Survival and Growth of Seedlings in Nursery and Forest Stands

Introduction

Success of regeneration of trees in a forest depends upon the response of naturally growing and transplanted seedlings to the prevailing microenvironment (Whitemore 1975, Gause & Stone 1979). Survival and growth of tree seedlings are determined by the interactive influence of biotic and abiotic factors of the forest environment (Augspurger 1984b). The effects of certain factors such as light intensity (Whitemore 1975, Fetcher *et al.* 1983, Burton & Muller- Dombois 1984, Vance & Running 1985, Clark *et al.* 1996), soil moisture (Muller- Dombois *et al.* 1980, Lawrence & Oechel 1983), soil temperature (Wyant *et al.* 1983), soil nutrient (Van Den Dricssche1982), pathogen (Muller-Dombois *et al.* 1983, Augsperger 1984b) and burning (Abott & Loneragan 1984, O'Dowd & Gill 1984) have been studied on seedlings growing in natural or in control conditions, but there is conspicuous lack of studies on the response of transplanted seedlings to different micro environmental conditions prevailing in the forest.

There is considerable difference in the responses of tropical forest tree species to irradiance, particularly in photosynthetic responses (Oberbauer & Strain 1984, Pearcy 1987, Turnbull 1991, Kitajima 1994, Chazdon *et al.* 1996, Press *et al.* 1996, Zipper & Press 1996) and relative growth rate (Coombe & Hadfield 1962, Okali 1972, Whitemore & Gong 1983, Pompa & Bongers

1991, Kitajima 1994, Agyeman *et al.*1999). In tropical rain forest, generally 1-2% of the radiation above the canopy reaches the forest floor (Chazdon 1988, Clark *et al.* 1996). Accordingly, growth rates of seedlings in the understory vary with availability of light.

Thus an experiment was carried out to study the growth and survival of nursery grown seedlings of Rudraksh under different canopy conditions.

Materials and Methods

Growth of seedlings in nursery:

One year old nursery-raised seedlings with uniform growth were picked up after cessation of germination trail. Seedlings were separated from root trainers in the month of May, 1999 and transplanted to polythene bags filled with well-mixed cow dung and farmyard manure in 2:3 proportions. Seedlings were tagged and numbered for future studies. Shoot elongation, collar diameter, leaf number and leaf area of the seedlings were measured over a period of one year at two month interval for the seedlings kept in nursery.

Growth of seedlings transplanted in forest stands:

Three forest stands having the mixed plantations of *Ailenthus grandis, Michelia champaca, Lagerstromia flosregini, Anthocephalus kadamba, Terminalia chebula, T. arjuna, Syzigium cumini, Bauhinia verigata, Cassia* sp. etc. and varying in terms of canopy and incoming solar radiation were selected Itanagar (27°07′ N latitude, 93 °22′ E longitude, 100 m altitude).

Environmental parameters of the three forest stands where the seedlings were transplanted are given in table VII.1. Stands I, II and III have open (canopy cover: 40%), sparse (canopy cover: 60%) and dense (canopy cover: 84%) canopy, respectively. Seedlings were transplanted on 15 May 1999 in all the three forest stands at a spacing of 3 m × 3 m distance. Prior to transplantation the seedlings were measured for shoot length, collar diameter, leaf number and leaf area.

In each forest stand the growth and survival of the transplanted seedlings were monitored over a period of one year at two-month interval. On each observation date, the shoot elongation, collar diameter, leaf number and leaf area of the seedlings were recorded. All the leaves of each seedling were measured for leaf area by portable leaf area meter (*LICOR 3000A*). Leaf infestation by different herbivores was counted individually on each seedling in the above mentioned three forest stands. Growth rate of the seedlings was determined by subtracting the values for height, collar diameter, leaf number and leaf area of each seedling obtained at a given observation date from the corresponding values for these parameters recorded at the subsequent observation date.

Humidity of air was measured by a digital hygrometer and air temperature by a thermometer. Soil temperature was measured by inserting the soil thermometer down to 10 cm depth. The samples were collected from each stand at different dates and soil moisture content was determined. Besides, the water holding capacity of the soil samples was also recorded following Keens up method. Light intensity was measured by a digital lux meter at 9 a.m., 12 noon and 3 p.m. on sunny days in different seasons (thrice in a month) and the means were calculated. Soil texture was determined by hydrometer method.

Results

Growth and survival of seedlings in nursery

As expected the growth rates of seedlings in nursery in terms of shoot length, collar diameter, leaf number and leaf area increased with time. The rate of shoot elongation was found more in September-October. Thereafter the shoot growth decreased and it was least in December-January and from February-March onwards it again increased. Seedling growth rate in terms of collar diameter decreased during September-November and was least in December, and from February-March onwards it increased again. Growth rate in terms of leaf number decreased from August to December and increased thereafter. Seedling leaf area also followed the same pattern; it decreased from August to December and thereafter it increased steadily. No seedling mortality was recorded in the nursery condition (Fig. VII.1).

Growth and survival of seedlings transplanted in the three forest stands

Shoot elongation:

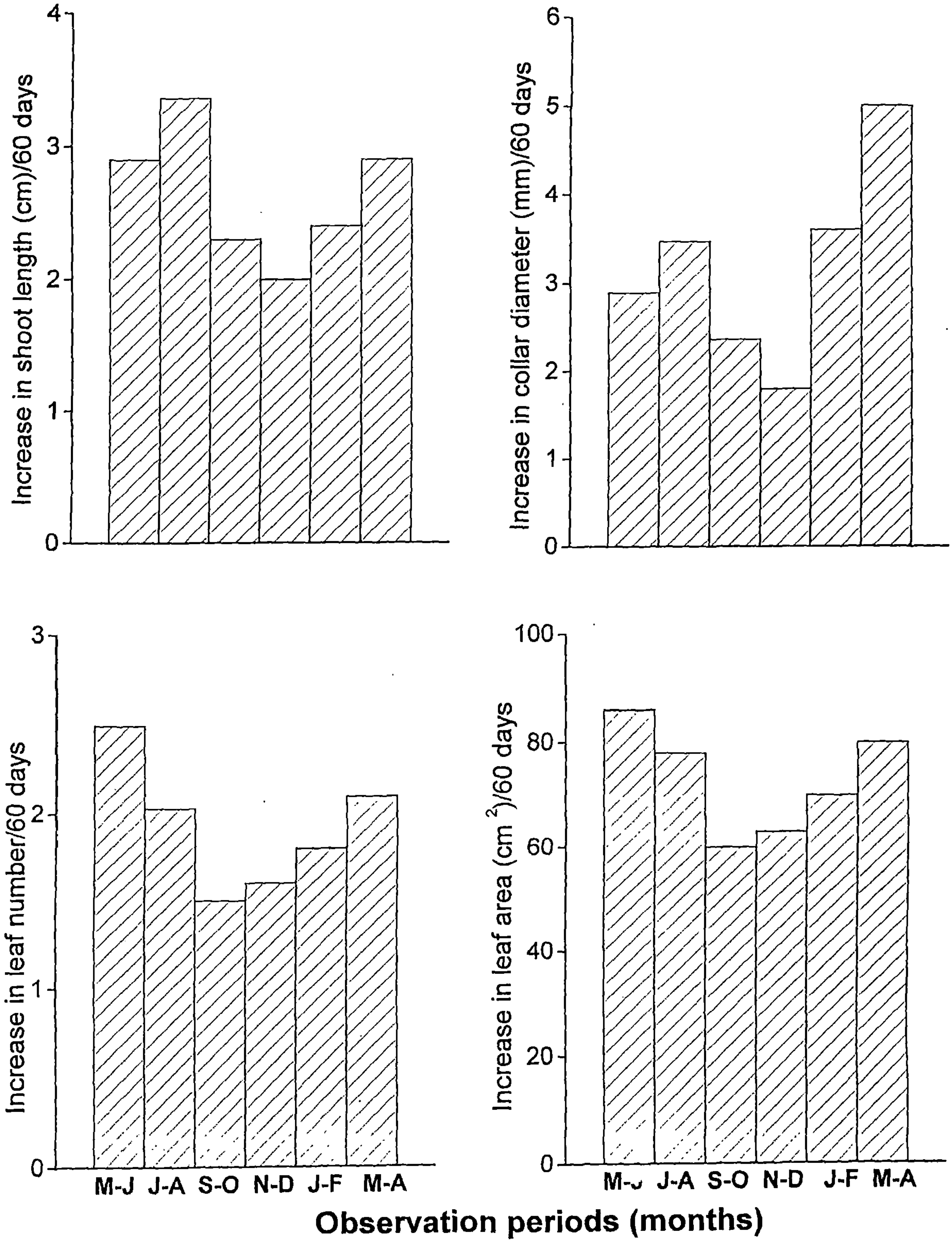

Figure VII.1. Seedling growth in terms of shoot elongation, collar diameter, leaf number and leaf area under nursery conditions.(M-J: 1 May to 30 June, J-A: 1 July to 31 August, S-O: 1 September to 31 October, N-D: 1 November to 31 December, J-F: January to 29 February, M-A: 1 March to 30 April).

Mean seedling shoot elongation rate varied significantly between the forest stands ($F=20.97$, $P<0.000$). Shoot elongation rate also differed significantly between the seedlings growing in a forest stand (Stand I, $F=29$, $P<0.01$; Stand II, $F=73$, $P<0.01$; Stand III, $F=192$, $P<0.01$). Stand III with dense canopy recorded relatively higher shoot elongation followed by stand II with sparse canopy (Fig. VII. 2 a).

Table VII. 1: Environmental parameters of the three forest stands where seedlings were transplanted (open canopy - stand I, sparse canopy – stand II and dense canopy – stand III).

Parameters	Stands		
	I	II	III
Light intensity (lux)	23000-28000	15000 - 8000	8000- 10000
Canopy cover (%)	40.0	60.0	84.0
Mean annual humidity (%)	65 ± 3.68	72 ± 2.47	80 ± 1.69
Mean annual soil temperature (^{0}C)	29.5 ± 3.73	28 ± 3.23	27.2 ± 3.26
Mean annual air temperature (^{0}C)	32.33 ± 4.57	30.16 ± 4.81	28.5 ± 2.81
Average soil moisture (%)	12.2 ± 0.65	16.41 ± 1.49	20.5 ± 2.13
Water holding capacity (%)	63 ± 10.27	67± 8.85	70 ± 8.45
Soil texture	Loamy sand. Sand-82.6% Silt-7.4% Clay-10%	Loamy sand. Sand-78.6% Silt-9.6% Clay-11.8%	Loamy sand Sand-79.1% Silt-6.5% Clay-14.4%

Seedling collar diameter

Mean collar diameter differed significantly between the forest stands (F=54.73, P<0.01). Collar diameter also varied significantly between the seedlings growing in a stand (Stand I, F=32, P<0.01; Stand II, F= 216.70, P<0.00, Stand III, F=44.76, P<0.01). Seedlings were of relatively greater diameter in stand III with dense canopy and of least diameter in Stand I with open canopy (Fig. VII. 2b). Growth rate of collar diameter was least in November-December and thereafter it increased steadily.

Leaf number

Leaf number differed significantly between the forest stands (F=54, P<0.01). Number of leaves differed significantly between the seedlings growing in a stand (Stand I, F=27.61, P<0.01; Stand II, F=118.25, P<0.01, Stand III, F=62.91, P<0.01). Seedlings grown in stand III with dense canopy had greater number of leaves. Growth rate in terms of leaf number decreased from July-August to January-February and thereafter it increased steadily (Fig. VII. 2c).

Leaf area

Leaf area per seedling differed significantly (Stand I, F= 54.62, P<0.001; Stand II, F=174.91, P <0.001; Stand III, F= 44.76, P<0.01) among the three forest stands. Highest leaf area was recorded in stand III with dense canopy and least in stand I with open canopy. Leaf area increment was rapid in May-June to July-August and thereafter it decreased and was the least in January-February due to leaf fall, and after February it again increased steadily (Fig. VII. 2d).

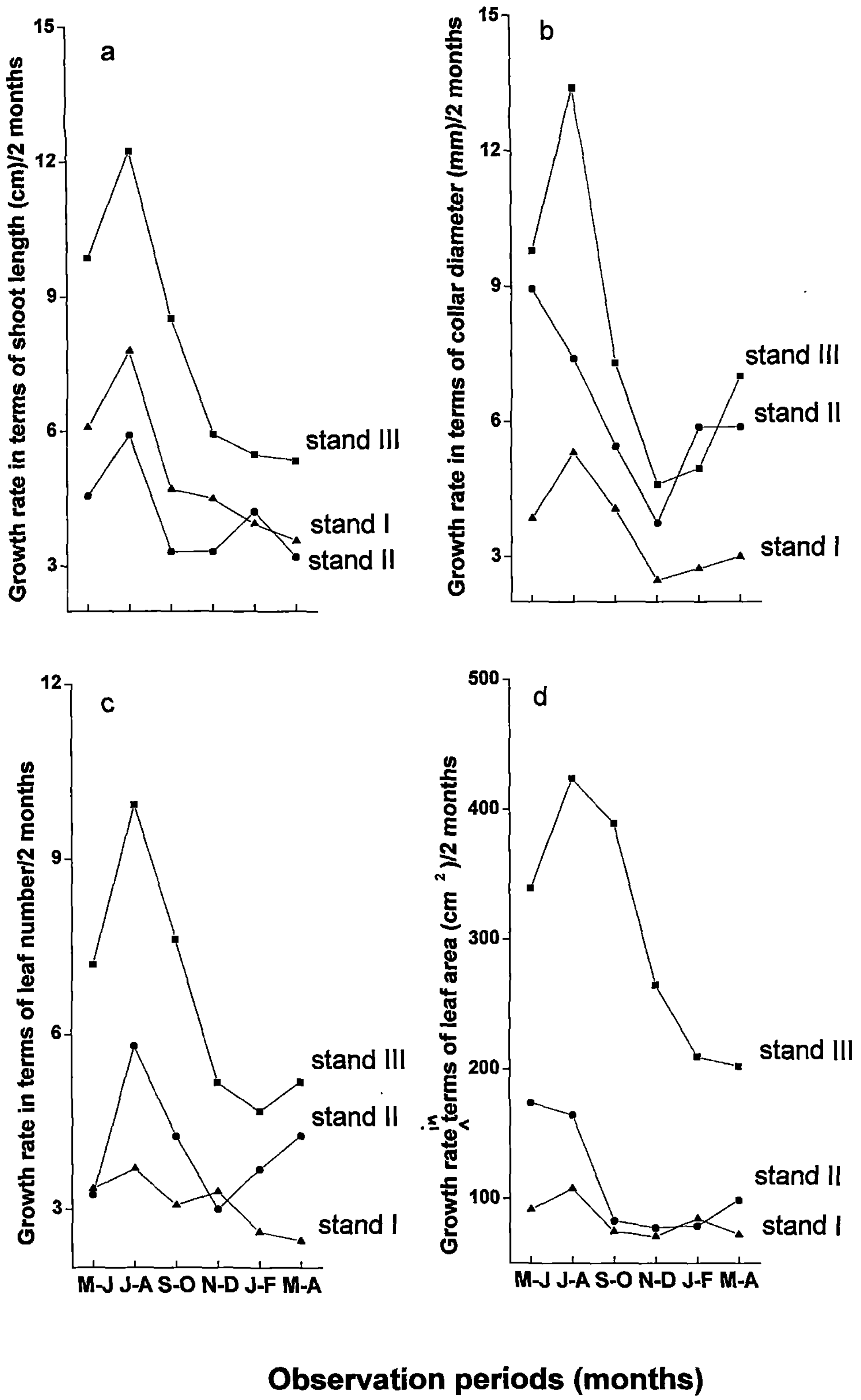

Figure VII.2. Growth rate of seedlings in three forest stands; open canopy (stand I), sparse canopy (stand II) and dense canopy (stand III). (M-J: 1 May to 30 June, J-A: 1 July to 31 August, S-O: 1 September to 31 October, N-D: 1 November to 31 December, J-F: 1 January to 29 February, M-A: 1 March to 30 April).

Seedling mortality and infestation by various herbivores are given in Table VII. 2. Highest seedling mortality was recorded in stand I with open canopy and least in stand III with dense canopy. However, spider web infestation was highest in stand III with dense canopy and least in stand I with open canopy. Insects with silken cocoon were observed in stand III with dense canopy. The shoot length, collar diameter, leaf number and leaf area of seedlings in the nursery and in the three forest stands after one year growth are given in figure VII. 3. The seedlings planted in stand III with dense canopy showed relatively better growth than those in stand II with sparse canopy and stand I with open canopy.

Table VII. 2. Survival of Rudraksh seedlings and their infestation by various agents in different forest stands.

Forest sites	Survival (%)	Pest Infestation (%)			
		Pathogen	Herbivory	Spider web	Unknown
Open canopy	75	17	75	8	-
Sparse canopy	80	6	57	31	6
Dense canopy	85	0	72	21	8

Discussion

Better growth and survival of the seedlings in stand III with dense canopy can be attributed to the microclimatic conditions favourable for growth. Further, the seedling growth might have been stimulated in open edges due to

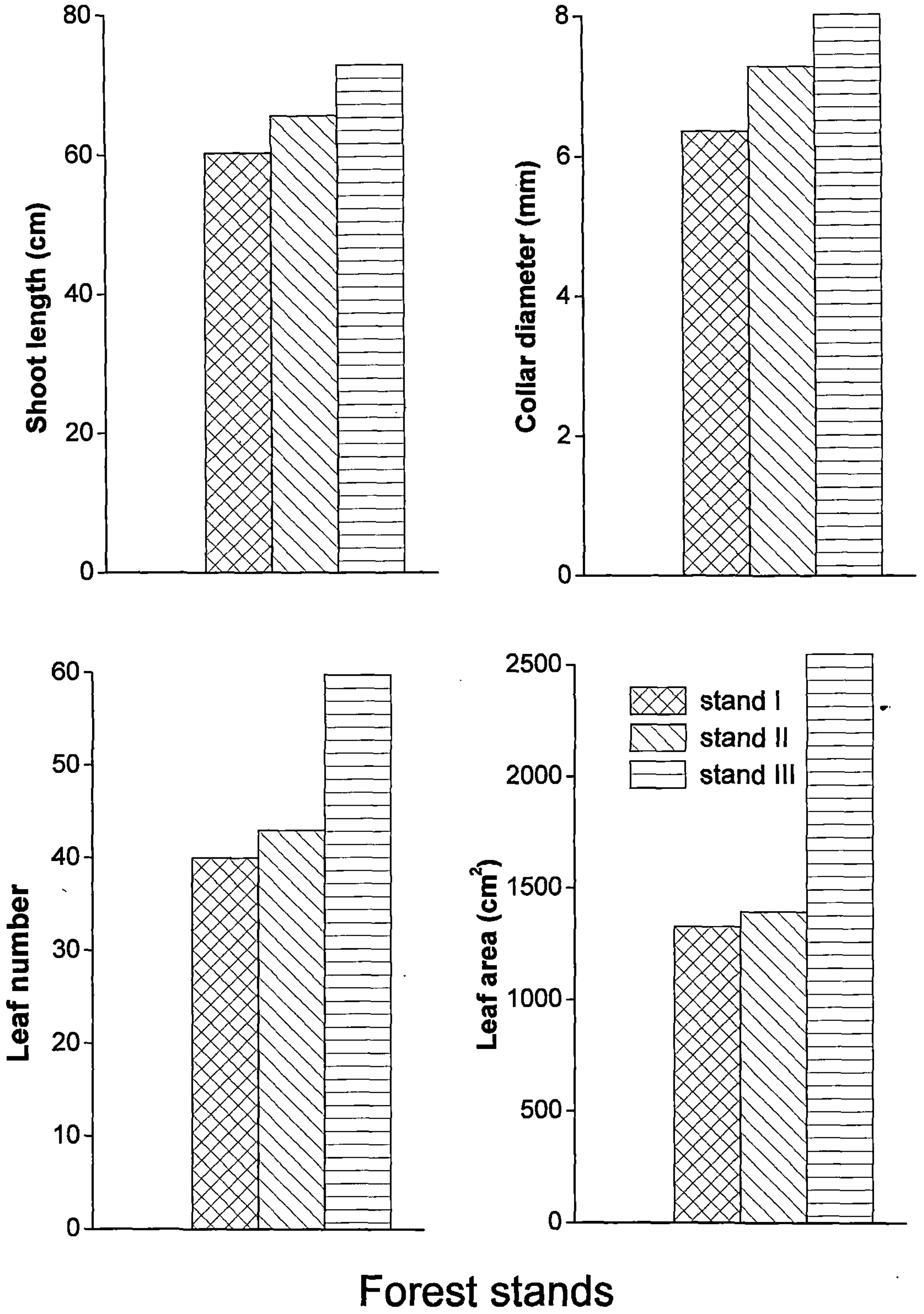

Figure VII.3. Growth of seedlings in terms of shoot length, collar diameter, leaf number and leaf area in stand I (open canopy), stand II (sparse canopy) and stand III (dense canopy) after one year period of transplantation.

better availability of light. Khan and Uma Shanker (2001) have reported better growth and survival of seedlings of *Quercus semiserrata* in medium light conditions. However, many studies have shown better growth and survival of seedling in sunny areas (Longman & Jenik 1974, Whitemore 1975, Hartshorn 1978, Lee 1978). Studies conducted by Augsperger (1984b) on tropical trees, Khan *et al.* (1986) on subtropical trees, Sasaki & Mori (1981) on some *Dipterocarpus* seedlings have also shown better growth and survival in sunny areas.

Relative increase in the leaf area was more in stand III with dense canopy. Seedling leaf area decreased with the increase in radiation. At low light plants enhance light interception by means of a high biomass allocation to leaves and the formation of thin leaves with high leaf area. On the other hand, under high radiation plants reduce transpiration loss and increase carbon gain by making small sized, thick leaves with low leaf area. Small size leaf area has thin boundary layer, which allows for a better convective heat loss to the environment and cooling down of the leaf in high light environment (Parkhrust & Loucks 1972, Givnish 1988). Leaf thickness is increased in high radiation owing to the formation of several photosynthetically active parenchyma layers enhancing photosynthetic capacity. Similar pattern has been reported in the seedlings and leaves of trees along a light gradient in the forest canopy (Oberbauer & Strain 1986, Poorter *et al.* 1995).

Growth rate of seedlings in terms of shoot elongation, collar diameter, leaf number and leaf area was more under the dense canopy with intermediate light radiation than in the other two stands. At full sun light net assimilation rate compensates for the decline in leaf area (Poorter 1999). Plants grown in full light suffered from water limitation in high soil temperature, which might have caused reduction in the above growth parameters, in the case of seedlings grown in the other two stands (stand I & II) which had open and sparse canopy. At high irradiance level photosynthetic system may be damaged causing bleaching of leaves (Oberbauer 1985, Chairiello *et al.*1987). High radiation load requires a larger biomass allocation to roots for water uptake to compensate for transpiration losses. Therefore, less biomass may be invested in leaf material, which slightly reduces photosynthetic rate and potential growth rate (Kormer 1994). In a study on the growth of *Liviodendron* under controlled light and water conditions, Holmgern (1996) found that maximum growth was realized at light level as low as 1%. Veenendaal *et al.* (1996) compared the growth of seedlings of 15 West African tree species at various light levels and reported that shade-tolerant species showed higher relative growth rate at 16 to 27% light, above which it declined while the pioneer species showed optimum growth between 26 and 100% light intensity in the field. Biomass loss is minimized by low leaf turnover (King 1994) and due to the storage and defense. Trees, which are less prone to herbivory, are characterized by high leaf toughness and low inherent growth rate (Cornelissen *et al.*1998). Shade plants and shade-tolerant plants allocate more resource to leaf production, giving rise to higher leaf area ratio, and lower root to shoot ratio or relative root mass. They may show greater activity in the apical meristem, leading to reduced branching and more slender stems (Poorter 1999).

Pathogen attack, insect herbivory and infestation with spider webs were the major causes of seedling mortality in all the stands. Pathogen and herbivory were more frequent in stand I with open canopy as compared to the other stands. Necrosis of stem tips during early stage of growth is the cause of seedling mortality. Relatively greater proximity of the transplanted seedlings to the trees in the dense canopy stand may increase the chances of pathogen infection since the parent trees act as host for a number of pests. Kitajima & Augspurger (1989) reported that the proportion of seedlings of *Tachigalia versicolor* killed by damping-off disease was significantly higher near the parent trees.

Damage to seedlings by insect herbivory in forest stand is the result of complex interactions between the direct and indirect responses of both plants and herbivores to shading and other micro-environmental conditions. In the present experiment, the damage by herbivory was more in stand I (with open canopy) and stand III (dense canopy) as compared to stand II with sparse canopy. The insect especially the caterpillar, beetle, fly and other coleopteran insects damaged the leaf blade along with the midrib resulting in the falling of leaf and sometimes scaletonized appearance of leaf (plate VII.1). The frequency of insect infestation indicated that the herbivores preferred the aged leaves to the younger leaves. This is in contrast to the findings of Coley (1983) who reported that insects preferred young leaves due to lack of

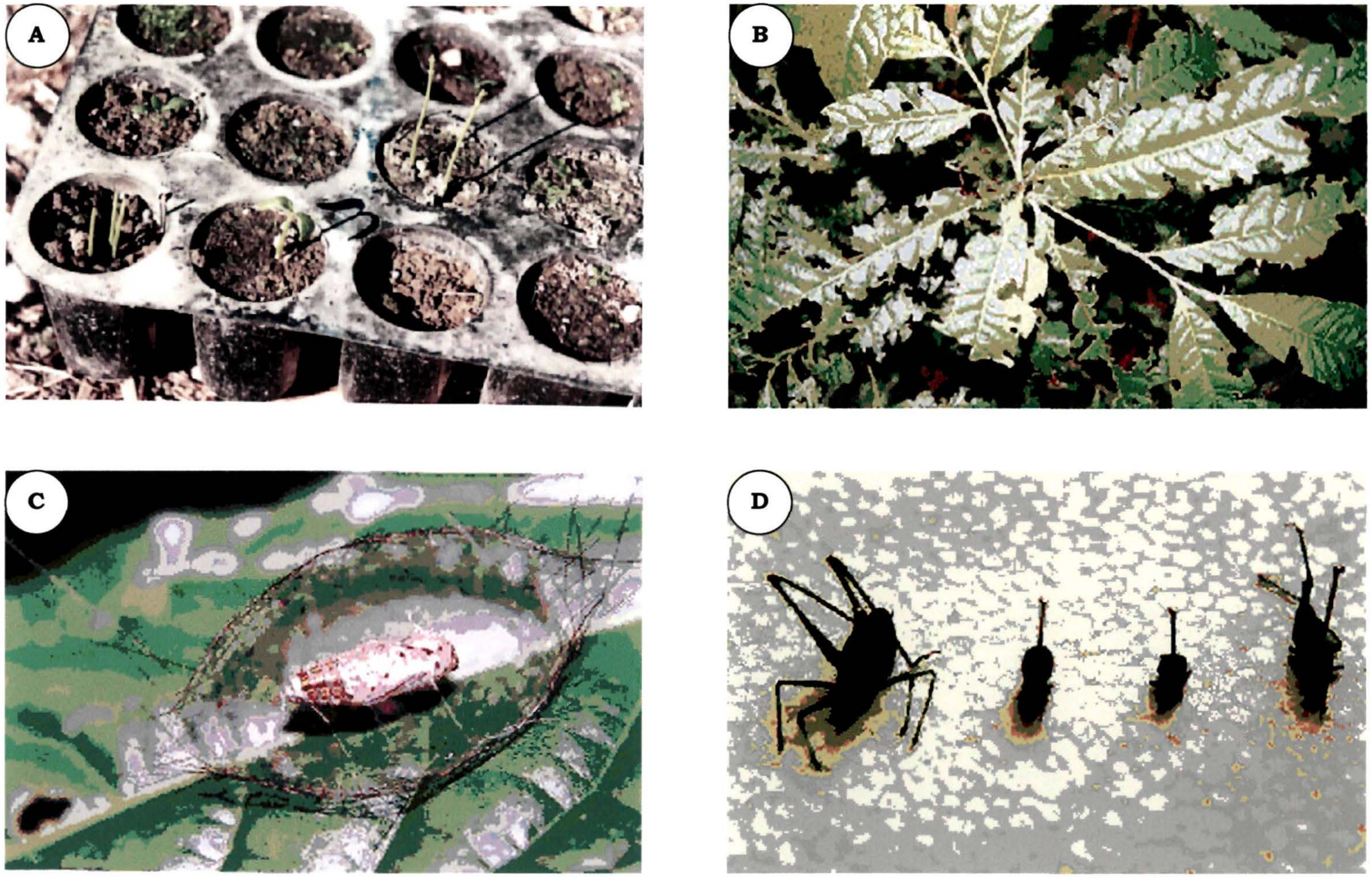

Plate VII.1. Herbivory in Rudraksh seedlings in nursery conditions (A) and in forest stands (B). Insects cocoon (C) and grasshoppers (D) noticed on the Rudraksh seedlings.

toughness, higher level of water and nitrogen. There was greater damage during rainy season which may be due to faster multiplication of insect herbivores on the luxuriantly growing neighbouring weeds especially in stand I and III which had open and dense canopy, respectively.

As mentioned above, the mature leaves were damaged more than the young leaves. This could be simply because the new leaves emerge during pre-monsoon period when insect herbivores are scarce, while the mature leaf stage is attained during the wet season when the herbivore populations are abundant. Degree of herbivore damage in stand I and III with open and dense canopy, respectively was more compared to stand II with sparse canopy, which may be due to higher frequency and good growth of weeds in the former two stands. The weed growth causes increase in insect and herbivore populations (Coley *et al.* 1985). However, frequent weeding might have reduced the herbivore populations in stand II whereby the damage by herbivores was minimized.

In general Rudraksh is a sub-canopy tree species expressing full growth and development in shaded condition. In the present experiment, relatively vigorous growth and development was observed in dense canopy conditions. Based on the present observations, it is suggested that plantation of Rudraksh should be raised as understory in the established forests/plantations with small canopy gaps or in slightly shaded localities for better success.