Seedling growth and survival of seven multipurpose Agroforestry tree species of Garhwal Himalaya

Thesis

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By

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CERTIFICATE

This is to certify that the thesis entitled "***Seedling growth and survival of seven multipurpose Agroforestry tree species of Garhwal Himalaya***" submitted in partial fulfilment of the requirements for the degree of **Master of Science in Forestry** with major in **Agroforestry** of the College of Post-Graduate Studies, VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, is a record of ***bonafide*** research carried out by **Miss. Kanchan Rawat, Id. No. UUHF/14271** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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CERTIFICATE

We, the undersigned, member of the Advisory Committee of **Miss. Kanchan Rawat, Id. No. UUHF/14271,** a candidate for the degree of **Master of Science in Forestry** with major in **Agroforestry,** agree that the thesis entitled "***Seedling growth and survival of seven multipurpose Agroforestry tree species of Garhwal Himalaya***" may be submitted in partial fulfilment of the requirements for the degree.

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"Scientific knowledge is part of the endowment we
Leave to future generations...."

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Ranichauri
August, 2016

Kanchan Rawat
(Author)

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ABBREVIATIONS USED

M	Meter
Mm	Millimeter
i.e	That is
Viz	Videlicet
^{0}C	Degree Centigrade
No	Number
G	Germination
MGT	Mean germination time
GI	Germination index
SVI	Seedling vigour index
FYM	Farm yard manure
cm	Centimeter
N	North
E	East
G	Grams
%	Per cent
/	Per
et al	et alia
Fig	Figure

Chapter- 1 INTRODUCTION

Multipurpose tree species (MPTs) refer to all woody perennials that are purposely grown so as to provide more than one significant contributions to the production and/ or service function. Those function may be food, animal, feed, medicine, fuel, timber, shade, shelter, ornamental, soil conservation *etc* and the cultivation of these trees is usually economically but also sometimes ecologically motivated, in a multiple- output land- use system (Burley and Wood, 1991).

MPT has applied to trees for agro forestry refers to their use for more than service or production function in an agroforestry system and there are fast growing and capable of growing successfully in a wide range of environment (Nair, 1990). The demands of the fast growing multipurpose trees in plantation programs are immense all over the world (Mahmud *et al*., 2005).

Commercial and economic tree species have been the main focus for afforestation and agroforestry (Fox *et al*. 1994), and little effort has been made to study the germination and growth of producing wood and food products (Tewari and Dhar, 1996). Establishment phase is the critical phase in the growth and development of any species which normally extends up to one year. The assumption was that these economically important species may be preferred if information on their germination and survival rates, and growth is available by analyzing a series of plant component growth attributes for each species.

Farmers grow along with agricultural crops various multipurpose trees on boundaries between agricultural fields. With the increasing recognition of agro forestry as an alternative land use, many scientists have focused their attention on trees. These trees contribute to sustainability of food production and are essential for the survival of local population (Tripathi *et al*., 2000).

Among the different seven MPTs, *Celtis australis, Grewia optiva, Bauhinia semla, Bauhinia variegata, Ficus auriculata, Quercus semecarpifolia, Quercus floribunda* are widely grown in different plantation programs. It is also important for reforestation and afforestation programs. That provides fuel and fodder and commercially important wood products appreciated by local people in Garhwal Himalaya. Rural folk of Central Himalaya cultivate various tree/shrub species in or around their agricultural fields, home gardens and in fallow lands, which

are not suitable for cultivation of agricultural crops. As many as 43 tree/shrubs have been identified as multipurpose for the region (Bhatt and Verma, 2002).

Bauhinia semla (Semla) belongs to family legumineaceae (sub-family Caesalpiniaceae) is distributed in tropical and subtropical to the Himalaya up to 1400 m elevation. The absolute minimum and maximum temperature in its natural zone ranges widely from 2^0C to 46^0C. The tree adapts wide range of rainfall from 500 mm to 2000 mm per annum, but restricts its distribution below 500 mm annual rainfall. It grows on a wide variety of rocks and soils. In the sub-Himalayan tract, it is mostly found on shale, sandstone and conglomerates (Troup, 1921).

Bauhinia variegata (Kachnar) is common in the sub-Himalayan region and outer Himalayan valley also found in Assam, M.P. and the Western parts of the Indian peninsula. It is widely cultivated throughout the country for its leaf fodder and beautiful flower. It grows well in the region with the maximum shade temperature up to 47^0 C and temperature as low as 0^0 C. The tree adapts itself to a wide range of rainfall from 500 to 2500m; optimum range being 760-1900 mm. The tree requires a wide variety of soils ranging from gravelly, shallow and rocky on the hill slopes to sandy loam and loamy soil in the valleys. The species occurs naturally in the North Indian moist deciduous and Northern tropical dry deciduous forests as distinguished by (Champion and Seth, 1968). *B. variegata* is found in the hills, plateaus, and valleys in the sub-Himalayas, upto 1800 m, but in the dry, rocky hills of the peninsular region only upto 1250 m. It is moderate light- demander, frost and drought hardy and with stand dry and rocky situations (Luna, 1996).

Bauhinia species are used mainly as fodder during the lean period (When there is no other feeding material available) particularly summer season. Farmers lop this tree to feed their cattle and buffaloes. Very little scientific and systematic information is available on these agroforestry species and its productivity potential *Bauhinia* species is an important species of subtropical forest ecosystems with a rich diversity of forms ranging from trees, shrubs to climbers and is represented by about 15 species in India. *Bauhinia semla* and *Bauhinia variegata* are ecologically as well as economically important, where need to be included in different agroforestry systems. Natural populations of both species are threatened by over exploitation for fodder and firewood. The local inhabitants used *B. variegata* flower for making pickles and

vegetable that seed formation decline and thus its natural regeneration is hampered (Anonymous, 1988).

Grewia optiva (Bhimal, Bihul) is one of the important multipurpose, lean season, nutritive fodder species belonging to family Tiliaceae. It is distributed from the foothills of the western Himalayas from Jammu & Kashmir to Nepal upto 2000 m elevation (Brandis, 1906). It is a sub-tropical tree and indigenous to India. *G. optiva* is a moderated-sized deciduous tree with a short straight trunk and smooth grey bark. It is a strong light demander and requires complete overhead light for its optimum growth. The tree is easily propagated from cuttings or from seeds (Uniyal, 1998). It can tolerate heavy pruning, having good coppicing and pollarding ability. It grows to the temperature ranges from -10^0C to 38^0C and annual rainfall from 700-2500 mm (Gupta, 1993). It can withstand mild drought and frost, but is fire-tender. Bark fibre extensively used for ropes, nets, sacs, brushes, brooms, *etc*, sticks after peeling off the bark used to lit fire (Gaur, 1982).

Celtis australis (Kharik) belongs to family Ulmaceae is a promising indigenous agroforestry tree species of Central Himalaya, India, extending eastwards to Nepal (Gaur, 1999). It is a moderate sized deciduous tree, commonly cultivated in Jammu and Kashmir, Himachal Pradesh, Uttaranchal and parts of Eastern Himalaya at altitudes between 500- 2500 m (Luna, 1996). It grows well in the region with the maximum shade temperature up to 38^0C and temperature as low as -8^0C and annual rainfall from 1200-2500 mm. It is a moderate light demander trees. It plays a vital role in the livelihoods of the hill people by supplying highly palatable, nutritious and tannin-free fodder for livestock, particularly during the lean period (Singh, 2004). Its timber is excellent and used for making tool and whip handles, cups, spoons, agricultural implements, *etc* (Bhatt and Verma 2002).

Ficus auriculata (Timla) belongs to family Moraceae is distributed in Meghalaya, Manipur, as well as in outer Himalaya from Himachal Pradesh to Bhutan, Bangladesh, Myarmar up to 1500 m elevation. It is sub deciduous trees and also known as Elephant Ear Fig. It grows on variety of soils but thrives well on loam soil. The maximum temperature in its natural habitat extends from 35 to 45˚C and a minimum of 0 to -4˚C. It is also fair coppice. Fruits are eaten raw and cooked as vegetable. They are made into curries or jam. The bark yields a coarse fiber (Bhatt *et al.*, 1992).

Quercus semecarpifolia (Kharshu) belongs to family Fagaceae is middle to a large gregarious, evergreen to nearly evergreen, forming a long clean bole under favorable conditions. The tree is found throughout the Himalayas from Bhutan westwards, mainly between 2400-3000 m elevation (Brandis, 1906). The tree grows in the temperate zone of Himalayas. The maximum temperature in its natural habitat extends from 30°C and a minimum of 0°C and annual rainfall varies from about 500 to 2500 mm. This oak is a light- demander and fails to establish under shade. It coppices and pollards fairly well, and the growth of coppice-shoots is slow. The direct sowing of seed has been successfully adopted in various parts of India (Chaturvedi, 1957). Wood used for construction and fuel and leaves as fodder.

*Quercus floribunda (*Moru) belongs to family Fagaceae is a large evergreen tree the Himalayan regions.the trees is found the Himalayas from Bhutan, mainly between 2100-2700 m elevation (Sharma *et al*., 2000). The maximum temperature in its natural habitat extends from 28°C and a minimum of 4°C and annual rainfall varies from about 1100 to 2400 mm (Stewart, 1984). It is frost- hardy and favours moist and cool locations with deep and fertile soil. Best growths are on well- drained clay loam. Wood used for house hold articles and as fuel; leaves provide fodder and fruits eaten by wild animals, charcoal, timber for construction and agriculture implements (Gaur, 1999).

Regeneration of *Q. semecarpifolia* and *Q. floribunda* in a subalpine forest of western Himalaya (Negi *et al*.,1992).Oaks forests are also considered as established and climax communities (Singh and Singh, 1992), Oaks as dominant tree species for fodder, fuel wood and timber for Garhwal region of Uttarakhand. The oak forests are source of fuel wood, fodder and can be correlated with natural springs and wildlife (Bargali *et al.*, 1998).

Growth and biomass production potential of multipurpose tree species vary from site to site (Radoglou and Teskey, 1997). Most of the fodder and fuel wood tree species of Garhwal Himalayas are under stress because of unplanned or unscientific lopping (Husen and Nautiyal, 2004). It has been remembered that the improvement and preservation of life in the third world will largely depend on the presences of forest and also availability of fuel wood (Perschel, 1991). Therefore, to meet this critical requirement of fodder and fuel wood tree species, and to reduce the pressure on natural forests stand, there is a strong need to screen the fast growing fodder and fuel wood tree species in hilly region of Garhwal Himalayas. Farmers widely prefer fast growing

multipurpose trees for their plantation programs. Legumes are found to get popularity because of its fast growth, nitrogen – fixing and coppicing behavior and ability to adapt in wide range of environments. The demands of fast growing multipurpose trees in plantation programs are immense.

Seed and seedling stage are two of the most critical phase during a plant's life history, while seed germination is irreversible process with high-risk, wrong timing and location of germination may cause the death of individual, impacting population recruitment (Harper, 1977). Seed germination and seedling growth are influenced by many abiotic and biotic factors; soil is thought to be very important factor for the seed germination of many plant species (Borchert *et al.*, 1989).

All the above facts in mind, the present study was planned to know the Seedling growth and survival of seven multipurpose agro forestry tree species (*i.e. Grewia optiva, Celtis australis, Bauhinia variegata, Bauhinia semla, Ficus auriculata, Quercus semecarpifolia, Quercus floribunda)* of Garhwal Himalaya, India with the following broad objectives:

- Evaluation of seed germination, survival and seedling vigour index of seven multipurpose tree species.
- Assessment of periodical growth performance of seven multipurpose agro forestry tree species.
- Estimation of biomass allocation of seven multipurpose agro forestry tree species.

REVIEW OF LITERATURE

A comprehensive review of literature is of great importance for any research and is an integral part of any investigation, as it not only gives an idea on the work done in the past and assists in delineation of problem area but also provides basis for interpretation and discussion of findings. This chapter briefly reviews the earlier studies conducted on the subject matter.

1: Evaluation of seed germination, survival and seedling vigour index of seven multipurpose tree species.

Paliwal and Kannan (2000) analyzed the morphological and nutritional characteristics of four MPTs. Seedlings *of Adenanthera pavonina* had a higher shoot/root ratio than the seedlings of other species in this study. The significant difference in shoot/ root ratio has benefits for survival of *Cassia siamea* and *Peitophorum petrocarpum* and *Albizia lebbeck* nursery condition.

Alam *et al*., (2004) carried out a study in growth performance of *Leucaena leococephala* under different condition at nursery stage. In dry season, the growth is poor, but starting the wet season, there was sharp rise in growth.

Mahmud *et al*., (2005) observed that germination behavior and initial growth performance of eight multipurpose tree species. Germination of *Leucaena leucocephala* was found highest (80%) followed by *Acacia auriculiformis* (68%) and *Acacia tortilis* was the lowest (8%). *Sesbania sesban* showed maximum height (127.17 cm in the nursery) followed by *Leucaena leucocephala* (336.13 cm), *Senna siamea* respectively. *Dalbergia sissoo* (7.23 cm) and *Acacia nilotica* (5.81 cm) was found to show the poorest growth performance in the nursery. In the planting site *L. leucocephala* showed maximum (100%) survival, followed by S. sesban (97%) and S. siamea (96.67%). The results also revealed that *S. sesban* and *L. leucocephala* are the best performing species and these species will be most suitable for plantations.

Jabbar *et al.,* (2010) studied that seed germination and seedling growth were assessed for shoot length, root length, collar diameter, fresh weight, dry matter production, leaf number and number of nodules of the seedlings. Seedlings raised in poly bags of 23 x 15 cm size revealed best performance in respect to germination and other growth parameters. However, root-shoot

ratio was higher in root trainer in comparison to other treatments. Poly bag size of 23 x 15 cm was found suitable in the nursery for quality seedling production of *Albizia procera.*

Yucedeg and Gultikin (2011) reported that seeds of twenty two leguminous species were sown without any pretreatment in order to investigate the effect of sowing time on their germination in the forest nursery. Three *Bauhinia* species, two *Colutea*. species two *Cytisus* species, *Gleditsia triacanthus,* two *Robinia* species, *Sophora japonica*, *Spartium junceum* seeds germinated successfully on all the studied sowing times. Besides, it was detected the sowing times that *Amorpha fruticosa, Calicotome villosa, Coronilla emerus* seeds had no germination. It could also be concluded that seed sowing in the early spring were more effective on germination percentages of all the species.

Alem *et al*., (2012) reported that performance of germination, growth of leguminous tree species under nursery condition. *Albizia procera, Albizia chinensis, Leucaena leucocephala, Acacia auriculiformis and Acacia mangium*. Germination percentage (99%) was found higher in *Albizia procera while L. leucocephala* species showed higher germination value (22.45%) and *Albizia richardiana* root- shoot ratio (2.72) in comparison to the remaining species. The shoot length, collar diameter and root length were higher in *L. leucocephala, A. procera* and *A. auriculiformis*. Total biomass, quality index and vigour index were significantly higher in *A. procera* and *L. leucocephala.*

Chavan *et al*., (2015) reported that standardization of nursery techniques in *Simarouba gluaca.* Silvicultural parameters of *Simarouba seedlings viz*. shoot length, root length, collar diameter fresh weight, dry matter production and numbers of leaves were maximum in poly bag. Vigour index and quality index were also significantly higher in poly bag. Poly bag was suitable for quality seedling production availability for commercial nursery.

2: Assessment of periodical growth performance of seven multipurpose agro forestry tree species.

Sharma and Purohit (1996) studied that seedling growth of nitrogen fixing *Alnus nepalensis* and *Albizia stipulate* was measured in nursery condition. Leaf area in both *A. nepalensis* and *A. stipulate* increased with seedlings age. *A. nepalensis* is a semi deciduous while *A. stipulate* is a deciduous. Leaf area ratio of *A. nepalensis* was higher than A. stipulate at 180 days seedling

stage and continued to remain higher supporting the fact that *A. nepalensis* performed more efficiently than *A. stipulate*.

Paliwal and Kannan (2000) analyzed the morphological and nutritional characteristics of four MPTs, *Cassia siamea, Adenanthera pavonina, Peltophorum peterocarpum* and *Albizia lebbeck* were compared for 6 month old seedlings grown in open nursery conditions. Among the four species *A. pavonina* seedlings attained poor root collar diameter and allocated comparatively little biomass to root rather than to shoot components.

Khan *et al.,* (2004) studied that performance of eleven multipurpose tree legume seedlings grown in the hill soils under nursery conditions. Seedling of *Acacia auriculiformis, Acacia* catechu, *Acacia mangium, Albizia lebbeck, Acacia procera, Acacia saman, Cassia fistula, C. siamea, Gliricidia sepium, Dalbergia sissoo* and *Leucaena leucocephala* were raised in polybags containing the soil of hilly areas. Initial growth response determined from shoot and root length, collar diameter, of the seedlings were found highest in *G. sepium* followed by *A. lebbeck* and *A. procera*. In comparison, *G. sepium, A. lebbeck* and *A. procera* possessed better growth performance while *C. fistula* was the poorest growth performance.

Sundriyal *et al.,* (2005) reported that seedling growth and survival of selected wild edible fruit species of Sikkim Himalaya. An enormous variety of wild growing plants are exploited at large scale for collection of their edible parts, of which 6 most prominently utilized fruit species (viz., *Baccaurea sapida, Diploknema butyracea, Elaegnus latifolia, Eriolobus indica*, *Machilus edulis* and *Spondias axillaris*) were investigated. The growth of nursery raised seedling was measured at 3 month intervals until two years old in terms of leaf area ratio, root shoot ratio, relative growth rate, root, shoot, leaf biomass. For all species, seedlings attained significant sizes after one year of age, and showed reasonable survival after transplantation into the farmer's fields.

Alvarado (2006) conducted a study in seedling were grown in plastic bag and planted out after 6 months by hand. Measurements of different growth parameters and leaf biomass over 15 years were evaluated. The species *Crescentia alata, Enterobium cyclocarpum, Gliricidia sepium* and *Haematoxylon brasilleto* tented to have better characteristics in nursery condition.

Ferdouse *et al.,* (2010) reported that comparative growth performance of *Leucaena leucocephala* seedlings raised in nursery bed, poly bag and root trainers seed germination and seedling growth were assessed for shoot length, root length, collar diameter, fresh weight, dry matter production, leaf number and number of nodules of the seedlings. Germination percentage was found better in nursery bed. Seedlings raised in poly bags of 23 x 15 cm size revealed best performance in respect to germination and other growth parameters. Poly bag size of 23 x 15 cm was found suitable in the nursery for quality seedling production of *Leucaena leucocephala.*

Yadav *et al*., (2014) reported that growth performance of Sal in Mahamaya Central Forest Nursery. There are prominent variations in the seedlings height during the 6 months period and one year aged seedlings. The root shoot ratio at 6 months stage of Sal seedling ranged between 0.67 to 0.82 the root shoot ratio at 1 year old Sal seedling ranged between 0.31 to 0.74 The growth performance of the Sal seedling is slower as compared to other tropical species in the nursery stage. Proper management practices should also be opted so that the good growth performance can be achieved.

Sarmin *et al.,* (2014) reported that seedling growths of four multipurpose tree species (MPTs) were grown to evaluate comparative seedling growth in four different types of container up to six months in nursery condition. *Gliricidia sepium, Delonix regia* were leguminous and *Terminalia arjuna* and *Swietenia mahagoni* were non-leguminous and containers were gunny bag, poly bag, earthen pot and bare rooted. Leguminous species showed better growth performance than the non-legume species. *G. sepium* performed better than the other three species in terms of plant height, collar diameter, and biomass production.

3. Estimation of biomass allocation of seven multipurpose agro forestry tree species.

Sharma and Purohit (1996) studied that seedling growth of nitrogen fixing *Alnus nepalensis* and *Albizia stipulate* was measured in nursery condition. The belowground to aboveground dry matter ratio increased with the seedling age in *A. nepalensis,* while it decreased in *A. stipulate. A. nepalensis* showed weaker proportion of belowground parts in the early stages of seedling and then slowly developed with age. In contrast, *A. stipulate* showed well-established belowground part right from one month old seedling stage.

Paliwal and Kannan (2000) carried out studies on *Cassia siamea* and *Peltophorum petrocarpum* seedlings had higher biomass production per unit nitrogen uptake and were found to be more efficient in utilizing nitrogen than *Adenanthera pavonina and Albizia lebbeck. Cassia siamea* and *Peltophorum petrocarpum* seedlings had a lower nutrient demand.

Khan *et al.,* (2004) studied dry weight of shoot and root of the seedlings were found highest in *Gliricidia. sepium* followed by *Albizia lebbeck* and *Albizia procera*. In comparison, *G. sepium, A. lebbeck* and *A. procera* possessed better growth performance while *Cassia fistula* was the poorest growth performance.

Mahmud *et al.,* (2005) studied that seeds of seven *Leucaena leucocephala* varieties were treated equally and sown polybags in the nursery. The result revealed that all of those exotic varieties have the potential to grow fast and Maximum biomass was found with the variety 1.1(432 gm).

Alvarado (2006) conducted a study in seedling were grown in plastic bag and planted out after 6 months by hand. The species *Crescentia alata, Enterobium cyclocarpum, Gliricidia sepium* and *Haematoxylon brasilleto* tented to have better characteristics in terms of growth annual rate 33- 62 cm in height and 1.7- 2.6 cm in diameter, while *Albizia caribaea, Albizia gauachapel, Caesalpinia velutina* (20- 30 cm in height and 1.2- 1.7cm in diameter) did not establish well due to susceptibility to frost.

Husen (2013) studied that growth characteristic, biomass of Garhwal Himalaya's fodder and fuel wood tree species at nursery stage. Seed *of Bauhinia purpurea, Bauhinia retusa, Bauhinia variegate, celtis australis, Ficus nemoralis, Ficus roxburghii, Grewia optiva, Leucaena leucocephala, Melia azedarach, ougeinia oojeinensis, Quercus leucotrichophora, Terminalia alata,* and *Toona ciliata* were collected from the superior trees and seedlings were raised in nursery. Biomass was found highest in *Q. leucotrichophora* which indicates photo synthetically this species was most active among the studied fodder and fuel wood tree species.

Chavan *et al*., (2015) reported that standardization of nursery techniques in *Simarouba gluaca.* Silvicultural parameters of *Simarouba seedlings* of fresh weight, dry matter production and numbers of leaves were maximum in poly bag and raised bed. Poly bag is suitable for quality seedling production availability for commercial nursery.

Chapter- 3

MATERIALS AND METHODS

The present investigation entitled **"Seedling growth and survival of seven multipurpose Agroforestry tree species of the Garhwal Himalaya"** was undertaken in the Department of Forestry, College of forestry (V.C.S.G. Uttarakhand University of Horticulture and Forestry) Ranichauri, Tehri Garhwal, Uttarakhand, during January 2015 to June 2016.

3.1 Site of experiment

3.1.1 Location

The experiment site were selected in the College of Forestry,V.C.S.G. Uttrakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal is located 10 km away from Chamba (Rishikesh-Gangotri Road) at an altitude of about 2100 meter mean above sea level, lying between 30^0 15' N latitude and 78^0 30' E longitudes under mid hills of Uttrakhand, India.

3.1.2 Climate of Ranichauri campus

The field parameters were carried out in the experimental block of forestry department nursery at College of Forestry, Ranichauri. Ranichauri campus experiences humid and temperate type of climate with chilled winters. The mean monthly maximum and minimum temperature during the study period (January to June, 2015-2016) varies between 40.3^0C to 13.5^0C, respectively. The average annual rainfall of 1.2 to 276.4 mm (2015- 2016). Major portion of annual rainfall occurs during August. Winter rains and snowfall occurs during December-February **(Table.1).**

Table 1: Monthly meteorological data during the period of investigation (January to May, 2015-2016)

Month	Temperature (^{0}c)	Relative humidity (%)	Rainfall (mm)	Sunshine (hrs.)
January	13.5	83	55.8	5.6
February	17.4	83	69.7	6.5
March	21.6	76	192.8	6.4
April	29.3	75	53.7	8.0
May	39.4	58	57.4	10.2
June	40.3	72	130.3	7.0
July	38.9	95	276.4	4.3
August	39	96	197	4.9
September	36.7	88	20.3	7.5
October	31.4	78	7.5	7.6
November	24.9	79	5.3	7.7
December	16.1	79	14.6	6.3
January	14.4	79	1.2	6.6
February	20.6	77	68.3	7.3
March	27.2	71	44.2	6.7
April	37.7	48	15.3	8.8
May	41	66	78.0	8.2

Source: Department of Agrometerology, College of Forestry, Ranichauri Campus, Tehri Garhwal Uttarakhand

3.2 Plant species selection and characteristic features:

The Seeds of *Bauhinia semla, Bauhinia variegata*, *Quercus floribunda, Quercus semecarpifolia, Celtis australis, Grewia optiva, Ficus auriculata* were collected from different regions of Garhwal Himalaya. The collected seeds were checked to remove the damaged seeds. The details of the selected MPTs (multipurpose tree species) are mentioned in **(Table.2).**

Table.2 Details of seven selected multipurpose tree species, their habit, habitat and distribution

Species	Local name	Family	Distribution	Plant habit	Habitat and range of elevation distribution	Seed source	Time of seed collection
Celtis australis	kharik	Ulmaceae	Western Himalaya eastward to Nepal, Manipur, Jammu & Kashmir, Himachal Pradesh and Uttarakhand	Deciduous tree, (25-30m)	Sub- tropical and temperate climate Between 500-2500 m	Maun	October
Grewia optiva	Bhimal	Tiliaceae	Western Himalaya from Jammu & Kashmir to Nepal, Bhutan.	Deciduous tree, 12 m	Subtropical forest between 1600 m	Darghi	November to January
Bauhinia semla	Semla	Caesalpiniaceae	The outer Himalayan tract and Shivaliks from Burma east- ward to Nepal, sub-Himalayas in the Chir pine and oak zone.	Deciduous tree, (20m)	Tropical and subtropical forest between 1400 m	Nagni	August to octobar
Bauhinia variegata	kachnar	Caesalpiniaceae	Sub-Himalayan tract:Nepal to Sikkim and Himachal Pradesh, Punjab,	Deciduous tree, (20m)	Tropical forest between 800-2000 m	Maun	March to June
Ficus auriculata	Timla	Moraceae	The outer Himalaya from Himanchal Pradesh to Bhutan, Myarmar and Uttarakhand.	Sub-Deciduous tree, (10m)	1500 m	Jhagdhar	July to August
Quercus semecarpifolia	Kharshu	Fagaceae	Throughout Himalaya : Garhwal, Kumaon, Bhutan, Nepal, Sikkim, Darjeeling, Arunachal Pradesh	Evergreen tree (24-30m)	Temperate zone between 2400-3000m	Chopta (Chamoli)	June to August
Quercus floribunda	Moru oak	Fagaceae	Western Himalaya, Nepal, Bangladesh	Evergreen 45 m	2100-2700 m	Chopta (Chamoli)	March to May

3.3. Germination media preparation

The germination experiments were conducted under the poly house condition. Before sowing of seeds in polybags, poly bags were filled with the mixture of soil, sand, and cow dung decomposed in 2:1:1 ratio. 100 polybags were arranged for sowing of seeds each species separately. Single seeds of each species were sown in each polybags and incase of *Ficus auriculata* for 4 seeds sowed in each poly bags. A single seedling was maintained per polybag after germination. Adequate watering and care were taken regularly. Seed germination was recorded daily up to 28 days.

After three month, 25 representative seedlings from each species were selected and 5 polybags were arranged in each row to make five replicates as described earlier. Seedlings of the seven species were raised in poly bags up to 12 months. Periodic measurement of various growth parameters in different plant components (stem, branches, root, and leaves) was recorded at three monthly intervals until plants were 12 months old.

3.3.1 Germination studies of MPTs.

3.3.1.1 Seed germination percent

The physiological process is the first stages of growth of seed. In seed germination, resumption of active growth in the embryo of a seed is demonstrated by the protrusion of the radical. In seed testing (ISTA definition), resumption of active growth in an embryo, which results in its emergence from the seed and development of those structures essential to normal plant development. It was the percent of sown seed germinated at the completion of test period, i.e., 28 days after sowing (ISTA, 1999). Germination percent was calculated by the formula:

$$\text{Germination (\%)} = \frac{\text{Total number of germinated seeds}}{\text{Total number of sown seeds}} \times 100$$

3.3.1.2 Mean germination time (MGT):

Mean germination time was calculated based on the following equation of Ellis and Roberts (1981).

$$MGT = \frac{\sum Dn}{\sum n}$$

Where, n is the number of seeds, which germinated on day D, and D is the number of days calculated from the beginning of the test.

3.3.1.3 Germination index (GI):

Germination Index was calculated the following formula given by Kendrick and Frankland (1969) as:

$$GI = \frac{\text{Total germination percent}}{\text{Time(hours)taken for 50\% germination}} \times 100$$

3.3.1.4 Survival of seedling (%):

Surviving plants in each bed were counted at the time of recording seedling traits (height, collar diameter, etc.) four months after sowing in the nursery and the survival per cent was worked out as follows:

$$\text{Survival (\%)} = \frac{\text{Total number of seedling survived}}{\text{total number of seedling}} \times 100$$

3.3.1.5 Seedling vigour index (SVI):

The seedling vigour index was calculated by given formula (Abdul-Baki and Anderson, 1973). Seedling vigour index was used for determining the germination percentage and seedling length for each tree species:

$$SVI = \text{Germination (\%)} \times \text{seedling length (cm)}$$

3.4. Growth characteristics recorded in polybags:

To assess the periodic growth, 25 seedlings of each species in each of the five replications were randomly tagged and data on morphological traits *viz*. plant height, diameter and number of leaves per seedling was recorded quarterly till 12 months. At the end of one year's growth, tagged seedlings were up rooted and seedling growths with regard to the following morphological parameters were recorded.

3.4.1 Shoot length(cm):

Shoot length was measured from the cut base to the shoot tip. The shoot length was calculated with the help of a measuring scale for 25 randomly seedlings were selected on periodic months 3, 6,9,12 for each replication.

3.4.2 Collar diameter (cm):

This was taken as the thickness of the stem from the ground level to the collar of the seedling. The collar diameter was calculated with the help of a using digital calliper (Mitutoyo Absolute). 25 randomly seedlings were selected on the periodic month 3, 6, 9, 12 for each replications.

3.4.3 Root length

The root length was measured with the help of a measuring scale from the cut base to the tip of the taproot. 25 randomly seedlings were selected for counting, after final one year for each five replications.

3.4.4 Root/ shoot length ratio:

The root length was divided by the shoot length of the same seedling to determine the root / shoot length ratio. 25 seedlings were selected for each five replication of each species.

3.4.5 Leaf area (cm^2)

10 leaves were taken from each tree species and leaf area was measured in cm^2 with the help of graphical method.

3.4.6 Number of leaves per seedling:

The total number of leaves per seedling was recorded from each seedling, which was counted by randomly selected 25 seedlings on periodic months 3, 6, 9 and 12 for each replication at seedling stages.

3.4.7 Seedling length (cm):

The total length of seedlings was recorded by adding root and shoot length for seedling length. 25 randomly seedlings were selected for each five replications of each species.

3.5 Determination of dry weight of seedling (biomass):

The biomass content was determined on dry weight basis as per ISTA rule, 1999. 25 randomly seedlings were selected for each five replications of each species. In the uprooted seedlings, shoot, root and leaves was detached and 10 gm of the materials will be put into samples viz., shoot, root and leaves.

3.5.1 Shoot dry weight (gm):

The shoot dry weight was obtained by drying at 72^0C for 24 hrs in oven. After drying shoot was weighed using electronic balance (Contech).

3.5.2 Leaves dry weight (gm):

Leaves dry weight was recorded in the same manner as the shoot dry weight.

3.5.3 Root dry weight

The root dry weight was recorded in the same manner as the shoot dry weight.

3.5.4 Root/ shoot dry weight ratio

The root /shoot dry a weight was work out by dividing the dry weight of root by the shoot dry weight of each seedling separately**.**

3.6. Statistical data analysis:

The field experiment data analysed according to the procedure of analysis of variance for two factor Randomized Block Design with five replication of seven multipurpose tree species. Data were collected on seed germination, growth performance and leaf area of seedling parameters were subjected to analysis using the statistical software (WASP version 1.0, ICAR GOA, India) online software package. The critical difference (5 % level of significance) will be calculated to compare the mean and standard deviation. The analysis of variance (ANOVA) procedures was used to test for significant effect of treatments. Correlation coefficient (Karl Pearson's) was also determined in order to know the strength of linear relationship among the parameters as dependent variables.

3.6.1 Standard Error of Mean SE (m): The data were subjected to statistical analysis as Described by Panes and Sukhatme (1978).

$$SE\ (m) \pm = \frac{\sigma}{\sqrt{n}}$$

Where,

SE = Standard Error of Mean

σ = Standard deviation all number of observations

n = Number of observations

Chapter- 4

RESULTS AND DISCUSSION

The experiment entitled **"Seedling growth and survival of seven multipurpose Agroforestry tree species of Garhwal Himalaya"** was conducted during the month of January 2015 to June 2016 at Department of Forestry research block, Ranichauri. In the present study seven multipurpose fast growing tree species (MPTs) were selected which is capable of growing successfully in a wide range of environment and used mainly as fodder, fuel, food, medicine etc. The results of seven studied species, *i.e*. *Bauhinia semla* and *Bauhinia variegata, Celtis australis, Grewia optiva, Ficus auriculata, Quercus semecarpifolia, Quercus floribunda* as per objective are as follows:

4.1: Evaluation of seed germination, survival and seedling vigour index of seven multipurpose tree species.

4.1.1 Nursery germination:

The results of seed germination percent in seven multipurpose tree species under nursery conditions are represented in Table 3. Significant differences ($p < 0.05$) were found among different tree species for nursery germination percent. On an average, seed germination ranged from 21 to 80 % among different tree species. The highest seed germination was recorded in *Grewia optiva* (80%), followed by *Bauhinia variegata* (75%) and *Bauhinia semla* (72%) whereas, minimum seed germination percent was recorded in *Quercus semecarpifolia* (21%). *Ficus auriculata, Quercus semecarpifolia* and *Quercus floribunda* demonstrated < 50% germination. *Celtis australis* exhibited 66% seed germination Table 3

4.1.2 Mean germination time (MGT)

The mean germination time ranged from 13.25 to 15.37 days. Significant ($p < 0.05$) differences were found among different tree species for mean germination time. The maximum mean germination time of 15.37 days have been recorded for *Quercus semecarpifolia,* followed by *Ficus auriculata* 14.59 days, and minimum mean germination time of 13.25 days was recorded in *Grewia optiva*. Highest MGT in *Quercus semecarpifolia* and *Ficus auriculata* indicated late and slow germination. Lowest MGT were recorded in *Grewia optiva* species indicates an early

and rapid germination as compared to other tree species. Mean germination time indirectly expresses the rapidity of germination as lower the mean germination time faster the germination, which was evidenced from the average value of MGT. Thus, the seeds of species *Quercus semecarpifolia* germination in 15.37 days whereas, *Grewia optiva* which process was faster, uniform germination and complete the germination in minimum 13.25 days (Table 3).

4.1.3 Germination index (GI)

The data on germination index of different multipurpose tree species revealed that the average mean GI values were significantly differing among all the seven tree species. On an average the germination index values ranged from 0.06 to 0.19. The maximum average germination index value was recorded for *Bauhinia variegata* (0.19), followed by *Grewia optiva* (0.18), whereas minimum GI value was recorded in *Quercus floribunda* (0.06) among different tree species. The corresponding higher values for germination index represent comparatively higher germination percentage, *e.g. Bauhinia variegata* had 75% germination.

4.1.4 Seedling vigour index (SVI)

Table 3 depicted the seedling vigour index of seven multipurpose tree species. The average mean SVI values were significantly differs among different tree species. The average SVI values ranged from 456.75 to 3840.80. The maximum average SVI value was recorded in *Grewia optiva* (3840.80) followed by *Bauhinia variegata* (32.96), whereas minimum seedling vigour index value was recorded in *Quercus semecarpifolia* (456.75).

Table 3: Germination percent, mean germination time, germination index and seedling vigour index of seven multipurpose tree species in nursery condition

Species name	Germination%	MGT(days)	GI	SVI
Celtis australis	66 ± 0.45^{ab}	13.84 ± 0.52^{c}	0.14 ± 0.05^{bc}	2744.94 ± 17.26^{bc}
Grewia optiva	80 ± 2.35^{a}	13.25 ± 0.54^{d}	0.18 ± 0.02^{ab}	3840.80 ± 22.62^{a}
Bauhinia variegata	75 ± 2.83^{a}	14.29 ± 0.50^{bc}	0.19 ± 0.03^{a}	2793.60 ± 21.96^{b}
Bauhinia semla	72 ± 3.65^{a}	13.48 ± 0.31^{c}	0.16 ± 0.01^{b}	3296.25 ± 23.48^{ab}
Ficus auriculata	58 ± 2.24^{b}	14.59 ± 0.93^{b}	0.10 ± 0.01^{d}	1413.12 ± 13.12^{c}
Quercus semecarpifolia	21 ± 1.10^{c}	15.37 ± 1.20^{a}	0.08 ± 0.02^{c}	456.75 ± 0.53^{c}
Quercus floribunda	27 ± 0.89^{c}	13.97 ± 1.00^{c}	0.06 ± 0.03^{d}	533.52 ± 5.12^{c}
LSD	**18.21**	**0.53**	**0.07**	**992.72**

Mean values followed by same letters are not significantly ($p < 0.05$) difference

4.2. Assessment of periodical growth performance of seven multipurpose agro forestry tree species.

Periodic growth such as shoot length, collar diameter, survival percent, leaf area (cm^2) and number of leaves/ plant of the seedlings of seven multipurpose tree species *viz. Celtis australis, Grewia optiva, Bauhinia semla, Bauhinia variegata, Ficus auriculata, Quercus floribunda* and *Quercus semecarpifolia* revealed that the *Celtis australis* represent shoot lengths in the intervals of 3, 6, 9 and 12 months were 22.67 cm, 32.46 cm, 40.49 cm, 43.51 cm respectively (Table 4). Significant differences ($p < 0.05$) were observed in the performance of seedling growth for shoot length at various stages of plant growth.

Root length of *C. australis* after one year of growth was recorded as 21.12 cm. After that total length of root and shoot length was accumulated as 64.63 cm and root/ shoot length ratio was 0.49 cm under nursery growth (Table 11).

The collar diameter of *C. australis* in periodic intervals of 3, 6, 9 and 12 months were recorded as 2.08 mm, 2.77 mm, 3.19 mm and 4.18 mm respectively. Significant differences were also observed in the performance of seedling growth for collar diameter at various plant growth stages (Table 4). The values extended on leaf number per plant in the periodic intervals in nursery were 6.54 cm, 9.82 cm, 10.39 cm, and 11.55 cm, respectively after 3, 6, 9 and 12 month's growth. Significant difference was observed in the performance of number of leaf at periodic intervals.

Wide variation was observed for leaf area in periodic intervals and the range of minimum and maximum values were extended from 79 cm^2 and 246 cm^2 after 3 and 12 month's growth. Significant variations were found in the performances of seedling growth for leaf area in periodic intervals. The data on survival percent in periodic intervals after 3, 6, 9 and 12 months in nursery were 27.27%, 24.24%, 22.73%, 21.35% respectively. A significant difference was found in the performance of seedling growth for survival percentage at periodic intervals.

Table 4: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival percent of *Celtis australis* in the nursery.

Month	Shoot length (cm)	Collar diameter (mm)	Number of leaves/ plant	Leaf area (cm^2)	Survival %
3	22.67 ± 2.85^{c}	2.08 ± 0.37^{c}	6.54 ± 1.25^{b}	79^{c}	27.27 ± 0.55^{a}
6	32.46 ± 5.83^{b}	2.77 ± 0.56^{bc}	9.82 ± 1.18^{a}	108^{b}	24.24±0.55a
9	40.49 ± 4.02^{a}	3.19 ± 0.85^{b}	10.39 ± 2.15^{a}	158^{b}	22.73 ± 0.71^{ab}
12	43.51 ± 5.49^{a}	4.18 ± 0.58^{a}	11.55 ± 2.00^{a}	246^{a}	21.35 ± 0.13^{b}
CV	**9.70**	**17.03**	**19.63**	**86.09**	**9.68**

Mean values followed by same letters are not significantly

It has been observed that the periodic shoot length of the seedlings of Grewia *optiva* in the intervals of 3, 6, 9 and 12 months were 29.05 cm, 37.53 cm, 42.08 cm, 50.00 cm respectively (Table 5). Significant ($P < 0.05$) differences were observed in the performance of seedling growth for shoot length at various stages of plant growth in *G. optiva*. Root length of *G. optiva* was measured as 25.1 cm only after one year of growth and the total length (root and shoot) of 75.10

cm was recorded and root/ shoot length ratio was 0.50cm in the nursery growth (Table 11). Collar diameter of *G. optiva* in periodic intervals of 3, 6, 9 and 12 months were recorded as 2.35 mm, 3.50 mm, 4.16 mm, and 4.84 mm, respectively. Significant variation was observed in the performance of seedling growth for collar diameter at various stages of plant growth.

The values of periodic data on number of leaf per plant at periodic were extended from 8.29 cm, 8.89 cm, 9.96 cm, and 10.39 cm, respectively after 3, 6, 9 and 12 months of growth. Significant differences in the performance of seedling growth were observed for number of leaf at periodic intervals. The leaf area of *G. optiva* seedlings at the age of 3, 6, 9 and 12 months were 86 cm^2, 179 cm^2, 285 cm^2, 339 cm^2 respectively. Significant ($P < 0.05$) differences in the performances of seedling growth were observed for leaf area at different periodic intervals. The data on survival percentage of *G. optiva* at periodic intervals was extended from 29.41%, 29.06%, 25.53%, 22.35% respectively, after 3, 6, 9 and 12 months growth. Significant differences in the performance of seedling growth were observed for survival percentage at periodic intervals (Table 5).

Table 5: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival % of *Grewia optiva* in the nursery.

Month	Shoot length (cm)	Collar diameter (mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival %
3	29.05± 1.26^{d}	2.35±0.68^{c}	8.29±1.28^{c}	86^{b}	29.41±0.45^{a}
6	37.53±1.45^{c}	3.50±0.63^{b}	8.89±1.45^{b}	179^{b}	29.06±0.35^{a}
9	42.08±3.98^{b}	4.16±0.31^{a}	9.96±1.12^{ab}	285^{ab}	25.53±0.45^{ab}
12	50.00±1.74^{a}	4.84±0.66^{a}	10.39±2.46^{a}	339^{a}	22.35±0.55^{b}
CV	**6.00**	**10.01**	**8.32**	**128.5**	**8.65**

Mean values followed by same letters are not significantly

In *Bauhinia variegata*, the shoot length in periodic intervals of 3, 6, 9 and 12 months were 25.67 cm, 28.64 cm, 40.62 cm, 43.95 cm respectively Table 6. Significant differences in the performance of seedling growth were observed for shoot length at various stages of plant growth (Table 6).

The root length of *B. variegata* was recorded as 23.04 cm after one 12 months growth. Total length of root and shoot was 66.99cm and root/ shoot length ratio was 0.52 cm after 12

months of growth (Table 11). Significant differences ($p<0.05$) in the performance of seedling growth were observed for collar diameter at various stages of plant growth. Collar diameter of *B. variegata* were observed as 2.12 mm, 3.35 mm, 3.87 mm, and 4.24 mm after 3, 6, 9 and 12 months of growth respectively. Significant differences ($p<0.05$) in the performance of seedling growth were observed for number of leaves at various stages of plant growth. The periodic data on leaf number per plant was 8.02 cm, 9.05 cm, 9.38 cm and 10.66 cm respectively, after 3, 6, 9 and 12 month's growth.

Leaf area of *B. variegata* was observed as 114 cm^2, 225 cm^2, 365 cm^2, 436 cm^2 after 3, 6, 9 and 12 month's growth respectively. There was significant ($p<0.05$) differences in the leaf area at periodic intervals.

The data on survival percentage was extended from 28.00%, 25.33%, 24.00%, 22.33% respectively, after 3, 6, 9 and 12 months of growth. Significant differences were recorded for survival percentage at different periodic intervals.

Table 6: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival % of *Bauhinia variegata* in the nursery

Month	Shoot length(cm)	Collar diameter(mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival%
3	25.67 ± 0.85^{b}	2.12 ± 0.49^{c}	8.02 ± 1.28^{c}	114^{c}	28.00 ± 0.55^{a}
6	28.64 ± 3.38^{b}	3.35 ± 0.54^{b}	9.5 ± 1.45^{b}	$225b^{c}$	25.33 ± 0.45^{a}
9	40.62 ± 4.86^{a}	3.87 ± 0.34^{ab}	9.38 ± 1.12^{b}	365^{a}	24.00 ± 0.55^{ab}
12	43.95 ± 3.42^{a}	4.24 ± 0.23^{a}	10.66 ± 1.46^{a}	436^{a}	22.33 ± 0.42^{b}
CV	**9.25**	**12.38**	**8.53**	**169.18**	**7.84**

Mean values followed by same letters are not significantly

Table 7 depicted the data on shoot length, collar diameter, number of leaves and leaf area of *Bauhinia semla* after different growth intervals. Significant ($p<0.05$) differences in the performance of seedling growth were observed for shoot length at various stages of plant growth. The shoot length of *B. semla* in periodic intervals of 3, 6, 9 and 12 months were 16.92 cm, 21.62 cm, 24.13 cm, and 33.80 cm respectively. Table 11 represents the root length, total length and root/ shoot length ratio of *B. semla*. Root length of 22.59 cm was recorded after one year's growth.

While total length was 56.39 cm and root/ shoot length ratio was observed as 0.67 cm after 12 months of growth in nursery condition.

There was significant ($p<0.05$) differences in the seedling growth performance were observed for all the growth attributes at various stages of plant growth. Collar diameter of *B. semla* was recorded as 1.89 mm, 2.27 mm, 3.2 mm, and 4.04 mm at periodic intervals of 3, 6, 9 and 12 months, respectively. The values extended for leaf number per plant in periodic intervals in nursery was 5.18 cm, 8.99 cm, 7.66 cm, and 9.32 cm after 3, 6, 9 and 12 month's growth respectively. Leaf area of *B. semla* was recorded as 169 cm^2, 335 cm^2, 482 cm^2, 556 cm^2 at periodic growth of 3, 6, 9 and 12 months of the seedlings, respectively in nursery.

The periodic data on survival percentage of *B. semla* was extended from 26.39%, 23.61%, 22.22%, 19.44% respectively, after 3, 6, 9 and 12 months of growth. Significant differences ($p<0.05$) in growth performance of seedling were observed for survival percentage at periodic intervals (Table 7).

Table 7: Periodic growth of shoot length (cm), collar diameter (mm), number of leaves/ plant, leaf area and survival % of *Bauhinia semla* in nursery.

Month	Shoot length(cm)	Collar diameter(mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival%
3	16.92 ± 1.84^{c}	1.89 ± 0.44^{c}	5.18 ± 0.30^{c}	169^{b}	26.39 ± 0.71^{a}
6	21.62 ± 3.83^{bc}	2.27 ± 0.19^{c}	8.99 ± 0.90^{ab}	335^{b}	23.61 ± 0.42^{b}
9	24.13 ± 3.50^{b}	3.02 ± 0.63^{b}	7.66 ± 0.79^{b}	482^{a}	22.22 ± 0.42^{b}
12	33.80 ± 3.85^{a}	4.04 ± 0.35^{a}	9.32 ± 1.19^{a}	556^{a}	19.44 ± 0.55^{c}
CV	**13.08**	**16.29**	**14.97**	**169.18**	**7.98**

Mean values followed by same letters are not significantly

The results of shoot length, collar diameter, number of leaves and leaf area of *Ficus auriculata* was given in Table 8. It has been observed that in *Ficus auriculata* shoot length in the periodic intervals of 3, 6, 9 and 12 months were 9.21 cm, 12.85 cm, 18.10 cm and 21.44 cm respectively. Significant differences in the performance of shoot length were observed at various stages of plant growth. Root length of *F. auriculata* was observed as 20.13 cm after one year's

growth. Total length of seedling was 41.59 cm and root/ shoot length ratio was recorded as 0.94 cm at the age of one year in the nursery (Table 11).

Collar diameter of *F. auriculata* seedling in the nursery was recorded as1.35 mm, 2.30 mm, 2.88 mm and 3.75 mm at periodic intervals of 3, 6, 9 and 12 months, respectively. Periodic data on leaf number per plant was observed as 6.81 cm, 7.45 cm, 8.14 cm, and 9.43 cm, after 3, 6, 9 and 12 month's growth respectively. Leaf area of *F. auriculata* was recorded as 32.25 cm^2, 59.25 cm^2, and 86.35 cm^2, 170 cm^2 at the age of 3, 6, 9 and 12 month's respectively (Table 8).

The survival percentage of the seedlings of *F. auriculata* was recorded as 25.00%, 22.92%, 20.83%, 18.97%, respectively after 3, 6, 9 and 12 months. Significant ($p< 0.05$) differences were recorded in survival percentage at periodic intervals.

Table 8: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival % of *Ficus auriculata* in nursery.

Month	Shoot length(cm)	Collar diameter(mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival%
3	9.21 ± 2.07^{d}	1.35 ± 0.25^{c}	6.81 ± 1.87^{c}	32.25^{b}	25.00 ± 1.58^{a}
6	12.85 ± 3.77^{c}	2.30 ± 0.46^{b}	7.45 ± 2.88^{bc}	59.25^{b}	22.92 ± 1.52^{b}
9	18.10 ± 1.77^{b}	2.88 ± 0.56^{b}	8.14 ± 1.72^{b}	86.35^{b}	20.83 ± 1.30^{c}
12	21.44 ± 2.77^{a}	3.75 ± 0.51^{a}	9.43 ± 1.28^{a}	170^{ab}	18.97 ± 1.52^{c}
CV	**7.08**	**18.01**	**11.24**	**80.19**	**3.74**

Mean values followed by same letters are not significantly

It has been recorded that shoot length in *Quercus semecarpifolia* was 5.56 cm, 9.41 cm, 11.13 cm, and 18.72 cm at periodic intervals of 3, 6, 9 and 12 months, respectively. Significant ($p<0.05$) differences in the growth performance were observed for all the growth attributes at various stages (Table 9).

Table 11 revealed that the root length of *Q. semecarpifolia* was 17.98 cm after 12 months of growth. Total length of seedling was 36.70 cm and root/ shoot length ratio was 0.96 cm after 12 months of growth in the nursery. Significant ($p<0.05$) differences was recorded for collar diameter at various stages of plant growth. Collar diameter of *Q. semecarpifolia* seedling in the nursery was recorded as 1.49 mm, 1.86 mm, and 2.19 mm and 2.45 mm at 3, 6, 9 and 12 months of periodic intervals, respectively (Table 9). The periodic data on leaf number per plant was 4.21

cm, 5.78 cm, 6.40 cm, and 6.94 cm, respectively after 3, 6, 9 and 12 month's growth. Significant ($p<0.05$) differences was recorded for number of leaf at periodic intervals. Leaf area of *Q. semecarpifolia* was found as 56.75 cm^2, 83.24 cm^2, and 116 cm^2, 183 cm^2 after 3, 6, 9 and 12 month's growth respectively. Survival percentage of 20.00%, 16.00%, 14.20%, and 12.00% in *Q. semecarpifolia* was recorded after 3, 6, 9 and 12 months of growth, respectively.

Table 9: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival % of *Quercus semecarpifolia* in nursery

Month	Shoot length(cm)	Collar diameter(mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival%
3	5.56 ± 0.62^{c}	1.49 ± 0.26^{c}	4.21 ± 0.73^{c}	56.75^{b}	20.00 ± 0.71^{a}
6	9.41 ± 0.51^{b}	1.86 ± 0.44^{bc}	5.78 ± 0.59^{b}	83.24^{b}	16.00 ± 0.45^{b}
9	11.13 ± 0.74^{a}	2.19 ± 0.24^{ab}	6.40 ± 1.08^{ab}	116^{b}	14.20 ± 0.55^{b}
12	18.72 ± 0.88^{a}	2.45 ± 0.47^{a}	6.94 ± 1.43^{a}	183^{ab}	12.00 ± 0.29^{c}
CV	**5.59**	**15.28**	**9.34**	**64.14**	**27.66**

Mean values followed by same letters are not significantly

The results of seedling growth performance of *Quercus floribunda* at different periodic intervals are given in Table 9. The shoot length of *Quercus floribunda* was 4.12 cm, 5.08 cm, 8.62 cm, 10.42 cm after 3, 6, 9 and 12 months of growth respectively (Table 10). The root length of *Q. floribunda* was observed as 26.26 cm at 12 months of growth. Total length of seedlings was 15.84 cm and root/ shoot length ratio was 0.52 cm in the nursery (Table 11). Collar diameter of *Q. floribunda* seedlings was recorded as1.55 mm, 1.75 mm, 2.07 mm, and 2.33 mm respectively after 3, 6, 9 and 12 months of growth. Significant differences in growth performance were recorded in collar diameter at various stages of plant growth (Table 10).

The data on leaf number per plant in periodic intervals under nursery was 2.08 cm, 3.49 cm, 5.04 cm and 5.32 cm after 3, 6, 9 and 12 month's growth, respectively. Nursery growth of *Q. floribunda* seedling further revealed that the leaf area at the age of 3, 6, 9 and 12 month's growth was 66.46 cm^2, 86.52 cm^2, 109 cm^2, 129 cm^2 respectively (Table 10).

Survival percentage of *Q. floribunda* seedlings was recorded as 22.58, 18.45, 14.29, and 10.71 % respectively at 3, 6, 9 and 12 months of growth. Significant ($p<0.05$) differences was recorded in growth performance for survival percentage at periodic intervals (Table 10).

Table 10: Periodic growth of shoot length, collar diameter, number of leaves/ plant, leaf area and survival % of *Quercus floribunda* in nursery.

Month	Shoot length(cm)	Collar diameter(mm)	Number of leaves/ plant	Leaf area(cm^2)	Survival %
3	4.12 ± 2.01^{c}	1.55 ± 0.21^{c}	2.8 ± 1.02^{c}	66.46^{c}	22.58 ± 0.45^{a}
6	5.08 ± 2.49^{c}	1.75 ± 0.30^{c}	3.49 ± 0.72^{b}	86.52^{b}	18.45 ± 0.45^{b}
9	8.62 ± 2.44^{b}	2.07 ± 0.31^{b}	5.04 ± 0.73^{a}	109^{a}	14.29 ± 0.55^{c}
12	10.42 ± 3.47^{a}	2.33±0.22a	5.32 ± 0.59^{a}	129^{a}	10.71 ± 0.53^{d}
CV	**16.59**	**8.17**	**8.35**	**31.76**	**19.17**

Mean values followed by same letters are not significantly

Table 11: Root length, Total length (root + shoot) and Root/shoot length ratio of one year old seven multiple tree species

Species	Root length (cm)	Total length (Root + Shoot)	Root/ shoot length ratio
Celtis australis	21.12	64.63	0.49
Grewia optiva	25.1	75.10	0.50
Bauhinia semla	22.59	56.39	0.67
Bauhinia variegata	23.04	66.99	0.52
Ficus auriculata	20.13	41.57	0.94
Quercus semecarpifolia	17.98	36.70	0.96
Quercus floribunda	15.84	26.26	0.52

3. Estimation of biomass allocation of seven multipurpose agro forestry tree species.

Seven multipurpose tree species *i.e. Celtis australis, Grewia optiva, Bauhinia semla, Bauhinia variegata,, Ficus auriculata, Quercus floribunda* and *Quercus semecarpifolia* were assessed for biomass allocation.

Figure 1 represents the data on the biomass production (dry weight basis) after 12 months growth of *Celtis australis*. Shoot dry weight, leaves dry weight, root dry weights and root and

shoot dry weight was 2.18 g, 1.2 g, 2.08 g and 0.95 g, respectively and the total dry weight was 5.46 g.

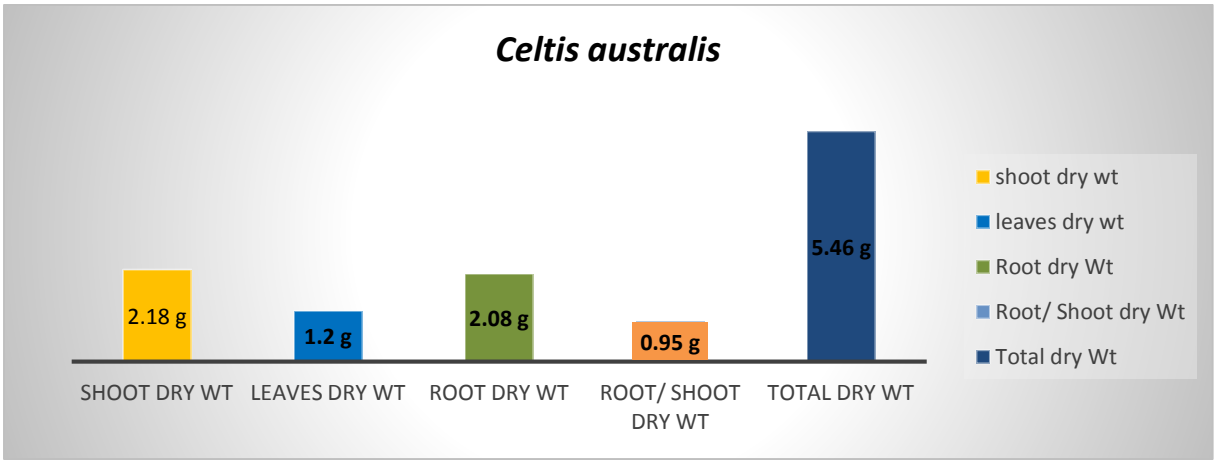

Figure: 1 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Celtis australis*

Shoot dry weight and leaves dry weight of *Bauhinia variegata* was recorded as 2.36 g and 1.16 g, respectively after 12 months of growth. While, root dry weight and root/shoot dry weight was recorded as 2.1 g and 0.88 g respectively and the total dry weight of seedling was 5.62 g after 12 months of growth (Figure 2).

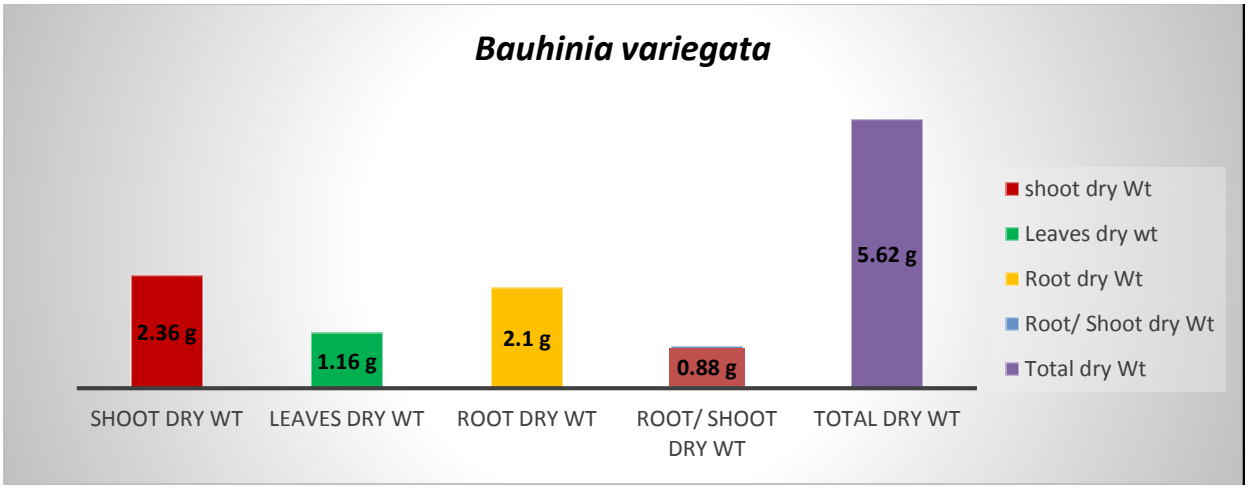

Figure: 2 Variation with respect to root-shoot and leaves dry weight (g/ plant) of the *Bauhinia variegata*

Figure 3 depicts the data on the biomass production of 12 months of seedling growth of *Bauhinia semla*. Shoot dry weight and leaves dry weight was recorded as 1.59 and 1.06 g, while,

the root dry weight and root/shoot dry weight ratio was recorded as 2.55 and 1.6 g, respectively. Total dry weight of *Bauhinia semla* seedlings after 12 month growth was 5.2 g.

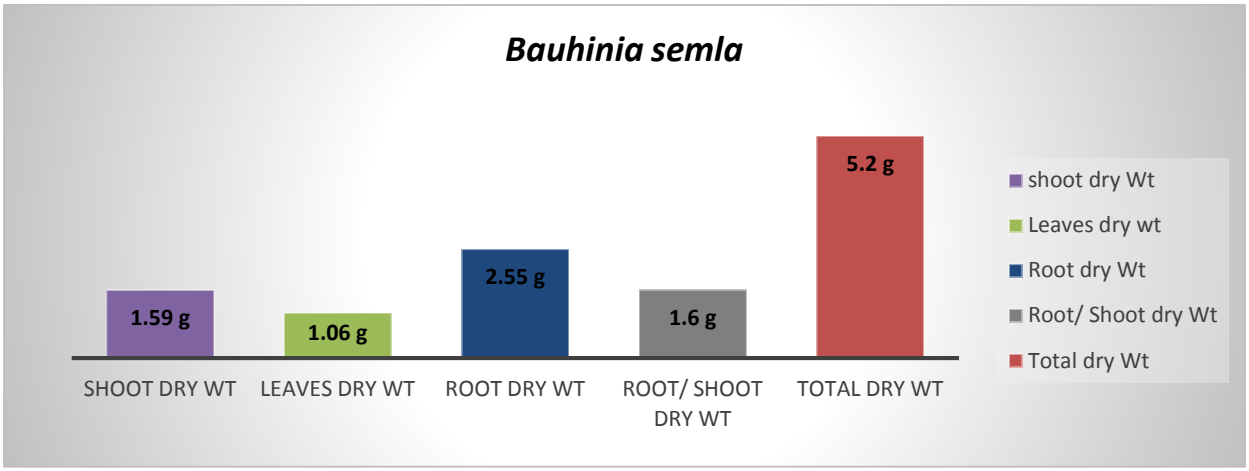

Figure: 3 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Bauhinia semla*

In *Grewia optiva* shoot dry weight was 3.21 g, the leaves dry weight was 1.14 g, the root dry weights was 2.12 g and root and shoot dry weight was 0.66 g, and the total dry weight of shoot, leaves and root was 6.47 g (Figure 4).

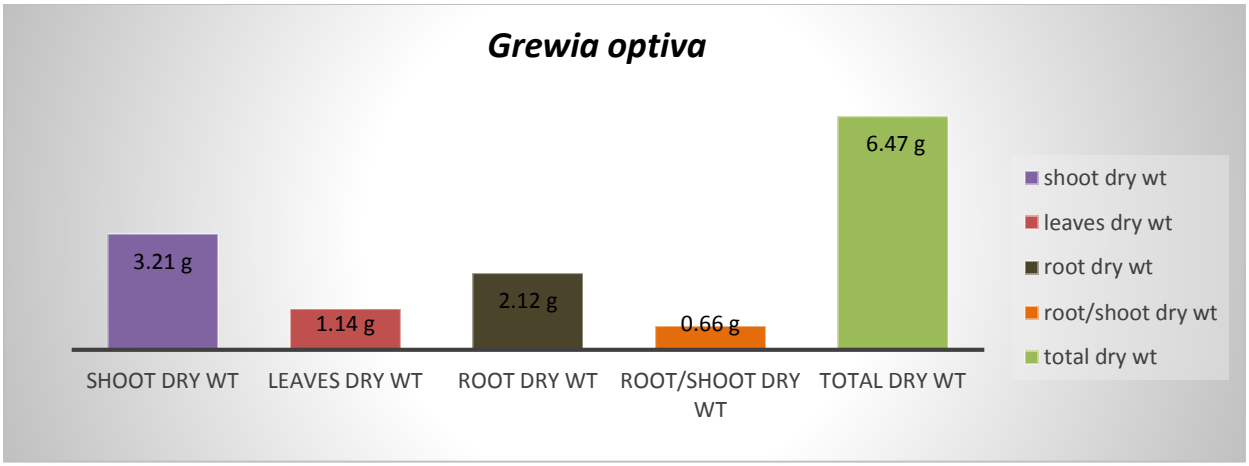

Figure: 4 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Grewia optiva*

In *Ficus auriculata*, shoot dry weight was estimated as 1.34 g, the leaves dry weight was 0.38 g, the root dry weights was 1.08 g and root and shoot dry weight was 0.81 g, and the total dry weight of shoot, leaves and root was 2.8 g (Figure 5).

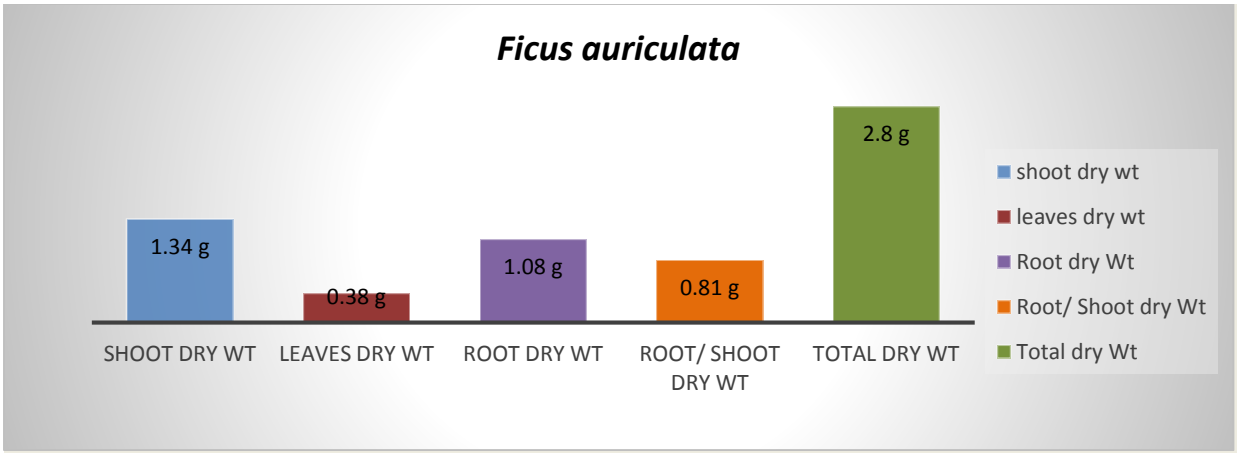

Figure: 5 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Ficus auriculata*

After 12 months growth, the shoot, leaves, root and root/shoot dry weight of *Quercus semecarpifolia* was recorded as 1.15 g, 0.24 g, 1.04 g and 0.91 g, respectively. Total dry weight of seedling after 12 months of growth was recorded as 2.43 g (Figure 6).

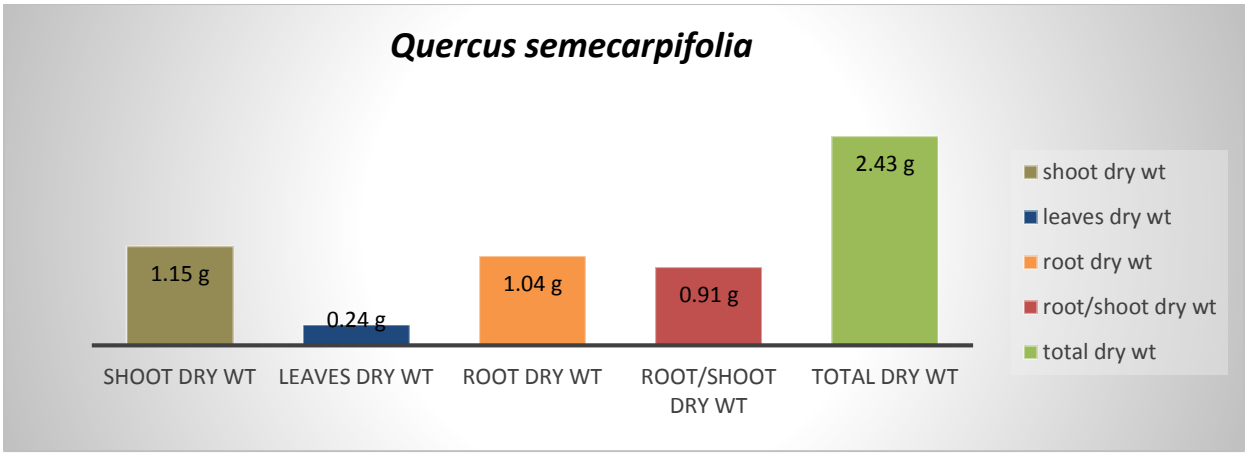

Figure: 6 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Quercus semecarpifolia*

Figure 7 represent the shoot dry weight 1.24 g, and leaves dry weight was 0.79 g, root dry weights 1.18 g and root/shoot dry weight 0.95 g of *Quercus floribunda*. The total dry weight of seedling was recorded as 3.21 g after 12 months of growths.

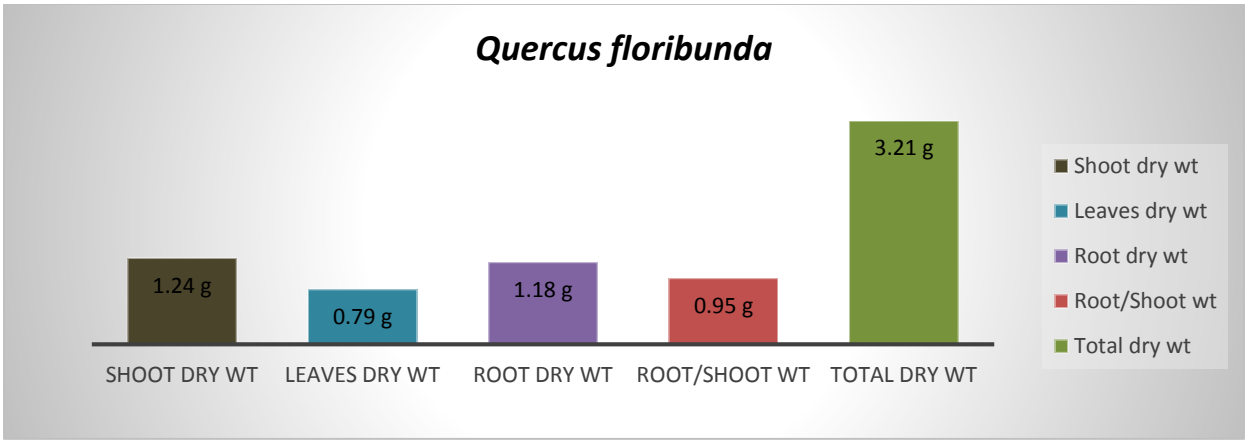

Figure: 7 Variation with respect to root- shoot and leaves dry weight (g/ plant) of the *Quercus floribunda*

Discussion:

Seed germination and seedling growth are both affected by a number of environmental factors including light, moisture, temperature and the availability of oxygen and CO_2. The management of these factors changes from one species to another. The knowledge of seed germination and seedling establishment is not only important for understanding the community processes such as plant recruitment and succession, but is also required for the success of efforts on augmentation, introduction, and reintroduction of species populations in restoration efforts. The information on the ecological requirements at seed and seedling stages are seldom articulated in forest conservation and management plans (Khurana and Singh, 2001).

According to Yucedag *et al.* (2011) the highest germination percentages for *Bauhinia variegata* (74.41%) and *B. racemosa* (75.37%) were obtained from the seed sowing in 1st February and 1st March, respectively. Pal and Nautiyal (2014) observed that the treated seeds started germination between 5 and 7 days after sowing which in the untreated seeds extended to 14th days. The integument breaking or softening is needed to remove dormancy imposed by seed coat hardness or impermeability.

All the species undertaken in this investigation are in high demand and they are used as fodder, minor timber and firewood purposes. Such multidimensional biotic pressure on these species has led to a reduction in their density and regeneration in natural stands (Sundriyal and

Sundriyal, 2004). Therefore, it is highly desirable that these species are propagated on a large scale in nurseries. However, it will also be necessary to study their growth strategies before they can be adopted into afforestation schemes as information on growth patterns will define the way in which these plant species develop. Fresh seed of *Bauhinia variegata* proclaimed high (95) percent germination. The bigger and heavy seeds provide large amount of reserve food material to the growing embryo, they are preferred for sowing in the nursery (Athaya, 1985). Freshly collected seeds of *Celtis australis* seeds freshly collected gives 66% germination in the nursery, which was at par with that of the study made by Ghosh, (1977) and very high as compared to that of the results obtained by Singh and Bhatt (2008), which was only 27.95% Sagwal (2003) reported that seed germination of *Celtis australis* starts within 10 days and continue for one month whereas in present study, it starts germination in 7 days. *Grewia optiva* germination starts within 10 days and taken one month to complete. About 65-80 % of total germination is achieved in 15 days. Recent studies have shown that if seed is sown in summer in May, it gives 65-85 % germination within 20 days and a uniform stock for planting is obtained in about 2.5 to 3 months in the winter.

Seedlings raised from heavy seed weight are healthier and better growing (Saleem *et al*., 1994). Seed size has been an important ecological attribute of plants to increase seedling survival in forest stands in low as well as high light conditions (Rose and Poorter, 2003) and such species persist longer in shaded conditions, which is a strong adapation and survival strategy (Leishman and Westoby, 1994). Large seed also produces larger seedling and thus results in an initial size advantage (Kidson and Westoby, 2000). Furthermore, seed mass plays an important role in seed dispersal, early seedling growth and competitive ability (Westoby *et al*., 1996).

Leaf area indicates leafiness in plant. The proportion of leaf biomass to total plant biomass was higher at early stages of growth in all species, and it decreased with the age of the seedling mainly due to an increase in root and shoot biomass. Total leaf area was directly related to the shoot growth. *Bauhinia variegata* and *Grewia optiva* registered higher shoot growth than the *Ficus auriculata* and *Quercus semecarpifolia*. Species that recorded fast growth also registered higher biomass allocation in stem and branches than the root component. This was contrary to the slow growing species where the root biomass was always higher than the shoot biomass (Singh and Singh, 1992). The rate of biomass allocation to the root component was slower than the shoot with the age of the seedlings. In general, maximum biomass was allocated to the main bole, which helps

to raise the canopy for maximum exploitation of light (Shukla and Ramakrishnan, 1984). Root biomass, in general, decreased in comparison to shoot biomass with advancement in seedling age (Toky *et al*., 1992).

Quercus semecarpifolia seeds proclaimed marginal germination while direct sowing (Negi and Naithani 1995), however, survival of nursery raised seedlings in plantation is very low, less than 4% in Nepal (Stewart, 1984). Due to lack of detailed information on seedling establishment and growth behavior of kharsu oak, the problems of poor survival of planted seedlings have remained unsolved (Jackson 1994, Shrestha and Paudel 1996).

There are three conditions that must be fulfilled before germination begins, *viz:* seed must be viable, adequate inner conditions (*eg*, living embryo, physiological and biochemical factors etc) and appropriate environmental condition (Hartman and Kester, 1983). However, such growth and survival in plants is a result of an interaction of environmental factors (light, moisture, nutrients, temperature *etc*) and plant internal physiological factors such as carbohydrate reserves, hormone levels, *etc* (Street and Opik, 1970). Thus, raising seedlings to a desired phenotypic in the nursery is possible by the manipulation of the plant material and the surroundings such as climatic and edaphic factors (Lavender, 1984).

According to the Cherdsak (2016) seeds of *Ficus auriculata* began to germination within 3-4 weeks after sowing and completed germination with 7-8 weeks and the germination percentage was 65%. In the present study, seed germination in *F. auriculata* was started at 8 days and had shown 58% seed germination and seedling survival of 18.97 percent. The recorded less survival is because the *Ficus* seeds are so small, they do not contain sufficient food reserves to support early seedling growth, which probably makes them unsuitable for direct seedling (Doust *et al.,* 2006).

Husen (2012) has found 119.34 cm height growth and 16.84 mm collar diameter reported of Grewia optiva seedling at the age of 9 to 12 months and *Celtis australis* was found to grow up 41.54 cm height, collar diameter 4.13 mm increment at nursery stage after 9 to 12 month. In present study, the recorded values are within the range in case of Celtis australis and twice less in case of Grewia optiva. All the studied species in the present study are indigenous and have shown good and survival except under nursery condition Quercus species which would excel their agroforestry potentials as well as afforestation and reforestation programs of this hilly region.

Bashir *et al*., (1989) reported that both the *Quercus* species are slow growing in nature and the result obtained in this study are also in agreement with the other study (Negi and Naithani, 1995, Saklani *et al* 1999). *B. varigata* and *B. retusa* are the N_2 Fixing ability and it's most suitable for the afforestation programme in agroforestry system of Garhwal Himalaya.

Chapter-5 SUMMARY AND CONCLUSION

The present investigation entitled "**Seedling growth and survival of seven multipurpose Agroforestry tree species of Garhwal Himalaya**" covers the following aspects.

- Evaluation of seed germination, survival and seedling vigour index of seven multipurpose tree species.
- Assessment of periodical growth performance of seven multipurpose agro forestry tree species.
- Estimation of biomass allocation of seven multipurpose agro forestry tree species.

The experiments were carried out during the year 2015-2016 in the nursery of the department of Forestry, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri,. Germination behavior, growth performance, leaf area and biomass allocation of different multipurpose tree species *(Celtis australis, Grewia optiva, Bauhinia retusa, Bauhinia variegata, Ficus auriculata, Quercus semecarpifolia, Quercus floribunda)* was evaluated. Seeds and Pods of all multipurpose tree species were collected from the natural habitat in the month of January and November with the purpose of studying the extent and pattern of variation in seed germination, periodic nursery growth of seedling, survival percentage, and biomass production.

Various aspects, *viz.* general description, species distribution uses and services have been briefly incorporated in the introduction with an aim to give complete information about the species for the use of research and development. The salient findings of the present investigation are summarized below:

1. Seed germination characteristics

❖ The maximum germination percent, germination index and mean germination time, vigour index of seven multipurpose tree species was recorded in the nursery stages.

❖ Variation was recorded in seed germination in all the analyzed species. Significant ($p < 0.05$) variations have been observed for seed germination traits. Further, maximum (80%)

seed germination was recorded in *Grewia optiva* and minimum (21%) in *Quercus semecarpifolia* (21 %).

- Significant ($p < 0.05$) variation was also observed for mean germination time (MGT) among tree species. However, MGT was recorded highest (15.37 days) in *Quercus semecarpifolia,* followed by (14.59 days) *Ficus auriculata* and minimum value (13.25 days) exhibited i*n Grewia optiva*. There was significant ($p < 0.05$) variation for germination index (GI) among multipurpose tree species. The germination index was recorded highest (0.19±0.03) in *Bauhinia variegata*, followed by *Grewia optiva* (0.18±0.02) *and* minimum value demonstrated in *Quercus floribunda* (0.06±0.03).

- Seedling vigour index (SVI) among all the tree species had shown significant variation. The value of seedling vigour index was recorded highest (3840.80±22.62) in *Grewia optiva,* followed by *Bauhinia variegata* (3296.25±23.48) and minimum vigour index were observed in *Quercus semecarpifolia* (456.75±0.53).

2. Seedling growth characteristics

- After 12 months of age, the growth of seedlings of seven multipurpose tree species were examined for different growth attributes i.e. shoot length, root length, collar diameter, number of leaves/plant and total biomass. Growth performance of seedlings of seven multipurpose tree species had demonstrated Significant ($p<0.05$) variations for all the seedling growth characteristics. Total root length was recorded maximum (25.1cm) i*n Grewia optiva* and minimum (15.84) in *Quercus floribunda*. Total Shoot and root length was exhibited the highest (75.10 cm) in *Grewia optiva*, followed by *Bauhinia variegata* (66.99 cm), and lowest (26.26 cm) *Quercus floribunda*. The root/ shoot length ratio have been recorded maximum for *Quercus semecarpifolia* (0.096 cm), which was followed by *Ficus auriculata* (0.94 cm*),* and minimum for *Celtis australis* and *Grewia optiva* (0.49 and 0.50cm, respectively).

- Periodic growth of collar diameter among analysed tree species revealed significant *var*iations ($p < 0.05$). The highest value of collar diameter of seedling was recorded for

Grewia optiva (4.84±0.66 cm), followed by *Bauhinia variegata* (4.24±0.23 cm), whereas lowest value was recorded for *Quercus floribunda* (2.33±0.22 cm).

- On an average, the number of leaves/ seedling was recorded highest in *Celtis australis* (11.55±2.00), followed by *Bauhinia variegata* (10.66±1.46), whereas lowest value was recorded for *Quercus floribunda* (5.32±0.59). Significant variations ($p<0.05$) have been recorded for periodic growth of number of leaves/ seedling among all the tree species.

- Significant variations ($p < 0.05$) have been recorded for periodic growth of leaf area among tree species. Highest value for leaf area was recorded for *Bauhinia semla* (556 cm^2), followed by *Bauhinia variegata* (436 cm^2), and the lowest value was recorded for *Quercus floribunda* (129 cm^2).

3. Biomass attributes (dry weight basis)

- Consistent variations were also obtained for biomass production in one-year-old seedling grown from different tree species. Shoot dry weight was recorded highest for *Grewia optiva* (3.21 g/plant), followed by *Bauhinia variegata* (2.36 g/plant) whereas lowest was recorded for *Quercus semecarpifolia* (1.15 g/plant). Similarly, leaves dry weight was highest recorded for *Celtis australis* (1.20 g/plant), followed by *Bauhinia variegata* (1.16 g/ plant) and lowest dry weight was found in *Quercus semecarpifolia* (0.24 g/plant). The root dry weight was recorded highest in *Bauhinia semla* (2.55 g/plant), followed by *Grewia optiva* (2.12 g/plant) whereas, lowest root dry weight was found in *Quercus semecarpifolia* (1.04 g/plant) tree species. Likewise, total dry weight was recorded highest in *Grewia optiva* (6.47 g/plant), followed by *Bauhinia variegata* (5.62 g/plant) and lowest was found in *Ficus auriculata* (2.8 g/plant).

- The root/shoot dry weight ratio was recorded highest in *Celtis australis* (0.95 g/plant), followed by *Quercus floribunda* (0.90 g/plant), whereas lowest dry weight was recorded for *Grewia optiva* (0.66 g/plant).

In order to meet the exigency of leaf fodders, it is imperative to plant multipurpose trees with high nutritive value on the wasteland and fallow land or to integrate with agricultural and fruit crops under agroforestry systems. Fodder tree species on which farmers bank upon during the winter lean period when the grasses are dry, less digestible and unpalatable.

Conclusion

The aim of this investigation was to measure the variability of seed and seedling morphological characteristics and germination in multipurpose tree species. The initial growth performance is very important for any MPTs, as it gives an idea or reflects about the performance in field. In this studied, *G. optiva* and *B. variegata* have shown maximum germination percent and survival percent. *Q. semecarpifolia* and *Q. floribunda* showed a poor germination in the nursery. *G. optiva* exhibited maximum growth in terms of height, vigour index and collar diameter at nursery stage and number of leaves was found highest in *C. australis* and *B. variegata*. Leaf area in each studied tree species increased with seedling age. *B. semla* had shown maximum leaf area in the nursery. Hence, selection for plantation of *G. optiva* and *B. variegata* around agriculture fields in different agro forestry system of Garhwal Himalaya for rapid growth and higher biomass production can be advantageous. So, *G. optiva* and *B. variegata* as a fast growing fodder and fuel wood tree species for Garhwal Himalayas which leads with wider relevance and they have a great potential for extensive afforestation programmes of the study region in particular and the Himalayan region in general.

Seven multipurpose tree species in polybags was studied in the nursery

Bauhinia variegata

Quercus floribunda

Quercus semecarpifolia

Ficus auriculata

Celtis australis

Bauhinia semla

Grewia optiva

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Appendix I

Appendix -1: Analysis of variance (ANOVA) for height (cm) allocation of seven multipurpose tree species

Source of variation	DF	*Celtis australis* (cm)	*Grewia optiva* (cm)	*Bauhinia variegata* (cm)	*Bauhinia semla* (cm)	*Ficus auriculata* (cm)	*Quercus semicarpifolia* (cm)	*Quercus floribunda* (cm)
Treatment	3	38.23*	67.65*	38.62**	25.44*	124.12*	389.85**	31.97**
Replication	4	4.83*	0.99NS	1.60NS	1.53NS	21.70**	2.02**	2.62NS

*Significant at P < 0.05, **Significant at P < 0.01, NS= Non- significant

Appendix -2: Analysis of variance (ANOVA) for collar diameter (mm) allocation of seven multipurpose tree species

Source of variation	DF	*Celtis australis* (cm)	*Grewia optiva* (cm)	*Bauhinia variegata* (cm)	*Bauhinia semla* (cm)	*Ficus auriculata* (cm)	*Quercus semicarpifolia* (cm)	*Quercus floribunda* (cm)
Treatment	3	14.32**	33.99*	24.36**	21.38*	23.67*	9.27**	24.25*
Replication	4	2.59NS	5.33NS	0.91**	0.60NS	1.47NS	2.05NS	50.88NS

*Significant at P < 0.05, **Significant at P < 0.01, NS= Non- significant

Appendix -3: Analysis of variance (ANOVA) for number of leaves/ plant (mm) allocation of seven multipurpose tree species

Source of variation	DF	*Celtis australis* (cm)	*Grewia optiva* (cm)	*Bauhinia variegata* (cm)	*Bauhinia semla* (cm)	*Ficus auriculata* (cm)	*Quercus semicarpifolia* (cm)	*Quercus floribunda* (cm)
Treatment	3	13.11**	7.59	9.09*	12.99*	7.86*	23.53**	7.36**
Replication	4	2.56*	10.47	5.54NS	1.05**	11.50NS	7.04 NS	1.47NS

*Significant at P < 0.05, **Significant at P < 0.01, NS= Non- significant

ABSTRACT

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The present investigation was carried out during the year 2015-16 in the Research Block of Department of Forestry, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, Uttarakhand. Seven multipurpose agroforestry tree species, namely- *Celtis australis, Bauhinia variegata, Bauhinia semla, Grewia optiva, Ficus auriculata, Quercus floribunda,* and *Quercus semecarpifolia* were taken for investigation. The growth of nursery raised seedlings was measured at three month interval until one year of establishment in the the nursery. Germination per cent, mean germination time, germination index, seedling vigor index and growth characteristics and biomass (*i.e*. shoot length, collar diameter, leaf area, number of leaves/plant, root length, shoot dry weight, root dry weight, leaves dry weight, total dry weight and root/shoot dry weight) of each multipurpose tree species were recorded. Fodder and fuel wood deficiency in the Himalayan region is well recognized because rural inhabitants are exploiting these forest resources for their livelihood for generations which leads to severe deforestation.

The outcome of the study revealed that germination of *Grewia optiva* was found highest (80%) and *Quercus semecarpifolia* was the lowest (21%). *G. optiva* showed maximum height (50.00 cm) followed by *Bauhinia variegata* (43.95 cm). *Quercus floribunda* (10.42 cm) was found to show the poorest growth performance. *Celtis australis* showed maximum number of leaves (11.55) and followed by *B. variegata* (10.66) in the nursery condition. *G. optiva* showed maximum survival percent (22.35%) followed by *B. variegata* (22.33%). Biomass was recorded highest in *G. optiva* (6.47 g) followed by *B. variegata* (5.62 g) and *C. australis* (5.46 g). *B. variegata and G. optiva* were found most energetic among all the selected multipurpose tree species.

From the study, it can be concluded that *G. optiva* and *B. variegata* are the overall best performing species and these species will be most suitable for plantations in the hilly regions of Garhwal Himalayas.

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शीर्षकः गढ़वाल हिमालय बहुउद्देशीय वृक्षों की सात प्रजातियों के अंकुर वृद्धि एवं उत्तरजीविता का अध्ययन

वर्तमान शोध वीर चन्द्र सिंह गढ़वाली, उत्त्राखण्ड औद्यानिकी एवं वानिकी विश्वविद्यालय, रानीचौरी परिसर के वानिकी विभाग के अनुसंधान प्रखण्ड़ में वर्ष 2015–16 में किया गया। बहुउद्देशीय कृषि वानिकी वृक्षों की सात प्रजातियां खड़ीक, (सैल्टीस औस्ट्रेलिस), कचनार (बहुनिया वैरीगाटा), सेमला (बहुनिया सेमला), भीमल (ग्रीवीया ओपटिका), तिमला (फाइकस औरिकुलाटा), मोरू बाँज (क्वैरकस फ्लोरिबन्ड़ा) तथा खस्रु (क्वैरकस सेमीकारपीफोलिया) अध्ययन के लिए चुनी गयी। नर्सरी में अंकुर वृद्धि प्रत्येक तीन माह के अन्तराल बाद एक वर्ष तक मापी गयी। प्रत्येक बहुउद्देशीय वृक्षों का अंकुरण प्रतिशत, बीज अंकुरण समय, अंकुरण सूचकांक, बीजों के चरित्र तथा शुष्क वजन (जैसे– तने की लम्बाई, तने का व्यास, पत्तियों की संख्या, जड़ की लम्बाई, तने, जड़ तथा पत्तियों का शुष्क एवं ताजा वजन दर्ज किया गया। हिमलाय क्षेत्र में चारे तथा ईंधन की कमी पायी जाती है क्योंकि इस क्षेत्र में ग्रामीण निवासी वन संसाधनों का उपयोग अपनी अजिविका के लिए करते हैं जिसके लिए वनो का दोहन किया जाता है। जिससे वन क्षेत्र कम हो जाता है।

शोध के परिणामों से यह पता चलाता है कि भीमल का अंकुरण प्रतिशत सबसे अधिक (80%) था। जबकि सबसे कम अंकुरण प्रतिशत (21%) खस्रु में पाया गया। सबसे अधिक (50.00 से0मी0) पौध की ऊँचाई भीमल में तदोपरान्त कचनार (43.95 से0मी0) में पायी गयी। चुनी गयी बहुउद्देशीय वृक्ष प्रजातियों में से मोरू बाँज की वृद्धि सबसे कम (10.42 से0मी0) पायी गयी। सबसे अधिक पत्तियों की संख्या (11.55) खड़िक में दर्ज की गयी उसके बाद कचनार (10.66) में की गयी। भीमल में सबसे अधिक (22.35%) उत्तरजीविता पायी गयी तथा उसे बाद कचनार में (22.33%) पायी गयी। कुल शुष्क वजन (6.47ग्रा0) भीमल में उसके बाद कचनार (5.62ग्रा0) तथा (5.46ग्रा0) खड़िक में दर्ज किया गया।

अंकुरण क्षमता एवं पौध वृद्धि के आधार पर भीमल और कचनार का पहाड़ी क्षेत्रों में कृषि वानिकी के अर्न्तगत वृहद स्तर पर रोपण के लिए संस्तुति की जाती है।

विधार्थी के हस्ताक्षर

VITAE

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