ECOLOGICAL STUDIES ON REGENERATION OF A FEW TREE SPECIES IN SUB-TROPICAL WET HILL FORESTS OF MEGHALAYA

By

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I certify that the thesis entitled "Ecological studies on regeneration of a few tree species in sub-tropical wet hill forests of Meghalaya", submitted by Mr. Mohd. Latif Khan, M. Sc. for the Degree of Doctor of Philosophy of the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph. D. Degree. The work has not been submitted for any Degree of any other University.

Date : 30 September, 1986.
Place : Shillong.

Signature of the Supervisor

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(Mohd. Latif Khan)

CONTENTS

GENERAL INTRODUCTION

Trees constitute one of mankind's most important assets and play a vital role in the maintenance of our environment. Forests are, indeed, God's gift to man, for as a young American poet, Joyee Kilburm, sang, 'Man can build a bridge, but God alone can make a tree'. Forests can contribute appreciably to world food supplies if proper exploitation, combined with satisfactory conservation, is carried out. In many places where arable crops and food grains would fail to grow, trees can flourish and yield abundantly. But unfortunately, instead of conserving forests for posterity, man looks on them as a source of wealth from too greedy harvesting.

Forests represent the largest, most complex and self-purpetua ting system which cover approximately 40% of earth's biomass (Olson 1975). According to the estimates of the Department of Forest Survey, Royal College of Forestry, out of 2800 million ha world's forest area tropical forests cover 1456 million ha (52%). In the last 20-30 years, Man's exploitation of these forest ecosystems has increased dramatically, not only in extent but also in intensity of impacts. Tropical forests are being severely modified or destroyed in response to pressures from the rapidly expanding populations of tropical countries. Accelerated search for new timber resources by industrial temperate countries is another cause of exploitation. Improved technology, commerce patterns, and infrastructure development have widely increased the effective impact of wood harvesting and land clearing activities. Most investigators agree that if the present trends continue and effective conservation measures are not implemented, most of the still-existing forests will be destroyed or replaced by degraded communities by the turn of the century. According to FAO (1981), by the year 2000 at least 500 million people will be unable to satisfy their minimum energy requirements. There is also disturbing scientific evidence to indicate that large scale loss of forest may bring about major, and perhaps irreversible changes in the global climate (Oza 1981a).

The natural vegetation of India is one or the other kind of forest. The various types of forests are (1) moist tropical forests, (2) dry tropical forests, (3) montane sub-tropical forests, (4) montane temperate forests, (5) sub-alpine forests, and (6) alpine scrub. According to official records the extent of forest cover in the country is 75 million hectares, i.e. about 23% of the total geographical area. But due to biotic disturbances (over-grazing, deforestation, rapid industrialization, shifting cultivation etc.) the natural vegetation has considerably deteriorated and presently, no more than 14% of country's land surface is forested (National Remote Sensing Agency Report, Govt. of India 1983). This has led to mass agitation of people in the form of 'Chipko movement' in Garhwal Himalayas (Joshi 1981) and Silent Valley movement in Kerala (Jha 1980). The Indian Society of Naturalists (INSON) is also engaged in promoting and supporting the World Campaign for the Biosphere, and has brought out strikers on 'Save Trees, Save India' and 'Save Trees, Save Our Biosphere' (Oza 1981b, 1982).

The North-Eastern region of India is endowed with vast forest resources which comprise a wide range of diverse plant species. However, the forests of North-Eastern India are depleting at an alarming rate not only due to age-old practice of shifting cultivation that involves cutting and burning of the forest and other plant communities, but also on account of road construction, hydro-electric projects, extensive cultivation of clean tilled crops, urbanization and setting up of certain industries in recent years. With increase in population pressure, the Jhum cycle (the intervening fallow period after which the same forested land is again cultivated, Kushwaha et al. 1981) has been considerably shortened as a consequence of which the Jhum fallows do not get enough time to develop protective vegetational cover. As soon as some vegetation develops on abandoned Jhum fallows the area is once again brought under 'slash and burn agriculture'. Thus, the forests of this region have been shrinking at a very fast rate and this has resulted into a series of ecological problems, such as rapid soil erosion, desertification in certain areas and dwindling of orchid wealth, valuable wild-life and other germ plasm resources of the region. The forest cover in Meghalaya state has been reduced from 63.98% in 1975 to 55.39% in 1982 (NRSA 1983), which is quite alarming. Besides, natural regeneration of the forest trees is quite poor. Therefore, a scientific analysis of the factors which contribute to the decrease in forest cover and poor regeneration needs to be undertaken. This may help in suggesting appropriate measures to maintain the forest wealth of the region.

Although certain aspects of forest ecosystem such as seed germination and seedling establishment (Boojh & Ramakrishnan 1981a, b, 1982a, Shukla & Ramakrishnan 1981, 1982a); growth pattern (Das 1980, Singh

& Ramakrishnan 1981, 1982a, 1983, Boojh & Ramakrishnan 1982b, c, 1983, Ramakrishnan et al. 1982, Shukla & Ramakrishnan 1984, 1986); phenology (Boojh & Ramakrishnan 1981c, Shukla & Ramakrishnan 1982b); litter dynamics (Singh & Ramakrishnan 1982b, Boojh & Ramakrishnan 1982d); nutrient cycling (Das 1980, Singh & Ramakrishnan 1982a, b, c); mycorrhizal association (Sharma 1981, Sharma et al. 1986) and impact of shifting agriculture (Parkash 1980) in North- East region of India have been studied, there is conspicuous lack of studies on regeneration of trees. Thus a study on the regeneration of important forest tree species of Meghalaya viz., Alnus nepalensis Don, Quercus dealbata L., Q. griffithii Hk. and Schima khasiana Dyer., was undertaken.

The present study on the regeneration of above tree species covers the following aspects:

(1) Analysis of age structure of the disturbed and undisturbed forest stands.

(2) Survivorship of tree seedlings and sprouts in the disturbed and undisturbed forest stands.

(3) The effect of diameter and height of tree stumps on sprouting and survival of the sprouts.

(4) The effect of burning and sprout density on the growth of sprouts emerged from the stumps of different diameter and height.

(5) Seed germination, and survival and growth of the seedlings in controlled and field conditions.

(6) The effect of factors such as soil texture, soil moisture and light regimes on the emergence, survival and growth of seedlings.

(7) Survival and growth of the transplants (nursery grown seedlings) in different ecological conditions.

The **'General Introduction'** which sets out the objectives of the thesis is followed by the **'Review of Literature'**. The experimental data on various aspects mentioned above have been presented in chapters **II-VI** which are preceded by a chapter on the climate, soil and vegetation of the study sites. Each chapter has been provided with a separate discussion. In addition to this, the results contained in various chapters have been discussed in an integrated manner under **'General Discussion'**.

REVIEW OF LITERATURE

Sustained forest management requires a knowledge of not only the existing stock of a forest but also of the forest regeneration to be expected in future. During the British regime, Dr. Districh Brandis, the first Inspector General of Indian forests inspected and surveyed the available forests in 1864 and submitted a report to the Government of India, which suggested the ways and means of forest management. In Andaman Islands, experiments to find out a proper natural regeneration technique for the Dipterocarpus were carried out between 1933 and 1936 by Changappa and based on those studies the present 'Andaman Canopy Lifting Shelter Wood System' was evolved. Iyppu (1960) mentioned about the various attempts that were made to manipulate the overhead canopies to achieve regeneration of various species. Ward (1961) studied the regeneration behaviour of the American beech. Hosner & Minckler (1963) followed the pattern of regeneration and succession of bottomland hardwood forests of southern Illinois. Sutton (1969) made a silvicultural study on white and engelmann spruce, and Dobbs (1972) on the regeneration of these plant species in north east of British Columbia. Griffin (1976) studied the regeneration of Quercus lobata in savanna of California. Regeneration behaviour of fir and beech in Japanese forests was investigated by Kohyama (1980, 1982, 1983, 1984), Kohyama & Fujita (1981) and Hara (1983). Many studies were undertaken to understand the regeneration potential of Pinus spp. (McMinn 1981, Hu & Linnartz 1981, Miller & Cummins 1982, Lea 1984, White 1985). In arid zone of south-eastern

Australia, regeneration of Casuariana cristata, Heterodendrum oleifolium and Myoporum platycarpum was studied by Chesterfield & Parsons (1985). Chrosciewiez (1976) and Johnston (1977) furnished some general guidelines for black spruce regeneration and the application of fire. Subsequently, many studies on the role of fire in tree regeneration were published (Little 1974, Barden 1978, Wyant et al. 1983, Aksamit & Irving 1984, Hill & Read 1984, Agee & Smith 1984, Abbott & Loneragan 1984, Auclair 1985, Malanson & Leary 1985). Weaver & Robutson (1981), Boring et al. (1981), Crouch (1983), Fox et al. (1984) and Hobbs & Mooney (1985) investigated the pattern of regeneration after clear-cutting of the forests. Gap phase regeneration in forests has been emphasised by Whitmore (1975), Runkle (1981), Nakashijuka (1983, 1984), Pickett (1983), Shimizu (1984), Brokaw (1980, 1982a, b, 1985) and White et al. (1985). Most of these authors reported that regeneration depends on time of gap creation and size of the gap. Better regeneration was reported in greater gap size especially in the case of light demanding species (Whitmore 1975, Pickett 1983). Failure of tree regeneration caused by heavy grazing was reported by Lange & Graham (1983) and Pigott (1983). Consequently, the effects of other factors (biotic and abiotic) on tree regeneration was studied by other workers (Good & Good 1972, Hurst & Thomas 1980, Smale & Kimberley 1983, Heaveldop & Neumann 1983, Eis & Craigdallic 1983, Ahmed 1983, Zasada et al. 1983, Sichier 1983, Weiss 1984, Dawson et al. 1985, Clark & Clark 1985, Lieberman et al. 1985, Ambrose et al. 1985, Horn 1985, Phillips & Murdy 1985, Harcombe 1986, Conner et al. 1986).

In Indian condition, some experiments were carried out by Lohani

(1972) on the natural regeneration of fir and spruce in Punjab. The natural regeneration of teak in old teak plantations in Kerala was studied by Nair (1981). Saxena & Singh (1984), Saxena et al. (1984) and Rao (1984) in Central Himalaya have studied the status and pattern of regeneration of the forest trees. Thangam (1982) has described some methods for improving the regeneration of Indian Diptercarpus species. Soil factors affecting the natural regeneration of silver fir and spruce in Himachal Pradesh have been studied by Jha et al. (1984). Sarma et al. (1985) studied the edaphic and microclimatic effects on regeneration of Sal (Shorea robusta). Rai (1985) developed some techniques on nursery and regeneration of some species occurring in southern tropical wet evergreen and semi-evergreen forests of Karnataka. Studies on regeneration were also conducted by Chandra (1975), Sharma (1979), Balasundaram et al. (1979) and Lall & Dakwale (1984) in other parts of the country. Singh (1976) evolved silvicultural system for the management of silver fir (Abies pindrow). Different means of vegetative propagation of several tree species have been studied by many workers (Chandra & Mahindra 1977, Dabral 1977, Somasundaram & Jagadees 1977, Chandra 1978, Gupta & Chandra 1979, Lahiri 1979, Husain Mahmood & Ponnuswamy 1980, Negi & Tiwari 1984, Nagpal & Schgal 1985, Uniyal et al. 1985).

Age structure of the populations of tree species has recently been studied by many workers to understand the regeneration status of forest trees (Marks 1974, Knight 1975, Veblen et al. 1979, Ross et al. 1982, Richard 1983, Knowles & Grant 1983, Saxena et al. 1984, Saxena & Singh 1984, Primack et al. 1985). Saxena & Singh (1984) suggested that the population structures characterised by the presence of sufficient number of seedlings, saplings and young trees, indicate successful regeneration.

Yeaton (1984) studied the population structure of sugar pine at three elevations and reported that number and growth rates of seedlings and saplings increased with increasing elevation. Pinero et al. (1984) proposed a population model of Astrocarpus maxicanum and emphasised the factors which regulate the population and its regeneration. The role of disturbances in regulating the age structure of population has also been emphasised (Bazzaz 1983). Fire frequency in the boreal forests of Jasper Park in the Canadian Rockies has determined the age structure of lodgepole pine communities (Tande 1979). Disturbance caused by man and by oak wilt disease has structured the age class distribution of Prunus serotina in southern Wisconsin (Auclair & Cottam 1971). Age structure of several species in northern hardwood forests in New Hampshire, U.S.A. has been used by Henry & Swan (1974) to reconstruct disturbance history of the area with regard to the timing of occurrence, frequency, kind and intensity of the disturbances.

Sprouts contribute a great deal to natural regeneration of the forests where tree felling is common (Johnson 1975, Bellanger 1976, Ashley 1979, Smith 1979, Kellinson et al. 1980, Beck 1980, Boring et al. 1981, Mroz 1983, Singh et al. 1984, Neelay et al. 1984). Generally, the percentage of sprouting has been reported to be greater for small-diameter stumps than for large-diameter stumps (Roth & Hepting 1943, Church 1961, Wendel 1975, MacDonald & Powell 1983, Mroz et al. 1985). However, Kectch (1944), Roy (1955), Solomon & Blum (1967), Johnson (1975), Prager & Goldsmith (1977), Mann (1984) and Harrington et al. (1984) reported that the percentage of sprouting increased with increasing parent-tree diameter upto a certain size, and then it decreased. Solomon & Blum (1967) found that height achieved by the sprouts decreased with increasing parent-tree diameter upto a certain size and then it increased. Harrington (1984) studied the effects of stump height and aspects of cut (i.e. angle and slope), tree age and season on sprouting and growth of sprouts in red alder. He found that the number and length of sprouts increased with the increasing stump height. Similar trend was also observed by Hook & DeBell (1970), DeBell (1971), Bellanger (1976), El Houri Ahmed (1977), Blake & Raitanen (1981) and Mroz et al. (1985) in other tree species. El Houri Ahmed (1977) and Harrington (1984) suggested that low-cut stumps decay rapidly, resulting in low sprouting. Crowther & Patch (1980) and Harrington (1984) in their discussion of coppicing in chestnut, hazel, willow and red alder, recommended a sloped or angled cut for better sprouting. Many authors (Mattoon 1909, Brown 1930, Buell 1940, Roth & Hepting 1943, Wenger 1953, Wilson 1968, DeBell & Alford 1972, Bellanger 1976, Strong & Zavitkovski 1982, Harrington 1984, MacDonald & Powell 1985) found that dormant period cuts produce more and taller sprouts than growing period cuts. Stoeckler (1947), Neal (1967), Borchert (1976) and Beck (1977) emphasized the importance of site quality on sprouting and growth of sprouts of Sequoia sempervirens, Populus tremuloides, Liriodendron tulipifera and found a more rapid sprouting and height growth of the sprouts on the sites rich in nutrient and moisture. Recently, Mroz et al. (1985) reported more sprouting and better growth of sprouts in some northern hardwood tree stumps at fertilized sites. In India, Sharma (1979) and Neelay et al.

(1984) studied the growth and coppicing capacity of Eucalyptus spp.

Seed is an important means of tree regeneration. Studies on flowering and seed production in some tree species were made by Downs & William (1944), Wright (1953), Sharp (1958), Sharp & Henry (1961), Sharp & Vance (1967), Grisez (1975), Verma & Sharma (1978), Palits (1980), Sharma (1981) and Rust & Roth (1981). The influence of climate on flowering and seed production in European beech was investigated by Holmsgaard (1972). Mathews (1963) stressed on the production of seeds in relation to biotic and abiotic factors. Singh & Singh (1984a) studied the dispersal pattern of seeds of silver fir and spruce. Singh & Singh (1981) emphasised the importance of seed source of spruce and silver fir in seed germination. Dabral (1976) developed the techniques for the extraction of teak seeds from fruits. Ecological studies on seed germination of some forest trees have been conducted by Athaya (1985a, b). Tang & Tomari (1973) emphasized the role of seed viability. Dunlop & Barnett (1983) reported that small and light seeds of loblolly pine lose their viability faster than the heavier seeds. Janzen (1978), Auld (1983), O'Dowd & Gill (1984) and Mittelback & Gross (1985) argued that predation is the major selective force affecting synchrony in reproduction and sizes of individual seed crops.

Germination and establishment represent two critical phases in the life cycle of a plant species and these two aspects have often been related to adaptation and distribution patterns of species in space and time (Kozlowski 1972, Ross & Harper 1972). Gupta & Kumar (1976), Gupta & Pattanath (1976), Sharma & Purohit (1980), Lockley (1980), Nagaveni & Srimathi (1980), McDowell & Moll (1981), Elliott & Taylor (1981), Madhwaraja (1982), Garwood (1983), Mathur et al. (1984) and Singh & Singh (1984b) studied the germination of seeds of many tree species in laboratory and field conditions. Many studies indicated that larger seeds show early germination and produce large and more vigorous seedlings compared with smaller seeds (Harper & Clatworthy 1963, Pollock & Roos 1972, Belcher & Gresham 1974, Ghosh et al. 1976, Kandya 1978, Sluder 1979, Schaal 1980, Chauhan & Raina 1980, Dunlop & Barnett 1983, Foster & Janson 1985). Conversely, Basada (1979) reported highest germination percentage in small seeds of Shorea contorta. Krishnaswami et al. (1982a) reported that neither germination percentage nor seedling growth varied due to capsule weight of Eucalyptus tereticornis.

The effect of physical factors on seed germination has also been studied by many workers (Patten 1963, Singh et al. 1975, Fechner et al. 1981, Campbell 1982, Enright 1982). Rao & Singh (1985) studied the response of environmental gradients on germination and seedling growth in two dominant forest tree species of Central Himalaya. Vyas & Agarwal (1970), Gupta & Pattanath (1976), Kumar & Bhatnagar (1976) and Khan & Tripathi (1986) reported better seed germination at alternating temperature in some tree species. McLemore (1971), Garwood (1979) and Campbell (1982) emphasized the role of light in seed germination and reported more germination lighted condition than in shade. Maull (1962), Satoo (1966) and Larson & Schubest (1969) observed poor seed germination at low moisture level in pine and other tree species. Singh et al. (1975), Chandra & Ram (1980), Bhatia & Chawan (1983), Singh et al. (1985) and Khan & Tripathi (1986) observed that germination decreased with increase in sowing depth. Ghosh et al. (1976) found that increase in sowing depth resulted in a corresponding delay in commencement of germination in Pinus patula, Pinus caribaea and Pinus elliottii. Besides, Ahlgren & Ahlgren (1981) emphasized the role of forest litters in seed germination.

Better seedling establishment is a pre-requisite for successful regeneration. Many workers have studied the influence of physical factors on establishment and survival of tree seedlings (Howard 1973, Sorensen & Ferrell 1973, Whitmore 1975, Chosh et al. 1977, Jamaluddin 1978, Bazzaz & Pickett 1980, Muller-Dombois et al. 1980, Enright 1982, Van Den Drissche 1982, Fetcher et al. 1983, Lawrence & Oechel 1983, Wyant et al. 1983, Abbott & Loneragan 1984, Augspurger 1984a, b, c, Burton & Mueller-Dombois 1984, Connell et al. 1984, Vance & Running 1985, Khan et al. 1986). Generally, seedlings of tree species showed better survival and growth in lighted condition (Whitmore 1975, Garwood 1979). Photoperiodic responses of seedlings of pinus species have been studied by Bhatnagar & Gupta (1975) and Bhatnagar & Talwar (1979). Augspurger (1984c) reported better survival and growth of the seedlings of eighteen neotropical tree species in sun than in shade. Langenheim et al. (1984) studied the photosynthetic response of the seedlings of some Amazonian and Australian rain forest trees in varying light conditions and observed leaf production and height to be greater in full sunlight than in shade. The effect of environmental desiccation on seedling survival of Cassia spp. has been studied by Daiya et al. (1982). Significance of undercanopy vegetation in determining the size of seedling population of trees through mortality has been emphasized by Shirley (1945), Gysel (1951), Sulser (1971), Daniels (1978), Eis (1981), Cross (1981), Brokaw (1983), Maguire & Forman (1983), Burton & Mueller-Dombois (1984) and Connell et al. (1984). Production of allelochemics from herbs which influence the seedling establishment of trees has been reported by Horsley (1977a, b). Carter et al. (1984) and Sands & Nambiar (1984) studied the competition between herb and pine seedlings for soil moisture and nutrients. The detrimental effect of soil moisture stress on the survival and growth of tree seedlings has been reported by Singh & Mahamood (1976), Pereira & Kozlowski (1977), McLeod & Murphy (1977), Mueller-Dombois et al. (1980), Tear et al. (1982), Schulte & Marshall (1983), Becker & Levy (1983), Gupta & Muthana (1985) and Vance & Running (1985). Osonubi et al. (1985) studied the influence of soil drought and waterlogging on Gmelina arborea seedlings. Knapp & Smith (1982) reported the detrimental effect of thick layer of forest litter on seedlings of Abies lasiocarpa and Picea engelmannii. The production of allelochemics from forest litter which influence the seedlings survival was reported by DelMoral & Cates (1971), Blaschke (1979) and Willis (1980). The role of herbivory and pathogen in determining the tree seedling population has been emphasized by Coley (1983), Ohmart et al. (1983) and Augspurger (1984b). Augspurger (1984b) reported greater pathogen-caused seedling mortality in shaded condition than in open. Van Den Driessche (1982, 1984) studied the effect of fertilization, spacing and root wrenching on survival, growth and physiology of the seedlings of Pseudotsuga menziessii, Picea sitchensis and Pinus contorta. The growth of transplanted silver fir seedlings as related to the seedling diameter was studied by Singh & Sharma (1981) who observed that growth of the transplants resulting from the seedling of smaller diameter was poor. Growth of several tree species has been studied in relation to various environmental factors by many workers in India (Singh 1980, 1982, Singh 1982, Singh 1982, Singh *et al.* 1982, Suri 1984). Kaul & Sharma (1982) emphasized the importance of initial spacing on growth of *Pinus caribaea*. Growth increment in saplings of *Eucalyptus tereticornis* Sm. in relation to age has been studied by Krishnaswami *et al.* (1982b).

Some fragmentary studies on seed germination of *Alnus nepalensis* and seedling establishment, growth pattern and phenology of *Schima khasiana* have been made by Boojh & Ramakrishnan (1981a, b, c, 1982a, b, c, d, 1983). However, extensive studies on natural regeneration of forest trees of India in general and of North-East region in particular, are lacking. In view of the fact that such studies could have significant implications for forest management, the present study on the ecology of regeneration of some important tree species of Meghalaya was undertaken.

CHAPTER I

The Study Sites : Climate, Soil and Vegetation.

Field studies :

Two natural forests growing in Upper Shillong and Mawphlang in Meghalaya state (25° 15' - 26° 5' N and 89° 56' - 92° 47' E) in India were selected for the study. Both the forests are classified as subtropical wet hill forest (Champion & Seth 1968) and are 19 km apart. The forest at Upper Shillong is 6 km and Mawphlang forest is 25 km south-east of Shillong, the capital town of Meghalaya.

The forest at Upper Shillong is exposed to various kinds of disturbances such as tree felling, occasional burning and grazing. Shifting cultivation involving slashing and burning of forest vegetation is also practiced. As a result, the canopy is relatively sparse. The forest at Mawphlang represents relic climax vegetation. The belief of the local people who maintain that the 'Sylvandeities' would be offended if trees are cut and flowers and fruits plucked, has given this forest the status of a 'Sacred grove'. This forest, therefore, has remained more or less undisturbed for the last several centuries. The two forests also differ in altitude and light conditions (Table 1.1).

Pot experiments :

The pot experiments were conducted on the campus of School of Life Sciences, North-Eastern Hill University, Shillong (25° 34' N, 91° 56' E), under the net house conditions.

A. Map of India showing the location of Meghalaya State.

B. Map of Meghalaya showing the location of the study sites.

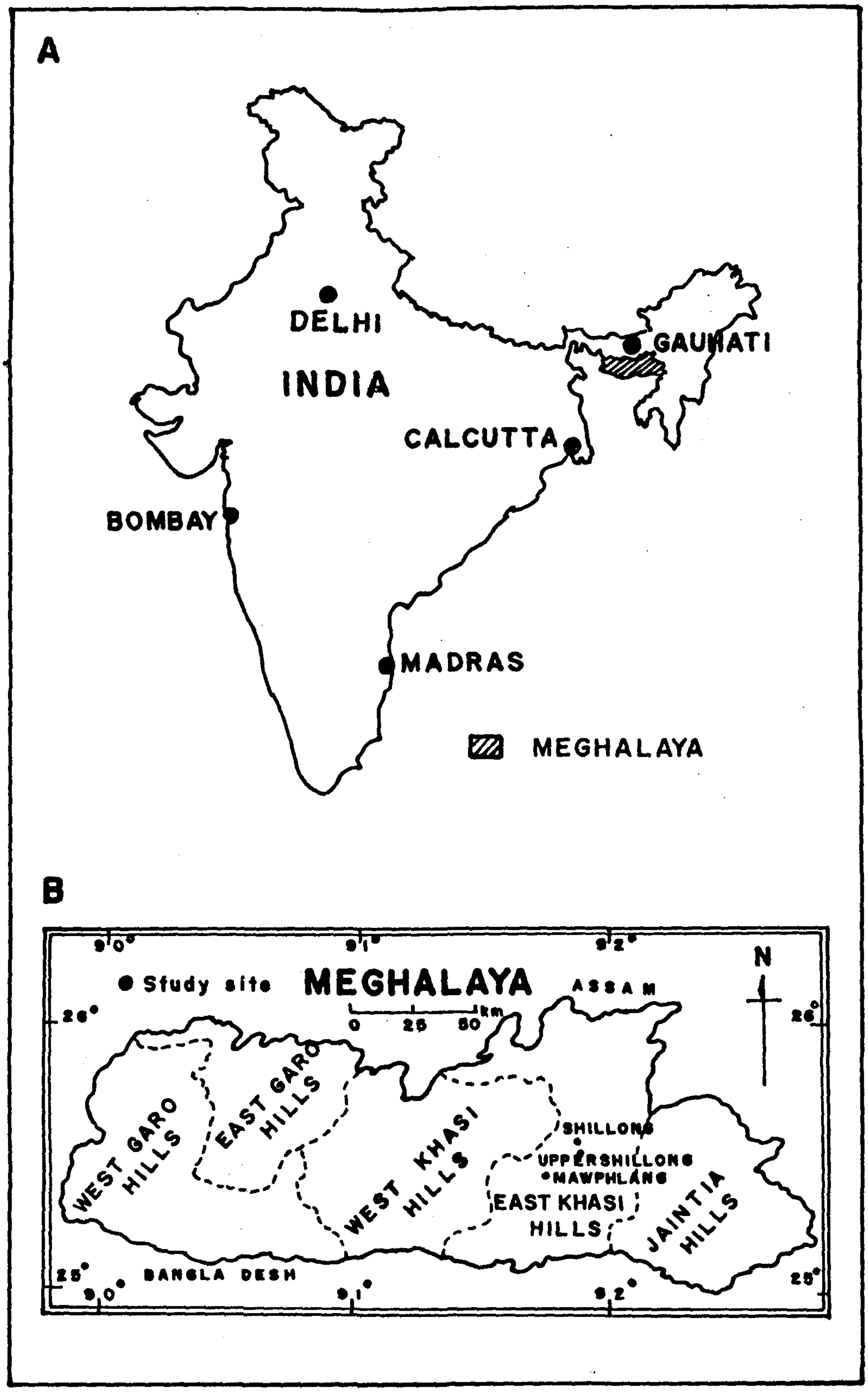

A
DELHI
INDIA
GAUHATI
CALCUTTA
BOMBAY
MADRAS
MEGHALAYA
B
90°
91°
92°
Study site
MEGHALAYA
ASSAM
0 25 50 km
N
26°
WEST GARO HILLS
EAST GARO HILLS
WEST KHASI HILLS
SHILLONG
UPPERSHILLONG
MAWPHLANG
EAST KHASI HILLS
JAINTIA HILLS
25°
BANGLA DESH

Plate 1. (A) Disturbed forest at Upper Shillong with a patch of less disturbed forest stand on the left side.

(B) Disturbed forest at Upper Shillong exposed to tree felling; the cut tree stumps are clearly seen.

PLATE 1A

PLATE 1B

Plate 2. Forest regeneration after about four years from selective tree felling in the forest at Upper Shillong.

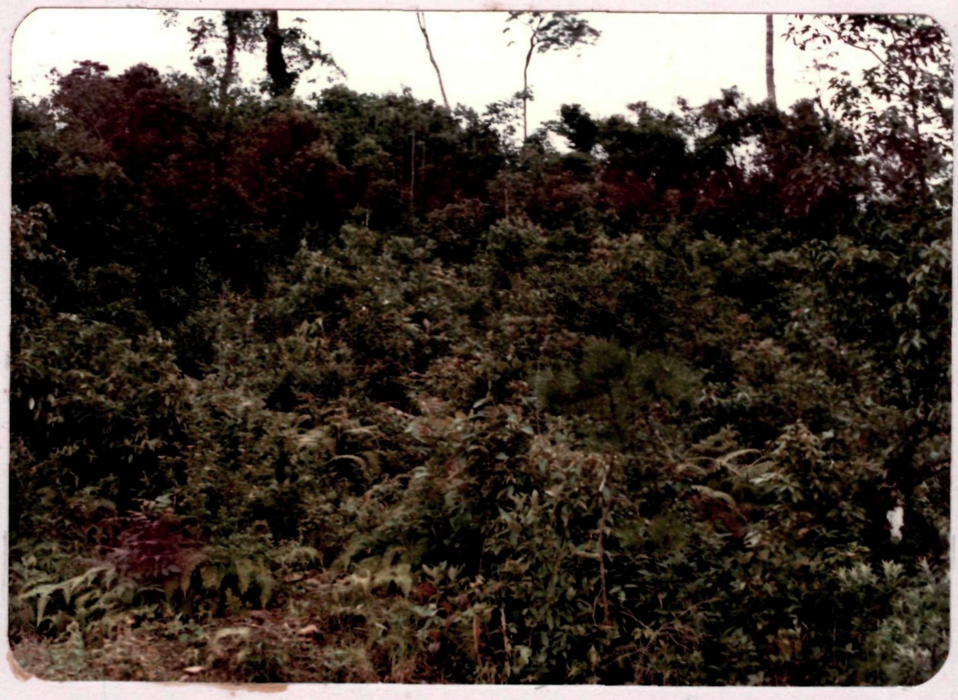


PLATE 2

Plate 3. (A) An overview of a part of the undisturbed 'Sacred grove' forest at Mawphlang.

(B) Close up of a small patch of the same forest.

PLATE 3A

PLATE 3B

Climate :

The south-west monsoon and north-east winter winds influence the climate of the area. The average rainfall, temperature and relative humidity data are given in Fig. 1.1a, b. The climate is quite wet (annual rainfall, 2500-3000 mm). The months from May to September represent wet season, although occasional showers are received during November to March as well. June and July are the wettest months. The year can be divided into four seasons: (i) Spring (March to April), (ii) Summer (May to September), (iii) Autumn (October to November) and (iv) Winter (December to February). The spring season is characterised by occasional showers and gradual increase in temperature over that in the preceding winter months. The spring is followed by the summer during which season strong winds blow upto May and abundant rainfall is received until September. The retreat of monsoon and fall in temperature herald the advent of autumn which is followed by cold winter season lasting from December to February. This period is characterised by low temperature, negligible rain and short photoperiod. Clear days during winter are usually followed by frosty nights.

Soil :

The Shillong plateau embracing the Garo, Khasi and Jaintia Hills of Meghalaya is made up largely of pre-cambrian rocks acutely folded and steeply dipping, with an overturned fringe of mesozoic and tertiary sediments. The rock distribution in the plateau reveals that the core of plateau is an ancient mass of gneiss much intruded by a coarse granite (Pascoe 1950). Sandstones, limestones and conglomerates with subordinate clays superimposed

Fig. 1.1. Rainfall & temperature (Fig.1.1a) and relative humidity (Fig. 1.1b) data for the study area during June 1983 to June 1985. △ , average rainfall; ○ , mean maximum temperature; ● , mean minimum temperature; ▲ , relative humidity.

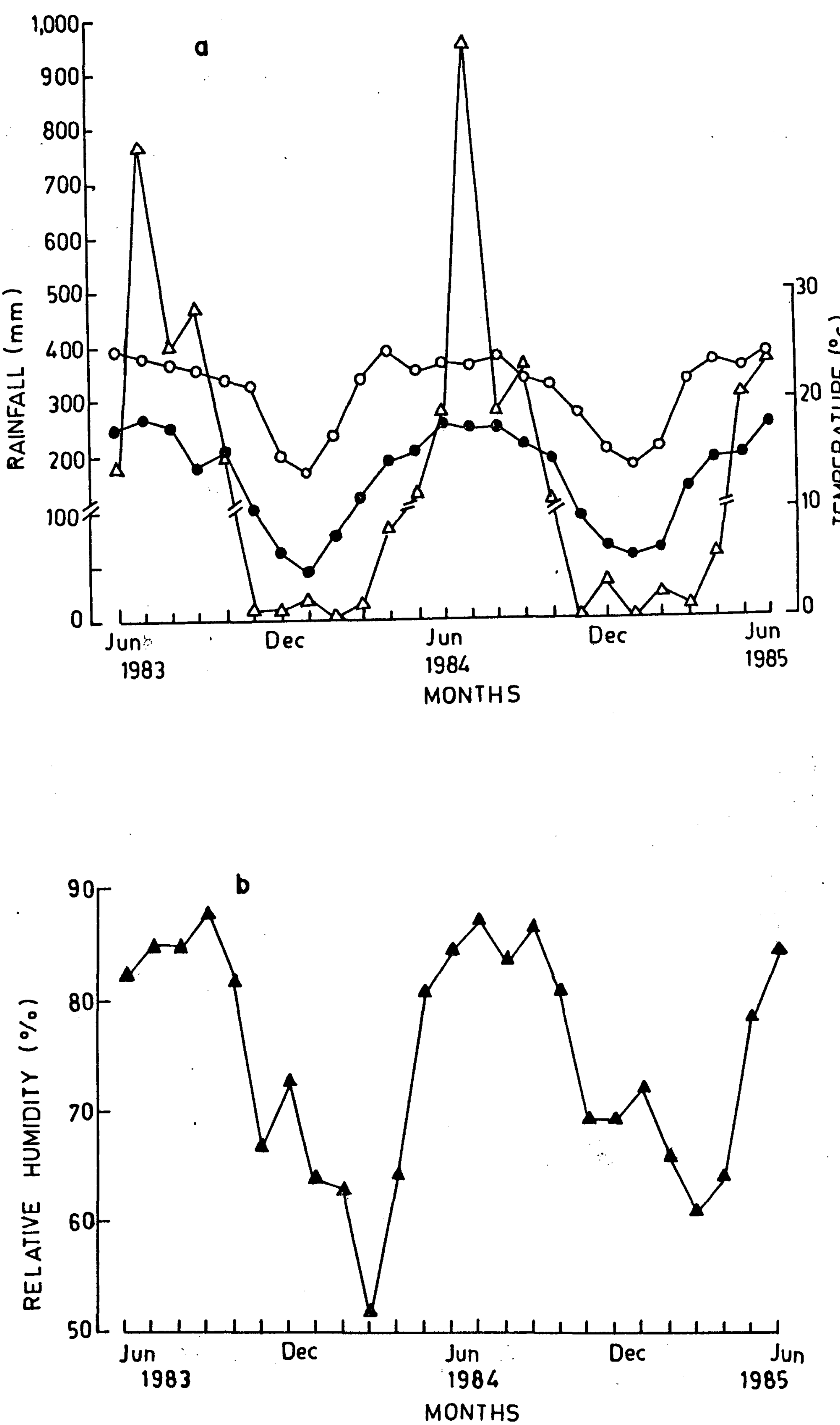

a
RAINFALL (mm)
TEMPERATURE (°c)
1,000
900
800
700
600
500
400
300
200
100
0
30
20
10
0
Jun
1983
Dec
Jun
1984
Dec
Jun
1985
MONTHS
b
RELATIVE HUMIDITY (%)
90
80
70
60
50
Jun
1983
Dec
Jun
1984
Dec
Jun
1985
MONTHS

Fig.1·1

over these rocks also occur in the Shillong plateau (Zimba 1977). Some of the physical and chemical properties of the top 10 cm soil are shown in Table 1.1.

Table 1.1. Physical and chemical attributes of the study sites.

Study site	Altitude (m)	Light intensity (Lux x 10^3)	Soil texture	Soil pH	Organic matter (%)	Nitrogen (%)
Upper Shillong	1955	16.7 (6.9)*	Sandy loam	5.3	2.9	0.17
Mawphlang	1720.	14.0 (5.4)*	Loamy silt	5.8	5.7	0.28

*Values in parentheses refer to light intensity in the forest stands in the centre.

Vegetation :

The vegetation of the two forests has some similarity (calculated Similarity Index* for tree species = 58.3%). In the forest at Upper Shillong,

*Similarity index was calculated using the following formula given by Sørensen (1948).

Similarity Index = (2C / A + B) x 100

Here, C = number of species common to two releves.

A = total number of species in releve A

B = total number of species in releve B

the dominant tree species are Pinus kesiya, Quercus dealbata, Schima khasiana at the periphery and Pinus kesiya, Quercus dealbata, Manglietia insignis, Schima khasiana in the centre (Table 1.2a). This forest is surrounded by pine (Pinus kesiya) plantations. Rhododendron spp., Eurya japonica, Myrsine semiserrata, Lindera pulcherrima and Symplocos spp. form the understorey. Litsea sp., Daphne shillong, Lantana camara, Cinnamomum spp. are the common shrubs (Table 1.3) and Osbeckia crinata, Eupatorium adenophorum, Coffea khasiana, Rubus spp. (Table 1.4) and some ferns and mosses represent the herbaceous ground flora.

The important tree species in the 'Sacred grove' forest at Mawphlang are Schima khasiana, Quercus griffithii, Q. dealbata, Rhododendron arboreum at the periphery and Manglietia caveana, Quercus dealbata, Schima khasiana, Manglietia insignis in the centre (Table 1.2b) with the understorey consisting of Rhododendron spp., Eurya japonica, Urena lobata, Daphne shillong, D. bhalua (Table 1.3 & 1.4), ferns and mosses.

Plate 4. (A) Luxuriant growth of *Quercus* *dealbata* and *Quercus* *griffithii* in the 'Sacred grove' at Mawphlang.

(B) A part of the 'Sacred grove' at Mawphlang dominated by *Schima khasiana*.

PLATE 4A

PLATE 4B

Table 1.2a. Density, frequency, basal cover and importance value index (I V I) of tree species at the periphery and centre of the disturbed forest at Upper Shillong.

Species	Density/ha		Frequency (%)		Basal cover (m^2/ha)		IVI	
	Periphery	Centre	Periphery	Centre	Periphery	Centre	Periphery	Centre
Alnus nepalensis Don	180	175	80	60	0.89	1.70	43.92	33.00
Daphniphyllum himalayense Muell.	0	30	0	50	0	0.12	0	10.37
Manglietia insignis (Wall.) Bl.	0	181	0	70	0	1.90	0	36.43
Myrica esculenta Buch. Ham.	58	122	50	80	0.22	1.30	18.15	29.67
Pinus kesiya Royle ex Gordon.	454	425	100	70	2.12	2.67	88.26	57.54
Prunus undulata Ham.	0	25	0	40	0	0.19	0	9.07
Quercus dealbata Linn.	168	225	70	90	1.67	2.20	51.73	44.49
Quercus griffithii Hk. f. & Th.	110	155	60	80	1.10	1.30	36.85	31.73
Rhododendron arboreum Sm.	60	80	40	40	0.20	0.38	16.01	13.96
Schima khasiana Dyer.	155	185	90	80	0.98	1.32	45.08	33.73

Table 1.2b. Density, frequency, basal cover and importance value index (I V I) of tree species at the periphery and centre of the undisturbed forest at Mawphlang.

Species	Density/ha		Frequency (%)		Basal cover (m^2/ha)		IVI	
	Periphery	Centre	Periphery	Centre	Periphery	Centre	Periphery	Centre
Castanopsis kurzii (Hance)B.	141	170	60	80	1.90	2.60	36.05	26.25
Corylopsis himalayana Griff.	0	239	0	60	0	2.00	0	25.08
Exbucklandia populnea (Griff.)Br.	46	0	30	0	0.50	0	12.75	0
Ficus nerifolia Sm.	53	95	40	60	0.64	1.0	15.90	14.75
Manglietia caveana Hk. f. & Th.	0	226	0	90	0	3.80	0	34.28
Manglietia insignis (Wall.)Bl.	0	205	0	80	0	2.90	0	28.96
Myrica esculenta Buch. Ham.	70	130	40	70	1.20	1.90	21.79	20.75
Phyllanthus glaucus Wall. ex. Hook.	0	137	0	60	0	1.60	0	18.87
Prunus undulata Ham.	0	103	0	50	0	1.20	0	14.74
Quercus dealbata Linn.	216	258	100	100	2.60	2.91	54.32	33.68
Quercus griffithii Hk. f. & Th.	235	147	90	70	2.90	2.80	56.16	24.76
Rhododendron arboreum Sm.	292	101	80	30	1.30	1.40	46.03	13.10
Schima khasiana Dyer.	328	231	100	100	1.90	2.20	57.00	29.90
Taxus baccata Linn.	0	92	0	40	0	1.70	0	14.87

Table 1.3. List of shrubby plant species in the forests at Upper Shillong and Mawphlang alongwith their density (±S.E.; data based on 10 quadrats of 10 m^2).

Species	Disturbed forest at Upper Shillong	Undisturbed forest at Mawphlang
Ardisia crispa (Thumb.) Dc.	2.4±0.3	3.6±0.3
Baliospermum micrantha Muell. Arg.	3.0±0.5	1.0±0.2
Camellia caduca C.B. Cl.	3.3±0.5	2.1±0.4
Cinnamomum spp.	1.0±0.1	0
Daphne shillong Banerjee	7.3±1.3	9.5±1.5
D. bhalue Buch. Ham. ex D. Don	6.4±1.2	9.3±1.6
Eurya japonica Thumb.	4.5±0.6	2.3±0.3
Helicia nilagirica Bedd.	3.0±0.3	4.2±0.5
Lantana camara Linn.	11.7±1.9	0
Lindera pulcherrima Benth.	7.3±1.2	3.1±0.5
Litsea elongata Wall.	5.4±0.7	2.2±0.2
Mahonia pyenophylla (Fedde) Takeda	2.3±0.2	3.6±0.4
Myrsine semiserrata Wall.	6.3±0.9	5.5±0.8
Symplocos spp.	6.5±6.8	4.0±0.4
Urena lobata Linn.	4.2±0.5	2.3±0.2
Viburnum foetidum Wall.	3.0±0.3	3.3±0.2
V. sinensis Wall.	2.5±0.2	3.6±0.3

Table 1.4. List of herbaceous plant species in Upper Shillong and Mawphlang forests alongwith their density (±S.E.; data based on 10 quadrats of 1 m^2 each).

Species	Disturbed forest at Upper Shillong	Undisturbed forest at Mawphlang
Artemisia nilagirica (Cl.) Pamp.	4.0±0.6	0
Arundinella khasiana Nees	8.3±1.3	2.0±0.3
Brunella vulgaris Linn.	10.4±1.6	4.3±0.7
Carex cruciata Vahl.	6.7±1.2	2.3±0.4
Centella asiatica Linn.	3.9±0.5	0
Coffea khasiana Linn.	2.0±0.3	0
Cyanotis cristata Linn.	4.4±0.7	1.2±0.2
Cyperus rotundus Linn.	8.7±1.5	3.3±0.5
Dioscoria alata Linn.	2.6±0.4	1.3±0.2
Drymeria cordata Willd.	4.8±0.8	2.3±0.4
Eupatorium adenophorum Spreng.	6.3±1.0	0
E. riparium Regel	7.9±1.3	0
Geranium sp.	4.6±0.6	2.3±0.4
Gleichenia longissima Bl.	10.7±1.8	7.3±1.2
Hypochaeris radicata Linn.	4.6±0.8	2.0±0.2
Linum spp.	1.3±0.2	0
Myriactis nepalensis	2.3±0.4	0
Osbeckia crinata Benth.	13.2±2.2	7.5±1.2
Panicum brevefolium Linn.	7.9±1.4	0
P. indicum Linn.	2.6±0.4	0
Pennisetum clandestinum Hochst.	3.4±0.5	0
Plantago major Linn.	4.6±0.8	1.2±0.1
Potentilla blanda	5.6±0.9	1.3±0.2
Ranunculus diffusus Dc.	3.7±0.6	1.2±0.2
Rubia cordifolia Linn.	2.5±0.3	1.3±0.2
Rubus spp.	5.3±0.8	0
Smithia sp.	3.2±0.5	0

CHAPTER II

Regeneration status, age structure and survival of tree seedlings and sprouts in disturbed forest at Upper Shillong and in 'Sacred Grove' at Mawphlang.

INTRODUCTION

Regeneration status of trees can be predicted by the age structure of their populations (Marks 1974, Vablen et al. 1979, Pritts & Hancock 1983, Saxena & Singh 1984, Saxena et al. 1984). Presence of sufficient number of seedlings, saplings and young trees in a given population, indicates a successful regeneration of the tree species (Saxena & Singh 1984). Regeneration of tree species is greatly influenced by the interaction of biotic and abiotic factors of the environment (Boring et al. 1981, Lange & Graham 1983, Aksamit & Irving 1984). These factors may affect the recruitment, survival and growth of tree seedlings and sprouts. Therefore, a study pertaining to age structure and survival of seedlings and sprouts was undertaken to assess the regeneration status of the tree species occurring in the two forest stands.

METHODS

The age structure of all tree species growing in a given forest was studied from June 1983 to February 1985 at four-monthly intervals. On each observation date, density of the trees belonging to four different age groups viz., seedlings ($<$ 20 cm height), saplings (20-150 cm height and $<$ 5 cm diameter), small trees (5 to 25 cm 'dbh') and big trees ($>$ 25 cm 'dbh') was recorded in twenty (20 m X 20 m) randomly laid permanent quadrats. Relative proportion (%) of each age group to the total density of tree species in a forest was calculated and the pyramid of age structure, keeping the seedling density as base, was drawn.

In a given forest, density of tree seedlings and stumps at the periphery and in the middle of the forest was separately studied in June,

1983. The two sites differed from each other in respect of light intensity and vegetation density. The light intensity (average for a day) at ground surface in the sparse forest stand at the periphery was 13,000-17,000 Lx and in the dense forest stand in the middle, it was 5,000-8,000 Lx. Density of the tree seedlings and stumps was determined in randomly laid 20 quadrats of 20 m X 20 m size in each of the two sites in a given forest.

For studying survival of the tree seedlings and sprouts, 35 - 50 seedlings and 10 stumps bearing 3 - 6 sprouts which were 10 - 20 leaved were tagged with labelled aluminium foil. Survival of the seedlings and sprouts was noted at two-monthly intervals in both the forests over one-year period. On each observation date, density of the ground vegetation was also determined in randomly laid twenty quadrats of 2 m X 2 m size.

The soil moisture content and thickness of the litter layer (organic matter above mineral soil) were estimated at bimonthly intervals at the periphery and at the centre of both the forests. On each sampling date, soil samples representing 0 - 10 cm depth were collected from 20 places and the soil moisture content was determined following the method outlined by Piper (1947). The litter depth was determined by line-intercept method as outlined by Mueller-Dombois & Ellenberg (1974).

RESULTS

Soil moisture content and litter accumulation :

The soil moisture content under the forest stands at the periphery and at the centre did not show wide variation in both forests. However, a marked seasonal trend in soil moisture was observed in both the forests, the values being maximum in the month of June and minimum in December (Fig. 2.1). Litter accumulation as measured by its depth, invariably depicted higher values in the forest at Mawphlang. The litter accumulation was more in the centre than at the periphery. Maximum litter accumulation was observed during winter and minimum in rainy season in both the forests (Fig. 2.1).

Ground vegetation :

In general, density of ground vegetation in both the forests was higher at the periphery than in the centre. The density was also higher in the forest at Upper Shillong than in Mawphlang. Maximum density of ground vegetation was observed in the month of June and minimum in December both on the periphery and in the centre of the two forests (Fig. 2.2).

Regeneration status and density of tree seedlings and stumps :

Out of 10 tree species in the forest at Upper Shillong, five (Alnus nepalensis, Myrica esculenta, Quercus dealbata, Q. griffithii and Schima khasiana) regenerated by both seedlings and sprouts. Daphniphyllum himalayense, however, regenerated only through sprouts and Pinus kesiya only by seedlings. At Mawphlang forest out of 14 tree species, four viz., Myrica esculenta, Quercus dealbata, Q. griffithii and Schima khasiana regenerated by both seedlings and sprouts. Regeneration of Rhododendron arboreum was only by seedlings and of Manglietia caveana only through sprouts.

Number of seedlings and stumps per unit area differed in the

Fig. 2. 1. Litter accumulation and soil moisture content in the two forest stands during the study period, Litter accumulation denoted by bars and soil moisture by curve, Filled symbols for dense stand at the centre and open symbols for sparse stand near the periphery of the forests.

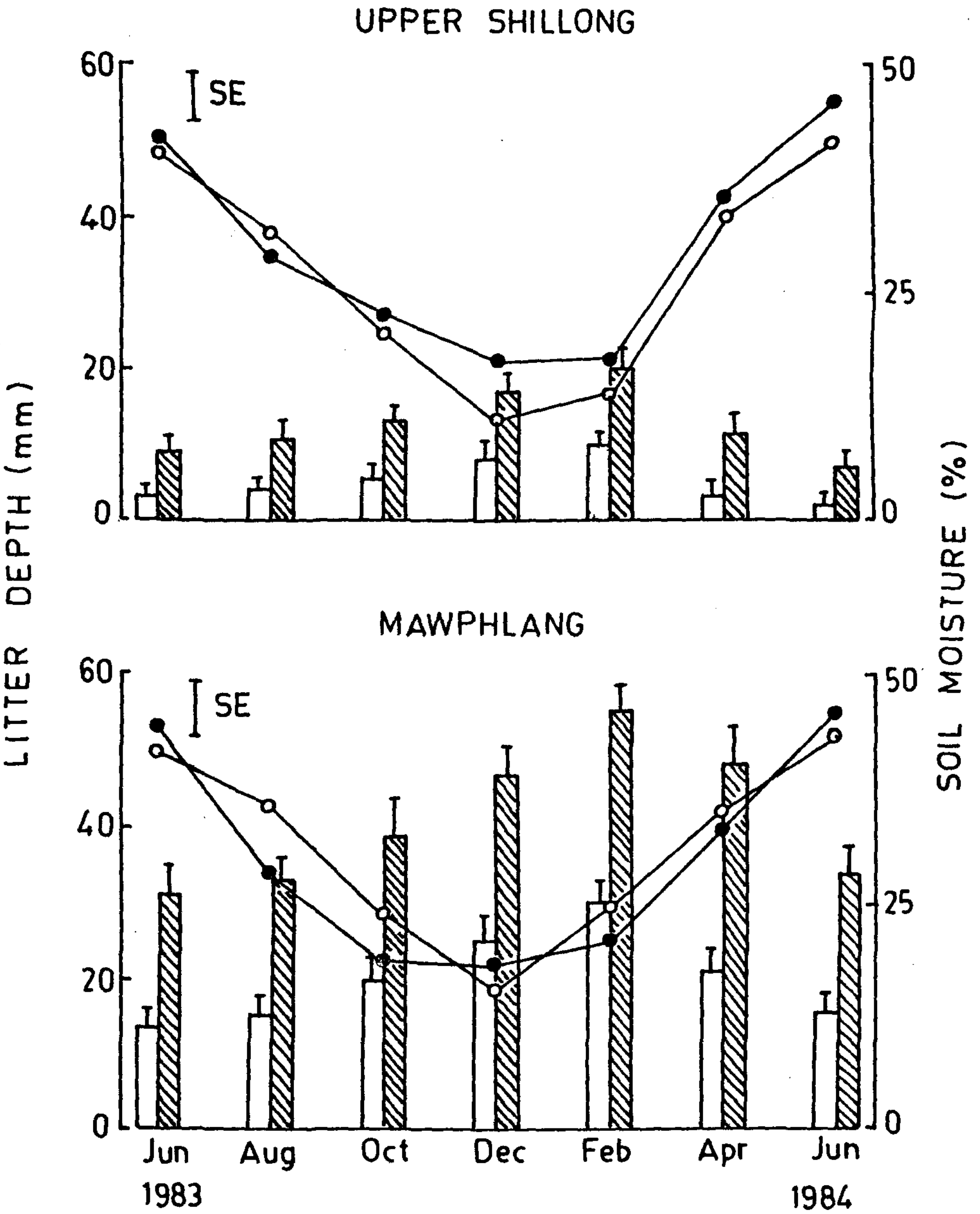

UPPER SHILLONG
MAWPHLANG
SE
LITTER DEPTH (mm)
SOIL MOISTURE (%)
0
20
40
60
25
50
Jun
Aug
Oct
Dec
Feb
Apr
1983
1984

Fig.2·1

two forests and also at the periphery and in the centre of a given forest. The number was greater in the forest at Upper Shillong than in Mawphlang. In general, the seedlings and stumps were more at the periphery of the forests than in the centre (Table 2.1). In the forest stand at the periphery of the 'Sacred grove' at Mawphlang, S. khasiana showed maximum seedling population and Q. dealbata had minimum number of seedlings, whereas in the centre, the maximum seedling density was shown by Quercus griffithii and minimum by Q. dealbata. In the forest at Upper Shillong, Pinus kesiya exhibited maximum and Myrica esculenta minimum number of seedlings. Manglietia caveana showed maximum number of stumps and Myrica esculenta minimum in the centre of the forest at Mawphlang, whereas at the periphery the corresponding values were observed in Schima khasiana and Quercus griffithii respectively. As for the number of stumps, Schima khasiana showed maximum and Myrica esculenta minimum values in the forest at Upper Shillong both at the periphery and in the centre (Table 2.1).

Survival of seedlings and sprouts :

Survival of the tree seedlings was lowest during winter months, while it was better during rainy season and in spring (Fig. 2.2). Further, survival of seedlings was poor in the dense forest stands. None of the seedlings of Myrica esculenta, Quercus spp. and Schima khasiana survived in dense stands, whereas at the periphery seedlings of Quercus spp. showed 35% survival and Myrica esculenta and Schima khasiana seedlings showed 10% survival. Seedling survival was better in Quercus griffithii than in Q. dealbata in both forests.

Table 2.1. Density (± S.E.) of the tree seedlings and sprout bearing stumps in the forests under study.

Forest stand	Tree species	Density/hectare	
		Seedlings	Stumps
Upper Shillong			
Forest stand in the centre			
	Alnus nepalensis	80±6.9	30±3.2
	Dephniphyllum himalayense	0	15±2.5
	Myrica esculenta	30±4.8	13±2.3
	Pinus kesiya	290±16.3	0
	Quercus dealbata	90±7.8	32±3.0
	Quercus griffithii	45±4.2	38±4.6
	Schima khasiana	70±3.8	40±3.2
Forest stand near the periphery			
	Alnus nepalensis	90±4.2	45±2.9
	Myrica esculenta	43±6.3	15±3.6
	Pinus kesiya	412±62.4	0
	Quercus dealbata	100±21.0	48±4.9
	Quercus griffithii	70±11.2	39±3.0
	Schima khasiana	90±13.8	70±6.9
Mawphlang			
Forest stand in the centre			
	Manglietia caveana	0	40±4.2
	Myrica esculenta	28±3.5	6±1.3
	Quercus dealbata	40±3.6	14±2.2
	Quercus griffithii	44±4.0	13±2.4
	Schima khasiana	42±2.8	12±1.2
Forest stand near the periphery			
	Quercus dealbata	64±6.3	38±4.0
	Quercus griffithii	98±9.8	41±2.8
	Rhododendron arboreum	90±10.0	0
	Schima khasiana	102±12.2	72±6.7

Fig. 2. 2. Survival of natural populations of the tree seedlings in dense stand in the centre and in sparse stand near the periphery of the forests at Upper Shillong and Mawphlang. Vertical bars represent density of ground vegetation.

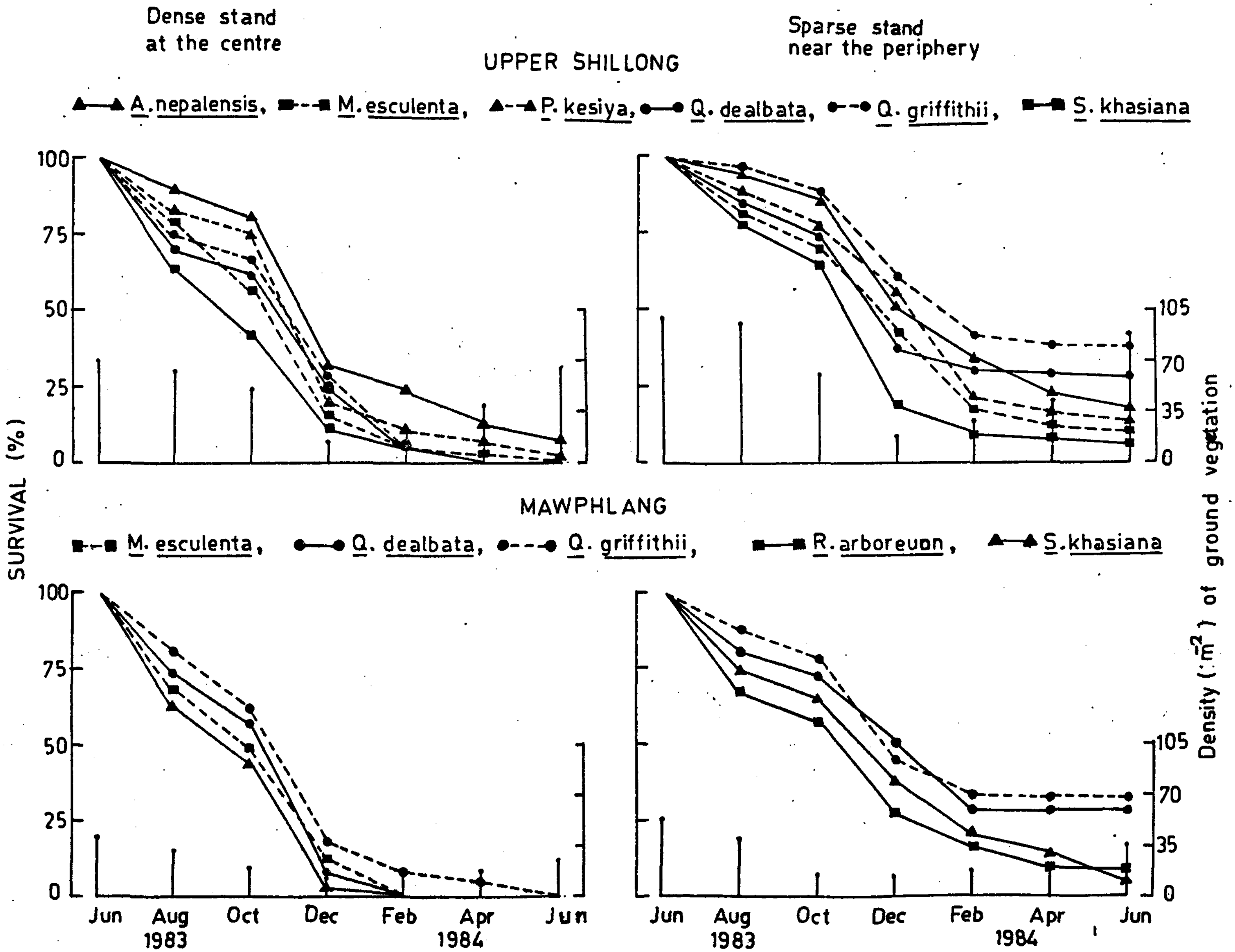

Dense stand
at the centre
Sparse stand
near the periphery
UPPER SHILLONG
A. nepalensis, M. esculenta, P. kesiya, Q. dealbata, Q. griffithii, S. khasiana
MAWPHLANG
M. esculenta, Q. dealbata, Q. griffithii, R. arboreuon, S. khasiana
SURVIVAL (%)
Density (m-2) of ground vegetation
100
75
50
25
0
105
70
35
Jun
Aug
Oct
Dec
Feb
Apr
Jun
1983
1984

Fig.2·2

The sprouts also exhibited similar survival trend as shown by the seedling population. However, mortality of the sprouts was less than that of the seedlings. The reduced light intensity in the dense forest stand resulted in greater mortality of the sprouts, especially in the forest at Mawphlang. In contrast to the seedling population, the sprout survival was better in Quercus dealbata than in Q. griffithii (Fig. 2.3).

Age structures of the two forests :

The distribution of the various age groups in the total population of all tree species differed markedly in the two forests. While the age structure was upright pyramidal in the forest at Upper Shillong, it was inverted in the forest at Mawphlang. Among the four age groups, seedlings contributed about 45% of the total density at Upper Shillong and only about 7% at Mawphlang. The seedling population decreased substantially in February in both the forests, the reduction being greater in Mawphlang (Fig. 2.4). The density of saplings was greater in the forest at Upper Shillong than in Mawphlang forest and it did not show marked seasonal variation. As compared to seedling and sapling populations, trees are more abundant in the forest at Mawphlang.

DISCUSSION

Greater number of seedlings and stumps in the forest stand at Upper Shillong is attributed to the creation of large number of microsites by tree felling and forest burning, which might help in germination/sprouting of large number of tree seeds/stumps. Removal of overstorey trees might

Fig. 2. 3. Survival of the tree sprouts in dense stand in the centre and in sparse stand near the periphery of the forests at Upper Shillong and Mawphlang.

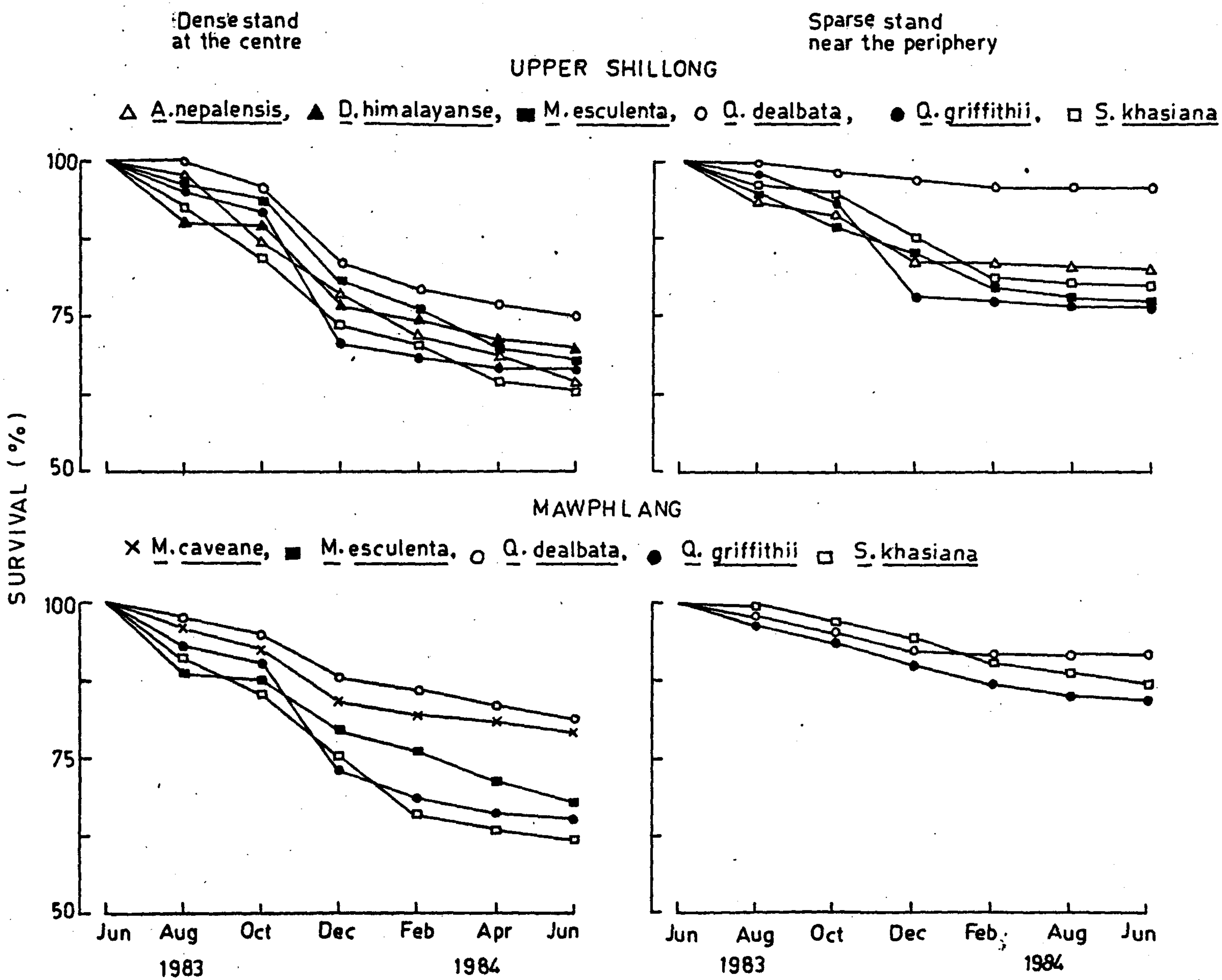

Dense stand
at the centre
Sparse stand
near the periphery
UPPER SHILLONG
△ A. nepalensis, ▲ D. himalayanse, ■ M. esculenta, ○ Q. dealbata, ● Q. griffithii, □ S. khasiana
100
75
50
SURVIVAL (%)
MAWPHLANG
× M. caveane, ■ M. esculenta, ○ Q. dealbata, ● Q. griffithii □ S. khasiana
100
75
50
Jun
Aug
Oct
Dec
Feb
Apr
Jun
1983
1984
Jun
Aug
Oct
Dec
Feb
Aug
Jun
1983
1984

Fig. 2·3

Fig. 2. 4. Age structure of the total population of all the tree species in the two forest stands. Percentages of the total density as seedlings ( ), saplings ( ), small trees ( ) and big trees ( ) are given. The density of trees in a stand is indicated above the corresponding pyramid.

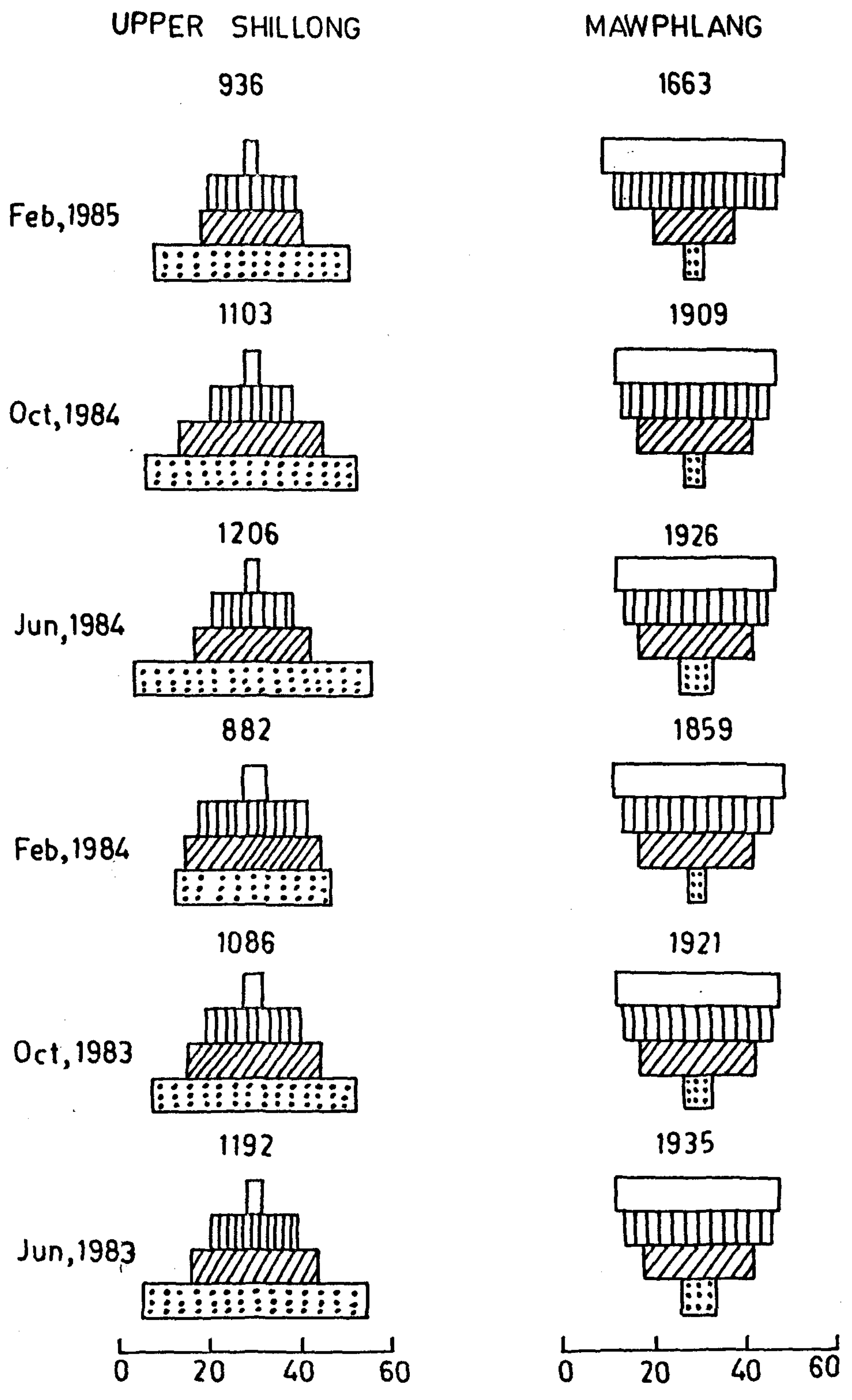

UPPER SHILLONG
MAWPHLANG
936
1663
Feb,1985
1103
1909
Oct,1984
1206
1926
Jun,1984
882
1859
Feb,1984
1086
1921
Oct,1983
1192
1935
Jun,1983
0
20
40
60
0
20
40
60

Fig. 2·4

have also favoured germination and seedling establishment through increased solar radiation on the forest floor and consequent increase in surface temperature and reduced competition with trees of upper canopy (Koller 1972, Noble & Slatyer 1980, Oliver 1981). On the other hand, poor seedling population in the forest at Mawphlang may be due to the unavailability of the same favourable conditions. Besides, thick layer of litter also acts as a mechanical barrier for seedling emergence (Telfer 1972, Grime 1979). The forest at Upper Shillong is characterised by an upright pyramid of age structure. Selective felling of older trees for timber and other purposes appears to be responsible for their decreased proportion in total population of trees. The climax forest at Mawphlang where tree felling and burning are completely prohibited due to belief of the local tribals, shows an inverted pyramid of age structure. Similar change in age structure of plant populations in forest communities due to various kinds of disturbances has also been reported by Heinselman (1973), Foster (1980) and Primack et al. (1985).

The tree seedlings/sprouts showed better survival in the stand near the periphery than in dense forest stands, which may be attributed to the lack of threshold light intensity available to the seedlings/sprouts for photosynthesis in the latter stand. This conforms with the observations of Whitmore (1975), Garwood (1979), Sasaki & Mori (1981), Abbott (1984), Augsparger (1984a, b, c), Langenhein et al. (1984) and Primack et al. (1985). Thick litter layer in the dense forest stands, especially in Mawphlang (Fig. 2.1) may also influence the survival of tree seedlings through production of allelochemics as reported by Blaschke (1979) and Tayler & Shaw (1983). The peak mortality of tree seedlings during winter months may be due to prevailing low temperature and high soil moisture stress (Fig. 2.2). The detrimental effect of soil moisture stress on the survival of tree seedlings has also been reported by earlier workers (e.g. Pereira & Kozlowski 1977, McLeod & Murphy 1977, Mueller-Dombois et. al. 1980, Schulte & Marshall 1983). Significance of under-canopy vegetation in determining the size of seedling population of trees through mortality has been emphasized by Eis (1981), Cross (1981), Maguire & Forman (1983), Burton & Mueller-Dombois (1984) and Connell et al. (1984). The undercanopy vegetation may also influence seedling survival of tree species through allelopathic effects, as has been reported by Rice (1974), Stewart (1975), Horsley (1977a, b), Willis (1980) and Ashton & William (1982). The decrease in population size of the tree seedlings during rainy season especially on the periphery of the forests is largely caused by the erosive action of the torrential rain on the hill slopes of Meghalaya.

Better regeneration of trees in the forest at Upper Shillong than in Mawphlang signifies the role of prevailing disturbances in the former. Harris & Farr (1974) and Boring et al. (1981) have also emphasized the positive role of mild disturbances in improving the regeneration of trees, though the role of severe disturbances has been regarded as deleterious to forest ecosystems (Levin 1976).

CHAPTER III

Effect of stump diameter and height on regeneration of four tree species through sprouts.

INTRODUCTION

The sprouts contribute a great deal to the natural regeneration of the forests where tree felling is common (Smith 1979, Kellison *et al.* 1980, Beck 1980), but relatively little is known about the role of tree stumps in regeneration through sprouting. Johnson (1975) found that the percentage of sprouted stumps of red oak increased with increasing stump diameter upto a certain thickness and then decreased. MacDonald & Powell (1983) observed that the percentage of sprouted stumps and the average number of sprouts per stump in *Acer saccharum* were greater for small diameter than for large diameter stumps. Recently, Harrington (1984) studied the effects of stump height and aspects of cut (i.e. angle and slope), tree age and season of year on sprouting of red alder. However, the interactive influence of diameter and height of stumps on sprouting and growth and survival of sprouts is not well understood.

The present study was carried out to examine the effect of diameter and height of stumps on sprouting and growth and survival of sprouts of *Alnus nepalensis*, *Quercus dealbata*, *Quercus griffithii* and *Schima khasiana* in the forest at Upper Shillong which is exposed to frequent tree cutting. For the sake of convenience the study was split into two sections. The first section deals with the effects of diameter and height of stumps on sprouting and survival of the sprouts, whereas the second section concerns with the study on growth of the sprouts as related to diameter and height of the stumps, sprout density and burning.

SECTION I. EFFECT OF STUMP DIAMETER AND HEIGHT ON SPROUTING AND SURVIVAL OF SPROUTS OF FOUR TREE SPECIES.

MATERIALS AND METHODS

Study site :

The study was conducted in a disturbed forest at Upper Shillong which is subjected to frequent tree cutting. Stumps of the cut trees in this forest show sprouting. Further details of the study site are given in Chapter I.

Methods :

Ten quadrats of 20 m x 20 m size were randomly laid during June, 1983 in the forest stand where trees were selectively cut during December, 1982. The density of stumps of Alnus nepalensis, Quercus dealbata, Quercus griffithii and Schima khasiana was determined in each quadrat. Diameter of the stumps of each species was measured and the stumps were grouped in five diameter classes viz., $\leq$ 15, > 15-30, > 30-45, > 45-60 and > 60 cm (Table 3.1). The number of the sprouted stumps in each diameter class was also counted. For determining the number of sprouts per stump, ten stumps of a given species in each diameter class were sampled. The thickness of the bark of these stumps was also measured.

To study the effect of stump height on sprouting, trees of the selected species representing the two most common diameter classes (> 15-30 and > 30-45cm) were cut at different heights and grouped into four height classes, 5-10, 25-30, 45-50 and 65-70 cm. The number of sprouts emerging from the stumps of different heights was counted to determine the effect of stump height on sprouting and data were processed for ANOVA.

For studying the survival of sprouts, ten stumps of a given species in each of the diameter and height classes were marked. The sprouts were labelled with aluminium foil and their fate was followed at two-monthly intervals over a period of one year.

RESULTS

The stumps of medium diameters (> 15-30 and > 30-45 cm) were more numerous than those of smaller and larger diameters (Table 3.1). The stump density was maximum in Schima khasiana and minimum in Quercus griffithii. In all the four species the percentage of stumps that sprouted decreased with the increase in stump diameter. The percentage of sprouted stumps was maximum in Alnus nepalensis and minimum in Quercus griffithii (Table 3.1). Thickness of the stump bark increased with the increase in stump diameter in all the species. The bark thickness was maximum in Quercus griffithii (Fig. 3.1).

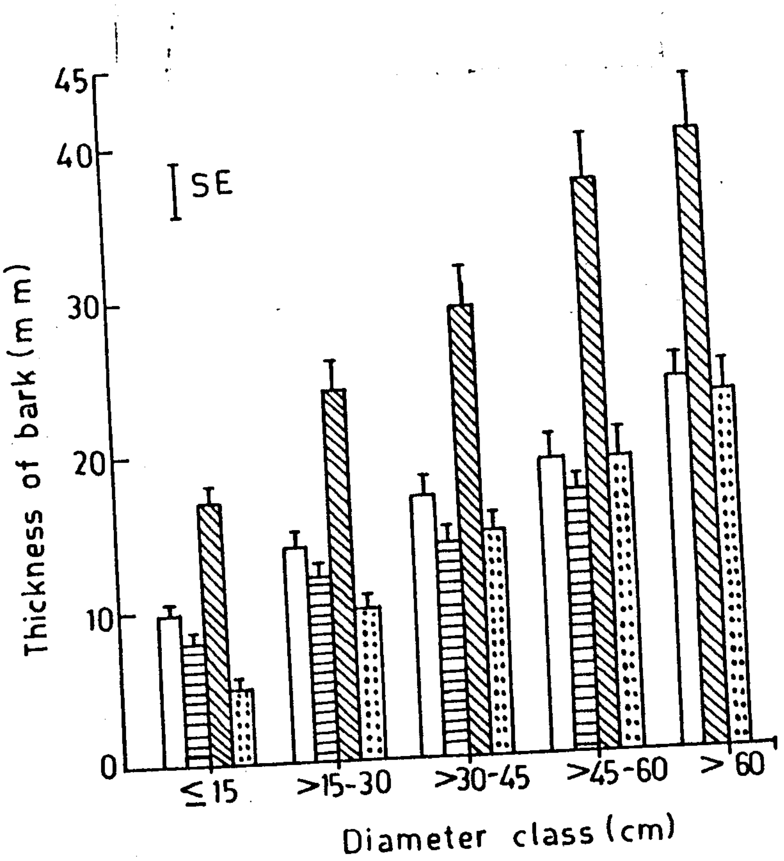
Both diameter and height of stumps had significant effect on their sprouting. In Quercus dealbata, Q. griffithii and Schima khasiana maximum number of sprouts was given out from the stumps of > 15-30 cm diameter, whereas in Alnus nepalensis the stumps of > 30-45 cm diameter showed maximum sprouting. In general, number of sprouts was maximum in Schima khasiana and minimum in Quercus griffithii (Fig. 3.2). The bark thickness was negatively correlated with the number of sprouts (Fig. 3.3). Sprouting from the stumps in all the species increased significantly with

Table 3.1. Per hectare mean density (± S.E.) of stumps of four tree species and sprouting percentage of stumps (in parentheses) of five diameter classes in the first growing season after six months of cutting in the forest at Upper Shillong.

Species	Stump diameter classes					Total
	≤ 15 cm	> 15-30 cm	>30-45 cm	>45-60 cm	>60 cm	
Alnus nepalensis	3 ± 1.3 (100.0)	33 ± 3.9 (92.9)	39 ± 4.7 (90.3)	25 ± 3.2 (84.0)	4 ± 1.4 (75.0)	104 ± 11.4 (89.4)
Quercus dealbata	7 ± 2.3 (71.4)	43 ± 5.3 (69.8)	40 ± 4.6 (62.5)	23 ± 2.9 (34.8)	-	113 ± 9.8 (60.2)
Quercus griffithii	3 ± 1.3 (66.7)	29 ± 2.9 (55.6)	33 ± 4.1 (42.4)	27 ± 2.9 (24.1)	2 ± 0.9 (0)	94 ± 8.9 (40.4)
Schima khasiana	15 ± 2.7 (100.0)	37 ± 4.2 (86.5)	43 ± 5.8 (83.7)	33 ± 3.6 (63.6)	8 ± 2.2 12.5)	136 ± 12.4 (77.2)

Dash indicates the absence of stumps.

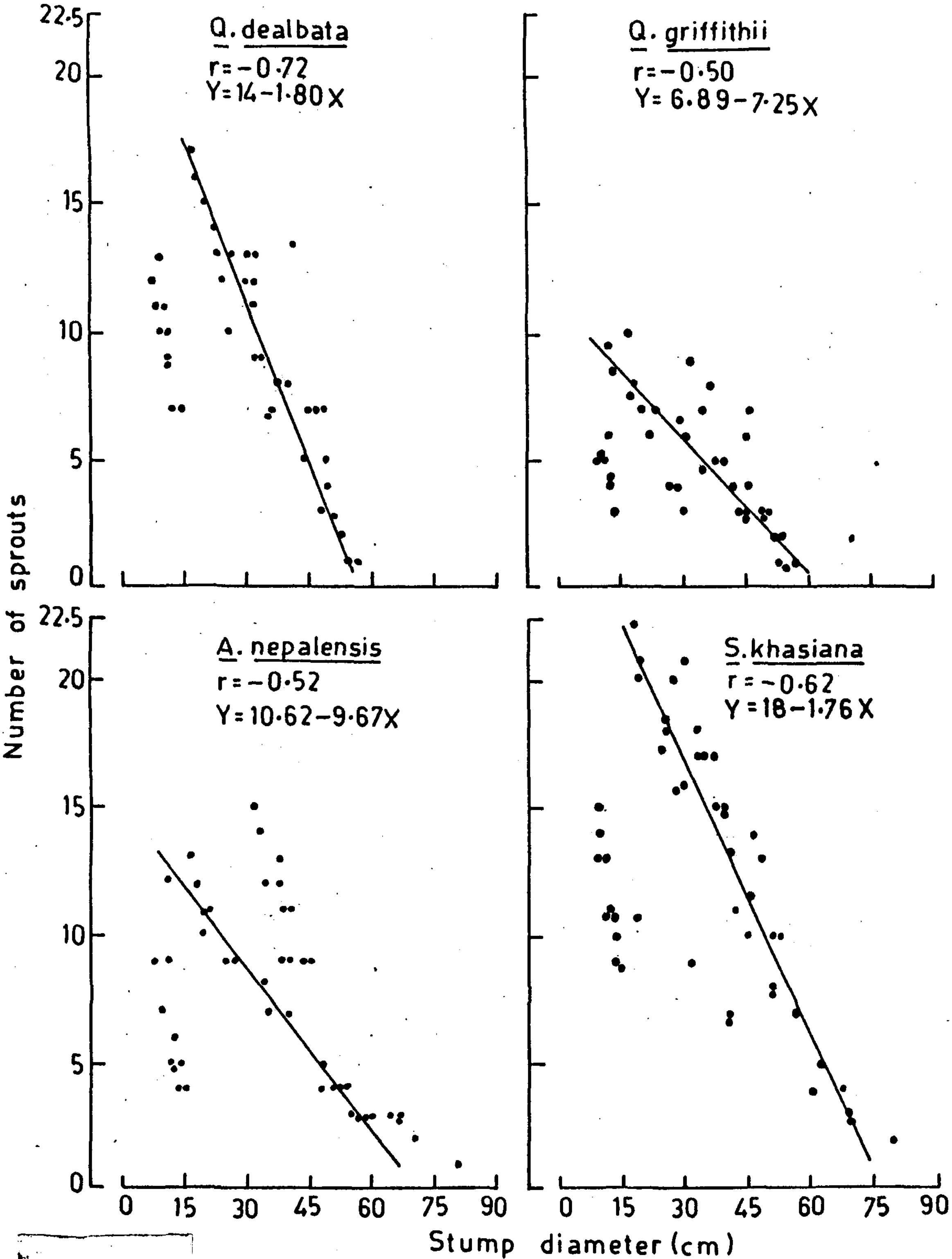
Fig. 3. 1. Thickness of bark as related to stump diameter in four tree species : □ , *Alnus nepalensis*; ▤ , *Quercus dealbata*; ▧ , *Quercus griffithii*; ⊡ , *Schima khasiana*.



45
40
30
20
10
0
SE
Thickness of bark (m m)
≤15
>15-30
>30-45
>45-60
> 60
Diameter class (cm)

Fig.3·1

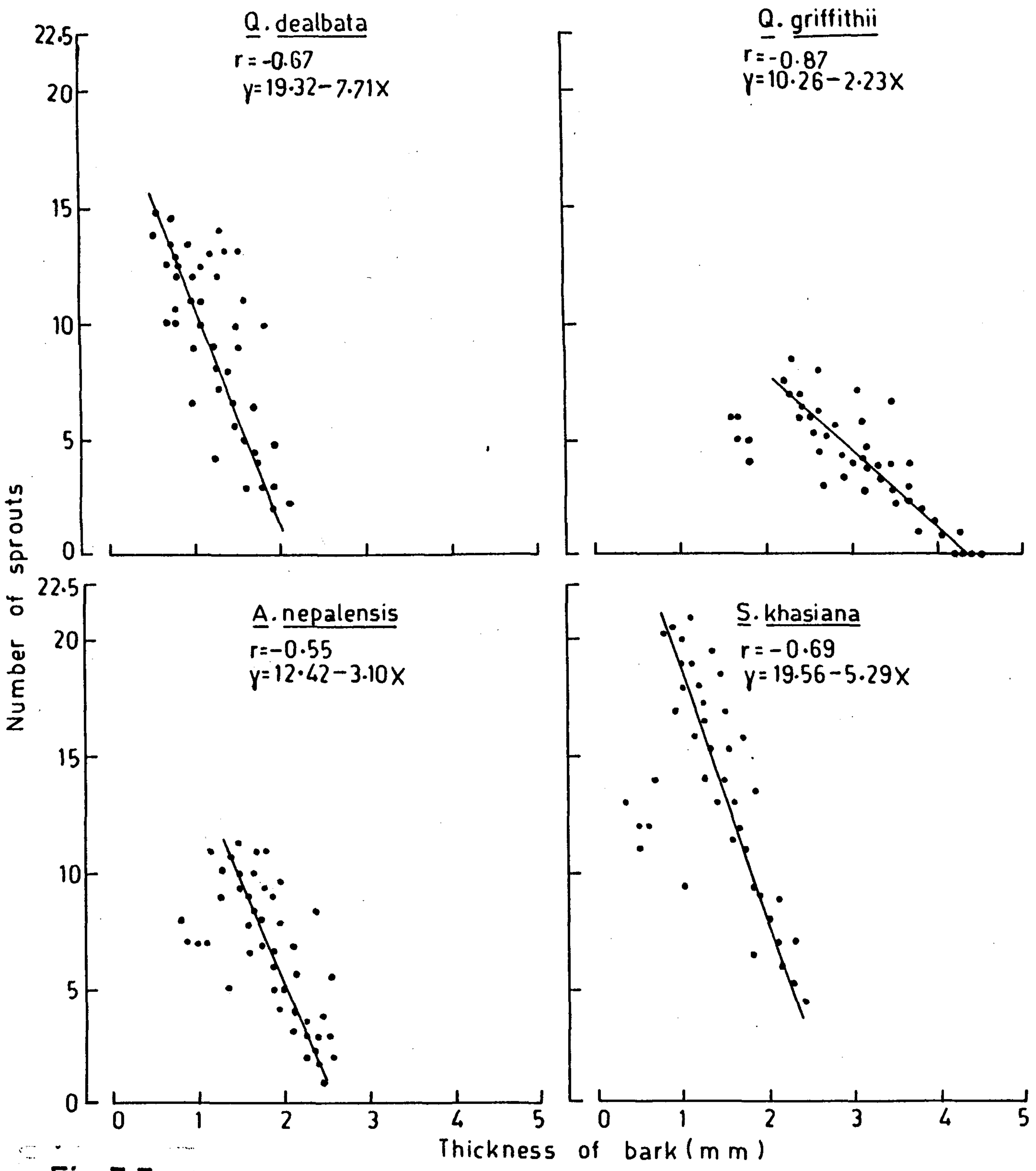
Fig. 3. 2. Relationship between the stump diameter and number of sprouts per stump. Y and X in the equations represent the diameter of the stumps and number of sprouts respectively. r values are significant at p = 0.001.



Q. dealbata
r=-0.72
Y=14-1.80X
Q. griffithii
r=-0.50
Y=6.89-7.25X
A. nepalensis
r=-0.52
Y=10.62-9.67X
S. khasiana
r=-0.62
Y=18-1.76X
Number of sprouts
Stump diameter (cm)
22.5
20
15
10
5
0
0
15
30
45
60
75
90

Fig. 3·2

Fig. 3. 3. Relationship between the number of sprouts per stump and thickness of the stump bark. Y and X in the equations represent the thickness of the bark and number of sprouts respectively. r values are significant at $p = 0.001$.



Q. dealbata
r = -0·67
y=19·32−7·71X
Q. griffithii
r=-0·87
y=10·26−2·23X
A. nepalensis
r=−0·55
y=12·42−3·10X
S. khasiana
r = −0·69
y= 19·56−5·29X
Number of sprouts
Thickness of bark (mm)
22·5
20
15
10
5
0
0
1
2
3
4
5

Fig. 3·3

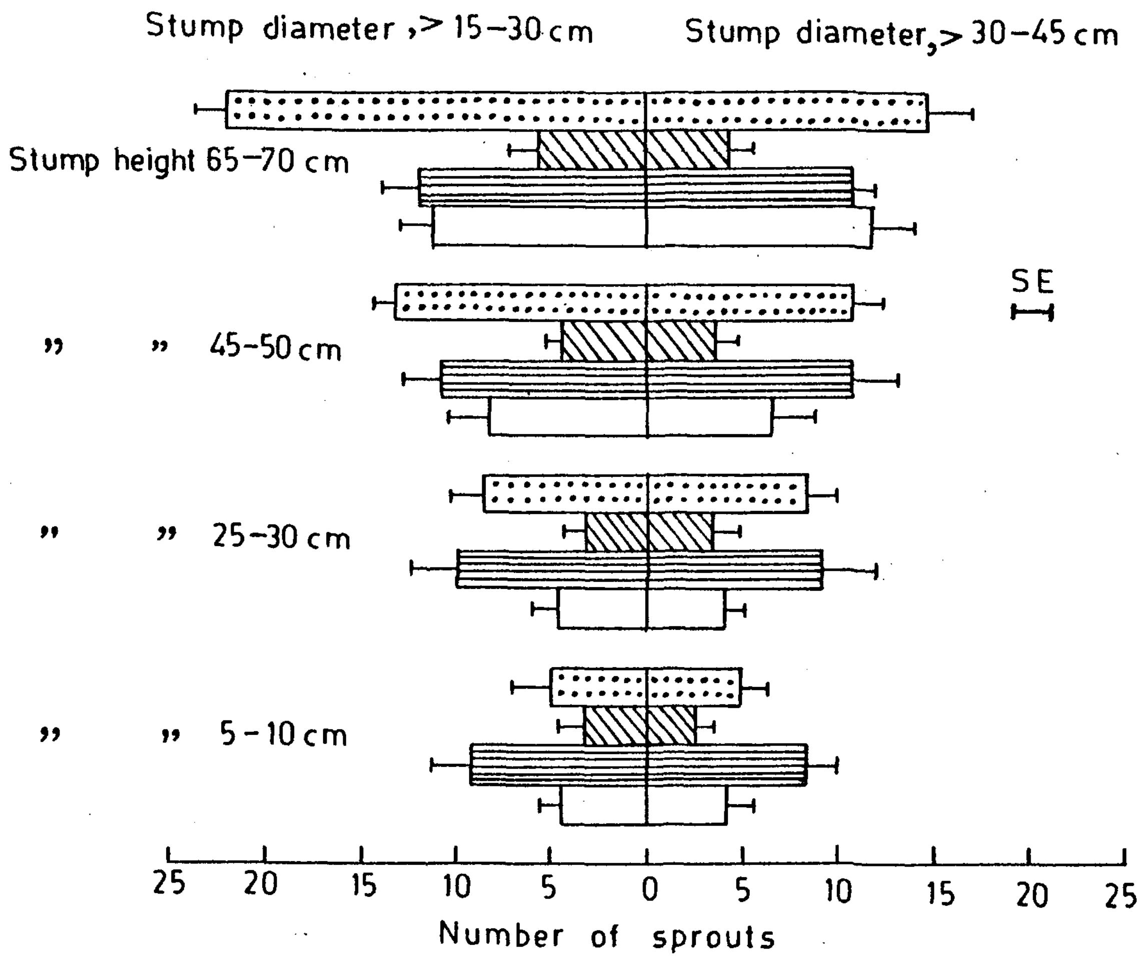
increase in stump height (Table 3.2), the increase being maximum in Schima khasiana and minimum in Quercus griffithii (Fig. 3.4).

Survival of the sprouts was also influenced by the stump diameter and height. Sprouts arising from the stumps of medium diameters (> 15-30 and > 30-45 cm) survived better than those from the thinner and thicker stumps. The sprout survival in Quercus dealbata was better than in Quercus griffithii (Fig. 3.5). The sprouts arisin from the stumps of medium height classes (25-30 and 45-50 cm) showed less mortality than those from the stumps of the less or greater height (Table 3.3). The variations in sprout mortality due to species, stump height and stump diameter were significantly different (Table 3.4). In general, mortality of the sprouts was maximum in Quercus griffithii and minimum in Schima khasiana.

DISCUSSION

Reduction in the number of sprouts with increase in stump diameter, also reported by MacDonald & Powell (1983) in Acer saccharum, may be attributed to the change in physiology of the trees with age. In general, vegetative reproduction predominates in the juvenile phase and sexual reproduction in the adult phase (Hartmann & Kester 1975). This argument has been used by many workers (Hawley 1946, Clark & Liming 1953, Solomon & Blum 1967) to explain the effect of stump thickness on sprouting. Besides, with the increase in tree age, the number of dormant buds which give rise to sprouts is also reduced due to their death (Roth & Hepting 1943, Clark & Liming 1953). The increasing thickness of the bark with advancing age of trees also offers mechanical hindrance to the sprout emergence (Clark

Fig. 3. 4. Effect of stump height and diameter on sprouting in four tree species : □ , *Alnus nepalensis*; ⊟ , *Quercus dealbata*; ⧅ , *Quercus griffithii*; ⬚ , *Schima khasiana*.



Stump diameter ,> 15–30 cm
Stump diameter,> 30–45 cm
Stump height 65–70 cm
" " 45–50 cm
" " 25–30 cm
" " 5–10 cm
SE
25 20 15 10 5 0 5 10 15 20 25
Number of sprouts

Fig.3·4

Table 3.2. Analysis of variance of the data presented in Fig. 3.4.

Source of variation	Degrees of freedom	Mean sum of squares	F-Ratio
Species	3	8477.69	40.92*
Diameter	1	892.53	4.31 NS
Height	3	6970.61	33.65*
Species X Diameter	3	187.28	0.90 NS
Height X Diameter	3	82.86	0.40 NS
Height X Species	9	1037.64	5.01*
Residual	9	207.17	-
Total	31	-	-

* Significant at $p = 0.05$

NS - Not significant

Fig. 3. 5. Survival (%) of the sprouts emerged from the stumps representing five diameter classes : ● , ≤ 15 cm; ▲ , > 15-30 cm; △ , > 30-45 cm; ○ , > 45-60 cm and □ , > 60 cm.

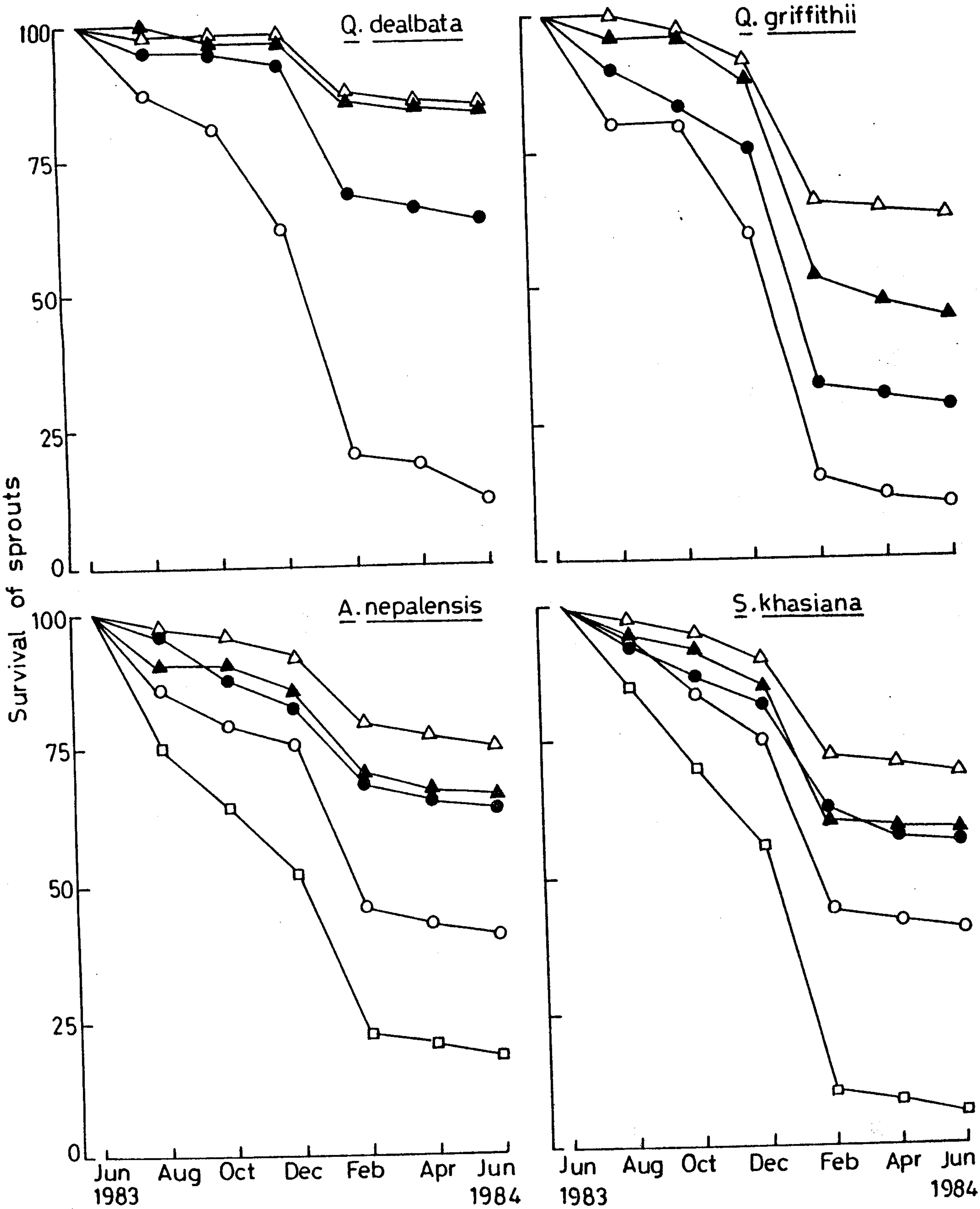

Q. dealbata
Q. griffithii
A. nepalensis
S. khasiana
Survival of sprouts
100
75
50
25
0
Jun
1983
Aug
Oct
Dec
Feb
Apr
Jun
1984

Fig.3·5

Table 3.3. Mortality (%) of sprouts emerging from the stumps of four different height classes under two medium diameter classes in four tree species after one year of cutting in the forest at Upper Shillong.

Species	Diameter (> 15-30 cm) Stump height classes (cm)					Diameter (> 30-45 cm) Stump height classes (cm)				
	5-10	25-30	45-50	65-70	Mean mortality ± S.E.	5-10	25-30	45-50	65-70	Mean mortality ± S.E.
Alnus nepalensis	81.2	24.5	37.5	73.5	54.17 ± 13.73	83.5	36.8	58.4	77.0	63.92 ± 10.49
Quercus dealbata	79.5	18.7	27.5	54.5	45.05 ± 13.78	86.2	21.7	31.7	57.5	49.27 ± 14.43
Quercus griffithii	86.8	36.8	44.2	70.4	59.55 ± 11.59	90.5	39.7	47.0	72.5	62.42 ± 11.70
Schima khasiana	50.0	31.4	38.5	40.2	40.02 ± 3.8	57.2	33.8	44.2	42.6	44.45 ± 4.82
Mean ± S.E.	74.37 ±8.27	27.85 ±3.95	36.92 ±3.47	59.65 ±7.70		79.35 ±7.52	33.00 ±3.95	45.32 ±5.48	62.40 ±7.80	

Table 3.4. Analysis of variance of the data presented in Table 3.3.

Source of variation	Degrees of freedom	Mean sum of squares	F-Ratio
Species	3	66374.17	63.64*
Diameter	1	22553.16	21.62*
Height	3	341848.34	327.77*
Species X Diameter	3	1834.09	1.85 NS
Height X Diameter	3	1084.87	1.04 NS
Height X Species	9	18710.28	17.94*
Residual	9	1042.97	-
Total	31	-	-

* Significant at $p = 0.05$

NS - Not significant

& Liming 1953, Kramer & Kozlowski 1960, Smith 1962). Incidentally, Quercus griffithii which has maximum bark thickness showed minimum sprouting (Fig. 3.1 & 3.3).

The increased sprouting with the increase in stump height as observed in the present study (Fig. 3.4) conforms with the observations of DeBell (1971), Bellanger (1976) and El Houri Ahmed (1977) in other species. Recently, Harrington (1984) also reported that sprouting in red alder (Alnus rubra) was poor when the stumps were cut at low height. In the case of stumps of low height the population of dormant or trace buds happens to be low (Hook & DeBell 1970) and this could cause decrease in sprouting from such stumps. The rapid decay of the low cut stumps, as also observed by El Houri Ahmed (1977) in Eucalyptus microtheca, may adversely affect sprouting, especially in North-East India where favourable moisture conditions may encourage microbial decomposition.

Survival of the sprouts is also influenced by the diameter and height of stumps. Poor survival of sprouts emerging from the stumps of smaller diameter may be attributed to inadequate reserves or nutrient supply base to support the growth of these sprouts (Mann 1984). The low survival of the sprouts from the stumps thicker than 45 cm diameter could not be explained, although it may be ascribed to the change in hormonal balance as a consequence of change in physiology of tree stumps with age (Robbins 1957). The maximum mortality of sprouts emerging from the stumps of low height could be due to the observed fast decay of such stumps at the study site. This agrees with the observations of El Houri Ahmed (1977). The dense growth of the shrubs and sprouts emerging from the stumps of greater heights at the study site considerably reduced the incoming solar radiation at the lower strata and this might have contributed to greater mortality of sprouts arising from the low cut stumps. The sprouts emerging from the stumps of greater height (65-70 cm) suffer heavier mortality than those from the stumps of medium height (e.g. 25-30 and 45-50 cm), presumably due to greater damage caused to them by the heavy rain and high wind velocity prevailing in the area. Better survival of sprouts emerging from the stumps of medium height may be attributed to slower decay of the stumps, availability of sufficient light and lower risk of damage to the sprouts from the heavy rain and high wind velocity.

The results indicate that the tree felling operations in which stumps of medium height and diameter are left in the forest could maximise regeneration of *Alnus nepalensis*, *Quercus dealbata*, *Q. griffithii* and *Schima khasiana* through sprouts.

Plate 5. Regeneration through stump sprouting in Quercus dealbata (A) and Quercus griffithii (B) in the disturbed forest at Upper Shillong.

A

PLATE 5

B

Plate 6. Regeneration through stump sprouting in _Schima khasiana_ in the disturbed forest at Upper Shillong; A - low density of sprouts, B - high density of sprouts.

A

PLATE 6

B

Plate 7. Regeneration of _Alnus nepalensis_ in the disturbed forest at Upper Shillong through sprouting from the stump of medium height and diameter (A), and from the thicker stump of greater height (B).

A

PLATE 7

B

SECTION II. EFFECT OF DIAMETER AND HEIGHT OF STUMPS AND SPROUT DENSITY ON THE SPROUT GROWTH OF FOUR TREE SPECIES IN BURNT AND UNBURNT FOREST PLOTS.

MATERIALS AND METHODS

Study site :

A part of the disturbed forest at Upper Shillong was surface-burnt in March, 1983 to study the effect of burning on growth of the sprouts. The sprout growth on the burnt plot was compared with that on an unburnt plot which was situated adjacent to the burnt plot.

Method :

Five stump diameter classes viz., $\leq$ 15, $>$ 15-30, $>$ 30-45, $>$ 45-60 and $>$ 60 cm were maintained as described in the first section of the chapter. The stumps representing four height classes viz., 5-10, 25-30, 45-50 and 65-70 cm were recognised in the diameter range of $>$ 15-45 cm. Two sprout density levels, low (2-3 sprouts per stump) and high (8-10 sprouts per stump), were maintained by thinning operation.

Five stumps from each of the two sprout density levels were sampled in each diameter and height class of a given species from the burnt and unburnt plots during the first week of September, 1983 and two sprouts on each stump were labelled with aluminium foil to study their growth behaviour. Data on sprout length, leaf number and leaf area were recorded at 3-month intervals over a 2-year period and were processed for ANOVA. The length of the sprout was measured from the point of its emergence on the stump. Area of 20 intact leaves, randomly selected from each sprout, was measured and average area per leaf was computed; average area per leaf multiplied by average number of leaves per sprout gave the leaf area per sprout. The rate of sprout elongation was determined during different seasons of the year. The observations were recorded over a 2-year period, but since there was no marked difference between the years, the data for the corresponding seasons during the two years were pooled.

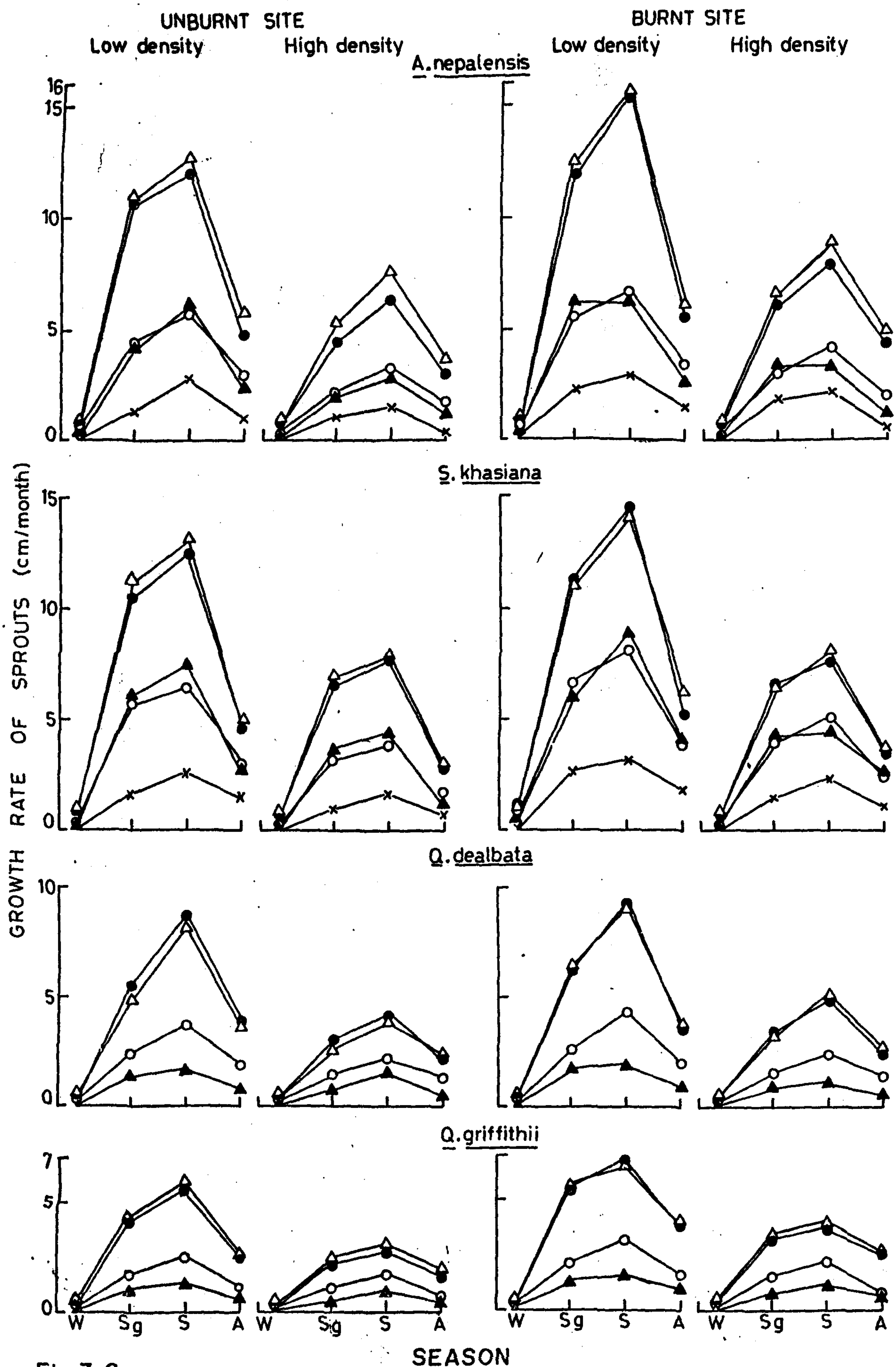
RESULTS

Growth of the sprouts was greatly affected by both diameter and height of stumps. Sprouts arising from the stumps of medium diameters (> 15-30 and > 30-45 cm) showed higher growth rate in their length as compared to those emerged from the stumps of smaller or larger diameters in all the four species (Fig. 3.6). Growth rate of the sprouts increased with the increase in stump height, the increase being maximum in A. nepalensis and minimum in Q. griffithii. In general, the growth rate of the sprouts was maximum in summer and minimum in winter (Fig. 3.6 & 3.7).

Increase in length of the sprouts during the study period and their total length were significantly greater ($P < 0.05$) for the sprouts emerged from the stumps of medium diameters in all the species (Table 3.5). These values increased significantly ($P < 0.05$) with the increase in stump height. In general, total length of the sprouts and the increase in sprout length were maximum in S. khasiana and minimum in Q. griffithii (Table 3.5 & 3.6).

The sprouts emerged from the stumps of medium diameter, > 15-30 and > 30-45 cm, produced maximum leaf area. The values were

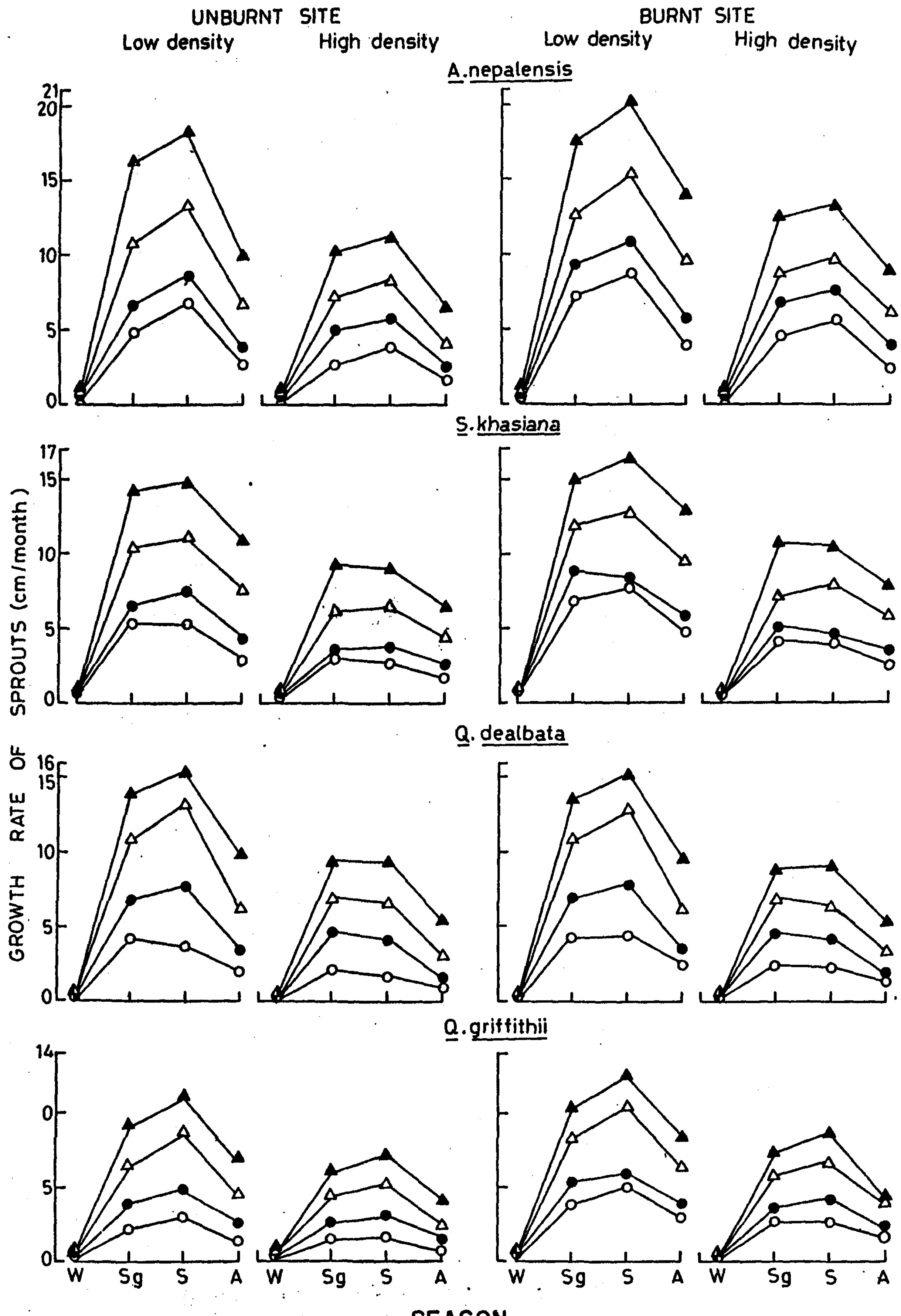
Fig. 3.6. Effect of stump diameter and sprout density on the growth rate of sprouts of four tree species in burnt and unburnt plots: ○, ≤ 15 cm; ●, > 15-30 cm; △, > 30-45 cm; ▲, > 45-60 cm and ×, > 60 cm. W, Winter; Sg, Spring; S, Summer; A, Autumn.



UNBURNT SITE
Low density
High density
BURNT SITE
Low density
High density
A. nepalensis
S. khasiana
Q. dealbata
Q. griffithii
GROWTH RATE OF SPROUTS (cm/month)
0
5
10
15
16
7
W
Sg
S
A
SEASON

Fig.3·6

Fig. 3. 7. Effect of stump height and sprout density on the growth rate of sprouts of four tree species in burnt and unburnt plots: ○ ,5-10 cm; ● , 25-30 cm; △ , 45-50 cm and ▲ , 65-70cm. W, Winter; Sg. Spring; S, Summer; A, Autumn.



UNBURNT SITE
Low density
High density
BURNT SITE
Low density
High density
A.nepalensis
S.khasiana
Q. dealbata
Q.griffithii
GROWTH RATE OF SPROUTS (cm/month)
21
20
15
10
5
0
17
15
10
5
0
16
15
10
5
0
14
0
5
0
W
Sg
S
A
SEASON

Fig.3·7

Table 3.5. Increase in sprout length during September, 1983 to August, 1985 and total length of the sprout of four tree species in relation to stump diameter and burning.

Species	Increase in sprout length (cm)				Total length per sprout (cm)			
	Unburnt plot		Burnt plot		Unburnt plot		Burnt plot	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2
A. nepalensis								
D_1	84.7	44.2	98.0	55.9	151.3	108.0	176.6	126.2
D_2	109.2	66.8	127.0	76.0	186.5	140.5	213.8	156.5
D_3	108.7	59.4	124.2	74.3	184.5	131.3	210.5	153.9
D_4	44.8	22.0	58.6	30.7	101.6	79.9	118.6	90.0
D_5	26.0	13.8	37.3	19.7	73.5	62.6	90.0	73.6
S. khasiana								
D_1	81.8	44.7	102.0	70.6	155.0	110.6	206.6	145.9
D_2	108.1	64.8	156.7	95.9	108.6	140.7	245.0	183.6
D_3	110.1	67.8	155.8	97.0	107.7	141.6	243.3	182.6
D_4	47.9	24.6	58.9	30.7	102.6	80.5	118.6	88.0
D_5	26.9	13.5	43.4	23.0	71.5	59.3	93.0	73.3
Q. dealbata								
D_1	45.3	21.2	52.4	24.7	104.9	75.5	106.0	82.0
D_2	64.4	41.9	75.2	40.6	135.0	111.7	145.7	108.9
D_3	64.7	40.1	65.1	33.0	134.0	107.7	135.6	104.3
D_4	21.7	10.6	26.1	10.6	65.3	47.5	68.9	51.3
Q. griffithii								
D_1	33.6	12.7	46.4	24.3	73.9	51.3	92.0	67.8
D_2	41.0	22.6	63.4	48.8	91.6	71.5	119.0	102.3
D_3	45.1	22.0	62.7	41.6	93.7	69.3	116.5	93.6
D_4	20.4	6.3	28.0	10.7	45.9	27.3	57.5	41.3

D_1, D_2, D_3, D_4, D_5 represent the stump diameter classes. D_1 - ≤ 15 cm, D_2 - $>$ 15-30 cm, D_3 - $>$ 30-45 cm, D_4 - $>$ 45-60 cm, D_5 - $>$ 60 cm.

d_1, d_2- Low and high sprout density levels respectively.

Note - ANOVA indicated significant differences at $P = 0.05$ due to stump diameter and sprout density.

Table 3.6. Increase in sprout length during September, 1983 to August, 1985 and total length per sprout of four tree species in relation to stump height and burning.

Species	Increase in sprout length (cm)				Total length per sprout (cm)			
	Unburnt plot		Burnt plot		Unburnt plot		Burnt plot	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2
A. nepalensis								
H_1	85.0	50.6	107.6	64.7	150.6	111.5	179.4	136.3
H_2	95.0	65.0	125.3	68.8	167.3	136.5	209.6	151.3
H_3	106.6	63.5	131.2	74.9	190.3	146.8	231.5	173.3
H_4	123.1	67.0	136.7	79.7	220.6	165.6	244.3	185.4
S. khasiana								
H_1	85.3	46.9	113.9	66.7	156.8	113.6	199.6	141.5
H_2	107.4	66.1	131.9	95.5	183.7	139.5	217.5	183.0
H_3	117.0	65.2	143.7	100.5	203.6	149.9	239.0	197.0
H_4	141.0	70.0	163.4	145.1	273.6	169.5	263.7	193.6
Q. dealbata								
H_1	57.0	32.0	54.4	33.9	108.3	83.6	110.5	84.6
H_2	74.6	56.9	72.8	56.9	140.2	125.5	142.6	123.6
H_3	90.1	59.7	63.9	60.0	167.9	133.4	170.8	134.6
H_4	95.9	65.4	101.6	71.1	183.5	154.9	186.9	157.8
Q. griffithii								
H_1	40.8	27.0	56.2	32.7	79.3	61.7	103.2	79.2
H_2	46.9	32.6	58.2	30.4	87.4	72.3	110.9	83.6
H_3	53.6	37.8	68.5	43.6	103.8	86.4	129.7	104.3
H_4	54.9	44.1	79.3	43.3	115.7	104.3	147.8	115.6

H_1, H_2, H_3, H_4 represent the stump height classes. H_1 - 5-10-cm, H_2 - 25-30 cm, H_3 - 45-50 cm, H_4 - 65-70 cm.

d_1, d_2- Low and high sprout density levels respectively.

Note - ANOVA indicated significant differences at P = 0.05 due to stump height and sprout density.

minimum for those sprouts which had arisen from the stumps having > 45 cm diameter (Fig. 3.8). The leaf area increased significantly ($P < 0.05$) with the increase in stump height (Fig 3.9). The leaf area was maximum for A. nepalensis and minimum for Q. griffithii (Fig. 3.8 & 3.9).

The number of leaves borne on sprouts followed the same trend as the leaf area. The values were significantly greater ($P < 0.05$) for the sprouts emerged from the stumps of medium diameters in all the four species (Table 3.7). Total number of leaves per sprout and increase in leaf number were correlated with the stump height (Table 3.8).

Growth of the sprouts was also influenced by sprout density and burning. Growth rate, increase in length and total length of sprouts, total number of leaves and leaf area per sprout and increase in leaf number and leaf area were significantly greater ($P < 0.05$) at the low sprout density than at high density. The values for various growth parameters were greater in the burnt than in the unburnt plot for A. nepalensia, S. khasiana and Q. griffithii. Quercus dealbata was, however, not much affected by burning (Fig. 3.6 - 3.9, Table 3.5 - 3.8).

DISCUSSION

Reduction in growth of the sprouts with increase in stump diameter may be attributed to the change in physiology of trees with age. Decline in sprout growth with the increase in stump diameter/age has also been observed by Solomon & Blum (1967) and Hobbs & Mooney (1985). Roth & Hepting (1943) and Black & Raitanen (1981) argued that tree age is an important factor governing the sprout growth. The vegetative reproduction

Fig. 3. 8. Increase in leaf area per sprout over a 2-year period and mean total leaf area per sprout attained by the four tree species as related to diameter and sprout density in burnt and unburnt plots. □ , low sprout density; ▨ , high sprout density; ■ increase in leaf area. ANOVA indicated significant differences at $p = 0.05$ due to stump diameter and sprout density.

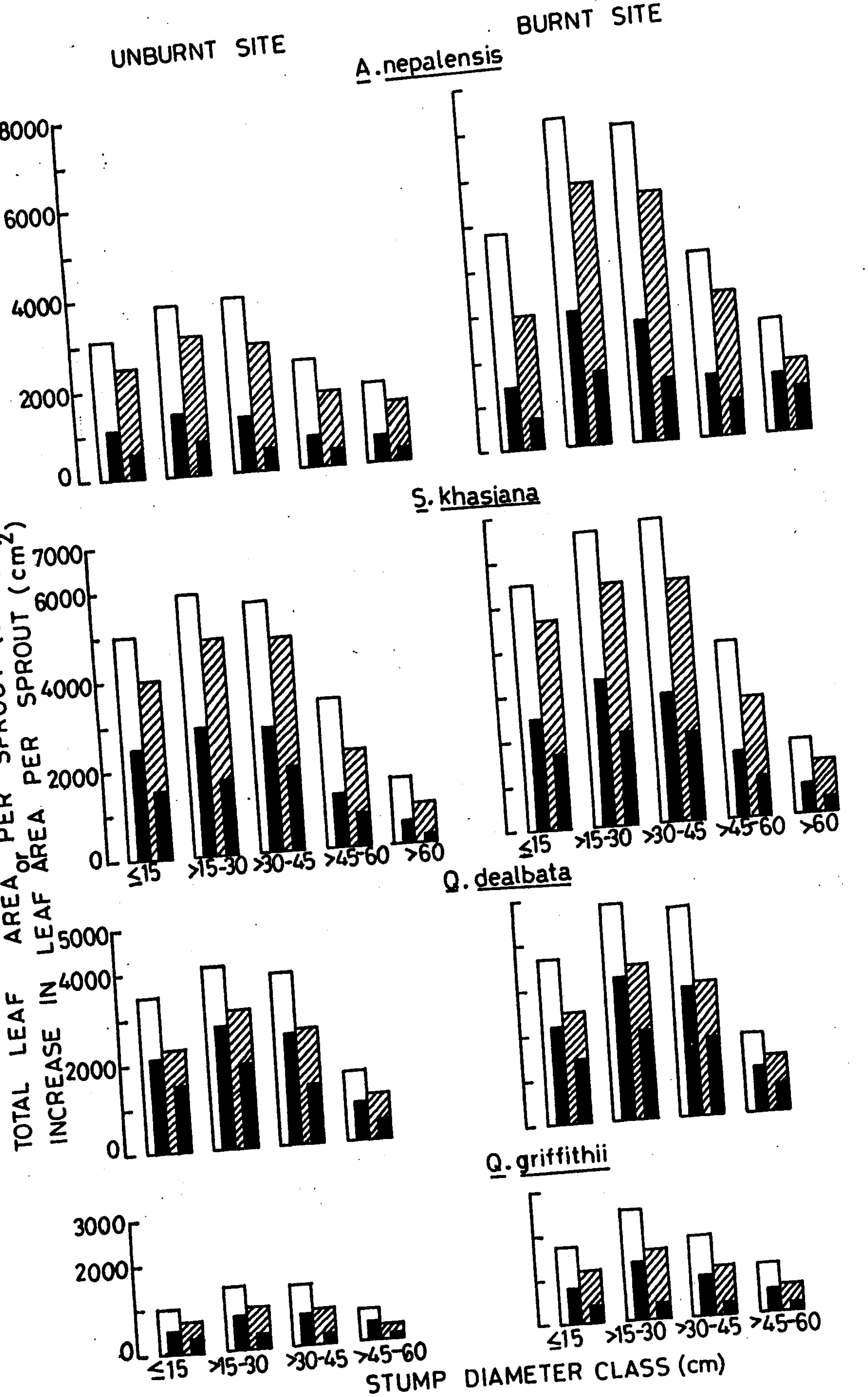

UNBURNT SITE
BURNT SITE
A. nepalensis
S. khasiana
Q. dealbata
Q. griffithii
TOTAL LEAF AREA PER SPROUT (cm²)
or
INCREASE IN LEAF AREA PER SPROUT (cm²)
8000
6000
4000
2000
0
7000
6000
4000
2000
0
5000
4000
2000
0
3000
2000
0
≤15
>15-30
>30-45
>45-60
>60
STUMP DIAMETER CLASS (cm)

Fig. 3·8

Fig. 3. 9. Increase in leaf area per sprout over a 2-year period and mean total leaf area per sprout attained by the four tree species as related to stump height and sprout density; Symbols as in Fig. 3.8, ANOVA indicated significant differences at $p = 0.05$ due to stump height and sprout density.

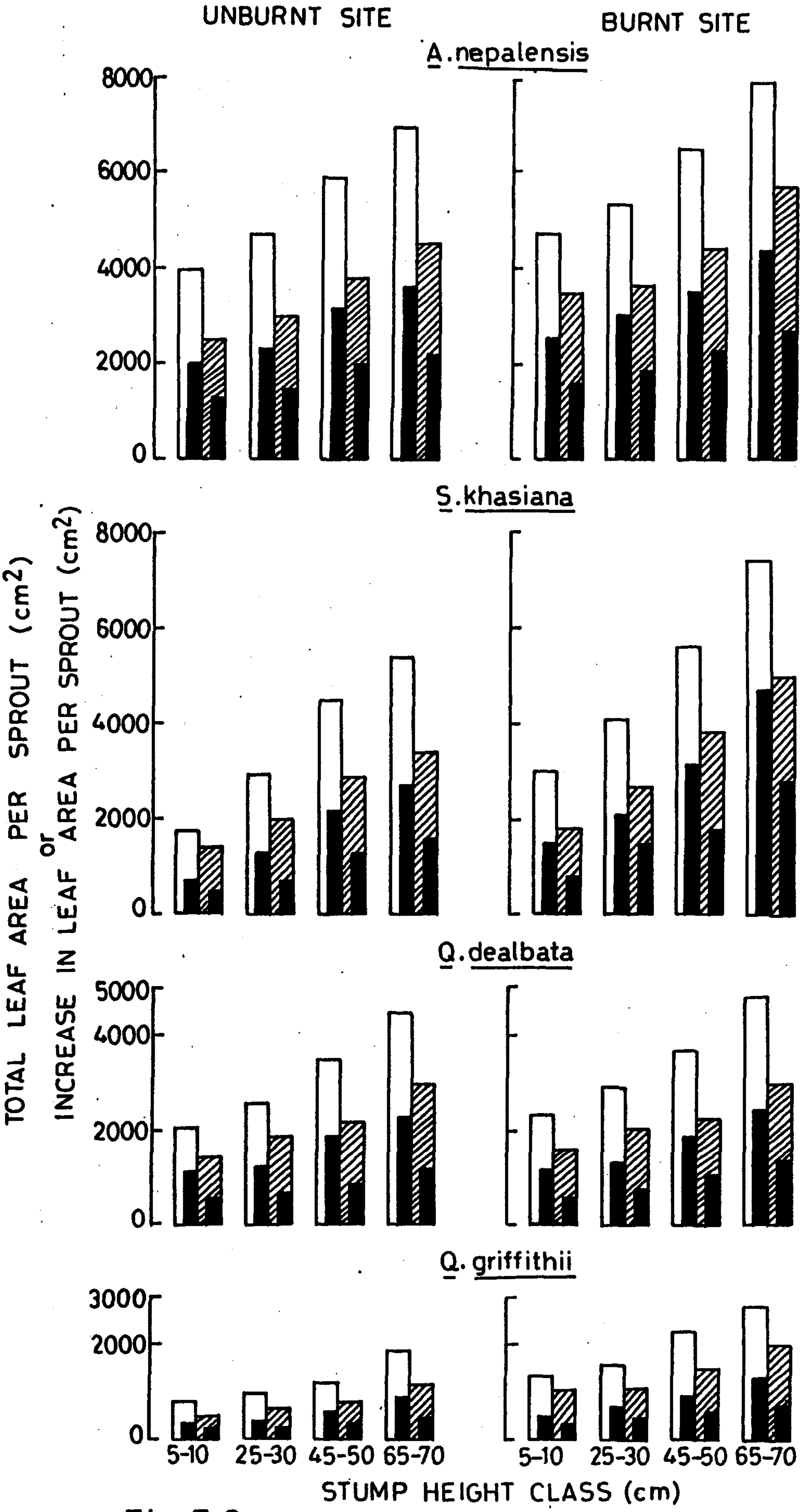

UNBURNT SITE
BURNT SITE
A.nepalensis
S.khasiana
Q.dealbata
Q. griffithii
TOTAL LEAF AREA PER SPROUT (cm²)
or
INCREASE IN LEAF AREA PER SPROUT (cm²)
8000
6000
4000
2000
0
5000
3000
5-10
25-30
45-50
65-70
STUMP HEIGHT CLASS (cm)

Fig. 3·9

Table 3.7. Increase in leaf number per sprout during September, 1983 to August, 1985 and total leaf number per sprout in August, 1985 of four tree species in relation to stump diameter and burning.

Species	Increase in leaf number				Total leaf number			
	Unburnt plot		Burnt plot		Unburnt plot		Burnt plot	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2
<u>A. nepalensis</u>								
D_1	20	12	25	16	72	60	93	75
D_2	27	16	55	30	89	76	139	110
D_3	28	14	48	27	90	73	132	104
D_4	15	6	25	12	59	51	79	67
D_5	14	8	15	12	49	40	60	46
<u>S. khasiana</u>								
D_1	51	35	61	46	136	108	156	124
D_2	62	43	69	47	160	143	102	150
D_3	90	45	96	43	161	140	179	147
D_4	24	18	35	19	97	83	117	97
D_5	13	2	21	9	66	43	70	51
<u>Q. dealbata</u>								
D_1	52	40	49	40	105	92	107	98
D_2	64	46	79	49	125	106	145	116
D_3	63	45	75	45	126	100	143	115
D_4	24	15	28	20	53	48	63	51
<u>Q. griffithii</u>								
D_1	16	8	7	3	28	20	36	22
D_2	21	9	28	5	40	27	45	30
D_3	20	6	24	4	39	25	36	28
D_4	13	6	17	10	24	18	27	19

D_1, D_2, D_3, D_4, D_5 represent the stump diameter classes. D_1 - 15 cm, D_2 - 15-30 cm, D_3 - 30-45 cm, D_4 - 45-60 cm, D_5 - 60 cm.

d_1, d_2- Low and high sprout density levels respectively.

Note - ANOVA indicated significant differences at $P = 0.05$ due to stump diameter and sprout density.

Table 3.8. Increase in leaf number per sprout during September, 1983 to August, 1985 and total leaf number per sprout in August, 1985 of four tree species in relation to stump height and burning.

Species	Increase in leaf number				Total leaf number			
	Unburnt plot		Burnt plot		Unburnt plot		Burnt plot	
	d_1	d_2	d_1	d_2	d_1	d_2	d_1	d_2
A. nepalensis								
H_1	10	7	16	13	36	26	61	47
H_2	15	8	18	12	56	40	78	60
H_3	20	12	26	15	71	60	108	81
H_4	24	14	33	19	84	70	143	155
S. khasiana								
H_1	62	41	74	53	125	101	147	120
H_2	72	49	99	64	145	120	175	146
H_3	89	62	100	72	176	152	215	179
H_4	100	62	123	86	215	175	258	219
Q. dealbata								
H_1	41	27	42	26	80	65	79	68
H_2	54	34	56	37	100	77	102	83
H_3	63	42	65	48	112	86	116	87
H_4	70	51	70	53	136	115	140	120
Q. griffithii								
H_1	8	5	12	9	21	17	31	25
H_2	11	8	13	10	27	20	31	24
H_3	14	11	17	13	32	25	44	36
H_4	18	15	23	19	39	32	53	45

H_1, H_2, H_3, H_4 represent the stump height classes. H_1 - 5-10 cm, H_2 - 25-30 cm, H_3 - 45-50 cm, H_4 - 65-70 cm.

d_1, d_2- Low and high sprout density levels respectively.

Note - ANOVA indicated significant differences at P = 0.05 due to stump height and sprout density.

predominates in the juvenile phase (Hartmann & Kester 1975). The size of the stump and root system (as these reflect nutrient, water and hormonal supplies available to the developing sprout) might favour growth of sprouts during juvenile phase (MacDonald & Powell 1983). Poor growth of the sprout from the stumps thicker than 45 cm diameter may be ascribed to the change in hormonal balance as a consequence of change in tree physiology with age (Robbins 1957, Trippi 1963, Kozlowski 1971). The sprouts emerging from the stumps of smaller diameter also showed poor growth, which may be attributed to inadequate reserves or nutrient supply to support their growth (Mann 1984, Hobbs & Mooney 1985).

The sprout growth increased with the increase in stump height. Harrington (1984) also reported an increase in sprout length in red alder (Alnus rubra) with increase in stump height. Poor growth of the sprouts emerging from the stumps of low cut may be attributed to the inadequate food reserves to support their growth. Further, dense growth of the shrubs and sprouts emerging from the stumps of greater heights at the study site considerably reduced the incoming solar radiation at the lower strata, which might have also contributed to the poor growth of the sprouts arising from the low cut stumps.

Seasonal variation in growth rate of the sprouts may be ascribed to the changes in climatic conditions (Kozlowski 1971). Very poor growth of the sprouts in winter may be linked with the prevailing low temperature and soil moisture and the best growth in summer may be attributed to the favourable temperature and rainfall conditions in Meghalaya (Fig. 1.1). Kramer

& Kozlowski (1960) have discussed the effect of temperature on growth of trees.

Poor growth of the sprouts at high density may be due to severe competition for resources among the sprouts. Similar results have been obtained by Radosevich *et al.* (1976) in conifers and Harrington *et al.* (1984) in tan-oak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*).

Better growth of the sprouts in the burnt plot as observed in the present study conforms with the observations of Morris & Mowant (1958) and Wyant *et al.* (1983) in ponderosa pine (*Pinus ponderosa*). Surface fire may increase the availability of resources such as soil moisture, nutrient and light to the surviving sprouts by reducing the severity of resource competition as most of the shrubs and ground vegetation are consumed by fire (Barrett & Youngbearg 1965, Hadley 1969, Wyant *et al.* 1983). Surface fire also produces an immediate flush of readily available nutrients (Wells *et al.* 1979), and increase in the sprout growth in the burnt plot could be linked to quick release of nutrients caused by fire. Incidentally, Mroz *et al.* (1985) reported an increase in growth of northern hardwood stump sprouts with the addition of fertilizer. Thus, as could be expected, burning favoured the growth of the surviving sprouts. Harrington & Kelsey (1979) also reported exceptional growth of ponderosa pine seedlings on the burnt plots. Further, increased soil and air temperatures on the burnt plot compared to the adjacent unburnt plot (unpublished data) might have also promoted the sprout growth as argued by Emminghan & Waring (1977).

The study indicates that regeneration of *Alnus nepalensis*, *Quercus* dealbata, Q. griffithii and Schima khasiana by the sprouts could be maximised if (i) cutting is restricted to the trees having medium diameter, (ii) the tree stumps of taller height are left in forest, (iii) density of sprouts on the tree stumps is low and (iv) the forest in question is exposed to burning with low intensity of fire.

CHAPTER IV

Effect of seed size on germination and survival and growth of seedlings of *Quercus dealbata* and *Q. griffithii* in different micro-environment.

INTRODUCTION

Seed size as indicated by weight or volume is considered as one of the factors determining germination response and seedling vigour in many weeds and crops (Abdullahi & Vanderlip 1972, Cooper et al. 1979, Payne & Koszykowski 1979, Rai & Tripathi 1982, Zimmerman & Weis 1983, Stanton 1984, Venable & Levin 1985, Winn 1985, Keddy & Constabel 1986, Wulff 1986a, b). The effect of seed size on germination and seedling growth has also been studied in a few major coniferous species (Belcher & Gresham 1974, Ghosh et al. 1976, Sluder 1979, Dunlop & Barnett 1983). Among the tree species selected for study, Quercus dealbata and Q. griffithii show remarkable seed polymorphism and it was thought worthwhile to study whether the seed size has any bearing on germination, and seedling survival and growth of the two species of Quercus. Several workers (Grime 1979, Alexander 1974, Eis 1981, Maguire & Forman 1983, Burton & Mueller-Dombois 1984) have reported that the forest floor characteristics also influence the seed germination, seedling survival and growth of many tree species. Therefore, the effect of seed size and litter accumulation on the forest floor and associated vegetation was studied on seed germination, seedling survival and growth of Quercus dealbata and Q. griffithii.

MATERIALS AND METHODS

Mature acorns of Quercus griffithii and Q. dealbata were collected in October, 1983 and March, 1984 respectively from the forest at Upper Shillong. The seeds were categorised as light (W_1), medium (W_2) and heavy-weight (W_3) on the basis of their weight (Table 4.1). Weight of seeds was determined by weighing 20 samples of 10 seeds of each group. Seeds were separately stored in sealed plastic bags at room temperature (min. 10^{o} and max. $22^{o}C$). Seeds of each of the three groups were separately soaked in distilled water at room temperature ($22 \pm 2^{o}C$) on 2nd April, 1984. The soaked seeds were placed on moist blotting paper underlain with cotton in plastic trays (30 X 25 cm area). Each tray containing 20 seeds served as a replicate and each treatment had five such replicates. The germination of the three categories of seeds was studied over 45-day period at room temperature. Germination was recorded every day and the seeds were considered as germinated when radicle protruded about 1 mm beyond the seed coat.

Table 4.1. Seed weight (mg/seed) classes of Quercus dealbata and Q. griffithii and their proportion (in parentheses) in seed sample.

	Seed weight classes		
	W_1	W_2	W_3
Q. dealbata	283-317 (20.3%)	622-680 (40.7%)	1185-1283 (39.0%)
Q. griffithii	245-295 (12.2%)	547-603 (58.3%)	1012-1080 (29.5%)

The seeds of the three categories were sown on 3rd April, 1984 in four different types of plots (T_1 to T_4 as mentioned below) of 1 m^2 size each in the forest at Upper Shillong.

T_1 - Control plots where the ground vegetation was allowed to grow and litter was not removed.

T_2 - The litter was removed but ground vegetation was allowed to grow.

T_3 - Ground vegetation was cleared, but litter was not removed.

T_4 - Both litter and ground vegetation were removed.

Five 1 m^2 plots were maintained for each of the four above mentioned treatments and 50 seeds of each of the three weight classes were separately sown in each plot. Germination was recorded weekly for a period of two months. Seedling survival was monitored at two-month intervals over a period of one year. Leaf area and biomass of seedlings were measured at the end of study period. For this purpose, 10 seedlings were excavated from each plot and the leaf area was measured by using graph paper. Biomass was estimated by drying the seedlings in an oven at 60°C to constant weight.

RESULTS

Seed germination of both species was greatly influenced by seed weight. Heavy seeds (W_3) germinated earlier and showed maximum germination in both the species. Seed germination was better in Q. griffithii than in Q. dealbata (Table 4.2 & 4.3).

Table 4.2. Germination behaviour of seeds of *Quercus dealbata* and *Q. griffithii* as related to seed weight.

Species	Seed weight class	Days for germination to start (± S.E.)	Days for 50% germination (± S.E.)	Total germination (%) over a 45-day period (± S.E.)
Q. dealbata	W_1	19±1.3	26±2.0	22±4.3
	W_2	17±1.6	22±1.7	38±1.2
	W_3	16±1.8	20±1.4	41±3.6
Q. griffithii	W_1	17±1.0	20±1.3	51±8.3
	W_2	14±0.7	18±2.2	69±6.7
	W_3	12±1.6	15±1.5	84±5.6

Germination of the seeds was also affected by the forest floor conditions. Germination was maximum under the treatment T_4 and minimum in T_1.

Table 4.3. Total germination (% ± S.E.) of seeds of different weight classes of Quercus dealbata and Q. griffithii over two months under four different treatments in nature.

Species	Seed weight class	Treatments T_1	T_2	T_3	T_4
Q. dealbata	W_1	8.3 (±0.5)	12.7 (±1.3)	14.3 (±1.2)	17.5 (±1.7)
	W_2	15.5 (±1.2)	19.3 (±1.7)	20.6 (±1.6)	24.6 (±1.9)
	W_3	23.1 (±2.2)	30.6 (±2.6)	32.4 (±2.7)	35.2 (±3.0)
Q. griffithii	W_1	23.8 (±1.7)	30.3 (±2.9)	27.3 (±2.7)	40.2 (±3.6)
	W_2	31.7 (±3.1)	43.6 (±4.0)	41.9 (±3.9)	52.1 (±4.7)
	W_3	51.5 (±5.2)	58.6 (±4.9)	54.6 (±5.2)	68.6 (±6.3)

Survival of seedlings emerged from heavy seeds (W_3) was better as compared to those resulting from the lighter seeds in both species. Further, the survival of seedlings was maximum in T_4 and minimum in T_1. More seedlings of Q. griffithii survived than those of Q. dealbata (Fig. 4.1). Seedlings emerged from the heavy seeds (W_3) and grown in the plots devoid of litter and ground vegetation produced maximum leaf area and biomass, whereas the seedlings resulting from the light seeds(W_1) and grown in

Fig. 4. 1. Survival of the seedlings emerged from the three categories of seeds of _Q. griffithii_ and _Q. dealbata_ in the field plots under four different treatments. T_1, control; T_2, litter removed but ground vegetation allowed to grow; T_3, Litter present but ground vegetation removed; T_4, both litter and ground vegetation removed. O, light seeds; ●, medium-weight seeds; △, heavy seeds.

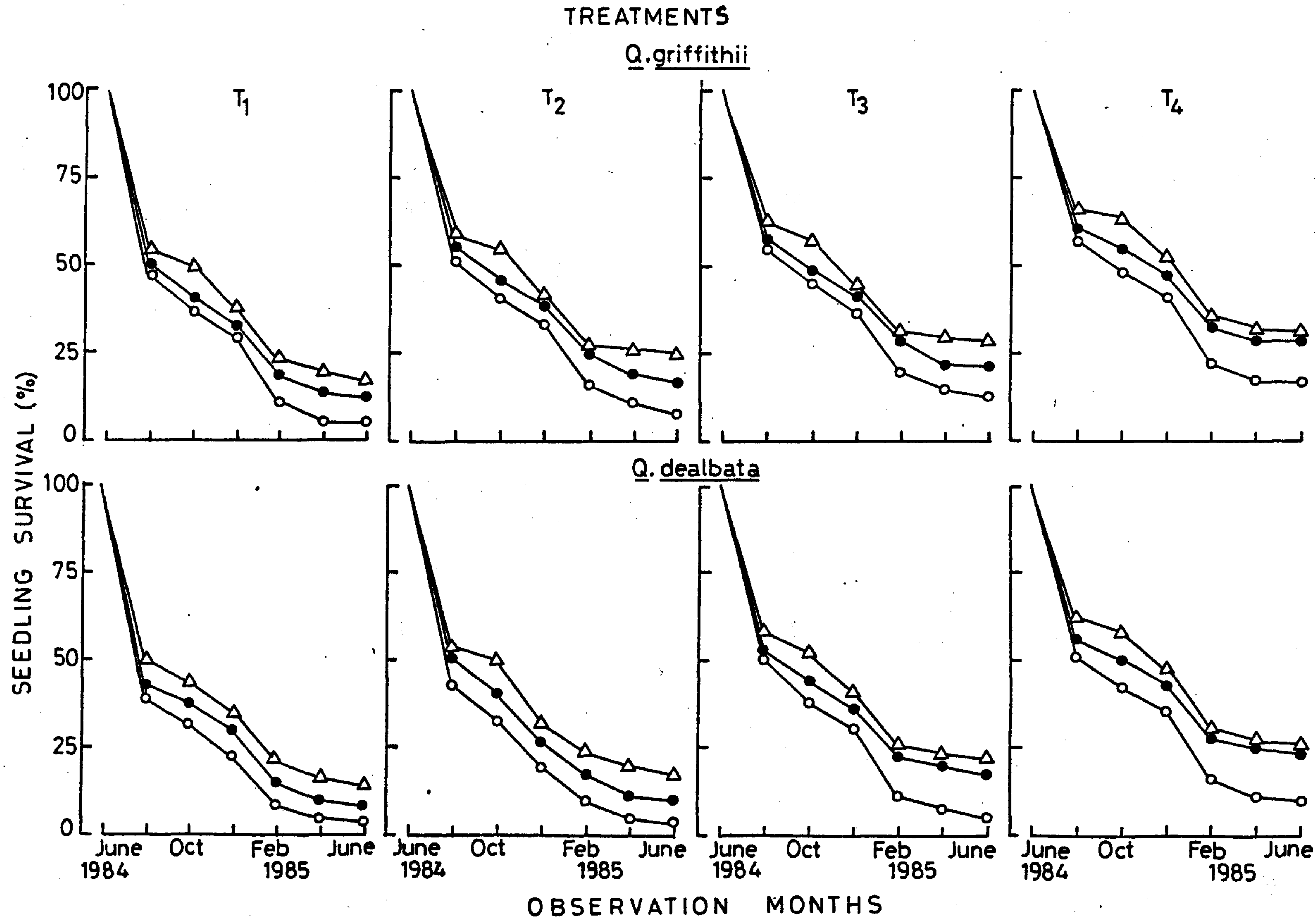

TREATMENTS
Q. griffithii
Q. dealbata
T1
T2
T3
T4
SEEDLING SURVIVAL (%)
100
75
50
25
0
June 1984
Oct
Feb 1985
June
OBSERVATION MONTHS

Fig. 4·1

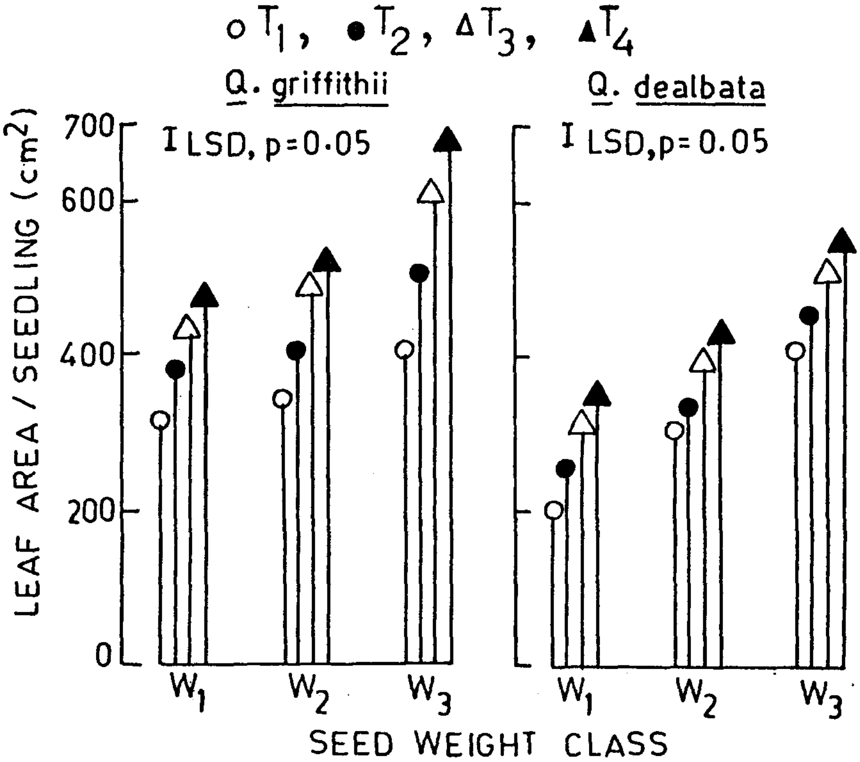
the control plots showed minimum values (Fig. 4.2 & 4.3).

DISCUSSION

Maximum and early germination of heavy seeds in both species of Quercus observed in the present study is in agreement with the observations of Dunlop & Barnett (1983), Griffin (1972) and Ghosh et al. (1976) in other tree species. This may be attributed to the larger food reserve in heavy seeds (Black 1956, Harper & Obeid 1967, Stanton 1984). Comparatively better survival and greater leaf area and biomass of the seedlings emerged from heavy seeds as observed in the present investigation are in agreement with Harper & Clatworthy (1963), Pollock & Roos (1972), Schaal (1980), Howe & Richter (1982) and Howe et al. (1985). As argued by Black (1956), Harper & Obeid (1967) and Stanton (1984), larger food reserve in the seeds may allow more pre-photosynthetic growth of seedlings and this in turn could contribute to better growth and survival of seedlings emerged from heavy seeds.

Poor survival and growth of seedlings of Q. dealbata and Q. griffithii grown under the treatments T_1, T_2 and T_3 may be attributed to the adverse effect of litter and ground vegetation. Forest litter may influence the seedling survival and growth through the production of allelochemics and by offering barrier to the seedling roots in establishing contact with soil (Del Moral & Cates 1971, Blaschke 1979, Grime 1979, Willis 1980). The poor moisture retention of litter compared to mineral soil as reported by Smith (1955), Prochau (1963), Day (1964) and Alexander (1974) may also adversely influence the survival and growth of seedlings. Resource competition

Fig. 4. 2. Leaf area per seedling resulting from the three categories of seeds of Q. griffithii and Q. dealbata as influenced by four different treatments. The treatments are same as given in the legend of Fig. 4. 1.



o T1, • T2, Δ T3, ▲ T4
Q. griffithii
Q. dealbata
I LSD, p=0.05
I LSD,p= 0.05
LEAF AREA / SEEDLING (cm2)
700
600
400
200
0
W1
W2
W3
W1
W2
W3
SEED WEIGHT CLASS

Fig. 4·2

Fig. 4. 3. Per seedling biomass of Q. griffithii and Q. dealbata as affected by seed weight and treatments. The treatments (T_1 - T_4) are same as given in Fig. 4. 1.

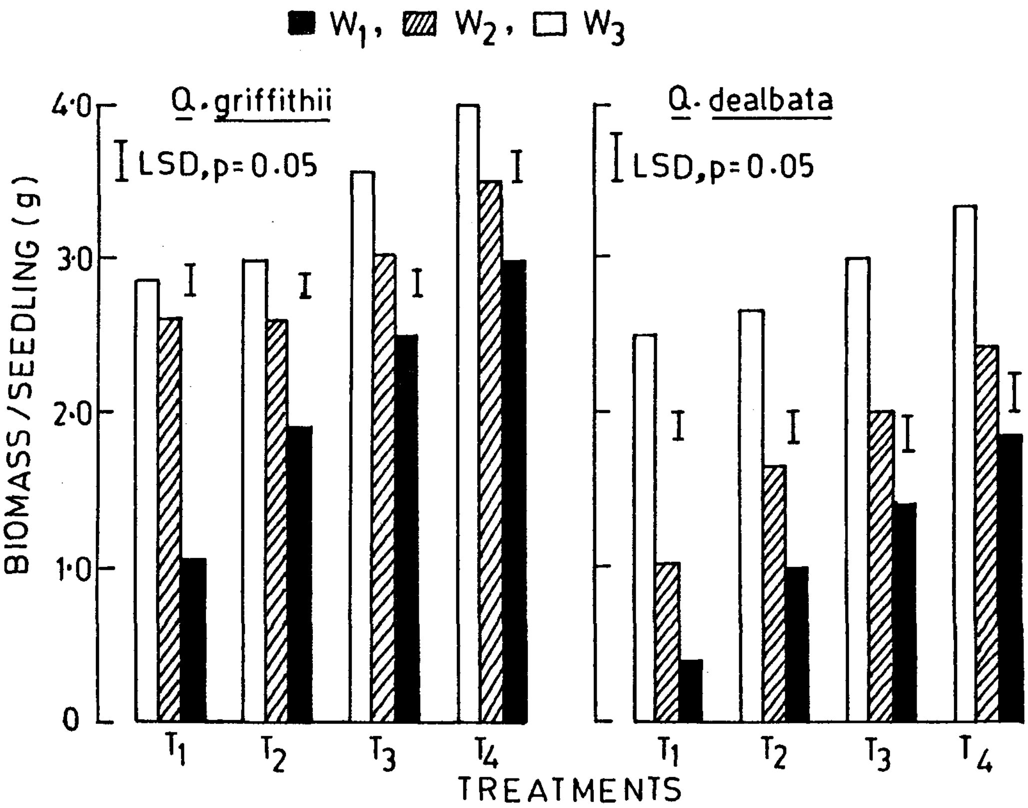

W1, W2, W3
Q. griffithii
Q. dealbata
LSD, p=0.05
LSD, p=0.05
BIOMASS / SEEDLING (g)
4·0
3·0
2·0
1·0
0
T1
T2
T3
T4
T1
T2
T3
T4
TREATMENTS

Fig. 4·3

and allelopathic effects of the associated plant species might also cause reduction in growth and survival of seedlings under the treatments T_1 and T_2 (Stewart 1975, Horsely 1977a, b). Significance of ground vegetation in determining the survival and growth of seedling populations of trees has also been emphasized by Eis (1981), Cross (1981), Maguire & Forman (1983), Burton & Mueller-Dombois (1984) and Connell et al. (1984).

The result indicates that seedlings resulting from the heavy seeds exhibit better survival and growth than those emerging from the light seeds indicating that in the forest community the plants produced from heavy seeds are likely to be more successful than those produced from the light seeds. Similar adaptive significance of seed polymorphism has been emphasized by several workers (Stebbins 1971, Maurya & Ambasht 1973, Flint & Palmblad 1978, Rai & Tripathi 1982) in many other plant species.

CHAPTER V

Effect of soil texture, moisture and light on emergence, survival and growth of seedlings of *Alnus nepalensis*, *Quercus griffithii* and *Schima khasiana*.

INTRODUCTION

Moisture content, nutrient relations and soil texture of the seed-bed and ability of rootlets of seedlings to penetrate the soil and exploit the available resources are among the important factors that influence the regeneration of trees. Smith (1962) considers that the most crucial features of seedbed which influence regeneration are the amount of overhead shade, competing vegetation and physical characteristics of seedbeds. Some studies pertaining to establishment and growth behaviour of trees as related to soil type have been done by Singh & Muhammad (1976), Eis *et al*. (1982) and McBride & Strahan (1984). Since intensive studies on the effect of soil moisture, soil texture and light conditions on emergence, survival and growth of tree seedlings are lacking, the present study was carried out to examine the role of these ecological factors on seedling emergence and growth of three common tree species of Meghalaya viz., *Alnus nepalensis*, *Quercus griffithii* and *Schima khasiana*.

MATERIALS AND METHOD

Mature seeds of *Alnus nepalensis*, *Quercus griffithii* and *Schima khasiana* were collected from the forest at Upper Shillong. The viability of seeds as tested by tetrazolium solution (Misra 1968) was 89% in *A. nepalensis*, 69% in *Q. griffithii* and 81% in *S. khasiana*. Seeds were sown in plastic pots (21 cm diameter and 19 cm depth and provided with a drainage hole in the bottom) filled with two types of soil, clay loam and sandy loam. Physical and chemical properties of both the soil types are given in Table 5.1. Nitrogen was estimated by micro-Kjeldahl method (Jackson 1962) and organic matter by rapid titration method (Walkley & Black 1934).

Table 5.1. Relative proportion of sand, silt and clay, nitrogen and organic matter content and pH of the two soil types (± S.E.).

Soil type	Sand (%)	Silt (%)	Clay (%)	Nitrogen (%)	Organic matter (%)	pH
Clay loam	46	20	34	0.25±0.01	3.70±0.2	6.1±0.2
Sandy loam	72	10	18	0.33±0.01	3.40±0.1	5.5±0.2

Thirty seeds of each of the three species were sown in separate pots (total number of pots 396) on 13th and 14th April, 1984 and soil was moistened by supplying each pot with 250 ml of tap water. Subsequently i.e. from 15th April onwards, two moisture regimes (high and low) were maintained. The high moisture regime was achieved by watering the pots on alternate days and low moisture regime by watering them at 10-day intervals. The pots were kept in two unheated net houses provided with polythene sheet roofing. In order to protect the pots in the net house from splashing water during rainy season four sides of the net houses were covered with polythene sheet upto a height of 70 cm. The three light regimes were created by differentially covering the net house with muslin cloth. One of the two net houses was partitioned in two equal halves of which one was covered on top with a double layered black muslin cloth and the other half with a single layered white muslin cloth to reduce the light intensity to about

20,500 Lx and 35,750 Lx respectively. The other net house was not covered with muslin cloth and had only the polythene roofing and the light intensity in this net house was about 51,000 Lx on a sunny day. The first and second halves of the first net house respectively received about 40% and 70% of the light intensity that was available in the second net house. These three light regimes are referred to as L_1, L_2 and L_3 respectively in the subsequent pages. The experimental design consisted of 3 species X 3 light regimes X 2 soil texture X 2 moisture regimes X 3 harvests. Three replicates were maintained for the first two harvests and five replicates for the third harvest. Seedling emergence, survival and growth were studied in relation to the various treatments mentioned above.

Seedling emergence in each pot was observed weekly until 14th June, 1984 i.e. for two months from the date of sowing, after which germination practically ceased. On 15th June, 1984 the seedling population was thinned to five in each pot and fate of the seedlings was followed at 2-month intervals over a period of one year.

Seedlings harvested 4, 8 & 12 months after thinning, were washed thoroughly to remove the soil particles adhering to the roots and leaf area and biomass were determined. Biomass was estimated by drying the seedlings in an oven at 60°C to constant weight.

RESULTS

Seedling emergence of A. nepalensis, Q. griffithii and S. khasiana was significantly affected by light and moisture regimes and soil texture ($P < 0.05$). Emergence was positively correlated with light intensity on both soil types and moisture regimes (Fig. 5.1). A. nepalensis and S. khasiana showed better germination in sandy loam soil, whereas germination in Q. griffithii was not affected by soil texture. The three species showed enhanced seedling emergence in the pots watered on alternate day (Fig. 5.1).

At both water regimes on the two soil types seedling mortality of the three species decreased with increase in light intensity from 20,500 Lx (L_1) to 51,000 Lx (L_3). A. nepalensis and S. khasiana showed greater seedling mortality in clay loam soil, while in Q. griffithii more seedling died in sandy loam soil. Seedling mortality was greater under low than under high moisture regime (Table 5.2). Mortality rate (%) of the three species plotted against time showed a bi-modal curve with two maxima, a major one in February and another less conspicuous one in August (Fig. 5.2).

Growth of seedlings of the three species are greatly influenced by light conditions. Maximum growth was observed under L_3 and minimum under L_1. Seedlings of A. nepalensis and S. khasiana produced greater leaf area and biomass in sandy loam than in clay loam soil (Fig. 5.3. & 5.4). Leaf area and biomass production was favoured by high moisture regime.

DISCUSSION

Results indicate that emergence, growth and survival of seedlings of the three species were favoured by increased light intensity. McLemore (1971), Garwood (1979) and Campbell (1982) also found more seedling emergence in lighted condition than in shade. Koller (1972) suggested that solar radiation striking on the surface could increase the soil temperature whereby the emergence and establishment of the seedlings in lighted condition

Fig. 5. 1. Seedling emergence of *A. nepalensis*, *S. khasiana* and *Q. griffithii* as influenced by light and moisture regimes on the two soil types. L_1, L_2 and L_3 represent 40%, 70% and full sunlight respectively. The filled columns represent high moisture regime and open columns low moisture regime.

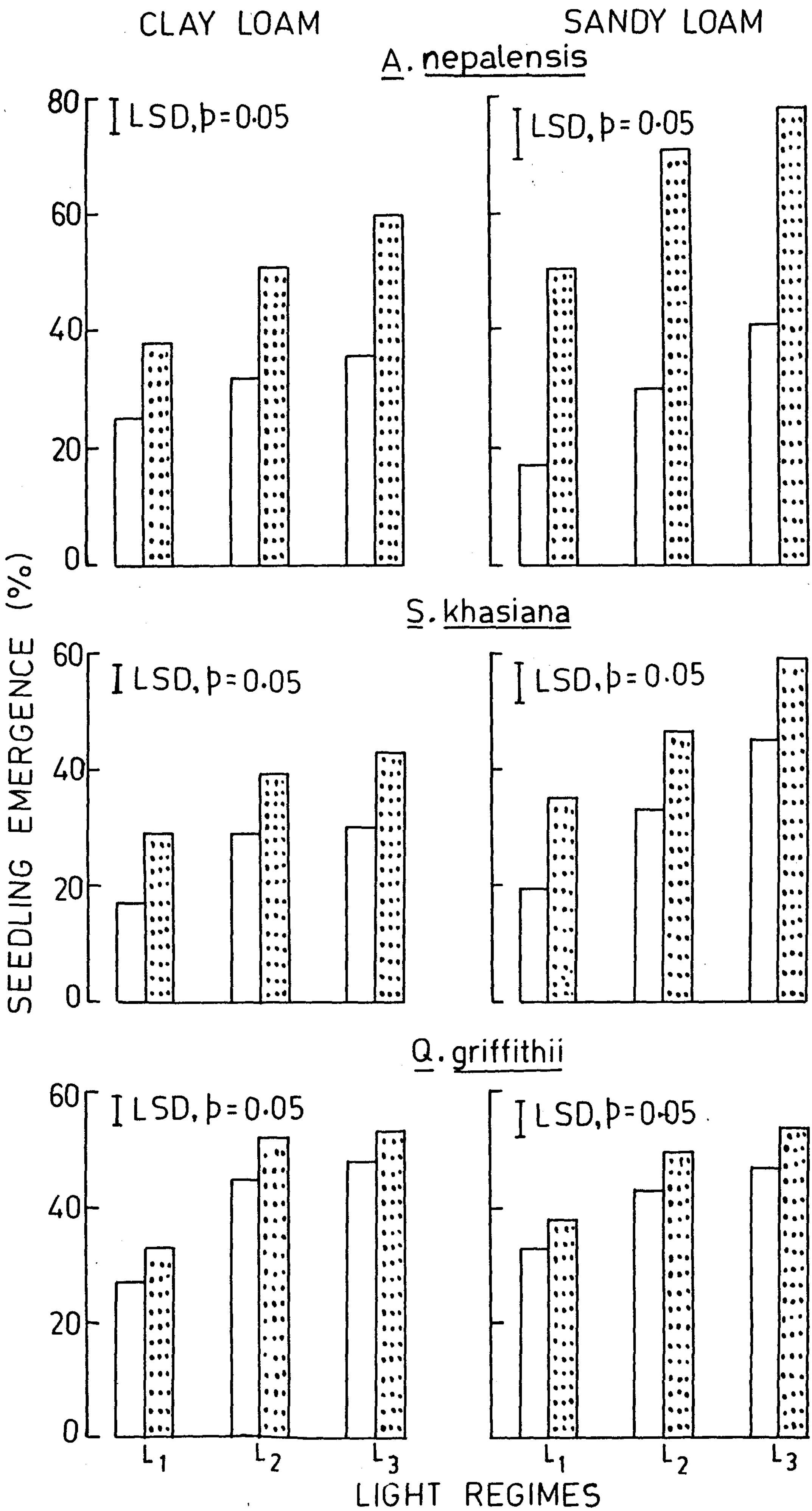

CLAY LOAM
SANDY LOAM
A. nepalensis
S. khasiana
Q. griffithii
LSD, p=0.05
SEEDLING EMERGENCE (%)
80
60
40
20
0
L1
L2
L3
LIGHT REGIMES

Fig. 5·1

Table 5.2. Seedling mortality (%) of Alnus nepalensis, Quercus griffithii and Schima khasiana as affected by soil texture and water and light regimes.

Tree species	Water regimes	Clay loam soil			Sandy loam soil		
		Light regimes			Light regimes		
		L_1	L_2	L_3	L_1	L_2	L_3
A. nepalensis							
	High	63	35	33	59	35	30
	Low	70	61	56	69	59	53
Q. griffithii							
	High	42	26	20	51	25	20
	Low	63	55	49	67	57	53
S. khasiana							
	High	66	47	35	61	42	25
	Low	77	67	57	70	65	50

Fig. 5. 2. Mortality rate of the seedlings under the three light regimes at two soil moisture levels and in two textures. L_1, L_2 and L_3 as explained in Fig. 5. 1. Continuous lines (------) represent high moisture regime and broken lines (- - - -) represent low moisture regimes; △ , A. nepalensis; ○ , S. khasiana; ● , Q. griffithii.

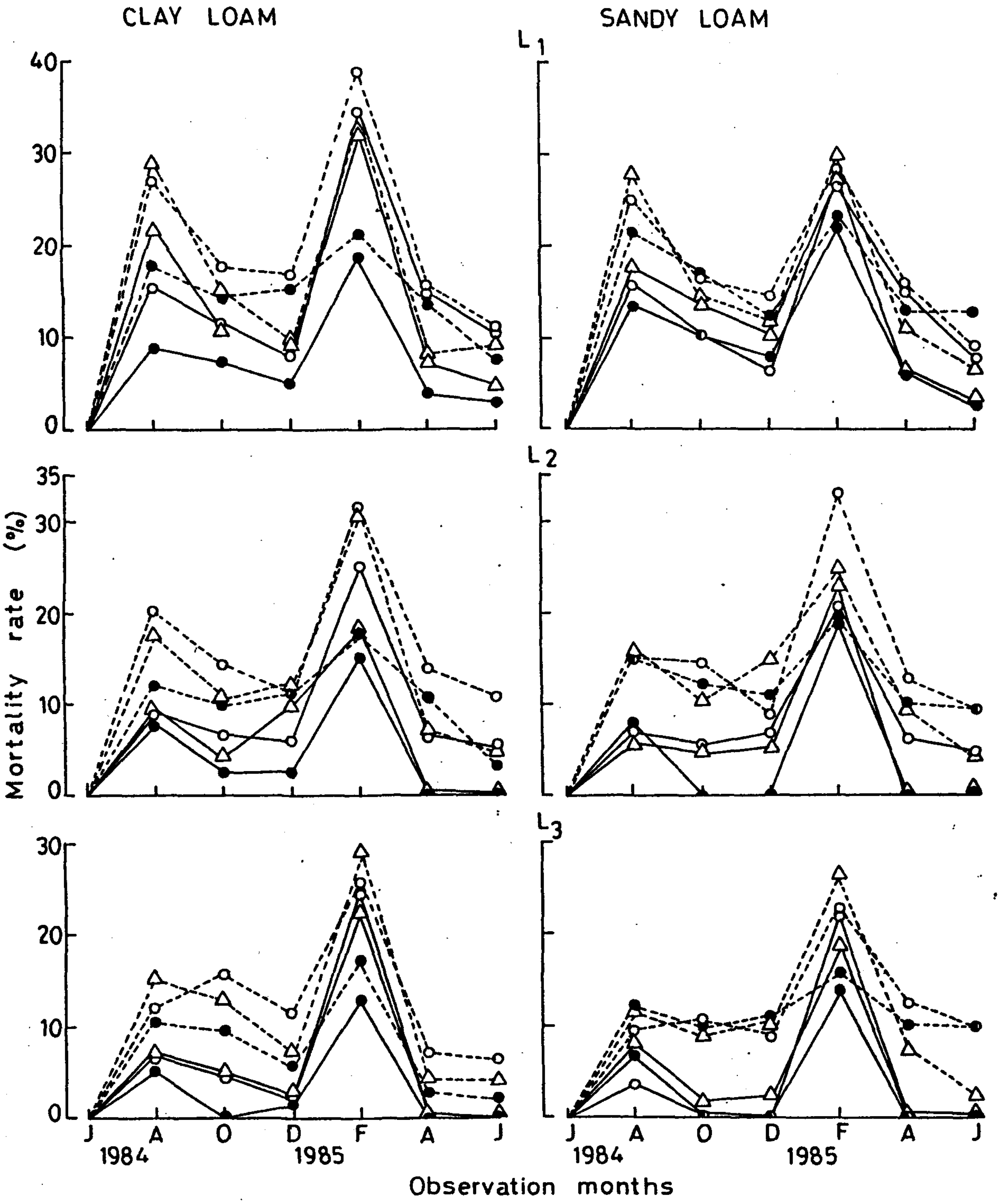

CLAY LOAM
SANDY LOAM
L1
L2
L3
Mortality rate (%)
J
A
O
D
F
A
J
1984
1985
Observation months
Fig.5·2

Fig. 5. 3. Leaf area per seedling of the three species as affected by light, moisture regime and soil texture. Explanation of the symbols is same as in Fig. 5. 2.

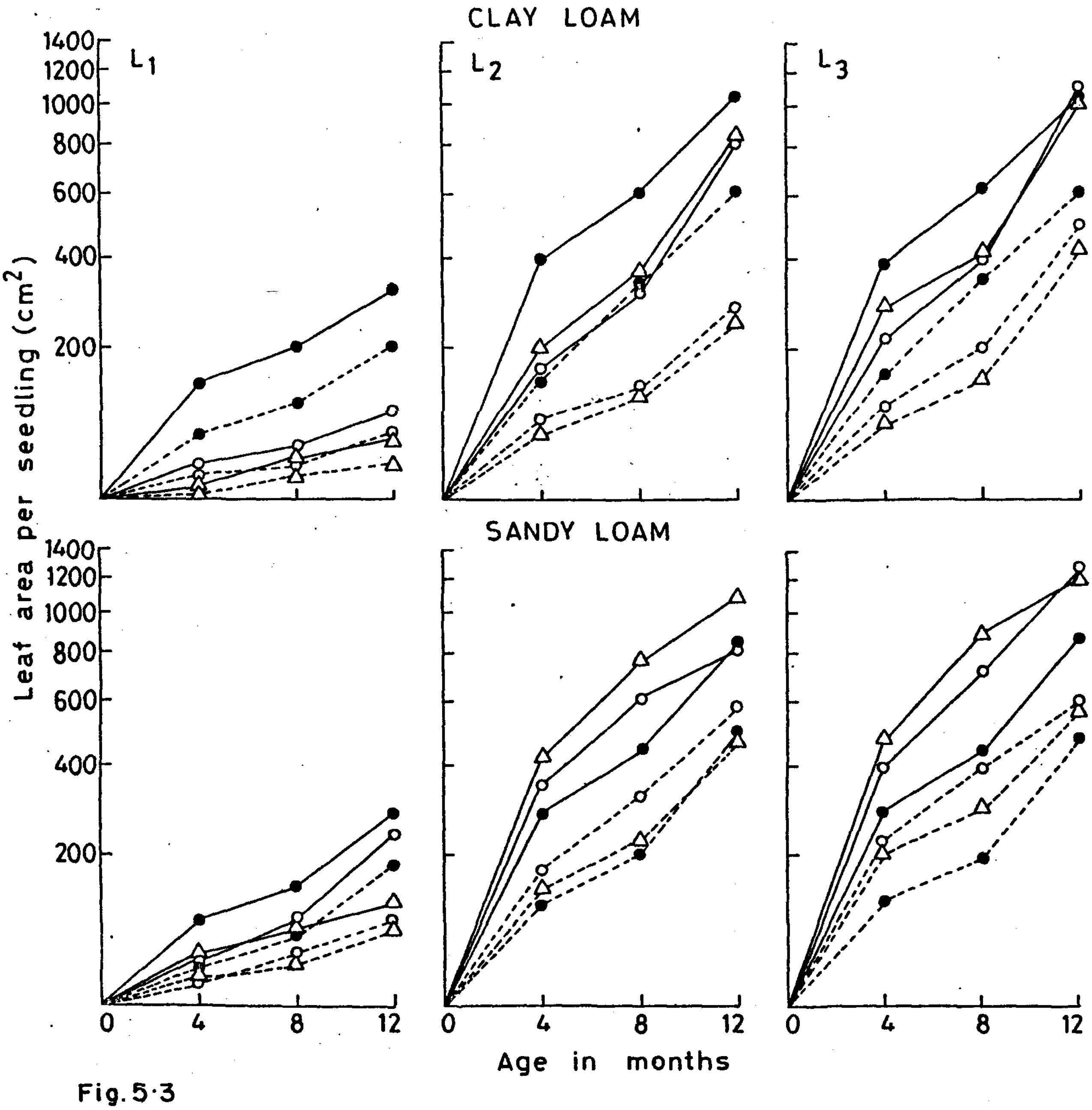
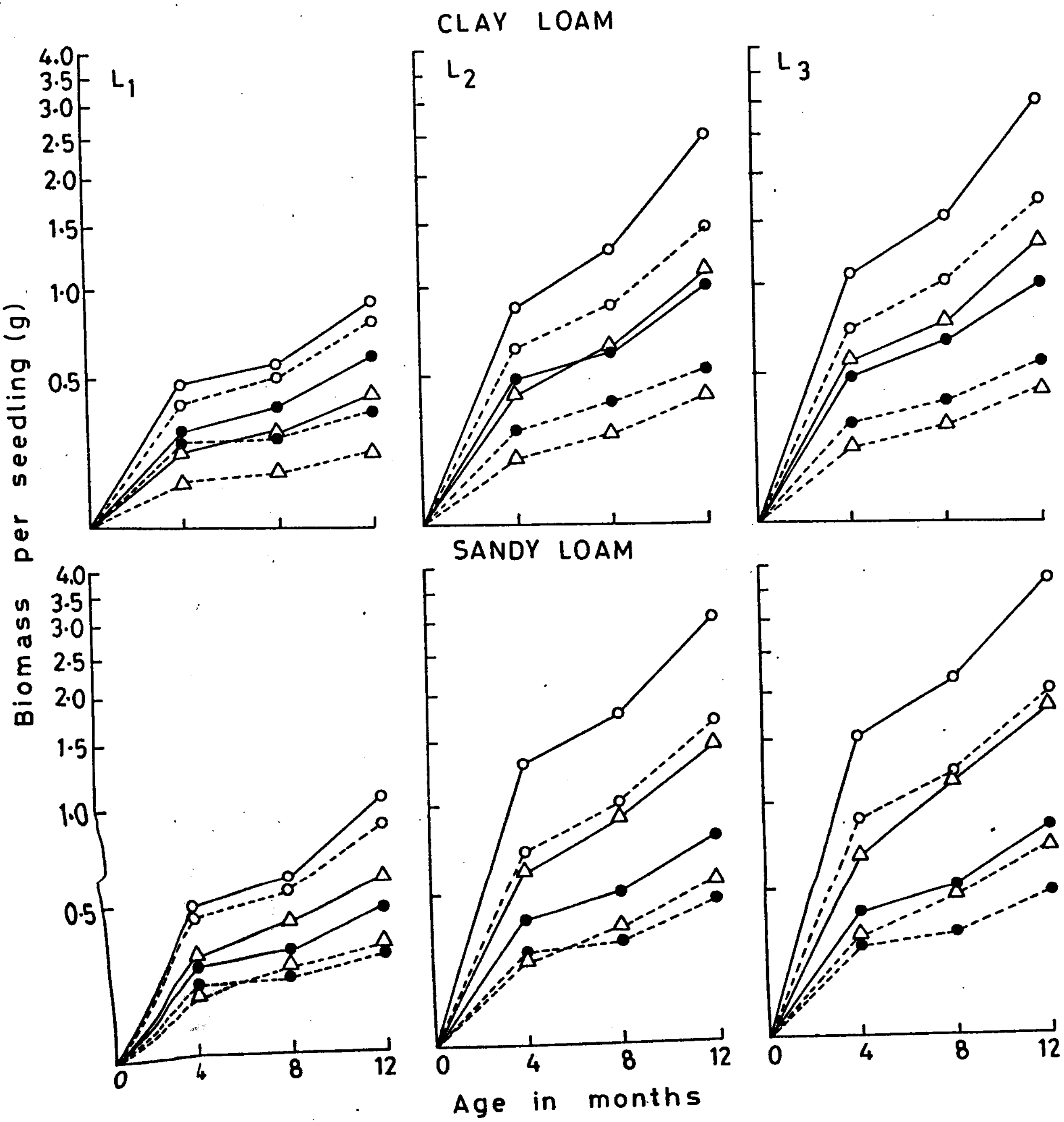

CLAY LOAM
SANDY LOAM
L1
L2
L3
Leaf area per seedling (cm²)
1400
1200
1000
800
600
400
200
0
4
8
12
Age in months

Fig. 5·3

Fig. 5. 4. Per seedling biomass of the three species as affected by light, moisture regime and soil texture. Explanation of the symbols is same as in Fig. 5. 2.



CLAY LOAM
SANDY LOAM
L1
L2
L3
Biomass per seedling (g)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
4
8
12
Age in months

Fig. 5·4

are favoured. Greater mortality of the seedlings in shaded condition particularly at L_1 observed in the present study may be attributed to the lack of threshold radiation for photosynthesis. Suppressed growth and decreased survival of the seedlings of the three species under the low light intensity are in agreement with the findings of Fetcher et al. (1983) who observed greater height, survival and biomass of the seedlings of two tropical trees in lighted condition than in shade. Ledig & Botkin (1974) reported that stem and root dry weight in European larch (Larix decidua) and Japanese larch (Larix leptolepis) increased five to six fold in late summer, which was attributed in part to relatively high photosynthetic rate due to greater availability of solar radiation. Recently, Augspurger (1984a, b, c) also reported better survival and growth of the seedlings of eighteen neotropical tree species in sun than in shade.

Relatively poor emergence, survival and growth of the tree seedlings at low moisture level signifies the role of soil moisture in their population growth. Poor seed germination in pine and other tree species at low soil moisture level has also been reported by other workers (Maull 1962, Satoo 1966, Larson & Schubert 1959). The observed poor growth and greater mortality of seedlings at low moisture level in the present study are in agreement with the observations of Noble & Alexander (1977), Schulte & Marshall (1983), Rao & Singh (1985) and Vance & Running (1985). Seedling growth could probably be restricted due to inhibition of cell enlargement as has been argued by Hsiao et al. (1976). Wellington & Noble (1985) found that mortality of seedlings of yellow mallee (Eucalyptus incrassata) was restricted to the dry summer months of the year. They also found that experimental increase in soil moisture over the period of a year caused a significant reduction in mortality of seedlings during the following summer.

The greater emergence, survival and growth of the seedlings of A. nepalensis and S. khasiana in sandy loam soil may be linked with better aeration and preponderance of large pores in coarse soil, which facilitate emergence and penetration of rootlets. Kozlowski (1971) suggested that the rootlets of seedlings can easily penetrate the sandy loam soil. McBride & Strahan (1984) have ascribed high seedling density of Salix spp. in sandy areas to greater emergence and survival of the seedlings on sandy soils.

The experimental results indicate that the interacting influence of light, soil texture and soil moisture could play a crucial role in regulating the size of the seedling population and subsequent growth of the tree species.

CHAPTER VI

Survival and growth of transplanted seedlings as affected by the associated vegetation at burnt and unburnt sites in dense and sparse forest stands.

INTRODUCTION

Regeneration of trees in a forest largely depends upon the response of naturally growing or transplanted seedlings to the prevailing microenvironment (Whitmore 1975, Gauch & Stone 1979). Survival and growth of tree seedlings are determined by the interactive influence of biotic and abiotic factors of the forest environment (Augspurger 1984a, b, c). The effects of certain factors such as light intensity (Whitmore 1975, Fetcher et al. 1983, Augspurger 1984a, b, c, Burton & Mueller-Dombois 1984, Vance & Running 1985), ground vegetation (Horsley 1977a, b, Maguire & Forman 1983), soil moisture (Mueller-Dombois et al. 1980, Lawrence & Oechel 1983), soil temperature (Wyant et al. 1983), soil nutrients (Jamaluddin 1978, Van Den Dricssche 1982), pathogen (Mueller-Dombois et al. 1983, Augspurger 1984a, b) and burning (Abott & Loneragan 1984, O'Dowd & Gill 1984) have been studied on seedlings that come up in natural or in controlled conditions, but there is conspicuous lack of studies on the response of transplanted seedlings to different microenvironmental conditions of the forest. Thus, an experiment was carried out to study the survival and growth of nursery grown seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana when transplanted under different ecological conditions prevailing in the forest.

MATERIALS AND METHODS

Study site :

The study was conducted in a disturbed forest at Upper Shillong. The details of the site are given in Chapter I of the thesis.

Methods :

Two forest stands, dense and sparse, were selected on the basis of forest canopy and incoming solar radiation. The light intensity on the ground surface in the sparse stand was 13,000-17,000 Lx, while in the dense forest stand it was 5,000 - 8,000 Lx. In each of the above two stands, the burnt (burning was done in March, 1984 by the local people) and unburnt sites located adjacent to each other were available and these were selected as the sub-plots to study whether the survival and growth of the transplanted seedlings differ due to burning treatment before transplantation. Nutrient level of the soil samples collected from the burnt and unburnt sites was also determined (Table 6.2). As the differences were negligible, data on nutrient level were pooled for dense and sparse stands. Sixty 1 m^2 plots were marked in each site under a given forest stand to give 20 sample plots for each of the three species viz., A. nepalensis, Q. griffithii and S. khasiana. Out of 20 plots earmarked for a given species, 10 plots were left as control and from the remaining 10 plots vegetation was regularly removed. Twenty five 2 month-old seedlings of each of the above three species were introduced in the plots on 29th June, 1984.

Table 6.1. List of herbaceous plant species in dense and sparse forest stands along with their density (± S.E.) in June, 1984 (data based on 10 quadrats of 1 m^2 each).

Species	Dense forest stand		Sparse forest stand	
	Burnt site	Unburnt site	Burnt site	Unburnt site
Arundinella khasiana Nees	7.4±0.6	6.9±0.7	8.6±0.6	11.3±1.3
Brunella vulgaris Linn.	6.2±0.9	8.3±0.8	13.4±1.3	14.6±2.1
Carex cruciata Nees	3.2±0.03	5.6±0.7	7.3±0.8	8.6±1.2
Centella asiatica Linn.	-	-	4.2±0.3	6.3±0.9
Cyanotis cristata Linn.	2.3±0.01	3.6±0.2	7.3±0.7	8.6±1.2
Cyperus rotundus Linn.	1.2±0.2	-	9.3±1.2	10.9±1.7
Dioscorea alata Linn.	-	-	-	2.6±0.03
Drymeria cordata Willd.	-	-	-	2.5±0.06
Eupatorium adenophorum Spreng.	3.4±0.06	7.6±1.1	5.7±0.8	8.6±1.2
E. riparium Regel	5.7±0.7	9.8±1.5	6.7±0.7	9.7±1.3
Geranium sp.	-	-	3.8±0.2	6.6±0.6
Gleichenia longissima Bl.	3.9±0.3	12.7±1.6	6.7±0.5	9.5±1.2
Hypochaeris radicata Linn.	-	-	4.5±0.6	5.3±0.7
Linum spp.	-	-	-	1.5±0.02
Myrioctes nepalensis	-	-	-	2.2±0.01
Osbeckia crinata Benth.	7.9±0.8	10.3±1.3	11.3±1.5	16.5±2.2
Panicum brevefolium Linn.	-	5.3±0.7	6.7±0.7	12.8±1.8
P. indicum Linn.	-	-	1.3±0.02	2.5±0.05
Pennisetum clandestinum Hochst.	-	-	-	3.7±0.6
Plantago major Linn.	-	-	3.5±0.2	7.3±0.8
Rubia cordifolia Linn.	-	-	1.2±0.01	3.2±0.02
Rubus spp.	-	-	3.6±0.07	6.7±0.6
Smithia sp.	-	3.2±0.3	1.5±0.02	3.3±0.2

\- indicates species absence.

Table 6.2. Nutrient level (± S.E.) at the burnt and unburnt sites in June, 1984 (data of the dense and sparse forest stands are pooled as the differences were negligible).

	Organic carbon (%)	Nitrogen (%)	Potassium Kg/ha	Phosphorus Kg/ha
Burnt site	2.72±0.31	0.28±0.03	128±9.32	6.7±0.83
Unburnt site	1.54±0.16	0.18±0.02	56±5.41	3.1±0.41

Survival of the transplanted seedlings was studied at 2-month intervals over one year period. On each observation date, density of herbaceous plant species was determined in the control plots and soil temperature was also measured at each site. Soil temperature was measured by inserting the soil thermometer down to 10 cm depth. Ten soil samples representing 0 - 10 cm depth were collected from the burnt and unburnt sites of both forest stands on each observation date and the soil moisture content was determined following the method outlined by Piper (1947).

Growth of the surviving transplants was analysed after one year from the date of transplantation. For growth measurement, 10 seedlings of each species were excavated from each site and their leaf area, biomass and leaf area ratio were determined. Leaf area was measured by using graph paper and biomass by drying the seedlings in an oven at 60 °C to constant weight. Leaf area ratio was calculated following the formula given by Evans (1972).

Organic carbon of the soil was determined by rapid titration method (Walkley & Black 1934), soil nitrogen by micro-Kjeldahl method (Jackson 1962), potassium by a flame photometer and phosphorus by molybdenum blue method (Allen 1974).

RESULTS

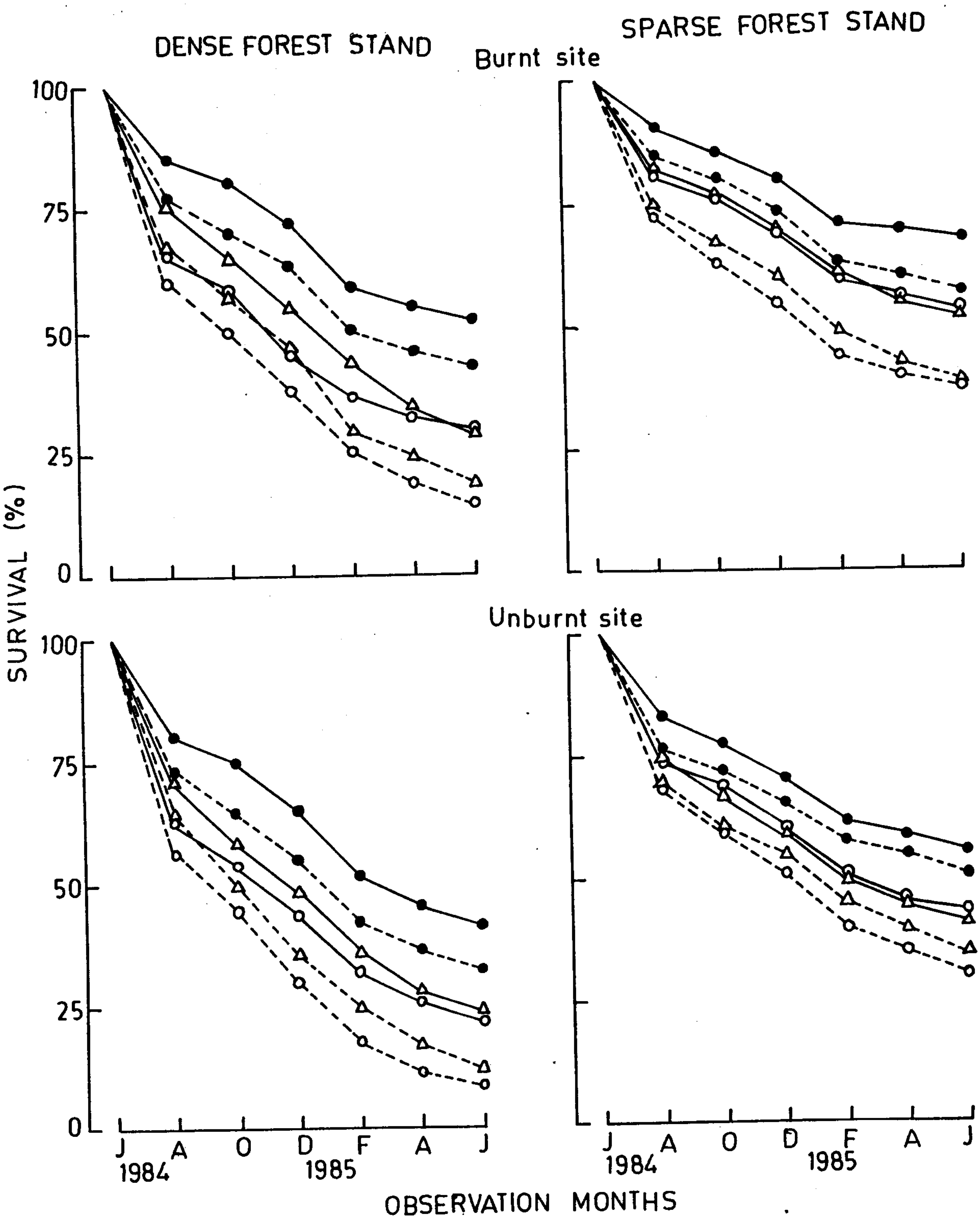
Density of ground vegetation, soil moisture and soil temperature :

Density of herbaceous plant species and soil temperature were higher in the sparse forest stand than in the dense stand, whereas soil moisture was greater in the dense stand. Herbaceous plant density and soil moisture were greater on the unburnt than on burnt site in both the stands, whereas the soil was warmer on the burnt site. Density, soil moisture and soil temperature were high during June to August and low during December to February (Fig. 6.2).

Survival and growth of transplants :

Survival and growth of the transplants were strongly affected by the forest canopy, study site and ground vegetation. The transplants exhibited better survival and growth in the sparse stand, burnt site and cleared plots than in the dense stand, unburnt site and uncleared control plots (Fig. 6.1, 6.3 & 6.4). Mortality in all the species was maximum in August followed by February. A. nepalensis and S. khasiana showed greater mortality as compared to Q. griffithii (Fig. 6.2). S. khasiana produced maximum leaf area and biomass and Q. griffithii the minimum (Fig. 6.3 & 6.4). Leaf area ratio of the three species did not differ much (Table 6.3).

Fig. 6. 1. Survival of the transplants of the three species as affected by forest canopy and associated vegetation at burnt and unburnt sites. Continuous lines (———) represent the plots without associates and broken lines (- - - -) with associates. △ , *A. nepalensis*; ● , *Q. griffithii*; ○ , *S. khasiana*.



DENSE FOREST STAND
SPARSE FOREST STAND
Burnt site
Unburnt site
SURVIVAL (%)
100
75
50
25
0
J
A
O
D
F
A
J
1984
1985
OBSERVATION MONTHS

Fig. 6·1

Fig. 6. 2. Mortality rate of seedlings of three species transplanted in the plots with and without ground vegetation at burnt and unburnt sites in dense and sparse forest stands. Vertical bars represent density/m^2 of ground vegetation. Other symbols are same as in Fig. 6. 1.

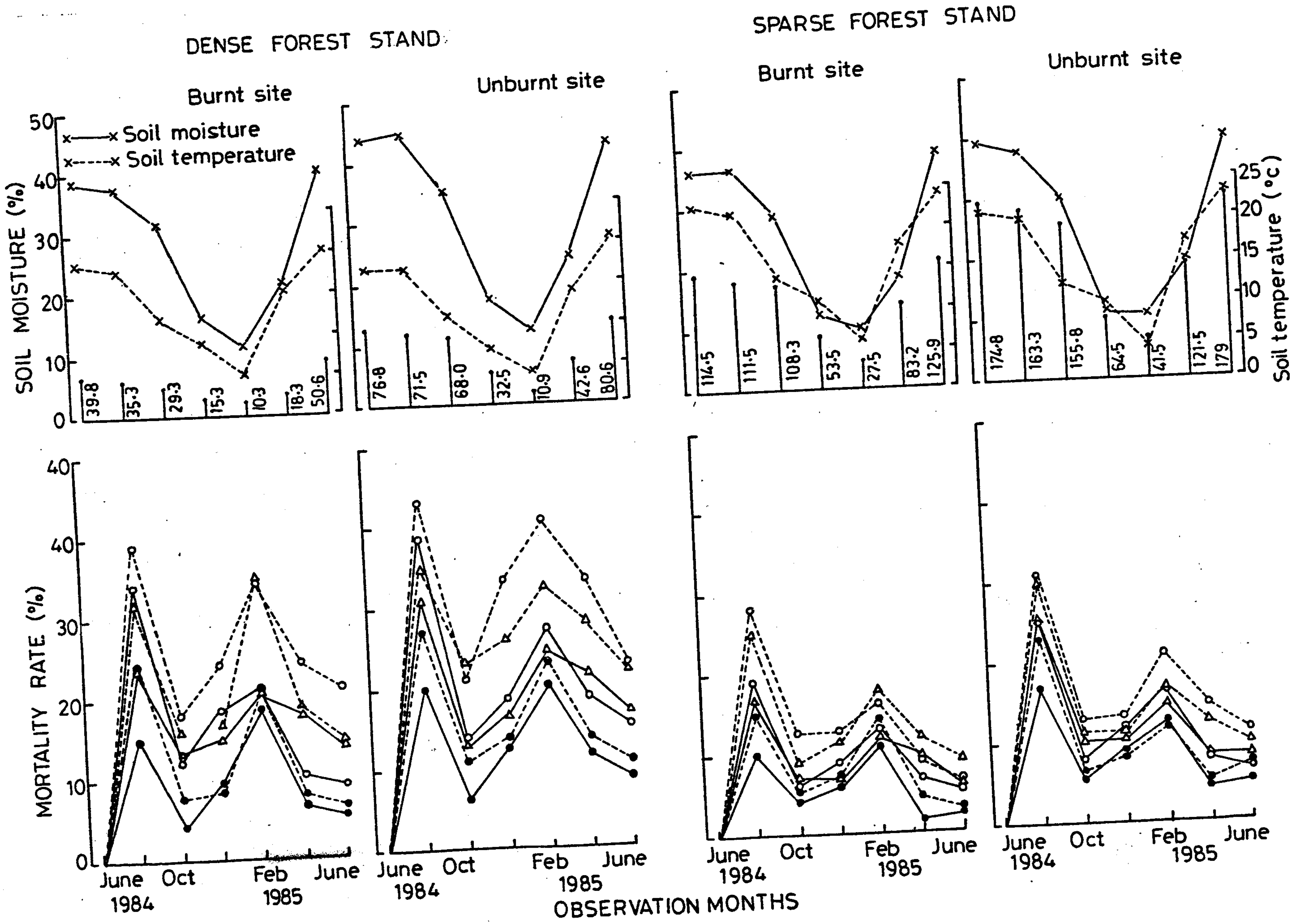
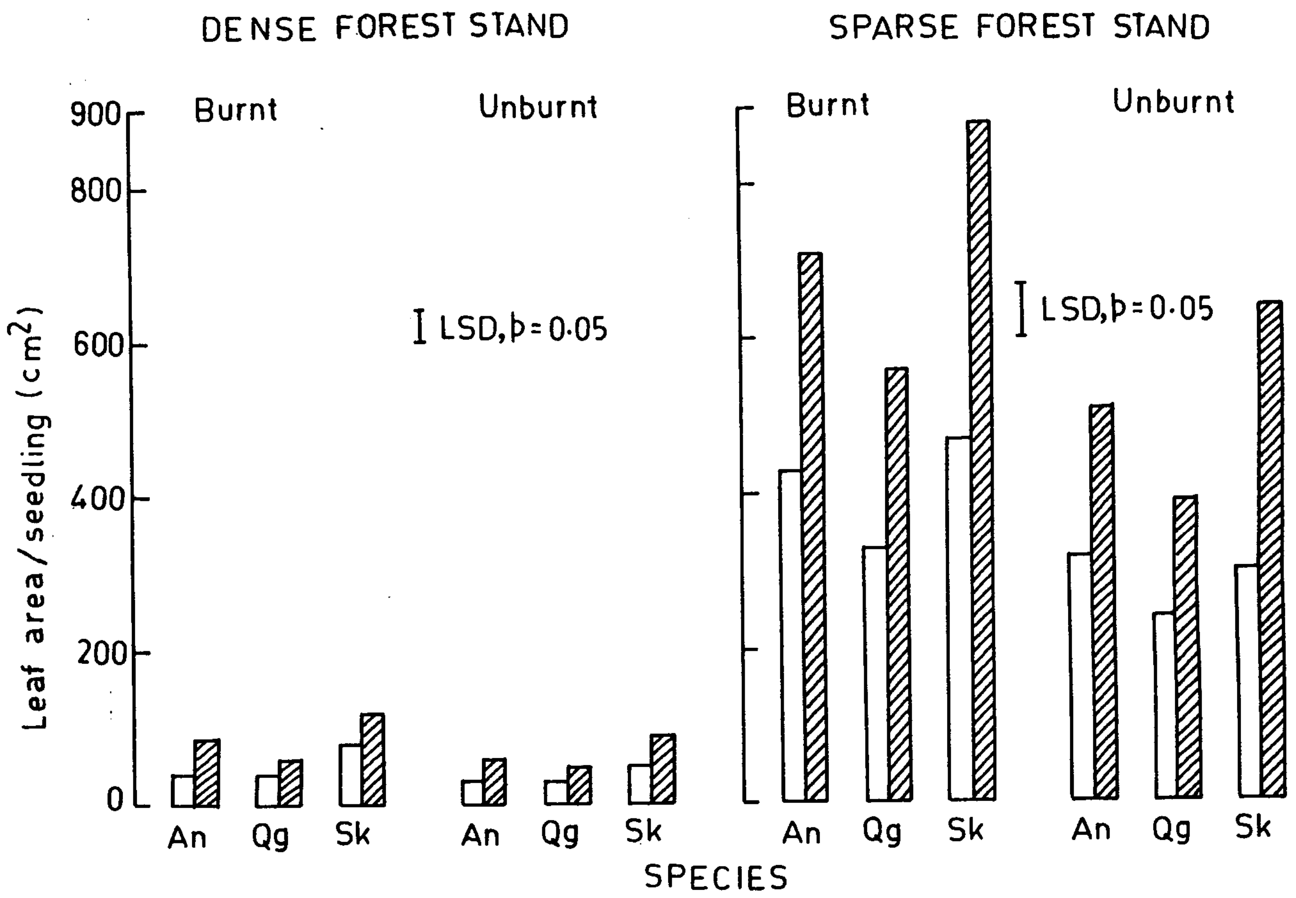

DENSE FOREST STAND
SPARSE FOREST STAND
Burnt site
Unburnt site
Burnt site
Unburnt site
Soil moisture
Soil temperature
SOIL MOISTURE (%)
Soil temperature (°c)
39.8
35.3
29.3
15.3
10.3
18.3
50.6
76.8
71.5
68.0
32.5
10.9
42.6
80.6
114.5
111.5
108.3
53.5
27.5
83.2
125.9
174.8
163.3
155.8
64.5
41.5
121.5
179
MORTALITY RATE (%)
June 1984
Oct
Feb 1985
June
OBSERVATION MONTHS

Fig.6·2

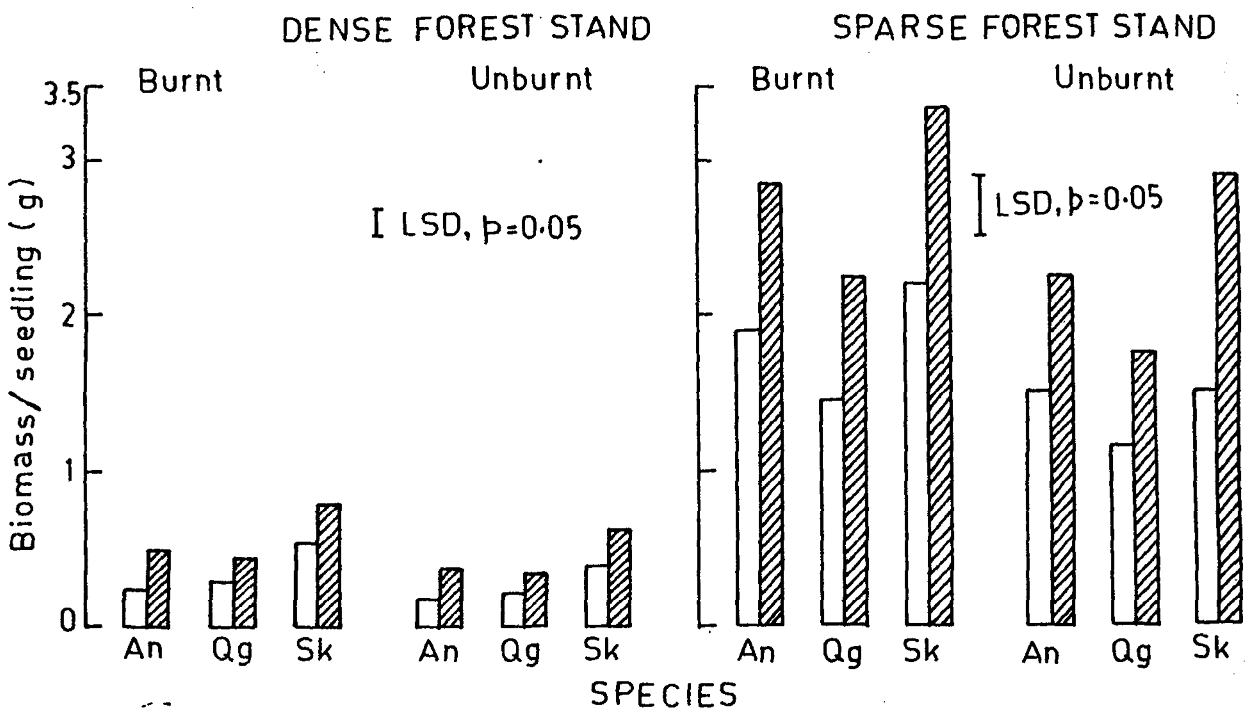
Fig. 6. 3. Leaf area per seedling of the three species as affected by forest canopy and associated vegetation at burnt and unburnt sites. The filled columns represent the plots without associates and open columns with associates. An, A. nepalensis; Qg, Q. griffithii; Sk, S. khasiana.



DENSE FOREST STAND
SPARSE FOREST STAND
Burnt
Unburnt
Burnt
Unburnt
900
800
600
400
200
0
Leaf area/seedling (cm2)
LSD, p = 0.05
LSD, p = 0.05
An
Qg
Sk
An
Qg
Sk
An
Qg
Sk
An
Qg
Sk
SPECIES

Fig. 6·3

Fig. 6. 4. Biomass per seedling of the three species as affected by forest canopy and associated vegetation at burnt and unburnt sites. Explanation of symbols is same as in Fig. 6. 3.



DENSE FOREST STAND
SPARSE FOREST STAND
Burnt
Unburnt
Burnt
Unburnt
3.5
3
2
1
0
Biomass/seedling (g)
LSD, p=0.05
LSD, p=0.05
An
Qg
Sk
An
Qg
Sk
An
Qg
Sk
An
Qg
Sk
SPECIES

Fig. 6·4

Table 6.3. Leaf area ratio (cm^2/g) of Alnus nepalensis, Quercus griffithii and Schima khasiana on the burnt and unburnt sites in the sparse and dense forest stands.

Species	Dense forest stand				Sparse forest stand			
	Burnt site		Unburnt site		Burnt site		Unburnt site	
	+ 'A'	- 'A'	+ 'A'	-'A'	+'A'	- 'A'	+ 'A'	- 'A'
A. nepalensis	158.14	180.85	147.96	163.23	228.79	250.02	215.63	227.49
Q. griffithii	174.08	197.26	143.73	174.39	222.35	255.58	207.99	225.53
S. khasiana	174.94	166.15	133.05	150.67	216.16	264.14	194.57	220.31

+ 'A' Growing in the plots from which associated vegetation was not removed.

- 'A' Growing in the plots from which associated vegetation was removed.

DISCUSSION

Better survival and growth of transplants of the three species in sparse forest stand than in the dense may be attributed to the greater availability of light in the former (Longman & Jenik 1974, Whitmore 1975, Hartshorn 1978, Lee 1978). Studies conducted by Augspurger (1984a, b) on tropical trees, Khan et al. (1986) on sub-tropical trees and Nicholson (1960) and Sasaki & Mori (1981) on some dipterocarp seedlings have also shown that survival and growth are better in sun than in shade. Modifications to the microclimate (air and soil temperature, evaporation, humidity) through canopy opening as discussed by Bazzaz & Pickett (1980) and Burton & Mueller-Dombois (1984) might have favoured survival and growth of the transplants in the sparse forest stand. Augspurger (1984b) observed that pathogens caused greater seedling mortality in some tropical tree species under shaded condition. In the present study too, greater mortality observed in the dense stand (visual observation) could be attributed to pathogenēs.

Greater survival and growth of the transplants of the three species at the burnt site may be ascribed to (i) an immediate flush of readily available nutrients (Table 6.2, Well et al. 1979, Mallik 1982); (2) greater soil temperature (Fig. 6.2, Rouse 1976, Humphreys & Craig 1981, Ahlgren 1981, Wyant et al. 1983); (3) destruction of microorganisms present in the soil litter, which could be inhibitory to plant growth (Florence & Crocker 1962); and (4) elimination of competitors and natural enemies of seedlings (Christensen & Mueller 1975, Evans 1976, Whelan et al. 1980). Harrington & Kelsey (1979), O'Dowd & Gill (1984) and Abbott & Loneragan (1984) also observed better performance of tree seedlings in burnt plots than in unburnt plots.

The greater mortality and poor growth of the transplants in the uncleared plots, signify the detrimental effects of ground vegetation as has also been emphasized by Horsley (1977a, b), Daniels (1978), Eis (1981), Maguire & Forman (1983) and Connell et al. (1984). Competition for resources (Stone & Thorpe 1971, Maguire & Forman 1983) and production of allelochemics (Stewart 1975, Horsley 1977a, b) by the ground vegetation may influence the survival and growth of tree seedlings.

The observed maximum value for seedling mortality on the date of first observation in August, 1984 may be ascribed to the disturbances caused to the root system of the seedlings at the time of transplantation. In addition, greater mortality is also caused by the erosive action of the torrential rain received during these months (June-August). Greater mortality during winter months may be due to prevailing low temperature and high soil moisture stress (Fig. 6.2). The detrimental effects of low temperature and high soil moisture stress on survival and growth of tree seedlings have also been reported by Mueller-Dombois et al. (1980), Schulte & Marshall (1983) and Lawrence & Oechel (1983).

GENERAL DISCUSSION

The data collected on regeneration behaviour of two selected forests reveal that regeneration is better in the disturbed forest at Upper Shillong than in undisturbed 'Sacred grove' forest at Mawphlang. The age structure of tree species in the disturbed forest was upright pyramidal, whereas in undisturbed forest it was inverted pyramidal. The regeneration of trees through seedlings and sprouts of stumps was greater in the disturbed forest. Survival of the seedlings and sprouts was also better in the disturbed forest. Variation in regeneration behaviour of the tree species in the two forest stands signifies the role of prevailing disturbances as also reported elsewhere (Heinselman 1973, Whitmore 1975, Foster 1980, Bazzaz 1983, Dunn et al. 1983, Saxena & Singh 1984, Primak et al. 1985, Oliver et al. 1985, White et al. 1985). The positive role of mild disturbances in improving the regeneration of trees has been emphasized by Kenoyer (1921), Harris & Farr (1974) and Boring et al. (1981). Greater seedling recruitment and sprouting of the stumps in the disturbed forest stand at Upper Shillong may be attributed to the availability of large number of microsites caused by tree felling and forest burning. Removal of overstorey trees may also favour germination and seedling establishment through increased solar radiation on the forest floor and consequent increase in surface temperature, and reduced competition from the trees of upper canopy (Koller 1972, Noble & Slatyer 1980, Oliver 1981). Conversely, poor seedling population in the undisturbed forest at Mawphlang may be due to the absence of the above mentioned favourable conditions.

Besides, the thick layer of litter in the undisturbed forest (Fig. 2.1) acts as a mechanical barrier for seedling emergence (Telfer 1972, Grime 1979). Poor emergence, survival and growth of Quercus dealbata and Q. griffithii seedlings (Chapter IV) in the plots from where litter was not removed confirmed the detrimental effect of forest litter on regeneration of forest trees.

The upright pyramid of age structure of the disturbed forest at Upper Shillong (Fig. 2.4) is attributed to the selective felling of older trees for timber and other purposes. On the other hand, in the undisturbed 'Sacred grove' forest at Mawphlang which does not experience such disturbances, the age structure is inverted pyramidal. Similar change in age structure of plant populations in forest communities caused by various kinds of disturbances has also been reported by Heinselman (1973), Foster (1980) and Primack et al. (1985).

The seedlings and sprouts showed better survival in the forest stands near periphery than in the dense forest stands (Chapter II). The results of the experiment concerning the effect of associated plant species on the transplanted seedlings also revealed better survival and growth in the sparse stand than in the dense one (Chapter VI), which may be attributed to the nonavailability of threshold light intensity for photosynthesis in the latter. This is in line with the findings of Whitmore (1975), Garwood (1979), Sasaki & Mori (1981), Abbott (1984), Laugenhein et al. (1984) and Primack et al. (1985). Studies conducted by Augspurger (1984a, b) on tropical trees and Nicholson (1960) and Sasaki & Mori (1981) on some dipterocarp seedlings also showed greater survival and growth in sun than in shade. Modifications in the microclimate (air and soil temperature, evaporation, humidity etc.) through canopy opening as discussed by Koller (1972), Bazzaz & Pickett (1980) and Burton & Mueller-Dombois (1984) might have favoured the emergence, survival and growth of the seedlings under sparse canopy. The data on emergence, survival and growth of seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana in controlled conditions (Chapter V) also indicate that the performance of these tree species is favoured by the increased light intensity. Greater seedling emergence in lighted condition than in shade was also reported by McLemore (1971), Garwood (1979) and Campbell (1982). Seedlings of Heliocarpus appendiculatus and Dipteryx panamensis in controlled conditions showed greater height, survival and biomass in lighted condition (Fetcher et al. 1983). Attack by the pathogens could be one of the reasons for the greater seedling mortality in the dense stand (visual observation). Augspurger (1984b) also observed greater mortality of seedlings caused by pathogens in some tropical tree species under shaded condition.

Survival and growth of seedlings were poor in the plots from which ground vegetation was not removed (Chapter V & VI). This signifies the detrimental effect of ground vegetation on tree seedlings as emphasized by Eis (1981), Maguire & Forman (1983), Burton & Mueller-Dombois (1984) and Connell et al. (1984). Greater seedling mortality during the rainy season could also be related to the luxuriant growth of ground vegetation in this season. Poor natural regeneration in many logged forest stands has been attributed to dense growth of herbs (Hough 1937, Hough & Forbes 1943, Sulser 1971, Horsley 1977a, b). Resource competition offered by the ground vegetation most likely causes seedling mortality in the uncleared plots as also suggested by Stone & Thorpe (1971), Maguire & Forman (1983). Besides, the ground vegetation may also influence seedling survival and/or growth through the production of allelochemics (Rice 1974, Stewart 1975, Horsley 1977a, b, Willis 1980, Ashton & William 1982, Rai & Tripathi 1984).

Peak seedling mortality observed during winter season (Fig. 2.2 & 6.2) may be attributed to the prevailing low temperature accompanied with high soil moisture stress (Fig. 6.2). Poor survival and growth of the seedlings at low soil moisture level was also observed in the controlled condition (Table 5.2, Fig. 5.3 & 5.4). The role of soil moisture in tree seedling establishment has been discussed by Noble & Alexander (1977), Schulte & Marshall (1983), Vance & Running (1985) and Wellington & Noble (1985).

Growth of sprouts and survival and growth of transplanted seedlings were greater in the burnt plots than in unburnt plots (Chapters **III & VI**). Harrington & Kelsey (1979), O'Dowd & Gill (1984) and Abbott & Loneragan (1984) have also observed better growth of tree seedlings in the burnt plots. Surface fire produces an immediate flush of readily available nutrients (Wells et al. 1979). Thus, burning might have favoured the growth of the seedlings and sprouts. Other possible roles of fire in relation to seedling/sprout survival and growth have been discussed in Chapters **III & VI.**

Seed germination is also regulated by various factors. Heavy seeds of Quercus dealbata and Q. griffithii germinated earlier than the light seeds and showed maximum germination (Table 4.2 & 4.3). Emergence of seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana was greater at high soil moisture level and in lighted condition (Fig. 5.1). The observed maximum and earlier germination of heavy seeds of Quercus dealbata and Q. griffithii as also reported by Griffin (1972), Ghosh et al. (1976) and Dunlop & Barnett (1983) in other tree species may be ascribed to the greater storage of food reserves in heavier than in lighter seeds (Black 1956, Harper & Obeid 1967, Stanton 1984). Better growth of seedlings emerged from the heavy seeds than those from the light seeds may be attributed to the larger food reserve in the former compared to the latter (Dunlop & Barnett 1983, Zimmerman & Weis 1983). Greater seedling emergence at high moisture level and in lighted condition conforms with the observations of Satoo (1966), Larson & Sehabert (1969), McLemore (1971), Garwood (1979) and Campbell (1982).

Sprouting of tree stumps in the forest plays an important role in the regeneration process. Density of the tree stumps was greater in the disturbed forest at Upper Shillong than in the undisturbed forest at Mawphlang (Chapter II), which is attributed to the tree cutting operation in the former. Sprouting of the stumps and survival and growth of the sprouts differed with the species. Stumps of Schima khasiana exhibited maximum sprouting while that of Quercus griffithii showed minimum (Chapter III, Fig 3.2). However, the sprout growth was better in Alnus nepalensis (Chapter III, Section II). Further, sprouting and survival and growth of the sprouts are influenced by diameter and height of the stumps. The sprouts arising from the stumps of medium diameters (> 15-30 and > 30-45 cm) showed better survival and growth than those resulting from the stumps of smaller and larger diameters. The number of sprouts emerging from the stumps of medium diameters was also larger than from the thinner and thicker stumps. The number and growth of the sprouts increased with the increase in height of the stumps. However, sprouts emerged from the stumps of medium height (25-30 and 45-50 cm) survived better than those emerged from the stumps of less or greater heights (Chapter III).

Less sprouting and poor survival and growth of sprouts that had emerged from the stumps of greater diameters may be attributed to the change in physiology of trees with age. The vegetative reproduction predominates in the juvenile phase and sexual reproduction in the adult phase (Hartmann & Kester 1975). This concept of phase change has been suggested as an explanation for the effect of diameter on sprouting (Hawley 1946, Solomon & Blum 1967). Poor growth of sprouts emerging from the stumps of smaller diameter could be linked with the inadequate reserves or nutrient supply to support the growth (Mann 1984). The increased sprouting and growth of sprouts with increasing stump height as observed in the present study (Chapter III) agree with the observations of DeBell (1971), Bellanger (1976), El Houri Ahmed (1977) and Harrington (1984) in other tree species. In the case of stumps of low height the population of dormant or trace buds happens to be low (Hook & DeBell 1970) and this could cause decrease in sprouting from such stumps. Poor growth of sprouts emerging from such stumps may be due to the inadequate food reserves in these stumps to support luxuriant sprout growth. Maximum mortality of the sprouts emerging from the stumps of low height could be ascribed to the observed fast decay of such stumps at the study site. The heavier mortality of sprouts that emerged from the stumps of greater height than those from medium height is presumably due to greater damage caused to the former by the heavy rain and high wind velocity prevailing in the area. Better survival of the sprouts emerging from the stumps of medium height may be attributed to slower decay of the stumps and less risk of damage to the sprouts from the heavy rain and high wind velocity. Other factors which might have influenced the stump sprouting and survival and growth of sprouts have been discussed in Chapter **III.**

It is concluded that the regeneration of tree species depends mainly on the interactive influence of biotic and abiotic factors of the environment. Though the prevailing disturbances in the forest at Upper Shillong play a positive role in the regeneration of trees, the impact of frequency and intensity of prevailing disturbances on regeneration needs to be investigated in detail. Tree seedling populations are largely regulated by overhead canopy, ground vegetation, litter accumulation, soil moisture and temperature. Sprouting and survival and growth of the sprouts are directly related to diameter and height of the stumps.

The present investigation throws light on certain important aspects of tree regeneration in Meghalaya. In order to gain further insight into the problem of regeneration of forest trees, the following studies need to be undertaken in detail:

(1) Studies on the impact of frequency and intensity of prevailing disturbances on regeneration and survival and growth of

tree seedlings and sprouts in different types of forests could give an idea of the extent of disturbances which a forest can withstand without much detriment to tree regeneration.

(2) A study pertaining to the recruitment, survival and growth of seedlings in different sizes of gaps occurring in the undisturbed forests which are supposed to represent the climax, could predict the future of undisturbed forests such as the 'Sacred grove' at Mawphlang.

(3) A study of the influence of predators on the seed and seedling populations in different habitats may explain the role of these organisms on population dynamics of the tree species.

(4) Studies on tree seed population dynamics in relation to various types of disturbances prevailing in the forests may reveal the effect of these disturbances on future prospects of important forest trees.

A thorough investigation of the above aspects could help in understanding the regeneration behaviour and population response of the tree species, based on which appropriate strategies could be evolved to conserve the forest wealth of the region.

SUMMARY

The thesis embodies scientific information on some of the important and hitherto less understood aspects of regeneration of a few tree species growing in the forests of Meghalaya. The studies presented in the thesis pertain to the following aspects :

(i) Regeneration status (i.e. age structure and survival of seedlings and sprouts) of tree species in the disturbed and undisturbed forests.

(ii) Effect of stump diameter and height on regeneration of Alnus nepalensis Don, Quercus dealbata L., Q. griffithii Hk. f. & Th. and Schima khasiana Dyer. through sprouts.

(iii) Effect of seed size and microhabitats (ground vegetation, litter and forest canopy) on seed germination, and survival and growth of the seedlings of Quercus dealbata and Q. griffithii in field conditions.

(iv) Seedling emergence and survival and growth of seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana have also been studied in relation to soil texture, moisture and light regimes in net house conditions to assess the ecological requirements of the tree seedlings.

(v) Survival and growth of the nursery grown seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana transplanted in different ecological conditions have been studied to find out the suitable site for transplantation and the factors which affect the seedling populations.

Major findings of the study are summarised below :

Regeneration status, age structure and survival of the tree seedlings and sprouts :

Age structure and survival of seedlings and sprouts were studied to assess the regeneration status of the tree species occurring in disturbed forest at Upper Shillong and in undisturbed 'Sacred grove' forest at Mawphlang. Regeneration is better in the disturbed forest than in the undisturbed one. The age structure of tree species in the disturbed forest is upright pyramidal (i.e. young individuals are more than old ones) whereas in the undisturbed forest, the age-pyramid is inverted (i.e. older individuals are larger than the young). Recruitment of seedlings and sprouting of stumps and survival of the seedlings and sprouts are greater in the disturbed forest compared to the protected forest. Survival of seedlings and sprouts is also better at the forest periphery than under the dense canopy, signifying the role of light in forest regeneration. Although the seedling mortality occurred throughout the year, it was particularly high during winter season due to prevailing low temperature and high soil moisture stress. The sprouts were, however, less susceptible to adverse environmental conditions.

Effect of stump diameter and height on sprouting and survival of the sprouts :

The effect of diameter and height of stumps on sprouting and survival of sprouts of *Alnus nepalensis, Quercus dealbata, Quercus griffithii* and *Schima khasiana* was studied in a disturbed forest at Upper Shillong. The observations on sprouting and survival of the sprouts were recorded on the stumps of different diameter and height classes. Sprouting percentage of the stumps and number of sprouts per stump decreased with the stump diameter. Number of sprouts per stump decreased with the bark thickness which increased with the increase in stump diameter in all the four species. However, sprouting increased with the increase in stump height. Production of sprouts was maximum in Schima khasiana and minimum in Quercus griffithii. In all the species, the sprouts arising from the stumps of medium diameters (i.e. >15-30 and >30-45 cm) and heights (25-30 and 45-50 cm) survived better than those from the stumps of smaller or larger diameters and heights.

Effect of diameter and height of stumps and sprout density on the sprout growth :

A study was carried out to determine the effect of diameter and height of stumps and sprout density on growth of the sprouts of Alnus nepalensis, Quercus dealbata, Quercus griffithii and Schima khasiana in the burnt and unburnt plots of disturbed forest at Upper Shillong. Observations on growth rate, height, leaf number and leaf area of sprouts of the four tree species were made over a 2-year period. The sprout growth decreased with increase in the stump diameter and it increased with the stump height. The sprout growth decreased with sprout density, but it was favoured by burning. In general, growth of the sprouts was maximum in Alnus nepalensis and minimum in Quercus griffithii. The effects of burning, diameter and height of the tree stumps, and sprout density on sprout growth have been discussed with reference to regeneration prospects of the species in the forests under study.

Effect of seed size and microhabitats on seed germination and survival and growth of the seedlings :

The effect of seed size, litter accumulation on the forest floor and associated vegetation was studied on seed germination, seedling survival and growth of Quercus dealbata and Quercus griffithii. Heavy seeds germinated earlier and showed maximum germination in both the species. Germination and survival and growth of the seedlings were maximum in the plots devoid of litter and ground vegetation and minimum in the control plots from where the ground vegetation and litter were not removed. Seedlings emerged from the heavy seeds showed better survival and growth as compared to those emerged from the lighter seeds.

Seedling emergence and survival and growth of seedlings in relation to soil texture, moisture and light regimes :

Emergence, survival and growth of seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana as related to soil texture, moisture and light were studied under controlled conditions with a view to assess the ecological requirement of the concerned tree species. The seedling emergence was better under high than under the low light intensity. The three species showed greater seedling emergence in the pots watered on alternate days than in those watered at 10-day intervals. Seedling emergence was greater on sandy loam than on clay loam soil. Seedling mortality decreased with increase in light intensity and moisture regime. Under high light intensity and alternate-day watering, the seedling growth was better on sandy loam than on clay loam soil.

Survival and growth of transplanted seedlings :

An experiment was carried out to study the survival and growth of nursery-grown seedlings of Alnus nepalensis, Quercus griffithii and Schima khasiana when transplanted in the forest under different ecological conditions. The transplants exhibited better survival and growth on burnt than on the unburnt site. Removal of the ground vegetation from the plots and sparse tree canopy favoured the seedling survival and growth. Alnus nepalensis and Schima khasiana showed greater mortality as compared to Quercus griffithii. Leaf area and biomass production were maximum in S. khasiana and minimum in Q. griffithii.

The study reveals that regeneration of the tree species occurs through both seed germination and sprouting of the stumps, and it is controlled by various factors of the forest environment. The prevailing disturbances of moderate intensity have been observed to play a positive role in regeneration of the tree species in the forests under study. Increase in seedling recruitment and stump sprouting in the disturbed forest has been attributed to the creation of large number of favourable microsites by tree felling and forest burning. It has been concluded that seed germination and survival and growth of seedlings of Alnus nepalensis, Quercus dealbata, Quercus griffithii and Schima khasiana are largely regulated by the overhead canopy, ground vegetation, litter accumulation and soil moisture. Sprouting and survival and growth of sprouts in these species are directly related to diameter and height of the stumps. Growth of the sprouts decreased when the sprout density on the stump was high. Mild burning has been observed to enhance the sprout growth of these species.

The fundamental scientific information gathered on various aspects of regeneration of the selected tree species could be profitably utilized in the management of forest resources of Meghalaya. The limitations of the work have been indicated and in the light of findings presented in the thesis, further studies on forest tree regeneration that need to be undertaken, have been suggested.

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*Original not seen.

APPENDIX

Publications arising from the thesis

Papers published:

1. Regeneration and survival of tree seedlings and sprouts in tropical deciduous and sub-tropical forests of Meghalaya. Forest Ecology and Management, 14: 293-304 (1986).

2. Tree regeneration in a disturbed sub-tropical wet hill forest of north-east India: Effect of stump diameter and height on sprouting of four tree species. Forest Ecology and Management (1986; in Press).

Papers communicated:

1. Age structure of some tree species in disturbed and protected sub-tropical forests of north-east India.

2. Effect of diameter and height of stumps and sprout density on the sprout growth of four tree speies in burnt and unburnt forest plots.