STUDY ON MULTIPURPOSE TREE SPECIES OF POPLAR, *EUCALYPTUS*, AND *AILANTHUS EXCELSA*

Final Report

Haryana Community Forestry Project
Panchkula, Haryana

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1.0 BACKGROUND

Forest Department, Government of Haryana, with financial assistance from the European Union (EU) is currently implementing the Haryana Community Forestry Project (HCFP) in ten districts of the State targeting 300 villages. The overall objective of the Project is capacity building of the local communities to improve the natural environment and to preserve land fertility by sustainable management of natural resources through activities undertaken in a participatory manner. One of the key activities of the Project is to encourage planting of multipurpose tree species like *Eucalyptus,* poplar, and *Ailanthus excelsa.* These three species have been and are being planted by the farmers on their land.

Accordingly, the HCFP felt it necessary to undertake a study, namely, "Study on Multipurpose Tree Species", to assess the growth potential of the above three species on different sites with a view to provide some guidelines for raising such plantations in future.

The HCFP therefore, commissioned the services of the Institute for Sustainable Development (ISD), New Delhi, to undertake the above Study with the following terms of reference (TOR).

- Collect growth data from *Ailanthus excelsa, Eucalyptus tereticornis* and poplar plantations raised on different sites/areas in Haryana and determine the most suitable ecological range for raising its plantation. Particular attention should be paid to soil depth, texture, nutrient content and the rainfall regime.
- Assess the quantity of timber of these species available for marketing annually.
- Identify the clones and/or planting material of *Eucalyptus* and poplar, which the farmers are planting at present and the sources from where these are obtained.
- Determine farmers' acceptance potential for high yielding clones of *Eucalyptus* and poplar and practices followed for raising the same so that a strategy for extension of high yielding clones and improved package of practices can be evolved.

- Make specific suggestions whether *Ailanthus excelsa* should be given the same emphasis, which it has received in the state plantation programme, or whether this needs to be modified.

This report is an output of the above Study that was carried out by the ISD through measurement of temporary sample plots (SPs) laid out for the purpose and field surveys, over the entire planting range of the three identified species, in the concerned forest divisions of the State. With regard to assessing the quantity of timber of the said species available for marketing annually (TOR 2), it was mentioned in our original proposal that this should from the subject matter of a follow up study. Accordingly this has not been dealt with in this report.

The report is being submitted to HCFP.

2.0 INTRODUCTION

2.1 Geographical Situation

The State of Haryana with a total geographical area of 43,910 sq km and a population of over 16 million (1991 census) is one of the smallest states of the Indian Union. Located between North latitudes 27° 30' and 30° 55' 30" and East longitudes 74° 27' 48" and 77° 36' 30", it is bounded by the states of Himachal Pradesh in the north, Uttar Pradesh in the east, Rajasthan in the south and southwest, Punjab in the west and northwest and Delhi in the southeast corner. The severely eroded Siwalik hills and Aravalli ranges in the north and south respectively, the Rajasthan Desert in the west and southwest and the river Yamunna in the east, flank the State.

2.2 Physical Features

The State presents a variety of physical features varying from hills in the north to almost level alluvial plains in the central parts and sand dunes in the southern districts. While a large part of the State forms a part of the Indo-Gangetic alluvial plains, it has four main physiographic regions, namely, the Siwalik Hills, Alluvial Plains, Aravalli Hills, and Aeolin Plains.

The Siwalik hills in the north have an altitudinal variation of 300 to 1,500 m. These hills are steep and rugged at lower elevations and subject to heavy erosion. The Aravallis in the extreme south is a discontinuous mountain chain of low elevations. Between these two hills features are situated the plains, almost in a bowl shape. Towards the borders of Rajasthan, in the south and southwest, extensive sandy plains exist, often with dune formations.

The entire state is drained by Yamuna and Ghaggar rivers and their tributaries mainly Markanda, Saraswati, Chautang and Tangri and other seasonal streams. Sahibi, Dohan and Krishnawati originating from Aravalli ridges are flowing from south to north.

2.3 Geology

The geological formations range from Precambrian to recent times and can be divided into 3 geological systems.

Aravalli System: The oldest geological formations found in the southwestern parts of the State covering Bhiwani, Mahendragarh and Gurgaon districts. They are composed of quartizites, quartizitic sandstone, mica schists, phyllites and crystalline limestone.

Siwalik System: Situated in the northern parts of Ambala/Panchkula districts it is composed of sedimentary rocks, the dominant rocks being sandstones, shales, clays and boulders.

Indo-Gangetic Alluvial Plains: It is formed by deposition of alluvial sediments between Siwaliks and Aravallis as a part of great Indo-Gangetic plain and consists of sands, silts, clays and occasional gravel beds. In parts of Bhiwani, Hissar and Sirsa districts, wind blown sand deposits are found in the form of sandy plains and sand dunes over alluvial deposits.

2.4 Climate

Haryana has a subtropical, arid, semi-arid and sub-humid monsoonic climate. There are four distinct seasons, viz., Winter (December to March), Summer (April to June), Monsoon (July to September) and Autumn (October to November).

The average annual rainfall in the State is of the order of 650 mm and varies from less than 300 mm in southwestern parts of Bhiwani, Hissar and Sirsa districts to about 1,500 mm in northeastern hilly tracts of Ambala/Panchkula districts; there being a gradual decrease in rainfall from the north to the south and southwest; the southern half receiving less rainfall spread over a few days in a year. There is normally a five-months dry season (December to April) and nearly 70 to 80% of the rainfall occurs from June to September. The receipt of rainfall is highly uncertain in time and space as the coefficient of variation even in the monthly rainfall for monsoon months of July and August in about 50%.

In general, 65% area of the State is characterized by arid and semi-arid climate and droughts are a recurring feature. Frost is common in drier areas during winter, and hailstorms occur in March-April; dust storms being common during summer in the southern and southwest region. Temperatures vary from 47°C (Hissar in June) to freezing levels (0°C, Narnaul, January) with high diurnal variations. The mean annual temperature ranges from 23 to 26° C.

The average mean daily open pan evaporation varies from 2.4 mm in December to 13.4 mm in June (Hissar). Comparisons of evaporation and rainfall for the same periods of the same observatory show that evaporation exceeds precipitation in all the months of the year. The potential evapotranspiration is about 200 mm per annum, in most parts of Haryana, ranging from about 70 mm in January-February to over 370 mm in May-June.

Table 1 gives DeMartonne's Aridity Index calculated for six meteorological stations (Ambala, Gurgaon, Hissar, Karnal, Narnual and Rohtak) in the State. Based upon this Index the humid months determine the growing season. Aridity Index is defined as $I = {}^{12\,p}/_{t+10}$ where I is the Aridity Index, p is the mean monthly precipitation and t is the mean monthly temperature. If I is greater than 20, in a particular month, it is a humid month contributing to the growing season, otherwise it is counted as an arid month. The

Table 1: Aridity Index

Month/ Station	Aridity Index					
	Ambala	Gurgaon	Hissar	Karnal	Narnaul	Rohtak
January	21.2	7.5	6.8	14.7	8.6	6.7
February	23.7	8.0	7.0	9.2	5.0	9.2
March	10.6	4.2	4.5	7.8	2.7	6.7
April	3.8	2.8	1.8	2.5	2.0	1.4
May	4.8	5.7	5.7	2.9	4.4	5.6
June	19.7	17.2	11.6	13.4	13.4	10.6
July	80.3	75.4	40.2	51.3	65.4	78.4
August	75.6	64.1	43.4	78.0	59.4	49.0
September	50.8	38.6	19.7	34.6	21.3	21.1
October	9.4	3.9	4.9	11.2	7.0	2.0
November	2.6	2.3	2.4	1.5	1.0	1.9
December	7.0	1.7	3.5	4.4	5.1	6.3
No. of growing season months	5	3	2	3	3	3

humid months contributing to the growing season thus seem to range from two (Hissar) to five (Ambala) reflecting the amount of precipitation received.

Based on the amount of rainfall, number of rainy days and monthly temperatures, the State has five main climatic regions as given below; their average annual rainfall and temperatures are shown against each.

Zone	Mean rainfall (mm)	Average temperature (^{O}C)
Hot Arid Zone	Below 300	30
Hot Dry Zone	300 – 500	27
Hot Semi-Dry Zone	500 – 750	26
Hot Sub-Humid Zone	750 – 1,000	24
Hot Humid Zone	Above 1,000	23

2.4.1 Hot Arid Zone

This zone includes the south-western parts of Sirsa, Hissar and Bhiwani districts where the normal rainfall is less than 300 mm; 9 months have a temperature of more than 20 ° C, and only one month has it less than 15 ° C; 313 days are dry in the year and 70% days in rainy season are also dry. Annual number of rainy days are less than 20. July and August are semi-dry, whereas the remaining 10 months are dry.

2.4.2 Hot Dry Zone

Parts of Sirsa, Hissar, Bhiwani, Gurgaon, Rohtak and Jind districts are included in this zone. Here the normal annual rainfall is 300 to 500 mm; 8 months have a mean temperature of more than 20 ° C; 2 months have it less than 15 ° C; 289 days are dry in the year and about 67% of days in the rainy season. Annual number of rainy days are 26 to 30, July is sub-humid, August is humid, September is semi-dry and other 9 months are dry.

2.4.3 Hot Semi-Dry Zone

This zone may further be divided into two sub-zones: (i) Hot Semi-dry South-eastern Zone, and (ii) Hot Semi-dry East-central Zone.

Hot Semi-dry South-eastern Zone includes parts of Gurgaon, Sonepat and Rohtak districts where the normal annual rainfall is 500 to 600 mm. Number of months with a mean temperature of more than 20 ° C are nine, and with less than 15 ° C are two. Number of dry days in a year are 278 and about 60% days in the rainy season are also dry. Normal rainy days are 36 to 40; July and August are per humid; September is humid and the balance of 9 months are dry.

The Hot Semi-dry East-central Zone includes parts of Jind, Kurukshetra, Karnal and Ambala districts. Normal annual rainfall is 500 to 750 mm. In other respects, this zone is similar to Hot Semi-dry South-eastern Zone.

2.4.4 Hot Sub-humid Zone (adjoining Siwaliks)

This zone consists of parts of Karnal, Kurukshetra and Ambala districts where the annual rainfall is 750 to 1,000 mm. Eight months have a mean temperature more than 20 ° C while 2 months have it less than 15 ° C. More than 270 days in the year are dry, but the percentage of dry days in the rainy season is between 50 to 60, indicating that the monsoon rains are more or less continuous here. Number of rainy days in a year is 41 to 45; July and August are per humid, September is humid, February is sub-humid, January and June are semi-dry while the remaining 6 months are dry.

2.4.5 Hot Humid Zone

Most northern parts of Ambala (Panchkula), i.e. extreme northern parts of Pinjore, Kalka, and Morni hills constitute the Hot Humid Zone. The normal annual rainfall of the zone is more than 1,000 mm with 8 months having a mean temperature of more than 20 ° C and 2 months having less than 15 ° C. Less than 260 days in the year are dry,

and less than 50% days in the rainy season. Number of rainy days in a year is 46 to 50; July, August and September are per humid, October is sub-humid, January is humid and remaining 7 months are dry.

2.5 Soils

Based on the annual rainfall and other climatic conditions (old classification), the soils of Haryana have been classified into five groups, namely, Reddish Chestnut Soil, Tropical Arid Brown Soils, Arid Brown Soils, Sierozem Soils, and Desert Soils. These soil groups broadly follow the rainfall contours of the State.

2.5.1 Reddish Chestnut Soils

These soils are found mainly in Naraingarh *Tehsil* of Panchkula District having an annual rainfall of more than 1,000 mm (Hot Humid Climate Zone). They are reddish brown in colour and have no lime or calcium carbonate layer below, but do have a horizon made up of enrichment of clay, with pH varying from 6.5 to 7.5. Soil erosion by water is a very serious problem. Surface texture is loamy sand and sandy loam. The availability of nitrogen, phosphorus and potassium varies from low to medium.

2.5.2 Tropical Arid Brown Soils

Tropical Arid Brown soils occur in the areas having an annual rainfall of 750 to 1,000 mm and cover the remaining parts of Panchkula/ Ambala districts and parts of Karnal and Kurukshetra districts. They do not have calcium carbonate layer within 1 m. There are however, some pockets of depressions, which are poorly to imperfectly drained. These soils are mainly sandy loam to loam. Available phosphorus and potash are medium and high, respectively, while availability of nitrogen is low to medium. Soil pH varies from 7.0 to 8.5. Soils of Karnal and Kurukshetra have high EC and pH at several places posing salinity and sodicity problems.

2.5.3 Arid Brown Soils

Found in parts of Kurukshetra, Jind, Karnal, Sonepat, Rohtak, Gurgaon, Hissar and Faridabad districts, where rainfall varies from 500 to 750 mm (Hot and Semi-dry Climatic Zone), these soils cover nearly one-third of the State. Salinity and sodicity are serious problems with monsoonal floods in irrigated areas. Normal pH varies from 7.5 to 8.5. Soils are calcareous in nature and in most areas a layer of calcium carbonate nodules occurs at a depth of 1 to 1.5 m. Texture is mainly sandy loam to loam. Potassium availability is medium to high and phosphorus is medium. Nitrogen availability is from low to medium.

2.5.4 Sierozem Soils

Occurring in parts of Gurgaon, Rohtak, Mahendragarh, Bhiwani, Hissar and Sirsa districts, where annual rainfall varies from 300 to 500 mm (Hot and Dry Climatic Zone), these soils cover more than one-fourth area of the State. They are mainly sandy to sandy loam and calcareous having lime nodules at a depth of 75 to 125 cm with pH varying from 8 to 8.6. Salinity and sodicity problems appear in irrigated area. Wind erosion is also a common feature of this group. Organic carbon being very low, these soils are very poor in nitrogen. Availability of potassium is medium to high, whereas that of phosphorus is low to medium. These soils are also responsive to zinc application.

2.5.5 Desert Soils

Desert soils are found in the farmost southwestern parts of the State along the Rajasthan border including parts of Mahendragarh, Bhiwani, Hissar and Sirsa districts, where annual rainfall is less than 300 mm (Hot and Arid Climatic Zone). Soil texture is mainly sandy to loamy sand. These soils are calcareous with impermeable layer of calcium carbonate concretions at a depth of few cm to 1.25 m. pH values therefore, are relatively higher, viz, 8.5 to 9.5. Organic matter content is very low with consequent poor availability of nitrogen. Potassium availability is from medium to high and that of phosphorus from low to high. Most of the soils in this area are zinc deficient. With the recent introduction of irrigation systems, the soils characteristics are changing leading

to development of considerable saline patches. Active sand dunes are very common in this area. Wind erosion is, therefore, a very serious problem.

2.6 Agro-Ecological Zones

There are four main agro-ecological zones in the State, each with its own peculiar problems of utilization and potentialities for use. These are:

- **Siwalik Hills** in the northeast, which are steep and comprise of friable sandstone and conglomerates. The hill slopes represent a severely eroded landscape, which has resulted in '*Cho*' (seasonal river) formation in the plains below, mainly due to removal of vegetation in the hill slopes above, through excessive grazing and indiscriminate exploitation of woody biomass (Ambala, Yamunanagar and Panchkula districts).

- **Central Plains** wherein as a result of cultivation on marginal lands and increase in irrigated cropping, large areas have been affected by soil erosion, water logging, salinity and lowering of groundwater (Kurukshetra, Karnal, Kaithal, Sonepat, Jind, Panipat, Rohtak, Jhajjar and parts of Bhiwani, Hissar, Mahendargarh, Rewari, Sirsa, Fatehabad, Ambala, and Gurgaon districts).

- **The Desert** comprising numerous low stabilized and shifting sand dunes in the southwest and characterized by recurrent droughts and overgrazing with consequent degradation of vegetation, soil erosion and inducement of livestock migration (Hissar, Bhiwani, Mahendargarh, Rewari, Fatehabad and Sirsa districts).

- **Aravalli Hills** traversing through the plains in the southwest. Super-imposed on this physical pattern is the rainfall pattern, which declines from north to south. Denudation of tree cover, uncontrolled grazing and quarrying of stone are the factors responsible for accentuating desertification in this zone (Gurgaon, Mahendargarh, Bhiwani, Rewari, and Faridabad districts).

2.7 Land Use

Of the total land area of 43,910 sq km, over 82% (3.622 million ha) is under agriculture; 0.170 million ha (3.9%) under forest and over 13% (0.599 million ha) under other land uses (Table 2). Nearly 0.3039 million ha constitute *Panchayat* land, 0.62 million ha are under sand dunes and the area affected by salinity and alkalinity stands at 0.45 million ha.

Table 2: Land Utilisation in Haryana

Land use	Area (Million ha)	% of the total
Agriculture (Net area sown)	3.622	82.5
Forest	0.170	3.9
Other land	0.599	13.6
Total	4.391	100.0

The cultivable area consists of 1.34 million operational holdings with an average size of 2.70 ha, 22% of which are below 0.4 ha. Nearly 2.2 million ha are under irrigation (over 60 % of the cropped area), irrigation water being available from two main canal systems and about 360,000 tube wells. Land varies in quality from prime cropland to highly degraded saline/alkali soils and moving sand dunes resulting from deforestation and poor management.

3.0 FOREST RESOURCES

3.1 The Resource Base

Forest ecosystems in Haryana occupy an area of 0.170 million ha constituting 3.9% of the total geographical area of the State. Social and Farm Forestry plantations in the last two Five Year Plans have helped extend the tree cover to over 8%. Natural forests covers only 40,000 ha, two-thirds of which is degraded and the remaining has a canopy density of 40%.

Per capita forest area in the State stands at 0.01 ha, far below the country's average of 0.11 ha, and Wood Balance studies have shown that currently (1997-98 to 1999-2000) the State is deficient in wood production. The Haryana Forest Department (HFD) plans to extend tree cover to over 25% of the land area of the State over a period of 20 years; the potential areas for which are the common lands, mainly owned by *Panchayats*, institutional land, river banks, privately owned sand dunes in western parts, salt affected and water logged areas in the central and southern plains and degraded hills in the north and the south. In addition, 350,000 ha of farm bunds also may be available for tree plantations.

3.2 Energy Consumption

Based on an average daily household consumption of 20 kg of fuelwood, the State's domestic energy requirement is around 12 million tonnes of fuelwood equivalent (FEW) per year as follows.

- Fuelwood, charcoal and agriculture waste - 8.0 million tonnes (66.6%)
- Dung cake (73% of the total dung production) - 3.5 million tonnes (29.3%)
- Non-renewable sources - 0.5 million tonnes (4.1%)

It is estimated that tree cover in Haryana would have to be increased 10 times to meet its fuelwood requirement. There is thus a clear need to increase fuelwood production to permit more dung to be used as manure, agriculture waste as fodder, and to reduce pressure on natural forests and other vegetation.

3.3 Livestock and Grazing

With a livestock population of over 9.9 million (1992), the pressure of grazing both in forest and common lands is very high. There are areas with (i) high livestock pressure (Ambala, Kurukshetra districts etc.), (ii) moderate livestock pressure (foothills of the Siwaliks), and (iii) low livestock pressure (Bhiwani, Rewari districts etc.) where sheep and goats predominate.

A large proportion of the livestock throughout the State is uneconomic and their unfettered grazing in public, community and even in private lands is no doubt, a case of environmental degradation. Evolving appropriate silvi-pastoral systems, need-specific breeding policy, encouragement of stall-feeding and establishment of *Gaushalas* (homes for stray cattle) are necessary for the success of any tree-planting programme.

3.4 Land Degradation

Of the nearly 44,000 sq. km land area of the State, almost a quarter is degraded, with mobile sand dunes in the southwest (about 0.62 million ha are affected by active sand dunes), saline and alkali soils in the Central Plains (estimated variously to be between 0.45 and 0.626 million ha) and severely eroded hills (Aravalli and Siwalik ranges) in the south and north.

This degradation is caused by over cutting and overgrazing of vegetation on public, community and even private lands, poor management of irrigation water in the Central Plain, increasing population pressure and uneven distribution of wealth in the rural communities. Landless Scheduled Castes (SC) and other disadvantaged groups in a poverty spiral have no alternative of income and depend on access to grazing, fodder and fuelwood on common and public lands.

The resulting pressure on these areas has depleted vegetation, caused soil erosion and diminished the yield of grass and fuelwood. Rural poverty is commonplace with SC, women and the landless being among the most disadvantaged groups. Afforestation is one way to reverse this degradation.

4.0 PRESENT SCENARIO

4.1 General

With predominantly an agricultural (nearly 83% of the land area is under agriculture) and a forest deficient State (3.9%), Farm Forestry and utilization of common lands are probably the most effective strategies for increasing the forest cover not only for the protection of the environment and maintenance of ecological balance but also for increasing forest production to meet the demands of the State's human (over 16 million) and livestock (nearly 10 million) population, for timber, fuelwood, pulp, fruits, fodder and other non-wood forest products (NWFP).

4.2 Species Introduction

While afforestation programmes have been going on in Haryana ever since its formation in 1966, a programme for raising *Eucalyptus* on farm boundaries was initiated in Ambala District in late sixties and early seventies. Some of the progressive farmers were able to get good financial returns by selling the material to industries (mainly paper industry) located in the District. Gradually this activity picked up momentum and spread to other areas. Today, of the total area of nearly 0.3039 million ha of *Panchayat* land in the State, more than 80,000 ha have been taken up for afforestation and *Eucalyptus* is one of the major species raised depending on site conditions.

In the seventies and eighties the Western India Match Company (WIMCO) propagated poplar clones, (mainly G-3 and G-48 clones of *Populus deltoides*) in areas where moisture availability was assured. A large number of big farmers as well as some small farmers have taken up poplar farming on their lands along with agricultural crops (Agroforestry). However, poplar requires more inputs and care. *Eucalyptus* has become more popular in Farm Forestry because of its vertical growth and comparatively less shade cast on the crops.

Ailanthus excelsa is a more recent introduction on farmlands. As yet, plantations of more than three to four years of age are not available.

4.3 Plantation Sites

Of the three multi-purpose tree species under consideration *Eucalyptus* hybrid (mostly *E. tereticornis*) is being raised almost throughout the State as strip plantations along roads, canals, railway lines and watercourses; on community lands, private agricultural lands as Farm Forestry plantations (on field bunds and also as block plantations) and in forest land.

Poplar plantations are mostly grown on farmlands (Agroforestry and Farm Forestry) in Ambala, Yamunanagar, Kurukshetra and Karnal districts though they have been extended to Sirsa and Hissar districts, as well.

Plantations of *Ailanthus excelsa* have been established on sandy loam soils (Gurgaon, Mahendargarh and Bhiwani districts) though the species has been planted on some clay soils also (negligible). This being a comparatively recent introduction on farmlands, plantations are still young with an age gradations of one to four years.

4.4 Nursery Stock

Nursery stock for raising plantations of the three species is being obtained by the farmers from the following sources.

Eucalyptus

1. From HFD either free under Farm Forestry scheme or on payment of Rs. 0.50 per seedling.

Poplars

1. From HFD at Rs. 10/- per entire transplant (ETP)
2. From private companies like WIMCO; Saibiotech; Nuchem Industries etc. at Rs. 18/- to 21/- per ETP.
3. From unorganized sector (private farmers' nurseries where there is no quality control and nursery stock is inferior) up to Rs. 10/- per ETP.

Ailanthus excelsa

1. From HFD free of cost at present as it is comparatively a new introduction on farmlands.

4.5 Current Production and Supply

Eucalyptus is commonly raised at a spacing of 3x3 m but closer spacing of 3x2 m and even 1x1 m (on ridges) may also be adopted. Poplar is usually grown at 5x4 m spacing, while a spacing of 3x3 m (block planting) and 5 m apart (row and line planting) is followed in *Ailanthus excelsa.*

The rotation age for *Eucalyptus* is generally 8 years though it may vary from 6 to 10 years depending on the condition of the crop. Poplar is also felled at 8 years but some farmers may harvest it at 6 years with high inputs of fertilizer and irrigation. As *Ailanthus excelsa* plantations in the State are very young, rotation age for this species is not yet fixed but it could range from 8 to 10 years.

At the age of eight years, in case of *Eucalyptus*, 30% of the total growing stock has a girth of 90 cm and above and 70% of the crop is below 90 cm, which could be as low as 30 to 40 cm. All material up to 8 cm girth is sold as fuelwood in billets of 1 m length at Rs. 130/- per m^3 stacked. Material between 8 to 45 cm girth is used as pulpwood and sold in billet sizes of 1 to 1.5 m length at Rs 600/- per m^3 stacked, though price may go up to Rs. 740/- per m^3 depending on the type of stack. All material above 45 cm in girth is classified as timber with the current sale rate being of the order of Rs. 2,200/- per m^3 (solid) for logs above 90 cm girth. Log sizes (length) vary from 1 to 4.90 m, with an interval of 0.30 m between different log lengths.

With regard to poplar all material up to 8 cm girth is sold as fuel in billets of 1 m length. Material between 8 to 45 cm girth is used for pulping and above 45 cm for veneer/ plywood. Billet size for pulping material is 1 to 1.5 m, while log size for veneer/ plywood is between 1.4 to 2.0 m. The sale prices for poplar wood are higher than *Eucalyptus,* for different size classes.

As per the current agreement with the State Government, nearly 30,000 m^3 of *Eucalyptus* pulpwood (stacked) is supplied to the mills from Government forests and 30,000 to 40,000 m^3 (purchased by weight) is supplied by the farmers. Similarly almost

1,00,000 m^3 of timber of *Eucalyptus* and poplar goes to the market from Government forests and about 6,00,000 quintals from Farm Forestry plantations; poplar timber being used mostly for veneer.

There seems to be no harvesting of *Ailanthus excelsa* from the farm sector at present as the plantations are very young.

In order to give maximum profit to the tree-growing farmers in the State, the Haryana Forest Development Corporation Ltd. (HFDC), under their Tree Purchase Scheme, have fixed purchase rates of standing trees, by different girth classes, for *Eucalyptus*, poplar, *khair* and other species grown in Haryana, with a profit sharing incentive. This support price is a great check on fluctuations in wood prices to the advantage of the farmers.

4.6 Utilization

While the three identified species have a number of other uses, which explains the multi-purpose nature of these species, their present utilization in Haryana is generally as under.

Eucalyptus	Pulp and paper
	Furniture
	Crates
	Construction timber
	Fruit packing cases
	Charcoal
Poplar	Veneer/Plywood
	Pulp wood
	Match splints
Ailanthus excelsa	Artificial limbs
	Sports goods
	Veneer/Plywood
	Match splints

4.7 Growth and Yield

Although plantation programmes have been going on in Haryana ever since its inception in 1966 and species introduction was initiated in the late sixties (*Eucalyptus*) and seventies/eighties (poplar), there have been no systematic efforts to determine suitable sites for raising of these species in the State. There have also not been any studies carried out on their growth and yield, both in terms of their cubic content (volume) and biomass, though considerable work has been done on these aspects of the said species in other parts of the country. There have, however, been some occasional studies undertaken in Haryana as well as the adjoining states on some of these aspects.

4.7.1 Poplar

Experience with the cultivation of poplar (*Populus deltoides*) in the Punjab plains has shown that the growth of the species depends on four major soil factors, namely, physical conditions, moisture availability during growing season, nutrient availability and aeration. It can survive on soils varying from sandy to fine sandy loam and fairly stiff clay but it makes best growth on moist well drained, deep, medium textured alluvial soils that are fertile and well aerated. Soil pH considered suitable for poplar ranges from 5.5 to 7.5 and they react unfavourably to excessive soil acidity and alkalinity. It is inferred from a pot culture experiment that none of the poplar clones viz., G-3, G-48 and D-121 can survive in salinity conditions, and in sodium treatment also the three clones survived only up to pH 8.5 (exchangeable sodium percentage–20).

It has been recommended that the following points should be considered while deciding about the suitability of any site for poplar plantations.

- Sites should be well drained; low-lying areas subject to water logging should be avoided and assured irrigation facility should be available.
- Fertile loam or silt loam soil rich in organic matter should be preferred. Heavy clay soils, very sandy soils, saline and alkali soils are unsuitable for poplar.
- Areas with high water table are best sites for poplar plantation.

- Soil pH over 5.5 is essential, and below 5.5 is marginal and should be avoided.
- Areas selected for poplar plantation should be above 28° N latitude.
- Areas known to be infested with termites should be avoided.
- Poplars are strong light demanders; areas affected by the shade from existing trees should be avoided.

The maximum mean annual increment (MAI) estimated for Quality I, II and III poplar crops from Uttar Pradesh are reported as 38.3, 25.2 and 14.4 m^3 /ha with a spacing of 3.5 x 3.5 m. As high a production as 46.92 m^3 /ha/year from 9 years old (3 x 3 m) plantation with a mean height of 23.4 m, has been achieved by a farmer in Punjab.

A Volume table for poplars showing timber volume over bark (OB) and total volume OB has been prepared for the State for departmental use, in 1996.

Biomass is being used in place of volume for productivity studies because it is the best measure of productivity in terms of total organic production per unit area at a given time. By measuring total production as oven dry weight (Kg/ha or t/ha) it is possible to compare forest production with the production of other ecosystems such as grasslands or agriculture crops. While in case of volume production only economic production, which is being harvested, is measured, biomass measurements take into account the actual total production. A particular species may be producing more non-wood biomass as compared to other species producing more economic stemwood volume, with the production levels well comparable. Thus biomass is the best measure to judge the performance of a species. Biomass is also required to estimate the nutrient uptake and return in studies of ecosystem dynamics.

Populus deltoides plantations raised in Yamunanagar Division, Chhachrauli Range, Haryana, have shown an increasing total standing biomass with increasing age from 14.2 tonnes/ ha (3 years) to 114.5 tonnes/ha (9 years) with the bole biomass contributing 50 to 73% of the total biomass at the two ages respectively. Regression equations for different biomass components using diameter at breast height (DBH) as independent variable are as follows:

1	Bole	$Y = 0.01587\ X^{2.97897}$
2	Bark	$Y = 0.0054\ X^{2.68283}$
3.	Leaf	$Y = 0.0468\ X^{1.67912}$
4.	Twig	$Y = 0.0903\ X^{1.6455}$
5.	Branch	$Y = 0.1253\ X^{1.4099}$
6.	Total aboveground biomass	$Y = 0.00985\ X^{3.1854}$

In these equations Y is biomass (Kg) and X is DBH (cm), and can be solved by taking logarithms of both sides.

Mineral contents of aboveground parts of the above poplar plantations (*Populus deltoides*) are shown in Table 3, which broadly indicates the nutrient requirement of the species.

Table 3: Mineral Contents in Aboveground Tree Components

Nutrient	Mineral contents (Kg/ha) at different ages			
	3 Years	5 Years	7 Years	9 Years
N	61.90	84.00	192.20	340.08
P	2.51	3.63	11.20	15.55
K	33.47	48.01	154.93	240.04
Ca	32.64	47.44	100.01	206.62
Mg	19.49	27.57	68.12	129.73

4.7.2 *Eucalyptus*

While *Eucalyptus hybrid* grows successfully in different edapho–climatic conditions, its growth however, depends on soil type and spacing adopted. It has been tried with varying success even in saline and alkali soils. Experience gained from *Eucalyptus* plantations on varying sites has indicated that they need well drained deep and fertile soils for achieving better growth. The lateratic and *murrham* soils have also been successfully afforested with this species. Good growth has also been observed on waterlogged areas in Hissar and Indri (Karnal). It is also growing in salt affected areas in Hissar and *kanker* pan areas in Kurukshetra Division.

It is inferred from spacing trials on *Eucalyptus*, that the spacing adopted will depend on the objective, site quality and inputs. For production of firewood, spacing range to be adopted varies from 1x1 m to 1.5x1.5 m with shorter rotation (generally five years). For pulpwood and poles, to get the desired thin-end diameter, spacing of 2x2 m to 3x2 m may be the most suitable with 8 years rotation. A longer rotation of 10 to 20 years with a spacing of 3x3 m is desirable for saw logs. On field bunds spacing of 1 m and on railway and roadsides, 1x1 to 3x2 m spacing may be adopted.

Growth rates of *Eucalyptus* hybrid plantations on some Government and private lands have been described as: The highest MAI of 29.6 m^3/ha was achieved on sandy loam soils with a spacing of 4x3 m at 14 years age, with an average diameter of 27.6 cm. Similarly on fine sand, MAI of 28.4 m^3/ha was observed at the age of 9 years at 1.7x1.7 m spacing with an average diameter of 12.4 cm. On sandy clay loam and medium sand, MAI of 22.8 and 20.5 m^3/ha respectively is reported. It is also reported on the basis of analysis of the data from various states that the MAI at the age of 8 years varies from 12.1 m^3/ha to 19.8 m^3/ha for Site Quality I with number of stems as 800 and 1800 per ha respectively.

A modified volume table for *Eucalyptus* hybrid was made in 1988 which gives the outputs of timber (Stem above 60 cm girth), pulpwood (wood between 60 and 20 cm) and fuelwood (small wood below 20 cm girth) expected from a tree of a given girth (OB at breast height). This table is useful in making financial valuation of trees and in assessing the efficiency of departmental harvesting operations.

The total aboveground biomass and its distribution among various tree components at different ages, in *Eucalyptus* hybrid plantations in Kurukshetra Division is given in Table 4.

Table 4: Total Standing Biomass (t/ha) in *Eucalyptus* hybrid

Tree component	Age (Years)							
	4	%	6	%	8	%	10	%
Bole	10.8	53.7	21.6	62.4	65.0	73.2	107.0	77.7
Bark	1.7	8.4	3.0	8.6	7.0	7.8	10.8	7.8
Leaf	1.6	7.9	2.0	5.7	2.7	3.0	3.5	2.5
Twig	2.2	10.9	2.8	8.0	5.9	6.6	5.2	3.7
Branch	3.8	18.9	5.2	15.0	8.1	9.1	11.2	8.1
Total aboveground biomass	**20.1**		**34.6**		**88.7**		**137.7**	

Note: % indicates % of the total

The regression equations between biomass Y (kg) and DBH (D) (cm) are given below.

1. Bole $y = (0.01876088)\ (D)^{3.015664}$
2. Bark $y = (0.009932606)\ (D)^{2.457389}$
3. Leaf $y = (0.1276455)\ (D)^{1.195067}$
4. Twig $y = (0.1269706)\ (D)^{1.331785}$
5. Branch $y = (0.1335883)\ (D)^{1.580798}$
6. Total aboveground biomass $y = (0.1353357)\ (D)^{2.416484}$

Harvesting of *Eucalyptus* hybrid crop of the age of 10 years in Kurukshetra Division would result in the removal of 341, 9, 199, 293, 139 kg/ha of N,P,K, Ca and Mg respectively. If bole and fuelwood are only removed, the loss would however, be reduced to 255, 8, 153, 215 and 121 kg/ha of N,P,K, Ca and Mg respectively. Mineral contents of plant parts are given in Table 5.

Table 5: Mineral Content in Tree Components of *Eucalyptus* hybrid Plantation (10 Years)

Plant part	Nutrients (Kg/ha)					
	N	P	K	Ca	Mg	Biomass (t/ha)
Bole	171.20	5.35	64.20	42.80	85.60	107.0
Bark	43-20	1.94	66.96	131.76	20.52	10.8
Leaf	60.90	0.60	19.25	37.10	8.40	3.5
Twig	25.48	0.78	27.04	41.08	10.40	5.2
Branch	40.32	0.78	21.28	40.32	14.56	11.2
Total	341.10	9.45	198.73	293.06	139.48	137.7

Substantial quantities of nutrients are returned to the soil through litter fall and mineral cycling is well balanced as shown in Table 6 in case of the same study.

Table 6: Nutrient cycling in *Eucalyptus* hybrid (10 yrs)

Age (Years)	Biomass (t/ha)	Nutrient pathway	Nutrient				
			N	P	K	Ca	Mg
10	138	Uptake	109	2	51	88	34
		Retained	34	1	20	29	14
		Returned	75	1	31	59	20
			(69%)	**(50%)**	**(61%)**	**(67%)**	**(59%)**

It is observed that the retention of nutrients in *Eucalyptus* hybrid plantation is greater than *shorea robusta* irrespective of their age. The accumulation of nutrients in non-photosynthetic components is more than that of photosynthetic ones in *Eucalyptus* hybrid, whereas *shorea robusta* is accumulating more nutrients in photosynthetic components. This suggests the most nutrient use efficiency in *Eucalyptus* hybrid.

5.0 APPROACH AND METHODOLOGY

5.1 Approach

The main approach to the present Study was to assess the growth potential of the three identified multi-purpose tree species on various sites, in different agro-ecological zones, with a view to determine their suitable ecological ranges, so that guidelines and improved packages of plantation practices could be evolved for raising future plantations of higher productivity with consequent remunerative returns to the farmers.

The Study was undertaken over the entire planting range of these species in the State, through measurement of representative temporary SPs laid out for collection of growth and other data. These SPs were laid out with reference to the four agro-ecological zones and the various sites/areas therein, different age gradations and the type of plantation (canal, roadsides, railway lines, block, farm bunds etc) in order to determine suitable sites for raising plantations of these species.

5.1.1 Sample plots

Looking at the extent of plantations raised in the State and the limitation of time, it was decided to lay out a total of around 200 SPs in the three species under reference, covering the various agro-ecological zones and the variations therein, with regard to species, age and type of plantation (roadside, railway line, block, farm bunds etc.). Sampling was proposed to be done in plantations aged around 5 and 8 years (rotation age) in all the three species. This has, however, not been possible because of nonavailability of the required aged plantations as will be observed in subsequent sections.

The distribution (specific representative location) and the number of SPs to be laid out for each species were finalised in consultation with the HCFP authorities. Tentatively the number of SPs to be laid was: *Eucalyptus* - 130; Poplar – 50 and *Ailanthus excelsa* - 20; each SP being of standard size (30 x 30 m).

5.1.2 Field Surveys

While the SP data on growth and yield of the identified species were being collected, information was also to be obtained on the following aspects through interviews with farmers. At least 5 to 10 farmers were interviewed at one site.

- Clones and/ or planting material of poplar and *Eucalyptus*, which the farmers are planting at present, and the sources of obtaining this material.
- Farmers acceptance potential for high yielding clones of poplar and *Eucalyptus*, and the practices followed for raising the same, in order to evolve a suitable strategy for extension of high yielding clones and improved package of practices
- Farmers views regarding growing of *Ailanthus excelsa* on their lands and modifications needed, if any, in the present system of raising plantations of this species.

5.2 Methodology

Sample plot studies were undertaken in Yamunanagar, Kurukshetra, Karnal, Hissar, Mahendargarh (including Narnual Division of Aravalli Project) and Rewari forest divisions of the State. A total of 207 standard size SPs of 30 x 30 m (area 0.09 ha) were laid out in plantations of poplar (59 plots), *Eucalyptus* (127 plots) and *Ailanthus excelsa* (21 plots). All the trees standing on each SP were measured for their DBH and a few standing sample trees for their heights (by Haga Altimeter) covering the entire range of diameter distribution in the plot.

Thirty four (34) sample trees of poplar and 19 trees of *Eucalyptus* were measured from areas where fellings were going on for volume estimation in these plots. The stem was divided into 3 m sections and diameters OB and under bark (UB) were measured at the middle of each section, the last section being not more than 4.5 m. Volume was estimated by multiplying the sectional area at the mid-section with length of the section and summing up the volumes of all the sections. Timber volume (defined as the volume of stemwood up 20 cm diameter OB) was measured separately along with the volume of

smallwood i.e., the volume of stem below 20 cm and upto 5 cm diameter OB. Total wood was measured as the sum of timber and small wood.

Regression equations were fitted between volume and D^2H. The equation model was: $V = a + b\ D^2H$; where, D is the diameter in m, H is the height in m, and V is the volume in cubic meters (m^3). These equations for total wood (OB and UB) and timber (OB and UB) for poplar and *Eucalyptus* are as follows. These regressions are also shown in Figure 1,2,3,4,5,6,7 and 8.

Poplar

Total wood (OB)	: V(OB) =	$-0.016628 + 0.328067\ D^2H$
Total wood (UB)	: V(UB) =	$-0.018585 + 0.278375\ D^2H$
Timber (OB)	: VT(OB) =	$-0.223476 + 0.354611\ D^2H$
Timber (UB)	: VT(UB) =	$-0.190529 + 0.300998\ D^2H$

Eucalyptus

Total wood (OB)	: V(OB) =	$0.009793 + 0.308811\ D^2H$
Total wood (UB)	: V(UB) =	$0.000861 + 0.238883\ D^2H$
Timber (OB)	: VT(OB) =	$-0.125785 + 0.242889\ D^2H$
Timber (UB)	: VT(UB) =	$-0.098243 + 0.189325\ D^2H$

Regression models $\log_e H = a + b \log_e D$ or $H = a + b \log_e D$ were also fitted for each plot and the model with minimum deviation squared was accepted. Crop height was calculated on the basis of mean basal area within the plot and top height was ascertained as the height corresponding to the mean basal area of 250 biggest diameters per ha as determined from height/DBH relationship. Volume was estimated by using volume equations for each tree of the sample plot and then summing up the volume of all the trees. The entire process was completed through a computer programme (SAMCAL) for all the SPs.

Plantations of poplar, *Eucalyptus* and *Ailanthus excelsa* have been raised, in Haryana, as block plantations, strip plantations (more than 3 rows – multiple rows), narrow strip plantations (3 rows) and single line plantations (one/two rows) in Government and private lands. While the just mentioned methodology was followed for block, strip and narrow strip plantations, a different approach was adopted for trees growing in line plantations (single/two rows) along field bunds, roadsides etc in that the various estimates were made **not on per unit area basis** but on the **basis of 100 trees**. This was done because trees of block plantations are subjected to more competition for nutrients and space as compared to trees growing in line plantations (single/double rows) with free growing space and nutrient availability, and as such are not comparable. Basal area, volume, and MAI were also calculated, on the basis of 100 trees for line plantation.

Simultaneously, subsidiary data on these SPs, like species/clone planted, spacing, year of plantation (age) etc were collected. Information on soil and rainfall of the area was also obtained as far as possible. Field surveys were also conducted to obtain information on various aspects indicated in Section 5.1.2

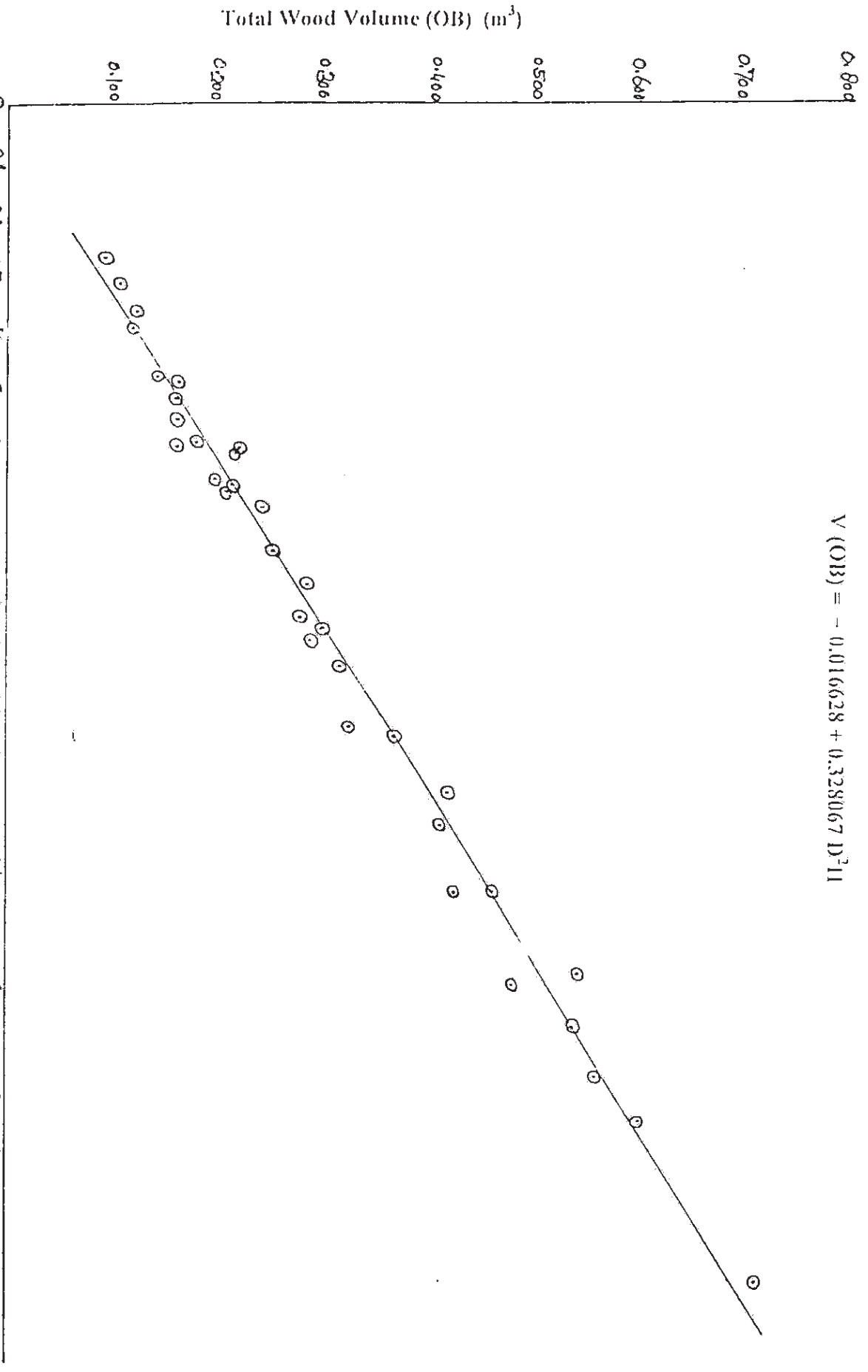


Figure 1: Total Wood OB/D²H Relationship in Poplar

$V\,(OB) = -0.016628 + 0.328067\,D^2H$

Figure 2: Total Wood UB/D^2H Relationship in Poplar

V (UB) = - 0.018585 + 0.278375 D^2H

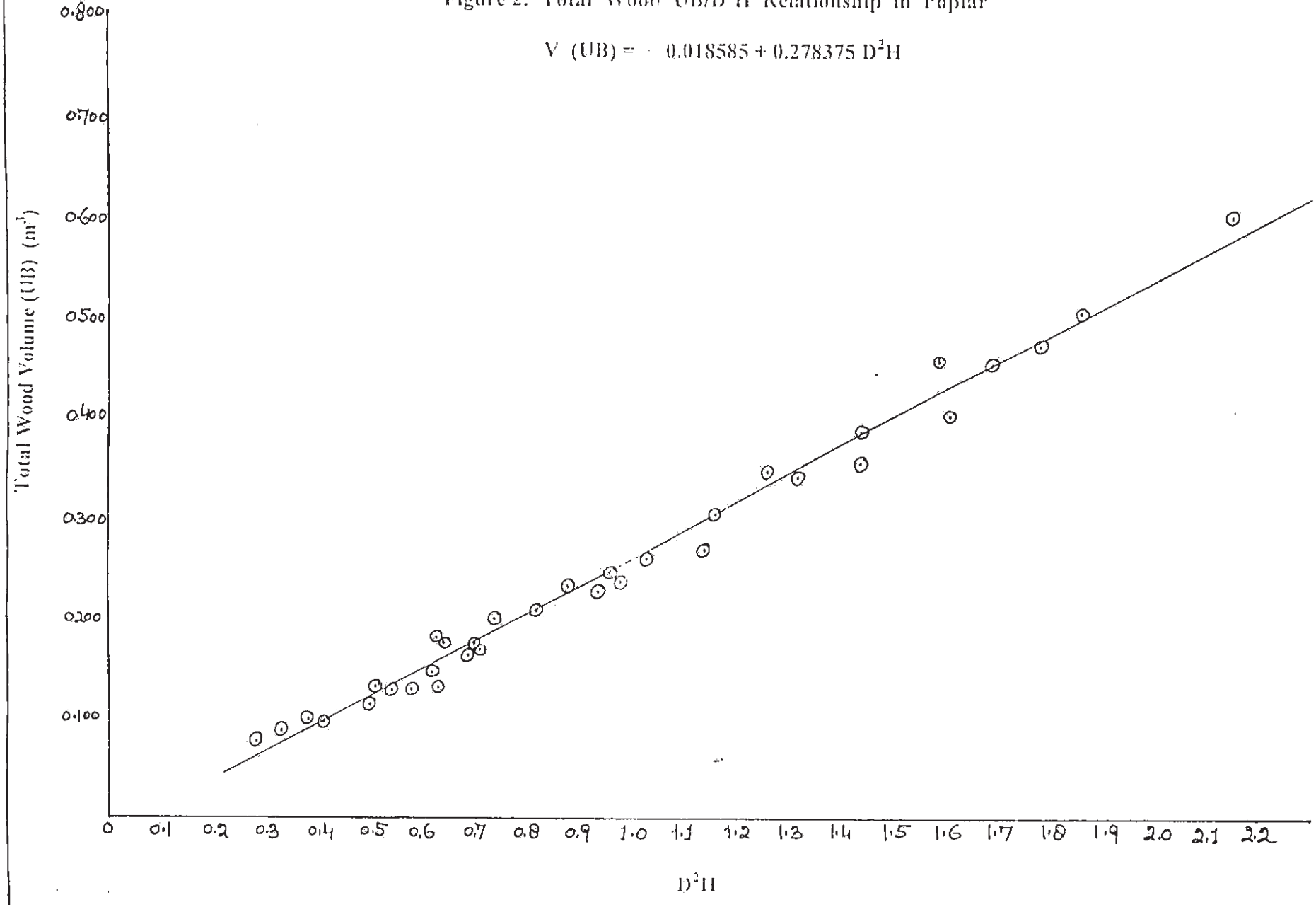


Figure 3: Timber OB/D^2H Relationship in Poplar

$$V\,T\ (OB) = -0.223476 + 0.354611\ D^2H$$

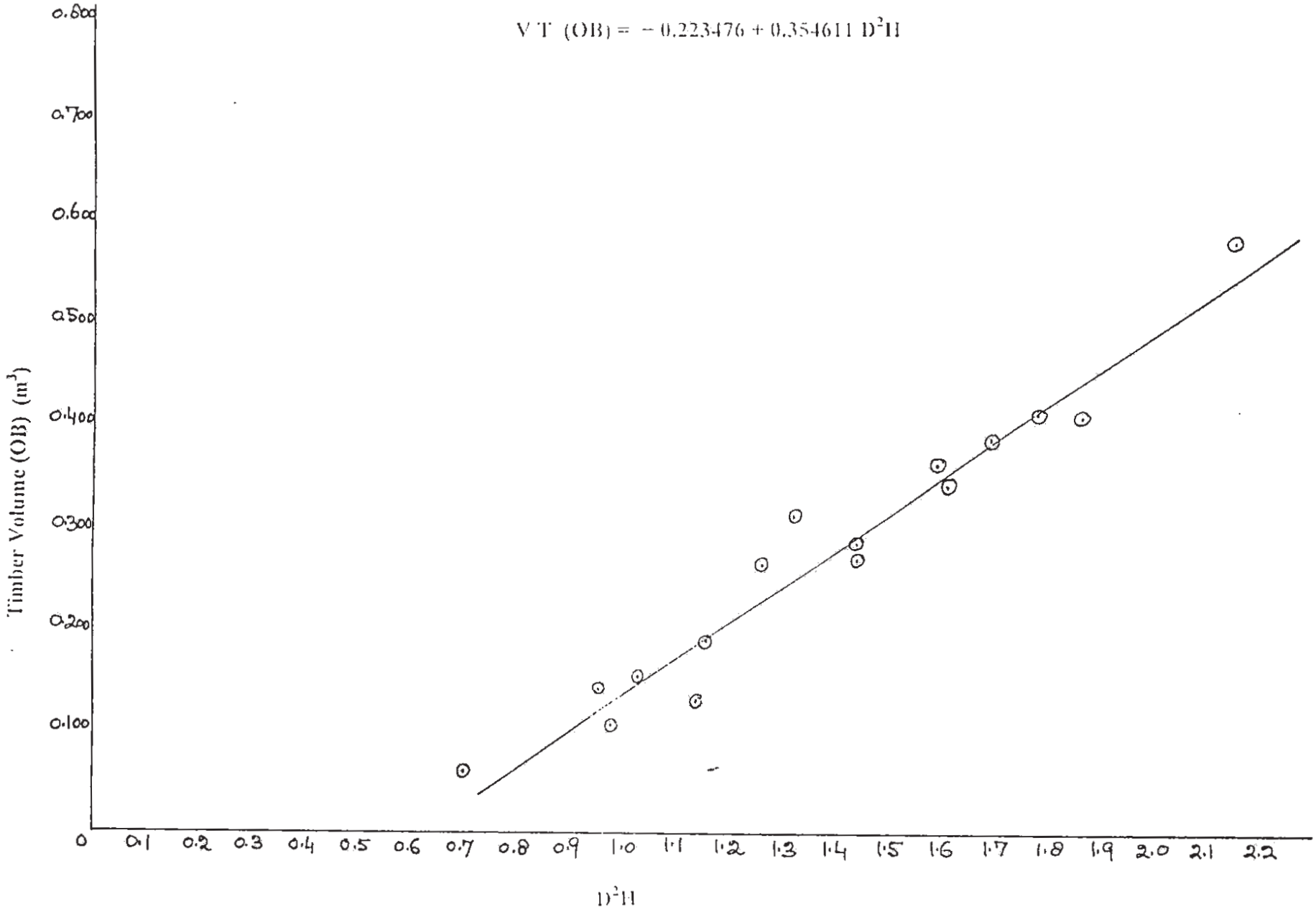


Figure 4: Timber UB/D^2H Relationship in Poplar

V_T (UB) = $-0.190529 + 0.300998\ D^2H$

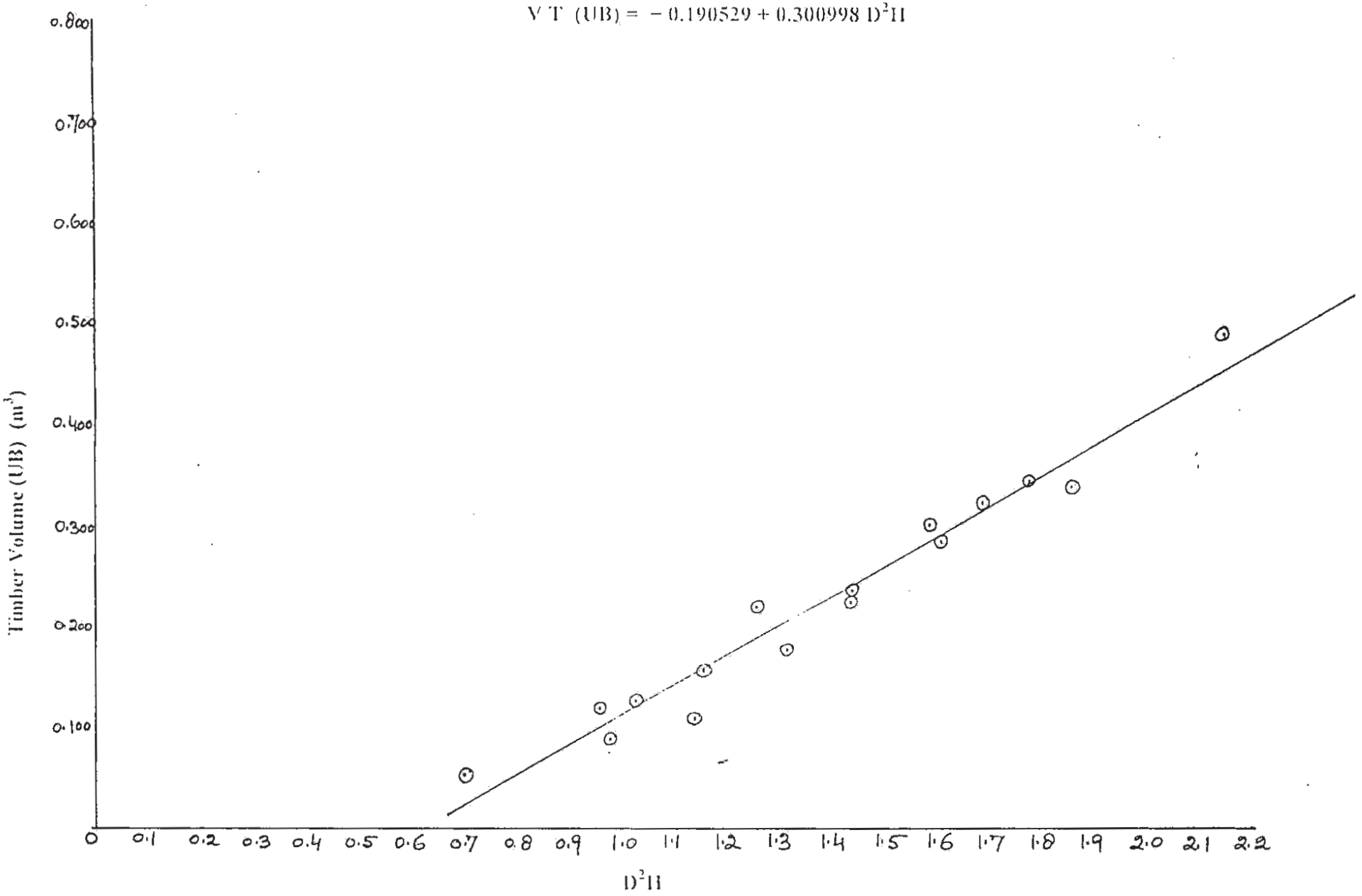


Figure 5: Total Wood OB/D^2H Relationship in *Eucalyptus*

$$V\ (OB) = 0.009793 + 0.308811\ D^2H$$

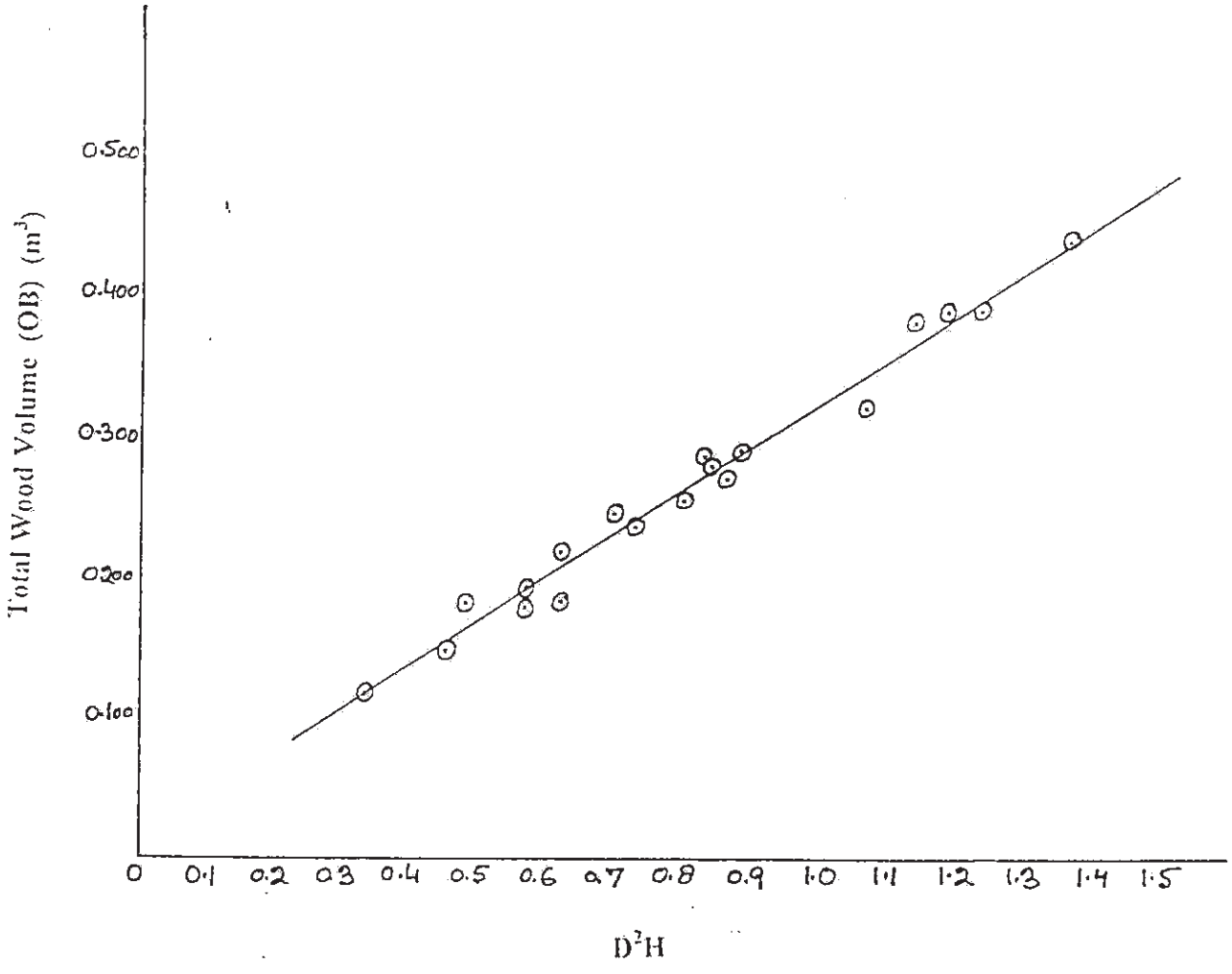


Figure 6: Total Wood UB/D^2H Relationship in *Eucalyptus*

V (UB) = 0.000861 + 0.238883 D^2H

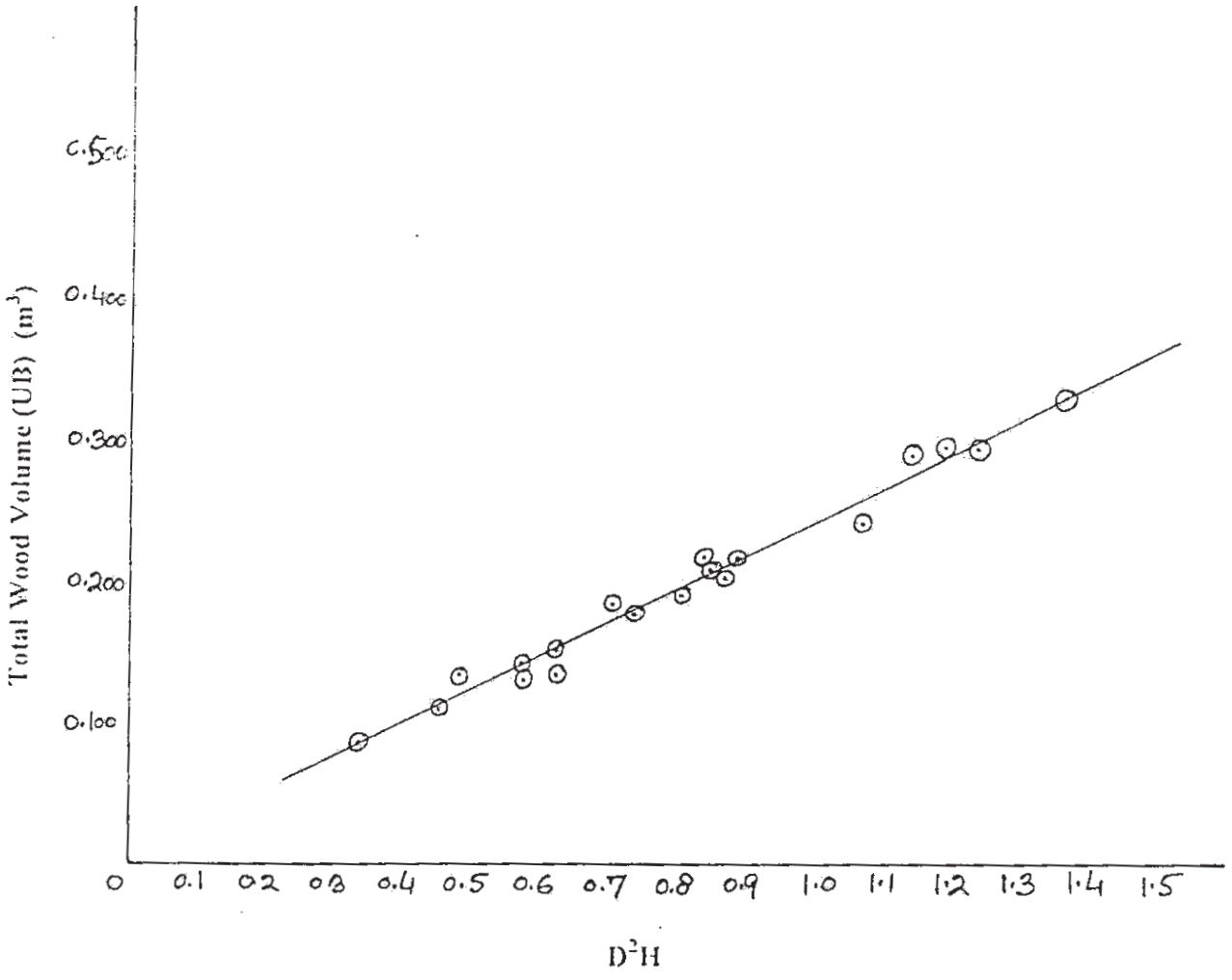


Figure 7: Timber OB/D^2H Relationship in *Eucalyptus*

$VT\ (OB) = -0.125785 + 0.242889\ D^2H$

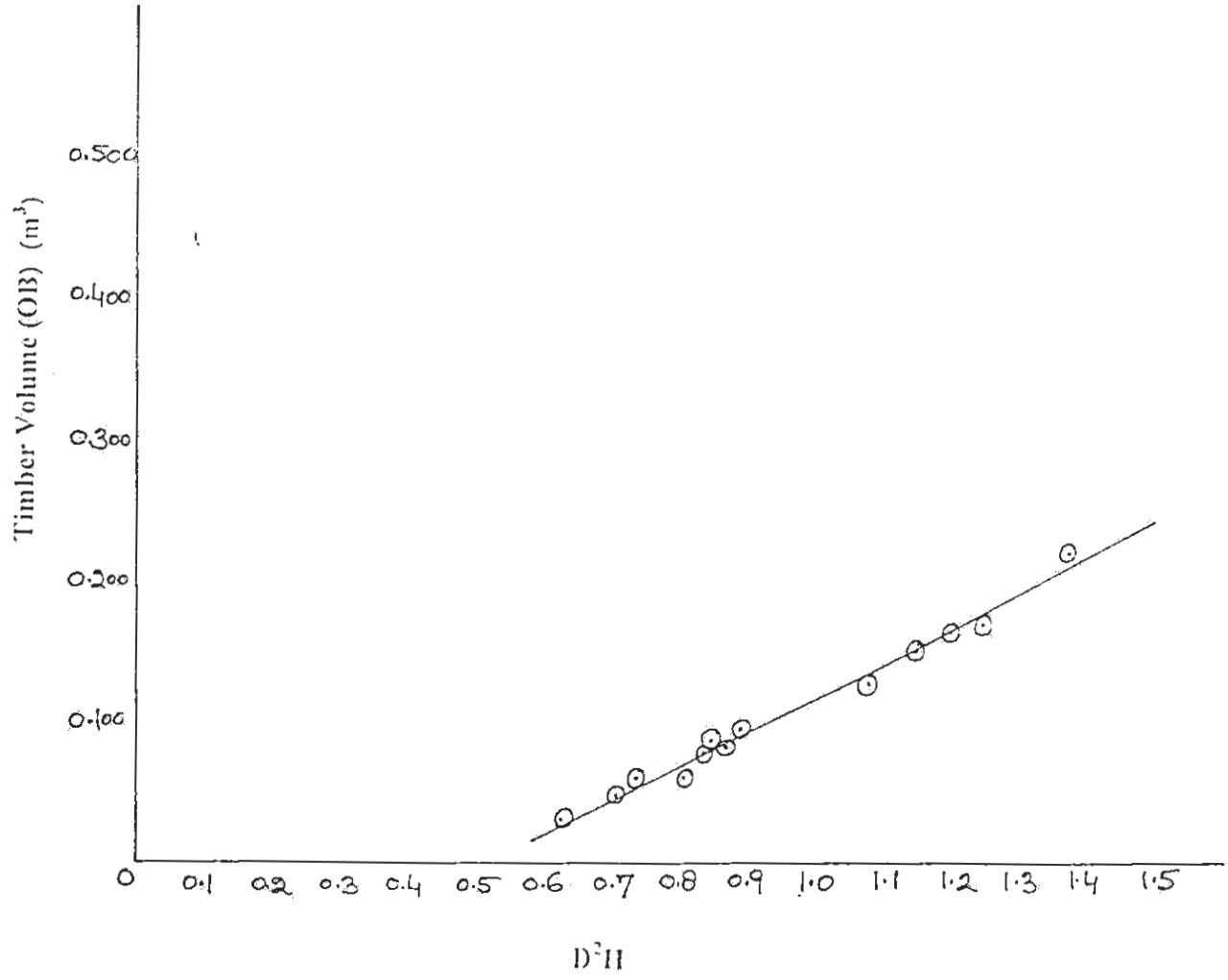
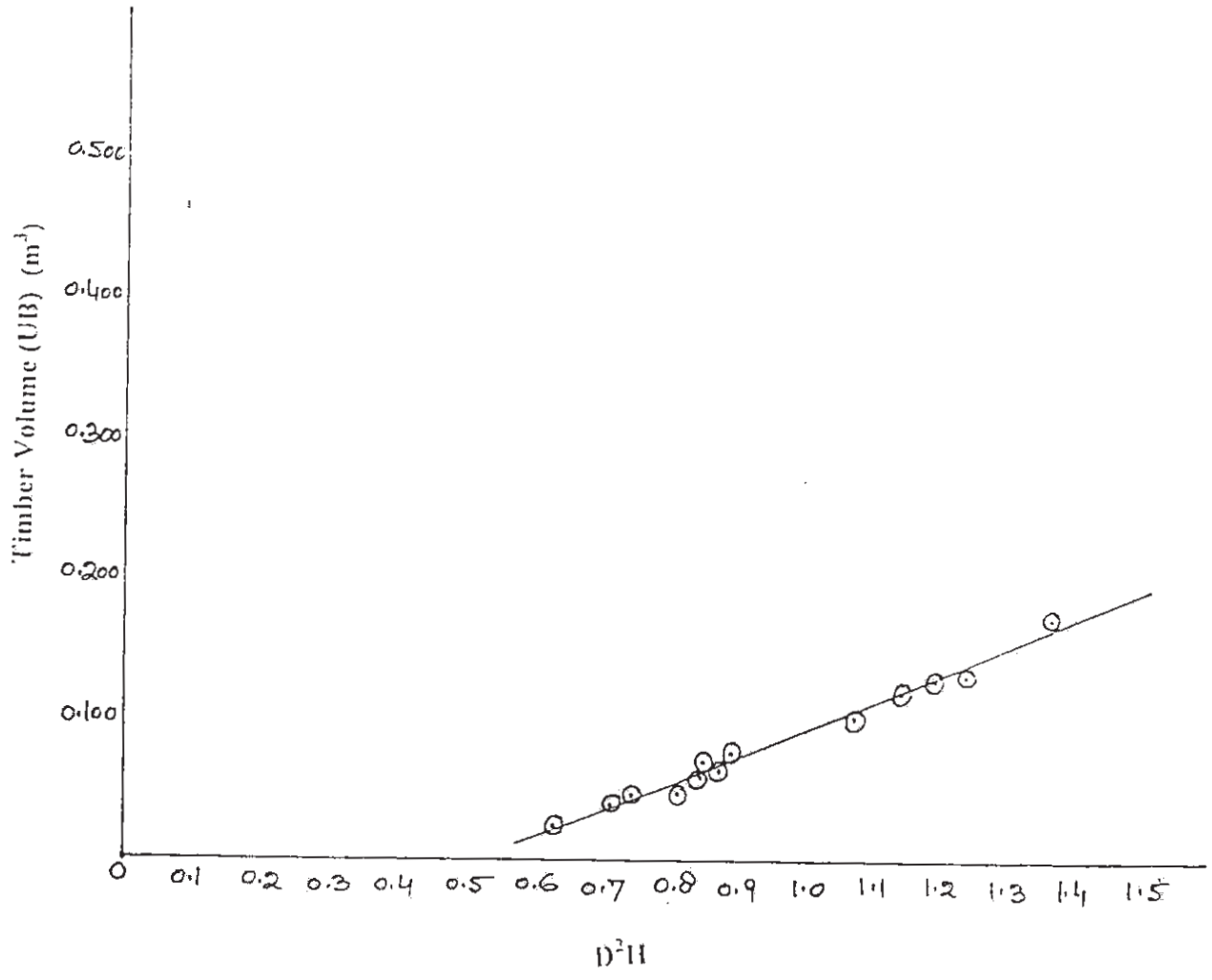


Figure 8: Timber UB/D^2H Relationship in *Eucalyptus*

$$VT\ (UB) = -0.098243 + 0.189325\ D^2H$$



6.0 POPLAR PLANTATIONS

6.1 General

Poplar plantations in Haryana have been mostly raised on farmlands (Agro-forestry), as block plantations, and as line plantations (single/double rows) along roadsides and on field bunds (Farm Forestry). The clones of *Populus deltoides* generally used for planting are G-3, G-48, G-57, U-DAI and S-7C15 (all WIMCO clones). One SP (SP No 114) was however, laid in a block plantation of *Populus deltoides* raised through tissue culture in 1994 with a spacing of 3 x 2 m in Seonser Reserve Forest, Pehwa Range, Kurukshetra Forest Division. This is an experimental plantation to watch the performance of tissue culture raised plantations.

6.2 Growth Parameters

6.2.1 Block plantations

Growth parameters of sampled poplar plantations are shown in Table 7 (block plantations) and 8 (line plantations). There are different growth responses at different sites as a result of effective climatic, edaphic and biotic factors. Site equality can be measured by dominant tree height or the top height, which is least affected by stand density. Starting from age 7 years, top height varies from 23.8 to 30.7 m (SP No 6 and 28), in Yamunanagar Forest Division while two plots of Kurukshetra Forest Division have a top height of 24.8 and 26.1 m respectively (SP No 111 and 110). This is indicative of the fact that poplar can perform well in Kurukshetra Forest Division provided moisture supply is adequate in summer months.

At the age of 6 years, top height ranges from 23.1 to 27.8 m (SP No 40 and 50) in Yamunanagar Forest Division with lowest top height of 16.1 m in Kurukshetra Forest Division recorded in a plantation raised through tissue culture (SP No 114). In case of 4 years old plantations, the best quality reaches a dominant tree height of 23 m in Yamunanagar Forest Division (SP No 35) while a lowest of 17.2 m is recorded in SP No 165 in Karnal (Indri) for S-7C15 clone. A better production could be expected through

Table 7 : GROWTH PARAMETERS OF POPLAR (BLOCK PLANTATION)

SP No.	SPACING (m)	CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
YAMUNA NAGAR DIVISION																				
1	4.5X4.5	S7C15	1996	0.0851	4	564	22.2	21.5	6.8	20.4	17.0	12.740	9.982	8.237	104.854	86.449	2.496	2.059	26.214	21.612
2	4.5X4.5	G3	1990	0.0934	10	503	28.2	27.0	11.4	27.0	21.7	18.640	115.853	97.927	201.743	168.930	11.585	9.793	20.174	16.893
3	2.8X2.1	G3	1993	0.0787	7	1092	25.5	21.7	5.4	25.8	16.5	23.370	53.199	44.778	193.973	159.787	7.600	6.397	27.710	22.827
4	4.8X4.8	G48	1995	0.0833	5	396	27.8	27.3	16.2	27.0	23.7	17.500	127.074	107.530	192.880	161.891	25.415	21.506	38.576	32.378
6	4.5X4.5	G3	1993	0.0853	7	375	23.8	22.0	14.0	31.8	21.4	13.480	55.100	46.533	117.494	98.018	7.871	6.648	16.785	14.003
8	4.0X4.0	G3	1996	0.0904	4	365	20.8	20.0	10.2	25.4	20.0	11.520	31.537	26.539	90.120	74.836	7.884	6.635	22.530	18.709
12	4.0X4.0	G48	1996	0.0793	4	630	20.2	18.5	5.4	20.4	15.4	11.680	4.344	3.598	79.706	64.867	1.086	0.900	19.927	16.217
13	4.5X4.2	G48	1995	0.0925	5	464	26.3	24.2	13.2	32.4	22.0	17.640	93.438	78.994	170.239	142.372	18.688	15.799	34.048	28.474
14	5.0X5.0	G3	1992	0.0921	8	347	32.2	30.8	23.6	38.2	30.4	25.180	272.133	230.698	317.820	268.125	34.017	28.837	39.728	33.516
15	4.5X4.5	G3	1998	0.1005	2	477	17.2	16.4	11.8	16.8	14.8	8.160	0.000	0.000	48.034	38.621	0.000	0.000	24.017	19.311
16	4.0X4.7	G48	1997	0.0710	3	633	19.7	18.4	8.4	18.4	15.0	11.210	0.327	0.248	75.748	61.438	0.109	0.083	25.249	20.479
17	4.0X5.0	G48	1996	0.0978	4	572	20.3	18.0	13.2	19.6	16.8	12.620	3.038	2.485	85.384	69.888	0.760	0.621	21.346	17.472
18	4.5X4.7	G57	1997	0.0823	3	473	19.0	18.2	7.0	20.0	16.1	9.640	1.194	0.973	65.480	53.472	0.398	0.324	21.827	17.824
19	4.7X4.7	UDAI	1997	0.0768	3	403	18.6	18.0	7.2	20.6	17.0	9.200	3.255	2.665	62.635	51.345	1.085	0.888	20.878	17.115
20	4.7X4.7	G48	1997	0.0883	3	453	22.0	21.4	15.8	22.0	19.4	13.380	29.659	24.847	112.245	93.216	9.886	8.282	37.415	31.072
21	4.5X4.0	G48	1994	0.1183	6	346	24.9	24.0	16.4	28.2	23.2	14.640	81.095	68.551	140.746	117.876	13.516	11.425	23.458	19.646
22	5.0X4.0	G48	1996	0.0846	4	472	22.9	22.0	14.0	24.6	18.5	12.760	24.557	20.540	109.449	90.754	6.139	5.135	27.362	22.689
27	5.0X5.0	G48	1996	0.0861	4	406	21.2	20.5	7.8	24.2	19.1	11.690	25.490	21.378	93.302	77.350	6.373	5.345	23.326	19.338
28	6.0X3.3	G48	1993	0.0890	7	483	30.7	28.9	16.6	30.8	24.2	22.140	180.533	152.838	258.876	217.501	25.790	21.834	36.982	31.072
29	4.5X4.0	G48	1995	0.0932	5	611	22.4	21.0	9.0	29.8	20.2	19.570	62.375	52.548	161.460	134.267	12.475	10.510	32.292	26.853
30	4.5X4.5	G48	1996	0.0960	4	510	22.4	22.0	14.4	23.2	19.4	15.130	38.124	31.963	130.453	108.408	9.531	7.991	32.613	27.102
31	4.5X4.5	G48	1995	0.0992	5	483	21.7	21.2	14.4	22.4	18.9	13.520	24.170	20.199	111.643	92.566	4.834	4.040	22.329	18.513
32	4.5X4.5	G48	1994	0.0925	6	497	23.9	23.1	15.4	22.6	18.9	13.910	34.999	29.345	125.933	104.632	5.833	4.891	20.989	17.439
33	5.0X5.0	G48	1992	0.0633	8	458	27.9	26.6	16.2	30.8	26.4	25.050	198.707	168.294	270.460	227.443	24.838	21.037	33.808	28.430
34	5.0X4.0	G3	1996	0.0867	4	530	23.1	22.2	10.4	23.8	19.1	15.190	37.432	31.390	132.228	109.824	9.358	7.848	33.057	27.456
35	4.5X4.5	G48	1996	0.0895	4	547	23.0	22.2	12.6	21.6	18.3	14.460	27.771	23.221	124.955	103.577	6.943	5.805	31.239	25.894
36	4.5X4.5	G48	1995	0.0903	5	531	26.1	24.9	12.0	27.6	20.7	17.950	85.182	71.890	177.487	148.223	17.036	14.378	35.497	29.645
39	4.5X4.5	G3	1994	0.0925	6	508	25.0	24.1	12.6	22.8	19.1	14.520	47.526	39.973	137.941	114.773	7.921	6.662	22.990	19.129
40	6.3X6.3	G48	1994	0.0930	6	290	23.8	23.1	11.6	26.8	23.0	12.060	62.522	52.835	111.652	93.441	10.420	8.806	18.609	15.574
41	4.0X5.0	G48	1996	0.0823	4	656	20.2	19.5	8.0	22.6	17.4	15.550	14.064	11.693	115.789	95.314	3.516	2.923	28.947	23.829

SP No.	SPACING (m)	CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
42	4.8X4.8	G48	1995	0.0949	5	526	23.8	22.7	10.8	24.2	19.2	15.320	46.057	38.722	136.422	113.400	**9.211**	**7.744**	**27.284**	**22.680**
43	3.6X3.6	G3	1990	0.0932	10	536	30.4	28.1	13.8	31.8	24.5	25.230	202.264	171.275	286.869	241.015	**20.226**	**17.128**	**28.687**	**24.102**
44	5.0X4.0	G48	1996	0.0908	4	528	23.1	22.8	15.6	22.4	19.8	16.310	50.370	42.330	146.667	122.085	**12.593**	**10.583**	**36.667**	**30.521**
50	4.7X6.0	G48	1994	0.0622	6	418	27.8	26.9	14.8	32.6	25.8	21.870	172.852	146.382	238.897	200.841	**28.809**	**24.397**	**39.816**	**33.474**
51	4.5X4.5	G48	1996	0.0761	4	538	20.9	20.2	12.2	19.6	17.1	12.340	6.757	5.531	94.898	78.113	**1.689**	**1.383**	**23.725**	**19.528**
54	4.2X5.3	G48	1994	0.0668	6	479	24.6	22.2	13.4	28.4	21.9	18.040	76.314	64.406	159.515	133.209	**12.719**	**10.734**	**26.586**	**22.202**
57	4.2X5.0	G3	1995	0.0830	5	506	28.6	27.3	9.4	26.2	21.8	18.960	124.013	104.865	208.085	174.301	**24.803**	**20.973**	**41.617**	**34.860**
59	5.0X4.0	G48	1995	0.0943	5	519	23.7	22.1	13.6	21.8	18.1	13.400	24.319	20.357	114.780	95.068	**4.864**	**4.071**	**22.956**	**19.014**
60	5.2X4.7	G48	1995	0.0889	5	393	21.6	19.1	8.2	26.2	17.7	9.630	25.508	21.520	70.353	57.963	**5.102**	**4.304**	**14.071**	**11.593**
	KURUKSHETRA DIVISION																			
90	4.0X5.0	S7C15	1995	0.1021	5	421	17.2	16.3	12.2	20.4	17.1	9.700	1.229	0.982	58.937	48.125	**0.246**	**0.196**	**11.787**	**9.625**
91	5.0X5.0	G3	1990	0.0991	10	242	22.4	21.8	17.0	35.8	26.8	13.640	80.179	67.858	120.063	100.793	**8.018**	**6.786**	**12.006**	**10.079**
110	4.5X4.0	G48	1993	0.0883	7	532	26.1	24.1	7.2	28.4	19.3	15.610	68.824	58.096	148.516	123.675	**9.832**	**8.299**	**21.217**	**17.668**
111	4.5X4.0	G48	1993	0.0883	7	498	24.8	23.0	11.0	32.8	20.4	16.210	68.555	57.881	147.510	122.936	**9.794**	**8.269**	**21.073**	**17.562**
114	3x2	G48	1994	0.0373	6	1206	16.1	15.0	10.6	23.2	17.6	29.420	9.207	7.613	164.257	133.976	**1.535**	**1.269**	**27.376**	**22.329**
	KARNAL DIVISION																			
164	3.5X4.5	S7C15	1996	0.0783	4	613	18.5	17.0	8.8	20.2	14.6	10.270	1.717	1.399	62.799	50.543	**0.429**	**0.350**	**15.700**	**12.636**
165	3.5X4.5	S7C15	1996	0.0805	4	596	17.2	15.9	8.2	19.6	14.2	9.440	0.224	0.180	52.912	42.228	**0.056**	**0.045**	**13.228**	**10.557**
	HISSAR DIVISION																			
183	3X3	S7C15	1997	0.0945	3	952	13.0	12.1	6.0	13.8	10.8	8.770	0.000	0.000	28.656	20.100	**0.000**	**0.000**	**9.552**	**6.700**
184	3X3	S7C15	1997	0.0930	3	1075	12.6	11.9	6.8	13.2	10.5	9.240	0.000	0.000	28.012	19.137	**0.000**	**0.000**	**9.337**	**6.379**

G-3 and G-48 clones. An interesting introduction of poplar in Hissar is indicated by two plots of S-7C15 clone where a top height of 13 m has been attained at the age of 3 years (SP No 183 and 184) in spite of summer temperatures of over 47° C. Sufficient irrigation is available to these plantations.

The highest volume production in terms of MAI that can be realized from these sites is 35 m^3 /ha/ year (Yamunanagar Forest Division) of total wood UB (SP No 57) at the age 5 years, and a minimum of 6 m^3/ha/year at Hissar (age 3 years). The production in Karnal and Kurukshetra divisions varies from a minimum of 10 to 22 m^3/ha/year at ages 4 and 6 years respectively. At younger ages the MAI has still to rise, hence there are chances of better production by the younger crops (age 3 or 4 years) at Hissar and Karnal. Another factor on which the volume production depends is stand density, which may not be the optimum due to low survival, mortality or biotic influences.

Reference also needs to be made to other sites in Yamunanagar Forest Division, which have shown a higher volume production in terms of MAI (total wood UB) that can be achieved at these sites. These are as follows (Table 7).

SP No	Clone	Age (Years)	MAI (m^3 - total wood UB)
4	G - 48	5	32
28	G - 48	7	31
44	G - 48	4	30
50	G - 48	6	33

Various production levels indicated in Table 7 can serve as a yardstick for production at different desired ages depending upon the inputs in the form of nutrients and irrigation. It is therefore, a very useful tool to convince the farmers about the possible and realizable production. Both G-3 and G-48 have been successful and best suited clones for poplar plantations.

6.2.2 Line plantations

Line plantations (single/double rows) generally indicate an increase in crop diameter and crop height with increasing age (Table 8) due to lesser competition as compared to

Table 8 : GROWTH PARAMETERS OF POPLAR (LINE PLANTATION)

SP No.	SPACING (m)	CLONE	SINGLE LINE/ DOUBLE LINE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA OF 100 TREES (sq m)	TIMBER (O.B.) OF 100 TREES (cu mt)	TIMBER (U.B.) OF 100 TREES (cu mt)	TOTAL WOOD (O.B.) OF 100 TREES (cu mt)	TOTAL WOOD (U.B.) OF 100 TREES (cu mt)	M.A.I. TIMBER O.B. OF 100 TREES (cu mt)	M.A.I. TIMBER U.B. OF 100 TREES (cu mt)	M.A.I. TOTAL WOOD O.B. OF 100 TREES (cu mt)	M.A.I. TOTAL WOOD U.B. OF 100 TREES (cu mt)
YAMUNA NAGAR DIVISION																			
11	3 m	G3	ROAD SIDE (S.L.) COPPICE	1996	0.0400	4	14.8	7.8	19.6	15.8	1.963	0.000	0.000	10.470	8.436	0.000	0.000	2.617	2.109
38	3 m	G3	ROAD SIDE (S.L.)	1983	0.0426	17	30.6	28.0	56.4	44.2	15.369	189.686	160.924	194.510	164.600	11.158	9.466	11.442	9.682
5	4.0X2.5	G3	F.B.(D.L.)	1992	0.0380	8	27.1	13.8	38.8	29.2	6.686	60.050	50.892	73.967	62.315	7.506	6.361	9.246	7.789
25	1.8 m	G3	F.B.(S.L.)	1994	0.0272	6	27.7	16.0	31.6	23.4	4.311	31.835	26.945	48.291	40.529	5.306	4.491	8.049	6.755
45	1.5 m	G48	F.B.(S.L.)	1996	0.0202	4	18.0	9.0	24.0	16.6	2.162	1.549	1.297	14.596	11.938	0.387	0.324	3.649	2.984
46	1.5 m	G48	F.B.(S.L.)	1995	0.0245	5	19.0	8.8	27.6	19.6	3.027	9.070	7.642	22.305	18.479	1.814	1.528	4.461	3.696
47	1.5 m	G48	F.B.(S.L.)	1995	0.0242	5	18.7	9.2	25.6	18.1	2.582	4.729	3.973	18.491	15.242	0.946	0.795	3.698	3.048
52	2.2 m	G48	F.B.(S.L.)	1995	0.0285	5	18.4	7.2	24.6	18.0	2.539	4.803	4.040	17.897	14.746	0.961	0.808	3.579	2.949
53	2.0 m	G48	F.B.(S.L.)	1992	0.0244	8	26.6	16.0	31.4	26.7	5.608	45.633	38.659	60.686	51.046	5.704	4.832	7.586	6.381
61	2.5 m	G48	F.B.(S.L.)	1994	0.0367	6	24.4	15.8	31.4	26.2	5.389	37.035	31.354	53.212	44.704	6.173	5.226	8.869	7.451
KURUKSHETRA DIVISION																			
102	2 m	G48	F.B.(S.L.)	1994	0.0234	6	16.3	11.8	27.6	20.2	3.200	5.267	4.427	20.171	16.668	0.878	0.738	3.362	2.778

F.B. - FIELD BUND
S.L. - SINGLE LINE
D.L. - DOUBLE LINE

block plantations. One plot (SP No. 102) in Kurukshetra Forest Division is somewhat comparable to that of Yamunanagar Forest Division in respect of crop diameter. Crop height is however, less than that attained in Yamunanagar where site quality is by far the best.

The MAI of these line plantations (which has been calculated on the basis of 100 trees as mentioned earlier in last para of Section 5.2), for various spacings (Table 8) ranges from 2.8 to 9.7 m^3/100 trees/year (Kurukshetra and Yamananagar Forest Divisions respectively; SP. No. 102 and 38). Farmers can thus choose the spacing according to size required and the space available.

6.3 Probable Sites

Looking at the overall success and growth performance of various clones of *Populus deltoides*, best growth has been obtained in areas of Yamananagar Forest Division followed by Kurukshetra, Karnal, and Hissar Forest Divisions. This strictly follows the climatic regions of the State, referred to earlier (Section 2.4) with decreasing rainfall pattern from Yamananagar (over 1,000 mm) to Hissar (360 mm). Included in the Hot Humid Climatic Zone (rainfall above 1,000 mm) soils of Yamananagar have a pH varying from 6.5 to 7.5 with reddish brown colour. Surface texture is loamy sand to sandy loam to clayey with good surface drainage and the availability of nutrients (nitrogen, phosphorus and potassium) varies from low to medium. Soils in Kurukshetra and Karnal areas are mainly sandy loam to loam with a pH ranging from 7.0 to 8.5 and low to moderate nutrient status – available phosphorus and potassium are medium and high respectively, while availability of nitrogen is low to medium.

The high rate of production of poplar clones in Yamunanagar Forest Division can also be better explained by the Aridity Index (Table 1). With more number of growing season months in the Division there is more production in poplar plantations. High moisture availability and good drainage coupled with sandy loam to loamy texture and high survival percentage are the most favourable factors for the growth of poplars in Yamananagar Division.

7.0 *EUCALYPTUS PLANTATIONS*

7.1 General

Eucalyptus has been raised in Haryana as block plantations, along the canals and roadsides as strip plantations (more than 3 rows – multiple rows). as narrow strip plantations (3 rows) or as line plantations of single/double rows. It has also been planted on field bunds (Farm Forestry) as single or double rows (line plantations). The species mostly raised (through seed) is *Eucalyptus* hybrid (*E. tereticornis*), though some clones and tissue culture raised seedlings of the species have also been planted on an experimental basis to see their performance in the field. The clones used are: Bhadrachalam – 3, Bhadrachalam – 7, Bhadarachalam – 10, Bhadrachalam – 27, Bhadrachalam – 91, Bhadrachalam - 128 and Bhadrachalam – 130 (SP Nos 76 to 82). Tissue culture raised plantations are: TERI – 2, TERI – 3, TERI – 7, TERI – 10, TERI – 26, and TERI – 362 (SP Nos 83 and 85 to 89). A plantation of local seed origin has also been planted as a control (SP No 84).

7.2 Growth Parameters

7.2.1 Block Plantations

The analysed data pertaining to 127 SPs laid out in *Eucalyptus* plantations growing in different areas as mentioned above, are shown in Tables 9 (block plantations), 10 (roadside plantations), 11 (canalside plantations) and 12 (line plantations).

Table 9 which summarizes the details of crop parameters of block plantations, indicates that top height at the age of 10 years in Yamananagar Forest Division varies from 29.5 m (SP No 9) to 33.44 m (SP No 7), though at the age of 12 years the range is from 27.1 m (SP No 37) to 31.3 m (SP No 69) all denoting best site qualities. Similarly at the age of 12 years in Karnal Forest Division the same trend is seen in top height with minimum of 26.7 m (SP No 166) and a maximum of 30.1 m (SP No 116). Some inferior qualities are being depicted in Yamananagar and Karnal Forest Divisions. For example, top height of 27.5 m (SP No 74) is attained at a higher age of 16 years in Yamananagar

Table 9 : GROWTH PARAMETERS OF EUCALYPTUS (BLOCK PLANTATION)

SP NO	SPACING (m)	SPECIES/ CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
YAMUNA NAGAR DIVISION																				
7	3X3	E.hybrid	1990	0.0890	10	494	33.4	30.1	8.0	60.2	24.0	22.350	162.433	126.559	269.083	204.832	16.243	12.656	26.908	20.483
9	3X3	E.hybrid	1990	0.0922	10	618	29.5	25.4	9.0	32.4	19.4	18.240	74.448	57.944	188.243	141.466	7.445	5.794	18.824	14.147
10	3X3	E.hybrid (Coppice)	1993	0.0818	6	867	22.1	18.0	6.8	21.6	13.0	11.470	4.708	3.644	89.713	63.570	0.785	0.607	14.952	10.595
26	3X3	E.hybrid	1989	0.0525	11	895	23.6	19.9	9.2	33.8	19.1	25.750	70.574	54.924	210.314	156.679	6.416	4.993	19.119	14.244
37	5X1	E.hybrid	1988	0.0845	12	1254	27.1	22.5	6.2	27.0	14.0	19.280	41.482	32.260	182.645	132.863	3.457	2.688	15.220	11.072
49	5X2	E.hybrid	1995	0.0829	5	916	13.4	11.5	3.4	14.0	8.8	5.610	0.000	0.000	34.358	20.422	0.000	0.000	6.872	4.084
55	3X2	E.hybrid	1992	0.0964	8	1265	20.5	16.1	4.2	21.2	11.9	14.150	5.724	4.440	102.137	70.511	0.716	0.555	12.767	8.814
56	3X2	E.hybrid	1993	0.0964	7	902	17.1	15.0	6.6	21.0	13.1	12.210	1.886	1.456	80.644	56.323	0.269	0.208	11.521	8.046
63	4.5X2.5	E.hybrid	1996	0.0886	4	880	12.4	11.3	3.4	13.0	8.3	4.740	0.000	0.000	29.728	17.085	0.000	0.000	7.432	4.271
64	4.5X1.5	E.hybrid	1996	0.0741	4	1187	11.0	9.1	2.4	12.0	6.3	3.750	0.000	0.000	25.056	11.408	0.000	0.000	6.264	2.852
65	4.5X2	E.hybrid	1996	0.0823	4	1044	11.7	10.4	3.2	12.8	8.0	5.180	0.000	0.000	31.332	17.220	0.000	0.000	7.833	4.305
67	5X1	E.hybrid	1997	0.0563	3	1474	13.1	11.4	3.6	14.2	8.4	8.180	0.000	0.000	50.980	29.537	0.000	0.000	16.993	9.846
69	3.7X3.7	E.hybrid	1988	0.0948	12	495	31.3	29.0	12.0	33.4	24.3	22.960	144.309	112.391	266.716	202.991	12.026	9.366	22.226	16.916
71	5X2	E.hybrid	1996	0.0902	4	864	13.4	11.9	4.0	14.6	9.7	6.320	0.000	0.000	37.991	23.582	0.000	0.000	9.498	5.896
73	4X3.5	E.hybrid	1986	0.0925	14	627	27.6	23.9	9.2	43.2	21.4	22.590	103.245	80.401	218.810	165.052	7.375	5.743	15.629	11.789
74	4.5X3.5	E.hybrid	1984	0.0927	16	474	27.5	24.1	12.2	35.8	21.2	16.690	67.064	52.199	162.744	122.705	4.192	3.262	10.172	7.669
75	3.5X2	E.hybrid	1980	0.0831	20	938	26.4	21.4	5.8	33.4	18.9	26.280	82.887	64.509	229.919	171.553	4.144	3.225	11.496	8.578
KURUKSHETRA DIVISION																				
76	3X3	Bhadra Challam 3	1993	0.0585	7	1059	26.7	25.3	10.0	17.0	13.6	15.400	6.137	4.728	163.423	119.301	0.877	0.675	23.346	17.043
77	3X3	Bhadra Challam 10	1993	0.0597	7	1088	23.5	19.7	7.4	20.8	14.3	17.590	9.530	7.379	147.203	106.559	1.361	1.054	21.029	15.223
78	3X3	Bhadra Challam 7	1993	0.0582	7	1116	24.8	21.9	6.6	17.4	14.2	17.630	8.021	6.191	162.836	118.463	1.146	0.884	23.262	16.923
79	3X3	Bhadra Challam 91	1993	0.0593	7	1062	20.8	19.2	10.8	21.6	15.2	19.310	9.673	7.495	156.213	113.706	1.382	1.071	22.316	16.244
80	3X3	Bhadra Challam 127	1993	0.0590	7	1050	22.2	19.8	8.8	19.0	14.4	17.210	5.800	4.469	144.086	104.403	0.829	0.638	20.584	14.915
81	3X3	Bhadra Challam 128	1993	0.0588	7	1088	21.2	18.9	3.6	16.6	11.7	11.710	0.350	0.266	97.837	68.374	0.050	0.038	13.977	9.768
82	3X3	Bhadra Challam 130	1993	0.0578	7	899	20.8	18.2	4.4	19.8	14.3	14.430	7.180	5.550	112.085	80.663	1.026	0.793	16.012	11.523
83	3X3	Teri 2 (T.C.)	1993	0.0585	7	1282	18.4	15.8	3.6	16.0	10.4	10.880	0.000	0.000	80.238	53.460	0.000	0.000	11.463	7.637
84	3X3	E.hybrid (Local)	1993	0.0588	7	1003	16.5	14.1	4.8	19.4	12.0	11.300	1.173	0.902	72.368	49.243	0.168	0.129	10.338	7.035
85	3X3	Teri 3 (T.C.)	1993	0.0595	7	890	20.4	17.2	3.6	18.8	11.5	9.320	1.486	1.153	71.605	49.409	0.212	0.165	10.229	7.058
86	3X3	Teri 7 (T.C.)	1993	0.0588	7	867	17.5	14.5	5.0	19.0	11.6	9.170	0.596	0.459	60.695	41.127	0.085	0.066	8.671	5.875
87	3X3	Teri 26 (T.C.)	1993	0.0548	7	711	20.1	17.5	5.4	22.0	13.0	9.490	4.895	3.796	72.116	51.007	0.699	0.542	10.302	7.287

SP NO	SPACING	SPECIES/ CLONE	YEAR OF PLANTA-TION	AREA	AGE	NO OF TREES PER HA.	TOP HEIGHT	CROP HEIGHT	DIAMETER			BASAL AREA PER HA.	TIMBER		TOTAL WOOD		M.A.I.			
									MIN	MAX	CROP		(O.B.) PER HA.	(U.B.) PER HA.	(O.B.) PER HA.	(U.B.) PER HA.	TIMBER		TOTAL WOOD	
	(m)			(HA.)	(Yr)		(m)	(m)	(cm)	(cm)	(cm)	(sq m)	(cu mt)	(cu mt)	(cu mt)	(cu mt)	O.B. (cu mt)	U.B (cu mt)	O.B. (cu mt)	U.B. (cu mt)
88	3X3	Teri 10 (T.C.)	1993	0.0586	7	631	19.2	16.5	2.6	18.4	12.2	7.350	1.723	1.330	53.937	37.484	0.246	0.190	7.705	5.355
89	3X3	Teri 362 (T.C.)	1993	0.0582	7	618	17.5	15.4	3.4	16.8	10.2	5.090	0.040	0.029	36.784	24.301	0.006	0.004	5.255	3.472
92	3X2	E.hybrid	1982	0.0915	18	786	33.1	28.3	8.8	38.4	21.5	28.500	159.215	123.984	324.812	245.977	8.845	6.888	18.045	13.665
93	3X2	E.hybrid	1982	0.0888	18	1036	31.3	26.6	8.6	38.6	18.3	27.220	114.350	89.012	294.426	220.799	6.353	4.945	16.357	12.267
94	3X2	E.hybrid	1982	0.0892	18	1244	33.1	28.4	8.2	36.6	18.0	31.720	146.963	114.417	366.210	274.929	8.165	6.357	20.345	15.274
95	3X2	E.hybrid	1983	0.0890	17	988	29.8	25.2	8.8	38.6	17.9	24.880	91.956	71.577	255.886	191.303	5.409	4.210	15.052	11.253
96	3X2	E.hybrid	1983	0.0845	17	733	34.2	29.8	10.4	36.4	22.1	28.170	171.319	133.419	337.113	255.849	10.078	7.848	19.830	15.050
97	3X2	E.hybrid	1984	0.0852	16	915	31.0	26.0	8.8	34.2	18.4	24.280	97.792	76.127	256.683	192.412	6.112	4.758	16.043	12.026
98	3X2	E.hybrid	1984	0.0802	16	735	31.0	27.0	7.6	30.0	19.7	22.380	104.368	81.250	244.795	184.423	6.523	5.078	15.300	11.526
99	3X3	E.hybrid	1995	0.0919	5	848	9.5	8.4	2.8	11.6	6.9	3.200	0.000	0.000	18.836	8.872	0.000	0.000	3.767	1.774
100	3X3	E.hybrid	1995	0.0922	5	911	9.5	8.4	2.8	13.6	7.7	8.430	0.000	0.000	23.030	11.697	0.000	0.000	4.606	2.339
101	3X3	E.hybrid	1994	0.0820	6	707	10.9	9.6	3.0	12.8	8.3	3.860	0.000	0.000	21.466	11.856	0.000	0.000	3.578	1.976
108	3X2	E.hybrid	1993	0.0713	7	1220	25.4	21.6	5.4	28.6	15.9	24.140	53.305	41.438	217.150	159.785	7.615	5.920	31.021	22.826
109	3X2	E.hybrid	1993	0.0583	7	823	19.1	17.0	4.8	24.7	16.6	17.840	22.116	17.173	127.116	92.803	3.159	2.453	18.159	13.258
112	3X3	E.hybrid	1994	0.0918	6	871	13.9	12.0	4.2	14.8	10.8	7.950	0.000	0.000	45.928	29.676	0.000	0.000	7.655	4.946
115	3X2	E.hybrid	1995	0.0828	5	1231	23.5	20.1	5.6	15.6	10.6	10.760	0.375	0.288	96.906	66.691	0.075	0.058	19.381	13.338
168	2x1	E.hybrid	1991	0.0661	9	1391	20.7	16.7	4.8	22.4	11.8	15.280	6.946	5.387	114.254	79.036	0.772	0.599	12.695	8.782
169	2x1	E.hybrid	1991	0.0883	9	1449	20.1	15.8	3.8	20.8	10.9	13.550	4.074	3.150	98.406	66.389	0.453	0.350	10.934	7.377
170	2x1	E.hybrid	1991	0.0935	9	1411	21.9	16.4	4.4	22.0	11.4	14.350	9.633	7.475	106.169	72.648	1.070	0.831	11.797	8.072
171	2x1	E.hybrid	1991	0.0645	9	1193	25.2	19.5	5.0	24.6	13.1	16.040	21.724	16.875	134.528	96.049	2.414	1.875	14.948	10.672
173	1.5x1	E.hybrid	1990	0.0698	10	1489	20.7	17.6	6.8	26.8	15.7	28.740	37.730	29.320	213.543	155.183	3.773	2.932	21.354	15.518
174	3x2.5	E.hybrid	1988	0.0908	12	903	22.5	19.5	7.6	26.0	17.2	21.030	36.374	28.267	170.267	125.648	3.031	2.356	14.189	10.471
175	3x2.5	E.hybrid	1988	0.0911	12	768	20.4	17.9	6.2	28.0	16.6	16.690	21.283	16.523	124.768	91.356	1.774	1.377	10.397	7.613
KARNAL DIVISION																				
116	3X2.5	E.hybrid	1988	0.0629	12	747	30.1	25.8	10.6	35.8	22.6	30.050	156.181	121.633	312.287	236.555	13.015	10.136	26.024	19.713
117	3X2	E.hybrid	1988	0.0661	12	695	26.9	23.5	10.2	33.6	18.7	19.070	62.815	48.874	183.342	137.153	5.235	4.073	15.279	11.429
118	3X2	E.hybrid	1993	0.0901	7	1265	22.8	19.6	5.4	22.8	13.7	18.700	13.777	10.686	156.292	112.405	1.968	1.527	22.327	16.058
119	3X2	E.hybrid	1994	0.0936	6	1132	21.0	17.7	6.6	22.6	13.8	16.970	9.189	7.122	128.958	92.152	1.532	1.187	21.493	15.359
125	3X2	E.hybrid	1995	0.0858	5	1317	10.5	8.9	3.0	10.6	5.8	3.520	0.000	0.000	25.201	10.651	0.000	0.000	5.040	2.130
126	3X2	E.hybrid	1995	0.0910	5	1373	15.3	12.4	3.4	14.2	7.4	5.930	0.000	0.000	42.265	23.471	0.000	0.000	8.453	4.694
127	3x2	E.hybrid	1995	0.0948	5	1265	14.7	12.7	4.6	14.0	9.0	8.040	0.000	0.000	52.586	32.179	0.000	0.000	10.517	6.436
128	2.5x2	E.hybrid	1982	0.0757	18	951	22.5	19.2	6.2	32.8	18.2	24.800	57.962	45.091	196.794	149.945	3.220	2.505	10.933	8.103
132	3x2	E.hybrid	1995	0.0876	5	1164	12.8	11.6	5.0	11.6	7.7	5.440	0.000	0.000	36.196	20.181	0.000	0.000	7.239	4.036

SP NO	SPACING (m)	SPECIES/ CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
137	2.5x2	E.hybrid	1992	0.0918	8	827	22.5	19.5	8.0	32.2	17.7	20.290	41.673	32.408	163.946	121.262	5.209	4.051	20.493	15.158
138	2.5x2	E.hybrid	1996	0.0895	4	1240	14.3	11.1	4.2	16.0	8.8	7.490	0.000	0.000	44.697	26.248	0.000	0.000	11.174	6.562
139	3x2	E.hybrid	1982	0.0879	18	762	25.4	21.8	7.0	27.4	16.2	15.800	39.146	30.447	143.005	105.505	2.175	1.692	7.945	5.861
140	3x2	E.hybrid	1982	0.0901	18	865	26.5	21.1	5.6	25.2	13.8	13.010	19.567	15.209	116.520	84.322	1.087	0.845	6.473	4.685
141	3x2	E.hybrid	1982	0.0910	18	747	21.0	18.7	8.6	25.8	15.6	14.320	18.940	14.714	112.772	82.218	1.052	0.817	6.265	4.568
142	2.5x2	E.hybrid	1993	0.0826	7	1876	18.3	13.2	3.8	18.2	9.3	12.690	0.441	0.338	84.170	52.510	0.063	0.048	12.024	7.501
143	2.5x2	E.hybrid	1993	0.0270	7	2555	18.0	14.9	3.8	22.0	12.4	31.000	7.493	5.789	206.307	142.430	1.070	0.827	29.472	20.347
147	3x2	E.hybrid	1994	0.0831	6	962	19.9	16.1	6.4	29.8	16.1	19.480	21.521	16.728	132.339	95.[illegible]	3.587	2.788	22.057	15.985
148	3x2	E.hybrid	1984	0.0927	16	463	23.3	20.1	11.2	36.2	21.8	17.230	53.108	41.331	140.690	105.872	3.319	2.583	8.806	6.617
149	3x2.5	E.hybrid	1995	0.0882	5	521	15.4	14.5	9.0	17.6	13.0	6.920	0.000	0.000	44.686	[illegible]	0.000	0.000	8.917	6.198
150	3x2	E.hybrid	1995	0.0936	5	833	14.4	12.9	7.4	17.0	11.0	7.970	0.000	0.000	48.447	31.881	0.000	0.000	9.689	6.376
151	3x2	E.hybrid	1995	0.0902	5	665	14.5	12.6	7.6	15.0	11.1	6.470	0.000	0.000	38.635	25.420	0.000	0.000	7.727	5.084
152	3x2	E.hybrid	1995	0.0857	5	875	15.7	14.4	6.2	17.4	11.6	9.180	0.000	0.000	60.525	40.[illegible]	0.000	0.000	12.105	8.189
155	2.5x1	E.hybrid	1984	0.0841	16	903	26.4	22.1	11.2	33.4	21.5	32.740	121.041	94.225	293.847	221.240	7.565	5.889	18.365	13.828
166	3x3	E.hybrid	1988	0.0827	12	568	26.7	23.2	12.4	38.0	24.4	26.550	124.360	96.845	247.892	187.943	10.361	8.070	20.658	15.662
167	3.5x2.5	E.hybrid	1990	0.0538	10	669	18.9	17.1	5.2	27.8	18.2	17.480	27.917	21.678	124.302	91.662	2.792	2.168	12.430	9.166
HISAR DIVISION																				
191	2x1	E.hybrid	1989	0.0902	11	1130	15.2	12.4	5.0	17.6	10.1	9.090	0.000	0.000	55.385	35.253	0.000	0.000	5.035	3.205
192	2x1	E.hybrid	1989	0.0586	11	1945	16.2	12.6	5.0	19.4	10.1	15.480	0.653	0.502	95.872	61.099	0.059	0.046	8.716	5.554

T.C. - Tissue culture raised seedlings of E.hybrid.

Forest Division, while at Karnal a top height range of 21 m (SP No 141) to 25.4 m (SP No 139) is observed at the age of 18 years. In Kurukshetra and Hissar Forest Divisions generally lower top heights are noticed at ages 9 to 12 years (SP Nos. 168 to 171, 173 to 175, 191, 192). However, contrary to this statement a better performance has been shown by the species in Kurukshetra (SP No 108 and SP No 115) where a top height of 25.4 m, and 23.5 m has been attained at ages 7 and 5 years respectively. The Bhadrachalam clones and TERI tissue culture raised plantations have performed well at the age of 7 years in that order, with top height varying from 21 to 27 m (Bhadrachalam) and 17 to 20 m (TERI).

Considering the ages 9 to 12 years (Table 9) the highest volume production is 20.5 m^3/ha/year (total wood, UB), at the age of 10 years and the minimum volume (11.1 m^3/ha/year) has been produced at the age of 12 years in Yamananagar Division. In Karnal Division the maximum MAI (19.7 m^3/ ha) is at the age of 12 years while the minimum (9.16 m^3/ha) has been shown at the age of 10 years. The picture is quite different in Kurukshetra Division where the total wood UB volume varies from 7.4 m^3/ha (9 years) to 15.5 m^3/ha (10 years). Comparatively a lower range of MAI (3.2 to 5.6 m^3/ha) is observed in Hissar at the age of 11 years. Some exceptionally better sites, as shown below, can be spotted where substantial volume production has been obtained at lower ages (Table 9). These highly productive plantations should be used as seed sources/clonal material for future planting.

SP No	Division	Age (Years)	MAI (m^3 - total wood UB)
76	Kurukshetra (Bhadrachallam – 3)	7	17.0
108	Kurukshetra	7	22.8
118	Karnal	7	16.0
143	Karnal	7	20.3

7.2.2 Roadside and canalside plantations

Roadside and canalside plantation data has been set in Table 10 and 11 respectively. In narrow strips (3 rows) the trees growing in outer most rows have more space and nutrient availability for better growth and as such are subjected to edge effect. The

Table 10 : GROWTH PARAMETERS OF EUCALYPTUS (ROADSIDE PLANTATION)

SP NO	SPACING (m)	SPECIES	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
YAMUNA NAGAR DIVISION																				
23	3.4X2.2	E.hybrid (Strip)	1990	0.0663	10	980	31.5	25.8	12.2	38.0	23.2	41.260	218.679	170.317	428.720	325.057	21.868	17.032	42.872	32.506
KURUKSHETRA DIVISION																				
103	3X2	E.hybrid (Strip)	1991	0.0511	9	978	22.2	18.0	10.4	28.2	20.8	33.160	74.010	57.555	244.377	182.469	8.223	6.395	27.153	20.274
104	3X2	E.hybrid (Strip)	1991	0.0779	9	706	22.4	18.4	10.4	32.1	20.6	23.540	55.375	43.066	176.875	137.082	6.153	4.785	19.653	14.676
105	3X1	E.hybrid (Strip)	1990	0.0605	10	1371	19.6	15.5	7.4	31.0	17.0	30.950	37.879	29.423	202.075	147.105	3.788	2.942	20.208	14.711
106	3X1	E.hybrid (Strip)	1990	0.0408	10	1568	21.2	17.5	7.4	24.6	15.7	30.210	37.049	28.770	222.910	161.941	3.705	2.877	22.291	16.190
157	3.5x2	E.hybrid (Narrow Strip)	1986	0.0783	14	613	30.9	28.0	14.4	35.6	24.2	28.130	166.903	129.979	315.745	240.130	11.922	9.284	22.553	17.152
158	3x1	E.hybrid (Narrow Strip)	1986	0.0323	14	1517	26.4	21.8	11.2	36.6	24.4	70.720	308.122	239.949	622.191	471.114	22.009	17.139	44.442	33.651
159	3x1	E.hybrid (Narrow Strip)	1986	0.0324	14	1265	32.0	27.4	13.0	36.4	26.0	66.980	410.622	319.830	734.163	559.439	29.330	22.845	52.440	39.959
172	3x1	E.hybrid (Strip)	1988	0.0479	12	1189	19.8	17.2	10.4	26.2	18.7	32.610	49.717	38.636	231.803	171.322	4.143	3.220	19.317	14.277
HISAR DIVISION																				
176	3x2	E.hybrid (Strip)	1983	0.0916	17	753	25.9	23.0	12.4	30.8	20.1	23.920	79.849	62.123	223.394	167.750	4.697	3.654	13.141	9.868
177	3x2	E.hybrid (Strip)	1983	0.0688	17	755	24.1	21.1	12.4	32.8	21.1	26.410	83.576	65.033	226.933	170.471	4.916	3.825	13.349	10.028
178	3x2	E.hybrid (Strip)	1983	0.0906	17	662	27.2	23.6	14.2	29.2	20.7	22.280	81.977	63.791	213.354	160.595	4.822	3.752	12.550	9.447
179	3x2	E.hybrid (Strip)	1983	0.0980	17	724	28.6	25.2	12.6	30.2	19.9	22.630	88.720	69.038	231.304	174.062	5.219	4.061	13.606	10.239
180	3x2	E.hybrid (Strip)	1982	0.0905	18	618	27.2	23.8	11.0	33.6	20.3	19.990	78.011	60.724	193.024	145.160	4.334	3.374	10.724	8.064
181	3x2	E.hybrid (Strip)	1982	0.0860	18	627	27.1	23.8	10.8	29.8	18.9	17.570	57.836	45.001	170.853	127.948	3.213	2.500	9.492	7.108
182	3x2	E.hybrid (Strip)	1982	0.0714	18	714	26.7	22.2	10.2	29.8	19.0	20.320	62.707	48.806	184.043	137.572	3.484	2.711	10.225	7.643
KARNAL DIVISION																				
136	3x2	E.hybrid (Strip)	1982	0.0726	18	619	30.6	27.4	19.8	46.0	29.1	41.190	270.737	210.909	449.414	343.486	15.041	11.717	24.967	19.083

Table 11 : GROWTH PARAMETERS OF EUCALYPTUS (CANALSIDE PLANTATION)

SP NO	SPACING (m)	SPECIES	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)	TIMBER (O.B.) PER HA. (cu mt)	TIMBER (U.B.) PER HA. (cu mt)	TOTAL WOOD (O.B.) PER HA. (cu mt)	TOTAL WOOD (U.B.) PER HA. (cu mt)	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
YAMUNA NAGAR DIVISION																				
24	4X3	E.hybrid (Strip)	1988	0.0931	12	558	31.3	26.5	12.4	41.2	25.8	29.130	173.838	135.414	308.924	235.220	14.487	11.285	25.744	19.602
KURUKSHETRA DIVISION																				
113	3X3	E.hybrid (Strip) Coppice	1992	0.0623	8	513	20.7	18.4	13.2	32.2	22.0	19.590	51.257	39.876	146.922	110.204	6.407	4.985	18.365	13.776
KARNAL DIVISION																				
120	3X1	E.hybrid (Strip)	1983	0.0909	17	451	25.4	23.5	14.8	41.0	27.4	26.550	136.902	106.633	249.187	189.732	8.053	6.273	14.658	11.161
121	3X1	E.hybrid (Strip)	1983	0.0852	17	434	29.7	26.3	10.8	42.4	23.7	19.190	107.521	83.751	202.460	153.698	6.325	4.927	11.909	9.041
122	3X1	E.hybrid (Strip)	1985	0.0887	15	822	28.8	24.1	12.0	41.4	22.4	32.410	148.442	115.598	314.946	238.103	9.896	7.707	20.996	15.874
123	3X1	E.hybrid (Strip)	1985	0.0903	15	686	29.7	26.0	10.8	41.0	20.4	22.400	104.562	81.420	235.306	177.413	6.971	5.428	15.687	11.828
124	2.5X1.5	E.hybrid (Strip)	1983	0.0887	17	586	26.6	22.0	8.4	28.2	17.7	14.340	39.959	31.086	129.794	96.467	2.351	1.829	7.635	5.675
129	3x1	E.hybrid (Strip)	1982	0.0883	18	600	30.5	26.3	8.8	30.2	18.2	15.580	66.302	51.611	167.132	125.256	3.683	2.867	9.285	6.959
130	3x1	E.hybrid (Strip)	1982	0.0858	18	815	30.6	25.3	8.8	32.0	18.1	20.986	81.243	63.240	217.009	162.390	4.514	3.513	12.056	9.022
131	3x1	E.hybrid (Strip)	1982	0.0895	18	681	25.5	21.8	9.8	36.2	18.5	18.310	52.861	41.1[illegible]9	163.283	121.732	2.937	2.285	9.071	6.763
135	3.3x1	E.hybrid (Strip)	1996	0.0662	4	1661	13.0	10.7	4.2	14.0	8.1	8.540	0.000	0.0[illegible]	52.057	29.110	0.000	0.000	13.014	7.278
144	2x1.5	E.hybrid (Narrow Strip)	1982	0.0371	18	1859	31.5	26.5	11.6	38.6	25.5	94.690	544.948	424.417	1005.931	765.657	30.275	23.579	55.885	42.537
145	4x1.5	E.hybrid (Narrow Strip)	1982	0.0376	18	1994	30.1	23.8	10.6	50.0	24.6	94.940	472.457	367.970	906.553	687.876	26.248	20.443	50.364	38.215
146	2x1	E.hybrid (Narrow Strip)	1982	0.0334	18	1377	26.3	21.6	11.8	37.8	24.2	63.330	263.532	205.197	550.452	416.559	14.641	11.400	30.581	23.142
153	1x1	E.hybrid (Strip)	1982	0.0424	18	1132	28.2	22.8	12.6	35.4	23.5	49.130	214.697	167.178	452.152	342.164	11.928	9.288	25.120	19.009
154	1x1	E.hybrid (Strip)	1982	0.0441	18	1043	28.6	24.0	11.2	40.4	25.8	54.530	276.812	215.586	523.752	398.148	15.378	11.977	29.097	22.119
156	2.5x1.5	E.hybrid (Strip)	1982	0.0749	18	667	25.5	23.5	17.8	33.8	24.9	32.480	152.174	118.483	306.771	232.823	8.454	6.582	17.043	12.935
160	3x1	E.hybrid (Strip)	1982	0.0474	18	1075	23.1	18.7	9.4	29.8	18.6	29.120	65.737	51.138	224.247	166.243	3.652	2.841	12.458	9.236
161	3.5x1.5	E.hybrid (Strip)	1982	0.0804	18	534	25.0	21.9	12.0	36.8	23.8	23.850	96.352	75.013	210.699	159.396	5.353	4.167	11.706	8.855
162	3.5x1.5	E.hybrid (Strip)	1982	0.0868	18	460	25.4	22.3	14.4	36.2	23.3	19.670	78.886	61.407	176.904	133.751	4.383	3.412	9.828	7.431
163	3.5x1.5	E.hybrid (Strip)	1982	0.0992	18	403	23.7	21.2	14.4	33.4	22.8	16.420	59.768	46.523	140.488	105.968	3.320	2.585	7.805	5.887

Narrow Strip - 3 Rows of trees
Strip - More than 3 rows of trees

productivity of such strips is not comparable to block plantations but they have shown better performance in most of the cases. SP No 157, 158 and 159 (Table 10) and SP No 144, 145, 146 (Table 11) are narrow strip plantations (3 rows) where edge effect is conspicuous and, therefore, by reasoning, not comparable to block plantations. The data has only been included to show the higher productivity on narrow strips, which should be accepted with caution and cannot be generalized. Again, a roadside strip plantation (more than 3 rows) (Table 10, SP No 23) has produced a MAI of 32.5 m^3/ha/year (total wood UB) in 10 years (Yamananagar Forest Division), which is exceptionally the best site. In general, on roadsides a productively of 7 to 20 m^3/ha/year of total wood (UB) is expected, while in canalside plantations the expected productively varies from 6 to 22 m^3/ ha/year (Table 11).

The data of canal strip plantations (more than 3 rows – multiple rows) (Table 11) is mostly from Karnal and of higher ages. Again, the strip plantation of Yamunanagar Division, at the age of 12 years shows a top of height of 31.3 m whereas the same height is attained at the age of 18 years in Karnal. A similar trend is observed in roadside plantations (Table 10) where top height of over 30 m is obtained at the age of 10 years in Yamunnagar Division, at age of 14 years in Kurukshetra Division and at 18 years in Karnal Division. Hissar Division is at the lowest level.

7.2.3 Line plantations

Growth data of line plantations (single/double rows) along roadsides and field bunds (which has been calculated on the basis of 100 trees as mentioned earlier in last para of section 5.2) is set in Table 12. Total wood (UB) volume per 100 trees is maximum in Yamananagar Forest Division, which varies from 30 to 39 m^3 at the age of 17 and 15 years respectively. At a younger age (4 years) the data pertaining to Karnal Forest Division is well comparable to Yamananagar Forest Division.

7.2.4 Bhadrachallam clones and tissue culture plantations

Table 13 and 14 set the data pertaining to Bhadrachallam clones and tissue culture plantations supplied by HCFP which has been utilized to find *Eucalyptus* clones

Table 12 : GROWTH PARAMETERS OF ECUCALYPTUS (LINE PLANTATION)

SP NO	SPACING (m)	SPECIES	SINGLE LINE/ DOUBLE LINE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA OF 100 TREES	TIMBER (O.B.) OF 100 TREES	TIMBER (U.B.) OF 100 TREES	TOTAL WOOD (O.B.) OF 100 TREES	TOTAL WOOD (U.B.) OF 100 TREES	M.A.I. TIMBER O.B. (cu mt)	M.A.I. TIMBER U.B. (cu mt)	M.A.I. TOTAL WOOD O.B. (cu mt)	M.A.I. TOTAL WOOD U.B. (cu mt)
YAMUNA NAGAR DIVISION																			
48	1.5X0.8	E.hybrid	F.B. (D.L.)	1995	0.0251	5	10.3	3.8	10.6	7.2	0.402	0.000	0.000	2.611	1.348	0.000	0.000	0.522	0.270
62	1 m	E.hybrid	F.B.(S.L.)	1983	0.0245	17	21.7	6.6	38.8	24.0	4.537	19.960	15.544	39.596	29.958	1.174	0.914	2.329	1.762
66	1 m	E.hybrid	F.B.(S.L.)	1996	0.0285	4	12.5	4.2	13.0	8.5	0.567	0.000	0.000	3.763	2.239	0.000	0.000	0.941	0.560
68	1 m	E.hybrid	F.B.(S.L.)	1997	0.0244	3	11.9	4.0	13.8	8.4	0.559	0.000	0.000	3.596	2.110	0.000	0.000	1.199	0.703
70	1.4 m	E.hybrid	F.B.(S.L.)	1993	0.0242	7	17.8	5.2	21.8	13.0	1.328	0.743	0.576	10.260	7.265	0.106	0.082	1.466	1.038
72	1 m	E.hybrid	F.B.(S.L.)	1985	0.0245	15	21.8	14.0	39.8	27.2	5.788	27.053	21.070	50.642	38.503	1.804	1.405	3.376	2.567
58	1 m	E.hybrid	Road side (S.L.)	1983	0.0245	17	24.2	9.8	38.0	22.8	4.075	18.747	14.597	39.717	30.052	1.103	0.859	2.336	1.768
KURUKSHETRA DIVISION																			
107	1 m	E.hybrid	Road side (S.L.)	1990	0.0240	10	18.2	7.4	27.6	16.3	2.094	3.102	2.411	[illegible]	[illegible]	0.310	0.241	1.600	1.170
KARNAL DIVISION																			
133	1 m	E.hybrid	Road side (S.L.)	1996	0.0365	4	8.7	3.8	12.2	7.8	0.477	0.000	0.000	2.606	[illegible]	0.000	0.000	0.652	0.336
134	3x1	E.hybrid	Road side (D.L.)	1996	0.0240	4	10.6	4.2	13.6	9.3	0.678	0.000	0.000	3.791	2.261	[illegible]	0.000	[illegible]	0.565

F.B. - Field Bund
S.L. - Single Line
D.L. - Double line

Table 13 : GROWTH PERFORMANCE OF BHADRACHALLAM CLONE

SP NO	SPACING (m)	SPECIES/ CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	MEAN HEIGHT (m)	AVERAGE DIAMETER (cm)	PER TREE VOLUME (T.WOOD) O.B. (cu mt)	AT 3 Yrs. TOTAL WOOD O.B./ha (cu mt)	AT 7 Yrs. TOTAL WOOD O.B./ha (cu mt)	CAI (cu mt)
KURUKSHETRA DIVISION												
76	3X3	Bhadra Challam 3	1993	0.0585	3	1059	12.50	8.89	0.040	42.360	163.423	30.266
77	3X3	Bhadra Challam 10	1993	0.0597	3	1088	12.52	10.00	0.048	52.224	147.203	23.745
78	3X3	Bhadra Challam 7	1993	0.0582	3	1116	13.25	9.88	0.050	55.800	162.836	26.759
79	3X3	Bhadra Challam 91	1993	0.0593	3	1062	12.34	10.02	0.048	50.976	156.213	26.309
80	3X3	Bhadra Challam 127	1993	0.0590	3	1050	11.81	9.71	0.044	46.200	144.086	24.472
81	3X3	Bhadra Challam 128	1993	0.0588	3	1088	11.44	9.31	0.040	43.520	97.837	13.579
82	3X3	Bhadra Challam 130	1993	0.0578	3	899	11.90	10.70	0.052	46.748	112.085	16.334

Note : $V_{ob} = 0.009793+0.0000308811\ D^2H$ (Where D= d.b.h. in cm, H= Tree height in metres)
CAI - Current annual increment
O.B. - Over Bark

Table 14 : GROWTH PERFORMANCE OF TISSUE CULTURE RAISED BY (TERI) IN EUCALYPTUS

SP NO	SPACING (m)	SPECIES/ CLONE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	MEAN HEIGHT (m)	AVERAGE DIAMETER (cm)	PER TREE VOLUME (T.WOOD) O.B. (cu mt)	AT 3 Yrs. TOTAL WOOD O.B./ha (cu mt)	AT 7 Yrs. TOTAL WOOD O.B./ha (cu mt)	CAI (cu mt)
KURUKSHETRA DIVISION												
83	3X3	Teri 2 (T.C.)	1993	0.0585	3	1282	9.46	7.63	0.027	34.614	80.238	11.406
84	3X3	E.hybrid (Local)	1993	0.0588	3	1003	10.40	9.50	0.039	39.117	72.368	8.313
85	3X3	Teri 3 (T.C.)	1993	0.0595	3	890	9.85	8.53	0.032	28.480	71.605	10.781
86	3X3	Teri 7 (T.C.)	1993	0.0588	3	867	9.37	8.52	0.031	26.880	60.695	8.454
87	3X3	Teri 26 (T.C.)	1993	0.0548	3	711	9.96	8.91	0.034	24.174	72.116	11.986
88	3X3	Teri 10 (T.C.)	1993	0.0586	3	631	9.47	8.92	0.033	20.820	53.937	8.279
89	3X3	Teri 362 (T.C.)	1993	0.0582	3	618	8.88	8.13	0.028	17.300	36.784	4.871

T.C. - Tissue culture raised seedlings of E.hybrid.

Note : $V_{ob} = 0.009793+0.0000308811\ D^2H$ (Where D= d.b.h. in cm, H= Tree height in metres)
CAI - Current annual increment
O.B. - Over Bark

of higher productivity. This has been done by calculating the current annual increments (CAI) between 3 to 7 years assuming stand density to be constant. Volume data at age 7 years for the same area is available in the present study of SPs. At the age of 3 years the volume has been worked out by substituting the value of average diameter and height of the plots in the volume equation derived on the basis of sample trees given in the text. In this manner, average volume per tree was calculated at the age of 3 years. Volume per ha was obtained by multiplying the volume per tree with the number of trees per ha. The difference of volume at the ages of 7 and 3 years when divided by 4 gives the CAI during this period (Table 13). It is quit clear from this table that Bhadrachallam – 3 (CAI, 30 m^3) and Bhadrachallam – 7 (CAI, 27 m^3) are the best clones, which is in agreement with earlier findings. Similarly TERI – 26 (CAI, 12 m^3), TERI – 2, and TERI – 3 (CAI, 11 m^3) are better, though most of these trees are forked and bent and some of them are forked below DBH level.

7.3 Probable Sites

Sample plot data have provided very useful information that *Eucalyptus* hybrid can be grown in varied types of soils in Haryana though longer rotations may be needed for poorer sites. However, best growth has been obtained in Yamunanagar, Karnal and Kurukshetra Forest Divisions followed by Hissar. It is evident that the species grows well in climatic regions with rainfall above 500 mm (Hot Semi-Dry Zone, Hot Sub-Humid Zone and Hot Humid Zone) though it does grow below a rainfall of 500 mm. Soil texture in these areas varies from loamy sand, sandy loam to loam with pH varying from 6.5 to 8.5 and nutrient availability being low to medium. The number of growing season months (Aridity Index – Table 1) has also contributed to more production in the above divisions.

8.0 *AILANTHUS EXCELSA* PLANTATIONS

8.1 General

Ailanthus excelsa is comparatively a recent introduction on farmlands in Haryana and plantations are still young ranging from 3 to 6 years. The species has been raised in blocks and along roadsides.

8.2 Growth Parameters

The various crop parameters for *Ailanthus excelsa* plantations on the basis of analysis of 21 sample plots of ages 3 to 7 years are shown in Table 15. Taking the age 5 years as reference age for Hissar and Rewari, the average top height varies from 6.6 m (Hissar) to 7.7 m (Rewari) with crop diameter as 11.0 cm and 11.8 cm respectively. A top height of 8.3 m and crop diameter of 12.3 cm is attained at 4 years on an average in Mahendergarh, which indicates a better production potential. At Narnaul the average top height at 6 years is 8.6 m with average crop diameter 14.9 cm, which shows a similar trend as seen in Rewari. The productivity at Hissar is somewhat at lower level possibly due to wider spacing. In general the performance of this species has been satisfactory capable of surviving in longer dry periods. The introduction of this species in plantation programme being of recent origin and due to paucity of growth data, no volume estimation could be made.

Biomass production of 3, 6, 11, 16 and 21 years old plantations of *Ailanthus excelsa* in Uttar Pradesh show that peak values of biomass 41.8 t/ha and 40.3 t/ha are obtained at the age of 6 and 11 years respectively. There was a decrease in the biomass of leaf and twig component with increasing age, possibly due to heavy lopping. It has been suggested that the rotation age of the species should be fixed between 11 and 16 years, when biomass production is maximum.

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Table 15 : GROWTH PARAMETERS OF AILANTHUS EXCELSA

SP No.	SPACING (m)	BLOCK OR ROAD-SIDE	YEAR OF PLANTA-TION	AREA (HA.)	AGE (Yr)	NO OF TREES PER HA.	TOP HEIGHT (m)	CROP HEIGHT (m)	DIAMETER MIN (cm)	DIAMETER MAX (cm)	DIAMETER CROP (cm)	BASAL AREA PER HA. (sq m)
HISAR DIVISION												
185	4x3	Block	1995	0.0927	5	1024	7.2	6.7	5.8	19.8	11.7	11.070
186	4x3	Block	1995	0.0732	5	587	7.1	6.2	5.2	20.4	11.5	6.110
187	4x3	Block	1995	0.0915	5	579	5.6	5.1	4.0	15.6	9.7	4.320
188	4x3	Block	1997	0.0867	3	1552	7.2	5.0	3.8	14.0	8.1	7.830
189	4x3	Block	1997	0.0860	3	1069	5.7	5.1	4.4	12.6	8.7	6.310
190	4x3	Block	1997	0.0948	3	1097	5.5	5.1	4.6	13.2	8.2	5.730
MAHENDERGARH DIVISION												
193	3x3	Block	1993	0.1078	7	899	8.8	7.6	6.2	26.8	14.1	14.130
194	3x3	Block	1996	0.0915	4	907	7.3	6.6	5.6	16.8	10.8	8.240
195	3x3	Block	1996	0.0921	4	890	7.8	7.3	4.8	17.0	11.8	9.660
196	3x3	Block	1996	0.0936	4	555	9.4	8.3	6.0	20.8	13.4	7.860
197	3x3	Block	1996	0.0885	4	553	9.3	8.4	5.0	24.6	14.4	8.960
207	3x3	Block	1996	0.0893	4	649	7.9	7.3	4.8	19.6	11.2	6.370
REWARI DIVISION												
198	3x3	Block	1995	0.0935	5	919	6.3	6.0	6.0	14.0	10.7	8.250
199	3x3	Block	1995	0.0898	5	668	5.7	5.4	5.6	13.6	9.5	4.720
200	3x3	Block	1995	0.0876	5	867	6.6	5.7	6.2	17.0	10.8	7.930
201	3x3	Block	1995	0.0949	5	569	11.8	10.3	9.0	23.0	17.1	13.120
202	3x3	Block	1995	0.0890	5	1168	8.2	6.7	5.6	17.0	11.1	11.280
203	3x3	Road side	1996	0.1224	4	416	7.5	6.9	5.0	20.6	12.7	5.280
NARNAUL DIVISION												
204	3x3	Road side	1994	0.0979	6	418	9.8	9.1	6.8	24.0	17.6	10.230
205	3x3	Road side	1994	0.0960	6	833	8.2	6.8	7.4	21.6	13.1	11.210
206	3x3	Road side	1994	0.0960	6	875	7.9	6.8	7.0	22.6	14.0	13.480

Regression equations for some tree components are given below.

1.	Bole weight	Log Y= −3.3547+2.4823 log X
2.	Bark weight	Log Y= −3.9039+2.3126 log X
3.	Branch weight	Log Y= −2.3662+1.4231 log X
4.	Total biomass	Log Y= −1.4658+2.0120 log X

Where Y is the biomass component in kg and X is diameter in cm. The regressions of leaf and twig weight were non-significant due to heavy lopping.

8.3 Probable Sites

While no inferences regarding the growth performance of the species can be drawn with the meager data available, indications are that the species has a better production potential in Mahendargarh and Narnaul areas, which fall in Hot Dry climatic Zone (annual rainfall 300 – 500 mm). The soils here are mainly sandy to sandy loam and are calcareous; pH varying from 8 to 9.5. They are low in organic carbon and hence poor in nitrogen; potassium availability is medium to high and that of phosphorus low to medium.

9.0 Field Surveys

While collecting field data of temporary SP laid out in the three identified species, information was also collected from the farmers on three aspects mentioned in Section 5.1.2. A large number of farmers (5 to 10 at one site) were interviewed with the following results.

- Farmers are planting poplar clones G-3, G-48, G-57, U-DAI and S-7C15 but more commonly G-48 is being planted, probably because this is available more freely. The sources of this planting material are WIMCO nurseries, HFD nurseries and some private nurseries (where there is no quality control). Some farmers maintain their own nurseries as well. Here it must be mentioned that farmers need to be helped and encouraged to grow quality planting material through improved nurseries and nursery practices.

- With regard to *Eucalyptus* mainly *Eucalyptus* hybrid is being planted. The planting material is being obtained mostly from the HFD. There are however, reports that some farmers have occasionally used clones of this species (mostly Badrachalam –3 and 7) though no such plantation was seen during this study.

- There seems to be an anti-*Eucalyptus* wave among the farmers for various reasons particularly because of supposedly high water requirement of the species and its effects on agriculture crops. This needs to countered through extension activities by the HCFP.

- Farmers are definitely willing to plant new high yielding clones of poplar and *Eucalyptus,* and would like to follow improved packages of practices to raise these plantations, provided the same are made available to them. This would involve a suitable strategy for extension work to be developed by HCFP/HFD.

- *Ailanthus excelsa* is a very promising species and grows in very dry areas. Farmers are willing to grow this species on their lands. It needs to be given greater emphasis in various plantation programmes, than at present, through an extension strategy.

- The farmers were very keen that the HCFP should look into problems of marketing and sale of their produce particularly of poplar and *Eucalyptus* as they had difficulties in the same and were not getting remunerative prices.

10.0 CONCLUSIONS

- The performance of G–3 and G–48 poplar clones has been very good. Other clone S-7C15 has also done well in Hissar and further growth needs to be monitored. Overall success and growth performance of various clones has shown that best growth has been obtained in areas of Yamananagar Forest Division (MAI 35 m^3/ha/year). Other areas in Haryana where irrigation is available can also be tried for poplar planting.

- Sample plot data have provided very useful information that *Eucalyptus* can easily be grown in varied types of soils in Haryana. Longer rotations may be needed for poorer sites. Bhadrachallam clones (Bhadrachallam – 3 and – 7) have proved to be very productive with MAI of 17 m^3/ha/annum at age 7 years. However, some other highly productive sites have also been spotted (MAI 16 to 22.8 m^3 at age 7 years). These plantations should be used as seed sources/ clonal material for future plantation activities.

- Farmers are procuring poplar planting material from WIMCO, HFD and private nurseries (where there is no quality control). Some farmers have their own nurseries. The planting material for *Eucalyptus* is being obtained from the HFD. HCFP/HFD should provide extension service to private nursery owners and help and encourage them to produce quality planting material through improved nurseries and nursery practices.

- Much extension work needs to be done to counteract the anti-*Eucalyptus* wave prevailing with the tree growers (farmers). The farmers need to be convinced that like other agriculture crops *Eucalyptus* needs fertilizers and water and can withstand water stress. It can be preferred to grow on field bunds and roadsides throughout Haryana.

- Farmers are definitely willing to plant new high yielding clones of poplar and *Eucalyptus* provided the same are made available to them along with the package of practices to be adopted, for raising plantations of these new high yielding clones.

- *Ailanthus excelsa* is a very promising species and has been observed to be growing even in very dry places. The species has good growth in Mahendergarh, Narnual; Rewari, Hissar and the Aravalli project area. More emphasis should be given to the species in plantation programmes.

- Farmers are of the opinion that all sale of poplars should be through the HFDC instead of a direct deal between wood suppliers and industries.

- Woodbased industries are meeting their needs of wood from neighbouring states at a cheaper rate and this is a sheer loss to tree growers (farmers) in Haryana. It was suggested that all material should first be obtained from Haryana and then purchases be made from outside the State, if more material is required

- Some indigenous species should also be included in plantation programmes for eco-restoration and environmental conservations. *Ailanthus excelsa* is a case in point.

- It is necessary to undertake a follow up study on assessing the quantity of Wood available annually of the three identified species from farmlands and other private sources, in view of the fact that substantial quantities of wood are being supplied by private sources in the State.

11.0 BIBLIOGRAPHY

1. **Anonymous** (1992). *Eucalyptus.* Indian Council of Forestry Research and Education, Dehra Dun
2. **Anonymous** (1992). Poplar. Indian Council of Forestry Research and Education, Dehra Dun.
3. **Anonymous** (1999). Haryana Community Forestry Project — An overview. Haryana Forest Department, Panchkula.
4. **Champion, H.G. and S.K. Seth** (1968). A revised survey of forest types of India. Manager of Publications, Delhi.
5. **Chauhan, K.S.**(1999). State forestry research plan. Forest Department, Haryana, Panchkula.
6. **Dahiya, I.S., A.V. Shanwal, Mahendra Singh, M.S. Kuhad** and **S.P. Karwasa** (1988). Land resources and Land use planning in Haryana. Directorate of Research, Haryana Agricultural University, Hissar.
7. **Maithani, G.P. and D.C. Sharma** (1987). Initial spacing in euclypt planting *Indian Forester,* **113** (5): 315-322
8. **Negi, J.D.S.** (1984). Biological productivity and cycling of nutrients in managed and man-made ecosystems. Ph.D thesis, Garhwal University, Srinagar, Garhwal, Uttar Pradesh.
9. **Negi, M.S. and V.N. Tandon** (1997). Biomass and nutrient distribution in an age sequence of *Populus deltoides* ecosystem in Haryana. *Indian Forester,* **123** (2): 111-117.
10. **Pande, M.C., V.N. Tandon and Mridula Negi** (1988). Biomass production in plantation ecosystem of *Ailanthus excelsa* at five different ages in Uttar Pradesh. *Indian Forester,* **114** (7): 362 – 371.
11. **Paterson, S.S. (1956).** The forest area of the world and its potential productively. The Royal University of Goteborg, Sweden.

12. **Sachdev, C.B., T. Lal, K.P.C. Rana and J. Sehgal (1995).** Soils of Haryana for optimizing land use (Executive Summary). National Bureau of soil survey and Land use planning (NBSS), Nagpur. Publication 44, Soils of India, Series 3.

13. **Singh, M., R.L. Ahuja and S.S. Khanna (1984).** Soils of Haryana. ***In.*** Soils of India. FertilizerAssociation of India, New Delhi: 130 - 148

14. **Singh, R.V.** (1980). Brief review of silvicultural requirements of *Populus deltoides* relevant to cultivation in Punjab plains. *Second For Conference*, FRI, Dehra Dun.

15. **Tandon, V.N., J.K. Rawat and Rajinder Singh** (1993). Biomass production and mineral cycling in plantation ecosystems of *Eucalyptus* hybrid in Haryana. 1. Biomass production and its distribution. *Indian. Forester*, **119.** (3): 232 - 237.

16 **Tandon, V.N., M.C. Pandy, H.S. Rawat and D.C. Sharma (1991).** Organic productivity and mineral cycling in plantation of *Populus deltoides* in *Tarai* region of Uttar Pradesh. *Indian Forester,* **117** (8): 596 – 608.

17 **Tandon, V.N., M.S. Negi, D.C. Sharma and H.S. Rawat** (1996). Biomass production and mineral cycling in plantation ecosystems of *Eucalyptus* hybrid in Haryana. 2. Distribution and cycling of nutrients. *Indian Forester,* **122** (1): 30– 38.

18. **Tiwari, D.N.** (1992). *Ecualyptus*. Surya Publications, Dehra Dun.

19. **Tiwari, D.N.** (1993). Poplar. Surya Publications, Dehra Dun.

20. **Yadav, R.B. and Om Prakash.** (1995). Effect of soil salinity and sodicity on growth and mineral nutrition of some poplar (*Populus deltoides*) clones. *Indian. Forester,* **121** (4): 283 – 288