Environment Conservation Journal 18(3) 61-69, 2017
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Cultivation of *Cassia fistula*, a medicinal plant under different conditions of soil

Ritu Vishnoi[1] ✉, G.S. Rajwar[2], Vineet Kumar Vishnoi[3] and Jaya Upreti[4]

Received: 25.03.2017 **Revised: 20.05.2017** **Accepted: 05.06.2017**

Abstract

The experiments were conducted to observe the effect of different soil and sand ratios on the growth of cassia fistula. Three different ratios of sand and soil viz; 60:40(sand: soil), 80:20(sand: soil) and 100:00(without adding sand) were taken for the cultivation and the growth was observed every month. Different growth parameters were also taken for calculating the difference among all the plants under different soil conditions as well as under different weather conditions. Different soil nutrients percentage was also calculated to find out the best nutrients requirement for cassia fistula.After observing the experiments it was concluded that the ratio 60:40 was most suitable soil condition for the growth of *Cassia fistula*.

Keywords: Cultivation, Cassia fistula, medicinal plant, soil conditions

Introduction

Despite a large number of trials on cultivation of Medicinal and Aromatic plants (MAPs), and also development of suitable technology package for many species, replication and adoption of such schemes/programmes at farmer level have been a major constraint. This is due to the fact that the medicinal plant sector is not well organized and 90% plants are used as raw-drugs and harvested from natural habitats (Sundriyal, 2005).

Soil is a function of climate, parent material, vegetation, topography and time. These factors can bring remarkable changes in soil characteristics. On the contrary soil changes would be expected to influence the growth of many plant species. Out of the environmental factors, which influence plant productivity and economic yield, soil conditions are of paramount importance. The heterogeneity in the texture, structure and composition of the soil impart some specific chemical and physical characteristics to the soil which affect the growth behaviour of plants (Mishra, 1980). The nutrients used by the plant species for growth and biomass production generally come from the internal cycling of the reserve materials, which require water for their solubilisation and translocation (Sanchez *et al.*, 1991).reservoirs of Nasik district.

Author's Address
[1] Department of Botany, Chinmaya Degree College, BHEL, Ranipur, Haridwar, Uttarakhand, India
[2] Department of Botany, Government Degree College, Narendra Nagar, Tehari Garhwal, Uttarakhand, India.
[3] Department of Microbiology, Gurukul Kangri university, Haridwar, Uttarakhand, India
[4] Department of Microbiology, Chinmaya Degree College, BHEL, Ranipur, Haridwar, Uttarakhand, India
E-mail: dr.ritu.vishnoi@gmail.com

Material and Methods

Different stages in the phenology of Cassia fistula were studied with different parameters viz., Whole length, Stem length, Root length, Emergence of leaves, Circumference, Basal area, Leaf area, Stem Biomass, Root Biomass and Leaf biomass (Misra, 1968) on the basis of the information provided by the local people, Ayurvedic practitioners and the available literature.

Preparation of Soil Treatments

Seeds of selected medicinal plants were sown in two sand and soil ratios and a control condition, which were as follows:

1. 80:20 (Sand : Normal Soil)
2. 40:60 (Sand : Normal Soil)
3. Control condition (Normal Soil)

The ratios of Sand and Soil were made by their volumes. In control condition there was no addition of sand. For all the three types the soil was collected from the college garden and then it was mixed with virgin sand.

Experiments for Cultivation Practi ces

Collection of Seeds

The seeds were collected from Prem Nursery, Dehradun and Sushila Tiwari Herbal Garden, Muni Ki Reti, Tehri Garhwal.

Sowing of Seeds

The sowing of the seeds was made between the months of April according to their sowing period. The seeds were sown in the small polybags at the depth of 5 cm.

Germination Period

The germination time of the plants was recorded after their sowing date.

Data Recording

After germination of the seeds, the data recording was made after every two months. The plants were uprooted and then washed with tap water to remove their soil and sand particles with proper handling. The length of root and stem, Number of Nodes and Internodes, Circumference, Basal area and Leaf Area were recorded.

Biomass

Root, stem and leaves were separately removed from the plants for the biomass estimation. Each part was wrapped with the papers and kept in the oven to dry their moisture.

Weighing

After drying root, stem and leaves were weighed for the biomass production.

Analysis of Soil

The separation of the sand, silt and clay particles which form the mineral components of the soil is known as the mechanical analysis of the soil. The **pipette method** was used forthis purpose. The organic matter content was determined by **Walkley and Black's Rapid Titration** method.**Kjeldahl method** was used for soil nitrogen determination.Potassium was estimated using **Flame photometer.**

Preparation of soil sample

Preparation of soil sample involved procedure of drying, grinding, sieving, mixing and partitioning.

Results and Discussion

The growth parameters of the cassia fistula were observed at an interval of two months and the influence of season along with the soil conditions on the various parameters of plants growth were recorded. The data were analyzed as factorial analysis using **GENSTAT 5** statistical package. The twofactors or say sources of variations were the seasons and the soil ratios. Their individual effects as well as the joint effect i.e., interactions were studied in respect to all the 13 growth parameters. The standard errors of means and least significant differences of means were also estimated to compare the effects of different seasons and soils on the studied parameters.The correlation coefficients between various parameters were also estimated. The findings of statistical analysis and the results are given in the subsequent section.

Whole Length

The variation among soil types was significant. The soil ratio of 80:20 gave highest value (103 cm) for whole length than other two soils (Table 1, Fig. 1).The whole length was significantly correlated with growth parameters viz., emergence of leaf, and biomass of different plant parts (Table 2).

Root Length

The soil types had not been found to vary significantly. However, root length in the soil ratio of 80:20 was found better as compared to other soil conditions (Table 1).The interaction of soils and seasons showed that in rainy season roots grew better in soil ratio of 80:20 (60.3 cm) and grew slowly in winter for control condition (Fig. 2).Root length of the plant had some influence on growth parameters viz., stem length, emergence of leaf, and biomass of different plant parts as the correlationship between them was highly significant (Table 2).

Stem Length

The difference in variations among the seasons was significant in respect to stem length. The stem length of plant was maximum (62.4 cm) in rainy season and minimum in winter (38.6 cm). It may be asserted that stem grew faster in the rainy season.The soil types differed significantly in respect to stem lengths. The soil ratio of 80:20 produced higher (57.9 cm) stem value (Table 1, Fig. 3). The interaction of soil ratio and seasons showed that during rainy season, the soil ratio of 80:20 gave stem length of 69.5 cm which was higher than stem lengths in other interactions of soil ratios and seasons.The length of the stem of plant was significantly correlated with the growth parameters viz., emergence of leaf, biomass root, stem and leaves (Table 2).

Table 1: Effect of different Soil types and Seasons on the growth of *Cassia fistula*

Serial No.		1	2	3	4	5	6	7	8	9
Parameters		*Whole lenth(cm)*	*Root length(cm)*	*Stem length(cm)*	*Circumference (cm)*	*Leaf area(cm^2)*	*Basal area(cm^2)*	*Root biomass (gm)*	*Shoot biomass(gm)*	*Leaf biomass (gm)*
Season	**Rain**	117.4	57.5	62.4	1.398	217	0.1707	2.617	1.849	3.3
	Winter	63.6	28.2	38.6	0.918	27	0.069	0.289	0.451	0.571
	Summer	88.8	43.7	45.1	0.977	52	0.1045	1.3	0.816	1.207
	CD	10.85***	5.89***	7.08***	0.173***	53.4***	0.03***	0.44***	0.32***	0.38***
Soil Type	**80:20:00**	103	46.3	57.9	1.457	97	0.1818	1.699	1.449	1.762
	40:60	85.1	41.9	45.7	0.928	90	0.0769	1.297	0.843	1.491
	Control	81.7	41.2	42.5	0.909	109	0.0854	1.209	0.823	1.826
	CD	10.85***	NS	7.08***	0.173***	NS	0.03***	NS	0.32***	NS

Table 2 Coefficient of correlation of *Cassia fistula* with different growth parameters

	Whl Lng	*Rt Lng*	*Sht Lng*	*circum*	*Lf area*	*Bsl Area*	*Rt Bioms*	*sht Bioms*	*Lf Bioms*
Whole length	1								
Root length	0.88	1							
Shoot length	0.865	0.625	1						
circumference	0.649	0.484	0.68	1					
Leaf area	0.648	0.551	0.608	0.542	1				
Basal area	0.725	0.528	0.755	0.905	0.578	1			
Root biomass	0.78	0.832	0.638	0.528	0.617	0.588	1		
Shoot biomass	0.789	0.659	0.737	0.681	0.75	0.785	0.653	1	
Leaf biomass	0.731	0.769	0.661	0.476	0.758	0.543	0.807	0.706	1

Table 3: Chemical and physical properties of the experiment soil

Soil	pH	OC (%)	OM (%)	N (%)	P (%)	K (%)	Sand	Silt	Clay	Textural class
80:20:00	7.52	1.04	1.79	0.023	0.003	0.009	85%	8%	7%	Sandy loam
40:60	7.55	2.06	3.52	0.062	0.005	0.007	65%	19%	16%	Loamy
Control	7.52	2.62	4.52	0.03	0.007	0.03	48%	32%	20%	Silty clay

Shoot Root Ratio: It has been found that differences among seasons and soils were not significant. The growth rate was same during all seasons and soils as most of the values were less than one. Analysis of the ratio among seasons as well as soils showed that there were significant variations. Stem and root did not grow simultaneously in equal proportion during all the seasons and in all the three types of soils. In winter the ratio was more than rest of the seasons.

Emergence of Leaves: It revealed that variation among seasons was significant. The number of emergent leaves per plant was maximum (7.94) in rainy season and minimum in winter (2.78).The soil types did not differ significantly although control condition was observed better as compared to other soil ratios (Table 1, Fig. 4).

Circumference of Plant: The variation in the circumference of the plant was highly significant among the seasons. It was 1.398 cm in rainy season and 0.92 cm in winter. The soil types differed in effect or say their variation was very significant. The circumference in soil ratio of 80:20 was more than the value in other types of soils (Table 1, Fig. 4).The interaction between seasons and soil types showed the same conclusion i.e., during rainy season the internodes grew better in soil ratio of 80:20. It was seen that circumference was not significantly related with any growth factor (Table 2).

Leaf Area: The difference in average leaf area from season to season was highly significant. The leaf area was highest (217 cm^2) in rainy season, whereas it was very less in winter (27 cm^2). The different soil conditions did not differ significantly but it was observed that leaf area in control condition was highest (109 cm^2) (Table 1, Fig. 5).The joint effect of soil types and seasons indicated that average leaf area during rainy season in control condition was best (248 cm^2). Leaf area was found to be correlated with most of the growth factors of the plant (Table 2).

Basal Area: The average basal area of the plant was found to be varying significantly with seasons as well as soil types. It was significantly highest in rainy season (0.1707 cm^2) but in winter, it was very low (0.069 cm^2).It was found that the average basal area among soil types in this experiment varied significantly. The basal area in soil ratio of 80:20 was maximum (0.1818 cm^2), whereas it was minimum (0.092 cm^2) in soil ratio of 40:60 (Table 1, Fig. 6).The joint effect of soil types and seasons showed that average basal area during rainy season in control condition was best. Basal area was found to have no significant corelationship with growth parameters (Table 2).

Root Biomass: The root biomass of plant varied significantly with seasons. It was found to be very high (2.617 gm) in rainy season and in winter it was very low (0.289 gm). The average root biomass due to different soil types used in the experiment did not differ significantly. In soil ratio of 80:20 it was on higher side (1.699 gm) than the other types of soil (Table 1). Root biomass was found to have significant correlationship with all growth parameters except leaf area, circumference and basal area (Table 2).

Stem Biomass: The findings of stem biomass of the plant were quite similar in pattern to root biomass analysis as it also varied significantly with seasons. It was higher in rainy season (1.849 gm) and minimum in winter (0.451 gm). The average values of stem biomass in different soil types differed significantly. The stem biomass in soil ratio of 80:20 was highest (1.449 gm) (Table 1). The average stem biomass during rainy season in soil ratio of 80:20 was 2.7 gm which was highest among all seasons and soil types. Stem biomass like root biomass was found to have significant correlationship with all growth parameters, except leaf area, circumference and basal area (Table 2).

Leaf Biomass: The analysis of leaf biomass of the plant was quite similar in pattern to root and stem biomass analyses. It was highest in rainy season (3.3 gm) and minimum in winter (0.571 gm). It was observed that the average stem biomass due to soil types did not differ significantly. The plant's leaf biomass in control condition was 1.826 gm which was highest (Table 1).The joint effect of soil types and seasons indicated that average stem biomass during rainy season in control condition was best as compared to any other soils in different seasons. Stem biomass like root biomass was found to have significant correlationship with all growth parameters except leaf area, circumference and basal area (Table 2).

The value of pH for the soil ratio of 80:20 was 7.52, whereas for ratio of 40:60 it was found 7.55 and for control condition it was recorded with the value of 7.52. It showed that the 40:60 ratio of sand and soil was highest as compared to all three soil types. The value of OC (%) was found to be highest (2.62 %) for control condition, however for the ratio of 40:60 it was recorded as 2.06, and for ratio of 80:20 it was 1.04 %. The value of organic matter was found 4.52, 3.52 and 1.79 % for control, 40:60 and 80:20 soil conditions respectively (Table 3). The value of N (%) was found to be highest (0.62) for the soil ratio of 40:60 (Sand: Soil), however it was 0.030 for control condition and 0.023 for 80:20 ratio of sand and soil. The percentage of P for all three types of soil was found to be highest (0.007 %) for

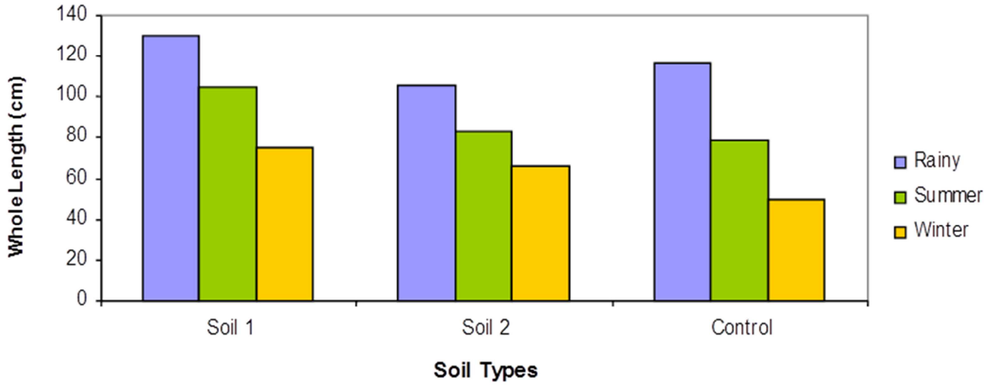

Fig 1 Variation in Whole Length of *Cassia fistula* with Seasons & Soils

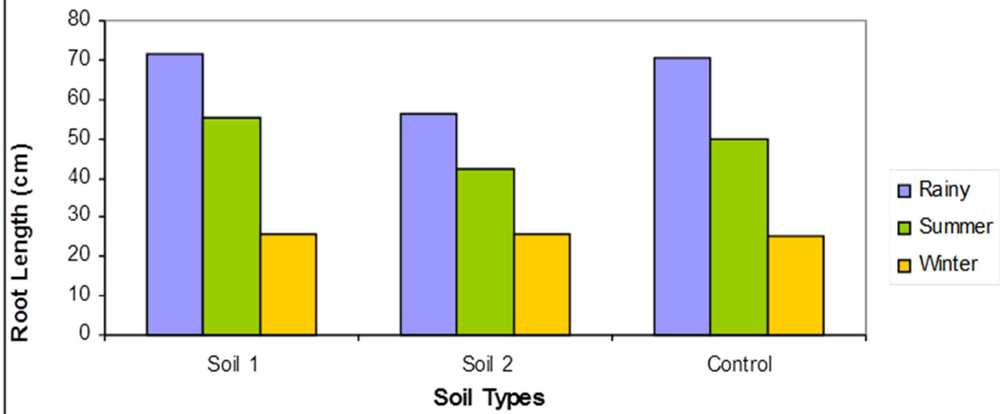

Fig 2 Variation in Root Length of *Terminalia arjuna* with Seasons & Soils

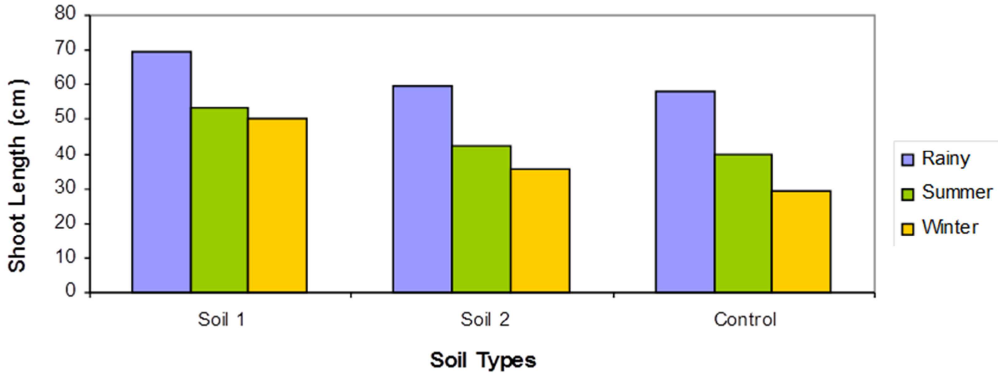

Fig. 3 Variation in Shoot Length of *Cassia fistula* with Seasons & Soils

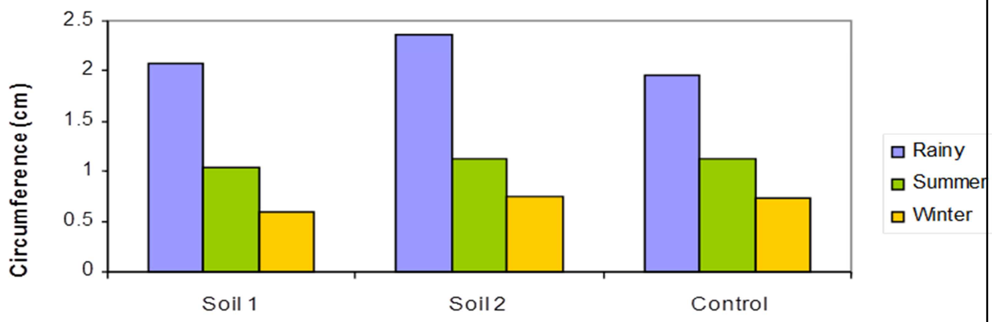

Fig 4 Variations in the Circumference of *Terminalia arjuna* with Seasons & Soils

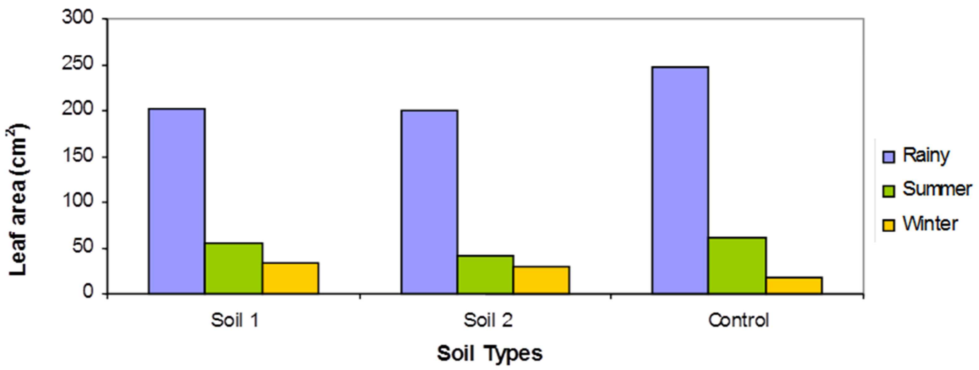

Fig 5 Variation in Leaf Area of *Cassia fistula* with Seasons & Soils

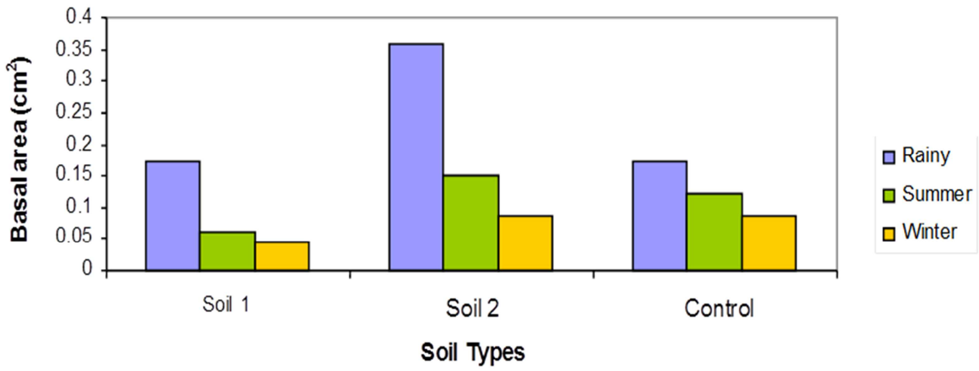

Fig 6 Variations in Basal area of *Tinospora cordifolia* with seasons & Soils

control condition, whereas 80:20 ratio showed lowest value (0.003 %). For ratio of 40:60 the P was 0.005 %. The soil ratio of 80:20 showed the lowest (0.009 %) percentage of K, however control showed highest value (0.03 %). The soil ratio of 40:60 recorded 0.007 % of K. The textural class has been determined on the basis of the sand, silt and clay percentages. For the soil ratio of 80:20 the percentage of sand, silt and clay was 85, 8 and 70% respectively under the class sandy loam. The percentage of sand, silt and clay was 65, 19, and 16 % respectively for the sand and soil ratio of 40: 60 with loamy texture (Table 3). For the control condition the ratio of sand, silt and clay was 48, 32 and 20 % respectively with the texture of silty clay.

Within the three soil conditions plants respond in different manner. *Cassia fistula*, showed better growth pattern for the soil ratio of 80:20. Soil texture is an important modifying factor in relation to the proportion of precipitation that enters the soil and becomes available to the plant. Clay holds maximum moisture per unit volume and provides moisture for tree growth, while sandy soil holds less moisture per unit volume but permits more rapid percolation of precipitation water than clay.

. Sandy-loam to sandy soils was the most suitable soil condition found in *Dalbergia sissoo* growth (Jacson *et al*., 1987). The pH was highest in the case of 80:20 ratio with the lowest value of clay (7%).The higher the amount of the clay in the soils, the lower the pH values. In other words, soil acidity increases with an increase in the clay content in the soil. However sand and silt did not show any significant correlationship with the pH of soil (Sah *et. al.,* 2003). Control condition appeared as a casual factor of reduced growth for the species. Waterlogging caused by higher amount of clay could be one of the causal factors of the reduced growth. Higher clay and silt contents reduce the growth of plant (Sah *et al.,* 2003). Among the seasons winter showed poor growth for the species. The factor responsible for this may be expressed as the extreme water stress from the outside atmosphere due to fog or frost conditions, which reduces the plant growth although plants can absorb some fog water directly through leaf and recover water balance (Zheng *et al*., 2006). For *Cassia fistula* the reduced leaf area was observed in the season of winter for the soil ratio of 80:20. It has been concluded that 80:20 soil ratio in the winter season did not have favorable effects on the species. Reduced leaf area due to water stress has been observed by Singh and Singh (2007), which indicated that the effect of soil water stress was greater on leaf growth than the growth of other parts of the seedlings. Reduction in growth rate at severe water stress has also been reported by for *Eucaylyptus grandis* (Paulilo *et al.* 1998). A small sized leaf has a thin boundary layer which allows for a better convictive heat loss to environment and can decrease its temperature (Gibson *et al.,* 1998). Some desert plants also form compact canopy with many small sized slender leaves (Gibson *et al.,*1998; Klich *et al.,* 2000). Forming many small sized leaves at dry condition might be common characteristics of different plant species occurring at different habitats. *Cassia fistula* was encountered with the deep root growth in comparison to stem growth. Fast and deep root system enhanced the chances of survival of *Cassia fistula* in the dry habitats. Ginvish *et al.,* (1986) also supported this type of investigation. Greater root growth as compared to stem growth might provide enough adsorptive surface to exploit water and nutrients from the soil, which indicated that plants meet their requirement from the deeper soil layer through deep penetrating root system (Singh *et al.,* 2003)

Root biomass ranged from 32.2 to 34.2% of total biomass as reported (Dhyani *et al.* 1990) who have reported 27 to 72% root biomass in different trees.

A nutrient element is one that is required to complete the life cycle of the organism and its relative deficiency produces specific deficiency symptoms. The availability of a nutrient in the soil is that fraction whose variation in amount is responsible for significant changes in yield and response (Bray *et al.,* 1948). Nitrogen is important in determining the nutrient use efficiency. Nutrient uptake usually varies in response to nutrient availability although species may have a specific pattern. Kannan and Paliwal (1992) found significant variations in nutrient uptake when grown in similar medium suggesting specific pattern for a particular species. Pandit and Thampan (1988) reported that during monsoon N_2 showed higher concentration, because the atmospheric N_2 comes to the soil with rainfall..The nutrients used by plant species for growth and biomass production generally come from the internal cycling to the reverse materials which require water for their solubilisation and translocation (Sanchez *et al.*, 1991). Different cultivars within the same species have their own characteristic response patterns when presented revealed that positive effect of whole length was counter balanced by high positive effect via root length (0.032) and stem length (0.969) to give an overall positive correlationship with other parameters. The leaf area and whole length showed least positive correlation (0.335). The positive effect of leaf area and root biomass (0.331) was in agreement. The negative correlation was held by the leaf area and basal area with value of 0.438. Shoot/root ratio represented low positive correlationship with whole length of the plant. All the plant characters co-operate in the same manner except leaf area which did not increase with an increase the height of the plant. The correlationship between all the characters registered a positive correlation except the basal area and shoot/root ratio. The highest positive correlationship was found with the stem length and whole length. The basal area did not show any significant association with stem length. The stem length did not increase with respect to breadth. The negative with a given a temporally changing edaphic environment (Zobel *et al.,* 1975). Similar results were found for several other cultivars (Smith *et al.,* 1991; Gulmon *et al.,* 1978). Coefficient analysis correlationship between basal area and shoot/root ratio revealed that lower the shoot/root ratio, higher is the basal area.

Conclusion

From the cultivation practices of the plants in the different sand and soil ratios, with the mutual effect of season and soils it was conducted that the sand and soil ratio of 80:20 (sand:soil) was most favourable ratio for *Cassia fistula.* For the species rainy season was found as most favourable season for their growth. The species showed better performance for the sandy soil condition i.e. 80:20 soil ratios can be considered for their commercial cultivation in the sandy or bare areas where they can easily adapt themselves and overcome the sand drift condition. The results of experiments on cultivation practices can be helpful in deciding the suitable soil types and suitable season for the particular species.

References

Bray, J.R., 1963. Root production and the estimation of net productivity. ***Can. J. Bot.*** 41: 65-72.

Bray, R.H., 1948. In: Kitchen, H.B. (Ed.) *Diagnostic Techniques for Soils and Crops.* American Potash Institute, Washington 6, DC. pp 53-86.

Dhyani, S.K., Narain, P. and Singh, R.K., 1990. Studies on distribution of five multipurpose tree species in Doon valley, India. ***Agrofor. Syst.*** 12: 49.

Gibson, A.C. 1998. Photosynthetic organs of desert plants. ***Bioscience***. 48: 911-920.

Ginvish, T.J., 1986. *On the Economy of Plant Form and Function.* Cambridge University Press, New Yolk.

Gulmon, S.L. and Turner, N.C., 1978. Differences in root and shoot development of tomato (*Lycopersicon esculentum* Mill.). ***Plant Soil***. 49: 127- 136.

Jackson, J.K., 1987. *Manual of Afforestation in Nepal.* Nepal-UK Forestry Research Project, Kathmandu, Nepal, 232 pp.

Kala, S. P. and Gaur, R. D., 1982. *A contribution to the flora of Gopeshwar (Chamoli, Garhwal), U.A. In: G.S. Paliwal* (Ed.) Vegetational Wealth of Himalaya, Puja Publication, New Delhi.

Kannan, D. and Paliwal, K., 1992. Dry matter production, chlorophyll, protein contents and foliar nutrient concentration in Peltophorum ferrugineum and Albizia lebbek under nursery conditions. ***For. Ecol. Mgmt.*** **50**: 265-273.

Klich, M.G., 2000. Leaf variations in *Elaeagnus angustifolia* related to environmental heterogeneity. *Environ.* ***Exp. Bot.*** 44: 171-183.

Mishra, K.C., 1980. *Manual of Plant Ecology.* Oxford and IBH Publishing Co., New Delhi.

Mishra, R., 1968. *Ecology Work Book.* Oxford and IBH Publishing Co., New Delhi.

Pandit, B.R. and Thampan, S., 1988. Total concentration of P, Ca, Mg, N, C in the soil of reserve forests near Bhavnagar (Gujrat State). ***Ind. J. For.*** 11(2): 98-100.

Paulilo, M.T.S., Fellippe, G.M., and Dale J., 1998. Root/shoot partitioning and water relations in quargrandiflora (Vochysiaceae) seedlings under water stress. Revista de ***Biologia Tropical*** 46: 41- 44.

Sah, S.P., Upadhyay, S.K., Pandit, P., and Lilles, J.B., 2003. Effects of soil on sissoo (*Dalbergia sissoo*, Roxb.) growth in a plantation forest of Nepal. ***Indian Forester.*** 129 (9-12): 1059-1068.

Sanchez, E.E., Rithetti, T.L., Suger D. and Lombard, P.B., 1991. Recycling of nitrogen in field grown 'coppice' pears. ***J. Hortic. Sci.*** 66: 479- 486.

Singh G., Bala N., Kuppusamy, V. and Rathod, T.R., 2003. Adaptability and productivity of *Cassia angustifolia* in sandy soil of Indian desert. ***Indian Forester.*** 129 (2): 213-223.

Singh J., Sinha K., Mishra N.P., Singh S.C., Sarma, Ashok and Khanuja S.P.S., 2003. Traditional uses of *Terminalia arjuna* (Arjun). ***J. Med. Arom. Pl. Sci.*** 25:1039-1042.

Singh, B. and Singh, G., 2007. Influence of soil water deficit on the growth and root growth potential of *Dalbergia sissoo* seedlings in an arid environment. ***Indian Forester.*** 133: 229-238.

Singh, G., Bala, N., Kuppusamy V. and Rathod T.R., 2003. Adaptability and productivity of *Cassia angustifolia* in sandy soil of Indian desert. ***Indian Forester.*** 129(2): 2003.

Singh, S., Singh, A.K. and Joshi, H.K., 2003. Storage behaviour of Indian goose berry (*Emblica officinalis*) cultivars under semi-arid ecosystem of Gujarat. ***Ind. J. Agric. Sci.*** 73(10): 530-534.

Smith, M.E. and Zobel, R.W., 1991. *Plant genetic interactions in alternative cropping systems: considerations for breeding methods.* In: Plant Breeding and Sustainable Agriculture: Considerations for Objectives and Methods. Crop Science Society of America Special Publication 18, pp. 57-81.

Sundriyal, R.C., 2005. Medicinal plant cultivation and conservation in the Himalaya: An agenda for action. ***Indian Forester.*** 131(3): 410-424.

Zheng, Y. and Feng, Y.L., 2006. Leaf water absorption of epiphytes and non-epiphytes in Xishuangbanna. ***Chinese J. Appl. Ecol.*** 27: 977-981.

Zobel, R.W., 1975. *The genetics of root development. In: Torrey*, J.G. and Clarkson, D.F. (Eds.) The Development and Function of Roots. Academic Press, London, pp. 261-275