HINDALCO's nursery

In order to achieve the rest of the targeted green cover (i.e. on 10 ha backfilled mine area) in the third phase of project, the seed germination process was initiated well in advance mainly to raise the healthy saplings in adequate number at Hutap nursery. Further, the procurement of quality seeds of Bahera, Harar, Chilbil, Neem, Mahuwa, Guava, Jamun, Bans, Khair, Mansiam, Shisham etc. was done at the right time during August, 2011 to March, 2012 for effective seed germination. The details of procurement can be referred from **table 1**.

Table 1 Seeds of tree and grasses species procured from various sources

Sr. no	Species	Quantity of Seed (in kgs)	Resources
1	Bahera (*Terminalia belerica)*	50	Collected from AsharamVidhyalaya Lohardaga
2	Harar (*Terminalia chebula)*	10	Collected from Chandoi
3	Chilbil (*Holoptelea integrifolia*)	03	Collected from neighbourhoods
4	Neem (*Azadirachta indica)*	10	Collected from Hutap nursery
5	Mahuwa (*Madhuca indica)*	15	Collected from Hutap nursery
6	Jamun *(Syzygium cumini)*	10	Collected from Hutap nursery
7	Khair (*Acacia catechu)*	05	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand
8	Bans *(Dendro calmusstrictus)*	05	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand
9	Mansiam (*Acacia mansiam*)	05	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand
10	Jangli anar (*Dodonaea viscosa*)	05	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand
11	Hamata (*Stylosanthes hamata*)	85	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand

Sr. no	Species	Quantity of Seed (in kgs)	Resources
12	Chara Jawar (*Indo pogon*)	85	Procured from M/s. Madhu Seed supplier 17- Panditwari, Dehra Dun, Uttarakhand
13	Dhencha (*Sasbania sesban*)	30	Procured from M/s. Dhartidhan, Ranchi
14	Arhar *(Cajanus cajan)*	10	Procured from M/s. Dhartidhan, Ranchi
15	Lemon grass (*Cymbo pogon*)	1200 (tufts)	Procured from divisional nursery of HINDALO, Lohardaga

Nursery beds were prepared and seed treatment with disinfectants was carried out well before the seed sowing process in the nursery. The seeds were sown in the nursery beds and seed germination took around 7 to 15 days from the date of seed sowing. Around 70 to 75% of seeds were germinated in the nursery as illustrated by **figure 1**. The germinated seedlings were well maintained in the nursery. Simultaneously weeding, grading, watering and shifting of the seedlings were done on regular basis in the nursery. When seedling of all species were grow into two to four leaves then they were transplanted in the poly bags of 22 cm x 15 cm and 20 cm x 12 cm sizes filled with nutrient material in the ratio of 2 : 2 : 4 of FYM, Sand and Fertile soil. Finally at the time of plantation, around 22,700 plants were available in healthy condition with an average height of 0.45 m. Out of total 22,700 healthy saplings, approximately 11,497 saplings were transported to Pakhar and approximately 4,330 saplings were transported to Bagru mine area for afforestation activities. Remaining saplings were planted by HINDALCO in other sites. The details of the plants raised in the nursery for the third phase of the project are provided in table no. 2 below. It can be observed that species of Bakain, Bahera and Shisham were raised to the higher numbers while Anar, Karam and Kathal were grown to lower numbers.

Table 2 Saplings raised at Hutap nursery during the third phase of the project

Sr. no.	Species	No. of sapling
1	Acacia (*Acacia auriculiformis)*	1000 (4.41)
2	Anola (*Emblica officinalis)*	1400 (6.71)
3	Anar *(Punica granatum*)	400 (1.76)
4	Arjun (*Terminalia arjuna)*	800 (3.52)
6	Bans*(Dendrocalmus strictus)*	1000 (4.41)
7	Bahera *(Terminalia belerica)*	2000 (8.81)

Sr. no.	Species	No. of sapling
8	Bakain (*Melia azadarach*)	2200 (9.69)
8	Ber (*Zizyphus nummularia)*	800 (3.52)
9	Chakundi *(Cassia siamea)*	1000 (4.41)
10	Chilbil *(Holoptelea integrifolia*)	1000 (4.41)
11	Harar *(Terminalia chebula)*	500 (2.20)
12	Imlee*(Tamarindus indica)*	1200 (5.29)
13	Jamun*(Syzygium cumini)*	500 (2.20)
14	Karam *(Adina cordifolia)*	300 (1.32)
15	Karanj*(Pongamia piñata)*	1200 (5.29)
16	Katahal (*Artocarpus heterophyllus)*	300 (1.32)
17	Khair *(Acacia catechu)*	1000 (4.41)
18	Mahuwa *(Madhuca indica)*	600 (2.64)
19	Neem *(Azadirachta indica)*	2000 (8.81)
20	Sagwan *(Tectona grandis)*	500 (2.20)
21	Siras *(Albizzia lebbeck)*	1000 (4.41)
22	Shisham (*Dalbergia sissoo)*	2000 (8.81)
	Total	**22,700**

*Figure in the parentheses refers to the percent of total saplings raised at Hutap nursery

Figure 1 Saplings raised at Hutap nursery

Maintenance of surplus horticulture plants

The need of horticulture plant species in the project area as demonstrated by local people was further achieved by the surplus saplings of horticulture species left during the second phase of nursery maintenance. Around 300 saplings of Mango (*Mangifera indica*), 200 saplings of Guava (*Psidium guyava*) and 200 saplings of Neebu (*Citrus medica*) species were left from the previous year which were maintained in Hutap nursery, these saplings were planted in the third phase of project activity. The detailed list of surplus species from last year is given below in **table 3** and shown in **figure 2**.

Table 3 Surplus saplings of 2011 maintained in Hutap nursery for third phase

Sr. no.	Species	No. of sapling
1	Mango (*Mangifera indica*)	300
2	Guava(*Psidium guyava*)	200
3	Neebu (*Citrus medica*)	200
	Total	**700**

Figure 2 Surplus horticulture saplings of previous year at Hutap nursery

Procurement of soil amenders and pesticides

Soil treatment with amenders and pesticides was done well before in advance to improve the water holding capacity as well as fertility of the soil. It was treated with a mixture of gypsum, vermicompost and neem cake before the plantation activity. In lieu of this, each pit was filled with 2 kg gypsum, 2 kg vermicompost and 120 grams of neem cake and then plantation activity was carried out. Whereas for rehabilitation of lease boundaries, this restoration activity was not achieved as the soil in the boundary areas were naturally fertile. The complete process of mixing soil amenders for filling the pits is illustrated in the figure 3, figure 4 and figure 5.

Figure 3 Amenders transported to plantation sites

Figure 4 Mixing of gypsum, fertile soil and vermicompost at the site

Figure 5 Mixing of seed with amenders for direct seed sowing

For direct seed sowing of grasses and bushes, the soil treatment was also carried out with gypsum, vermicompost and neem cake in the ratio of 1 kg seed: 2 kg gypsum: 2kg vermicompost: 200 grams neem cake and 5 kg fine top soil. The procurement details of these amenders according to the quantity needed in both the project sites are given below in table 4.

Table 4 Procurement of soil amenders

Amender	Mines wise supply in Qtls.		Total in Qtls.	Sources
	Pakhar	Bagru		
Gypsum	100	90	190	Center store of HINDALCO
Vermicompost	100	65	165	Center store of HINDALCO
Neem cake	10	6	16	Center store of HINDALCO

Transportation of saplings from Hutap nursery

The required saplings for third phase afforestation activities and replacement of mortality of first and second phase were fully engrossed from Hutap nursery and not a single sapling was procured from outside the nursery, while excessive demand of horticulture plant species met through last year surplus horticulture plants in the nursery. These surplus

saplings were collected & transported from 2011 plantation areas & kept in nursery and were maintained up to 2012 plantation season. Moreover 15,827 saplings of various species were transported to third phase plantation site. Around 4,330 saplings were transported to Bagru plantation site and 11,497 saplings were transported to Pakhar plantation site. Details of saplings transported from Hutap nursery to project sites are listed below in table 5.

Table 5 Saplings transported from Hutap nursery during the third phase of the project

Sr. no	Species	No. of saplings transported from the Hutap nursery		Total
		Bagru plateau	Pakhar plateau	
1	Acacia (*Acacia auriculiformis)*	95	0	95
2	Mango (*Mangifera indica)*	50	198	248
3	Anola (*Emblica officinalis)*	377	754	1,131
4	Amrud (*Psidium guyava*)	189	428	617
5	Anar (*Punica granatum*)	50	0	50
6	Arjun (*Terminalia arjuna)*	52	500	552
7	Asho (*Polyalthia longifolia*)	0	110	110
8	Bahera (*Terminalia belerica)*	242	350	592
9	Bakain (*Melia azadarach*)	415	650	1,065
10	Bans (*Dendrocalmus strictus)*	320	600	920
11	Ber (*Zizyphus nummularia)*	0	300	300
12	Chakundi (*Cassia siamea)*	290	100	390
13	Chilbil (*Holoptelea integrifolia)*	785	200	985
14	Gamahar (*Gmelina arborea)*	13	50	63
15	Gulmohar (*Delonex regia*)	50	110	160
16	Harar (*Terminalia chebula)*	50	300	350
17	Imlee (*Tamarindus indica)*	200	800	1,000
18	Jamun (*Syzygium cumini)*	200	950	1,150

Sr. no	Species	No. of saplings transported from the Hutap nursery		Total
		Bagru plateau	Pakhar plateau	
19	Karam (*Adina cordifolia)*	50	250	300
20	Karanj (*Pongamia pinata)*	386	800	1,186
21	Katahal (*Artocarpus heterophyllus*)	50	35	85
22	Khair (*Acacia catechu)*	0	850	850
23	Mahuwa (*Madhuca indica)*	50	400	450
24	Neebu (*Citrus medica*)	50	157	207
25	Neem (*Azadirachta indica)*	100	675	775
26	Sagwan (*Tectona grandis)*	216	500	716
27	Sagwan- bare rooted (*Tectona grandis)*	0	200	200
28	Sirus (*Albizzia lebbeck)*	50	650	700
29	Shisham- bare rooted (*Dalbergia sissoo)*	0	500	500
30	Subabul (*Leucaena leucophala)*	0	80	80
	Total	4,330	11,497	15,827

Step by step process to raise quality saplings at Hutap nursery

There were many objectives of building in house capacity to raise saplings for plantation activity at the project site. First was to ensure the adequate availability of saplings for plantation activity in third phase as well as for the replacement of mortality of earlier phases plantation. Second was to avoid the higher cost of purchasing from outside nurseries and reducing the risk of quality inferiority. Third was to produce healthy saplings capable of withstanding in tough physiological conditions equivalent to project site. Fourth was to enable HINDALCO to scale up the plantation activities from sites other than project area from the Hutap nursery. Fifth was to build a strong in house capacity for HINDALCO staff to raise qualitative saplings of various species.

To develop the superior quality saplings for afforestation activities at the mine spoil areas following procedures were adopted:-

Procurement of quality seed

Seed procurement was very important step for building strong in house capacity as it ensures production of quality and healthy saplings which would have higher survival rates for species in degraded areas. Selection of quality seeds by TERI experts is shown below in figure 6. We adopted two processes for seed selection and procurement. In the first, we collected seed directly from various sites by selecting the mother tree wherein the seeds were fully ripped in the mother tree. In the second, we initiated the process to purchase seed directly from the seed suppliers by enlisting & identifying the good suppliers of the region. Supplier’s credibility, history, and cost effectiveness were comparatively analyzed and then certified seeds were purchased and then these seeds were sown in the bed at the right time because some seeds have limited vivacity such as Neem, Mahuwa, Jamun, Chilbil etc. Before sowing the seeds in the germination beds, seeds were cleaned and treated with disinfectants properly as shown in figure 7.

Figure 6 Selection of quality seeds

Figure 7 Seed treatment before sowing in germination bed

Procurement of poly bags and quality materials:

Size of the poly bags (i.e. length and diameter) highly depends on the period to which sapling is to be kept in nursery and on the growth of the species. Accordingly, black sheet polybags were purchased. For plants such as Neem, Mahuwa, Guava, Jamun, Bahera, Anola, etc. which were to be kept in nursery for at least one year, poly bags of 23 cm x 12 cm sizes were purchased. While for species like Khair, Cassia etc. which were kept for short duration of time in nursery, polybags of 20 cm x 08 cm sizes were purchased.

Procurement of nutrition rich soil:

Nutrient rich soil is a very essential element for raising robust nursery plants. Nutrient sufficient soil is an important factor in determining the growth of plants raised in nursery. For selecting the soil type in nursery, pH and soil particles were considerate and in this regard river belt soil and forest soil was procured for raising the nursery plants which is shown below in figure 8.

Figure 8 Procurement of fertile soil

Procurement of Farm Yard Manure (FYM)

Presence of nutrients in the soil was necessary for raising various species in nursery. FYM mixed in soil helped in achieving the desired growth of saplings. In nutshell, addition of manure in the soil was done to increase the fertility of the soil. Procurement of rotten Farm Yard Manure (FYM) and Vermicomposting as shown in figure 9 is assumed to be the best manure for nursery plantation.

Figure 9 Procurement of FYM

Mixing of soil elements

Proper mixing of elements in the ratio of 1: 2: 3 (Sand: FYM: Fertile soil) was done before filling it in the poly bags. This provides adequate availability of nutrients in the soil which was crucial for the growth of nursery plants. Filling of poly bags by the local workers is demonstrated in figure 10 below.

Figure 10 Filling of poly bags with various mixers

Pricking of seedlings

Pricking of seedlings was done at the time when seedlings had grown into less than 6 leaves. Then transplantation of these seedlings was done from seed germination beds to the poly bags. The schematic transplantation of seedlings is shown below in figure 11.

Figure 11 Transplanting seedlings in the poly bags

Maintenance of saplings

Maintenance of saplings comprise following exercise i.e. watering, weeding, shifting and grading. Timely irrigation of nursery plants according to seasons was essential to ensure the survival and the growth of the plants. Generally in peak winter, daily watering was done while in normal winter weekly irrigation was enough to maintain water utility for nursery plants. Whereas coiling of the root was avoided by shocking the saplings through shifting it from polybags (after two to three months) to germination beds. However, grading exercise was performed just before two to three week to transportation. Graded saplings prepared before transportation to project site is shown below in figure 12.

Figure 12 Graded saplings before transportation for planting

Handling, packing, loading-unloading of plants

Proper handling, packing, loading-unloading and keeping plants species wise should be done properly at the plantation site. Scientific method for proper handing, head load transportation, loading in the truck and unloading at the plantation site and finally keeping plants species wise was adopted to avoid the chances of damaging the plants. Moreover, the workers were trained and demonstrated on packing, handling, loading and unloading aspects of plant transportation. Safe loading-unloading, transportation and species wise keeping of saplings at the project site is shown in figure 13, figure 14 and figure 15 respectively. Though bare root saplings were packed with biomass to transport them without any damage and their mode of raising at site is demonstrated in figure 16 and figure 17.

Figure 13 Transportation of saplings for afforestation activity

Figure 14 Safe loading process of poly bags sapling in the truck

Figure 15 Transported poly bags saplings and their species wise arrangement at plantation site

Figure 16 Bare root saplings being packed by biomass before transportation

Figure 17 Bare root saplings ready for planting activity

Tools and techniques adopted for the reclamation of backfilled mine areas

Advance soil work

The project areas of HINDALCO bauxite mines were distributed among three locations i.e. Pakhar plateau, Bagru plateau and railway slopes of Lohardaga. In Pakhar and Bagru plateaus, generally two types of degraded land existed, the one which was excavated and overburdened with soil of bauxite, commonly referred as "dump" and resembled the shape of hill while the other degraded land was backfilled pits after excavation of bauxite. These dumps were physically, nutritionally and biologically poor in nature. The phenomenon of natural succession on these lands also takes longer time. So development of vegetative cover on bauxite mine spoil area of Lohardaga plateau was tough and challenging due to problems like compaction, infertility, high acidity or salinity of soil, poor water-holding capacity and extreme temperatures.

We first treated the degraded land of dump i.e. hilly shape so as to make the undulating hillock workable. To make this area plain, we started levelling from top of the hill through heavy dozer or by JCB machine. After certain distant from top provided by the allowed condition of the topography, again the second bench was made through cutting the soil dump. This process was repeated till the bottom of the dump. The soil of these dumps mainly comprises of morrum and literate, so the top fertile soil layer was required to spread over these benches for raising the vegetative cover over it.

While in the backfilled areas (area after excavation of Bauxite) treatment was done to refill and restore the soil nutrients in the site. It was packed as per the natural process i.e. first

layer of boulder then the layer of morrum and last layer of top soil. After completion of the aforesaid process pit digging for plantation of tree species of 0.45 m x 0.45 m x 0.45 m size was done. In some places, where particles of morrum were thick 0.60 m x 0.60 m x 0.60 m pit size was dug for planting the saplings. However, in slope areas pit sizes were of 0.45 m x 0.45 m x 0.45 m and 0.30 m x 0.30 m x 0.30 m for planting saplings as well as planting the tufts respectively. While for seed sowing of grasses and bushes, palm size pits were dug. In the plain areas line to line plant distance was kept 3 m x 3m, and thereby approximately 1,112 plants per hectare were planted. But in slope areas spacing was kept 2 m x 2 m which yielded around 2,500 plants planted per hectare. Further, plantation model in different spacing pattern at different project areas is mentioned in table no. 6. It enlists the advance soil work of pit digging of various sizes and area covered in phase third of project activity.

Table 6 Area covered under rehabilitation during third phase of the project

Sr. no.	Mine	Location	No. of pits	Spacing (in mts.)	Net area (in ha)
1	Pakhar plateau	Lease area 96.25 Dump IInd Bench slope of 2011 II bench	671	3 x 4	0.805
		Seed sowing pits of grass species of 0.3mx0.3mx0.3m size in between plants where spacing 4m plant to plant	200		Already included in tree species
		Lease area 96.25 dump 2 bench area below of the slope	382	3 x 3	0.344
		Lease area 96.25 dump 3 bench area slope of balance area of 2011 & 2012 bench slope	1220	4 x 2	0.976
		Lease 96.25 area dump no 3 IInd bench & balance area with in fencing of 2011 bench	1275	3 x 3	1.148
	Pakhar mine B lease area	Lease 270 area pick at area bench	141	3 x 3	0.127
		Lease 270 area pick at area bench pick at slope	366	4 x 4	0.586
		Seed sowing pits of grass species of 0.3mx0.3mx0.3 m size in between plants where spacing 4m plant to plant	150		Already included in tree species
	Pakhar mine lease area 84.38 acre	Back filled area plot 1st near Yatrik shed	635	3 x 3	0.572
		Back filled area near mango tree plot 2nd	1031	3 x 3	0.928
		Back filled area plot 3rd Near mahuwa tree	843	3 x 3	0.759
	Pakhar mine lease 84.38, A&B	Boundary	635	3 x 3	0.572

Sr. no.	Mine	Location	No. of pits	Spacing (in mts.)	Net area (in ha)
		Rest area of the boundary	1431	3 x 2.5	1.073
		Mine office compote	65	2 x 2	0.026
	Sub - total	1. Pit for tree species	**8,695**		**7.916**
		2. Pit for seed sowing of grass species in between tree species	**350**		
2	Bagru Plateau	Back filled area of Bandi bench 1st	2054	3 x 3	1.848
		Back filled area bench 2nd	516	3 x 3	0.464
		Bench slope of1st bench	572	3 x 2	0.343
		Bench slope of agriculture plot	438	3 x 2	0.28
		Rehabilitation through cultivation of agriculture crop of pigeon pea	As per physical measurement		0.750
	Sub - Total		**3,580**		**3.685**
	G Total		**12,275**		**11.601**

Afforestation activities

The solution to the various problems that accompanied after bauxite mining lies in the establishment of an economically feasible and permanent cover of vegetation on the mine spoils. Henceforth, continuation of plantation activity in third phase was started from 2nd fortnight of July and completed till 2nd fortnight of August. In the dump area, five type of plantation activity was achieved viz. plantation of tree species (i.e. Mango, Guava, D. sisso, Jamun etc), plantation of seed sowing tree species (i.e. Khair, Cassia), plantation of soil binder grass (i.e. *Indopogon, Stylohamata* etc.), plantation of bushes (i.e. *Dadonaea Viscosa*, *Zizyphus nummularia etc.*) and plantation of nutrient fixing species (i.e. *Sasbania sesban*). While in the bench area of backfill site, three types of species were planted i.e. tree species, grasses and nutrient fixing species. Consequently the rehabilitation of Pakhar and Bagru Bauxite mines in third phase constituted 7.92 ha and 2.94 ha area respectively, transformed through afforestation activity of near about 8,695 and 3,610 saplings respectively. Plantation of trees was carried out given the priority to income generation, local need & desires of people and fulfilment of ecological conditions. Fruit bearing species (like Mango, Guava, Neebu etc.), species of medicinal value (like Anola, Harar, Bahera, Neem, Arjun, Mahuwa etc.) and species of domestic value for fuel and fodder (like Bakain, Sagwan, Shishaml, Bans etc.) were planted.

In addition to this, in Bagru mine a part of backfilled area (nearly 0.75 ha) of bauxite mines reclaimed through cultivation of agriculture crop i.e. Pigeon Pea. This was done on an

experiment basis so as to estimate the land eligibility for agriculture crops. Cultivation of agriculture crops in the project site not only exhibit restored capacity of severely degraded mine area but also presents a scope of large scale agriculture activities in other mine spoil restored area also, which will enable local people to earn their livelihood incessantly. Further afforestation activity in Pakhar and Bagru plateaus is illustrated by the figure 18 and figure 19. Further location wise detailed plantation plan at Pakhar and Bagru plateau is provided in the table 7 below.

Table 7 Breakup details of the total plantation area during third phase of the project

Mine	Location of the plantation area	Species	No. of sapling planted
1. Pakhar mines	Lease area 96.25dum2 bench slope of bench Slope 2011 IInd bench	Mango	5
		Bakain	37
		Bans	55
		Ber	14
		Jamun	4
		Karam	30
		Karanj	49
		Khair	90
		Neem	14
		Sagwan	134
		Siras	74
		Shisham (B)	135
		Subabul	30
		Sub total	**671**
	Lease 96.25 Dump 2 bench area of below the slope	Am	5
		Anola	19
		Ashok	28
		Bakain	38

Mine	Location of the plantation area	Species	No. of sapling planted
		Bans	35
		Gulmohar	10
		Jamun	28
		Karanj	45
		Katahal	5
		Mahuwa	5
		Neem	17
		Sagwan	88
		Siras	59
		Sub -total	**382**
	Lease 96.25 Dump 3 bench slope of balance 2011 & slop area of 2012 bench	**Anola**	13
			23
		Bahera	17
		Bakain	121
		Bans	155
		Ber	109
		Gamahar	35
		Harar	19
		Imlee	37
		Jamun	35
		Karanj	41
		Khair	151
		Neem	5
		Sagwan	105

Mine	Location of the plantation area	Species	No. of sapling planted
		Siras	161
		Shisham (B)	193
		Sub total	**1220**
	Lease 96.25 Dump no 3 II bench & balance area of 2011	Am	20
		Anola	85
		Guava	60
		Arjun	125
		Bahera	30
		Bakain	110
		Bans	50
		Gamahar	10
		Harar	70
		Imlee	80
		Jamun	200
		Karanj	145
		Katahal	5
		Mahuwa	30
		Neebu	25
		Neem	95
		Sagwan	55
		Siras	80
		Sub total	**1275**
	INDAL lease 270 area Pick at area Bench	Mango	9
		Anola	32

Mine	Location of the plantation area	Species	No. of sapling planted
		Guava	16
		Bahera	2
		Ber	30
		Imlee	18
		Jamun	3
		Neebu	31
		Sub total	**141**
	INDAL lease 270 area Pick at slop	Anola	31
		Bakain	10
		Ber	141
		Jamun	12
		Khair	145
		Mahuwa	12
		Siras	15
		Sub total	**366**
	Back filled area plot 1st in 270 area near Yatrik shed	Arjun	50
		Bahera	50
		Cassia	50
		Chilbil	50
		Harar	50
		Imlee	50
		Jamun	75
		Karam	50
		Karanj	120

Mine	Location of the plantation area	Species	No. of sapling planted
		Mahuwa	15
		Neem	25
		Siras	50
		Sub total	**635**
	Back filled area near mango tree Plot 2nd 84.38 area	Mango	20
		Anola	105
		Guava	20
		Arjun	100
		Bahera	97
		Bakain	10
		Bans	10
		Harar	45
		Imlee	60
		Jamun	185
		Karam	10
		Karanj	60
		Mahuwa	129
		Neebu	10
		Neem	170
		Sub total	**1031**
	Back filled area Plot 3rd 84.38 are	Anola	228
		Guava	35
		Bahera	147
		Bans	57

Mine	Location of the plantation area	Species	No. of sapling planted
		Imlee	178
		Khair	60
		Mahuwa	28
		Neem	78
		Sagwan (B)	20
		Shisham (B)	12
		Sub total	**843**
	Part of lease area 84.38,A &B boundary part 1st	Anola	12
		Bakain	47
		Bans	29
		Imlee	16
		Karam	2
		Karanj	64
		Khair	95
		Mahuwa	24
		Neem	20
		Sagwan (B)	171
		Shisham (B)	155
		Sub total	**635**
	Rest part of lease area 84.38,A &B boundary	Arjun	44
		Bakain	97
		Bans	95
		Ber	6
		Cassia	44

Mine	Location of the plantation area	Species	No. of sapling planted
		Chilbil	139
		Gulmohar	64
		Imlee	140
		Jamun	5
		Karam	138
		Karanj	57
		Khair	200
		Mahuwa	25
		Neem	135
		Siras	192
		Subabul	50
		Sub total	**1431**
	Mine's office compound	Ashok	40
		Gulmohar	25
		Sub total	**65**
Total Pakhar mine			**8695**
2-Bagru BAUXITE mine	**Bandi mines lease bench plot 1st**	Anola	
			334
		Guava	182
		Anar	50
		Arjun	52
		Bahera	147
		Bakain	250
		Chakundi	50

Mine	Location of the plantation area	Species	No. of sapling planted
		Chilbi	50
		Gamahar	48
		Imlee	190
		Jamun	172
		Karam	23
		Karanj	50
		Katahal	50
		Mahuwa	50
		Neem	95
		Sagwan	216
		Siras	45
		Sub -Total	**2054**
	Bandi mines lease bench plot 2nd	Acacia	18
		Anola	43
		Guava	7
		Bahera	95
		Bakain	49
		Chakundi	90
		Chilbi	97
		Gamahar	15
		Karanj	102
		Sub total	**516**
	Bandi mines lease slope of plot 1st	Acacia	47
		Bakain	100
		Bans	203

Mine	Location of the plantation area	Species	No. of sapling planted
		Chilbi	138
		Karanj	84
		Sub total	**572**
	Bandi mines lease slope of plot 2nd	Bakain	16
		Bans	117
		Chilbi	155
		Karanj	150
		Sub -total	**438**
	Bagru mines total		**3,580**
	G total of third phase afforestation work		**12,275**
3-Bagru bauxite mine	Reclamation of back filled bauxite mine through agriculture crop cultivation		Pigeon pea 08 kg cultivated

Figure 18 Afforestation activities at the Pakhar plateau

Figure 19 Seed sowing on ridge of contour trenches at the Bagru plateau

Overall 12,275 saplings of various trees and horticulture species were planted covering 11.60 ha area in both Pakhar and Bagru plateaus along with 0.75 ha area rehabilitated through cultivation of agriculture crop during the third phase of the project. Species wise saplings planted is given in the table 8 below. Further demonstration of each plantation activity via seed sowing, broadcasting and pit digging is shown in figure 20, figure 21 and figure 22.

Table 8 Species wise details of saplings planted during the third phase of the project.

Species	No. of saplings planted	
Acacia (*Acacia auriculiformis)*	95	(0.77)
Mango (*Mangifera indica*	59	(0.48)
Anola (*Emblica officinalis)*	902	(7.33)
Guava (*Psidium guyava*)	320	(2.60)
Anar (*Punica granatum*)	50	(0.41)
Arjun (*Terminalia arjuna)*	394	(3.20)
Ashok (*Polyalthia longifolia*)	68	(0.55)
Bahera (*Terminalia belerica)*	585	(4.75)
Bakain (*Melia azadarach*)	885	(7.19)
Bans (*Dendrocalmus strictus)*	806	(6.55)
Ber (*Zizyphus numularia)*	300	(2.44)
Chakundi (*Cassia siamea)*	234	(1.90)

Species	No. of saplings planted	
Chilbil (*Holoptelea integrifolia)*	629	(5.11)
Gamahar (*Gmelina arborea)*	108	(0.88)
Gulmohar (*Delonex regia*)	99	(0.80)
Harar (*Terminalia chebula)*	184	(1.50)
Imlee (*Tamarindus indica)*	769	(6.25)
Jamun (*Syzyzium cumini)*	719	(5.84)
Karam (*Adina cordifolia)*	253	(2.06)
Karanj (*Pongamia piñata)*	937	(7.86)
Katahal (*Artocarpushetero phyllus*)	60	(0.49)
Khair (*Acacia catechu)*	741	(6.02)
Mahuwa (*Madhuca indica)*	318	(2.58)
Neebu (*Citrus medica*)	66	(0.54)
Neem (*Azadirachta indica)*	654	(5.31)
Sagwan (*Tectona grandis)*	598	(4.86)

Species	No. of saplings planted	
Sagwan- Bare root (*Tectona grandis)*)	191	(1.55)
Siras (*Albizia lebbeck)*	676	(5.49)
Shisham – Bare root (*Dalbergia sissoo)*	495	(4.02)
Su babul (*Leucaena leucocephala)*	80	(0.65)
Total	**12,275**	

*Value in the parentheses refers to the percent of total number of plants planted at the project site

Figure 20 Seed sowing in back filled bauxite mine area at Pakhar

Figure 21 Seed broadcasting in slope areas at Pakhar plateau

Figure 22 Seed sowing in slope areas at Pakhar plateau

Soil and moisture conservation activities:

Soil and moisture conservation activities in the landscape were promoted right from the selection of tree species. Only those tree species were selected for afforestation which utilizes less water unlike poplar trees which has detrimental effect on the water table of the region. Further many other activities of soil and water conservation were done at a project site as illustrated below:

i) Construction of contour terraces, contour trenches

All the sloping areas which were part of reclamation activity across both the mines were treated through construction of renovating structures and spread of green cover. The slopes in the terrain were very steep as a result contour terraces of 0.60 m wide were made while length had varied depending upon the topography of the site conditions. This was done by cutting the slope soil and creating flat space for planting of saplings, seed sowing of trees, shrubs and grass species. These contour terraces thus check the soil erosion, reduce the angle of repose, conserved the moistures and provided ease at the site to perform plantation activities in tough hillock areas. Construction of contour terraces in sloppy Pakhar mine area is illustrated in figure 23.

The contour trenches were made in back filled areas where slope gradient was more than 20 degree, the main reason for magnified level of soil erosion at the project site. These contour trenches check the run-off water by limiting its speed and thus reduce soil erosion and conserve the rain water for moisture in the soil. Normally, these trenches were constructed of 3 m x 0.45 m x 0.45 m size in a scattered manner. These trenches were very useful for neighbouring vegetation in a long run because of their capability to retain moisture and soil nutrients. Approximately, 156 contour trenches were constructed in the Bagru plateau. The measurement details of contour terraces and contour trenches location wise are given below in table 9. Further, construction of contour trenches in backfilled Bagru bauxite plateau is illustrated in figure 24.

Table 9 Details of contour terraces and contour trenches constructed for soil and moisture conservation

Mines	Location of area	Measures constructed	
		Contour terrace in running meter	No. of contour trenches
Pakhar	Lease area 96.25 Dump 2 Bench slope of 2011 II bench	1080	
	Lease area 96.25 dump 3 bench area slope of balance area of 2011 & 2012 bench slope	1500	
	Lease 270 area Pick at area BenchPick at slope	225	

Mines	Location of area	Measures constructed	
		Contour terrace in running meter	No. of contour trenches
Bagru	Bandi lease area bench slope of 1st bench	423	
	Bandi lease area slope of agriculture bench	212	
	Bandi lease area back filled area of Bandi bench 1st		156
	Total	**3440**	**156**

Figure 23 Construction of contour terraces in slope areas of Pakhar plateau

Figure 24 Construction of contour trenches at Bagru plateau

ii) Seed sowing of tree, shrub and grasses species:

Ground flora is the essential part of any plantation activity because it helps in the improvement of top soil, check the runoff water and increase the humus and humidity in the soil. So, sowing of various fast growing species, soil binders and nutrient fixing species of tree, shrubs and grasses were also carried out through seed broadcasting and dibbling in all the sloppy areas of project site. While in the back filled plain areas seeds of grasses and nutrient fixing species were sown through seed broadcasting and on the trenches of top dug soil. Around 85 kgs *Stylo hamata*, 85 kgs *Indo pogon,* 30 kgs *Sesbania sesbain*, 5 kgs *Dodonaea*, 2 kgs *Acacia catechu* seeds were consumed for this activity.

iii) Railway siding track slopes Lohardaga:

Construction of cemented toe walls and diversion channels at the bottom of the slopes in railway siding track is under progress. And after completion of construction works, when slopes would gradually become workable at that time planting of tree species is planned. Thus in the third phase only maintenance of last year planted species was done which include mulching, weeding, saucer making etc. In addition to this about 1,200 Lemon grass (*Cymbo pogon*) tufts were planted in these slope areas for protecting soil and conservation of moisture. Railway side track afforestation and restoring activity is shown in figure 25.

Figure 25 Construction of toe wall & planting of *Cymbo pogon* tufts at railway siding track slope

Replacement of mortality and maintenance

Maintenance of the previous year's plantation was done through weeding, mulching, hoeing and safeguarding from cattle grazing etc. But because of lack of irrigation facilities during peak summers and peak winters, mortality of planted saplings especially horticulture species were observed. Replacements of such dead plants were carried out during the rainy season in the third phase of the project activity. Replacement was done on the basis of inventory of saplings types with us at hutap nursery as well as on the suitability of species in the region.

Mortality replacement in first phase reclaimed area

The area reclaimed during 1st phase in year 2010 of backfilled bauxite mines in Pakhar plateau, wherein 13.5% mortality was observed among the planted saplings. The main reason of mortality was observed as drought conditions at site with no arrangements for irrigation. The replacements of mortality was done in the third phase are shown below in the table 10 which shows higher replacement of Jamun tree out of all the tree species.

Table 10 Species wise saplings planted in mortality replacement

Sr. no.	Species	No. of sapling replaced
1	Anola (*Emblica officinalis)*	23
2	Guava (*Psidium guyava*)	1
3	Arjun *(Terminalia arjuna)*	47
4	Bakain (*Melia azadarach*)	49
5	Bans *(Dendrocalmus strictus)*	15
6	Harar (*Terminalia chebula)*	4
7	Jamun *(Syzyzium cumini)*	132
8	Karam *(Adina cordifolia)*	3
9	Karanj *(Pongamia piñata)*	24
10	Khair *(Acacia catechu)*	20
11	Mahuwa *(Madhuca indica)*	14
12	Neem (*Azadirachta indica)*	6
13	Sagwan *(Tectona grandis)*	10
14	Black Sirus (*Albizzia lebbeck)*	8
Total		**356**

Replacement of mortality in second phase reclaimed area:

Overall mortality in 2011 rehabilitated area of Pakhar and Bagru plateaus was observed about 15.45% of the total planted 15,157 saplings in both mines area where approximately 2341 saplings of various types were replaced. Majority of mortality was perceived in horticulture plants like Mango and Anola. Further, all purchased hybrid Anola species from outside nurseries died at both the sites while the Anola raised in Hutap nursery have shown notable growth. Moreover reasons accountable for higher rate of mortality were late arrangement of irrigation facility and less effective fencing at the plantation site. The area wise mortality replacement of second phase rehabilitated area done in third phase is illustrated below:-

A. Pakhar plateau

A.1 - Back filled area H4: This area was reclaimed through afforestation activity in phase two of project by planting 601 plants of various horticulture and fruit bearing plants like Mango, Anola, Guava and Imlee etc. But unfortunately all horticulture plants died because of lack of irrigation and late fencing. Consequently this part of project rehabilitated area witnesses the highest mortality percentage of 77.5%. In second phase 601 species were planted out of which 466 species died and thus were replaced by various species. Replacement of the mortal plants was done during third phase of the project and replaced numbers of sapling is shown in the table no. 11 below:-

Table 11 Species wise no. of saplings replaced in H4

Sr. no	Species	No. of sapling replaced
1	*Mango (Mangifera indica)*	14
2	Anola (*Emblica officinalis)*	105
3	Guava (*Psidium guyava*)	175
4	Arjun (*Terminalia arjuna)*	16
5	Bakain (*Melia azadarach*)	1
6	Imlee (*Tamarindus indica)*	57
7	Jamun (*Syzyzium cumini)*	11
8	Katahal (*Artocarpus heterophyllus*)	7
9	Mahuwa (*Madhuca indica)*	20
10	Neebu (*Citrus medica*)	60
Total		**466**

A. 2 –Back filled area in front of HINDALCO Hospital:

The area was rehabilitated through planting horticulture species like Mango, Guava, Neebu and Anola which were procured from outside nurseries. But for the same reasons i.e. lack of effective watch & ward and no irrigation activity resulted into 47% of plant mortality. In second phase 187 species were planted out of which 88 species died and thus were replaced by various species type. Mortality of saplings replaced and species planted is shown in the table 12 below:-

Table 12 Species wise no of sapling replaced in front of HINDALCO hospital

Sr. no.	Species	No. of sapling replaced
1	*Mango (Mangifera indica*	53
2	Anola (*Emblica officinalis)*	9
3	Guava (*Psidium guyava*)	15
4	Neebu (*Citrus medica*)	11
	Total	**88**

A.3 – Dump 2 top bench of lease area 96.25

During second phase of the project 1,125 saplings were planted at this site for the rehabilitation but 22% of saplings died due to drought conditions. Mortality replacement was done through planting of various species as shown in table 13 below:-

Table 13 Species wise number of sapling replaced in Dump-2

Sr. no	Species	No. of sapling replaced
1	Bakain (*Melia azadarach*)	37
2	Harar *(Terminalia chebula)*	47
3	Karam *(Adina cordifolia)*	39
4	Karanj *(Pongamia piñata)*	90
5	Mahuwa (*Madhuca indica)*	02
6	Neem *(Azadirachta indica)*	32
	Total	**247**

A.4 – Dump 2 bench II lease area 96.25

The area was rehabilitated during the second phase of project with plantation of 1,911 saplings of various species but mortality rate of 26% of saplings was observed mainly because of lack of safe guard of plants because barbed wire fencing was provided after five months of the plantation due to this reason planted saplings were grazed by the domestic cattle. Moreover drought conditions in the region with no irrigation facilities boosted the mortality rate among the plants. Species planted in the replacement of mortality in the third phase is shown below table no 14.

Table 14 Species wise number of sapling replaced in Dump2 bench II

Sr. no	Species	No. of sapling replaced
1	*Mango (Mangifera indica)*	27
2	Anola *(Emblica officinalis)*	17
3	Guava (Psidium guyava)	18
4	Arjun *(Terminalia arjuna)*	15
5	Ashok (*Polyalthia longifolia*)	11
6	Bakain (*Melia azadarach*)	14
7	Bans *(Dendrocalmus strictus)*	14
8	Harar *(Terminalia chebula)*	11
9	Imlee *(Tamarindus indica)*	50
10	Jamun *(Syzyzium cumini)*	84
11	Karam *(Adina cordifolia)*	8
12	Karanj *(Pongamia piñata)*	90
13	Katahal (*Artocarpus heterophyllus*)	5
14	Khair *(Acacia catechu)*	37
15	Mahuwa *(Madhuca indica)*	29
16	Neebu (*Citrus medica*)	4
17	Neem (*Azadirachta indica)*	37
18	Sagwan *(Tectona grandis)*	27
	Total	**498**

A.5 – Dump 3 bench of lease area 96.25

For the rehabilitation of these bench 3,792 numbers of saplings of various species i.e. horticulture, valuable non-timber produce, timber, fodder and fuel wood species were planted during the second phase of project. Among these 14 % of mortality among the planted saplings was observed due to drought conditions and lack of effective watch and ward. Replacement was done through planting the sapling in this phase as shown the table 15 below:-

Table 15 Species wise number of sapling replaced in Dump3 bench of the lease 96.25

Sr. no.	Species	No. of sapling replaced
1	*Mango (Mangifera indica)*	31
3	Guava (*Psidium guyava*)	14
4	Arjun *(Terminalia arjuna)*	40
5	Ashok (*Polyalthia longifolia*	31
6	Bakain (*Melia azadarach*)	34
7	Bans *(Dendrocalmus strictus)*	81
8	Harar *(Terminalia chebula)*	38
9	Imlee *(Tamarindus indica)*	93
10	Jamun *(Syzyzium cumini)*	22
13	Katahal (*Artocarpus heterophyllus*)	06
14	Khair *(Acacia catechu)*	52
15	Mahuwa *(Madhuca indica)*	35
18	Sagwan *(Tectona grandis)*	70
Total		**547**

B – Bagru plateau:

No area was taken for rehabilitation of this plateau in the 1st phase of the project and in the 2nd phase of the project about 4 ha area was rehabilitated through afforestation of 4,293

saplings of various species. Out of these around 12% saplings were died because of lack of watch & ward and barbed wire fencing which allowed the cattle to easily graze inside.

B.1 – Lease area of Bauxite mines V 1

In the second phase of the project 1,126 saplings of various species were planted at the time of reclamation of the area but out of them 22% sapling were damaged or died. Replacement of these plants was done during this phase and numbers of saplings replaced are shown in the table 16 below:

Table 16 Species wise number of sapling replaced in V1 back filled area

Sr. no.	Species	No. of sapling replaced
1	Cassia (*Acacia auriculiformis)*	100
2	Chilbil *(Holoptelea integrifolia)*	150
Total		**250**

B.2 – Lease area of Bauxite dump bench

This bench was rehabilitated during 2nd phase of the project through afforestation activity and plantation of 1,391saplings of various species including fruit bearing, timber species, fuel and fodder etc. were carried out but out of them 17.6% of saplings were died or pull out from soil by cattle grazing. Table 17 shows the species replaced during this phase.

Table 17 Species wise number of sapling replaced in dump bench

Sr. no.	Species	No. of sapling replaced
1	Cassia (*Acacia auriculiformis)*	50
2	Chilbil *(Holoptelea integrifolia)*	195
	Total	**245**

Capacity building and participatory approach

Non existence of communication between project planners, implementation agencies and local communities ranks high as a major cause of failures in most of the projects. Any project plan designed for rehabilitation of site must be clearly understood by all the stakeholders so that they can be responsive to project needs and desires. Also, to ensure sustainability of rehabilitation of plantation site community ownership and their involvement must be the foundation upon which the project should be built. Consequently, the first major activity done was to bring together all the stakeholders of the project and then to make them aware of project activity.

Capacity building assumes to be one of the significant parts of the proposed project. It was done through the involvement of local people and HINDALCO staff in the afforestation activity right from the nursery works till the maintenance of the plantation. Thus training was provided for nursery development and its maintenance right from site preparation, selection of quality seeds , seed treatment processes, sowing methods, pricking, weeding, shifting, handling, transportation, unloading and safe keeping of saplings etc. While for afforestation activity they were made aware about the right alignment of pits and terraces, pit digging, mixing amenders, planting, maintenance of plants through weeding, hoeing, mulching & saucer making for water conservation etc.

Providing employment to the local people and showing them a right way of doing an activity was the major part for their capacity building training. Participatory exercises were done with HINDALCO staff and local people to understand their needs & requirements and then accordingly go for the afforestation activity. The result of this exercise was the demand of horticulture and medicinal species by the stakeholders in the project site and accordingly 35% of total planted species were purely medicinal and horticulture species. In addition to this 26% of total dead saplings were replaced through planting these species during third phase of project.

Thus plantation of species as suggested by the local people not only emphasizes that their concerns are being heard & implemented but also it will facilitate interest and involvement of local people to safeguard these plantation especially in Pakhar plateau. So the project activity presumed to shape better relationship between the HINDALCO and local people and also enable company to earn goodwill of the community. Figure 26 illustrates the involvement of HINDALCO staff in the project activity as well as participation of local dwellers.

Figure 26 Capacity building of HINDALCO staff through involving them into afforestation activity

Maintenance and supervision of the plantation areas

Monitoring, maintenance and supervision of the entire afforested area was one of the most critical and important activity of this project. Although HINDALCO especially in Pakhar mines engaged two supervisors and 6 watch and ward for protection of planted saplings from domestic cattle, grazing, fire and monitoring the plant diseases.

In Bagru plateau, fencing of the rehabilitated areas was done with barbed wire and wooden post. But last year forest department officers objected for this kind of fencing because of use of wood in fencing and thus ban this activity. One of the other options with project owner was to establishment of RCC pillars for fencing of project site but it would have taken longer time and higher cost. In view of this TERI suggested an idea of bio fencing at the project site through *Vitex negundo, Nerium indicum, Lawsonia inermis, Ipomea* etc. species which were widely available in that area. Bio-fencing presumed to delineate the project boundary as well as increase the green cover of the project area with relatively low cost of establishment. Thereafter, bio-fencing activity was started in the third phase for rehabilitation of back filled area in third plot of lease area 84.38 via *Vitex negundo*. Bio fencing approach was a low cost option to the project sites which can be reputed as demonstration model for replicating the same activity at other mining sites also. Further species of bio-fencing sprouts within a short period of time and look evergreen. Bio-fencing is illustrated below in figure 27.

Figure 27 Bio fencing of the plantation area through *Vitex negundo*

Monitoring and evaluation of project site

Monitoring of growth parameters of the plantation was an important activity of the on-going project. We have developed a monitoring framework, which was followed regularly to measure the growth parameters such as height, collar diameter, number of leaves, branches, crown diameter and shoot length of each tree species. While in case of grass species shoot length and number of tufts was calculated. There were three monitoring research quadrates plotted on different altitudes and sites during first phase of monitoring activity. The same plots were considered for capturing the growth data of each type of species in these sample plots during second phase of monitoring activity. Besides data collection, monitoring of the plantation, silvicultural operations such as hoeing, control of diseases, pests and weeds removal were also advised regularly from time to time during the field survey of the professionals from TERI.

Results and Discussions

In order to evaluate the effectiveness of plantation activity data collection and its analysis was done on growth parameters of each species type. For both the phases of plantation activity systematic data collection activity was achieved. For tree species, growth data was collected by measuring six growth parameters viz. height, collar diameter, number of branches, crown diameter, number of leaves and shoot length. While for the grass species, number of tufts and shoot length were measured to analyze their growth pattern. Permanent sample plots and tagging of species was done in order to ensure the replication of data for the same species which were considered during first phase of data collection. Besides data analysis of plants and grasses, changes in the soil characteristics will also be analyzed by taking the pre and post project soil samples from the plantation sites.

It was interesting to find out that the plantation activity in both the phases has shown impressive growth rate despite higher mortality rate. In first and second phase of plantation site, horticultural species like Anola, Mango, Bel, Ber etc. medicinal species like Harar, Bahera, Bakain, Mahuwa and timber & fodder species like Shisham, Neem etc. have shown impressive growth in the tough terrains. Further the entire hybrid Anola and Naspati which were purchased from outside nurseries during first phase of plantation died while the nursery raised Anola has shown notable growth rate. Thus it seconds the importance of in house capacity building at Hutap nursery, which had provided quality saplings for afforestation activity in the degraded area.

Moreover ocular estimation by TERI experts showed a better growth rate of replaced plants. Further through consultation and discussion with local dwellers, it was observed that the local people were satisfied with the plantation activity as it has converted their dump and degraded land to a productive land and it will also cater to their economy through horticultural and medicinal plant species.

Detailed analysis and discussion for each growth parameters of every species planted during both phase of plantation activity is given below. While tabular representations (under each growth parameter) of graphical analysis are referred in Annexures.

Growth status of first phase of the plantation

Growth status of saplings:

Baseline growth data was taken in the month of October 2010 and second growth data was taken in the month of June 2011 while subsequent data was collected in month of November 2011, April 2012 and August 2012 on parameters like height, collar diameter, shoot length, crown diameter and number of branches from the three research plots of the first phase of the project sites. All the three monitoring research quadrates were plotted on different altitude and sites. Data for all the parameters was taken by physical measurements for at least five to ten individual saplings of each species from all the three research plots. In this section five monitoring data taken across different seasons under each parameter were analyzed and compared. The results of all the species are presented separately for each parameter.

Height:

Species of Harar, Bakain and Anola have attained highest average increment in height among all other species. Harar has grown seven times of its height, Bakain has grown six times of its average height and Anola has grown five times of its height compared to first year's heights. While species such as Jamun and Imlee has shown lower average increment in their heights and has grown just double the height from previous year because these species are water consuming and lack of irrigation facility has impeded their growth rate. Other species like Bel, Arjun, Bahera, Neem and Kanji has shown an average increment of 200%.

Increment in height of species is a direct indicator for growth of any species as well as evidence of suitability of the species on the ecological condition of that site. While Harar, Bakain and Anola tree species shows an average increment of 481% (highest) and species of Jamun and Imlee shows an average increment of 87% (lowest). And an overall increment in the height of all the species from all the three sample quadrate is 256% which demonstrate the suitability of all species at the plantation site. Graphical analysis of height for each

species type during different time period is shown below where standard deviation is represented by two pointer range line on the column of each species. Tabular representation of graphical analysis can be referred in Annexures.

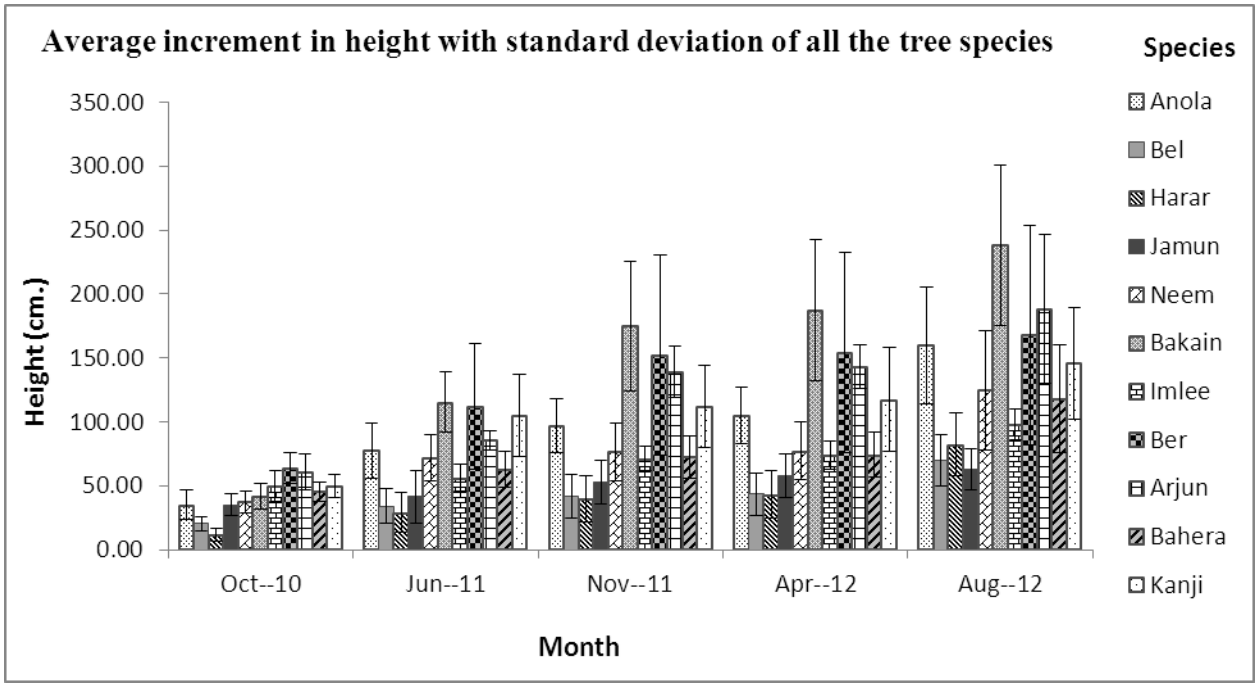

Figure 28 Average increment in height with standard deviation of all the tree species

Collar Diameter

Species of Harar, Imlee and Bahera have attained a higher average increment in collar diameter among all the species. It is observed that Harar has grown impressively eleven times of its collar diameter and Imlee and Bahera has grown seven times of its average collar diameter compared to first year's collar diameter of respective species. While species like Jamun and Kanji has shown lower average increment in their collar diameter and has grown triple to previous year's collar diameter. Other species like Bel, Arjun, Anola, Bakain, Neem and Kanji has shown an average increment of 200%.

Unlike height, crown diameter, branches and leaves, collar diameter is considered to be a finest parameter for capturing growth status of any species as it is least affected by grazing. Overall increment in the collar diameter of all the species from all the three sample quadrates is found to be 486 %, wherein Harar, Imlee and Bahera tree species shows an average increment of 723% (highest) as these species has natural tendency to grow faster at initial stage and species of Jamun and Kanji shows an average increment of 239% (lowest) as they are slow growing species. This indicates the robust growth trajectory of all the species in this plantation site. Graphical analysis of collar diameter for each species type during different time period is shown below where standard deviation is represented by two pointer range line on the column of each species.

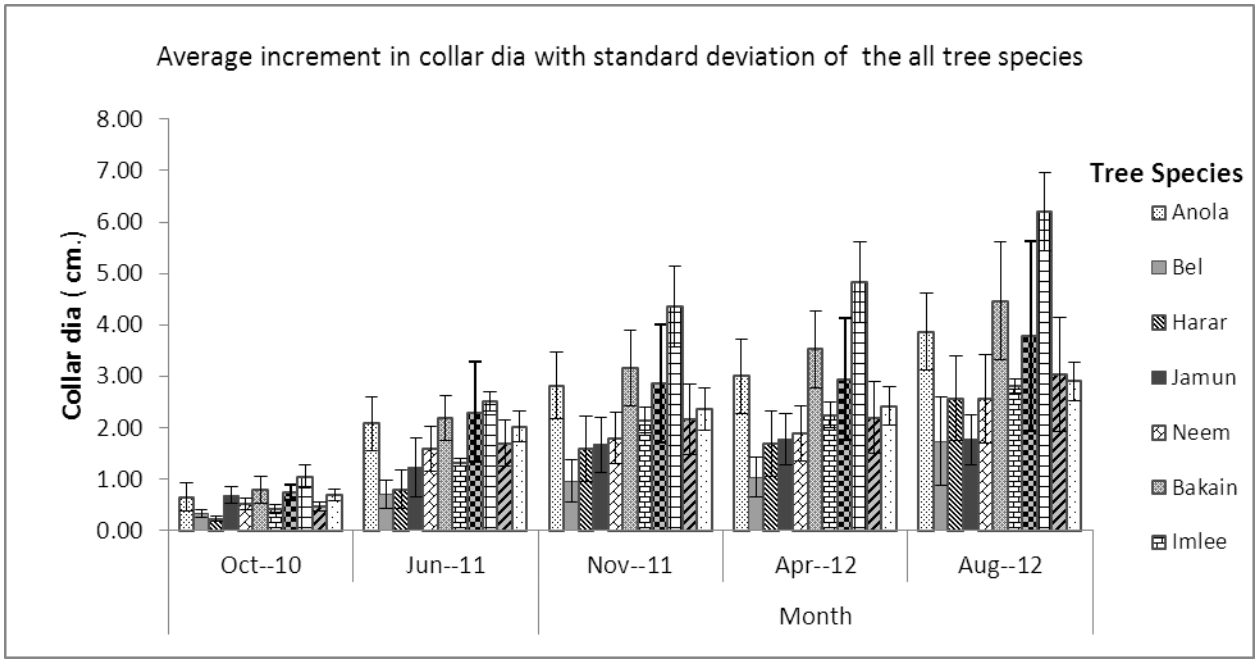

Figure 29 Average increment in collar dia with standard deviation of all the tree species

Crown Diameter

Species of Harar has attained a highest and species of Jamun has attained the lowest average crown diameter increment among all the species. It is find out that Harar has grown twelve times of its previous crown diameter while Jamun has grown only twice its previous crown diameter. Rest other species like Bel, Arjun, Bahera, Neem, Bakain, Anola, Ber, Imlee and Kanji have shown an average increment of 361%.

Thus overall increment in the crown diameter of all the species from all the three sample plots is found to be impressive which is 413 %, wherein Harar species shows an average increment of 1149% (highest) and species of Jamun shows an average increment of 145% (lowest). Graphical analysis of collar diameter for each species type during different time period is shown below where standard deviation is represented by two pointer range line on the column of each species.

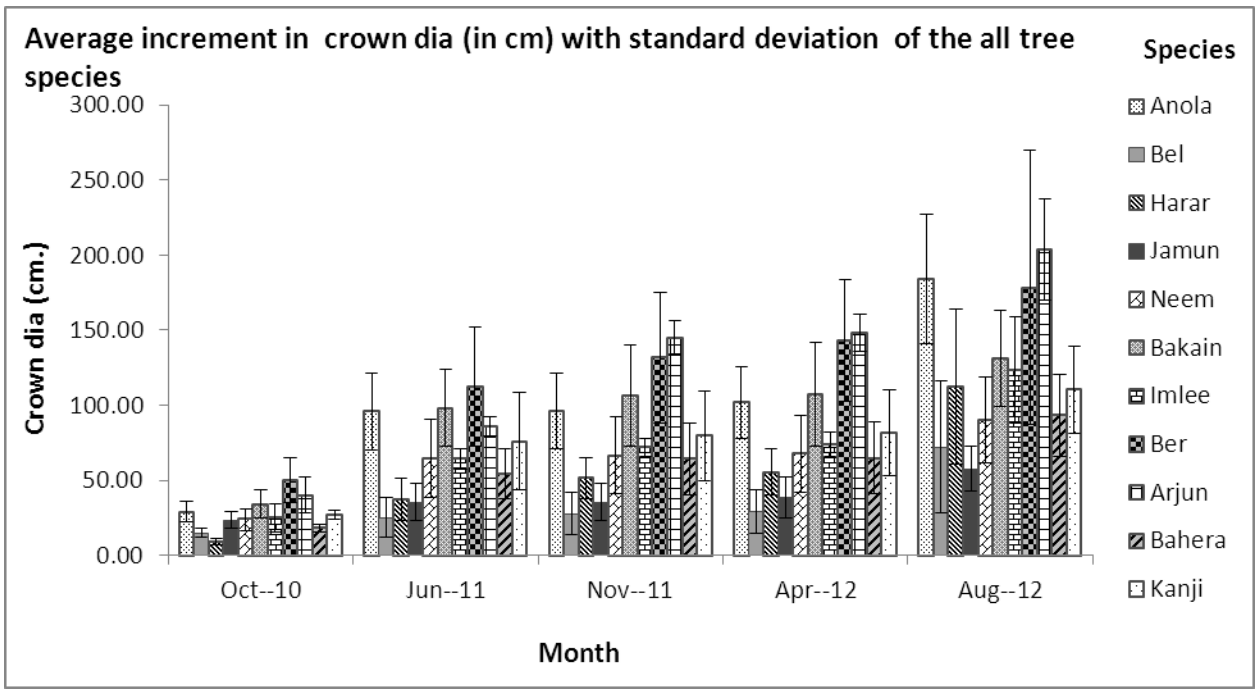

Figure 30 Average increment in crown dia with standard deviation of all the tree species

Number of Branches:

Species of Harar, Bel and Bakain have grown into maximum number of branches among all the species as fruit bearing species have natural tendency of growing more branches. It is find out that Harar has grown twelve times its branches, Bel has grown ten times its branches and Bakain has grown ten times its branches compared to first year's number of branches of respective species. While species of Ber and Jamun have shown least growth rate and their number of branches grows at an average of 63%. Other species like Arjun, Bahera, Neem, Anola, Imlee and Kanji has shown an average increment of 256%. Thus overall impressive increment in the number of branches of all the species from all the three sample quadrates is found to be 412%. Further species wise growth is represented below.

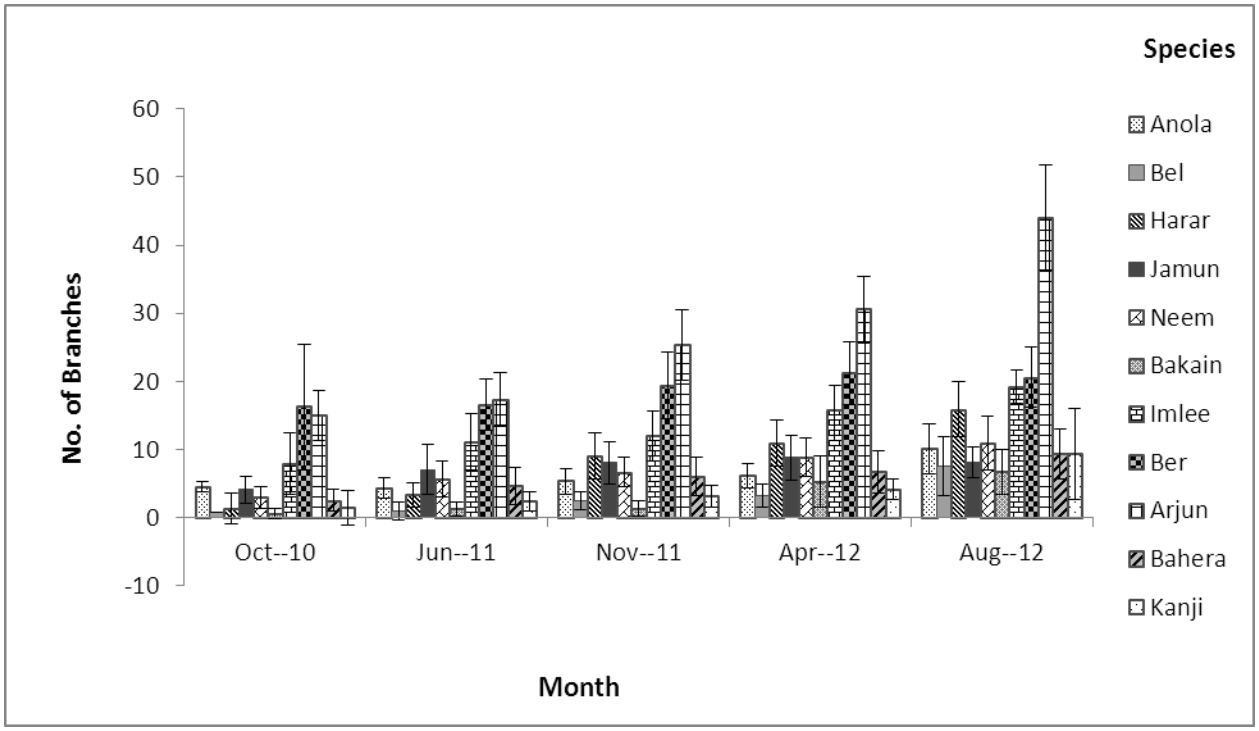

Figure 31 Average increment in number of branches with standard deviation of all the tree species

Number of Leaves:

Species of Ber and Bahera have grown into maximum number of leaves among all the species. It is find out that on an average Ber species has grown its leaves number from 19 to 2072 and Bahera species has grown its leaves from 18 to 1002 in duration of 10 months i.e. (Nov, 2011 to Aug, 2012). While species of Arjun, Jamun, Bel and Anola have not shown such impressive growth rate as shown by Ber and Bahera. Overall increment in the number of leaves of all the species from all the three sample quadrates is robust and encouraging. Further, species wise growth is represented below.

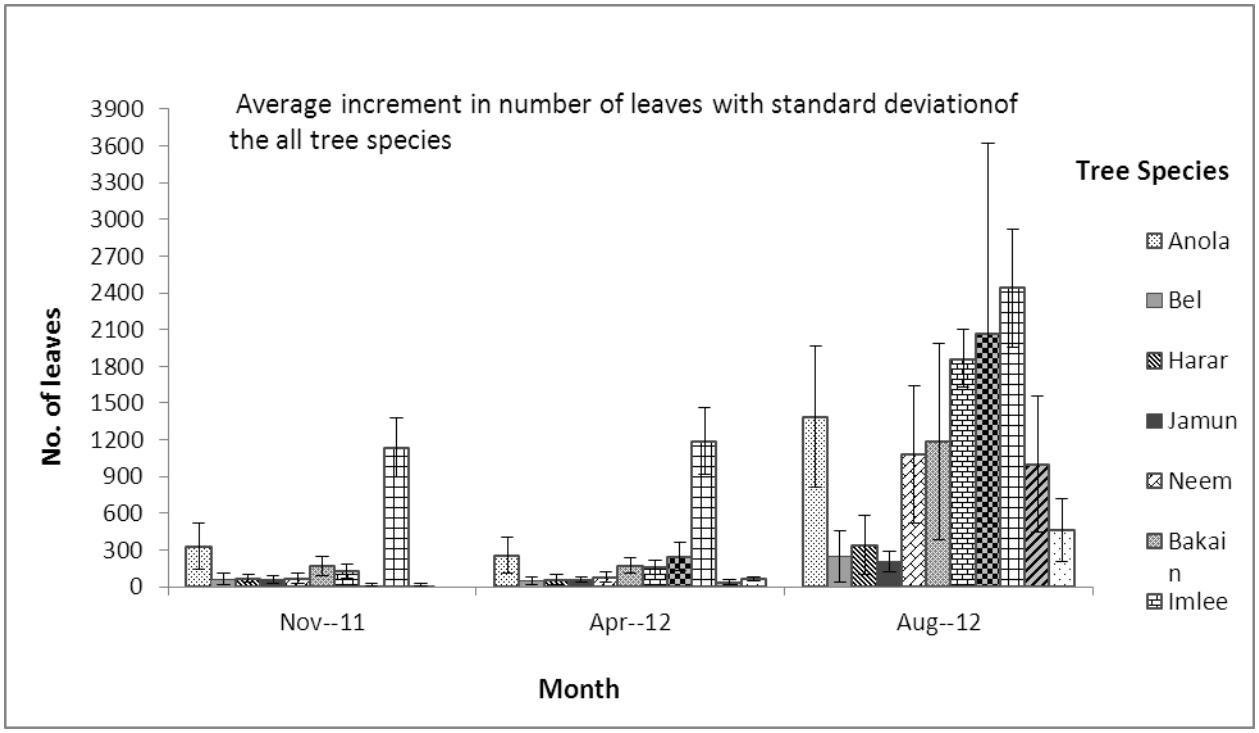

Figure 32 Average increment in number of leaves with standard deviation of all the tree species

Shoot Length:

Bakain, Ber and Bel lead the growth rate in shoot length among all the species. Shoot length for Bakain increased from an average of 8.16 cm to 83.87cm, for Ber from an average of 0.15 cm to 1 cm and for Bel from an average of 1.50 cm to 8.40 cm. It is observed that shoot length for Kanji species on an average has shown a negative trend i.e. from an average of 12 cm to 3.80 cm (during Oct, 2010 to Aug, 2012). This decrease in shoot length is due to the fact that number of shoots in the species must have increase which in turn has reduces the shoot length of overall species type. Further average growth rate for all the species type is found to be 247% and the details are enlisted below in graphical representation.

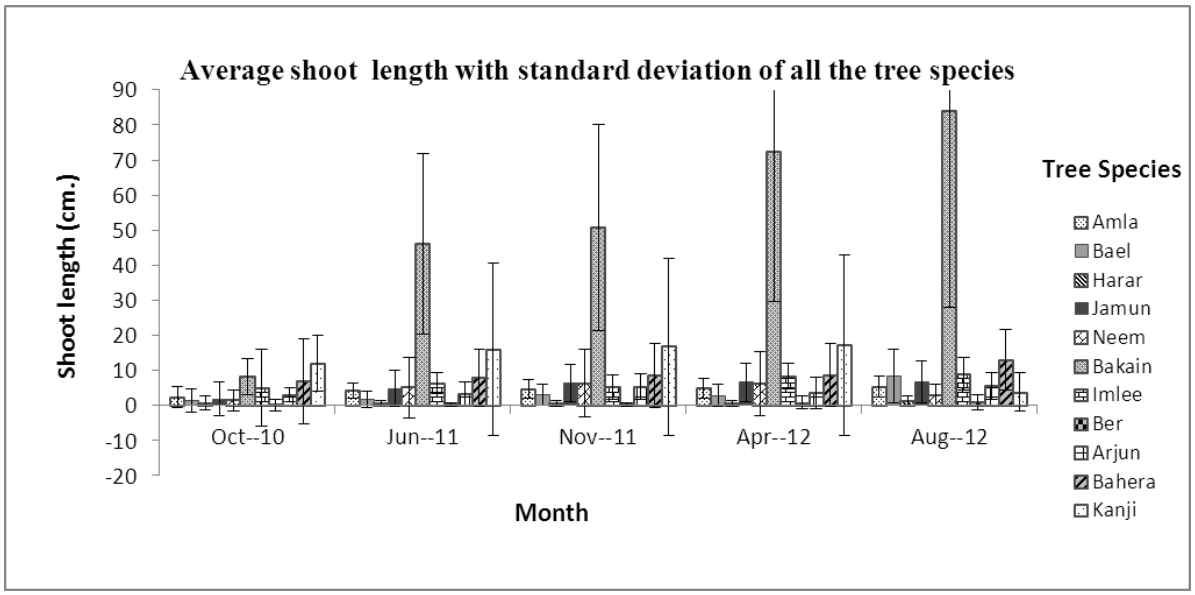

Figure 33 Average shoot length with standard deviation of all the tree species

Growth status of grass species:

Two monitoring data were collected and compared with each other to find out the percent increase in the number of tufts and average shoot length. The baseline data was collected in the month of October 2010 and June 2011 while subsequent data is taken in the month of Nov 2011, Apr 2012, and Aug 2012 from the three sample quadrates of the first phase of the project.

Number of tufts increased in *Stylohamata* grass was from an average of 13.11 to 33.78 while for *Sesbania sesbain*, number of tufts decreased from 72.56 to 33.11. Shoot length for both the grass species has shown positive growth rate and their overall growth rate is observed to be 329% wherein *Stylohamata* shows an average growth rate of 573% while *sesbania sesban* shows an average growth rate of 84%. Details of the overall average number of tufts in all the three plots for both the grass species are provided in the graphical representation.

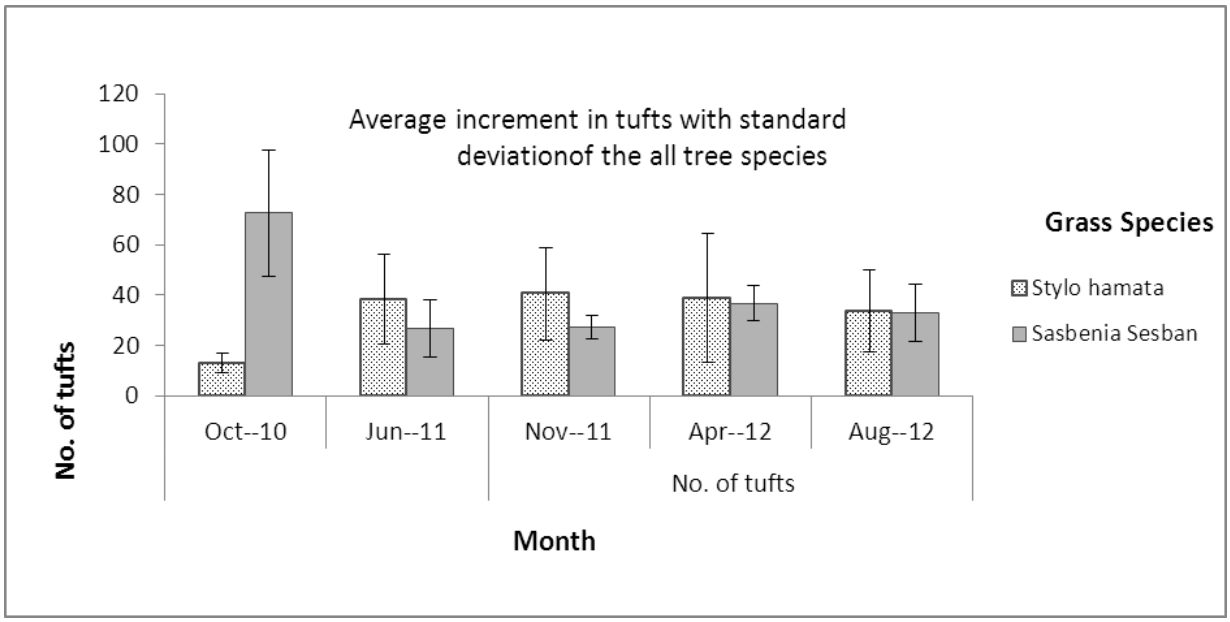

Figure 34 Average increment in tufts with standard deviation of all the tree species

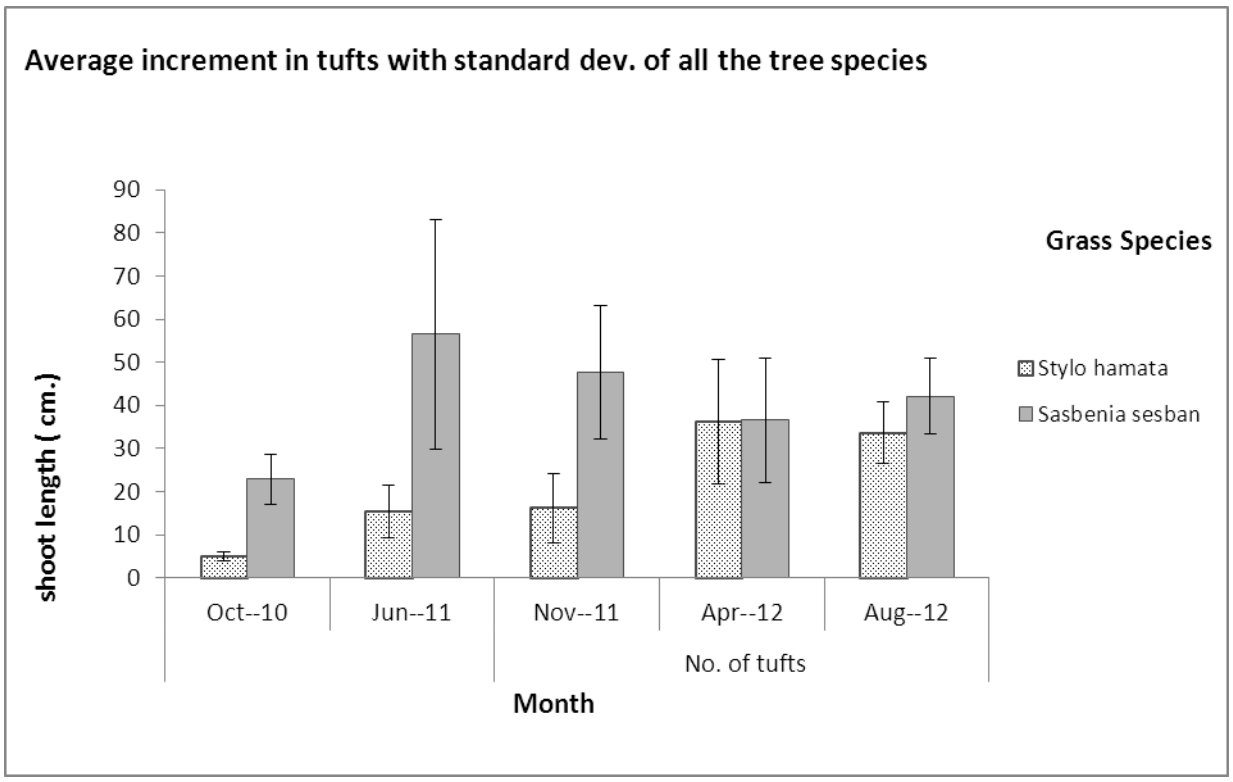

Figure 35 Average increment in tufts with standard deviation of all the tree species

Growth status of Second phase of the plantation:

Growth status of saplings:

The baseline growth data was taken in the month of November 2011 and second and third growth data was taken in the month of April 2012 and August 2012 on parameters like height, collar diameter, shoot length, crown diameter and number of branches from the six research plots of the second phase of the project sites. Data for all the parameters was taken by physical measurements for at least five to ten individual saplings from each species from all the six research plots. In general it is observed that growth of species at Pakhar plateau has superseded species growth at Bagru plateau because of mainly three reasons viz. First, at Pakhar plantation site there were stringent manual watch and ward, while no watchmen was present to look after Bagru plantation site. Second, at Pakhar site there was very effective barbed wire fencing which protected the site from grazing whereas at Bagru plantation site ineffective fencing presented a scope of uncontrolled grazing. Third, at Pakhar plantation site rain water harvesting structures were practiced which provided better soil and moisture conditions for plants growth while the same practice were not performed at Bagru plantation site. The results of all the species are presented separately for each parameter.

Graphical analysis under each parameter for each species type during different time period is shown below in respective graphs where standard deviation is represented by two pointer range line on the column of each species. Tabular representation of graphical analysis can be referred in Annexures.

Height:

Increment in height of species is a direct indicator for growth of any species as well as it provisions an evidence of suitability of the species on the topographic condition of that site. Following observations at both the sites are observed.

At Pakhar plantation site, species of Ber, Bakain, Arjun and Neem have shown maximum average height growth of 138%, 111%, 99% and 98% respectively. Whereas, Shisham and Mango species has shown less increment as compared to the other species. Moreover, lower percentage growth in Shisham species is observed because it was planted bare root and on the trial basis and thus less resources were spend on it (i.e. no soil amenders were mixed and no seed treatment). Average height of all the species has increased from 53.78 cm (November 2011) to 71.37 cm (August 2012) which is impressive and suggests the viability and suitability of all the planted species in the topological and environmental condition of Pakhar plateaus.

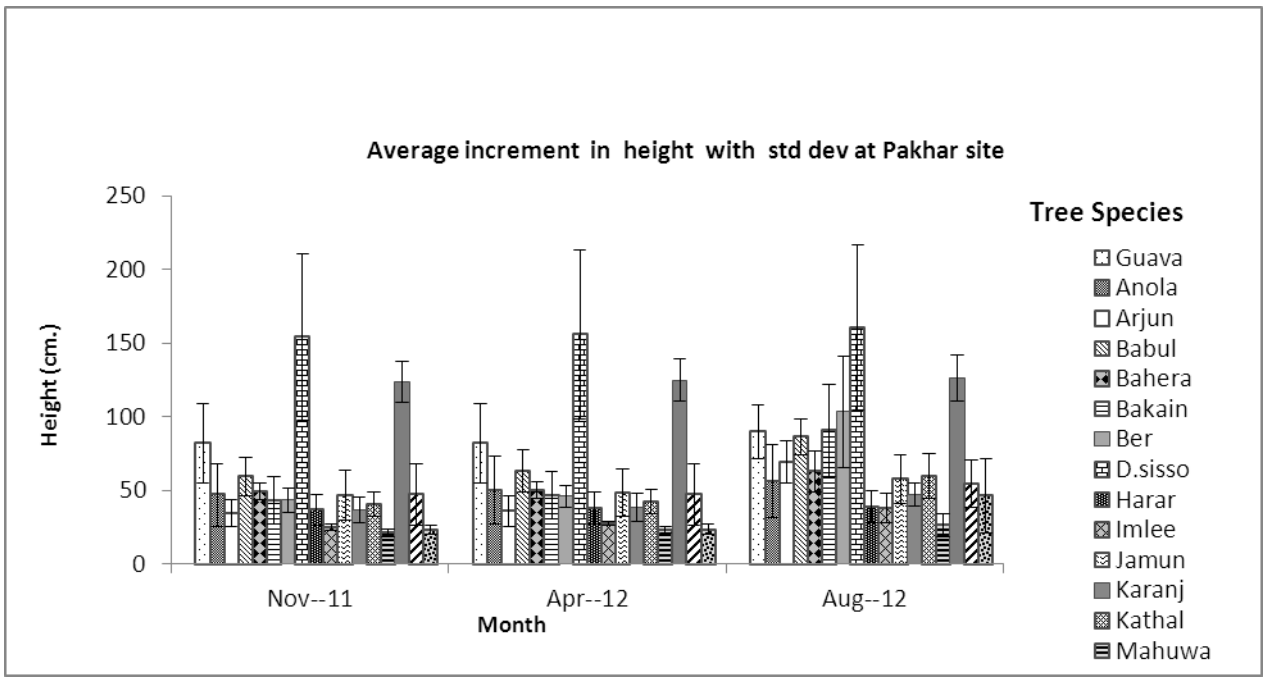

Figure 36 Average increment in height with standard deviation at Pakhar site

At Bagru plantation site, average height for species like Bahera, Babul, Jamun, Imlee, Mango etc is found to be constant. Though, as evident from Pakhar sites, these species must also have shown increment in their height but because of ineffective fencing these species would have been grazed and thus showing constant height. While Ber, Karanj etc. species have shown impressive increment in their height because these species are most suitable for desert and humid conditions. Provided these sites get due ward and watch and effective fencing be implemented then the region will also yield robust growth.

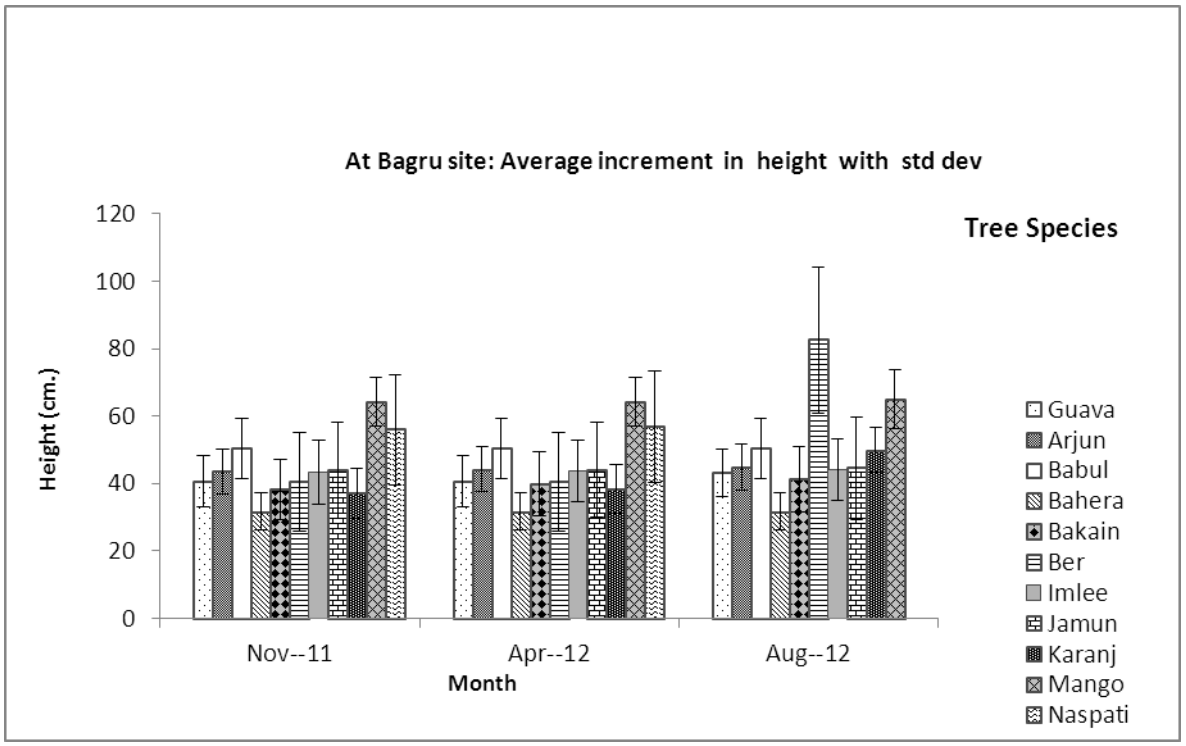

Figure 37 Average increment in height with standard deviation at Bagru site

Collar Diameter:

The only parameter which is least affected by grazing unlike height, crown diameter, branches etc. is collar diameter and could be considered as a sturdiest parameter for capturing growth status of species. At Pakhar plantation site, out of total 17 species, 15 species have shown an average growth rate of 109% for collar diameter. This clearly indicates the robust growth trajectory of all the species except a few. Guava attains an increment in collar diameter of 13% only because this species has natural tendency of having lower growth while Mango has grown at an average of 18% only because they were replaced by new plants. Further Bahera, Imlee, Arjun and neem have shown an impressive collar diameter growth rate of 216%, 189%, 165% and 150% respectively. While Bagru plantation site suffered from the same problem of uncontrolled grazing and ineffective ward and watch and thus an overall average collar diameter increment is found to be only 47%. Though Ber and Babul species have shown an impressive growth rate in their collar diameter (i.e. of 148% and 83% respectively) because these species are least affected by grazing due to presence of thorns.

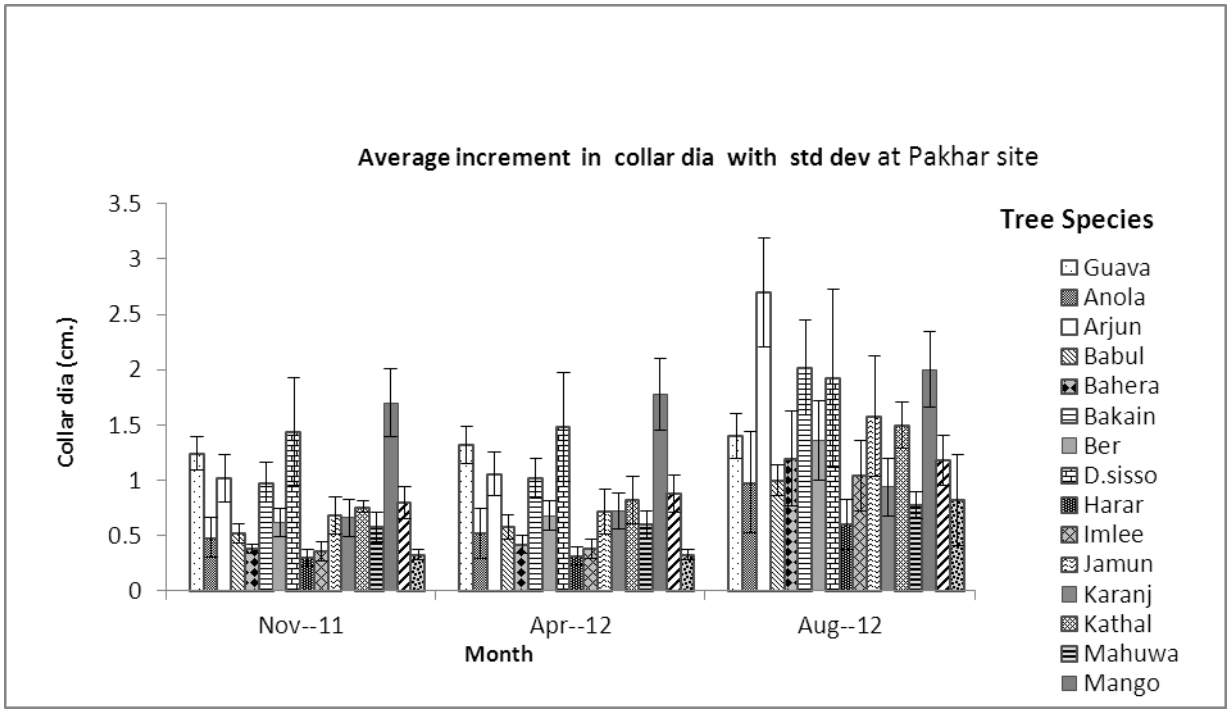

Figure 38 Average increment in collar dia with standard deviation at Pakhar site

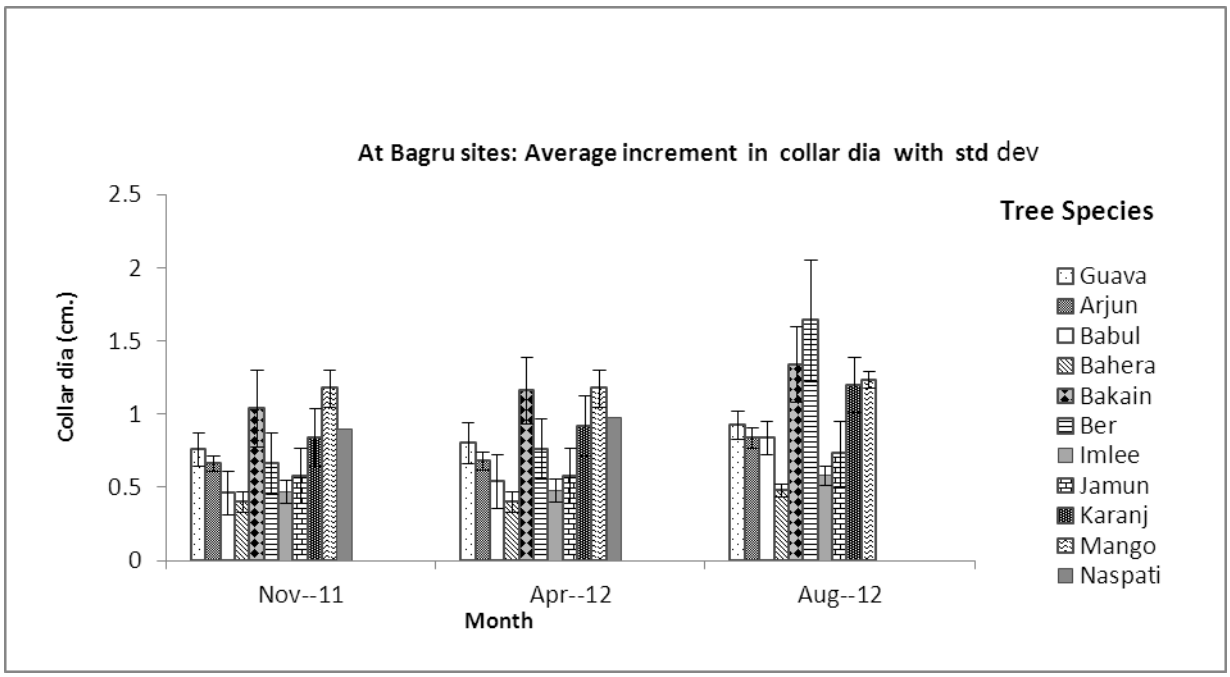

Figure 39 Average increment in collar dia with standard deviation at Bagru site

Crown Diameter:

Crown diameter is one of the important parameter to evaluate the growth of any tree species and its suitability to the topographic conditions. Further crown diameter is considered to be an inverse function of height for any species in general i.e. species who have tendency of achieving higher height assumes to have lower crown diameter and vice versa (like Imlee and Mahuwa species have shown higher growth in their crown diameter but have shown less than average growth in height).

At Pakhar plantation site, an overall average percentage growth in crown diameter for all the species is found to be very encouraging i.e. 169%. This depicts the suitability of each species planted at Pakhar plantation site. Species of Arjun, Imlee, Bahera, Neem, Mahuwa, Bahera, and Bakain etc. showed robust growth rate of 460%, 431%, 291%, 270%, 227%, 209% and 198% respectively. While Mango and Guava species have shown lower growth rate in crown diameter because they were already planted with higher crown diameter and their crown diameter during first measurement was found to be 123.50 cm and 82 cm against the average of 22.63 cm for other species.

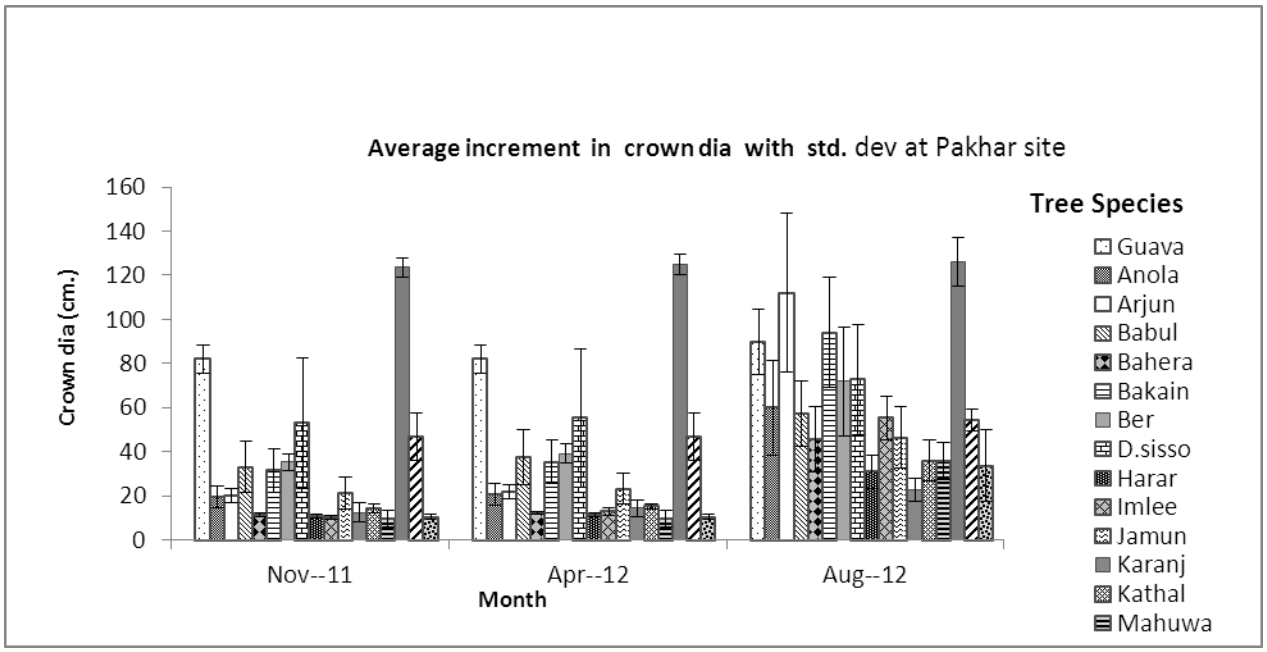

Figure 40 Average increment in crown dia with standard deviation at Pakhar site

While at Bagru plantation site, Babul, Ber and Karanj species have shown an impressive growth rate in crown diameter of 151%, 110% and 91% respectively while species of Arjun, Mango, Guava, Bahera etc showed no improvement in their crown diameter because these species were more prone to grazing and ineffective fencing facilitated grazing at project site. Babul species has shown exceptionally good crown diameter increment as it was planted in the sloppy areas where high crown diameter and less height is a common feature of such terrain.

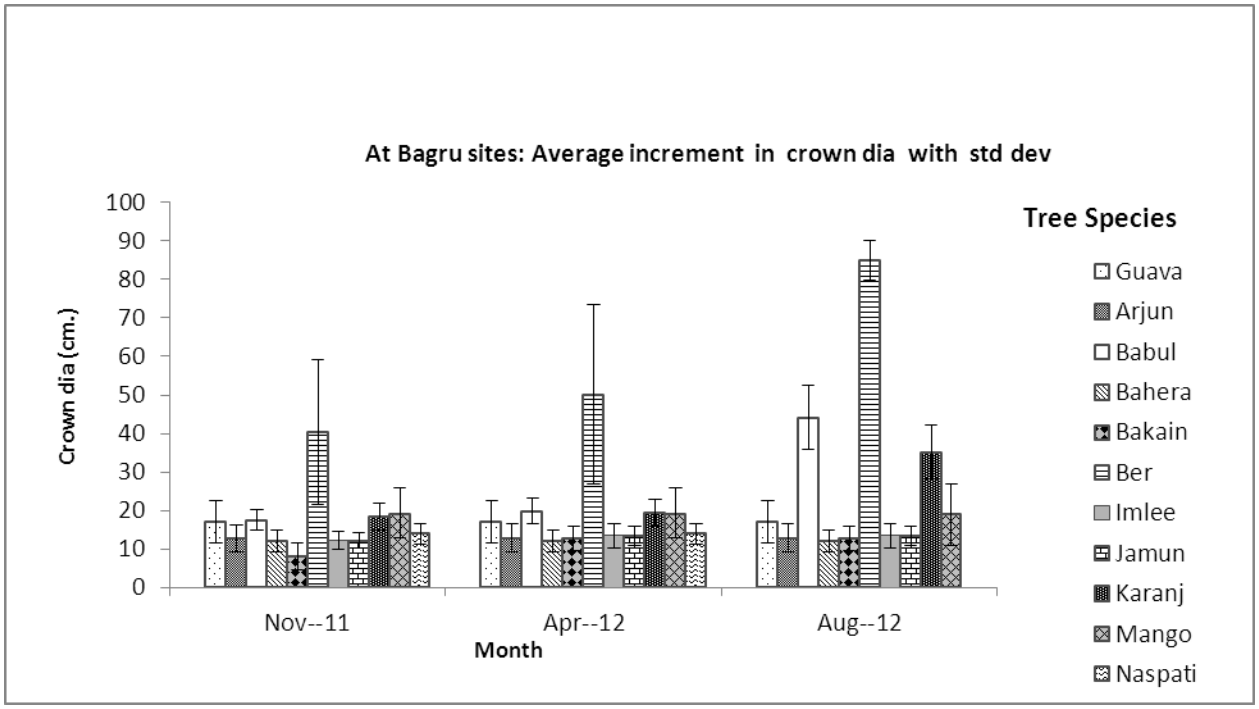

Figure 41 Average increment in crown dia with standard deviation at Bagru sites

Number of Branches:

In general it is observed that fruit bearing species like Anola, Mango, Imlee etc. have grown good number of branches while timber species like Shisham have developed less number of branches. At Pakhar plantation site, average growth rate in the number of branches for all the species is impressively at 167% wherein species like Anola, Imlee, Bahera, and Mango has attained the growth rate in number of branches as 1100%, 550%, 333% and 167% respectively. While at Bagru plantation site, species of Mango, Ber and Naspati showed a negative trend in their number of branches because of grazing issues.

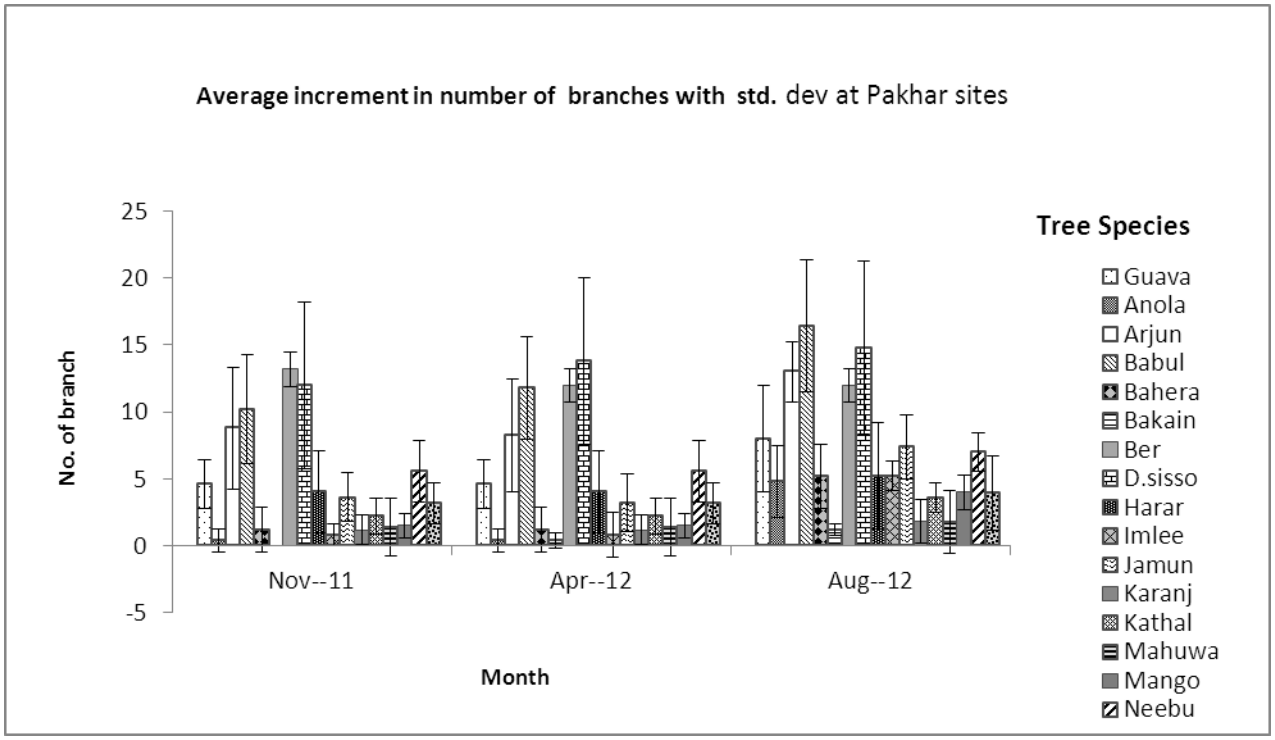

Figure 42 Average increment in number of branches with standard deviation at Pakhar sites

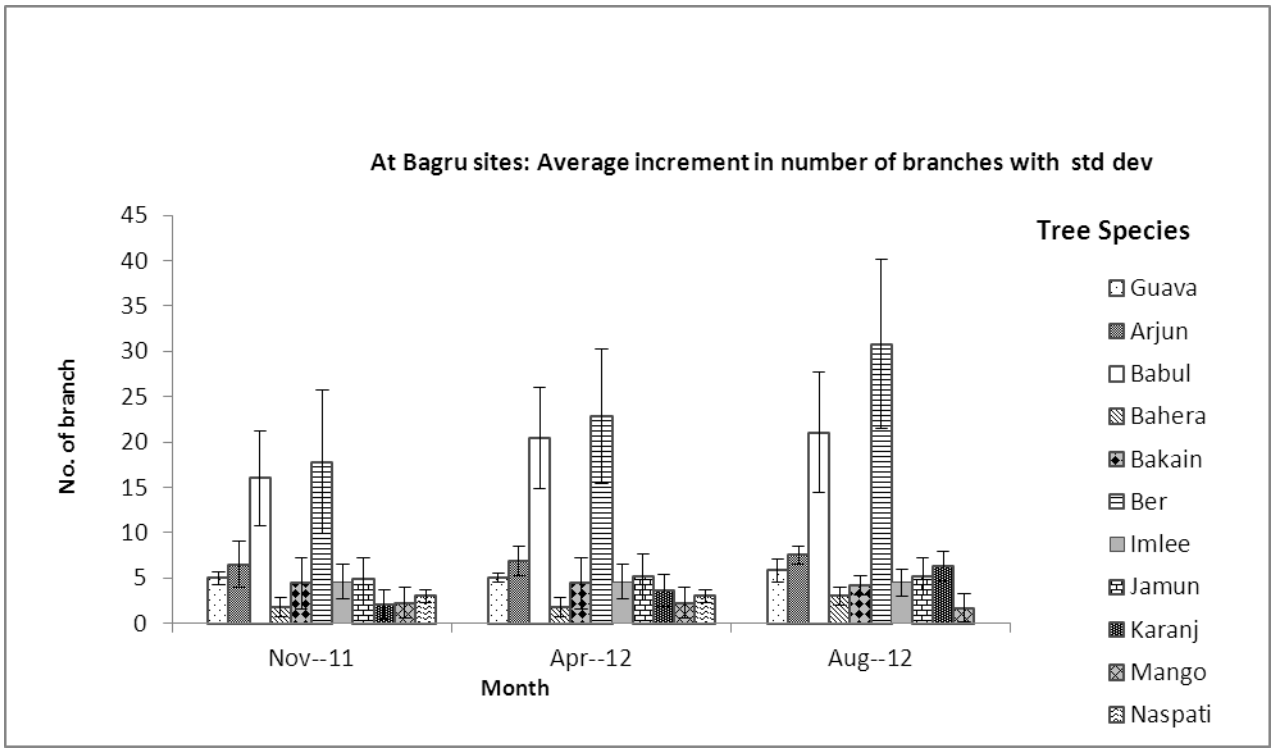

Figure 43 Average increment in number of branches with standard deviation at Bagru sites

Number of Leaves:

At Pakhar plantation site, every species has shown a positive growth rate in number of species. Infect species of Anola, Arjun, Bahera, Guava, Neebu and Karanj has shown phenomenal increase in their number of leaves while rest others have shown above average growth. This infers a suitable environmental condition and effective ward and watch for all the planted species at Pakhar site. While at Bagru plantation site, some species like Guava, Arjun, Jamun etc. have shown a negative trend which demonstrate the presence of grazing activity at this site.

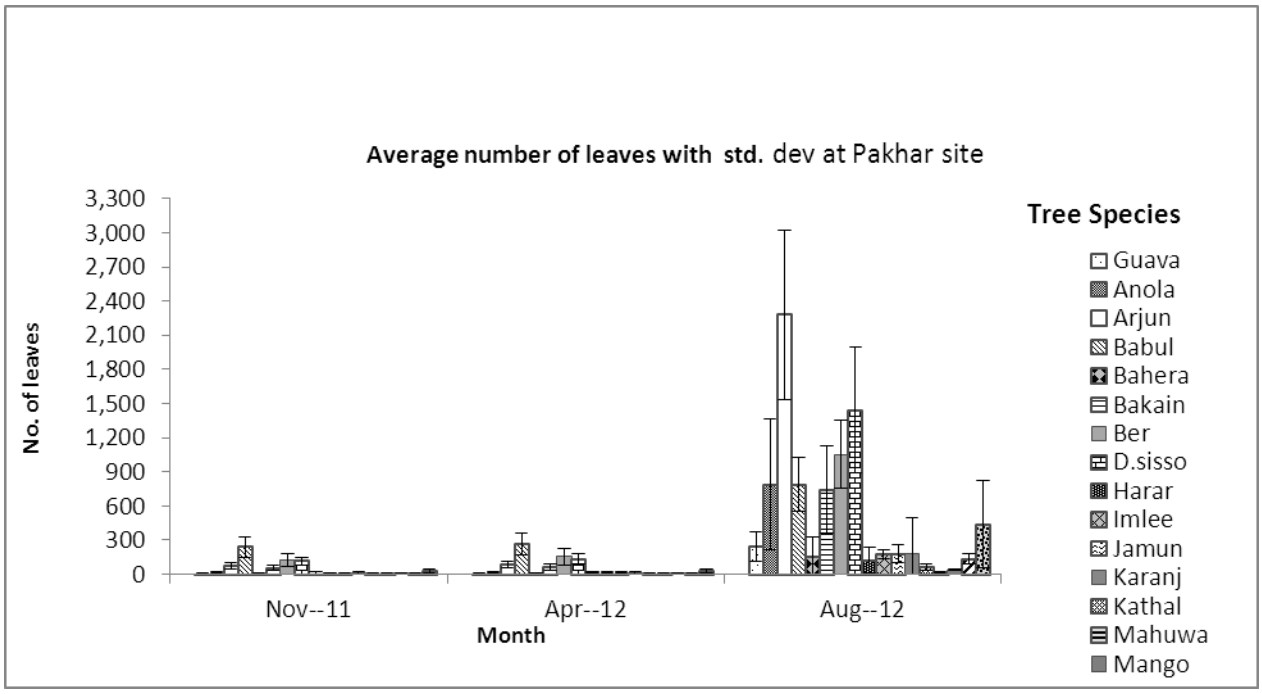

Figure 44 Average number of leaves with standared deviation at Pakhar site

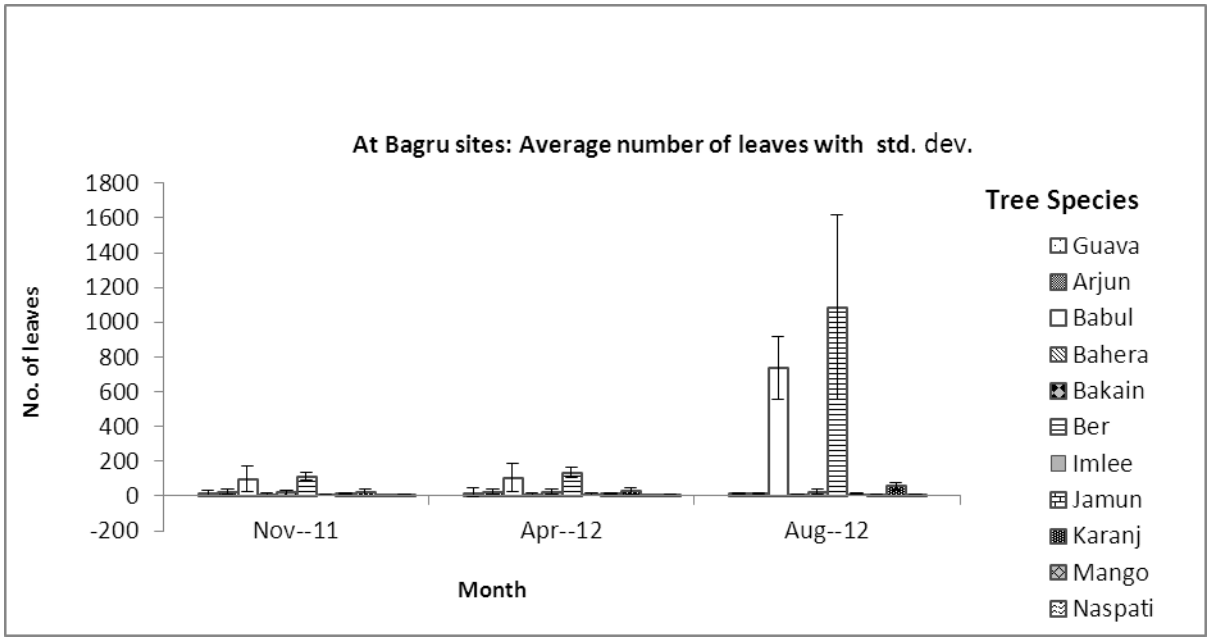

Figure 45 Average number of leaves with standard deviation at Bagru sites.

Shoot length:

At Pakhar plantation site, Shisham, Kathal and Arjun lead the growth rate in shoot length among all the species. Shoot length for Shisham increased from an average of 8 cm to 20.6 cm, for Kathal from an average of 6 cm to 12.20 cm and for Arjun from an average of 1.60 cm to 2.60 cm. It is observed that shoot length for Guava, Anola, Bahera, Ber, Mango and Neebu species on an average has shown a negative trend. This decrease in shoot length is due to the fact that number of shoots in the species must have increase which in turn has reduces the shoot length of overall species type.

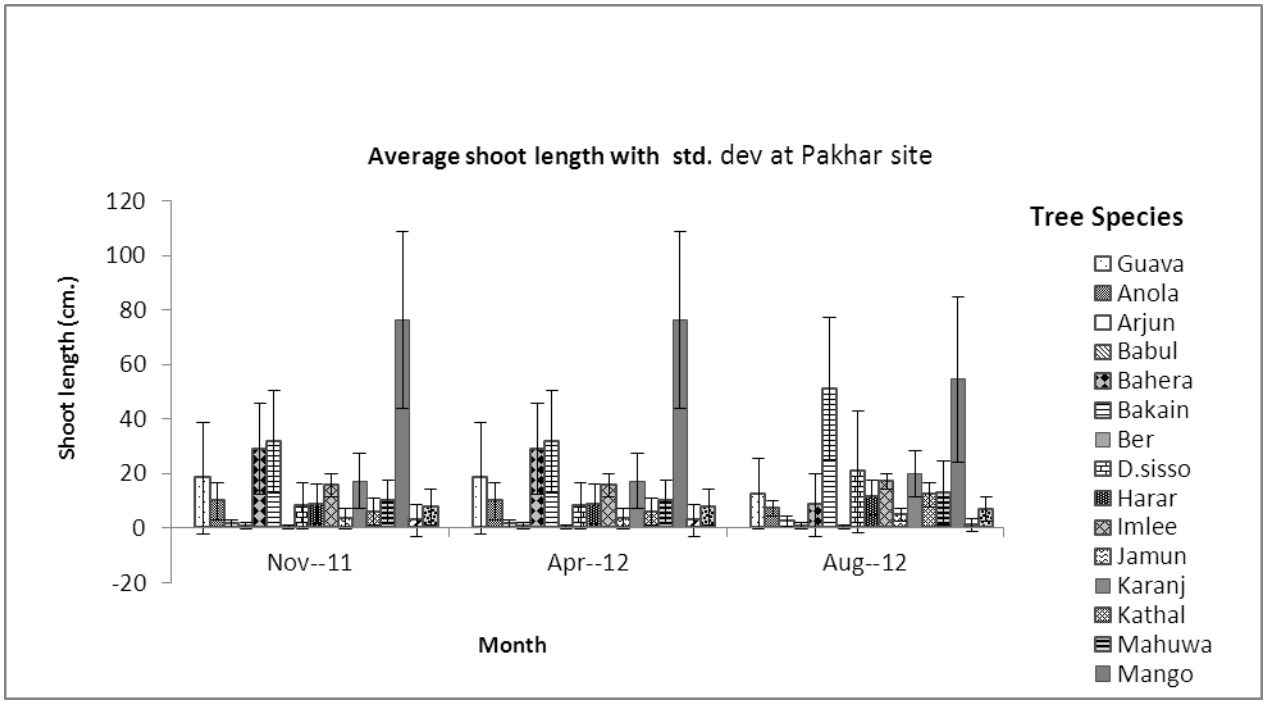

Figure 46 Average shoot length with standard deviation at Pakhar site

Further at Bagru plantation site, Babul and Bakain species have shown maximum shoot length among all the species i.e. from 1.20 cm to 1.60 cm and from 1.40 cm to 2 cm. While Imlee and Karanj species has shown decrement in their shoot length because of sprouting of new shoots.

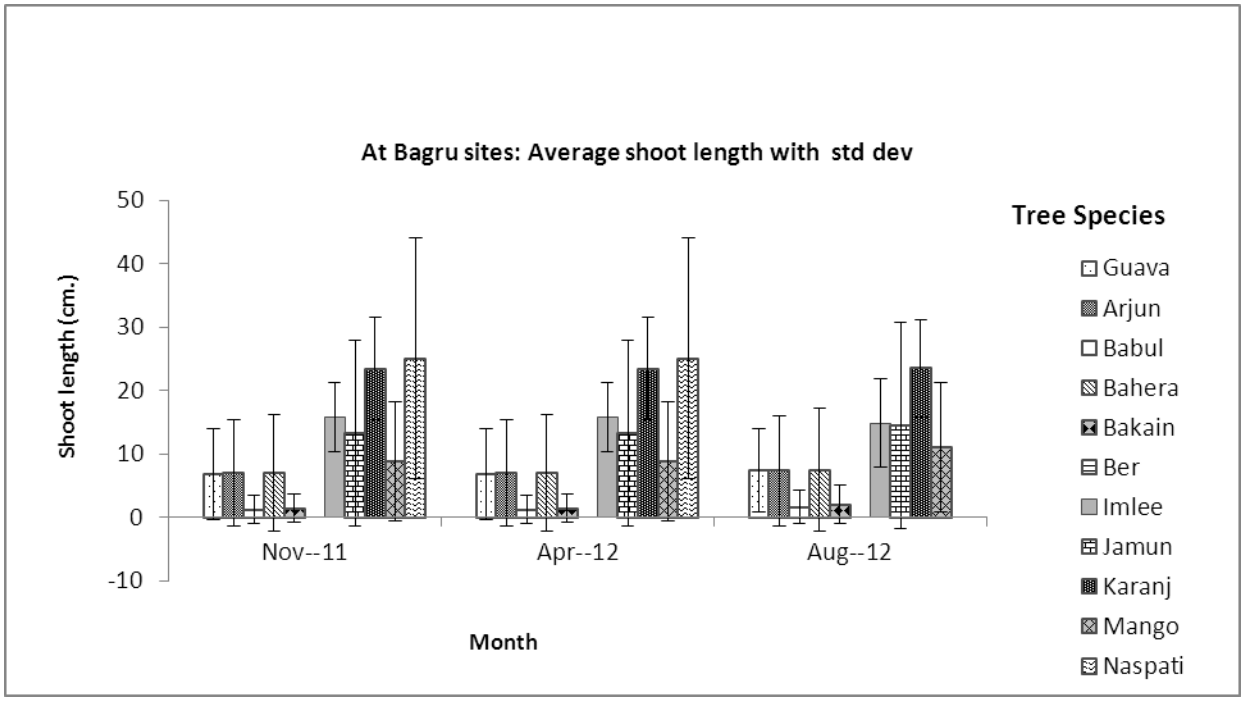

Figure 47 Average s hoot length with standard deviation at Bagru sites

Growth status of grass species:

Two monitoring data were collected and compared with each other to find out the percent increase in the number of tufts and average shoot length. The baseline data were collected in the month of Nov 2011, April 2012 and Aug 2012 from six sample plots of the second phase of the project.

Number of tufts increased in *Stylo hamata* grass was from an average of 13.47 to 16.53 while for *Sesbania sesban*, number of tufts decreased from 16.83 to 15.58. The negative trend of *Sesbania sesban* is due to the fact that mulching activity was performed on tufts of these grasses. Shoot length for both the grass species has shown positive growth rate and their overall growth rate is observed to be 163% wherein *Stylo hamata* shows an average growth rate of 192% while *Sesbania sesban* shows an average growth rate of 135%. Details of the overall average number of tufts in all the six research plots for both the grass species are provided in the graphical representation.

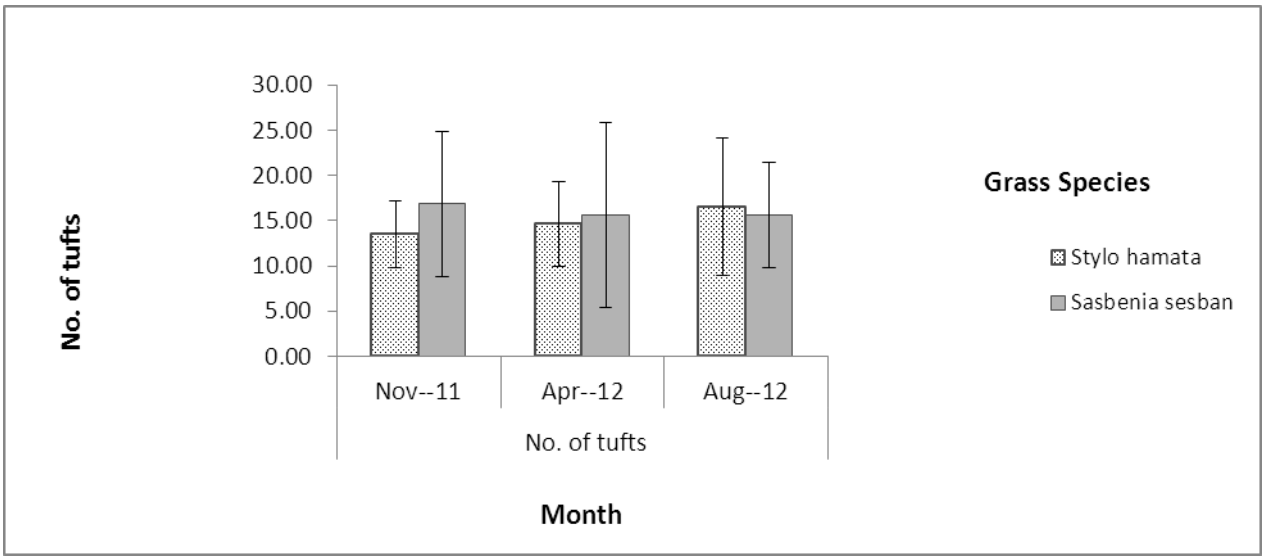

Figure 48 Average number of tufts of grass species

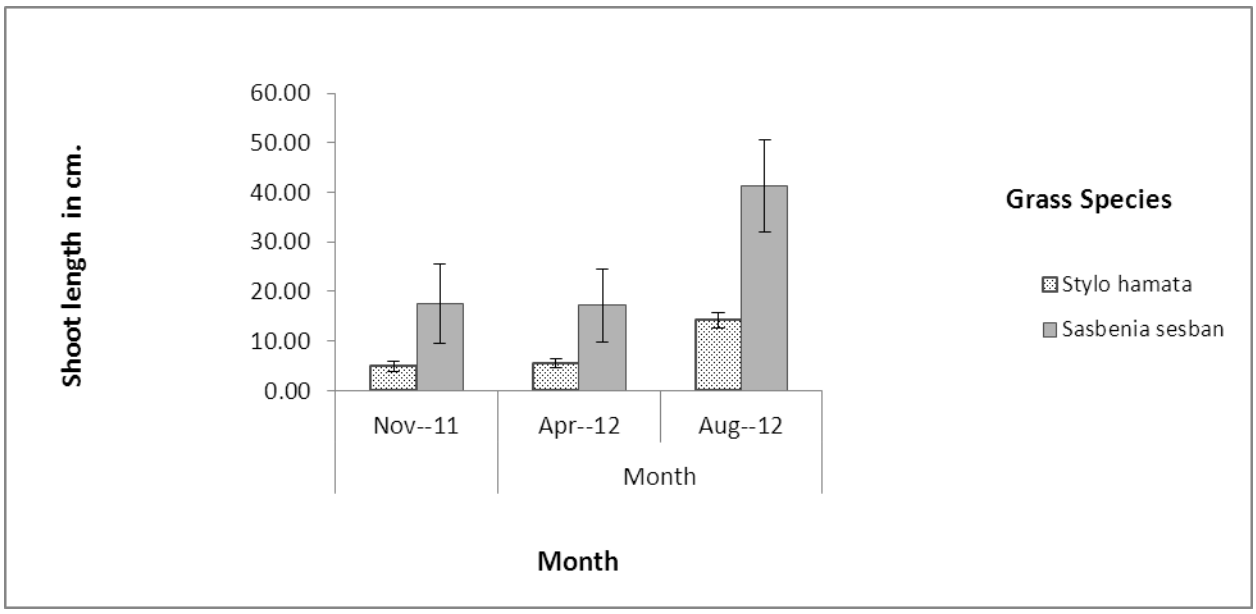

Figure 49 Average shoot length of grass species

Recommendations and conclusion

In order to ensure good survival and better growth of the plants at the project areas, following suggestions and recommendations are given.

1. Effective fencing should be carried out immediately to cover the entire plantation area of third phase. As demonstrated in Pakhar mines (plot 3rd in lease area 84.38), bio- fencing through live branches of *Vitex negundo* has to be replicated especially in Pakhar mines where maximum plantation is done. While in Bagru, where all rehabilitated areas are fenced through barbed wire but are not very effective as there are many gaps in it. Therefore, these gaps must be closed through fixing of live branches of *Vitex negundo, Neriumindicum*, *Henna, and Ipomea* etc.
2. During the month of September, first weeding and saucer making, hoeing and mulching is strongly recommended in all the plantation sites of third phase. While in first and second phase plantation, weeding and saucer making is to be done during October and November. Second weeding, hoeing and mulching should be carried out in the month of April in all the plantation areas.
3. At the top of the slopes, where gully erosion has occurred, construction of diversion channels is strongly recommended. The diversion channels will divert the path of the run-off water and help in reducing the rate of the soil erosion. Also, plantation of soil binding shrubs such as *Vitex nigundo* (Siwali), *Losonia alva* (Mahandi), *Lowsonia alba* (Hina), *Vincarosea, Bouganvilla* (flowering shrub), *Zizyphus jujube* (Ber) and *Carissa carandas* (Karonda) or grass species such as *Cynodonda ctylon, Chryso pogonfulvus, Sachcharum munja* and *Cenchrus setigerus* are strongly suggested to stabilize the loose soil at the gully formation area.
4. Rainwater harvesting structures or recharge ponds should be excavated at the plantation sites of second and third phases. This will retain the soil moisture for longer duration, which will help in good growth and better survival rate of the plants.
5. Grasses sown during the second phase of the project has grown well, these grasses should not be harvested till one more year from the eroded soil, rain cuts and sloping areas. The increase of grass cover by spreading more mature seeds at the sites will help in binding the loose soil and also provide micro nutrients to the plants. While seed collection for grasses sown during first phase of plantation activity should be initiated for next year vegetation enhancement activity.
6. After completion of the construction of toe wall and diversion channel at railway siding slope, planting of tree species, grasses, tufts and seed sowing of soil binder bushes like Jangli anar (*Dodonaea viscosa)* etc should be carried out in next coming monsoon seasons. This will capture the soil erosion of sloppy areas as well as retain the moisture in the soil.

Annexure - 1: Monitoring Data for first phase of plantation

Growth status of saplings:

Annexure 1 A: Average increment in height of the all the tree species:

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	Anola	35.00±11.33	77.53±21.57	96.67±21.20	104.67±21.99	159.93±45.71
2	Bel	20.33±5.67	33.93±13.65	41.73±17.43	43.33±16.89	70.07±20.21
3	Harar	11.50±5.00	28.8±15.53	39.4±18.14	42.9±18.61	82.2±24.35
4	Jamun	35.00±8.50	41.50±20.77	52.90±17.37	58.00±16.99	62.80±15.88
5	Neem	37.33±8.67	72.20±18.17	76.40±22.74	77.13±22.42	124.80±46.91
6	Bakain	41.67±9.67	115.47±23.88	175.00±50.56	187.33±55.17	238.20±62.44
7	Imlee	50.00±12.00	56.20±10.59	71.00±9.62	74.00±10.84	97.75±11.93
8	Ber	64.00±12.00	111.80±49.37	152.00±78.47	154.20±78.44	168.00±86.00
9	Arjun	61.00±14.00	85.60±7.30	139.00±19.81	143.00±16.81	188.40±58.42
10	Bahera	45.50±7.50	62.80±14.40	72.30±16.87	74.20±17.88	118.10±42.05
11	Kanji	50.00±9.00	105.00±32.02	111.60±32.10	117.40±40.36	145.80±43.51

Annexure 1 B: Average increment in collar diameter of the all the tree species:

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	Anola	0.65±0.27	2.08±0.52	2.81±0.65	3.00±0.72	3.87±0.75
2	Bel	0.32±0.07	0.70±0.27	0.95±0.41	1.03±0.39	1.73±0.86

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
3	Harar	0.23±0.05	0.8±0.39	1.58±0.64	1.68±0.63	2.57±0.83
4	Jamun	0.69±0.17	1.23±0.58	1.67±0.54	1.77±0.50	1.77±0.48
5	Neem	0.52±0.11	1.59±0.44	1.80±0.49	1.89±0.54	2.56±0.85
6	Bakain	0.79±0.26	2.18±0.43	3.16±0.73	3.53±0.74	4.47±1.14
7	Imlee	0.42±0.09	1.32±0.08	2.14±0.25	2.24±0.25	2.80±0.14
8	Ber	0.74±0.15	2.30±0.97	2.86±1.15	2.94±1.18	3.78±1.84
9	Arjun	1.05±0.23	2.50±0.19	4.36±0.78	4.82±0.79	6.20±0.77
10	Bahera	0.46±0.09	1.70±0.45	2.16±0.68	2.19±0.70	3.04±1.11
11	Kanji	0.69±0.12	2.02±0.29	2.36±0.40	2.42±0.38	2.90±0.38

Annexure 1 C: Average increment in crown diameter of the all the tree species:

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	Anola	29.00±7.00	95.73±25.48	96.40±25.00	101.80±24.29	183.73±43.13
2	Bel	15.00±3.00	25.37±13.47	27.80±14.03	29.27±14.22	72.27±44.01
3	Harar	9.00±2.00	37.2±14.24	51.4±13.60	55.5±15.58	112.4±52.00
4	Jamun	23.50±5.50	35.50±12.63	35.50±12.63	38.70±13.82	57.65±14.89
5	Neem	24.00±7.33	64.70±25.93	66.60±25.45	67.80±25.77	90.47±28.79
6	Bakain	34.00±9.33	98.13±25.65	106.20±33.57	107.53±34.58	131.07±32.04
7	Imlee	25.00±9.00	64.40±6.62	71.80±6.26	74.20±7.95	123.75±35.44
8	Ber	50.00±15.00	112.60±39.84	131.80±43.34	143.00±40.56	178.40±91.33
9	Arjun	40.00±12.00	85.80±6.42	145.00±11.18	148.40±12.36	203.60±33.54

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
10	Bahera	18.50±2.50	54.05±16.69	64.20±24.03	64.80±23.82	93.10±27.54
11	Kanji	27.00±3.00	76.00±32.28	79.60±30.20	81.80±28.71	110.60±29.06

Annexure 1 D: Average increment in number of branches for the all the tree species:

Sr.no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	Anola	4.57±0.72	4.33±1.52	5.40±1.88	6.20±1.76	10.13±3.73
2	Bel	0.77±0.03	1.00±1.26	2.53±1.31	3.27±1.65	7.53±4.31
3	Harar	1.35±2.25	3.4±1.79	9.1±3.41	11±3.34	15.9±4.02
4	Jamun	4.10±2.06	7.10±3.75	8.10±3.13	8.80±3.25	8.15±2.20
5	Neem	2.93±1.57	5.67±2.65	6.67±2.16	8.87±2.83	11.00±3.91
6	Bakain	0.67±0.73	1.29±1.05	1.40±1.10	5.33±3.74	6.73±3.27
7	Imlee	8.00±4.50	11.20±4.15	12.00±3.74	15.80±3.63	19.25±2.50
8	Ber	16.30±9.20	16.60±3.85	19.40±4.83	21.20±4.60	20.60±4.39
9	Arjun	15.00±3.74	17.40±3.91	25.40±5.18	30.60±4.83	44.00±7.71
10	Bahera	2.50±1.60	4.70±2.72	6.10±2.81	6.70±3.07	9.40±3.68
11	Kanji	1.50±2.50	2.40±1.34	3.20±1.64	4.20±1.48	9.40±6.69

Annexure 1 E: Average increment in shoot length of the all the tree species:

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	Anola	2.43±3.09	4.17±2.11	4.73±2.76	5.00±2.78	5.40±3.03
2	Bel	1.50±3.31	1.67±2.25	3.00±2.95	2.87±3.21	8.40±7.77
3	Harar	0.70±2.10	0.8±0.77	0.6±0.69	0.7±0.87	1.4±1.28
4	Jamun	1.85±4.80	4.90±5.00	6.30±5.28	6.60±5.38	6.75±5.98
5	Neem	1.50±2.97	5.20±8.62	6.47±9.63	6.27±9.24	2.93±3.00
6	Bakain	8.16±5.15	46.13±25.70	50.67±29.36	72.53±42.85	83.87±55.88
7	Imlee	5.00±11.00	6.40±3.05	5.20±3.56	8.40±3.65	9.00±4.55
8	Ber	0.15±1.60	0.20±0.45	0.20±0.45	0.80±1.79	1.00±2.24
9	Arjun	3.14±1.90	3.40±3.21	5.40±3.58	3.60±4.62	5.60±3.78
10	Bahera	6.93±12.00	7.95±8.24	8.50±9.08	8.70±9.03	13.00±8.56
11	Kanji	12.00±8.00	16.00±24.61	16.80±25.28	17.20±25.62	3.80±5.50

Annexure 1 F: Average increment in number of leaves of the all the tree species:

Sr. no.	Species	Month		
		Nov--11	Apr--12	Aug--12
1	Anola	329.20±190.11	261.00±147.87	1390.07±575.31
2	Bel	64.20±47.90	50.80±32.51	253.00±208.51
3	Harar	73±30.28	61.46±44.52	340.2±240.16
4	Jamun	58.00±31.14	59.80±18.56	206.00±86.29
5	Neem	69.50±42.55	82.00±38.62	1082.47±561.41

Sr. no.	Species	Month		
		Nov--11	Apr--12	Aug--12
6	Bakain	170.60±78.58	176.67±66.33	1185.60±799.53
7	Imlee	129.60±57.37	160.00±58.31	1861.75±235.32
8	Ber	18.80±13.68	249.00±119.50	2072.00±1546.92
9	Arjun	1139.00±239.62	1190.00±270.19	2440.00±482.70
10	Bahera	17.60±14.01	35.20±20.17	1002.00±551.85
11	Kanji		65.00±15.81	464.00±253.34

Growth status of grass species:

Annexure 1 G: Average increment in number of tufts for all the grass species:

Sr. no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	*Stylo hamata*	13.11±4.01	38.44±17.86	40.67±18.36	38.89±25.63	33.78±16.17
2	*Sesbania sesban*	72.56±25.27	26.89±11.29	27.22±4.58	36.78±6.94	33.11±11.31

Annexure 1 H: Average increment in shoot length of all the grass species:

S.no.	Species	Month				
		Oct--10	Jun--11	Nov--11	Apr--12	Aug--12
1	*Stylo hamata*	5.00±1.03	15.44±6.14	16.22±8.02	36.33±14.43	33.67±7.10
2	*Sesbania sesban*	22.89±5.69	56.56±26.57	47.56±15.48	36.56±14.38	42.11±8.77

Annexure – 2 Monitoring Data for second phase of plantation

Growth status of saplings

Annexure 2 A: Average increment in height of the all the tree species at Bagru plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Height (cm.)**	**Height (cm.)**	**Height (cm.)**
1	Guava	40.6±7.54	40.6±7.54	43.2±7.12
2	Arjun	43.7±6.65	44.2±6.65	44.9±6.88
3	Babul	50.4±8.85	50.4±8.85	50.4±8.85
4	Bahera	31.6±5.5	31.6±5.5	31.6±5.5
5	Bakain	38.2±8.9	40±9.43	41.4±9.66
6	Ber	40.6±14.6	40.6±14.6	82.6±21.63
7	Imlee	43.4±9.39	43.7±9.17	44.2±9.17
8	Jamun	43.9±14.12	44±14	44.65±15.2
9	Karanj	37.1±7.49	38.3±7.24	49.9±6.62
10	Mango	64.25±7.23	64.25±7.23	65±8.66
11	Naspati	56±16.26	57±16.54	

Annexure 2 B: Average increment in height of the all the tree species at Pakhar plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Height (cm.)**	**Height (cm.)**	**Height (cm.)**
1	Guava	82±27.06	82±27.06	89.8±18.29

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Height (cm.)**	**Height (cm.)**	**Height (cm.)**
2	Anola	47±21.39	50±22.99	56.2±24.53
3	Arjun	34.6±8.96	36±10.27	69±14.37
4	Babul	59.6±13.16	63.2±14.04	86.4±12.42
5	Bahera	49.4±5.64	50.2±5.89	62.8±14.11
6	Bakain	43±16.05	46.8±15.94	90.8±31.16
7	Ber	43.4±8.23	46±7.21	103.4±38.01
8	Shisham	154±56.5	155.8±57.63	160.6±56.2
9	Harar	37±10.37	37.8±10.85	38.6±10.74
10	Imlee	25.2±2.05	27.6±1.67	37.8±10.11
11	Jamun	46.8±16.93	48.2±16.07	57.6±16.47
12	Karanj	36.6±8.68	38.4±9.21	47.2±8.11
13	Kathal	40.6±8.62	42.6±8.2	59.8±15.07
14	Mahuwa	21.2±2.68	23.2±2.17	26.5±7.68
15	Mango	123.5±13.92	124.88±14.37	126.29±15.47
16	Neembu	47±20.8	47±20.8	54.4±16.23
17	Neem	23.3±3.21	23.4±3.43	46.125±25.33

Annexure 2 C: Average increment in collar diameter of the all the tree species at Bagru plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Collar dia (cm)**	**Collar dia (cm)**	**Collar dia (cm)**
1	Guava	0.76±0.11	0.8±0.14	0.925±0.1
2	Arjun	0.66	0.68±0.06	0.84±0.07

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Collar dia (cm)**	**Collar dia (cm)**	**Collar dia (cm)**
3	Babul	0.46	0.54±0.18	0.84±0.11
4	Bahera	0.4	0.4±0.07	0.48±0.04
5	Bakain	1.04	1.16±0.23	1.34±0.26
6	Ber	0.66	0.76±0.21	1.64±0.42
7	Imlee	0.47	0.48±0.08	0.58±0.06
8	Jamun	0.58	0.58±0.19	0.73±0.22
9	Karanj	0.84	0.92±0.21	1.2±0.19
10	Mango	1.18	1.175±0.13	1.23±0.06
11	Naspati	0.9	0.98±0.18	

Annexure 2 D: Average increment in collar diameter of the all the tree species at Pakhar plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Collar dia (cm)**	**Collar dia (cm)**	**Collar dia (cm)**
1	Guava	1.24±0.15	1.32±0.16	1.4±0.2
2	Anola	0.48±0.18	0.52±0.23	0.98±0.45
3	Arjun	1.02±0.22	1.06±0.19	2.7±0.49
4	Babul	0.52±0.08	0.58±0.11	1±0.14
5	Bahera	0.38±0.04	0.42±0.08	1.2±0.43
6	Bakain	0.98±0.18	1.02±0.18	2.02±0.43
7	Ber	0.62±0.13	0.68±0.13	1.36±0.36
8	Shisham	1.44±0.48	1.48±0.5	1.92±0.8
9	Harar	0.3±0.07	0.32±0.08	0.6±0.22

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Collar dia (cm)**	**Collar dia (cm)**	**Collar dia (cm)**
10	Imlee	0.36±0.09	0.38±0.08	1.04±0.32
11	Jamun	0.68±0.16	0.72±0.2	1.58±0.54
12	Karanj	0.66±0.17	0.72±0.16	0.94±0.26
13	Kathal	0.76±0.05	0.82±0.21	1.5±0.21
14	Mahuwa	0.58±0.13	0.6±0.12	0.775±0.13
15	Mango	1.7±0.3	1.775±0.32	2±0.34
16	Neembu	0.8±0.14	0.88±0.16	1.18±0.23
17	Neem	0.33±0.05	0.33±0.05	0.825±0.41

Annexure 2 E: Average increment in crown diameter of the all the tree species at Bagru plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**crown dia (cm.)**	**crown dia (cm.)**	**crown dia (cm.)**
1	Guava	17±5.42	17±5.42	17±5.42
2	Arjun	12.75±3.62	12.8±3.66	12.8±3.66
3	Babul	17.6±2.61	19.8±3.27	44.2±8.29
4	Bahera	12±2.74	12±2.74	12±2.74
5	Bakain	8±3.46	12.8±3.11	12.8±3.11
6	Ber	40.4±18.72	50.2±23.35	85±5.1
7	Imlee	12.25±2.4	13.5±3.17	13.5±3.17
8	Jamun	12.2±2.06	13.3±2.49	13.3±2.49
9	Karanj	18.4±3.61	19.4±3.6	35.2±7.11

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	crown dia (cm.)	crown dia (cm.)	crown dia (cm.)
10	Mango	19.25±6.5	19.25±6.5	19±7.94
11	Naspati	14±2.65	14±2.65	

Annexure 2 F: Average increment in crown diameter of the all the tree species at Pakhar plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	crown dia (cm.)	crown dia (cm.)	crown dia (cm.)
1	Guava	82±6.23	82±6.23	89.8±14.71
2	Anola	19.4±4.93	20.8±4.87	60±21.51
3	Arjun	20±3.08	21.8±2.95	112±36.16
4	Babul	33±11.51	37.4±12.4	57±14.83
5	Bahera	11.6±0.89	12.2±0.84	45.4±14.88
6	Bakain	31.5±9.97	35.4±9.76	94±25.11
7	Ber	35.2±3.83	39.2±4.32	72±24.7
8	Shisham	53±29.7	55.2±31.22	72.6±25.03
9	Harar	10.8±1.1	11.6±0.89	30.8±7.79
10	Imlee	10.4±0.89	12.8±1.48	55.2±9.76
11	Jamun	21.2±7.16	23.2±7.12	46.4±13.94
12	Karanj	12.4±4.51	14.4±3.78	22.8±5.22
13	Kathal	14±2	15.2±1.1	36±9.41
14	Mahuwa	9.6±3.65	9.6±3.65	35.5±8.39
15	Mango	123.5±4.37	124.875±4.57	126.29±11
16	Neembu	47±10.71	47±10.71	54.4±4.88

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	crown dia (cm.)	crown dia (cm.)	crown dia (cm.)
17	Neem	10.3±1.2	10.3±1.2	33.65±16.07

Annexure 2 G: Average increment in number of branches for the all the tree species at Bagru plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	Branch	Branch	Branch
1	Guava	5±0.71	5±0.5	5.8±1.3
2	Arjun	6.5±2.55	6.9±1.59	7.5±0.94
3	Babul	16±5.24	20.4±5.55	21±6.63
4	Bahera	1.8±1.1	1.8±1.1	3±1
5	Bakain	4.4±2.79	4.4±2.79	4.2±1.1
6	Ber	17.8±7.89	22.8±7.4	30.8±9.34
7	Imlee	4.6±1.94	4.6±1.94	4.5±1.47
8	Jamun	4.9±2.35	5.1±2.48	5.15±2.07
9	Karanj	2.1±1.65	3.6±1.79	6.3±1.63
10	Mango	2.25±1.71	2.25±1.71	1.67±1.53
11	Naspati	3±0.71	3±0.71	

Annexure 2 H: Average increment in number of branches for the all the tree species at Pakhar plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	Branch	Branch	Branch
1	Guava	4.6±1.82	4.6±1.82	8±3.94

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Branch**	**Branch**	**Branch**
2	Anola	0.4±0.89	0.4±0.89	4.8±2.68
3	Arjun	8.8±4.55	8.2±4.21	13±2.24
4	Babul	10.2±4.02	11.8±3.83	16.4±4.93
5	Bahera	1.2±1.64	1.2±1.64	5.2±2.39
6	Bakain	0±0	0.4±0.55	1.2±0.45
7	Ber	13.2±1.3	12±1.22	12±1.22
8	Shisham	12±6.2	13.8±6.22	14.8±6.42
9	Harar	4±3.08	4±3.08	5.2±3.96
10	Imlee	0.8±0.84	0.8±1.67	5.2±1.1
11	Jamun	3.6±1.82	3.2±2.17	7.4±2.41
12	Karanj	1.2±1.1	1.2±1.1	1.8±1.64
13	Kathal	2.2±1.3	2.2±1.3	3.6±1.14
14	Mahuwa	1.4±2.19	1.4±2.19	1.75±2.36
15	Mango	1.5±0.93	1.5±0.93	4±1.29
16	Neembu	5.6±2.3	5.6±2.3	7±1.41
17	Neem	3.2±1.53	3.2±1.53	3.925±2.75

Annexure 2 I : Average increment in shoot length for the all the tree species at Bagru plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Shoot length (cm.)**	**Shoot length (cm.)**	**Shoot length (cm.)**
1	Guava	6.8±7.12	6.8±7.12	7.4±6.5

		Nov--11	Apr--12	Aug--12
2	Arjun	6.9±8.39	6.9±8.39	7.3±8.64
3	Babul	1.2±2.17	1.2±2.17	1.6±2.61
4	Bahera	7±9.14	7±9.14	7.4±9.69
5	Bakain	1.4±2.19	1.4±2.19	2±3.08
6	Ber	0±0	0±0	0±0
7	Imlee	15.8±5.48	15.8±5.48	14.8±6.96
8	Jamun	13.2±14.65	13.2±14.65	14.425±16.26
9	Karanj	23.4±8.07	23.4±8.07	23.5±7.65
10	Mango	8.75±9.43	8.75±9.43	11±10.15
11	Naspati	25±19.03	25±19.03	

Annexure 2 J : Average increment in shoot length for the all the tree species at Pakhar plantation site:

		Nov--11	Apr--12	Aug--12
Sr. no.	**Species**	**Shoot length (cm.)**	**Shoot length (cm.)**	**Shoot length (cm.)**
1	Guava	18.4±20.38	18.4±20.38	12.6±13.05
2	Anola	9.8±6.8	9.8±6.8	7.2±3.03
3	Arjun	1.6±1.52	1.6±1.52	2.6±1.82
4	Babul	0.8±1.1	0.8±1.1	0.8±1.1
5	Bahera	29±16.57	29±16.57	8.4±11.52
6	Bakain	31.8±18.82	31.8±18.82	51±26.15
7	Ber	0.4±0.55	0.4±0.55	0.4±0.55
8	Shisham	8±8.37	8±8.37	20.6±22.38

		Nov--11	Apr--12	Aug--12
9	Harar	8.8±7.46	8.8±7.46	11.2±6.38
10	Imlee	15.8±4.27	15.8±4.27	17±2.83
11	Jamun	3.4±3.91	3.4±3.91	4.8±2.28
12	Karanj	17.2±9.98	17.2±9.98	19.8±8.44
13	Kathal	6±4.85	6±4.85	12.2±4.49
14	Mahuwa	9.8±7.6	9.8±7.6	13±11.69
15	Mango	76.25±32.46	76.25±32.46	54.57±30.3
16	Neebu	2.8±5.72	2.8±5.72	1±2.24
17	Neem	7.5±6.55	7.5±6.55	6.9±4.41

Annexure 2 K : Average increment in number of leaves for the all the tree species at Bagru Plantation site

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	No. of leaves	No. of leaves	No. of leaves
1	Guava	18.8±12.46	18.8±24.91	16.2±4.82
2	Arjun	24.6±14.3	26.1±15.46	13.6±5.06
3	Babul	95.6±73.53	105.6±79.75	740±180.31
4	Bahera	9.6±5.5	9.6±5.5	6.6±3.51
5	Bakain	20.4±15.19	23±15.83	24.8±14.75
6	Ber	112±24.14	134.4±30.19	1084.6±530.73
7	Imlee	9±4.57	11.4±4.85	12.8±2.42
8	Jamun	13.6±3.93	13.6±3.93	9.1±2.89
9	Karanj	21.2±15.43	27.3±17.15	57±23.12
10	Mango	3±2.94	4.5±1.73	7.33±2.08

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	No. of leaves	No. of leaves	No. of leaves
11	Naspati	4.8±1.79	6.8±1.3	

Annexure 2 L: Average increment in number of leaves for the all the tree species at Pakhar plantation site

		Nov--11	Apr--12	Aug--12
Sr. no.	Species	No. of leaves	No. of leaves	No. of leaves
1	Guava	11.6±4.77	11.6±4.77	242±130.65
2	Anola	16±4.18	18±4.24	790±579.22
3	Arjun	76±27.93	87.2±31.59	2280±746.32
4	Babul	242.2±90.8	265.4±97.99	790±240.83
5	Bahera	7±1.87	8.8±1.1	158±164.68
6	Bakain	55±25.98	63.2±27.89	742±383.5
7	Ber	128±58.48	154.8±72.51	1054±295.43
8	Shisham	116.8±34.11	133.8±43.12	1444±547.38
9	Harar	11.6±6.54	14.4±7.67	124±109.68
10	Imlee	12.2±4.38	16±4	172±41.47
11	Jamun	11.8±4.71	17.4±7.09	181.4±81.01
12	Karanj	10.2±7.46	12.4±7.33	176±321.22
13	Kathal	9±3.32	10.8±3.77	64±27.93
14	Mahuwa	5.6±4.04	7.4±3.36	19±2.71
15	Mango	8.125±3.76	10.25±3.92	38.57±7.48
16	Neebu	7±5.7	7.2±5.63	136.8±41.73
17	Neem	26.6±19.23	29±19.03	441.45±386.97

Growth status of grass species:

Annexure 2 M: Average increment in number of tufts for all the grass species:

Sr. no.	Species	Month		
		Nov--11	Apr--12	Aug--12
1	*Stylo hamata*	13.47 ± 3.74	14.60 ± 4.64	16.53 ± 7.55
2	*Sesbania sesban*	16.83 ± 8.06	15.58 ± 10.22	15.58 ± 5.81

Annexure 2 N: Average increment in shoot length for all the grass species:

Sr. no.	Species	Month		
		Nov--11	Apr--12	Aug--12
1	*Stylo hamata*	4.87 ± 1	5.53 ± 1.01	14.2 ± 1.5
2	*Sesbania sesban*	17.58 ± 8.05	17.17 ± 7.37	41.33 ± 9.25