GUIDELINES FOR FOREST PLANTATION
ESTABLISHMENT AND MANAGEMENT
IN UTARAKHAND

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<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>2.</td>
<td>UTTARAKHAND: A BRIEF PROFILE</td>
</tr>
<tr>
<td>3.</td>
<td>GEOLOGY</td>
</tr>
<tr>
<td>4.</td>
<td>NURSERY TECHNOLOGY</td>
</tr>
<tr>
<td>5.</td>
<td>PLANTATION TECHNIQUES</td>
</tr>
<tr>
<td>6.</td>
<td>SOIL AND WATER CONSERVATION MEASURES</td>
</tr>
</tbody>
</table>
Introduction:

Trees are one of the most prominent constituents of our ecosystem because of their conspicuous size and shape. Trees are important to the mankind not only economically, environmentally, industrially but also spiritually, historically and aesthetically as they sustain human life by providing a large number of goods such as food, fodder, fuel and services like soil and water conservation, pollution control, climate regulation, recreation aesthetic functions etc. Trees improve the quality of air we breathe and play a vital role in maintaining the oxygen cycle, which is essential for the survival of all living being. When properly grown, they act as barriers against sun, wind, dust, noise and other pollutants. Even individual tree, if strategically planted adjacent a house, can provide relief from dust, noise and annoying lights at night. Trees thus reduce stress on human beings. They help to reduce temperature by providing shade and by intercepting, absorbing and reflecting solar radiation, especially in warmer places, where there is year round warmth and sunshine. Trees also function as natural air conditioners by evaporating water from their leaves through the process of transpiration.

Large scale urbanization and industrialization in the Himalayas have led to the development of severely eroded, barren and denuded areas in many parts of the state. Afforestation thus has immense potential to bring not only greenery to the Himalayas and other urban and rural regions of the state but also stability to the environment by restoring the ecological balance. There is an immense scope of undertaking plantation works on community and panchayat lands, van panchayat areas, civil and soyam areas, road side plantation along national and state highways and other village roads. Trees intercept rains and help in the percolation of water thus play an important role in the recharging of the natural aquifers.

Uttarakhand: A Brief Profile

The Uttarakhand is comparatively a new state, which came into existence on 9th Nov, 2000 as the 27th state of the Republic of India. It was carved out from the larger state Uttar Pradesh by taking hill districts of Almora, Bageshwar, Chamoli, Champawat, Dehradun, Nainital, Pauri Garhwal, Pithoragarh, Rudraprayag, Tehri Garhwal, Uttarkashi with the districts of Udham Singh Nagar in the Terai and Hardwar in the foothills. It lies between 28°53′24″ and 31°02′50″N latitudes and between 77°03′27″ and 81°00′22″ longitudes. The state is strategically located and forms part of the northern boundary of the country sharing its border with China and Nepal. Himachal Pradesh and Haryana lie to its West and Uttar Pradesh to its South. Blessed with the enchanting beauty of nature and for historical and mythological regions, the state has its own uniqueness. About 64.7 % of the area is covered by forests and is rich with numerous species of plants, animals and birds. About 93 % area is hilly and the remaining 7 % is covered by plains. The elevation extends approximately from 300 m to over 7,000 m amsl.

GEOLOGY:

Uttarakhand Himalayas have wide range of intra regional variations in respect of topography, geology and texture of soil. The region is characterized by mountains broken by valleys and deep gorges. It consists of faulted and folded mainly sedimentary rocks. The region has abundance of various kinds of minerals such as limestone, dolomite, phosphorite, magnetite etc. There is predominance of boulders and gravels in Bhabhar and marshy tract containing fertile soil with good water retention capacity in Terai.
1. WHAT IS A FOREST PLANTATION

A forest plantation is defined as "a forest crop or stand raised artificially, either by sowing or planting". In the literature, "afforestation", "reforestation" or "forestation" is used to distinguish new planted forests. The term "afforestation" is used in describing forests established artificially on land that previously did not carry forest. For example, when man establishes a new forest on grassland or sand dunes, such afforestation is clearly artificial and can be termed a plantation. "Reforestation" is used when forests are established artificially on land which has carried forest within the previous 50 years, involving the replacement of the previous crop by an essentially different one. Sometimes, the term "forestation" is used for both "afforestation" and "reforestation".

In general, forestry plantation establishment is broadly divided into three management phases: 1. Seed Collection & Handling; 2. Nursery Practices; 3. Plantation Establishment & Management, and 4. Soil Moisture Conservation work. This manual includes guidelines related to the entire range of planting activities from species selection for the site to tree felling. The initial plantation establishment phase is divided into the following activities: species selection, site preparation and planting operation. The plantation management phase includes silvicultural activities as follows: protection, tending (weeding and fertilising), pruning, thinning, felling and regeneration/replanting.

The sequence of these activities is shown Table 1.

<table>
<thead>
<tr>
<th>Usual silvicultural operation</th>
<th>Main Decisions</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Obtain seeds</td>
<td>Species? Provenance?</td>
<td>Not applicable</td>
</tr>
<tr>
<td>3. Site preparation</td>
<td>Intensity?</td>
<td>Not applicable</td>
</tr>
<tr>
<td>4. Planting</td>
<td>Spacing? Fertiliser</td>
<td>Young trees</td>
</tr>
<tr>
<td>5. Tending</td>
<td>Frequency? Methods?</td>
<td>Saplings</td>
</tr>
<tr>
<td>7. Thinning</td>
<td>Timing? Intensity?</td>
<td>Large poles</td>
</tr>
<tr>
<td>8. High pruning</td>
<td>Need? Height?</td>
<td>Large poles</td>
</tr>
<tr>
<td>10. Regeneration/Replanting</td>
<td>Changes in species or culture?</td>
<td>Second crop</td>
</tr>
</tbody>
</table>

2.0 WHY PLANT FOREST TREES

In making any efforts towards the development we first need to learn that environmental conservation is very important aspects of sustainable development. Sustainable development as defined, "The Development that meets the need of present without compromising the ability of the future generation to meet their needs". A development is a development in its true sense only when it's sustainable one.

The direct benefits of forest plantations on the value of the land are forest products such as saw timber, fuel wood, charcoal, poles, food products and fodder for livestock, medicinal products and shade for agricultural crops. Indirect benefit includes all environmental and ecological benefits. The objectives and desired end products of the forest plantation will influence selection and application of establishment and management activities.
Plantation activities and financial investment will vary depending on the objectives and the type of plantation to be established (Table 2):

- large-scale industrial forest plantation (industrial forestry)
- large-scale non-industrial forest plantation (ecological & environmental purposes)
  - small-scale village/community forest plantation (social forestry) and agroforestry systems

### Table 2. End-products and forest plantation systems and methods

<table>
<thead>
<tr>
<th>End products</th>
<th>Plantation systems</th>
<th>Planting methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timber</td>
<td>Large-scale industrial plantation</td>
<td>Block planting</td>
</tr>
<tr>
<td></td>
<td>Small-scale community plantation</td>
<td>Block planting, Enrichment planting</td>
</tr>
<tr>
<td>Fuelwood / charcoal</td>
<td>Large-scale industrial plantation</td>
<td>Block planting/Coppice Block planting/Coppice</td>
</tr>
<tr>
<td></td>
<td>Small-scale community plantation</td>
<td></td>
</tr>
<tr>
<td>Posts / boundary</td>
<td>Agroforestry system</td>
<td>Trees planted individually or in line</td>
</tr>
<tr>
<td>Food</td>
<td>Agroforestry system</td>
<td>Trees planted individually or in line</td>
</tr>
<tr>
<td>Fodder</td>
<td>Agroforestry system</td>
<td>Trees planted individually or in line</td>
</tr>
<tr>
<td>Medicinal products</td>
<td>Agroforestry system</td>
<td>Trees planted individually or in line</td>
</tr>
<tr>
<td>Shade</td>
<td>Agroforestry system</td>
<td>Trees planted individually or in line</td>
</tr>
<tr>
<td>Land reclamation</td>
<td>Large/small-scale non-industrial</td>
<td>Block planting/Nitrogen fixing species</td>
</tr>
<tr>
<td></td>
<td>plantation</td>
<td></td>
</tr>
<tr>
<td>Aesthetics/Biodiversity</td>
<td>Large/small-scale non-industrial</td>
<td>Enrichment planting</td>
</tr>
<tr>
<td></td>
<td>plantation</td>
<td></td>
</tr>
</tbody>
</table>

The block planting method is a full planting used where there is no existing forest. Enrichment planting (line conversion planting, gap planting, under planting) is a method to improve an existing secondary forest. The last planting method called "trees planted individually or in line" includes trees planted in pastures, boundary planting, live fences and line planting between agriculture crops (taungya or intercropping).

From an ecological point of view, the reconstruction of a vegetation cover through forest plantation restores the productivity of the land in terms of reduction of air pollution, regulation of water quality and regime, control of potential soil erosion, improvement of soil fertility and creation of habitat for wildlife (Table 3). The socio-economic effects are enhancement of the beauty of the landscape, creation of an environment beneficial to the health and increase in the value of the land.
<table>
<thead>
<tr>
<th>Ecological parameter</th>
<th>Large-scale industrial forest plantation</th>
<th>Large-scale non-industrial forest plantation</th>
<th>Small-scale village/community forest plantation</th>
<th>Agro-Forestry Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>Positive effects comparable with those of natural forests Very positive effects compared with degraded sites</td>
<td>Improvement of the microclimate Only locally effective; in combination with terracing good chance to rehabilitate small catchments</td>
<td>Improvement of microclimate Only locally effective; in combination with terracing good chance to rehabilitate small catchments</td>
<td>Tree lines serve as windbreaks As trees are planted in steps and in strips along the contour Line, sustainable reduction of runoff and erosion is achieved</td>
</tr>
<tr>
<td>Water balance and erosion control</td>
<td>Increased runoff and soil erosion during establishment/young plants phase Stabilisation (at complete area coverage) Use of heavy machinery promotes soil compaction, runoff, and erosion</td>
<td>Large-scale terracing as site preparation quickly controls runoff and erosion</td>
<td>Forest roads built for forest plantation establishment often enhance erosion.</td>
<td></td>
</tr>
<tr>
<td>Soil fertility</td>
<td>Mechanical removal of the vegetation cover in combination with ploughing and partial removal of organic soil matter is more disadvantageous for plants than burning the vegetation Planting of fast-growing species with short rotations favours depletion of soil nutrients</td>
<td>Reduction of runoff and erosion creates conditions for enrichment with organic matter and nutrients</td>
<td>Small-scale positive effects could be achieved provided that erosion is stopped and nutrients are released to the soil by the organic matter</td>
<td>Shade protects the humus layer; therefore the destruction of the soil structure is counter-balanced Positive effects prevail because often nitrogen-fixing species are used, negative effects possible through root and light competition</td>
</tr>
<tr>
<td>Species diversity</td>
<td>The establishment of monocultures is accompanied by a reduction of species diversity</td>
<td>Species diversity of agriculture areas is improved through tree groups, tree strips and small-scale village and community woodlots</td>
<td>Species diversity of agriculture areas is improved through tree groups, tree strips and small-scale village and community woodlots</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Ecologic effects of forest plantation activities**
2.2 WHERE TO PLANT FOREST TREES

First, the availability of land for forest planting on public or private lands must be known and second, the quality of the available land must be known to ascertain if it is appropriate to the objectives of the planned forest plantation. In order to meet the TPA-1976 requisites. Large-scale development of plantation forestry, especially on degraded lands, seems essential.

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Texture class</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sand</td>
<td>Loose and single-grained. Individual grains can be seen and felt. Squeezed in the hand when dry, it will fall apart when pressure is released. Squeezed when moist it will form a cast which will crumble when touched.</td>
</tr>
<tr>
<td>2.</td>
<td>Sandy loam</td>
<td>Contains enough silt and clay to make it somewhat coherent. Sand grains are readily seen and felt. Squeezed when dry the cast will readily fall apart. Squeezed when moist the cast will bear careful handling without breaking.</td>
</tr>
<tr>
<td>3.</td>
<td>Loam</td>
<td>Mellow, with a somewhat gritty feel, yet fairly smooth and plastic when moist. Squeezed when dry, the cast will not break if handled carefully. When moist a cast can be handled freely without breaking.</td>
</tr>
<tr>
<td>4.</td>
<td>Silt loam</td>
<td>When dry it may appear cloddy but the lumps are easily broken. When pulverised it feels soft and floury. When wet the soil puddles. Casts formed of either dry or moist soil can be readily handled without breaking. When moistened soil is squeezed between thumb and finger it will not &quot;ribbon&quot;, but will form flat &quot;pastry flakes&quot;.</td>
</tr>
<tr>
<td>5.</td>
<td>Clay loam</td>
<td>When dry it forms hard lumps or clods. When moist it can be squeezed to form a thin ribbon, which will break readily, barely sustaining its own weight. When moist the soil is plastic and will form a cast that will take much handling.</td>
</tr>
<tr>
<td>6.</td>
<td>Clay</td>
<td>Forms very hard aggregates when dry. When wet it is plastic and sticky. Moist clay can be pinched out between thumb and finger to form a long flexible ribbon. Note that some clays are friable and lack plasticity in all moisture conditions.</td>
</tr>
</tbody>
</table>
2.3 WHICH TREE SPECIES TO PLANT:-

In many cases, species selection directly determines the success of the plantation. Whether selecting species for a large-scale plantation or a small-scale multipurpose tree plantation, a set of criteria is applied in various combinations. The criteria are determined by the purpose of the forest plantation, ie, industrial or domestic uses, environmental protection, requirements of the local population, etc. and species are selected which are best suited to the site, in terms of climate and soil.

Criteria for Species Selection by Forest Plantation Systems:-

<table>
<thead>
<tr>
<th>Large-scale Forest plantation</th>
<th>Large-scale non-industrial forest plantation</th>
<th>Small-scale village/community forest plantation</th>
<th>Agroforestry systems</th>
<th>Large-scale Forest plantation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield over 10-15 m³/ha/yr Easy propagation Clonal propagation Marketing Valuable timber Suitable for monocultures Resistance to pests Fire/wind resistance Auto-tolerant Ease of pruning Good wood properties Availability of proven seeds Site-specific</td>
<td>Intensive root system Good survival and growth Suitable for marginal lands Undemanding Multiple uses Good natural regeneration Easy propagation Coppicing Soil improvement Robust against browsing Site-specific</td>
<td>Easy propagation Coppicing Multiple uses Fast growth Short rotation High acceptance Site-specific</td>
<td>Multiple uses N₂ fixation Deep rooting Coppicing Fast growth Light crowns High acceptance Site-specific</td>
<td>Yield over 10-15 m³/ha/yr Easy propagation Clonal propagation Marketing Valuable timber Suitable for monocultures Resistance to pests Fire/wind resistance Auto-tolerant Ease of pruning Good wood properties Availability of proven seeds Site-specific</td>
</tr>
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</table>

2.4 HOW TO ESTABLISH FOREST PLANTATION

The establishment of a forest plantation includes three stages:

- Lay-out
- Site preparation; and
- Planting operation

Activities for each stage normally decrease in number and time required (investment) from large-scale forest plantations, enrichment planting to intercropping tree planting. For example, intercropping tree planting or agroforestry systems do not generally require thinning and fertilising operations.

Lay-out:-

For large-scale forest plantations, planning the plantation lay-out is complex as it must include the exact location and shape of the forest plantation; road network plan; location of waterways for fire-fighting purposes; subdivision into sub-units (compartments) with open lines between for fire breaks and access; spacing; marking; and mapping.

For small-scale village/community forest plantations, lay-out planning consists of four activities:

- Spacing decision
- Area survey and marking operation
- Establishment of firebreak line around the forest plantation as boundary protection line, and
- Mapping the location of the plantation
Seedlings are the basic pre-requisite of an afforestation programme. The success of plantations depends primarily on the quality of seedlings. A nursery can be defined as the site or place where quality seedlings are produced. Nurseries can be permanent (also known as central or main nursery), or temporary (also known as site nursery, field nursery, or flying nursery), depending upon the duration of the plantation programme. In a continuing programme that is likely to go on for more than five years, it is desirable to have at least a few permanent nurseries with proper infrastructure. However, in case of afforestation project lasting five years or less, temporary or semi-permanent nurseries can be established in which the cost can be reduced by dispensing with some of the infrastructure elements such as construction of permanent structures for green houses, store and other nursery sheds, fencing with angle iron posts and irrigation facilities. The establishment of a nursery and raising of quality seedlings is a technical process. It has been described systematically in the following steps:

### 3.1 SELECTION OF SITE

It is one of the most important aspects for the establishment of a proper and quality nursery. One has to consider not only the physical aspects for the selection of the site but also the end use of the seedlings. Following points may be kept in mind while selecting a site for the nursery.

#### 3.1.1 Location

The site should be centrally located with easy access for transportation of seedlings. It should be close to the area where seedlings are to be utilized. The site should be as square as possible. Sites used earlier for agriculture may be avoided and preference be given to former forest sites where weed problems will be less and beneficial mycorrhizae forming fungi are often endemic.

#### 3.1.2 Water

Enough water should be available especially during the dry season. A natural source of water, at a higher level, will be cheaper, as it can be tapped by gravity. If no natural source of water is available, ground water may be used. It is estimated that the water requirement for a semi-arid area is minimum of 2,000 lit per day during summer, for every 1,00,000 seedlings. Requirement of water will be somewhat less for moist or cold areas.

#### 3.1.3 Topography and drainage

The area should be almost flat with good drainage. This can be managed by providing gentle slope (5 degrees) and channels should be dug to drain out excess water from the nursery. In the hills...
Northern aspect is desirable up to 1,200 m elevation and beyond it, Western or South Western aspect is best for moist areas and Northern for dry areas. Nursery site should not be selected close to the edge of a high forest or in the middle of the grassland. Frost pool should be avoided.

### 3.1.4 Soil

The ideal forest nursery should have sandy loam to loamy texture. Sandy soils may be given preference over heavy soils. Soil should have pH 5.5 to 7.5, moderate fertility, with a minimum of 2.5% organic matter. The higher the organic matter content of the nursery soil, the better it is. A high organic matter content ensures good retention of nutrients and water and may improve the working properties of the soil. The depth of soil should not be less than 25 cm. It is not always possible to get good soil everywhere. Under such circumstances, one has to get extra soil, sand as well as farm yard manure from outside; therefore, location of nursery should be close to such areas.

### 3.2 Layout of Nursery

#### 3.2.1 Size and shape

As far as possible the nursery should be of a rectangular shape; so that it can be divided into smaller nursery beds of rectangular shape, leaving space for roads, inspection paths, dumping of manure, hut for Mali and space for people working in the nursery to rest during rain or intervals. In a bigger nursery (one ha and above), a road of a minimum width of 3 m should be constructed to facilitate transport of sand and manure inside the nursery and to carry the plants from the nursery, leaving space for turning of the vehicle.

The requirement of the total area for the nursery can be calculated by adding together the area required for mother beds, polypots, entire plant/root shoot cuttings and beds required for rooted cuttings. Another 40% area may be added for making the path. Area will also increase if seedlings are kept in the nursery for more than one year, specially for raising tall plants. Area required for sheds, water tank, storage of seed, manure etc. should also be kept in mind.

Polypots of size 18 x 5.5 cm need 1 m² for keeping 772 bags and slightly larger bags 18 x 7.5 cm need 1 m² for keeping 400 polypots. Accordingly 1,00,000 polypots will require 250 m² area plus 40% for paths. Thus for raising 1,00,000 polypot seedlings, an area of 350 m² may be sufficient.

### 3.3 Establishment of Nursery

#### 3.3.1 Site preparation

The site should be cleared properly by removing all stumps, roots, lops and tops. Stones collected from the site may be used for metalling the main nursery road. Thorough ploughing or hoeing to a depth of 30 cm should be done, especially in places where plants are to be raised in the nursery beds. The soil should be levelled to form an even slope or, if a site is flat, should be slightly domed. As far as possible, removing of top soil must be avoided. Drainage channel should be dug as early as possible to avoid soil erosion. Drains should be dug on both sides of the paths and connected to main drain. In plains, drain should be adequately sloped and steps should be used in hills to check the flow of water.
3.3.2 Types and size of beds

Beds are prepared to germinate seeds, keep polypots and transplant pricked out seedlings. In the plains, beds of 10 x 1 m size and in the hills beds of 2 x 1 m are generally prepared. However, size can be changed depending on the availability of the area. Width of beds should not be more than 1.2 m otherwise watering of seedlings; especially in the middle part of the bed shall be a problem. The beds should be oriented in East-West direction in the plains and should follow contours in the hills. In areas where lifting may be restricted due to frozen ground, orienting beds in a North-South direction will facilitate early thawing by the morning sun, and thereby lifting. Following types of beds are prepared in the nursery.

3.3.3 Sunken beds

These are 15 cm deep and used in arid areas and hot places to protect young seedlings from hot winds, and also to reduce the rate of evaporation, thus reducing the consumption of water.

3.3.4 Raised beds

These types of beds are generally used in moist areas. The beds are raised 15 cm above the ground to increase drainage and promote warming of seedbed. Beds are given side supports of bamboos, twigs, bricks or other locally available materials.

3.3.5 Preparation of seedbeds

The plot where seedbeds are to be prepared must be ploughed and levelled and sloped (1 to 3%), depending upon the texture of soil (less slope for sandy soils). It should be ascertained that the soil in the seedbed is light. If necessary, sand and soil (1:1) may be mixed so that the seedlings can break through when germinate, and this will also be helpful when plants are lifted for pricking out (Plate-1). The seed beds should not be filled in completely, so as to avoid the washing away of top soil and seed. The surface of the seedbed should be made firm by sprinkling water and then using a wooden plank. These beds are generally used for the following reasons:

- to provide a small reserve of seedlings which can be used to replace direct seeded plants that did not germinate or that died,
- for sowing seeds which germinate slowly or unevenly, like teak and
- for the seeds whose quality is not known.
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- for the seeds whose quality is not known.

Plate - 1

**Nursery seedlings raisings methods**

Sand  Soil  Farm yard manure

Seed bed  Sunken bed  Line Sowing

Filling of polythene bags  Plastic cane used for watering  Transplanting of seedlings
Components of forest Nursery

- Poly house
- Seedlings from cuttings
- Poplar seedlings from cuttings
- Seedlings grown in polybags
- Temporary green house
- Trolley for transportation
- Barbed wire fencing
- Stand for seedlings transportation
- Composting unit

Plate - 2

3.4 SEED COLLECTION AND STORAGE

3.4.1 Whether to buy or to collect seeds

Seeds can be purchased from reputed nurseries or collected from known stands of trees. Seed collection is considered as the best approach since the quality and provenance of seeds are known (Plate-3). Seed sellers may, of course, also offer good quality seeds and sometimes even better than what one has at hand in the local stands of trees. Moreover, all required species may not be available locally. In any case, it is better to divide seeds into two categories: those that are used in the main afforestation programme and are locally available and those which are raised for distribution to the general public and usually not available locally. The former should be collected from healthy middle-aged trees of good quality and the latter can be purchased from the reputed nurseries or suppliers. It is improper to collect seeds from a mongrel population of trees and to use them in a nursery. Different species have different seeding time; therefore it is necessary to have a time table for collection or purchase of seeds. Seed viability and dormancy are also important factors, which decide the sowing time. Species with very short seed viability must be sown immediately otherwise the germination percentage will go down drastically. Seeds with long viability should be sown when temperatures are moderate, i.e. between July to October and February to March. Whether the required plants are to be of six months, one year or one and a half year age will also affect the sowing time. Following precautions are required to be followed at the time of seed collection:

- Only fully matured seeds should be collected as the unripe seeds of most species do not germinate e.g. Haldu, Harar, Bahera, Arjun and Walnut.
- Mother trees should not the damaged or heavily lopped for seed collection, otherwise the seed tree may die or stop seeding.
- The cones of trees like pine or other coniferous trees should be dried in sun instead of breaking them by hard hitting because drying in sun helps in opening spontaneously.
- Seeds of pulpy fruits can be collected by rubbing them in water followed by washing, drying, cleaning respectively e.g. Mehal, Bakain, Mulberry, Bel, Kadam etc.
- The collected seeds must be dried properly before storing to avoid any possibility of its damage. However, excessive drying should be avoided and properly treated seeds should be stored in a place of good ventilation and free from moisture to safeguard them from decaying or losing viability.

3.4.2 Estimating seed quantities

It is necessary to compute the required quantities. Factors like germination percentage, number of plants to be raised and amount of wastage involved, all affect quantity of seeds. It is convenient to have a seed weight chart depicting the species wise details of the number of seeds per kilogram to make it handy while computing the quantity of seed required. Per kilogram number of seeds, collection period, viability and pre-sowing treatment of some of the common species is mentioned in Table 3.1.
3.4 SEED COLLECTION AND STORAGE

3.4.1 Whether to buy or to collect seeds

Seeds can be purchased from reputed nurseries or collected from known stands of trees. Seed collection is considered as the best approach since the quality and provenance of seeds are known (Plate-3). Seed sellers may, of course, also offer good quality seeds and sometimes even better than what one has at hand in the local stands of trees. Moreover, all required species may not be available locally. In any case, it is better to divide seeds into two categories: those that are used in the main afforestation programme and are locally available and those which are raised for distribution to the general public and usually not available locally. The former should be collected from healthy middle-aged trees of good quality and the latter can be purchased from the reputed nurseries or suppliers. It is improper to collect seeds from a mongrel population of trees and to use them in a nursery. Different species have different seeding time; therefore it is necessary to have a time table for collection or purchase of seeds. Seed viability and dormancy are also important factors, which decide the sowing time. Species with very short seed viability must be sown immediately otherwise the germination percentage will go down drastically. Seeds with long viability should be sown when temperatures are moderate, i.e. between July to October and February to March. Whether the required plants are to be of six months, one year or one and a half year age will also affect the sowing time. Following precautions are required to be followed at the time of seed collection:

- Only fully matured seeds should be collected as the unripe seeds of most species do not germinate e.g. Haldu, Harar, Bahera, Arjun and Walnut.
- Mother trees should not be damaged or heavily lopped for seed collection, otherwise the seed tree may die or stop seeding.
- The cones of trees like pine or other coniferous trees should be dried in sun instead of breaking them by hard hitting because drying in sun helps in opening spontaneously.
- Seeds of pulpy fruits can be collected by rubbing them in water followed by washing, drying cleaning respectively e.g. Mehal, Bakain, Mulberry, Bel, Kadam etc.
- The collected seeds must be dried properly before storing to avoid any possibility of its damage. However, excessive drying should be avoided and
- Properly treated seeds should be stored in a place of good ventilation and free from moisture to safeguard them from decaying or losing viability.

3.4.2 Estimating seed quantities

It is necessary to compute the required quantities. Factors like germination percentage, number of plants to be raised and amount of wastage involved, all affect quantity of seeds. It is convenient to have a seed weight chart depicting the species wise details of the number of seeds per kilogram to make it handy while computing the quantity of seed required. Per kilogram number of seeds, collection period, viability and pre-sowing treatment of some of the common species is mentioned in Table 3.1.
3.5 PRE-SOWING TREATMENT OF SEEDS

Seeds contain tiny, fragile plants that live under the hard seed shell. They need water to germinate. Some seeds have such a hard shell that water cannot easily enter the seed to help it sprout. Pre-sowing treatment of seeds facilitate germination, therefore, all plants will be of the same size and will be ready for out planting at the same time. Following methods can be used for the treatment of different seeds to enhance their germination:

3.5.1 Boiling water treatment

This method is generally used for the species which have a very hard coat e.g. Acacia and Prosopis. Water is boiled in a pan and seeds are kept in the water only for 1 to 2 minutes. After 2 minutes, pour off the water and replace it with the cold water. Let the seed soaked in cold water for 2 to 3 days or until the seed swells. Seeds are sown immediately after the treatment.

3.5.2 Hot water treatment

This method is generally used for the species which have a hard shell e.g. Albizia, Cassia, Callindra, Leucaena, Sesbania, Samanea etc. Sufficient quantity of water is boiled in a container. Once it is boiled, water is taken off the fire and allowed to cool for about 10 minutes. After that, the seeds are poured into the container and kept as such for 2 days or until most of the seeds have swelled. The water of the container can be changed everyday and seeds are sown immediately after the treatment.

3.5.3 Cold water treatment

Some seeds need lots of water to facilitate germination. Others may have chemicals inside the seed which must be removed before the seed can germinate. Examples are Citrus, Gliricidia, Neem and Pinus. Seeds are kept in sufficient water for 1 to 2 days. Water can be changed after every 12 hours and seeds that float on the top must be discarded. Plant all swollen seeds immediately.
Pre-sowing treatment of seeds facilitate germination, therefore, all plants will be of the same size and will be ready for out planting at the same time. Following methods can be used for the treatment of different seeds to enhance their germination:

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Precautions required during seed collection and storage

Seeds must be stored in a dry cool place. Store large and soft seeds in open baskets.

Hard shelled seeds e.g. subabul, teak, pine, eucalyptus, acacia, etc. can live for a long time in storage. Dry them properly before putting them in plastic bags. Be sure that all the air is forced out of the bag before you close and seal it. Never store seeds on the ground. Store seed bags on shelves in a rat proof shed.

Do not place the freshly collected seeds in the sun. They may get killed due to excessive heat.

Do not leave seeds in the rain, or in wet areas. Seed will root and die.

Do not put soft seeds like neem in a large gunny bag. It may generate much heat to kill the seeds.
Table 3.1: Seed weight, collection time, viability and pre-sowing treatment of some common species

<table>
<thead>
<tr>
<th>Local Name</th>
<th>Seed collection Time</th>
<th>Number of seeds/kg.</th>
<th>Viability (Months)</th>
<th>Pre-sowing treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akhrot</td>
<td>Sep-Oct</td>
<td>75</td>
<td>6</td>
<td>Keep in refrigerator for one month and sow</td>
</tr>
<tr>
<td>Amaltas</td>
<td>Nov-Mar</td>
<td>900</td>
<td>1-6</td>
<td>None</td>
</tr>
<tr>
<td>Angu</td>
<td>Oct-Dec</td>
<td>7400</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Ardu</td>
<td>Feb-Mar</td>
<td>9600</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Arjun</td>
<td>Mar-Apr</td>
<td>775</td>
<td>6-12</td>
<td>Soak in water for 48 hours</td>
</tr>
<tr>
<td>Bahera</td>
<td>Nov-Feb</td>
<td>425</td>
<td>12</td>
<td>Alternate soaking and drying 5-6 times</td>
</tr>
<tr>
<td>Bakain</td>
<td>Jan-Feb</td>
<td>800</td>
<td>12</td>
<td>Soak in water for 24 hours</td>
</tr>
<tr>
<td>Ban oak</td>
<td>Nov-Jan</td>
<td>600</td>
<td>13</td>
<td>None</td>
</tr>
<tr>
<td>Bel</td>
<td>May</td>
<td>5300</td>
<td>1-6</td>
<td>None</td>
</tr>
<tr>
<td>Bhojpatra</td>
<td>Aug-Oct</td>
<td>150000</td>
<td>6</td>
<td>Keep in refrigerator for one month and sow</td>
</tr>
<tr>
<td>Cheura</td>
<td>Jun-Jul</td>
<td>1000</td>
<td>&lt;1</td>
<td>Sow immediately after collection</td>
</tr>
<tr>
<td>Chir</td>
<td>Dec-Mar</td>
<td>9000</td>
<td>24</td>
<td>Soak in water for 24 hours</td>
</tr>
<tr>
<td>Deodar</td>
<td>Oct-Nov</td>
<td>7000</td>
<td>1-6</td>
<td>Store without drying and sow in March</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>Sept-Oct</td>
<td>360000</td>
<td>24</td>
<td>None</td>
</tr>
<tr>
<td>Fir</td>
<td>Sep-Nov</td>
<td>27000</td>
<td>3</td>
<td>None</td>
</tr>
<tr>
<td>Gulmohar</td>
<td>Jan-Mar</td>
<td>2500</td>
<td>Very long</td>
<td>None</td>
</tr>
<tr>
<td>Gutel</td>
<td>Jul-Dec</td>
<td>6800</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Haldru</td>
<td>Jan-Mar</td>
<td>110000</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>Harad</td>
<td>Jan-Mar</td>
<td>150-250</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>Jamun</td>
<td>Jun-Aug</td>
<td>1200</td>
<td>1 week</td>
<td>None</td>
</tr>
<tr>
<td>Kachnahr</td>
<td>May-June</td>
<td>2500</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>Kadam</td>
<td>Jan-Aug</td>
<td>1600000</td>
<td>12</td>
<td>Fungus treatment before sowing</td>
</tr>
<tr>
<td>Kail</td>
<td>Sep-Nov</td>
<td>20000</td>
<td>12</td>
<td>Soak in water for 24 hours</td>
</tr>
<tr>
<td>Kanji</td>
<td>Mar-May</td>
<td>800-1500</td>
<td>3-6</td>
<td>Soak in water for 24 hours</td>
</tr>
<tr>
<td>Kanju</td>
<td>Apr-May</td>
<td>27000</td>
<td>6</td>
<td>None</td>
</tr>
<tr>
<td>Khair</td>
<td>Oct-Nov</td>
<td>40000</td>
<td>6-12</td>
<td>Soak in cold water</td>
</tr>
<tr>
<td>Kharik</td>
<td>Feb-Mar</td>
<td>4600</td>
<td>12</td>
<td>Boiling water or hot water</td>
</tr>
<tr>
<td>Kharsu oak</td>
<td>Jun-July</td>
<td>400</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Kwiral</td>
<td>Jan-May</td>
<td>4000</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>Neem</td>
<td>Jan-Aug</td>
<td>3000</td>
<td>2 weeks</td>
<td>None</td>
</tr>
<tr>
<td>Pangar</td>
<td>Sep-Oct</td>
<td>30-40</td>
<td>&lt;1</td>
<td>Sow immediately after collection</td>
</tr>
<tr>
<td>Pula</td>
<td>Mar-Apr</td>
<td>32000-37000</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>Reetha</td>
<td>Nov-Dec</td>
<td>650</td>
<td>24</td>
<td>Soak in Conc. Sulphuric acid for five minutes</td>
</tr>
<tr>
<td>Robinia</td>
<td>Jul-Aug</td>
<td>50000</td>
<td>36-48</td>
<td>Hot water</td>
</tr>
<tr>
<td>Sagon</td>
<td>Nov-Jan</td>
<td>1800-3000</td>
<td>24</td>
<td>Alternate soaking and drying in water for 6-7 times</td>
</tr>
<tr>
<td>Semal</td>
<td>Mar-May</td>
<td>20000</td>
<td>12-24</td>
<td>None</td>
</tr>
<tr>
<td>Shisham</td>
<td>Nov-Mar</td>
<td>50000</td>
<td>6-12</td>
<td>None</td>
</tr>
<tr>
<td>Silver oak</td>
<td>Jun</td>
<td>100000</td>
<td>12-24</td>
<td>None</td>
</tr>
<tr>
<td>Siris</td>
<td>Jan-Mar</td>
<td>7000</td>
<td>12</td>
<td>Soak in hot water for one hour</td>
</tr>
</tbody>
</table>
### 3.5.4 Wet and dry method

This method is generally used for teak seeds. Seeds are soaked in the cold water for one day. Next day, they are spread in the sun to dry for at least 1 day. When dry, they are again soaked for overnight. The process is repeated for about 20 to 30 days after that seeds are sown in a germination bed.

### 3.5.5 Cracked shell treatment

The method of seed treatment is generally used for the seeds which are contained within a nut. When the shell is cracked, water enters the seed and they germinate immediately. The nuts are kept on a solid surface and hit with a piece of wood or a small hammer. One has to be careful not to hit too hard to crush the seed inside. Once the seed is cracked, sow it immediately.

### 3.5.6 Pre-sprouting treatment

This method is used for the seeds which have a very short viability e.g. neem. Seeds are spread between the pages of newspaper. Wet the paper and put them in the shade. Seeds start germinating and must be transplanted immediately when the roots emerge.

### 3.6 SEED SOWING

Sowing can be done either by broadcasting/scattering, or in lines along the width of the bed. Broadcasting method is used for minute seeds such as Eucalyptus. These are generally mixed with equal amount of fine sand to facilitate uniform seed distribution. Better germination can be obtained if such seeds are sown in small wooden boxes or other containers (Plate-1), which can be kept under controlled environment, so as to protect seeds from excessive heat, rains etc. The small and medium sized seeds are sown in lines or drills 5 to 10 cm apart, the seed is covered with sand or sieved soil and gently firmed.

Sowing depth is crucial for the production of a uniform bed of seedling. Best germination is obtained in the case of small and medium sized seed, when they are sown as deep (0.3 to 0.6 cm) as necessary to cover them. The general rule is that the upper surface of the seed should be at a depth equal to the diameter of the seed.

Seedbed density and spacing also play an important role in germination. Too dense sowing may result in damping off disease. Mulching by covering the seedbed with dry grass or paddy straw is helpful, as it helps retain moisture, reduces weeds and improves germination. Seed beds sown with minute seeds should be well shaded. After germination, the shade should be removed gradually in stages and the mulch should also be removed. It has been found that different species have different germination potential. For example, seeds of 'Siris', 'Mango' etc give 90-100 per cent germination whereas in case of 'Pipal', germination is only 1-5 per cent. Sometimes instead of seeds the whole fruit...
can be sown to obtain better results i.e. ‘Timla', 'Pipal', 'Bedu' and 'Banyan', etc. Germination percentage of some seeds is given in Box – 1.

<table>
<thead>
<tr>
<th>Box-1</th>
<th>Germination Percentage of Some Tree Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species</strong></td>
<td><strong>Germination percentage</strong></td>
</tr>
<tr>
<td>Amla, Chullu, Jackfruit, Kachnar, Khair, Malu, Mango, Sal, Siris, Tungla</td>
<td>90-100</td>
</tr>
<tr>
<td>Bakain, Bhimal, Cheura, Dhak, Kharik, Maple, Mehal, Pine, Ritha, Robinia, Wild cherry, Walnut</td>
<td>70-90</td>
</tr>
<tr>
<td>Bamboo, Birch, Kafal, Ringal, Rohani, Shisham, Imli</td>
<td>50-70</td>
</tr>
<tr>
<td>Cedar, Chamkharik, Hisaru, Ruins, Semal, Teak</td>
<td>50-70</td>
</tr>
<tr>
<td>Kakra, Fir, Thuza, Tun</td>
<td>20-30</td>
</tr>
<tr>
<td>Amalta, Jecaranda, Sadabahar</td>
<td>10-20</td>
</tr>
<tr>
<td>Kumkum Papri, Surai, Spruce</td>
<td>5-10</td>
</tr>
<tr>
<td>Alder, Bakli, Banyan, Bedu, Khaina, Pipal, Timla</td>
<td>1-5</td>
</tr>
</tbody>
</table>

3.6.1 Direct sowing of seeds in polythene bags

Sometimes seeds are directly sown in the polythene bags viz. seeds of gulmohar. In such cases the bags should be completely filled with dry soil and left standing for few days, so that the soil settles. The bags should be watered well the day before sowing. Two seeds should be sown per bag and then covered with sand or with a mixture of sand and soil. Heavy soil should not be used for covering, as the germinating seeds may not be able to break through this hard covering. Seeds directly sown into bags normally attain more growth compared to pricked out seedlings and become ready for planting much earlier. After germination, only one healthy seedling per bag should be retained and the other be pricked out into vacant bags.

3.7 PROPAGATION OF PLANTS BY CUTTINGS

Seedlings are generally raised from seeds but, in some cases where seed is difficult to get or germination is poor due to small size of seed or infertility, plants are raised by vegetative methods. Cuttings of sections of roots, stems, branches or twigs, which are taken from suitable mother trees. A light, loose rooting medium should be used for this purpose. The soil should be dug 30 cm deep and sand and compost mixed with it. Cuttings of 5–10 mm diameter and 15–20 cm length should be obtained from young vigorous trees. The leaves should be stripped off the cuttings to reduce the transpiration. It is better to keep such cuttings for rooting into small poly houses to maintain humidity and temperature (Plate-2). Some of the common species which are raised through cuttings are mentioned in Box 2.

<table>
<thead>
<tr>
<th>Box - 2</th>
<th>Species Raised Through Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species raised through cuttings</strong></td>
<td><strong>Period of planting</strong></td>
</tr>
<tr>
<td>Chullu, Mehal, Mulberry, Poplar, Siris, Subabul</td>
<td>February to March</td>
</tr>
<tr>
<td>Cheura, Timla</td>
<td>July to August</td>
</tr>
</tbody>
</table>
Some species such as Shisham, Arjun, Kanji, Jamun, Aam, Neem and Imli grow slow. These species should be grown in beds and should be taken out for planting as ball plants.

3.8 PROVIDING SHADES IN THE NURSERY

Most of the tree species need shade in the early stage of germination while the seedlings are still tender. Studies at FRI, Dehradun have shown that the shade is more important before and after the monsoon, and had a great effect in increasing the survival of seedlings. Dry grass, bamboo mat, palm leaves or wheat straw can be used as shading material but tin sheets should be avoided. Shade should be slanting towards North-South to protect the seedbeds or seedlings from the hot sun.

3.9 MULCHING

It is also beneficial, before and after the monsoon, to protect the surface of seedbeds against becoming hard, and thereby inhibiting seedlings in breaking through resulting in delaying or leading to poor germination.

3.10 PREPARATION OF POTTING MIXTURE

The potting mixture should be prepared with meticulous care and control. A fine mixture of soil, sand and manure in the ratio of 6:1:3 should be prepared. Before mixing, the soil and sand should be sieved and pebbles and other undesirable material separated. The manure should not be sieved but rubbed with hands to make it fine and twigs and other impurities should be removed. Insecticides in the prescribed proportion should be mixed in the mixture. The main characteristics of a good potting mixture are:

- It must be light in weight
- It must be well drained and not hold too much water
- It must be free from insects, diseases and weed seeds
- It must not contain clay soil or large amount of ashes and
- All materials must be well decomposed.

3.10.1 Filling of polythene bags

The polybags should be punched with a sharp punching tool to make sufficient number of holes to enable drainage of excess water. By using a pincer like punch, twenty or thirty bags can be punched together. A scoop can be used for filling the potting mixture into the polythene bags or it can be made from locally available materials (Plate -1). After first fill the bags should be struck on ground to let the soil settle in and firm in and then the pot should be filled again. If loosely filled, soil will settle later and make polybags limp, resulting in dislodgement of roots and heavy mortality of plants during handling. Atleast half to one inch from top of the pot should be kept empty to avoid spillage. Filled polybags should be placed erect within the sunken beds meant for the purpose.

3.10.2 Transplanting of seedlings

Plants sown in germination beds have to be transplanted into polybags. Transplanting age and time vary, but on an average, it has been seen that earlier transplants are more successful. Too big
plants in germination beds may have their roots entangled, and disentangling them may cause seedlings to die. As a general guide to transplanting age, 20 to 30 days (excluding germination period) is adequate for most of the species. For transplanting, a scoop may be used to lift a group of plants with soil. From this soil the individual plantlets can be separated and inserted into holes made in the polybag soil by thrusting a sharp punch (Plate-1). The depth of the hole should be equal to the length of the root of the seedling, so that the root does not bend while being pushed into the hole. After inserting the plantlet roots, the hole is closed over up to the collar of the plantlet. The transplanting work should be done in the afternoon so as to avoid mortality of plants in hot sun. A bed of polybags is gently irrigated after all the pots have been transplanted in. If transplanting is done in hot weather, proper shade should be provided over the beds to prevent the tender seedlings from getting scorched to death.

3.11 AFTER CARE OF SEEDLINGS

Young seedlings are vulnerable to many factors and major losses can occur if these are not taken care of. Seeds may not germinate or may be lost to predators or diseases, if proper care is not taken. In addition, seedlings may have to survive pricking out shock, dry conditions, heavy rains and hail storms, scorching sun, high temperature and weed competition. Seedlings require after care till they are planted out in the field. This includes weeding, watering, manuring, hardening, protection against adverse climate, diseases and insect pests.

3.11.1 Weeding

Weeds come with manure, clay or sand transported from outside. Sometimes undesirable seeds get mixed with the seed sown. It is a simple matter to remove weeds by pricking them out. This operation should be carried out at the earliest opportunity after the weeds have become visible. If two seedlings of the species sown have come up in a polythene bag, one of these should be immediately pricked out and transplanted into another polybag. If any clutter or muck fills up the bags, these should be cleaned. In the mother beds, it is also desirable to hoe the soil periodically, apart from removing the weeds. These seemingly simple operations matter a great deal in determining the growth of plants.

3.11.2 Watering

The soil surface of the seedlings should not be allowed to dry. As a rule, finer textured soils require more frequent watering than coarser ones. Seedbeds and transplant beds should be watered twice a day. Too much watering during germination, however, is not desirable. Excess watering promotes the growth of fungi by decreasing the temperature and increasing soil moisture (Plate-4).

Light and frequent watering of polypots is not as good as more thorough, but less frequent watering. Light watering results in the water not penetrating deep into the soil and the seedlings soon dry out. In the exposed surface of the nursery bed, soil surface temperatures can rapidly rise to over 45°C on a warm sunny day. It can damage the root-collar area and kill the seedlings. To prevent damage, the soil surface should be kept cool by proper watering. There are a number of methods of watering. The one most commonly used is sprinkling water by a rose can or through hoses (Plate-4). Following points must be remembered while watering in a nursery:
Following points must be remembered while watering in a nursery:

- Do not water at a fixed time each day. Water when the plants need it,
- All species do not require the same amount of water,
- Small seedlings don't need much water,
- Large plants need more water and more often,
- Plants growing in the shade need less water,
- Plants growing in the sun need more water, more often and
- Plants need more water, often on windy days.

### 3.11.3 Control of diseases

Periodical spray of insecticides and fungicides is essential to control insect and fungal diseases in the nursery. Some of the common fungicides and insecticides are captan, zineb, blitox, cumin, dithane M-45, thimet, endosulphan, chloropyrophos etc. These should be used immediately when disease or insects appear according to the manufacturers’ instructions.

### 3.11.4 Protection against white ants and rats

Considerable damage is caused by white ants and rats in the nurseries. White ants live in colonies deep inside the soil and their number increase rapidly where vegetative waste is available. In order to control them, Endosulphan 20 EC or Chloropyrophos 20 EC should be sprayed after mixing 3 to 4 litres of any of these insecticides in 1000 litres of water. For the control of rats zinc phosphide or aluminum phosphide should be used.

### 3.11.5 Shifting and grading of plants

It is essential to provide adequate growing space in the beds for speeding up the growth of plants in the nursery. Therefore, the surplus plants should be removed carefully and planted in new beds. The beds should be irrigated before the shifting and grading operations. The ultimate spacing between the plants at the time of final shifting should be 15x22 cm. While shifting, plants should be graded according to their heights and put in the beds grade wise.

While shifting the polythene bags, the roots of the plants protruding outside the bags should be cut with sharp scissors. It is better to keep these bags over a polythene sheet to avoid roots penetrating the soil. However, keeping such bags on mounted beds gives better result and avoids root coiling by facilitating air pruning of roots.

### 3.11.6 Pruning

Some species grow very fast in the nursery. Sometimes tall seedlings do not have enough roots to support the many leaves. When these seedlings are planted in the field, they may grow slowly or even die because of roots cannot supply enough water to the leaves. In order to avoid this problem, cut off the tops of seedlings that have grown too tall. Use a sharp knife to trim the tops of these species. For example Casuarina, Eucalyptus, Leucaena, Gliricidia, Neem, Sesbania etc. Root pruning is also essential to avoid deep penetration of roots in the soil and in the process, the plant gets hardened. Pruning of roots helps in the development of tertiary roots.
Precautions to be followed during watering the seedlings

1. Pour small quantity of water on small seedlings whenever they need it.
2. Big plants should be regularly watered with larger quantity.
3. Watering to seedlings, when kept under shade, should be less and not very often.
4. Watering to the seedlings/plant, kept in open or under sun, should be more often.
5. During dry and windy days watering to seedlings/plants should be more and often.

Plate-4
3.11.7 Hardening off of seedlings

Life is easy for the plants in the nursery since they receive good care there. However, once planted in the field, life is much harder for them. They may not have enough water or food to live very well. Therefore, seedlings must be made tough to survive well in the field. This is called hardening off. It is achieved by gradually reducing the frequency of watering before one month of planting. However, care must be taken that seedlings are not burnt in the process.

3.11.8 Replacement of dead/damaged plants

Care should be taken to replace the dead or damaged plants immediately by sowing of fresh seed or replacing the dead or damaged plants from the existing seedling beds.

3.12 TRANSPORTATION OF SEEDLINGS

Seedlings are very delicate and should be handled properly. The polypot seedlings should always be held by the bag and never by the plant itself. Seedlings should be watered thoroughly before carrying them to the field. Seedlings should be transported in the trays, boxes or baskets (Plate- 2) and not tied in bundles with strings or grass. In case of stumps, they should be bundled, wrapped with a wet sack and transported to the field. The plants should be kept in shade and plants not planted the same day should be sprinkled with water in the morning and evening.

While transporting bare root seedlings, the nursery beds from which the plant is taken should be irrigated so as to facilitate making of ball plants. After making ball plants, they should be graded according to their height and put in shade. In order to keep the earthen balls around the roots intact the balls should be wrapped in grass and tied by sutli (Thick thread).
Forests play an important role in the economy of the State. They meet our requirement of timber, fuel wood, fodder, paper pulp, sports goods, match wood, plywood, resin, packing cases, agricultural implements, other minor forest produce and medicinal plants. Owing to increasing pressure on forests due to enhanced grazing and other human interference, the natural regeneration on which we had depended a few decades ago is now very scarce. It has therefore, become necessary to restock them by planting suitable tree, shrub and grass species.

The National Rural Employment Guarantee Scheme launched by the Govt. of India provides an opportunity of restocking these valuable forests with the participation of the villagers in various forestry works such as nurseries, plantations, soil and water conservation works, fire protection etc. thus increasing their productivity and economic value. Raising of plantation is a technical process and its various components and activities are discussed below:

4.1 SELECTION OF SPECIES

Tree line in the Himalayas extends up to 3500 m altitude. Climatic variations occurring due to altitudes, aspects, temperature, rain fall, soil types have resulted into a number of forest types and vegetation types that vary from place to place due to these factors. Because of this, it is not possible to recommend any particular tree species for every area. However, while selecting the species for planting in a particular area the following points should be considered:

- The soil and climate of the area is suited to the growth of particular tree species,
- The species selected for planting are in accordance with the plantation policy of the Government,
- The species selected meet the fodder, fruit and other requirements of the villagers living in the vicinity,
- The species selected suit the needs of birds and wild animals dwelling in the area. The species selected for planting should provide suitable cover and food to herbivores and carnivores. In Tarai and Bhabar areas efforts should be made to plant Rohini, Bamboo, Sandan, Narkul and Ficus species for wild elephants,
- The species should be useful for water and soil conservation such as Banj oak, Pangar and Burans etc. and
- The species should be able to meet the industrial and other needs of the country. For example, Eucalyptus and poplar plantations in Tarai and Bhabar and Chir plantations in Garhwal and Kumaon.
It should be borne in mind that the growth behaviour of any plant is considerably influenced by sunlight, temperature and fertility of soil. Some species have low moisture requirement, such as Bakain, Khair, Amaltas, Tungla and can be grown on South facing slopes because these slopes are comparatively drier due to their exposure to direct sun. Contrary to this, North facing slopes are much humid. Here species like Banj oak, Kafal, Anyar, Burans, Pangar and Maple can be grown successfully.

**Table 4.1: Species recommended for plantation at different altitudes**

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 to 1000 m</td>
<td>Aam, Ailanthus, Amaltas, Amrood, Anwla, Ashoka, Bakain, Bamboo, Bel, Ber, Cassia, Eucalyptus, Ficus, Gulmohar, Gutel, Haldu, Imli, J acaranda, Jamun, Jhingan, Kathal, Khair, Neem, Paper mulberry, Haldu, Poplar, Pula, Ritha, Safed Siris, Sainjna, Sal, Salix, Shisham, Silver oak, Semul, Teak (in plain areas), Tendu, Tun</td>
</tr>
<tr>
<td>1000 to 2000 m</td>
<td>Acacia mollissima, Akhrot, Amla, Angu, Banj, Bans, Burans, Chinar, Chir, Deodor, Exotic Chir, Genthi, Kafal, Kail, Kala Siris, Kharik, Kweiral, Mehal, Moru, Padam, Pangar, Poplar, Putli, Ringal, Ritha, Robinia, Salix, Silver oak, Surai, Tejpat, Tun, Utis</td>
</tr>
</tbody>
</table>

Proper selection of species according to the aspects is very essential between 1000 to 2000 m. Uttarakhand is located in the North of equator and sun is always in the South. Therefore, the Southern and adjoining Western and Eastern aspects are warm. Contrary to this, the Northern and adjoining North-Western and North-Eastern aspects are cool. Following species are recommended for planting in these cool aspects.

The success of some species is doubtful in hot aspects like - Akhrot, Angu, Banj, Burans, Chamkharik, Deodor, Kail, Maple, Moru, Pangar, Robinia, Ringal.

Bhojpatra, Deodar, Fir, J uniperus, Kharsu, Moru, and Spruce are suited to zones above 2,000 m.

**Box-3**

**Classification of Species According to Their Uses**

- **Timber:** Aam, Ailanthus, Akhrot, Angu, Anwala, Bahera, Bamboo, Banj, Chamkharik, Chir, Deodor, Eucalyptus, Fir, Haldu, Harar, Jamun, Kafal, Kail, Maple, Neem, Poplar, Ringal, Sain, Sal, Salix, Semul, Shisham, Siris, Spruce, Surai, Tejpat and Tun.
- **Fuel-wood:** Acacia, Banj, Haldu, Eucalyptus, Jamun, Kweiral, Kharsu, Moru, Sain, and Shisham.
- **Fodder:** Bakil, Bans, Bhimal, Banj, Dhauri, Kharsu, Kharik, Kweiral, Maple, Moru, Neem, Phalyat, Robinia, Shahtoot, Siris and Timla.
- **Fruits:** Aam, Akhrot, Amrood, Anwla, Bahera, Ber, Harar, Imli, Jamun, Kafal, Malta, Mehal, Nimbu, Shahtoot and Timla.
- **Rejuvenation of depleting water sources:** Akhrot, Banj, Deodar, Maple, Phalyat, Ringal, Siris and Utis.
In Uttarakhand, in addition to the Govt. Reserve Forests, there are Civil and Soyam Forests, Van Panchayat Forest and Private Forests. For plantation works in the Reserve Forests working plans of various forest divisions prescribe the species of trees to be planted in particular area. In case of Van Panchayat, Civil and Soyam and Private Forests no such planting scheme has been prescribed. It is therefore necessary to plan plantation operations in these forests with the involvement and advice of local communities.

4.2 SELECTION OF SITE

The selection of site and selection of species are interdependent. The selection of site is however more important as the selection of species depends upon the selection of site. The site selected for planting should be suitable for the growth of species desired to be planted. For this purpose, the soil type, its depth, study of vegetation in the neighbourhood, local factors and other conditions should be given due consideration and advice of the local villagers should be taken.

Selection of planting site should be done by the end of September. In case of Reserve Forests the areas to be taken up for planting are listed year wise in the working plans of the respective Forest Divisions. Therefore site selection has already been done for plantation works year wise. The position in case of Civil and Soyam and Panchayat Forests is however, different. In such areas plantations are taken up after obtaining resolution from the Panchayats / villagers. Plantations can be raised as a block plantation if large area is available or trees can be planted along the boundary of agriculture fields or school, offices, road sides etc.

Fig. 4.1: Geometry of plantation
4.3 SITE DEVELOPMENT

This includes clearance of planting site, bush cutting, control burning, lopping of tree branches, checking of soil erosion, soil conservation works in 'nalas', construction of vegetative or stone check dams, preparation for agave planting where necessary, marking of pits for planting of saplings and other soil works.

In addition, demarcation of boundary wall or fencing and inspection paths should be made to facilitate the movement of people engaged in plantation works. This work should be completed by the end of November. In hilly areas, Lantana shrubs should be cut at one inch height from the ground. These should not be uprooted to avoid soil erosion. Parthenium and other invading shrubs should be uprooted and burnt before the onset of rains. While developing the site for planting, care should be taken to retain all indigenous species of trees and shrubs that are naturally growing in the area. They should not be cut and burnt along with weeds and thorny species. Preferably they should be adopted in the plantation and thanwalas should be made around each of these plants for retention of moisture and for protection against fire and damage by grass cutters.

4.4 DIGGING OF PITS

After clearing the land and before digging of pits, pit sites should be identified by using a measuring tape to ensure the desired spacing and then mark with wooden or bamboo sticks at the spot that will be the centre of the pit. Pits of the size 30 cm x 30 cm and 45 cm depth should be dug. Pits should be deep enough to ensure that the roots of the plants do not curl up once the planting material is placed in it. The soil dug from the pits should be dumped close to the pit. While digging stones, roots of trees, grass or shrubs, if any, should be separated so that while filling the dug up earth back in the pits these are not mixed with the soil. The spacing of pits varies according to the planting scheme for different areas. Generally the spacing between pit to pit along the contour line is 2 m and the distance between lines (Contour) is 3 m. In hilly areas, it may not be possible to follow this spacing strictly due to presence of boulders or trees. No pits should be dug within the vicinity of five meters from a tree. The spacing between the pits should however, not be less than 2 x 2 m. Pits should always be dug along the contour lines. The procedure of making the contour lines has been described in Fig. 4.2. The pits in the second line should be dug in such a way that they fall between the pits dug in the first line as shown i.e., staggered (Fig. 4.3).

The triangular planting method, which is specially practiced in the hills, checks the flow of rain water and facilitates its percolation in the ground. This method should also be applied while digging contour trenches (Fig. 4.4).

4.5 PROTECTION OF PLANTATION SITES

The proper fencing of plantation areas is essential to protect the seedlings from damage by the cattle and wild animals. The choice of fencing depends on the type of terrain, soil depth and the kind of soil. Since most of the afforestation programmes are employment oriented, a fence type with high labour input is preferred. Cost of fencing is another important criterion, but normally no compromise should be made on this count, because if fencing is not effective, all other measures, how far effective, will come to a naught. Some of the common fencing types are discussed below:
Adjust a frame on the slope to bring plumb line/string to the center of the A-frame (Point E). Mark spot on the slope. These spots will form a contour line. Distance between contour hedgerows should be approximately 4 m - 6 m.

If the spots located by the A-frame zigzag too much, while planting consider only those points that form a smooth contour.

**Fig. 4.2:** Alignment of pits in areas with undulating topography
Adjust a frame on the slope to bring plumb line/string to the center of the A-frame (Point E). Mark spot on the slope. These spots will form a contour line. Distance between contour hedgerows should be approximately 4 m - 6 m. If the spots located by the A-frame zigzag too much, while planting consider only those points that form a smooth contour.

Fig. 4.2: Alignment of pits in areas with undulating topography

Fig. 4.3: Staggered alignment of the pits in plain areas

Fig. 4.4: Alignment of pits in hilly areas

Fig. 4.5: Pits in row with equal square spacing
4.5.1 Stone-wall fencing

A stonewall fence is the ideal choice in hilly areas where stones are generally available and local people are able to make it themselves. Dry stone masonry wall of sufficient height and width is constructed to keep cattle out. Specifications may vary, but it is better to adhere to standard sections only. The cost of stone wall fence depends upon the availability of stones and the average distance of their transportation. Sometimes stones may have to be quarried using the crowbar, in which case the cost may go up. The dimension and cross section of stone wall are mentioned in Fig 4.7. However, these can be modified according to the ground situations.

The stone wall does not last long because it is built dry therefore, live hedge fencing can be developed by planting agave or euphorbia species. For this purpose planting can be done at a spacing of 50 cm along the outer periphery of the walls during the rainy season (Fig. 4.8).
4.5.2 Barbed-wire fencing

In areas where stones are not easily available or where cartage of stones is expensive due to long distances, the plantation area should be protected by barbed wire fencing. Wooden posts are used for this purpose with a length of 3 m and a girth of 30 cm to 45 cm. The upper ends of the posts are fashioned in conical shape to avoid rain water from rotting it. The lower end which remains in contact of the soil is painted with coal tar to avoid damage by white ants and wood decay fungi. The posts are dug 30 cm deep and placed 2.5 m to 3 m apart. Three strands of barbed wire at the height of 22, 52 and 74 cm from the ground level are stretched and fixed to these posts with the help of iron staples. To make this barbed wire fencing more effective thorny bushes are put along the fencing. For entry in the plantation area wooden ladders are provided. From the landing point of the ladder an inspection path is made inside the plantation area. Areas having nilgai menace or damage by animals like deer etc. requires at least 4 rows of barbed wire fixed at an interval of 30 cm each with two strands of barbed wire inclined at 45° to the poles to provide extra strength (Fig. 4.9).
4.5.3 Social fencing

In community areas and areas close to habitations, local villagers must be encouraged to resolve among themselves about not sending their cattle in plantation areas and protect grasses in the plantation areas to be cut after maturity by mutual agreement. Van Panchayats should be made models of such social fencing efforts. In such cases, the money earmarked for fencing must be utilized to pay the villagers who choose to stay at the plantation site and protect it from grazing. The grasses so produced can be shared by the villagers as per the mutual agreement.

4.5.4 Fire protection

A 1.5 m wide strip along the outer periphery of the fencing should be cleared of grass and bushes and the strip scrapped with spade for fire protection so that any fire from outside may not enter the plantation area. A hut should be constructed inside the plantation area, preferably at the entrance point. This can be used for the stay of the people during rains and heat. After the plantation work is over the hut can be used for the stay of Chowkidar deputed to look after the plantation.

4.6 FILLING OF PITS

This work should be completed in the first week of June. The dug earth dumped near the pits should be filled back after about a month or before the monsoon, so that the pit and the earth to be filled are exposed to sunlight. Insecticides may also be mixed in the soil while filling into the pit. The pit should be filled a little above the ground level so that after the earth settles the upper surface of the pit is level to the ground thus avoiding any water logging. While filling the pits, the area surrounding the pit should be scraped with spade to remove grasses or weeds. Top soil should be filled in the bottom of the pit and after this, subsoil should be filled.

4.7 PLANTING OF SAPLINGS

The plantation of sapling must be done in the first week of July when monsoon rain has begun. Planting of naked root plants should be completed as early as possible so as to take full advantage of the rain. The planting work should be done either in the afternoon or during light rain or cloudy sky. The roots of the plants should be kept straight and the plant put straight in vertical position. For this a hole should be made with the help of a stick or small crow bar. The collar of the plant should be kept at the surface level of the pit. After planting the sapling, the earth around it should be firmly pressed by hands or feet and while doing so the plant should be pulled about half inch to make sure that its roots is not bending. Species suitable for naked root planting are Pangar, Akhrot, Angu, Utis, Deodar etc.

Bagged plants should be sprayed with water before planting. The polythene should be carefully removed so that the plant is not damaged. The plant with the soil intact should then be placed in the pit in straight position, the collar of the plant being in level with the ground. The soil around the plant should then be pressed firmly by hands only. Pressing by feet is likely to disturb the soil of the plant. The planted saplings should be of suitable thickness and height. Ideal plantable size of some species is given below in Table-4.2.

### Table 4.2: Ideal plantable size of some species

<table>
<thead>
<tr>
<th>Species</th>
<th>Height (cm)</th>
<th>Age (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Species like Akhrot, Angu, Maple, Pangar, Poplar, Salix, Tun, Khair, Deodar, Fir, Chir, Fir are planted in winter months.
4.8 WINTER PLANTING

Species like Akhrot, Angu, Maple, Pangar, Poplar, Salix, Utis etc. are planted in winter months. Most of these species remain leaf less during winter. These can be planted in January or beginning of February. By March the buds sprout. If at the time of planting there is lack of moisture in the soil, it is advisable to irrigate the plants once or twice after sprouting to ensure the success of the plantation.

4.9 REPLACEMENT OF DEAD PLANTS OR BEATING UP

Dead, dying or dry plants should be replaced within 15 days of completion of planting work.

4.10 SOIL WORKING AND WEEDING

Thanwalas should be made around all the seedlings having inward slopes. For this purpose a semicircular pit about 15 cm deep, 25-30 cm apart from the plant should be dug. The earth taken out from the pit is put around the base of the plant. This has double advantages; firstly, there will be no water logging at the base of the plant which may otherwise cause damage to the plant; secondly, the rain water collected around the plant will help in retaining the moisture for the plant. Naturally growing species which have been adopted at the time of site development should also be included in Thanwala making and weeding / hoeing operations.

After the rains are over, capillary actions begin in the pits. This causes loss of moisture due to evaporation in the hot sun. To check this, weeding should be done in and around the pits. During this operation, grasses and weeds should be removed and the earth clumps should not be broken. Second weeding should be done in September end. Third weeding should be done soon after the winter rains.

4.11 MAINTENANCE AND AFTER CARE

A Chowkidar must be deputed for five years in the plantation area to look after it soon after the planting work is over. Following duties should be assigned to him:

- Periodical weeding and removal of grasses suppressing the plants,
- Maintenance and repair of inspection paths,
- Repair of boundary wall or fencing where ever necessary,
- To protect the plantation area from grazing and damage by wild animals and villagers cutting grass,

### Table 4.2: Ideal plantable size of some species

<table>
<thead>
<tr>
<th>Species</th>
<th>Height (cm)</th>
<th>Age (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fir</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>Chir</td>
<td>25</td>
<td>9</td>
</tr>
<tr>
<td>Deodar</td>
<td>40</td>
<td>26</td>
</tr>
<tr>
<td>Khair</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Bakli</td>
<td>45</td>
<td>4</td>
</tr>
<tr>
<td>Neem</td>
<td>50</td>
<td>12</td>
</tr>
<tr>
<td>Shisham</td>
<td>45</td>
<td>12</td>
</tr>
<tr>
<td>Tun</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Acacia</td>
<td>40</td>
<td>6</td>
</tr>
</tbody>
</table>
- To protect the area from fire, cleaning of dry grass and twigs, etc. from the area and cleaning of inspection paths,
- Cleaning of the outer periphery of the plantation area in two meter width,
- Keeping regular watch over the plantation area during the fire season and
- Seeking help and co-operation of the neighbouring villagers in the protection of the plantation area.

4.12 MAINTENANCE IN SUBSEQUENT YEARS

4.12.1 Second year

Beating up works should be carried out in the second year. In this operation the dead plants are replaced by planting fresh saplings immediately at the onset of monsoon rains. Under normal conditions not more than twenty per cent plants are required to be planted during the beating up operation in the second year. The reasons for mortality should be ascertained. The dead plants should be replaced by the species which are growing successfully. At least one weeding should be done and thanwalas be made. Protection wall or fencing should be repaired where ever necessary.

4.12.2 Third, Fourth and Fifth year

Normally no beating up operations are carried out during these years but full attention is given to protect the area from grazing and fire. However, soil working and weeding around the plants during the rainy season promoted the growth of seedlings. Therefore, provision of sufficient funds should be made for this purpose too.

4.13 CAUSES OF FAILURES OF PLANTATIONS

Following are the main causes of failure of plantation works:

- Wrong selection of species such as planting of deodars at low altitudes,
- Planting of weak and damaged saplings,
- Untimely planting of saplings,
- Carelessness in cartage of plants. The bagged plants need very careful handling during loading/unloading. If, cartage is done by head load they should be carried in trays or baskets to avoid damage,
- Lack of supervision at the time of growing plants in the nursery and while planting in the plantation area,
- When proper shifting, grading and root cutting of plants is not done in the nursery as prescribed, before taking plants to the planting site and
- Proper attention is not paid in planting, weeding and other works.

In addition to the above, grazing, frost, lack of desired rainfall or excessive rain and fire are other adverse factors causing failure.

4.14 PLANTING OF GRASSES AND SHRUBS

Since vegetation of any particular area is always adapted to the local conditions of that place, therefore the varieties of grasses belonging to that place are different. According to the vegetative conditions, Himalayan forests can be divided into three categories.
- Humid temperate forests
- Dry temperate forests
- Alpine forests

As evident from the names of these forests that cold places having sufficient moisture are called 'Humid temperate forest', forests where the moisture is comparatively low and climate is dry and cold are called 'Dry temperate forests'. Whereas, the snow covered areas are called 'Alpine forests'. Similarly the grasses found in these three areas are also different (Table 4.3)

Table 4.3: Classification of grasses according to forest areas and vegetation types

<table>
<thead>
<tr>
<th>Type of forest</th>
<th>Vegetation type</th>
<th>Grasses inhabited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid temperate</td>
<td>Chir-Ban Oak forest (1500-1700m)</td>
<td>Batanya, Durva, Fulvi, Fulkiya, Hewaiya, Jhangori, June grass, Kummer, Kush, Naktura, Motia, Seru, Van-cheena, Vanjovata</td>
</tr>
<tr>
<td>forests</td>
<td>Ban oak- Blue pine (1700-2200m)</td>
<td>Batanya, Broom grass Chiruva, Durva, Faagu, Fulni, Jhangori, Kummer, Laaya, Nadi grass, Naktura, Paluva, Vanjovata</td>
</tr>
<tr>
<td></td>
<td>Ban oak- conifers (2000-3000m)</td>
<td>Babula, Batanya, Broom grass, Durva, Faagu, Falwan, Jhangori, June grass, Khor, Kummer, Kush, Laaya, Nadi grass, Mathanya, Naktura, Phulakya, Vanjovata</td>
</tr>
<tr>
<td>Dry temperate</td>
<td>Ban oak- Blue pine (1700-2200m)</td>
<td>Same as above</td>
</tr>
<tr>
<td>forests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alpine forests</td>
<td>Above 3000m</td>
<td>Bughyali grass, Babula, Chirva, Cocks foot, Fulakya, June grass, Khor, Kush, Laaya, Prarhari grass, Naktura, Nadi grass, Sathia, Vanjovata, Van kauni</td>
</tr>
<tr>
<td>Sub-tropical</td>
<td>400-1400m</td>
<td>Baalo Doob, Dalis, Kaans, Khas-Khas, Kush, Kunura, Kumraya, Makhmali grass, Moonj, Palms, Reshmi grass, Tachula, Vanshi grass</td>
</tr>
</tbody>
</table>

4.14.1 Shrubs

Shrubs are important not only for men but for forests also. The forest composed of trees, shrubs and grasses is in fact a true forest. The middle portion is left which can accommodate plants of intermediate height. Shrubs are most suitable to fill up this gap. Thus shrubs can significantly contribute to the productivity of a forest area. Shrubs are generally considered as a nuisance when managing any piece of forest land. There are few shrubs which are weeds and cause problems in the area e.g. Lantana, Kalabansa, Sulla etc. However, large number of useful shrubs are also found in hills of Uttarakhand which are closely associated with the culture of the region.

At present per annum demand of forest products is 3.6 lakh m³ in hills. This demand is likely to be increased in near future. This enormous demand can only be met out if efforts are made to enhance the productivity of land. Shrubs may be one of the important tools in this regard. Shrubs may be advantageous in the following respects:

- They produce a variety of fruits, medicines, minor forest products like fibre, gum, lac and also provide fodder and fuel,
- Shrubs can be well adapted to the adverse climatic conditions and a variety of soils,
- Shrubs are suitable for soil conservation as their roots penetrate the soil densely. It helps similarly as iron rods in reinforced cement concrete,
- Being small, they can be pruned and easily managed,
- Being compact in size, these are resistant to high wind velocity,
- They can even be grown in areas having poor soil and dry conditions,
- They can be used for bio–fencing and
- Some shrubs are good for nitrogen fixing thus increase soil fertility.

4.15 MAINTENANCE OF FIRE LINES

Forest fires are a common feature in Uttarakhand, especially between 1,000 to 1,800 m in fire adapted chir-pine forests. As per the National Remote Sensing Agency (NRSA), Hyderabad report, in one of the greatest forest fires in the region in 1999, around 22.64 per cent forest area was affected by the fires and 1,225 km² forest area got severely burnt. The extent of fire was more in the dense forests than in open forest area and the former suffered greater damage due to these fires. Almost all fires are man-caused (intentional or accidental). The total damage from forest fires is very large. Small trees and regeneration are often killed; severe fire can kill the large trees also.

Protection of forests against fires is one of the important operations in forestry. Fire lines of sufficient width are cleared of vegetation and maintained all around the forests and run criss-cross inside the forest so that a compact block or area is separated from other area. The width of these fire lines depends on many factors such as, type of forests, density, terrain, wind speed in the area etc. Such fire lines are usually cleared before the start of the fire season in order to avoid the spread of fires from one area to another.

This activity can be taken under NREGA by the Van Panchayats and in other areas as well where damage by forest fires is common. The schedule or rates for this activity has been presented in table 6.5.

Table 4.4: Important shrubs of Uttarakhand and their uses

<table>
<thead>
<tr>
<th>Uses of Shrubs</th>
<th>Zone A (upto 1000 M), Tropical Zone</th>
<th>Zone B (1000-1500M)</th>
<th>Zone C (1500-2400M)</th>
<th>Zone D (&gt;2400M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Champawat (Pt.), Dehradun (Pt.), Udham Singh Nagar, Nainital (Part), Pauri Garhwal (Part) and Haridwar</td>
<td>Almora (Pt), Dehradun (Pt), Nainital (Pt), Pauri Garhwal (Pt), Champawat (Pt), Bageshwar (Pt)</td>
<td>Cool Temperate Zone Nainital (Pt), Almora (Pt), Pauri Garhwal (Pt), Dehradun (Pt), Chamoli (Pt), Rudraprayag (Pt), Uttarkashi (Pt), Pithoragarh (Pt) and Bageshwar (Pt)</td>
<td>Chamoli (Pt), Pithoragarh (Pt), Uttarkashi (Pt), Tehri (Pt), Rudraprayag (Pt), Bageshwar (Pt)</td>
</tr>
<tr>
<td>Food and Fruit</td>
<td>Berberis asiatica, Murraya koenigii, Zizyphus mucumularia, Rhus parviflora, Indigofera cassidodes,</td>
<td>Berberis asiatica, Berberis lyceum, Tetrastigma serrulatum, Ampelopsis latifolia, Rhus parviflora, Rhus cirtinus, Indigofera cassiodides,</td>
<td>Berberis lyceum, Berberis chitria, Tetrastigma affine, Vitis himalayana, Ampelopsis latifolia, Rhus cirtinus, Rubus</td>
<td>Berberis chitria, Vitis himalayana, Rubus paniculatus, Prinsepia utilis, Rosa</td>
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<td>Plantation Techniques</td>
<td>Table 6.5.</td>
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<td><strong>Table 4.4: Important shrubs of Uttarakhand and their uses</strong></td>
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<td><strong>Shrubs</strong></td>
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<td>Cassia leavigata, Callicarpa macrophylla, Pyrus pashia, Rosa brunonii, Carissa opaca</td>
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<td>macrophylla Rosa rericea, Viburnum cotinifolium</td>
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<td>Cajanus cajan, Callicarpa macrophylla, Rubus elliptica, Pyrus pashia, Pyracantha renulata, Rosa brunonii, Punica granatum, Viburnum cotinifolium, Viburnum mullaha</td>
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<td><strong>Fodder</strong></td>
<td>Rhus parviflora, Rhus cortinus, Indigofera cassioides, Indigofera heterantha, Mucuna nigrians, Lespedeza stenocarpa, Sesbania cannabina, Cajanus cajan, Bauhinia vahlii, Callicarpa macrophylla, Pyrus pashia, Spermacctyon suaveolens, Artermisia vulgaris, Diospyrus motana, Sesbania cannabina, Adhatoda vasica, Xylosma longifolia, Xeromphi spinosa, Rhmnus verigata</td>
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<td>Euonymus tingens, Rhus cortinus, Desmodium tiliaeolium, Indigofera heterantha, Pyrus pashia, Leptodermis lanceolata, Artermisia vulgaris, Colebrookea oppositifolia, Ficus nerifolia, Ficus palmate, Dendrocalamus strictus, Cotoneaster bacillaris, Salix wallichiana, Symplocos chinensis</td>
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<td>Murraya paniculata, Murraya koenigii, Rhus parvimora, Indigofera cassioides, Mucuna nigrians, Lespedeza stenocarpa, Millettia auriculata, Sesbania cannabina, Cajanus cajan, Cassia leavigata, Bauhinia vahlii, Callicarpa macrophylla, Pyrus pashia, Spermacctyon suaveolens, Artermisia vulgaris, Diospyrus motana, Sesbania cannabina, Adhatoda vasica, Xylosma longifolia, Xeromphi spinosa, Rhmnus verigata</td>
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<td><strong>Fuel</strong></td>
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<td>Cocculus laurifolius, Berberis asiatica, Cosearea elliptica, Xylosma longifolia, Urea lobata, Calastrus paniculatus, Rhus parviflora, Indigofera cassioides, Indigofera</td>
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<td>Cocculus laurifolius, Mohonia borealis, Berberis lyceum, Berberis chitria, Zanthoxylum arimaturn, Buxus sempervirens, Picrasma guassioides, Euonymus tingens, Sageretia filiformis, Rhus parviflora</td>
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<td>Rhus cortinus, Coriaria</td>
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<td>Schedule of rates for forestry related work in Uttarakhand under NREGA</td>
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Forests play a very important role in soil and water conservation. Tree leaves intercept the rain and allow its water to percolate deep into the ground thus charge the ground water reservoir. The dense network of roots hold the soil and prevent erosion thus plays an important role in maintaining soil fertility. The productivity of agricultural lands is decreasing day by day due to population pressure and unsustainable exploitation of natural resources. The ground water table is also going down very fast due to excessive tapping. The development of lands and water resources cannot be considered independent of each other for sustainable natural resource management. Conservation and management of rain water is very important for the development of agriculture especially in the hills where most of the agriculture is rain fed. This situation can be improved by taking suitable soil and water conservation measures at appropriate places with the involvement of local communities under NREGA, 2005. As per schedule 1 of the Act, the focus of the Rural Employment Guarantee Scheme must be on the following works:

- water conservation and water harvesting and
- drought proofing, including afforestation and tree plantation

Following remedial measures are being suggested under these activities:

### 5.1 GULLY PLUGGING AND NALA CONTROL

In control of gullies and nalas the erosive velocities are reduced by flattening out the steep gradient of the gully by constructing a series of checks which transform the longitudinal gradient into a series of steps with low riser and long flat treads. This involves construction of check dams (vegetative, stone and crate wire or wire mesh check dams). Spur walls and retaining walls can also be constructed for bank protection to save valuable agricultural fields from being cut up. Mechanical measures (check dams) are supplemented by planting in gullies behind check dams. All gully or nala control work should start from the top of gully/nala and this activity must cover both non-arable and arable land.

The stabilization of gullies through vegetation is difficult task as gullies have to be used for conveying run off during the time vegetative measures are undertaken and these measures get damaged by run off. Therefore, mechanical measures have to be adopted to prevent washing away of vegetative measures by large volume of run off. Vegetation once established is able to take care of gully. Thus mechanical measures, temporary or permanent, are necessary in gully control to be supplemented by vegetative measures since mechanical measures weaken and vegetative measures get strengthen with the passage of time. Following types of check dams are being suggested under mechanical measures:

| Bio-fencing | Murraya koenigii, Rhus parviflora | Mohonia borealis, Sageretia filliformis, Rhamnus virigatus, Rhus parviflora, Rhus cortinus, Coriaria nepalensis | Mohonia boealis, Zanthoxylum arimatum, Sageretia filliformis, Rhamnus virigatus, Rhus cortinus, Rhus wallichii, Coriaria nepalensis | Zanthoxylum arimatum, Rhus wallichii, |
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5.1.1 Brushwood check dams

The main requirement of temporary control structures is that they must be quick and easy to construct and use cheap readily available materials. In brushwood check dams small branches preferably of coppiceable species are fixed in two parallel rows across the gully or nala and packed with brushwood between the rows of these vertical stakes (Fig. 5.1). The vertical stakes can be tied down with wires or fastened with sticks across the top. The important point in erecting brushwood check dams is to pack the brushwood as tightly as possible and to secure it firmly. Brushwood check dams are generally meant for small gullies or at the starting stretch of the gullies.

![Diagram of brushwood check dam with seedlings and compensation gradient](image)

Fig. 5.1: A double row brushwood check dam
Posts are set in trenches (0.3 x 0.2 m in size) across the gully to a depth of about 1/3 to 1/2 of the post length, and about 0.3 to 0.4 m apart. The length of the posts is 1.0 to 1.5 m and their top-end diameter is 3 to 12 cm. Any tree or shrub species, such as alnus, pine, bamboo, salix, poplar, etc., can be used as posts. The flexible branches of trees (Salix, Poplar, Gliricidia, Cassia, etc.) flexible stems of shrubs (Tamarix, Arundinaria, etc.), and the strips made of bamboo stems may be used as interlink material. These materials are woven between wooden posts driven into the ground. The ends of interlink materials should enter at least 30 cm into the sides of the gully. The space behind the brushwood check dams must be filled with soil to the spillway. If sprouting species (Salix, Poplar, etc.) are selected as posts and interlink materials, brushwood check dams should be constructed when the soil in the gully is saturated or during the early rainy season. If non-sprouting species (pine and alnus as posts, bamboo strips as interlink materials) are used, brushwood check dams can be constructed during any season.

5.1.2 Stone check dams

For constructing R.R. dry stone check dams, the site where it is to be constructed is cleared and the sides are sloped 1:1. The bed of gully is excavated for foundation to a uniform depth of 0.45 m to 0.60 m and dry stones are packed from that level (Fig. 5.2). Over the foundation, R.R. dry stone masonry super structure of check dam can be constructed. The stone are dressed and properly set in with wedges and chips. The width of check dam at the base should be approximately equal to maximum height and successive courses are narrower so the section is roughly a trapezium. It is common to find upstream face of check dams vertical with all slopes on the down stream face but while there is sound engineering reason for this in case of large dams but it is not of any consequence in small gully control dams. In the centre of the dam portion sufficient waterway is allowed to discharge the maximum run off. The dry stone work should go up to 0.30 m to 0.60 m in the stable portion of the gully side to prevent end-cutting. Sufficient apron should be provided to prevent scouring of the structure. The thickness of the apron packing should be about 0.45 m and gully sides above the apron have to be protected with packing to a height of atleast 0.30 m above the anticipated maximum water level to prevent side scour being formed by the falling water.

5.1.3 Crate wire or wire mesh check dams

When a dry stone check dam is held down with woven wire netting, the life and strength of the structure is enhanced many fold. The mesh of wire is generally 0.15 m x 0.15 m and care should be taken that stones used are larger than the mesh size so that stones do not pass through the mesh. The wire netting is spread below the stone foundation and in the sides before stone work and after completion of stone work the wire netting is tied, covering the masonry tightly so that the whole structure becomes one piece. The stability is secured by careful masonry work, setting and wedging. Wire mesh stone check dams have proved very useful and more lasting than ordinary stone check dams (Fig. 5.2).
5.2 DIVERSION DRAINS

Diversion drains intercept the storm water which could otherwise flow down from higher ground on to the arable land which it protects. It is the first line of defense and vital for protection systems and structures below as it effectively controls the run off from outside the arable land and conducts it safely to natural outlet. The diversion drains should be aligned on non erosive and non silting grades. It must also be protected from silting. A narrow and deep ditch does not get silted up as rapidly as a broad and shallow ditch of the same cross sectional area and is therefore, self maintaining. The soil excavated from the diversion drain shall be deposited on lower side of the drain, leaving a berm of 0.30 m and sectioned in a trapezoidal shape with side slopes not steeper than 1:1. The outlet end of the diversion drain should be taken to the existing or stabilized safe natural drainage lines or outlets so as to conduct the run off properly without causing erosion. Suitable spreading type of grasses must be planted. Panicum repens has been found the best for the alluvial soil of Dehradun followed by Brachiaria multica, Cynodon plectostachys, C. dactylon and Paspalum rotatum (Sharda et al., 2006).

The maintenance operations include periodical removal of weeds, filling of the patches with grass and proper cutting of grass.

5.3 LEVELLING /BENCH TERRACING OF SLOPING CULTIVATION FIELDS

Bench terracing is one of the most popular mechanical soil conservation practices adopted by the farmers in India and other countries. In the hills, intensive farming can only be adopted with bench terracing. It consists of construction of step like fields along contours by half cutting and half filling. Original slope is converted into level fields. Thus hazards of erosion are eliminated and manure and fertilizer applied are retained in the field.

However, in hill areas, most of the cultivation fields are sloping and improperly terraced. These sloping fields need to be bench terraced by cutting and filling with filling supported by retaining stone wall (Fig. 5.3 and Fig 5.4). Terraces may be designed to collect runoff expected from storm of 4 years recurrence interval and 6-hour rainfall. For planning contour trenches, their horizontal and vertical spacing have to be decided. The trench cross section of trapezoidal, rectangular and triangular shape is usually constructed for runoff impoundment. The relationship between the spacing of the trenches, area of cross section and expected runoff can be expressed as follows (Sharda et al., 2006)

For continuous trenches, the following formula may be used for working out the horizontal spacing, assuming the trench to be rectangular

$$\text{Spacing (in meters)} = \frac{\text{Cross section area of the trench (cm}^2\text{)}}{100 \times \text{Expected runoff (cm)}} = \frac{\text{Area of cross section}}{\text{Expected runoff}}$$

Where,
- \(Q\) = Depth of the expected runoff from the area (cm)
- \(W\) = Width of the trench (cm)
- \(d\) = Depth of the trench (cm)
- \(HI\) = Horizontal Interval (m)

Soil and Water Conservation Measures

Fig.5.2: A dry stone check dam
(A: Front view;  B: 'A'-‘A' cross section, C: Live structure)
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For continuous trenches, the following formula may be used for working out the horizontal spacing, assuming the trench to be rectangular

\[ \text{HI (in meters)} = \frac{\text{A (cm}^2\text{)}}{100 \times Q} \]

Where,

- \( Q \) = Depth of the expected runoff from the area (cm)
- \( W \) = Width of the trench (cm)
- \( d \) = Depth of the trench (cm), and
- \( \text{HI} \) = Horizontal Interval (m)
For staggered trenches, with the in-between gap not equal to the length of trench

$$ HI = \frac{W \times d}{100 \times Q \times (1 + X/L)} $$

Where,

- $X$ = Gap between the trenches and
- $L$ = Length of the trench

The vertical spacing between the trenches is determined by the equation

$$ VI = \frac{S \times HI}{100} $$

Where,

- $VI$ = Vertical Interval (m),
- $S$ = Land slope (%),
- $HI$ = Horizontal Interval (m).

Trench specifications designed to store 25 mm runoff produced by 4 years 6 hours storm of 80 mm on different land slopes is given in Table 5.1 and Fig. 5.3.

**Table 5.1: Trench specifications to store 25 mm runoff**

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>Trench + spoil bank width (m)</th>
<th>HI(m)</th>
<th>VI(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.65</td>
<td>5.50</td>
<td>0.55</td>
</tr>
<tr>
<td>20</td>
<td>1.85</td>
<td>5.50</td>
<td>1.10</td>
</tr>
<tr>
<td>30</td>
<td>2.10</td>
<td>5.50</td>
<td>1.10</td>
</tr>
</tbody>
</table>

(After Sharda et al., 2006)

**Fig. 5.3:** Trench specifications to store 25 mm runoff on different land slopes
Farmers are generally interested in the construction of irrigated (levelled) bench terraces for reason of higher productivity. The specifications of such terraces are mentioned in Table 5.2, which shows that by constructing a steep stone riser, the area lost due to bench terracing is reduced considerably (Fig. 5.4). The shoulder bund may also be put under leguminous crops like beans or peas.

Table 5.2: Specifications for irrigated benches in N-W Himalayas

<table>
<thead>
<tr>
<th>Slope (%)</th>
<th>VI (m)</th>
<th>Bench width (m)</th>
<th>Terrace width (HI)</th>
<th>Depth of cut (m)</th>
<th>Depth of soil required (m)</th>
<th>Bench length (m)</th>
<th>Area lost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.6</td>
<td>8.5</td>
<td>8.6</td>
<td>0.3</td>
<td>0.6</td>
<td>1163</td>
<td>1.4</td>
</tr>
<tr>
<td>10</td>
<td>0.75</td>
<td>7.5</td>
<td>7.6</td>
<td>0.4</td>
<td>0.7</td>
<td>1307</td>
<td>2.0</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
<td>5.0</td>
<td>5.2</td>
<td>0.5</td>
<td>0.8</td>
<td>1923</td>
<td>3.8</td>
</tr>
<tr>
<td>30</td>
<td>1.2</td>
<td>4.0</td>
<td>4.2</td>
<td>0.6</td>
<td>0.9</td>
<td>2358</td>
<td>5.6</td>
</tr>
<tr>
<td>40</td>
<td>1.5</td>
<td>3.8</td>
<td>4.0</td>
<td>0.8</td>
<td>1.0</td>
<td>2469</td>
<td>7.4</td>
</tr>
<tr>
<td>50</td>
<td>1.8</td>
<td>3.5</td>
<td>3.9</td>
<td>0.9</td>
<td>1.2</td>
<td>2590</td>
<td>9.3</td>
</tr>
</tbody>
</table>

1 = (After Sharda et al., 2006)

Fig. 5.4: Bench terrace constructed by cutting and filling

5.4 CONTOUR TRENCHING

Contour trenches are widely used for moisture conservation in plantation areas. It is a practice of excavating trenches along a uniform level across the slope of land. Bunds are formed along the trenches on the downstream side with material taken out of them. The expected service life of a trench is about 3 to 4 years, after which, the vegetation is supposed to perform the conservation function.
Contour trench break the velocity of run off and store whole or part of runoff. If contour trenches are constructed on the slope at the interval, just before runoff water attains erosive velocity, their life will be much more. Trenches should be designed to store 60-70 per cent of runoff from 6 hours storm with 4 years return period in coarse textured soil (Sharda et al., 2006). The intercepted runoff percolates through the soil slowly and is made available to the plants. The structural details of a contour trench have been mentioned in Fig. 5.5.

![Fig. 5.5: Sketch of a contour trench showing various details](image)

They are normally used in the upper portion of watershed for the plantation of forestry/horticultural plants. Fodder grasses should be planted on the bund and trees may be planted just downstream of the trench or in the trench itself in gravelly soil. Contour trenches are of two types:

5.4.1 Continuous trenches

The trenches are called continuous when there is no break in length and can be 10-20 m long across the slope depending upon the width of the field. Trenches are generally used in low-rainfall areas and dug with a cross section varying from 30 cm to 45 cm x 45 cm (Fig. 5.6).

5.4.2 Staggered trenches

These are generally made in high rain fall areas as there is a danger of overflow and breach in case of continuous trenches in such areas. In staggered trenching, the trenches are located directly below one another in alternate rows and in a staggered fashion. These may be 2 m to 3 m long and the spacing between the rows may vary from 3 m to 5 m (Fig. 5.7).
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Fig. 5.6: Continuous trenching in hilly agricultural fields

Fig. 5.7: Staggered trenching
5.5 STABILIZATION OF LANDSLIDES

5.5.1 Stream bank protection

One of the main reasons for the frequent occurrence of land slides in the hill areas is toe cutting by streams and rivers. In order to confine the flow and protect the bank, construction of spur walls/retards is desirable to deflect water of torrents from toe cutting of banks particularly at the curves. As a matter of fact R.C.C. block spur wall involves large scale work with heavy cost. Therefore, wire mesh boulder or stone spur walls must be constructed as there is no dearth of boulders or stones in the hills.

A method for locating the spur wall or retard is shown in Fig. 5.8. The first major retard at A is located by the intersection of the projected centre line of flow with the concave bank. In locating the second major retard C, a line HB is drawn parallel to the above projected centre-line and through the end of retard A. The intersection of this line with the concave bank locates point B. AC is then made equal to twice AB. Additional retards are located by intersection of a line connecting end points of two previous retards with concave bank (see D). An auxiliary retard at K is located at a distance AB upstream from A and is extended into the stream about one half the lengths of other retards.

![Fig. 5.8: Design and location of retards](image)

The retard of spur walls should extend into the stream at an angle of 45 degree for a distance of about 30 per cent of the channel width. On small streams the spacing of retards may be made equal to stream width and length 0.25 times the spacing. In the silt setting between parallel lines of spur walls, species which grow well near stream beds should be planted e.g. Alnus nepalensis, Ipomoea carnea, Populus ciliata, Salix, Vitex negundo and local grasses etc.
5.6 STABILIZATION OF LAND SLIPPED SLOPES

Following measures are suggested for stabilization of land slipped slopes:

(i) **Protective measures against biotic pressure:**

Four strand barbed wire fencing should be erected around the affected area to prevent cattle, sheep, goats and other animals grazing in the area.

(ii) **Structural measures:**

Stone retaining walls along contour should be constructed to withhold and help in stabilizing the land slip.

(iii) **Vegetative measures:**

Slip area should be planted and well covered with quick establishing species of trees and shrubs e.g. Agave, Alnus nepalensis, Ipomoea, Populus ciliata, Salix, Vitex, Woodlandia, etc.

(iv) **Covering with netting:**

Wherever possible land slipped slopes should be provided with cover of wire netting, rope netting or sack (coarse jute fabric) etc. including wattling and mulching. Several types of netting can be used woven with wire, jute yams or cannabis ropes etc. To use these nettings, slopes should be smoothened, seeded and fertilized and layer of mulch is spread and the netting unrolled over the mulch and anchored by wire staples.

(v) **Diversion channel:**

Diversion channel well above the landslide can check rain water coming to fragile site and divert it to safe natural course nearby.

5.7 DEVELOPMENT OF NATURAL PONDS, LAKES AND SPRINGS

Ponds and springs in the hills are of small size while lakes are quite large. Development of ponds and springs in the forest areas should be done according to the local conditions after consulting the villagers. If during consultation with the villagers technical shortcomings come to light, solutions should be decided again in consultation with the villagers for which a plan should be worked out keeping the following in mind:

(i) Topographic survey of ponds and springs falling in the area

(ii) Identification of problems such as premature silting, diversion of rain water, soil erosion etc. in the area.

(iii) Consultation with the local people and users.

(iv) Knowing the object of ponds, springs and lakes such as drinking water for cattle, irrigation and drinking water, seasoning of branches of 'Bhimal' and 'Bhang' for extracting fibre or any other purpose.

(v) Feasibility of action plan as per advice of villagers and technical problems.
Convergence is an evolving process and while broad principles can be laid out at the Centre, the actual contours of convergence will be determined by the resources at the district and the field context. Also to fully identify the possibilities of convergence it may be necessary to make a beginning with select programmes so that the experience of implementation may further inform and refine strategies for convergence.

With this perspective a Task force on convergence with NREGA was set up with representative from different Ministries and Departments implementing programmes with complementarities with NREGA. The Task Force recommended beginning with select programmes of select Ministries. The Ministry of Forest and Environment which was represented on the Task force was identified as an important partner to NREGA, as afforestation and plantation are permissible activities under NREGA. Possibilities of convergence between NREGA and the programmes of MoEF were discussed between the two Ministries and based on these discussions, convergence areas and modalities were identified and the following guidelines for convergence of afforestation/plantation works taken up under NREGA and under the programmes of the MoEF.

### 6.1 CONVERGENCE BETWEEN NREGA AND NAP

6.1.1 Convergence between NREGA and NAP is mutually beneficial. Ministry of Environment and Forests has the task of achieving one third of the land area under forest and tree plantation as envisaged in the National Forest Policy, 1988. This cannot be accomplished by the MoEF alone due to enormity of the task. Convergence with NREGAS will provide additional resources. Operational guidelines of NAP also suggest co-ordination with rural development programmes so that the forest fringe areas and community/privately owned forests can be developed on watershed approach in a holistic manner. The integrated area development approach with ecological concerns will benefit NREGA leading to better quality planning and selection of works capable of generating sustainable employment.

### 6.2 NATIONAL AFFORESTATION PROGRAMME (NAP)

6.2.1 NAP is being operated as a 100% Central Sector Scheme. The overall objective of the scheme is to develop the forest resources with people's participation, with focus on improvement in livelihoods of the forest-fringe communities, especially the poor. NAP scheme aims to support and accelerate the ongoing process of devolving Joint Forest Management Committee (JFMC) at the village level and Forest Development Agency (FDA) at the forest division level. Financial support under NAP Scheme is meant for afforestation. For its success, ancillary activities are supported as well. The financial support is available for:

- **Crate wire with loose boulders**
- **Drain line treatment with stone wall**
- **Stream bank protection**