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Survival and growth of seedlings of Rudraksh (*Elaeocarpus ganitrus*) under varied canopy conditions after transplant

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Abstract: An experiment was carried out to study the survival and growth of the nursery seedlings of Rudraksh (*Elaeocarpus ganitrus*) transplanted in the forest stands having dense, sparse and open canopy. The transplants exhibited better growth in terms of shoot length, collar diameter, leaf number and leaf area and survival in dense than in sparse and open canopy. The pathogen attack on seedlings was more in open canopy whereas spider webs were more in sparse canopy. The damage by herbivory was more in open and dense canopy as compared to sparse canopy. Based on the present observations, it is suggested that plantation of Rudraksh should be raised as understory under the established forests/plantations with small canopy gaps or in slightly shaded localities for better success.

Resumen: Se llevó a cabo un experimento para estudiar la supervivencia y el crecimiento de plántulas producidas en vivero de rudraksh (*Elaeocarpus ganitrus*), transplantadas a rodales de bosque con dosel denso, ralo y abierto. Las plantas transplantadas al bosque con dosel denso mostraron un mejor crecimiento en términos de longitud del vástago, diámetro basal, número de hojas y área foliar, y mayor supervivencia que las plantas transplantadas bajo los doseles ralo y abierto. El ataque de las plántulas por patógenos fue mayor en el dosel abierto, mientras que hubo más telarañas en el dosel ralo. El daño por herbivoría fue mayor en los doseles abierto y cerrado en comparación con el dosel ralo. Con base en estas observaciones, se sugiere que para obtener un mayor éxito, la plantación de rudraksh debe ser establecida a manera de sotobosque bajo plantaciones/bosques establecidos que tengan pequeñas aberturas del dosel, o en localidades ligeramente sombreadas.

Resumo: Uma experiência foi efectuada para estudar a sobrevivência e o crescimento das plântulas de "Rudraksh" (*Elaeocarpus ganitrus*) transplantadas para parcelas florestais que apresentavam copados densos, esparsos e abertos. As plantas transplantadas exibiram um melhor crescimento em termos de comprimento do lançamento terminal, diâmetro do colo, número de folhas e área folhear, bem como sobrevivência, sob os copados densos em comparação com os ralos e abertos. O ataque de patogénicos nas plântulas foi mais intenso nas parcelas com copado aberto enquanto as teias de aranha eram em maior número nas parcelas de copado esparso. Os danos causados pelos herbívoros foram maiores nas parcelas com copado aberto e denso quando comparado com as parcelas com copado ralo. Com base nas observações presentes, sugere-se que para um melhor sucesso a plantação com "Rudraksh" deve ser efectuada no sob coberto da floresta/plantação estabelecida com pequenos aberturas no copado ou em locais com sombreamento ligeiro.

Key words: Canopy cover, rudraksh, seasonal growth, seedlings, survival.

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Introduction

Success of regeneration of trees in a forest depends upon the response of naturally growing and transplanted seedlings to the prevailing microenvironment (Gause & Stone 1979; Whitemore 1975). Survival and growth of tree seedlings are determined by the interactive influence of biotic and abiotic factors of the forest environment (Augspurger 1984). The effects of certain factors such as light intensity (Clark *et al.* 1996), soil moisture (Lawrence & Oechel 1983), soil temperature (Wyant *et al.* 1983), pathogen (Augspurger 1984) have been studied on seedlings growing in natural or in control conditions. However, there is conspicuous lack of studies on the response of transplanted seedlings to different micro-environmental conditions prevailing in the forest.

Population of Rudraksh (*Elaeocarpus ganitrus*) in the tropical wet forests of Arunachal Pradesh has been decreasing day-by-day due to increased anthropogenic pressure. The nut collection for beads has caused the shrinkage of the seed bank in the soil, adversely affecting the regeneration of the species. Also, the frequent disturbances make the survival and growth of the Rudraksh seedlings exceedingly difficult (Bhuyan *et al.* 2002; Khan *et al.* 2004). The introduction of nursery-grown seedlings into the forest could be considered as one of the options to address this problem. However, before adopting this measure to improve the regeneration of Rudraksh, the response of the introduced seedlings to interactive influences of various biotic and abiotic factors of the forest environment need to be carefully studied. In view of this, the nursery-grown seedlings of Rudraksh were transplanted in plantation forests, having varied canopy cover, to evaluate the performance in terms of survival and growth.

Materials and methods

Growth of seedlings in nursery

One-year old nursery raised seedling (n=100) with more or less uniform height, leaf number and leaf area 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 (2:3). Seedlings were tagged and numbered.

Growth of seedlings transplanted in forest stands

Three study sites having the mixed plantations of *Ailanthus grandis, Michelia champaca, Lagerstroemia flosregine, Anthocephalus cadamba, Terminalia chebula, T. arjuna, Syzygium cumini, Bauhinia variegata, Cassia* sp. etc. and varying in terms of canopy and incoming solar radiation were selected in and around the North Eastern Regional Institue of Science & Technology, Itanagar (27° 07′ N latitude, 93° 22′ E longitude, 100 m altitude). Physico-chemical properties of the sites are given in Table 1. Hundred seedlings were transplanted

Table 1. Physico-chemical properties of the three study sites: open canopy, sparse canopy and dense canopy.

Parameters	Sites			Variance of means
	Open	Sparse	Dense	
Light intensity (lux) range	23000 – 28000	15000 – 18000	8000 – 10000	68250000*
Canopy cover (%)	40.0	60.00	84.00	485.33*
Mean annual humidity (%)	65.00 ± 3.68	72.00 ± 2.47	80.00 ± 1.69	56.3*
Mean annual soil temperature (^{0}C)	29.50 ± 3.73	28.00 ± 3.23	27.20 ± 3.26	1.36^{NS}
Mean annual air temperature (^{0}C)	32.33 ± 4.57	30.16 ± 4.81	28.50 ± 2.81	3.69*
Mean annual soil moisture (%)	12.20 ± 0.65	16.41 ± 1.49	20.50 ± 2.13	17.22*
Water holding capacity (%)	63.00 ± 10.27	67.00 ± 8.85	70.00 ± 8.45	12.33*
Soil texture	Loamy sand	Loamy sand	Loamy sand	
	Sand – 82.6%	Sand – 78.6%	Sand – 79.1%	4.75**
	Silt – 7.4%	Silt – 9.6%	Silt – 6.5%	2.54**
	Clay – 10%	Clay – 11.8%	Clay – 14.4%	4.89**

*,**Significant at 0.001 and 0.05 P level respectively; ^{NS}indicates not significant.

on 15 May, 1999 in each of the three sites having open, sparse and dense canopy at a spacing of 3m x 3m distance. Prior to transplantation the seedlings were measured for shoot length, collar diameter, leaf number and leaf area.

Observations were taken over a period of one year at two-months interval for survival, shoot elongation, collar diameter, leaf number and leaf area of the seedlings maintained in nursery as well as transplanted under different canopy cover. All the leaves of each seedling were measured for leaf area by a portable leaf area meter (LICOR 3000A). Leaf infestation by different herbivores was counted individually on each seedling at different sites. Seasonal growth of the seedlings was estimated both in nursery and transplanted sites by subtracting height, collar diameter, leaf number and leaf area of each seedling over the values for these parameters recorded at the preceding observation date (Khan & Tripathi 1989).

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 soil samples were collected from each site thrice in a month to determine the moisture content and average was calculated for 12 months. Besides, the water holding capacity of the soil samples was also recorded following Keen's box method (Piper 1944). Light intensity was measured by a digital luxmeter at 9 a.m., 12 noon and 3 p.m. on sunny days in different seasons (thrice in a month) and averages were calculated. Soil texture was determined by Bouyouncos hydrometer method (Bouyouncos 1962).

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 varied in different seasons (Fig. 1). In general the seedling growth for all

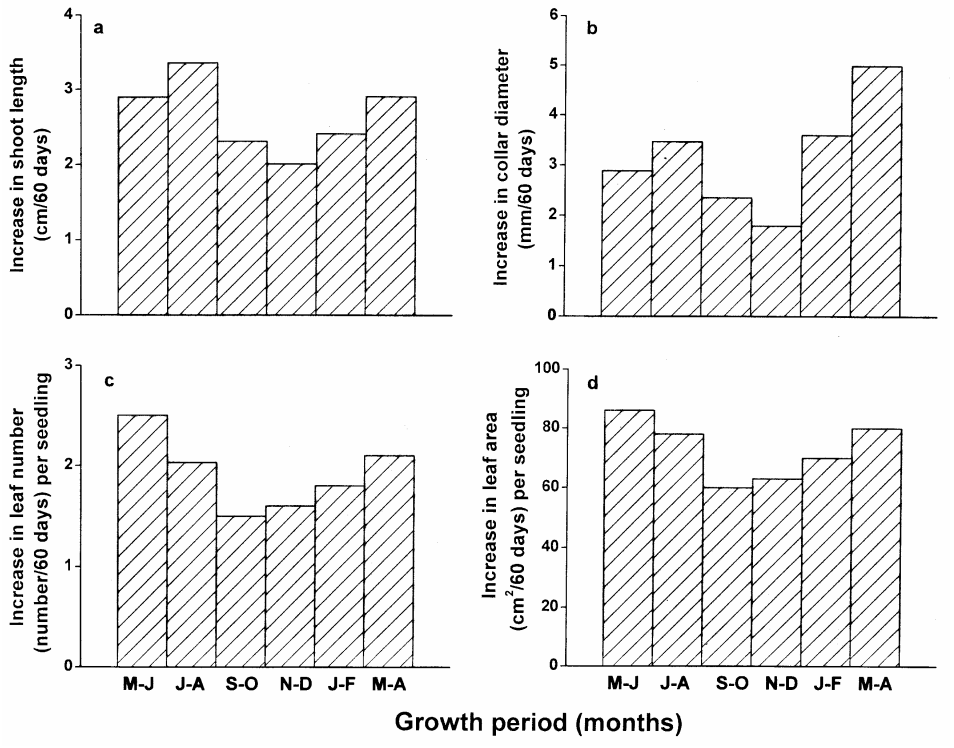

Fig. 1. Seasonal growth of seedlings in terms of shoot length (a), collar diameter (b), leaf number (c) and leaf area (d) under green house conditions (M-J: 1st May to 30 June, J-A: 1st July to 31 August, S-O: 1st September to 31st October, N-D: 1st November to 31st December, J-F: 1st January to 29th February, M-A: 1st March to 30 April).

the studied parameters was higher during wet and warm season (May-August) and it was least during winter season (November-January). No seedling mortality was recorded in the nursery condition in entire year.

Growth and survival of seedlings transplanted under varying forest canopy cover

The mean seasonal seedling growth in terms of shoot elongation, collar diameter, leaf number and leaf area varied significantly under different canopy cover (shoot elongation: F=20.97, collar diameter: F=54.73, leaf number: F=54, leaf area: 152.3; P<0.01). In general seasonal growth was higher under the dense canopy followed by spare canopy (Fig. 2). Further, the seedling growth peaked during wet and warm season (May-August) and it was minimum during winter season (November-January) (Fig. 2a). Seasonal growth of collar diameter was minimum in November-December and thereafter it increased steadily (Fig. 2b). Leaf number decreased from July-August to January-February thereafter it increased steadily (Fig. 2c). Increment in leaf area was rapid in May-June to July-August and thereafter it declined in January-February due to leaf fall (Fig. 2d).

Seedling mortality and infestation by various herbivores are presented (Table 2). Highest seed-

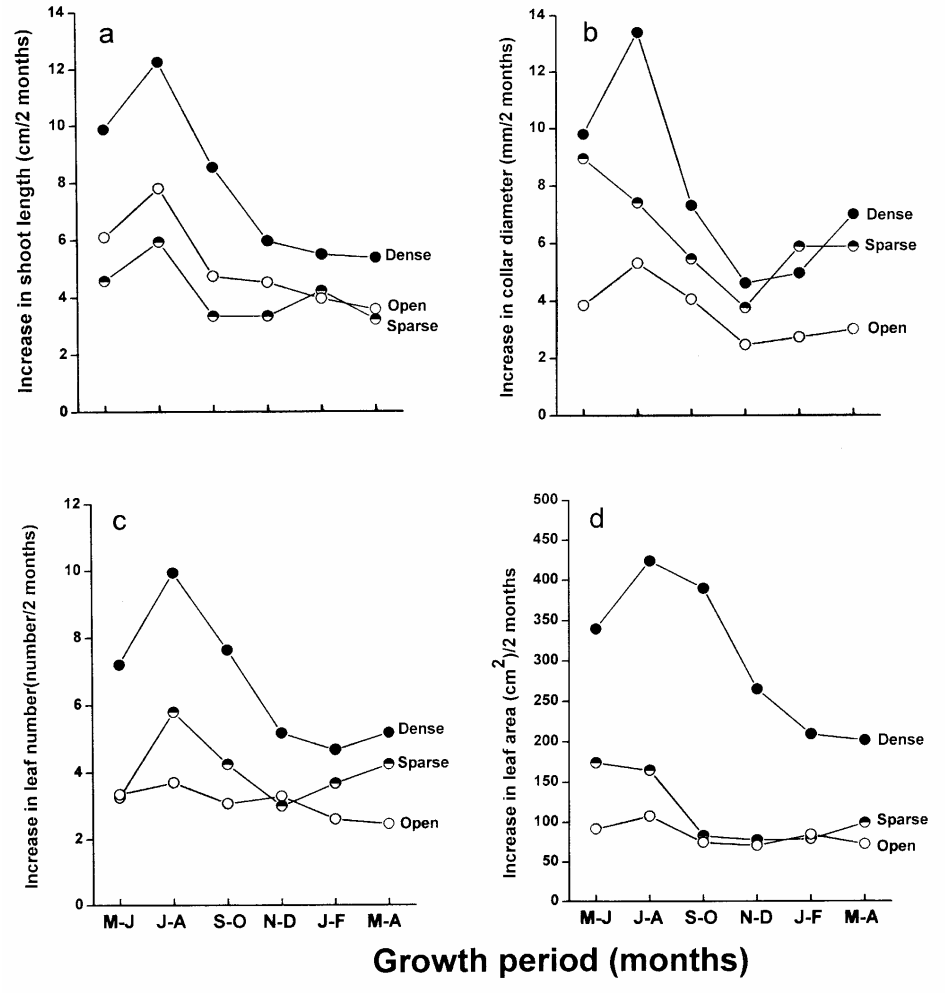

Fig. 2. Seasonal growth of seedlings in terms of shoot length (a), collar diameter (b), leaf number (c) and leaf area (d) in open canopy, sparse canopy and dense canopy. Legends for growth periods as in Fig. 1.

Table 2. Survival of Rudraksh seedlings after transplantation and relative mortality caused by various agents under different canopy cover one year after they were transplanted.

Sites	Survival (%)	Relative mortality (%) due to various agents			
		Pathogen	Herbivory	Spider web	Unknown
Open canopy (n=100)	75	17	75	8	0
Sparse canopy (n=100)	80	6	57	31	6
Dense canopy (n=100)	85	0	72	20	8
Variance of means	25*	74.33*	93*	132.33*	17.33*

*Significant at 0.001 p level.

ling mortality was recorded in open canopy and lowest in dense canopy. Likewise, pathogen attack was more frequent in open as compared to the sparse and dense canopy. However, spider web infestation was highest in sparse canopy and least in open canopy. The damage by herbivory was more in open and dense canopy as compared to sparse canopy.

The shoot length, collar diameter, leaf number and leaf area of the transplants under three different canopy cover after the completion of experiment are depicted (Fig. 3). Dense canopy showed relatively high absolute growth followed by sparse and open canopy.

Discussion

Better growth and survival of the seedlings in dense canopy may be attributed to the microclimatic condition (e.g. threshold light intensity, moderate temperature, high humidity etc.) favourable for the growth of Rudraksh seedlings. Similar results of best seedling growth in two tree species *Gordonia acuminata* and *Cornus controversa* under relatively dense canopy cover have been reported elsewhere (Cornelissen 1992, 1993). Bazzaz & Miao (1993) also reported better growth of seedlings of a late successional red oak in low than high light. However, Khan & Uma Shanker (2001) reported better growth and survival of seedlings of *Quercus semiserrata* in medium light condition.

Seasonal growth of seedlings in terms of shoot elongation, collar diameter, leaf number and leaf area was more under the dense canopy than in the sparse and open canopy. Seedlings grown in sparse and open canopy might have suffered from water limitation due to higher soil temperature and hence might have caused reduction in the above growth parameters. At high irradiance level photosynthetic system may be damaged causing bleaching of leaves (Chiariello *et al.* 1987; Oberbauer 1985). 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%. Veennendaal *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.

Pathogen attack, insect herbivory and infestation with spider webs were the major causes of seedling mortality in all the sites. Pathogen attack was more frequent in open as compared to the sparse and dense canopy. Necrosis of stem tips during early stage of growth was the cause of seedling mortality. 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. 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. 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 toughness, higher level of water and nitrogen. There was a greater damage during rainy season than the winter which may be due to faster multiplication of insect herbivores in the neighbouring weeds especially in open and dense canopy. 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

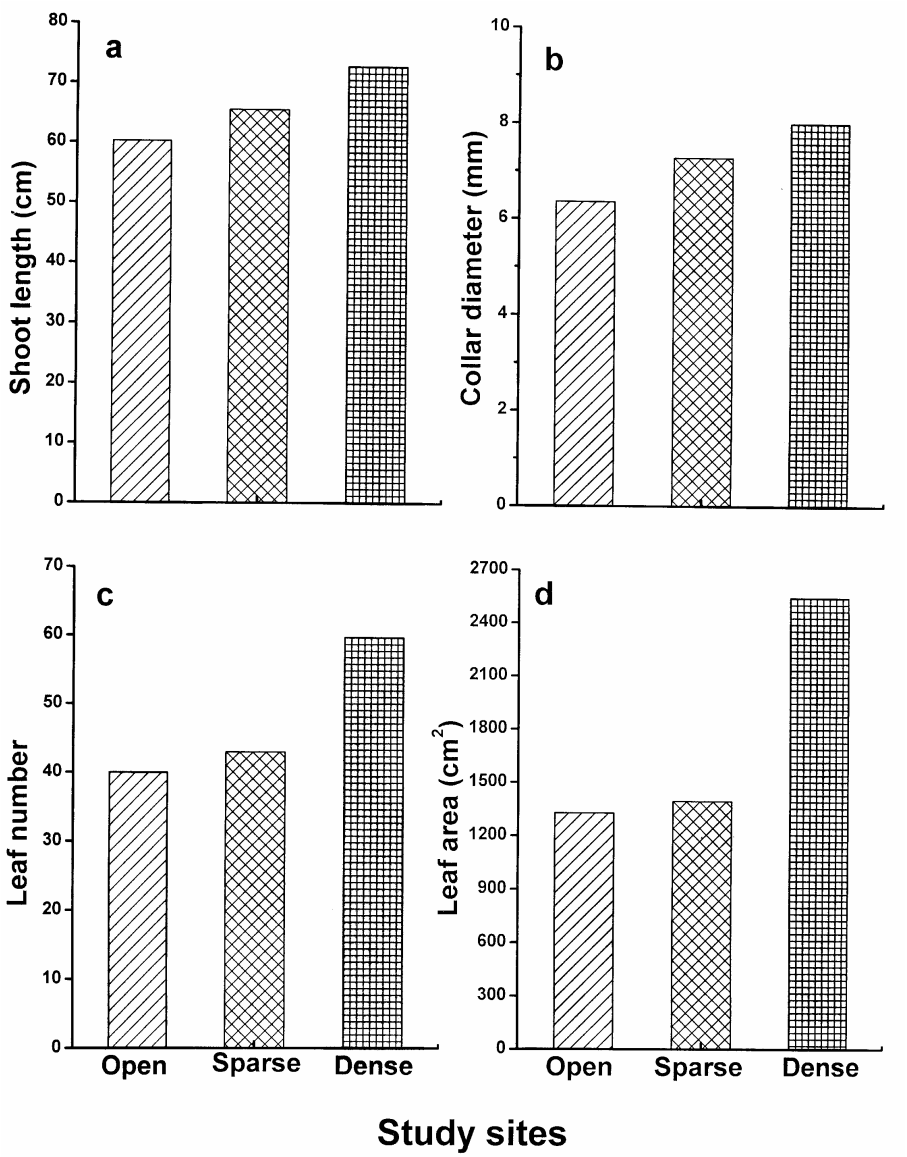

Fig. 3. Absolute growth of seedlings in terms of shoot length (a), collar diameter (b), leaf number (c) and leaf area (d) in open canopy, sparse canopy and dense canopy during one year growth after transplant.

when the herbivore population are abundant. Degree of herbivore damage in open and dense canopy was more compared to sparse canopy, which may be due to higher diversity and density of weeds in those stands that harbour the insects and herbivores (Coley *et al.* 1985). However, frequent weeding by the Social Forestry Wing of State Forest Department might have reduced the herbivore populations in sparse canopy 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 under the established forests/plantations with small canopy gaps or in slightly shaded localities for better success.

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