# GROWTH PERFORMANCE OF TREE SPECIES IN MIXED PLANTATIONS RAISED IN FALLOWLAND, CHAPRA, INDIA

**Sami Shrivastava * and A.K. Jha**

Department of Botany, Jai Prakash University ,Chapra
Chapra- 841301 , Bihar , India
email: ashokjhabotany@gmail.com, mobile no. : 09934826083
***Corresponding** author: samishrivastava1990@gmail.com
Mobile number: 07277752453

**Abstract**

Evaluation of growth performance study was conducted for following tree species *: Mangifera indica* , *Psidium guajava* , *Phyllanthus emblica* , *Syzigium cumini* (all fruit trees) , *Dalbergia sissoo* and *Tectona grandis* ( timber trees ) in three year old mixed plantations raised in abandoned cropland in J.P. University, campus , Chapra in August 2015. Data were collected for height and diameter of trees , length and diameter of twigs , and number of leaves on twigs . H:D ratios and tree volumes were also calculated . Better growth performance was observed in *T.grandis* in height and H:D ratios , *P.guajava* in diameter growth , *D,sissoo* in length of twig and tree volume , *M.indica* in growth of twig diameter and *P.emblica* in number of leaves on twigs . The plant species performance varied from site to site . Although the timber yielding tree species showed better performance in height , H:D ratios and tree volume considerably than the fruit trees .

**Keywords:** Growth performance, Height, Diameter, H:D ratios, Tree volume, Fallowland

**{Citation:** Sami Shrivastava, A.K. Jha. Growth performance of tree species in mixed plantations raised in Fallowland, Chapra, India. American Journal of Research Communication, 2016, 4(4): 16-29} www.usa-journals.com, ISSN: 2325-4076.

**Introduction**

Plantations raised in fallowland , wastelands ,mine spoils etc are helpful in reducing noise pollution (Fan et al 2010 ; Fang & Ling 2005), effective carbon sink( Graham et al 1992), supplier of vital oxygen (Broecker 1970) & conserve soil and water (Gokturk et al 2006). On the other hand plantations are useful in silviculture, agro-forestry and all other industrial sectors that depend on the trees. It is also helpful in restoration of biodiversity, ecosystem structure and functioning. Piotto(2007) proposed that the performance of planted native species of economic importance must be known to precisely prescribe appropriate species for enrichment planting for selecting potential species and predict their response. For every tree species height and diameter profile and survival rates varied from site to site, climatic factors and for other conditions which species is performing better is essential to know . Makela et al.(2000);Sievanen(1993); Landsberg and Waring (1997) ;Valentine et al. (1997) ; Bartelink (1998) ; Albrektson and Valinger (1985) ; Hashim (2005) and Piotto et al(2003) have evaluated the performance of the different tree plantations by some simple measurement and statistics. According to Opio et al (2000) height to diameter ratio (HDR) has been proposed as an alternative competition index to be used in determining the vigour and `free growing' status of crop trees. HDR is an individual tree based index and is calculated by dividing the height of the crop tree either by the diameter at the root collar or diameter at breast height (DBH) of the tree. HDR has been used in Germany as a thinning tool in second growth stands of Douglas fir *(Pseudotsuga menziessi* (Mirb.) Franco var. *menziessi*) and western hemlock *(Tsuga heterophylla* (Raf.) Sarg) (Smith, 1986) . The technique has the potential to provide a morphological measure of the influence of competing vegetation on crop trees (Mustard and Harper, 1998). HDR has been used for determination of the influence of various growth variables on height and diameter growth of crop trees (Lanner 1985; Waring and Schlesinger 1985;Salisbury and Ross 1985; Ross et al. 1986; Waring 1987; Hughes et al. 1990; MacDonald et al. 1990; Wagner and Radosevich 1991 a,b ; Morris and MacDonald 1991; Tesch et al. 1993; Nilsson 1994;Messier 1996; Tanner et al. 1996; Coopersmith and Hall 1999). Generally the height and diameter growth are influenced by a combination of genetic potential, and physiological and morphological responses to environmental factors (Vogt et al. 1983; Cole and Newton 1987a; Harrington et al. 1991; Kelty et al. 1992; DeLong, 1991 ; Bi and Turvey 1994 ;Leiffers and Stadt 1994; Comeau and Sachs 1996; Simard and Heineman 1996; Davis 1998; Mustard and Harper 1998; Makinen *1998; Wang 1998)*. Cremer et al.(1982) and Nykanen et al (1997) reported that height: diameter ratios as a gauge for susceptibility to snow and wind damage for many years. Brunig(1974) and Faber(1975) showed that the relationships between height : diameter ratios and incidence of damage have been very strong .Lohmander and Helles (1987) and Nykanen et al.(1997) reported that conifer trees in northern Europe increased probability of damage with increases in height: diameter ratios. Cremer et al (1982) proposed that no damage at height :diameter ratios below 74 and almost complete damage at ratios above 90 for radiata pine (*Pinus radiata*) in New Zealand .Baker et al (2003)reported that understanding the factors that control tree growth in successional stands is particularly important for quantifying the carbon sequestration potential and timber yield of secondary tropical forests .Uriarte et al (2004) reported that tree growth integrates competitive interactions for resources between trees at the stand level.Keddy (1989) and Whittaker (1975) proposed that H:D ratios are indicators of suitability of local environmental conditions for a given tree species (i.e.,niche partitioning).

The present study was conducted to understand the growth parameters of important timber yielding plants such as *Tectona grandis* and *Dalberga sissoo* , and fruit trees *Mangifera indica* , *Psidium guajava* , *Syzygium cumini* and medicinal plant *Phyllanthus emblica* .

## MATERIALS AND METHODS

Four sites were selected in Jai Prakash University Campus Chapra, Bihar for growth performance study of trees species . The plantations were raised in 2012 by the village panchayats under Bihar Government schemes. The study sites are situated between 25° 36' and 26° 15' north latitude and 84° 24' and 85° 15 ' longitude in the Saran division Chapra Bihar. For the present study a total number of 118 individuals of six tree species were marked . On each marked individual two twigs were marked with the help of white paint . On the basis ofavailbility of plants thirty individuals for *Mangifera indica* , twenty six for *Psidium guajava* , twenty six for *Phyllanthus emblica* , sixteen for *Dalbergia sissoo* , ten for *Tactona grandis* and six for *Syzygium cumini* were selected and marked in four study sites . In the month of August 2015 growth parameters such as height and diameter , height : diameter ratios ,and tree volume of trees , length and diameter of twigs and number of leaves on twigs were determined . The height of trees was measured by using marked bamboo sticks or tape . The diameter at breast height (DBH) for tall trees at 1.34 m and for small individuals were determined above 20 cm from the soil surface with tape . The length and diameter of twigs were measured with the help of tape. Height: diameter ratio values were calculated by dividing the values of height by diameter. Tree volume growth (v) was calculated as a cone; v= $d^2h$ (where d is denoted by diameter and *h* is denoted by height of tree).

## RESULTS

The mean values for height, diameter , height : diameter ratios ; length and diameter of twigs and tree volumes recoded are in Table 1 in different study sites

### Height of trees

For *M.indica* values for height ranged from 260.0 cm to 224.8 cm ; 287.60 to 229.9 cm for *P.guajava* ; 331.7 to 249.6 cm for *P.emblica* ; 268.16 to 422.4 cm for *D.sissoo* ; 156.6 cm for *S.cumini* and 570.2 cm for *T.grandis* at different study sites (Table 1).

### Diameter of trees

The values for diameter ranged from 22.1 to 19.0 cm for *M.indica* , 27.9 to 21.0 cm for *P.guajava* , 26.5 to 15.8 cm for *P.emblica* ; 8.6 to 18.6 cm for *D.sissoo* ; 12.0 for *S.cumini* and 16.9 cm for *T. grandis* (Table 1).

**Table1: Height, diameter, height: diameter ratios, length and diameter of twigs and numbers of leaves in 3 year old plantations**

| s | Plant species | sites | Mean height (cm) | Mean diameter (cm) | Mean length of twigs (cm) | Mean diameter of twigs (cm) | Mean number of leaves | Height / diameter ratio | Tree volume ( $m^3$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | ! | 237.4 | 22.1 | 64.65 | 2.21 | 53.8 | 10.74 | 0.116 |
| | | 2 | 22.4 | 20.3 | 49.8 | 4.55 | 37.6 | 11.07 | 0.009 |
| | | 3 | NA | NA | NA | NA | NA | NA | NA |
| | | 4 | 260 | 19 | 49.45 | 3.85 | 26.7 | 13.68 | 0.09 |
| 2 | *Psidium guajava* | 1 | NA | NA | NA | NA | NA | NA | NA |
| | | 2 | 247.4 | 18.7 | 49.15 | 1.53 | 27.3 | 13.22 | 0.087 |
| | | 3 | 229.9 | 21.4 | 57.1 | 2.07 | 15.4 | 10.74 | 0.105 |
| | | 4 | 287.6 | 27.9 | 54.05 | 2.8 | 20.45 | 10.31 | 0.224 |
| 3 | *Phylllanthus emblica* | 1 | 249.6 | 15.8 | 58.16 | 1.50 | 69.4 | 15.80 | 0.062 |
| | | 2 | 276 | 26.5 | 63.5 | 1.75 | 84 | 10.42 | 0.194 |
| | | 3 | 331.7 | 25.2 | 74.6 | 1.45 | 57.25 | 13.16 | 0.211 |
| | | 4 | NA | NA | NA | NA | NA | NA | NA |
| 4 | *Dalbergia sissoo* | 1 | 268.16 | 8.6 | 64.91 | 2.0 | 34.41 | 31.18 | 1.983 |
| | | 2 | 422.4 | 18.8 | 70.1 | 2.09 | 37.5 | 22.71 | 0.149 |
| | | 3 | | | NA | NA | NA | NA | NA |
| 5 | *Syzygium cumini* | 1 | NA | NA | NA | NA | NA | NA | NA |
| | | 2 | NA | NA | NA | NA | NA | NA | NA |
| | | 3 | 156.66 | 12 | 32.5 | 1.65 | 12.8 | 13.06 | 0.0226 |
| | | 4 | NA | NA | NA | NA | NA | NA | NA |
| 6 | *Tectona grandis* | 1 | 570.2 | 16.6 | NA | NA | NA | 33.74 | 0.145 |

**Length of twigs**

The mean values for length of twigs varied from 49.8 to 64.65 cm for *M.indica* ; 49.15 to 57.10 cm for *P.guajava* ; 58.16 to 74.6 cm for *P.emblica* ; 70.1 to 64.91 for *D.sissoo* and 32.5 cm for *S.cumini* at different study sites .

**Diameter of twigs**

For *M.indica* the mean values for diameter of twigs ranged from 3.85 to 4.55 cm ; 1.53 to 2.80 cm for *P.guajava* ; 1.45 to 1.75 cm for *P.emblica* ; 2.0 to 2.90 for *D.sissoo* and 1.65 cm for *S.cumini.*

**Number of leaves**

The mean values for number of leaves on twigs ranged from 26.7 to 53.8 for *M.indica* ; 15.4 to 27.3 for *P.guajava* ; 57.25to 84.0 for *P. emblica* ; 37.15 to 34.41 for *D.sissoo* and 12.8 for S.cumini at different study sites (Table 1) .

**Height : Diameter Ratios**

These values ranged from 10.74 to 13.68 for *M.indica* ; 10.31 to 13.22 for *P.guajava* ; 10.42 to 15.80 for *P.emblica* ; 22.71 to 31.18 for *D.sissoo* ; 13.06 for *S.cumini* and 33.74 for T. grandis in different study sites (Table 1).

**Tree volume**

For *M.indica* values for tree volume ranged from 0.09 to 0.116 $m^3$ 0.087 to 0.224 $m^3$ for *P.guajava*; 0.062 to 0.211 $m^3$ for *P.emblica* and 0.149 to 1.983 $m^3$ for *D.sissoo*. This value was 0.0226 $m^3$ for *S.cumini* and 0.145 $m^3$ for *T.grandis* (Table1).

**Discussion**

In the present study *T.grandis* showed better performance than other species in height growth (Fig 1a) . The other species can be arranged in decreasing order as *D.sissoo* , *P.emblica* , *P.guajava* , *M.indica* and *S.cumini*. *P.guajava* showed better growth in terms of diameter growth than other species (Fig 1b) . The remaining species can be arranged as *P.emblica* , *M.indica* , *T. grandis* , *D.sissoo* and *S.cumini* . In *D.sissoo* the growth of length of twigs was better than other species (Fig 1c). The other species were *P.emblica* , *M.indica* , *P.guajava* and *S.cumini* .*M.indica* showed better performance than other species in case of growth in diameter of twigs (Fig 1d) . The other species were *P.guajava* . *D.sissoo* , *S.cumini* and *P.emblica* . The number of leaves was maximum in *P.emblica* than other species studied (Table 2; Fig 1e ).

**Table 2:Mean values 0f different sites for different parameters studied**

| Plant species | Height (cm) | Diameter (cm) | Twig length (cm) | Twig diameter (cm) | No. of leaves | H:D ratios | Tree volume ($m^3$) |
|---|---|---|---|---|---|---|---|
| *M.indica* | 173.27 | 20.47 | 54.63 | 3.54 | 39.37 | 11.83 | 0.072 |
| *P.guajava* | 254.97 | 22.67 | 53.43 | 2.13 | 21.05 | 11.42 | 0.139 |
| *P.emblica* | 285.77 | 25.5 | 65.42 | 1.57 | 70.22 | 13.13 | 0.156 |
| *D.sissoo* | 345.28 | 13.7 | 67.51 | 2.05 | 35.78 | 26.95 | 0.066 |
| *S.cumini* | 156.66 | 12.0 | 32.5 | 1.65 | 12.8 | 13.6 | 0.0226 |
| *T. grandis* | 570.27 | 16.0 | NA | NA | NA | 33.74 | 0.145 |

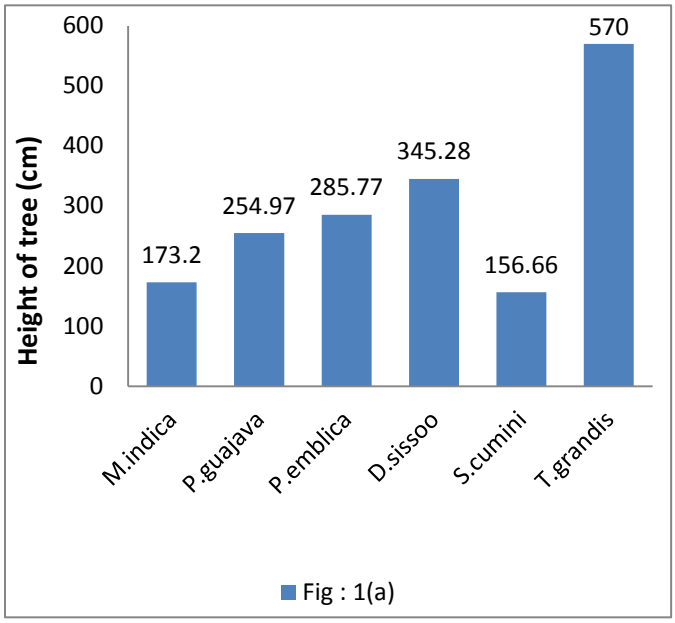


**Fig :1(a) Height of trees (cm)**

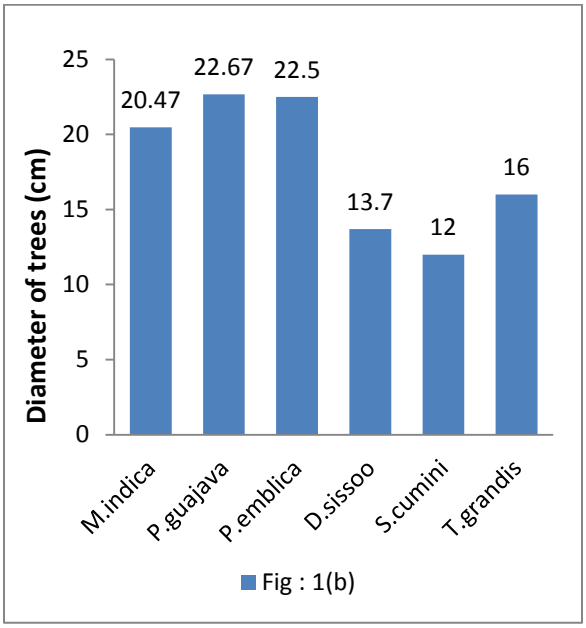


**Fig : 1(b) Diameter of trees (cm)**

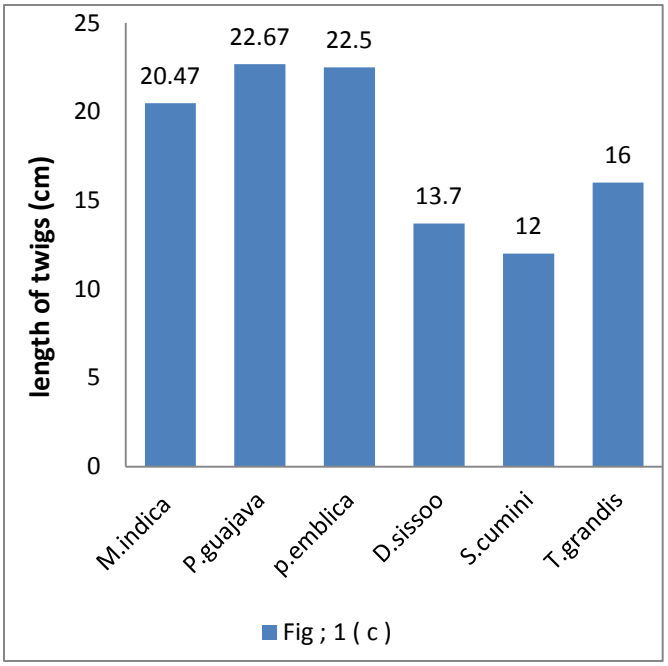


**Fig : 1( c ) Length of twigs (cm)**

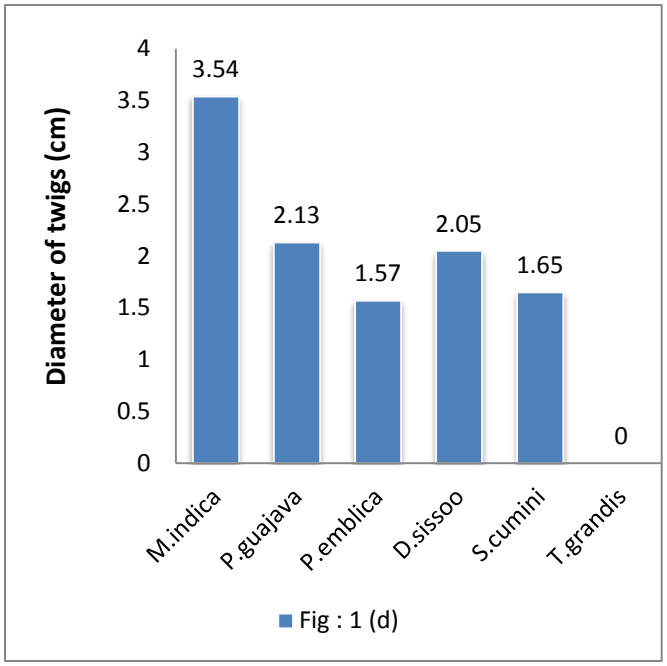


**Fig : 1 (d) Diameter of twigs (cm)**

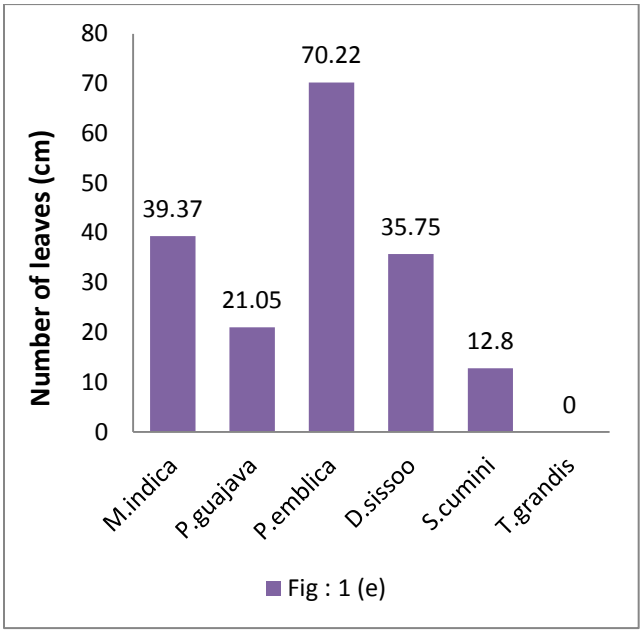


**Fig : 1(e) Number of leaves /twig (cm)**

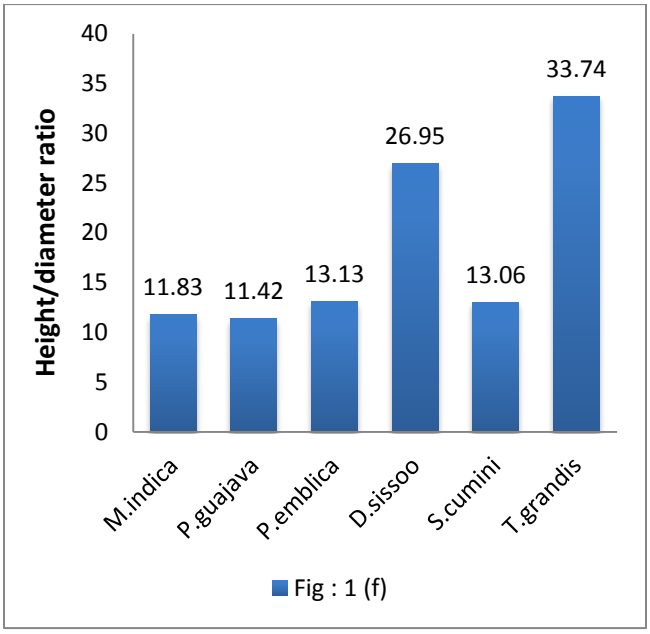


**Fig : 1(f) H:D Ratios**

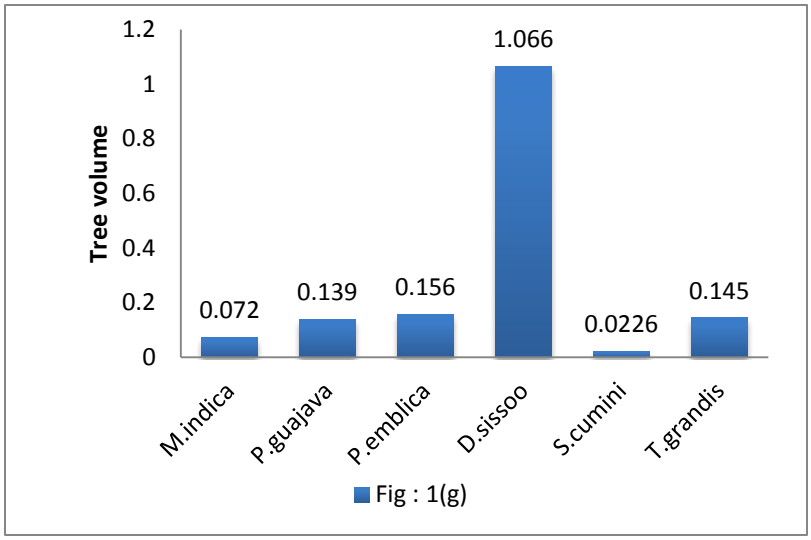


**Fig : 1 (g) Tree volume ($m^3$)**

*T.grandis* showed maximum values for H:D ratios than other species studied (Fig 1f) . The other species can be arranged as *D.sissoo* , *P.emblica S.cumini* , *M.indica* and *P.guajava* . *D.sissoo* produced maximum value for tree volume than other species (Fig 1g) . The other species were in decreasing order as *P.emblica* , *T.grandis* , *P.guajava* , *M.indica* and *S.cumini* (Table 2) .

Differences in the growth parameters were observed within the same tree species between different study sites . Piotto (2007) has also repoted variations for every tree species height and diameter profile varied from site to site . The growth of companion species is suppressed by fast growing species in mixed plantations ( Hansen and Dowson 1982 ; Jha 2012). Singh et al (1997 ) reported that the lowest per tree height , diameter and volume increment in *Pangamia pinnata* when grown with other legume *Acacia catechu* . Singh (2006) observed that the highest value for height , diameter and volume were realized by *T.grandis* when grown with *Dendrocalamus strictus* . Cole and Newton (1986,1987b) and Shainsky and Radserich (1992) proposed that competition for resource as a dominant process which influences the performance of species in mixed plantations . Singh (1997) reported that height , diameter and volume increment had significant positive relationship with foliar nitrogen than phosphorus concentrations .

The present study conducted in three year old mixed culture plantations indicated that in terms of height , diameter and tree volume growth satisfactory performances were shown by *M.indica* , *P.guajava* , *P.emblica, D.sissoo* , *S.cumini* and *T.grndis* . Long term monitoring of growth performances are essential including regeneration and survival rates of these tree species.

**ACKNOWLEDGEMENTS**

I am thankful to the Head, other Teaching staff and Research colleagues of Department of Botany for support during the present study .

## References

Albrektson , A and E. vallnger ,(1985): Relations between Tree Height and Diameter , Productivity Allocation of Growth in a Scots Pine (*Pinus sylvestris* ) Sample Tree Material . In: , Tigerstedt , P., P. Puttonen and V.koski (Eds.) Crop Physiology of Forest Trees. University of Helsinki , Fineland , pp: 95-106.

Baker TR, Swaine MD, and Burslem DFRP,(2003) : Variation intropical forest growth rates: combined effects of functional group composition and resource availability. Perspectives in Plant Ecology, Evolution and Systematics 6:21-36.

Bartelink , HH.,(1998): Simulation of growth and competition in mixed stands of douglas-fir and beech.Ph.D. Thesis , Landbouw University , Wageningen .

Bi, Hui-Quan and Turvey, N.D., (1994): Effects of *Eucalyptus obliqua* density on young stands of 11-aged *Pinus radiata*. New Forests 8:25-42

Broecker , W.,(1970): Man's oxygen reserves . *Science* , 168:1537-1538.

Brunig , E.F.(1974):Das Risiko der forstlichen Funktionen – planung , dargestellt am Beisptiel der Sturmgefahrdung . *Allgemeine Forst - und Jagd – Zeitung* 145 :60-67.

Burkhart and D.y.Hollinger,(1997): A stand-level model of carbon allocation and growth , Calibrated for loblolly pine . Canadian Journal of Forest Research ,27:817-830.

Cole , E.C and Newton M . (1986) . fifth year responses of Douglas – fir to crowding and non coniferous competition . Canadian Journal of Forest Research . 16: 727-732.

Cole, E.C. and Newton M. (1987): Fifth-year responses of Douglas-fir to crowding and non-coniferous competition. Canadian Journal of Forest Research 17: 181-186.

Cole , E.C and Newton M. (1987b) : Nutrient,moisture and light relation in five year old Douglas – fir plantation under variable competition . Canadian Journal of Forest Research , 17 : 181-186

Comeau, P.,and Sachs, D., (1996): Modelling interactions between red alder and Douglasfir.In:Comeau,P.G,Harper,G.J.,Blache,M.E.,Boateng,J.O.,Gilkeson,L.A. (Eds.), Integrated Forest Vegetation Management.FRDA ReportNo.187.BC Ministry of Forests, Victoria, BC,

Coopersmith, D.,and Hall, E., (1999): Experimental project 1077 Ð the Siphon creek mixedwood trial: the use of a simple height-to diameter ratio to predict the growth success of planted white spruce seedlings beneath aspen canopies. Research Note No. PG-17. Prince George Forest Region. Prince George, BC, 9 pp.

Cremer, K.W., Borough C.J., Mckinnell F.H., and Carter P.R..(1982). Effects of stocking and thinning on wind damage in plantations. Newzealand Journal of Forest Science 12(2):244–268.

Davis, I., (1998): Non-crop vegetation, detrimental or not?:redefining free growing. BC Ministry of Forests, ForestPractices Branch. Victoria, BC, 101 pp.

DeLong . S.C.,(1991): The light interception ; index : a potential tool for assisn in vegetation management accisions. Canadian Journal of Forest Research 2: 1037-1042.

Faber: P.J. (1975): Stability of stands to wind: a theoretical approach. *Nederlands Bosbauw Tijdschrift* 47(7/8):179–193.

Fan,Y, Zhiyi B. Zhujun Z. and Jiani L. (2010): The investigation of noise attenuation by plants and corresponding noise-reducing spectrum. Journal of Environmental Health 72:8-15

Fang.C.F. and Ling D.L., (2005): Guidance for noise reduction provided by tree belts . Landscape Urban plan ., 71:29-34.

Gokturk ,A., Olmez Z. and Temel F., (2006): Some native plants for erosion control efforts in coruh river valley , Artvin , Turkey . Pakistan Journal of Biological Science, 9: 667-673.

Goma-Tchimbakala,J.and Makossoo S., (2008): Soii organic matter and biological changes in a natural to planted forest succession : *Terminalia superba* plantations grown on deforested plots in congo . Journal of Applied Science ,8: 4346-4353.

Graham ,R.L., Wright L.L. and Turhollow A.F. , (1992): The potential for short-rotation woody crops to reduce U.S. $co_2$emissions. Climate Change, 22: 223-238.

Hansen , E.A. and Dawson J.O. (1982 ): Effect of *Alnus glutinosa* on hybrid populous light growth in a short rotation intensively cultured plantation . Forest Science 18:49-59

Harrington, T., Timothy, B., and Tappeiner, J.C., (1991): Competition affects shoot morphology , growth duration and relative growth rates of Douglas-fir saplings. Canadian Journal of Forest Research 21: 474-481.

Hashim,M.N.,(2005).Survival and growth of two *Araucaria* species established at mata ayer forest reserve , perlis Journal of Tropical Forest Science, 17: 319-321.

Hughes, T.F., Tappeiner, J.C., Newton, M. ( 1990) : Relationship of Pacific madrone sprout growth to productivity of Douglas-fir seedlings and understory vegetation. West. Journal of Applied Forest 5 ,20-24.
Jha,A.K.(2012): A study on Revegetation of coal mine spoil. Nirmal Publication , Delhi, 231p.

Keddy PA, (1989): Competition. Chapman and Hall, London, UK.

Kelty, M.J., Larson, BC, Oliver, C.D. (Eds.), 1992: The Ecology and Silviculture of Mixed-Species Forests. Forest Sciences Series vol. 40. Kluwer Academic Publishers, Dordrecht, 287pp.

Landsberg,J.J. and Waring R.H, (1997) : A generalized model of forest productivity using simplified concepts of radiation use efficiency , carbon balance and partitioning . Forest Ecology and Management ,95 : 209-228.

Lanner, R.M. (1985). On the insensitivity of height growth to spacing. Forest Ecology and Management 13:143–148.

Leiffers, V.J.,and Stadt, K.J.,(1994).Growth of under story *Picea glauca , Calama grostis cana densis, and Epilobium angustifolium* in relation to overstory light transmission . Canadian Journal of Forest Research 24:119-1198.

Lohmander, P., and Helles F. (1987). Windthrow probability as a function of stand characteristics and shelter. Scandian Journal of Forest Research 2:227–238.

MacDonald, B., Morris, D.M. and Marshall, P.L., (1990). Assessing components of competition indices for young boreal plantations. Canadian Journal of Forest Research 20: 1060-1068

Makela, A., Sievanen R. , Lindner M. and Lasch P., (2000): Application of volume growth survival graphs in the evaluation of four process – based forest growth models . Tree Physiology., 20: 347-355.

Makinen, H., (1998): The suitability of height and radial increment variation in *Pinus sylvestris* (L.) for expressing environmental signals. Forest Ecology and Management 112: 191-197

Messier, C. (1996) : Managing light and understory vegetation in boreal and temperate broadleaf-conifer forests. In: Comeau,P.G., ThomasK.D.(Eds.), pp. 59-81 Silvicultur of Temperate and Broadleaf-Conifer Mixtures. BC Ministry of Forests. Victoria,BC,.

Milner, K.S. (1992): Site index and height growth curves for ponderosa pine,western larch, lodgepole pine, and Douglas-fir in western Montana. West. Journal of Applied Forestry 7(1):9–14.

Mustard, J. and Harper, G. ( 1998): A summary of the available information on height to diameter ratio. BC Ministry of Forests. Victoria, BC, 120 pp.

Nilsson, U. (1994): Development of growth and stand structure in *Picea abies* stands planted at different initial densities. scandian Journal of Forest Research 9: 135-142.

Nykanen , M.-L., Peltola H., Quine C.P., Kellomaki S. , and Broadgate M.(1997): Factors affecting snow damage of trees with particular reference to European conditions. Silva Fennica 31(2):193–213.

Opio,C.Jacob,N. and Coopersmith,D. (2000): Height to diameter ratio as a competition index for young conifer plantations in northern British Columbia , Canada.Forest Ecology and Management 137:245-252.

Piotto,DD.,(2007): Growth of native tree species planted in open pasture , young secondary forest and mature forest in humid tropical costa Rica.Journal of Tropical Forest Science ,19:92-102.

Piotto, D. Montagnim,F., Uglade L. and Kanninen M., (2003) . Performance of forest plantations in small and medium – sized farms in the Atlantic lowlands of costa Rica. Forest Ecology and Management., 175:195-204.

Ross, M., Flanagan, L.B. and La Roi, G.H., (1986): Seasonal and successional changes in light quality and quantity in understory of boreal forest ecosystems. Canadian Journal of Botany. 64: 2792-2799.

Salisbury, F.B.,and Ross, C.W., 1985. *Plant Physiology*, 3rd ed.Wadworth Publishing Company. Belmont, California, 540 pp

Shainsky, L.J. and Radosevich S.R . 1992. Mechanism of competition between Douglas – fir and red alder seedlings . Ecology 73 : 30-45

Sievanen , R.,(1993): A process-based model for dimensional growth of even – aged stands Canadian Journal of Forest Research ,8:28-48.

Sievanen, R., Lindner M., Makela A. and Lasch P.,(2000) : Volume growth and survival graphs : A Method for evaluating process-based forest growth models . Tree Physiology ., 20:357-365.

Singh,A.(2006). Growth and leaf nutrient status of companion species as influenced by neighbouring species in mixed plantations raised on mine spoil. Tropical Ecology 47(2). 259-269

Singh,Arvind , Jha , A.K. & Singh, J.S . 1997.Influence of a developing tree canopy on the yield of *Pennisetum pedicellatum* sown on a mine spoile . Journal of Vegetation Science 8: 537-540

Sinnard ,S.,and Heineman, J., (1996): Nine-year response of Douglas-fir and the mixed hardwood –shurb complex to chemical and manual treatments on an ICHm $w^2$ site near salmon Arm. BC Ministry of for Victoria , BC,24pp.

Smith, J.H.G.,( 1986): Projections of stand yields and values to age100 for Douglas-fir western red cedar, and western hemlock and implications for management from the UBC forest spacing trials. Faculty of Forestry, University of Britis Columbia.Vancouver, BC, 16 pp.

Tanner, D., DeLong, S.C., and Eastham, A.,( 1996): Investigations of white spruce under an aspen canopy. In: pp. 114-121.Comeau, P.G.,Thomas, K.D. (Eds.), Silviculture of Temperate and Broadleaf-Conifer Mixtures. BC Ministry of Forests. Victoria, BC,

Tesch, S.D., Korpela, E.J.,and Hobbs, S.D., (1993):Effects of sclerophyllous shrub competition on root and shoot developmentand biomass partitioning of Douglas-fir seedlings. Canadian Journal of Forest Reasearch 23: 1415-1435.

Uriarte M, Canham C, Thompson J,and Zimmerman JK, (2004):A neighborhood analysis of tree growth and survival in a hurricane-driven tropical forest. Ecological Monographs 74: 591-614.

Valentine, H.T., Gregoire T.G., Burkhart H.E. and Hollinger D.Y., (1997): A stand – level model of carbon allocation and growth , calibrated for loblolly pine . Canadian Journal of Forest Research , 27:817-830.

Vogt, K.A., Moore, E.A., Vogt, D.S., Redlin, M.M.,and Edmonds,R.L., (1983) : Conifer fine root and mycorrhizal root biomass within the forest floors of Douglas-fir stands of different ages and site productivity. Canadian Journal of Forest Research 13: 429-437.

Wagner, R.G., and Radosevich, S.R., (1991a). Interspecific competition and other factors influencing the performance of Douglas-fir saplings in the Oregon Coast Range. Canadian Journal of Forest Research 21: 821-828.

Wagner, R.G., and Radosevich, S.R., (1991b). Neighborhood predictors of interspecific competition in young Douglas-fir plantations. Canadian Journal of Forest Research. 21: 829-835.

Wang, G.G., (1998): Is height of dominant trees at a reference diameter an adequate measure of site quality? Forest Ecology and Management 112: 49-54.

Waring, R.H., and Schlesinger, W.H., (1985): Forest Ecosystems:Concepts and Management . Academic Press Inc., Orlando,Florida, 340 pp.

Waring, R.H., (1987): Characteristics of trees predisposed to die.BioScience 37: 569-574.

Whittaker RH, (1975): Communities and Ecosystems. 2nsd ed., New York, USA.