EFFECT OF PROVENANCE VARIATION ON SEED CHARACTERISTICS, GERMINATION AND SEEDLING GROWTH OF TREE BEAN (*PARKIA ROXBURGHII* G. DON)

By

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ABSTRACT

THESIS SUBMITTED
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ABSTRACT

The northeastern region is regarded as the primary and secondary source of origin of *Parkia roxburghii* (Singh *et al.* 2000). *P. Roxburghii* is the most widespread species of *Parkia* in the Indo-Pacific region, and the only one to occur on both sides of Wallace's line (Thangjam *et al.* 2003 & Hopkins 1994). In India, it is distributed in Arunachal Pradesh, Cachar hills of Assam, Garo and Khasi Hills of Meghalaya, Lushai Hills, Kolasib – Bukpui and Sialsuk road in Upper Thenzawl area of Mizoram and Imphal, Kangpokpi and Pachao of Manipur (Hajra et al. 1996; Singh et al. 2002; Singh et al. 2002). The species is also reported from Chittagong and Sylhet of Bangladesh, Myanmar and Malay Peninsula (Hooker 1973). A tree legume, *Parkia roxburghii* G. Don. (Syn. *Parkia timoriana* (DC.) Merr.), is a popular non-conventional source of nutritional, medicinal and recreational values. The genus *Parkia* has 31 species distributed through the rainforests of the Amazon Basin, Africa & Madagascar and Indo-Pacific region (Luckow and Hopkins 1995). Ten species occur in the Indo-Pacific region (Luckow and Hopkins 1995) and four of these are indigenous to India, viz., *Parkia roxburghii* G. Don., *P. biglandulosa* W. & A., *P. leiophylla* Kurz. and *P. insignis* Kurz. (Don and Singh 1986). The pod is edible and available from November till April and is a potential source of protein and fat (Longvah *et al.* 1998). It is consumed in all developmental stages starting from the green tender pods to mature seeds.

P. roxburghii shows a wide range of variation in phenotypic traits among provenances. Although morphological characters and agronomic traits have been used traditionally to characterise levels and patterns of diversity, these traits alone represent only a small

portion of the plant genome and are also influenced by environmental factors, thereby limiting their utility in describing the potentially complex genetic structures which may exist within and between taxa (Avise, 1976). The knowledge of the origin of genetic variation within and between plant populations is also important for the effective utilisation and conservation of species (Thangjam *et al.* 2003 & Hamrick, 1987). The observations show that *Parkia roxburghii* trees are dwindling in wild as well as in homegardens due to harvest of fruits and seeds and due to loss of habitats. Besides seeds being lost to rodents and primates in the wild, Almond moth (*Cadra cautella*) also causes serious damage to the pod as well as seeds (Thangjam *et al.* 2003). The information on the provenance variation and regeneration ecology of *P. roxburghii* is lacking. Hence, the present study is has been undertaken with the following objectives:

- to assess population structure of *Parkia roxburgii* in different provenances in northeastern India, and
- to study provenance variability in fruit and seed traits, seed germination and seedling growth.

In the present study, we encountered *P. roxburghii* in the wild along tropical semi-evergreen and subtropical broadleaved hill forests of the northeastern India where *Schima wallichii, Areca catechu, Tectona grandis, Artocarpus macrophylla, Pinus kesiya, Duabanga grandiflora, Gmelina arborea, Quercus serrata* occur. The present study was carried out in four States of northeastern region of India, viz., Manipur, Meghalaya, Mizoram and Nagaland (Fig. 3.3). A reconnaissance survey for exploration of natural populations of *P. roxburghii* was carried out in September, 2004. The 23 surveyed populations of *P. roxburghii* belonged to modified communities and only few trees were found growing in the wild with signs of poor or no regeneration (Table 3.2). The most occurrences were in homegardens and *jhum* fallows.

Of these, seven provenances (populations) were selected that contained higher concentration of *P. roxburghii* individuals. The selection of site was also due to the presence of healthy trees, accessibility of trees to climb on, and accessibility of the sites in all weather conditions round-the-year and known history of the sites. The study sites or provenances was made after comparing their distance apart with not less than 10 km and their variation in altitudes of a minimum 100 m within a State.

The phytosociological analysis was done following standard methods (Mueller-Dombois *et al.* 1974, Greigh-Smith 1983, Uma Shankar 2001) and frequency, density, dominance and importance value index of all species were determined. Whitford's index (abundance-to-frequency ratio) was used as a measure of dispersion (Whitford 1949). The dispersion is considered regular for A/F ratio <0.025, random for 0.025 to 0.05 and contagious (clumped) for >0.05 (Singh et al. 2006). Species richness index was estimated following Whittaker (1972). Shannon's diversity index (H'), Simpson's dominance index (λ) and Pielou's evenness index (Pielou 1966) were calculated following Magurran (1988). The similarity between two sites was calculated following Sorensen's similarity index (Sorensen 1948). The 2 x 2 contingency table was prepared to calculate index of association between two species, phi-coefficient of association and Pearson's chi-sqaure test of association (Sokal and Sneath 1963).

The data on fruit characteristics were averaged for 25 fruits in each provenance. The variability of mean values is presented in terms of standard deviation and coefficient of variation. Similarly, the seed characteristics were worked out across the number of seeds recovered from 25 fruits in each provenance. The interrelationships between fruit and seed characteristics were analysed by using linear regression model. Seed viability test was performed for hundred healthy seeds from each provenance after removing the seed coat. The seeds were immersed in 1% solution of 2, 3, 5-triphenyl tetrazolium chloride (TTC) for 9 h at 35 °C (Moore 1985). For germination the seeds were sown in root trainers containing a 1:1 mixture of loam and sand and were placed in a mist chamber at 25°C temperature and 80-90% relative humidity. Germination was examined daily until no further germination occurred. Seed germination characteristics and leaf emergence time were observed following standard methods (ISTA 1976, Jayashankar et al. 1999, Uma Shankar 2006, 2012, Uma Shankar and Synrem 2012). Seeds were considered germinated when radicle emerged from the seed coat. The time between germination and expansion of first pair of leaves was recorded as 'leaf emergence time'. The seeds that failed to germinate were retrieved from the root trainers to confirm death. One month old seedlings were regularly transferred from a root trainer to a polythene bag in the open nursery to allow greater space for spreading roots. Shoot height, collar diameter, leaf number and leaf fall of seedlings was measured at regular intervals (Jayashankar *et al.* 1999, Khan *et al.* 1999, Uma Shankar 2006, 2012). The data were analyzed statistically for mean, standard deviation and coefficient of variation. One-way analysis of variance was used to test the differences between group means. Pair-wise comparisons were made using Tukey's post-hoc test.

The phytosociological analysis of seven habitats in the four states of northeastern region of India revealed that: 1) *P. roxburghii* is widely distributed in northeastern region of India, (2) *P. roxburghii* inhabits ecosystems varying from plantations through *jhum* fallows to natural habitats, (3) *P. roxburghii* is not a dominant species at any of the sites, (4) *P. roxburghii* is randomly dispersed, (5) *P. roxburghii* reveals an association with *Schima wallichi* and (6) the natural regeneration of *P. roxburghii* is very poor.

The provenances showed variation in floristic composition, species richness and diversity. Only two provenances were dominated by the naturally occurring species, i.e., Kangpokpi by *Quercus serrata* and Khaibung by *Schima wallichi*. All other provenances were dominated by the planted species. From all seven provenances, 1,510 individuals of >10 cm gbh were recorded which belong to 117 species, 75 genera and 44 identified families. The maximum numbers of species (38 species) were recorded from Mawriang provenance in Meghalaya, despite the fact that this site is dominated by a planted species, *Areca catechu*. The least number of species were recorded from Thingkhangphai provenance in Manipur where *Pinus kesiya* is the most dominant species.

In all seven provenances, the most dominant species was characterized by a high value of IVI. When the data from all seven provenances were pooled, the IVI of the most dominant species, *Schima wallichii*, declined below 30 (Table 4.8). In all, only seven species showed IVI >10. Among these species *Schima wallichii* occurred in all provenances and showed a random dispersion. In these provenances, more than one-half of the species richness was contributed by the rare species with an IVI <1. This is a general trend in most tropical forest in India where the species richness is mostly due to the rare species, as observed in native *sal* forests (Uma Shankar 2001, Uma Shankar et al. 1998, Pandey and Shukla 1999, Pandey 1999, Kushwaha and Nandy 2012), dry-deciduous forests (Sukumar et al. 1992, Murali et al. 1996, Sagar et al. 2003), moist-deciduous forests (Sundarapandian and Swami 2000), evergreen forests (Nath et al. 2005, Deb and Sundriyal 2011, Ayyappan and Parthasarthy 2004, Parthasarathy and Karthikeyen 1997) montane forests (Sundriyal et al. 1994 and Rikhari et al. 1997) and scrub forests (Uma Shankar et al. 1998).

The provenance Khaibung was characterized by the most natural vegetation and high value of species richness, Shannon diversity index and evenness index, and was dominated by *Schima wallichii.* Only three species were characterized by the random dispersion pattern. These are *P. roxburghii*, *Schima wallichii* and *Phyllanthus emblica. P. roxburghii* and *Schima wallichii* showed a high value of index of association (0.5) and a Chi square test confirmed that these two species are associated with each other and do not occur independently in studied plots. The phytosociological attributes of *P. roxburghii* and *Schima wallichii* showed a significant correlation.

Evidently, *P. roxburghii* is not a dominant element in any of the communities, which is in conformity with other studies from *P. roxburghii* habitats (Don and Singh 1986, Hopkins 1994, Rocky and Sahoo 2002 and Amzu et al. 2007). The density of *P. roxburghii* was between 6 and 18 individuals per hectares. The low dominance of *P. roxburghii* in the present studies indicates is because of the poor regeneration. The population structure of *P. roxburghii* clearly reveled paucity of newly requiring individuals in smaller girth classes. Similarly there was a paucity of individuals of *P. roxburghii* in smaller height classes. In fact, not even a single individual of *P. roxburghii* was recorded in the ground layer in any the seven provenances. The poor regeneration of *P. roxburghii* is presumably because of the harvest of tender as well as mature fruits for consumption as vegetable by the local people.

During the study, we observed that neither the entirely capitula nor the self-pollinated capitula containing 3000 to 4000 flowers of *Parkia roxburghii* set fruit. Thus, variation in fruit and seedling characteristics is more prominent compared to other plant species. The genus *Parkia* has been reported to have variations in fruit width and length among provenances and sometimes such variations are also observed among trees (Olorunmaiye *et al.* 2011).

As expected, the relationships among fruit parameters of *Parkia* from all provenances showed positive linearly significant trends with stronger relationships between fruit weight and other parameters in both the years of study.

The seeds across the genus *Parkia* have been observed to display different colour, smoothness of the coat and variation in weight, length, width, thickness and volume among provenances (Hopkins 1983 and 1994, Olorunmaiye *et al.* 2011). This investigation revealed similar results suggesting an inbreeding effect across its distribution. As assumed, the weight of germinated seed was affected by its length, width, thickness and volume. The study revealed a strong relationship between seed weight in (*y*-axis) to other seed parameters in *x*-axis (width and volume). The scatter plot of both the germinated and ungerminated seeds revealed a more visible distinct population in the year 2006 suggesting the effect of seed parameters especially the seed weight as an indicator on the germination behaviour of seeds. Uma Shankar (2006) recommended seed weight as an indicator of choosing a seed for better success in germination and seedlings establishment of Hollong (*Dipterocarpus macrocarpus*). However, the vague picture of the subsequent year (2007) contradicts the decision on predicting germination on the basis of seed weight only in the case of *P. roxburghii*. The distribution of populations appeared fussy with many seeds both germinated and ungerminated overlapping across the middle section.

Provenances varied significantly in most traits of fruit and seed. A single best provenance based on morphometric traits of fruits and seed was Kongpokpi in 2006 and Kawnpui in 2007.

The fruit is indehiscent with seeds embedded in a thick hard coat bounded by strong sutures. Seeds may have to remain in the fruit long after it is ripened and rely on other mechanisms such as decay or predation to release the contents. Moreover, the seed may not escape from predation when its size may not be determined from the fruit cover (Uma Shankar 2006). This character of the fruit may have been the factor of low regeneration in the wild. Detaching from the branch the chime-like pendent fruits are also seen entangled on the lower branches till they naturally rots. How viable the seed must be, the species will face natural stress of regenerating itself when very few fruits are developing from a capitulum that are further withheld by the stout indehiscent fruit cover. Luckow and Hopkins (1995) termed *P. roxburghii* as the most complex species across the genus that produce only 9 to 17 fruits from thousands of its fertile flowers in a capitulum. This study also observed another contrasting feature in context to germination when only 35 percent of seeds germinated in spite of producing huge lump of seeds per fruit. Provenances differed significantly among themselves but are not remarkable to convince any environment or genetic influence. The present study wondered if the species follow a self-suicide trend when a few portion of fruits are developed from numerous fertile flowers, also embedding its seeds within an indehiscent fruit, but producing huge non-germinating viable seeds. Literature search yielded scarce information to explain the question hence needs further investigation.

It is assumed that seeds having large diameter and heavier weight will assure high germination (Khan and Uma Shankar 2001, Uma Shankar 2006). The study also followed the same trend. Interestingly, all seeds from 2006 collection are larger, heavier and thicker as compared to those collected during 2007. However, fuzzy distribution of the seeds germinated and those failed across dimensions will not guarantee a definite success when heavier, larger and thicker seeds are considered for sowing. The seeds of *P.roxburghii* that will be successful in germination may not be predicted easily. The study observed mild differences in seed dimension affecting the growth of the seedling across provenances. Hence, the study cannot conclude whether heavier, larger and thicker seeds will assure healthier seedlings. The seed that would germinate and finally developed in to a healthy seedling is influenced by provenance and not merely of the fruit and seed dimensions.

The study revealed confirmatory results with the findings of Longvah & Deosthale 1998. However, the fat content in seeds was recorded 5.84% less than the findings of Longvah & Deosthale (1998) in *P. roxburghii* and 6.7% more than that reported by Oladunmoye (2007) in *P. biglobosa*. Immature fruit of *P. roxburghii* recorded a higher mean fiber percent to that of the seeds, depicting to high content of non-degradable fibers (Messina 1999) as well as reduction in carbohydrate content (Esenwah & Ikenebomeh 2008) approaching its maturity. Screening and extraction of edible oils from *Parkia* may be as important (Longvah & Deosthale 1998) as many other vegetable oils that will increase the energy density and act as a transport vehicle for fat soluble vitamins if included in foods meant for infants and children (Mariam 2005). Seeds of *P. roxburghii* from Bilkhawthlir, Mawriang and Kawnpui may be collected for edible oil production in northeastern India. Nonetheless, maturity advancement of the fruits that led to higher accumulation of protein and fat contents (Longvah & Deosthale 1998) may have continued till the seeds are fully ripened.

Among micronutrient of *P. roxburghii*, all six minerals determined from Kangpokpi provenance are more related to that reported by Longvah & Deosthale (1998) because both Kangpokpi and Imphal belongs to the same state, Manipur. However, mineral contents in seeds of Khaibung provenance may be compared with similar constituent of other beans (Messina 1999, Oladunmoye 2007 and Longvah & Deosthale 1998).

This study provides an ample scope of screening some genotypes from the selected high nutrient provenances for further mass production and introduction into the *jhum* affected areas, road plantation, agroforestry systems and also degraded forest areas of the region. Targeting the food security in the region, *Parkia roxburghii* from Bilkhawthlir may be an important source of planting material accumulating maximum important nutrients both in fruit and seeds. However, fruits and seeds from Mawriang may prove beneficial to the health of consumers due to low accumulations of antinutrients both in seed and fruit.

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SHILLONG 793 022, INDIA

2012

Dedicated to my Mother

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DECLARATION

I, Mr. Kitboklang Nongrum, do hereby declare that the thesis entitled "**Effect of Provenance variation on seed characteristics, germination and seedling growth of tree bean (*Parkia roxburghii* G. Don)**" embodies a record of original and independent research work carried out by me in the Department of Botany, North- Eastern Hill University, Shillong. The work is original and no part of the thesis forms the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree or diploma in any University / Institute.

The thesis is being submitted to the North- Eastern Hill University for the award of the degree of Doctor of Philosophy in Botany.

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(Kitboklang Nongrum)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The local communities in northeastern region of India including more than 200 dominant tribes and many sub-tribes have from ages developed ingenious uses of wild plants to supplement nutritional requirements (Singh and Arora 1978, Longvah and Deosthale 1998, Murugkar *et al.* 2004), cure diseases and improve environment around them. A tree legume, *Parkia roxburghii* G. Don. (Syn. *Parkia timoriana* (DC.) Merr.), is a popular non-conventional source of nutritional, medicinal and recreational values.

The genus *Parkia* has 31 species distributed through the rainforests of the Amazon Basin, Africa & Madagascar and Indo-Pacific region (Luckow and Hopkins 1995). Ten species occur in the Indo-Pacific region (Luckow and Hopkins 1995) and four of these are indigenous to India, viz., *Parkia roxburghii* G. Don., *P. biglandulosa* W. & A., *P. leiophylla* Kurz. and *P. insignis* Kurz. (Don and Singh 1986). The northeastern region is regarded as the primary and secondary source of origin of *Parkia roxburghii* (Singh *et al.* 2000b). *P. Roxburghii* is the most widespread species of *Parkia* in the Indo-Pacific region, and the only one to occur on both sides of Wallace's line (Thangjam *et al.* 2003b, Hopkins 1994). It grows in humid tropical plains extending to subtropical climate in the hills. Broadly, the species grows between 400 and 1,200 m and attains a height of up to 30 m. Owing to its multipurpose nature, it is extensively planted in the homegardens, shifting cultivation areas and forests in Manipur, Meghalaya, Mizoram, Nagaland, and hills of Assam such as North Cachar Hills and Sibsagar (Kanjilal *et al.* 1938, Sharma *et al.* 1993, Rocky *et al.* 2004).

In northeastern India, the tree of *P. roxburghii* is locally known as *Khorial* and *Manipuri-urohi* in Assam, *Zongta* in Mizoram, *Yongchak* in Manipur, *Aoelgap* in Garo

Hills, *Barri-phang* in Cachar, *Unkam Pinching* in Nagaland (Sharma *et al.* 1993) and *Sohbtar* or *Jingbam Tngaw* in Khasi hills. *P. roxburghii*, a less known multipurpose tree is playing a key role in ensuring socioeconomic security in northeastern region of India. The pod is available from November till April and is a potential source of protein and fat (Longvah and Deosthale 1998). It is consumed in all developmental stages starting from the green tender pods to mature black seeds. Since the fruit is traded, *P. roxburghii* augments rural economy besides maintaining the ecological balance of the habitats (Don and Singh 1986). The bark of the genus *Parkia* is used for curing toothache (Usher 1954) and stomach upset and diarrhoea (Lewis and Lewis 1977).

P. roxburghii shows a wide range of variation in phenotypic traits among provenances. People in Manipur generally believe that narrow and uniform pods with light green colour are superior in flavour and accordingly thirteen cultivars in the state were identified based on their morphological characters (Meitei and Singh 1990). Similarly, nine varieties of tree beans were reported from different tree bean growing belts in Manipur based on their palatability and other eating qualities (Salam and Singh 1997). Although morphological characters and agronomic traits have been used traditionally to characterise levels and patterns of diversity, these traits alone represent only a small portion of the plant genome and are also influenced by environmental factors, thereby limiting their utility in describing the potentially complex genetic structures which may exist within and between taxa (Avise 1976).

Populations in different provenances might be preferred for different traits. For instance, some populations might be preferred for the taste of pods and others for high nutritive value or superior seed characteristics for germination and seedling growth. Hence, available variation in quantifiable phenotypic traits such as tree vigour, seed characteristics and germination behaviour of *Parkia roxburghii* shall be studied to select the best geographic source of planting material (seeds) and the traded product, i.e., fruit (Wright 1976, Egenti 1978, Abideen *et al.* 1993, Keratadikara and Prat 1995, Jayashankar *et al.* 1999). The knowledge of the origin of genetic variation within and between plant populations is also important for the effective utilisation and conservation of species (Hamrick 1987, Thangjam *et al.* 2003b). The observations show that *Parkia roxburghii* trees are dwindling in wild as well as in homegardens due to harvest of fruits and seeds and due to loss of habitats. Besides seeds being lost to rodents and primates in the wild, Almond moth (*Cadra cautella*) also causes serious damage to the pod as well as seeds (Thangjam *et al.* 2003a) A seminar in 2009 held in Manipur University voiced concern about its conservation and scientific measures for insect and/or fungus attack. It is therefore imperative to save this important tree from extinction.The information on the provenance variation and regeneration ecology of *P. roxburghii* is lacking. Hence, the present study has been undertaken with the following objectives:

- to assess population structure of *Parkia roxburgii* in different provenances in northeastern India, and
- to study provenance variability in fruit and seed traits, seed germination and seedling growth.

REVIEW OF LITERATURE

Parkia is a genus of Fabaceae (earlier sub-family: Mimosaceae) named after the African explorer and a Scottish surgeon Mungo Park by Robert Bran in 1826 (Oladunmoye, 2007). Luckow and Hopkins (1995) identified the genus *Parkia* as many as ≈ 31 species that are distributed through both the New World and Old World tropics and is taxonomically most diverse in the rainforests of the Amazon Basin in addition to four species found in Africa and Madagascar and about ten in the Indo-Pacific region. Species of *Parkia* show a large degree of sympatry in both the New and Old world and different characters might embody various degrees of dependence on the evolutionary hypothesis. The Indo-Pacific species are distributed from northeast India to Fiji whose section is closely related to the African counterpart. New World taxa were all included in an area designated as South America even though *P. pendula* is also found in Central America. 'Africa' and only one species restricting to 'Madagascar' became two areas, and Indo-Pacific region was also divided into 'India/Malaysia' (included Asia, the Malay Peninsula, and the Malay Archipelago as far as the Vogelkop, W. New Guinea) and 'Pacific' (included central & eastern New Guinea, the Solomon Islands, Fiji, Ponaoe and Palau). The African species are basically red-flowered while the Asian ones have cream or yellow flowers (Fig. 2.1).

Genus *Parkia* is is the most speciose groups of chiropterophilous plants known, yet several of them are entomophilous with ability to attract diverse pollinators which has largely contributed to a wealth of morphological variations (Luckow and Hopkins 1995). However, Indo-Pacific species have not been explored much of pollination behaviour as compared to the African and South American counterparts.

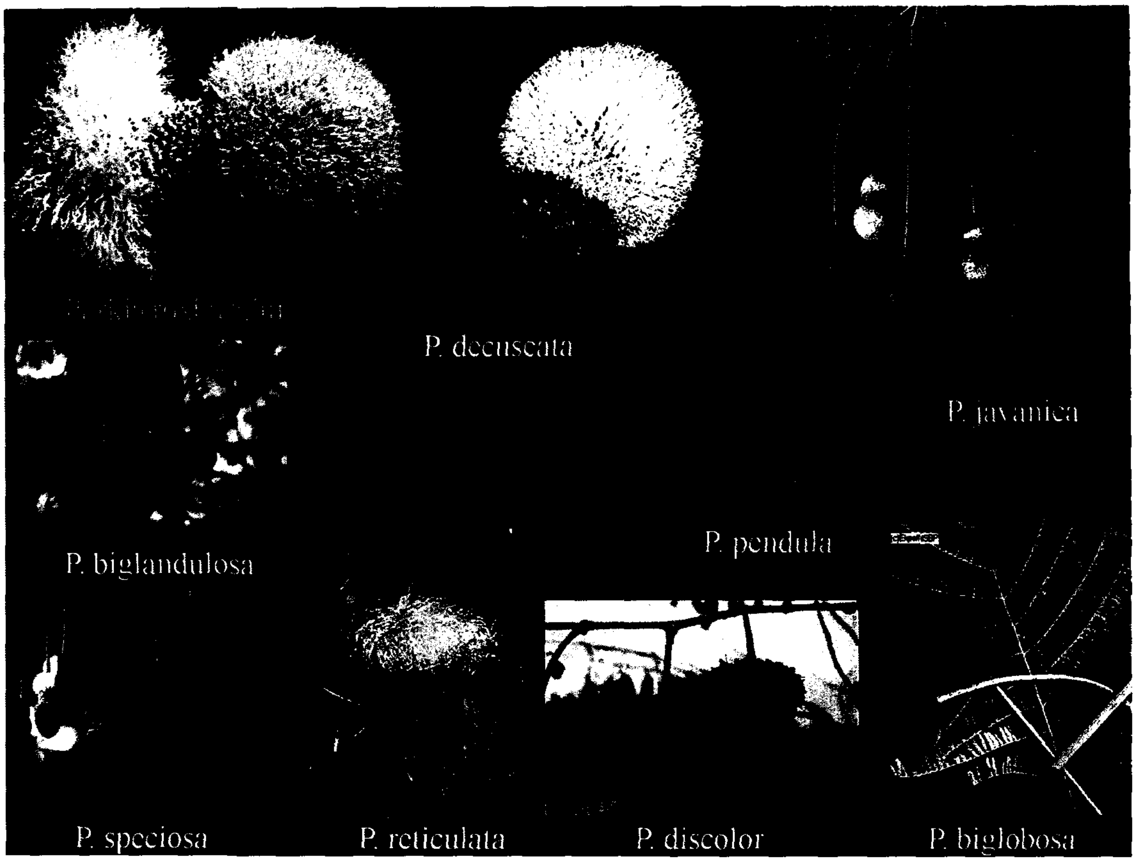


Fig. 2.1. Variation in flower color among species of *Parkia* genus.

Bats were first spotted visiting *Parkia* in Java and few authors have then reported chiropterophilous pollination in some more species of both the Old and New World (Hopkins 1984). Bats visits most often between 2000 to 2100 hrs and each of them land on the capitulum for a mean of 2 seconds even during rains (Hopkins 1994). Confirmation on bat as pollinator needs more study on many species, although the structure of a capitulum might suggests the same. Pollen vectors must land on the capitulum to become dusted. Luckow and Hopkins (1995) analyzed the genus *Parkia* cladistically and their consensus tree supports monophyletic with the section *Platyparkia* and paraphyletic with *Sphaeroparkia*. Inflorescences varied among three sections based on the different kinds and arrangement of flowers in the capitulum

(Hopkins 1986). *Parkia* has the most complex type of capitulum, variation in dehiscence and differs in seed morphology and seedlings growth pattern (Luckow and Hopkins 1995).

Parkia has a pantropical distribution divided into three disjunct parts from Honduras to southern Brazil, and is most diverse in the Amazon basin. Four species are indigenous to India, viz., *Parkia roxburghii* G. Don., *P. biglandulosa* W. & A., *P. leiophylla* Kurz. and *P. insignis* Kurz. (Don and Singh 1986). While the information on geographical distribution of the last three species is not available, *P. roxburghii* is indigenous to northeastern India. *Parkia roxburghii* is an evergreen tree belonging to the family Mimosoidae with 70-80 feet in height (Don and Singh 1986, Longvah and Deosthale 1998, Singh *et al.* 2000, Thangjam *et al.* 2003a). *Parkia roxburghii* G. Don is believed to have its primary and secondary origin from the northeastern states of India and grows from 400 to 1,200 m in the tropical forests (Don and Singh 1986, Singh *et al.* 2000). The tree is handsome with shiny bipinnate foliage and bunches of beautiful flowers that enhance the aesthetic value of the place that it grows. The complete leaf shedding occurred simultaneously with the fruit ripening at the end of the dry season. The begin of leaf shedding, and the dates of total defoliation and newly foliated crowns took place two to four weeks earlier in the forest than in the domesticated habitats.

The flowers are grouped together to form a semi rounded head with a long common stalk (Longvah and Deosthale 1998) with flower heads resembling fluffy yellow gong-sticks (staminodial flowers proximally, fertile flowers distally and nectar secreting flowers between them), and they produce bunches of pendent, sometimes twisted, strap-shaped pods (Hopkins 1994) which decorates the tree as a free flow green ribbons wrapped in a rubber strap. The fruits are long pods in clusters of about 20 to 40 attached to a common stalk (Don and Singh 1986). The fruit are green in color and measure up to 50 cm in length. Exudation of the sticky seedpod gum starts a few weeks after flowering. A fully matured fruit is deep black in color and contains yellow dry powdery, mealy, sweet edible pulp in which black colored seeds remain embedded (Aliero 2001, 2004) and vary widely (Singh *et al.* 2000) in weight, length, width, angle of twist, taste, pedicle length and number of seeds embedded from one variety to another. This study observed a number of *P. roxburghii* pods decreasing drastically due to abortion during fruit development. The bark is light grey with patches. Its pod and seeds are eaten raw or cooked in the form of chutneys and fermented form by many people residing around its natural occurrence (Longvah and Deosthale 1998, Hassan and Umar 2005, Achi 2005, Kaur *et al.* 2005). Its flowers can also be relished as raw or cooked (Don and Singh 1986). Favourite dishes like *Petai* in Malay-Peninsula, *Dawa dawa* in Africa and *Aromba* in Manipur of India have been an age long traditional delicacies that this tree has been offering. Naga tribes of India have a practice of domesticating this species in their home gardens as a sign of wealth especially before they engaged the groom to the bride for marriage.

It is a multipurpose tree known for its subsistence products and a source of cash income. Livelihood generation through tree bean has the potential to generate sizeable household income of Rs. 3,500 that may be comparable to, as even more than the income from the sale of agricultural crops (Rocky *et al.* 2002, 2004). Its timber is valued for making boxes, decorative articles (Sharma *et al.* 1993) and light furniture. The genus is a good fodder tree whose fruit serves as food, wood as firewood and timber in the humid zone of Nigeria (Sabiiti and Cobbina 1992), had good association with crops in various agroforestry systems of West Africa (Kater *et al.* 1992), recycle nutrients from deep soil and also prevent soil erosion (Alabi *et* al. 2005). The bark contains 6-15% tannin reported to be useful in tannin industry and the wood can also be used as a source of paper pulp (Anonymous 1966). High fat content and high degree of unsaturation may boost extraction of some edible oils from the genus. Salam *et al.* (1995) reported for the first time the effect of 1-2 % seed oil of *P. roxburghii* a potential insecticide on aphids. *Parkia* is also useful as a shade tree to tea plantations (Dhyani and Chauhan 1990) and to farmers as well (Alabi *et al.* 2005). It is a highly preferred agroforestry tree species in the home gardens and *jhum* affected areas of northeastern India being a fast growing nitrogen-fixing tree with edible fruits. In favourable season, a mature tree of *P. roxburghii* bears fruit which can fetch approximately Rs. 8,000 to Rs. 10,000 per annum to the grower (Rocky *et al.* 2004). The seeds and pods of *P. roxburghii* are reported to cure stomach disorders and regulate liver functions. Pods pounded in water are used in washing face and head (Burkill 1935, Quisimbing 1951, Sharma *et al.* 1993). The bark and leaves are used in making lotion for skin diseases and ulcers. Fomentation of decoction of leaves to the rheumatic affected parts is beneficial (Sharma *et al.* 1993). Lectins extracted from seed of *P. roxburghii* were found to show anti-proliferative effect on two murine macrophage cancers and have mitogenic properties (Kaur *et al.* 2005)

2.1. *Regeneration and multiplication*

Population dynamics of seedlings and saplings in the forest community determines the regeneration status of a species. Success of natural regeneration is governed by the presence of sufficient number of seeding trees, seedling, saplings (Duchok *et al.* 2005, Pokhriyal *et al.* 2010), minimum biotic interference, congenial environment for the newly dispersed seeds to germinate and the power of each seedling to establish into a sapling/tree (Clement 1936, Bhuyan *et al.* 2002, Teketay 2005). While the presence of established saplings and adult trees will determine the future composition of a community, the age structure of their populations will predict the regeneration status (Pokhriyal *et al.* 2010).

Multiplication and propagation of *Parkia* is mainly through seeds as the seeds germinate easily. However, fruit and seed of *P. roxburghii* are a favourite food of many insects (Thangjam *et al.* 2003a), rodents and primates posing a threat to a chance of natural regeneration in the wild. Seedlings of the genus *Parkia* are rarely seen in the wild (Aliero 2004) and the existing trees are ageing and fast disappearing. We failed to spot any seedling of *P. timoriana* throughout the surveyed area of the northeastern region of India. Genetic and environmental factors influence the seed germination behaviour and continue to do so during the seedling development. Therefore, seed germination constitutes a critical phase for the survival of the plant species. The position of *Parkia* genus is uncertain within the Mimosoideae due to difficulty to interpret homologies when comparing them with other taxa (Lewis and Elias 1981, Luckow and Hopkins 1995). Many ecotypes of *Parkia roxburghii* must have developed during the process of evolution due to a vast distribution in different climatic and edaphic zones of this part of the region. A wide range of diversity was observed in *Parkia roxburghii* genotypes within Manipur due to climatic and altitudinal variations (Singh *et al.* 2000).

Delineating and selecting the best available geographic source of seeds as planting material will help identifying the most important ecotype of this species. Studies in several forest trees have revealed that the seed character of a particular species can be indicative of the quality of the seed through their strong correlation with seed germination (Toon *et al.* 1990). Uma Shankar (2006) reported that seeds heavier in weight regulated the success of germination and early seedling growth of 'hollong' (*Dipterocarpus macrocarpus*) which otherwise germinated but failed to develop into seedlings. Significant differences in seed dimensions and germination characteristics due to variation in provenances have also been observed (Kumar 1979, Bedell 1989). Large diameter and heavy seeds have more success of germination compared to large diameter but small weight and small diameter with light weight in 'hollong' (Uma Shankar 2006). A weak correlation was reported between seed characteristics and germination of *Tectona grandis*; the higher dimensions could be attributed to better differential seed filling based on site factors or locality (Jayashankar *et al.* 1999), seed nutrient content (Abideen *et al.* 1993) and environmental influences (Willan 1985). Nonetheless, vegetative propagation aims at obtaining plants of desired genetic constituents to improve growth and yield. Yet, vegetative propagation of *Parkia* to maintain purity of strain/variety is little known so far (Don and Singh 1986). *Parkia* could be successfully cultivated through stump planting (Singh *et al.* 2000) and branch cuttings for true to type siblings. The performance, quality and genetic potential of stumps in teak (*Tectona grandis*) had a positive relationship between height and collar diameter of the seedlings prior to modifying them into stumps (Jayashankar *et al.* 1999). Healthy seedlings may however be achieved through provenance trial followed by a proper selection of superior seed populations for further multiplication.

2.2. *Nutritional prospects*

From time immemorial, genus *Parkia* has been contributing towards healing stomach upsets and several skin diseases through concoctions and direct consumption. The genus is known for its edible immature pod and in some species seeds are also consumed. *Parkia clappertoniana, P. biglobosa, P. filicoideaei* in Nigeria and *P. roxburghii* in northeastern India are used regularly as food resources (Longvah and Deosthale 1998). The nutrient composition and food potentiality of genus *Parkia* have been carried out by various workers since a few decades (Longvah and Deosthale 1998 and Kaur *et al.* 2005 in *P. roxburghii*, Alabi *et al.* 2005, Hassan and Umar 2005 and Esenwah and Ikenebomeh 2008 in *P. biglobosa,* Achi 2005 in *P. filicoidea* and Kaur *et al.* 2005 in *P. biglandulosa*). The genus was reported rich in lipid, protein, carbohydrate, soluble sugars, ascorbic acids, amino acids and fatty acids. With maturity of fruits, *P. roxburghii* accumulated more protein, fats, behenic acids, lignoceric acids and amino acids whereas, a concomitant decrease of ash, carbohydrate, palmitic and linoleic acid was observed (Longvah and Deosthale 1998). Investigations conducted in Manipur (part of the northeastern states of India) to evaluate organoleptic characteristics from nine tree bean types from separate source revealed that Thingmai followed by Tamenglong type gave the best taste. Jiri type was the least satisfactory. It appears that the dry matter accumulation at different sites has a relationship with specific gravity in tree bean (Meitei and Singh 1990). Salam *et al.* (1992) studied biochemical and nutritional value in different developmental stages of fruits of *P. roxburghii* grown in Kangchup, Manipur and reported comparatively higher values of acidity, vitamin C, crude proteins and nitrogen free extract in tender stage than young, mature and over mature pods. They further stated that seeds of over mature pods show the highest crude fats, total digestible nutrients, digestible energy and metabolizable energy. The protein content in *P. roxburghii* was 29 % in seed kernel, ranged between 13–19 % in pods whereas; the fat content was higher (34%) in the kernels and ranged between 1–16 % in pods (Longvah and Deosthale 1998). The protein content in *P. roxburghii* is slightly lower to those reported by Alabi et al. (35 %; 1993 & 34.02 %; 2005), Hassan and Umar (32.40 %; 2005), Obizoba (34.30 %; 1998) and Okpala (31.60 %; 1990) in *P. biglobosa*. However, we failed to identify a document fully dealing with the evaluation of nutritional and antinutritional properties of seed kernels and immature fruits of *P. timoriana* across geographical distribution in northeastern India.

Post-harvest products and fermented foods such as '*dawadawa*' from *P. biglobosa* in Africa and '*petai*' from *Parkia speciosa* in Southeast Asia have been reported by several authors. These processed condiments are rich in proteins and adds flavor to the diet. The effect of fermentation on protein content is not clear as statements of some authors are contradicting to each other. While Oladunmoye (2007) reported a decrease in protein content after fermentation of *P. biglobosa* seeds, Esenwah and Ikenebomeh (2008) contradicted the former findings. However, fermentation following soaking and boiling of seeds further reduces the carbohydrate, ash (Oladunmoye 2007, *Esenwah et al.* 2008), ether extract, fats, crude fibers contents, pH and anti-nutritional factors (Esenwah and Ikenebomeh 2008). Oladunmoye, (2007) reported some bacteria (*Staphylococcus aureus* and *Baccilus* sp.) and fungus (*Fusarium* sp., *Aspergillus* sp. and *Penicillium* sp.) are involved in the fermentation process. Pelig-Ba (2009) studied the effect of adding external agent viz., ash, potassium hydroxide (KOH) and millet to *dawadawa* fermentation process, and observed an increase in protein content with the addition of ash and millet while decreased with KOH.

2.3. *Population structure*

Literature survey reveals a lack of studies on population structure of the genus *Parkia.* The typical habitat of *Parkia* throughout its range is lowland rain and hill forests. Neotropical species of *Parkia* are associated with nutrient-poor, white sand soils but no Indo-Pacific species are reported from any heath forest (Luckow and Hopkins 1995). *P. timoriana* is spotted naturally in evergreen primary and rain forest, moist mixed deciduous forest and dry evergreen forest on flat and hilly ground usually between 170 – 980 m elevations with meager information on its ecology. *P. timoriana* is cultivated in *Jhum* affected areas and home gardens on various soils and climatic zones of the northeastern India. *Parkia* trees are often felled in the process of forest clearing for shifting cultivation especially in Meghalaya, owing to the fact that until recent time the local populace had no knowledge of its edible potentiality. Throughout the region, seedlings of *P. timoriana* are rarely seen in the wild inspite of seeds germinating easily. Seeds/pods are consumed both by human and animals (white ants, rodents and primates) reducing the chance of natural germination within. Unabated pace of *jhum* cultivation in fresh forests throughout the region and fruit collection for nominal business has potentially caused the shrinkage of the seed bank in the soil. Over exploitation in Rudraksh (Bhuyan *et al.* 2002) is a similar finding with this study where *P. timoriana* also experiences a sporadic occurrence. Therefore, biological conservation is necessary to avoid threatened category.

Highly exploited plants are often a victim of less germination and multiplication within its ecological niche. Bhuyan *et al.* (2002) recorded only two to four saplings of *Elaeocarpus ganitrus* against 200 seedlings per hectare in the mildly disturbed to undisturbed forests, no saplings and a hundred seedlings in the moderately-disturbed forest with no trace of both saplings and seedlings in the highly disturbed forests. Seeds germinated easily but poor density of adults and saplings of *E. ganitrus* in all studied stands suggests a severe mortality of seedlings. Survival of seedlings after one year showed better growth response in mildly-disturbed (59 %) and undisturbed (50 %) forests. However, establishment of germinated seedlings of *E. ganitrus* to either saplings or adults are reportedly restricted due to competition for resources, allelopathic reaction and folivory by leaf-eating caterpillars. In this study, low density of *P. timoriana* was also observed with sparse distribution in natural stands. Lack of seedlings and saplings throughout the growing habitat of *P. timoriana* invites a risk of severe genetic drift and/or extinction if left unattended. Moreover, the mature existing trees are ageing and fast disappearing due to a possible dieback disease from all over the region. Thorough study to identify responsible pest on *P. timoriana* needs more attention from research scientists to safeguard its existence.

P. biglobosa from Africa (Aliero 2004, Odebiyi *et al.* 2004) suggests a similar threat to regeneration and establishment in the parklands as well as in the wild. Odebiyi *et al.*

(2004) assessed the distribution and population of *P. biglobosa* in the cultivated and fallow land use in three ecozones (moist woodland or derived savannah, dry woodland or southern Guinea savannah and northern Guinea savannah), where an overall density of *P. biglobosa* is only 6.6 plants/ha and same species replacement and regeneration was low. While saplings of *P. biglobosa* were not recorded in their studied ecozones, large trees accounted for 39 % and 38 % of the population in cultivated and fallow land uses, respectively. Further, they reported similar distribution of girth classes of *P. biglobosa* in the two land use system of all zones.

Typification, synonymy and confusion have often been observed in describing the species and sub-species of genus *Parkia* throughout its distribution (Hopkins 2000, Luckow and Hopkins 1995). A brief taxonomic description on species of the genus *Parkia* found from the New as well as Old world have been well distinguished (Luckow and Hopkins 1995, Hopkins 1984, 1994). Two new species, first being *Parkia paya* from swamp forest of Malesia of the Indo-Pacific region and the other is *Parkia barnebyana* from Venezuelan Guyana were discovered in the 21st century which till then known as synonyms or confused with other related species (Hopkins 2000,). Cultivation has played a significant role in the taxonomy of *Parkia* species. For instance, *Parkia pedunculata* is known only from cultivation from northeast India and various botanical gardens, and its origin remains a mystery (Hopkins 1994). Is *P. pedunculata* another species found in this region? However, Hopkins (1994) failed to specify the exact location of the species and also did not describe elsewhere its taxonomy, biology, distribution, ecology etc. Apart from '*Parkia timoriana*' or as synonym species '*P. roxburghii*', local/regional floras of northeastern India as well as scientific literatures revealed no possibility of any existence of another species within the genus.

THE SPECIES AND STUDY SITES

3.1. *The Species*

Parkia roxburghii G. Don. (Syn. *Parkia timoriana* (DC.) Merr.) of Fabaceae (Mimosaceae) occurs in Southeast Asia and Pacific region (Fig. 3.1). In India, it is distributed in Arunachal Pradesh, Cachar hills of Assam, Garo and Khasi Hills of Meghalaya, Lushai Hills, Kolasib – Bukpui and Sialsuk road in Upper Thenzawl area of Mizoram and Imphal, Kangpokpi and Pachao of Manipur (Hajra *et al.* 1996, Singh *et al.* 2002, Singh *et al.* 2002). The species is also reported from Chittagong and Sylhet of Bangladesh, Myanmar and Malay Peninsula (Hooker 1973).

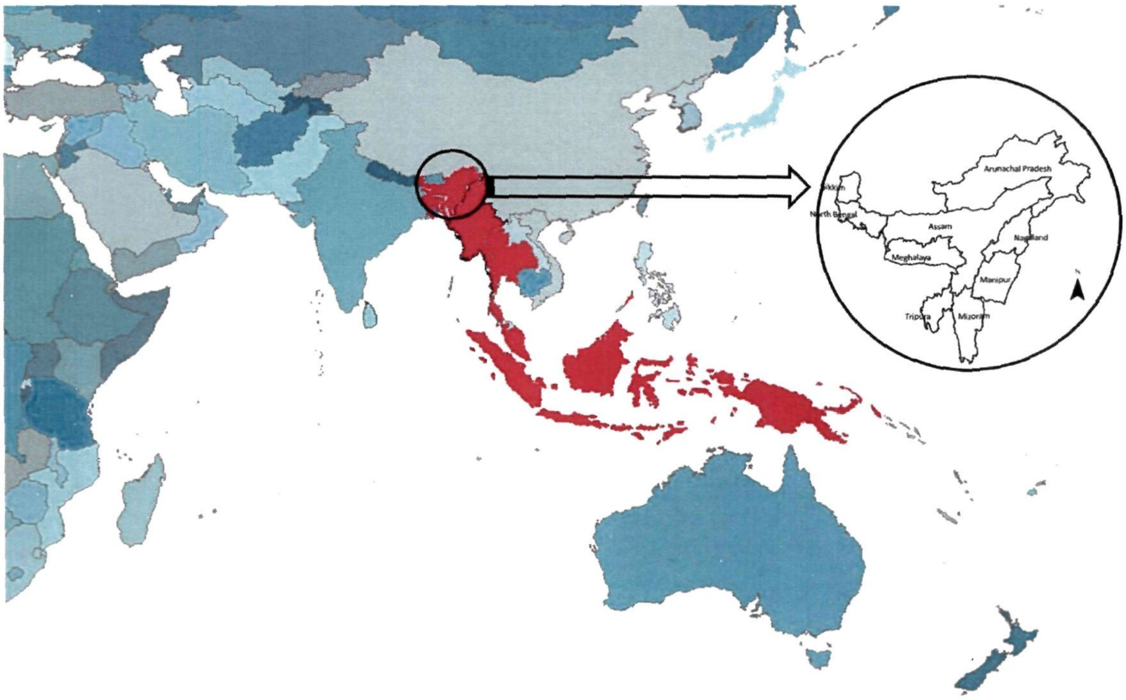


Fig. 3.1. Distribution of *Parkia roxburghii* in the world (red). The study sites in northeastern India are encircled. Source: Longvah and Deosthale (1998), Hopkins (1993, 1994), Ridley (1992), Meitei and Singh (1990) and Kanjilal *et al.* (1938).

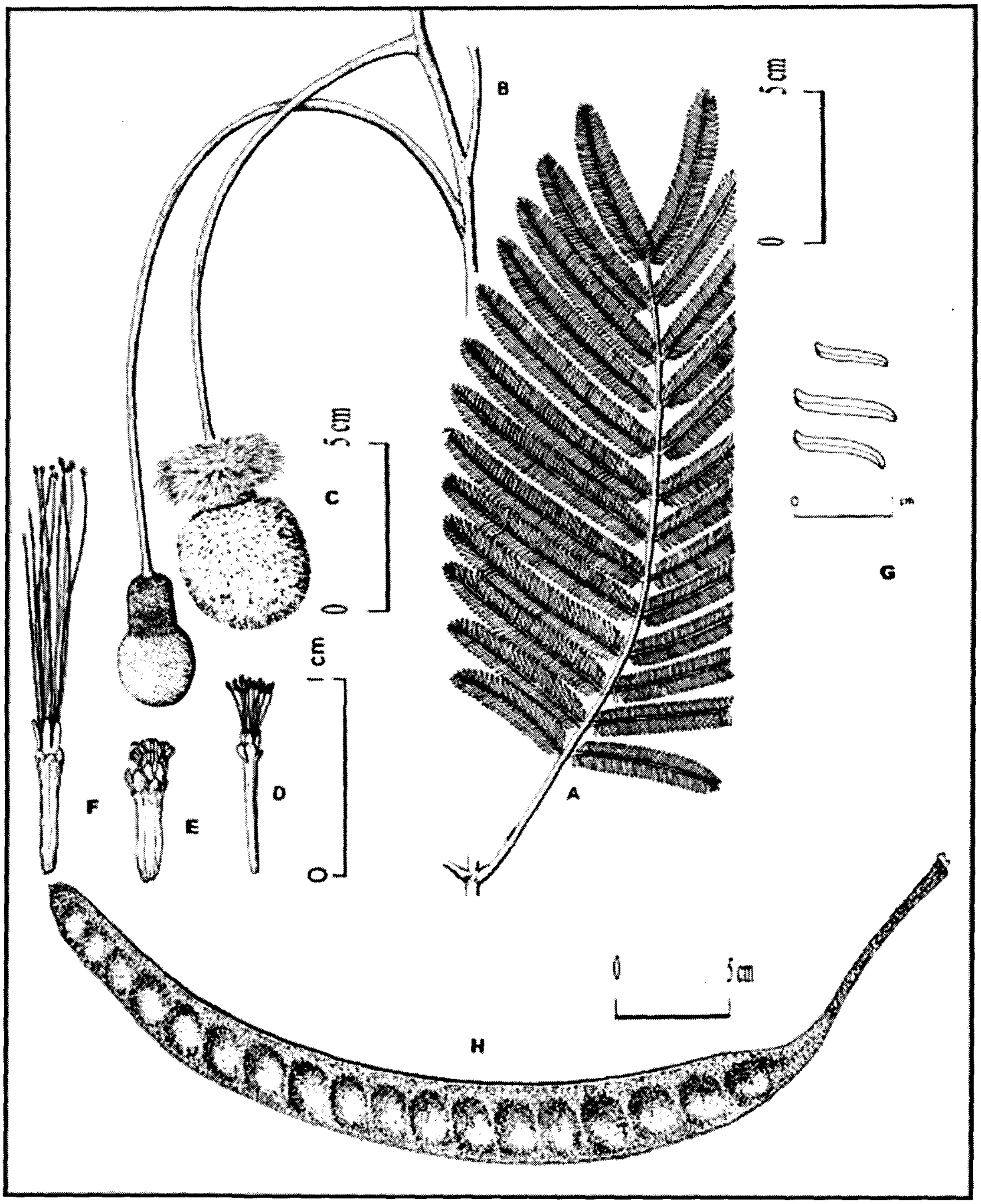
Parkia roxburghii is popularly known as 'tree bean' in English and with many other names in local languages of many other parts of the world (Table 3.1).

Table 3.1. Vernacular names of *P. roxburghii* in various parts the world.

Country	State/island	Vernacular name/s
India	Assam	Khorial and Manipuri-urohi, Barri-phang
India	Mizoram	Zongtah (Sumai), Chaaw (Sa ua)
India	Manipur	Yongchak, Manipuri Seem
India	Nagaland	Unkam Pinching
India	Meghalaya	Sohbtar and Jingbam Tngaw (Khasi), Armaregup, Aoelgap (Garo)
Burma	-	Mai-Karien (Shaan)
Thailand	-	Riang, Karieng, and spelling variants (Thai)
Malay Peninsula	-	Kedawong, Kada-ong, Petai kerayong, Gudayong, Kuayong, Neneting, Tayur
Indonesia	Sumatra	Alai, Alei
Indonesia	Java	Kedawoeng and spelling variants (mid & E. Java), Peundeuj, Dawoeng, Petir (W. Java), Pondej
Indonesia	Sumbawa	Kopang
Indonesia	Sulawesi	Olimbopo (Tolalaki)
Indonesia	Kalimantan	Koepang (Bandji)
Malaysia	Sarawak	Buah batar (Kelabit)
Malaysia	Sabah	Timbarayong
Philippines	Palawan	Amarang
Philippines	Luzon	Cupang or Kupang (Taf, Tagalog, Visayan)

P. roxburghii is usually a medium-sized tree having a grayish-brown bark with 15-25 m height (Bose et al. 1998, Singh et al. 2000). The leaves are alternate with 18-42 cm long primary rachis including petiole and consist of 14-31 pairs of pinnae arranged opposite or subopposite (Fig. 3.1). The lower pinnae are often caducous. The 52-72 pairs of leaflets on each pinnae are with stiff white hairs that are dens on upper surface (abaxial) but sparse on lower surface (adaxial). The peduncles are alternately arranged usually 4-7 per compound inflorescence (Fig. 3.2). The capitulum is somewhat biglobose at anthesis with central constricted nectar-secreting region and short broader basal staminodial region (Hopkins 1994). The flowers are hermaphroditic with calyx 9-10.5 mm long including pseudopedicel, corolla 10-11 mm long and filaments exserted 2-3.5 mm beyond calyx. The flowers appear from September to October and develop into a strapped-shaped fruit in about four months from anthesis and are available for harvest during February to March (Holttum 1931, 1940).

P. roxburghii is often reported as a synonym of *P. timoriana* (Bose et al. 1998, Singh et al. 2000, Thangjam et al. 2003a/b). However, Prain (1897-98), Merill (1910), Ridley (1922) and Hopkins (1994) expressed doubts of the conspecificity between *P. timoriana* and *P. roxburghii* when samples from Southeast Asia and northeast India are compared, respectively.



Source: Figures A to G, redrawn from Hopkins (1995).

Fig. 3.2. An illustration of plant parts of *Parkia roxburghii*: (A) a leaf, (B) a drooping capitulum, (C) flowers at anthesis, (D) a fertile flower (E) a nectar secreting flower (F) a staminode, (G) leaflets, and (H) a mature fruit (pod).

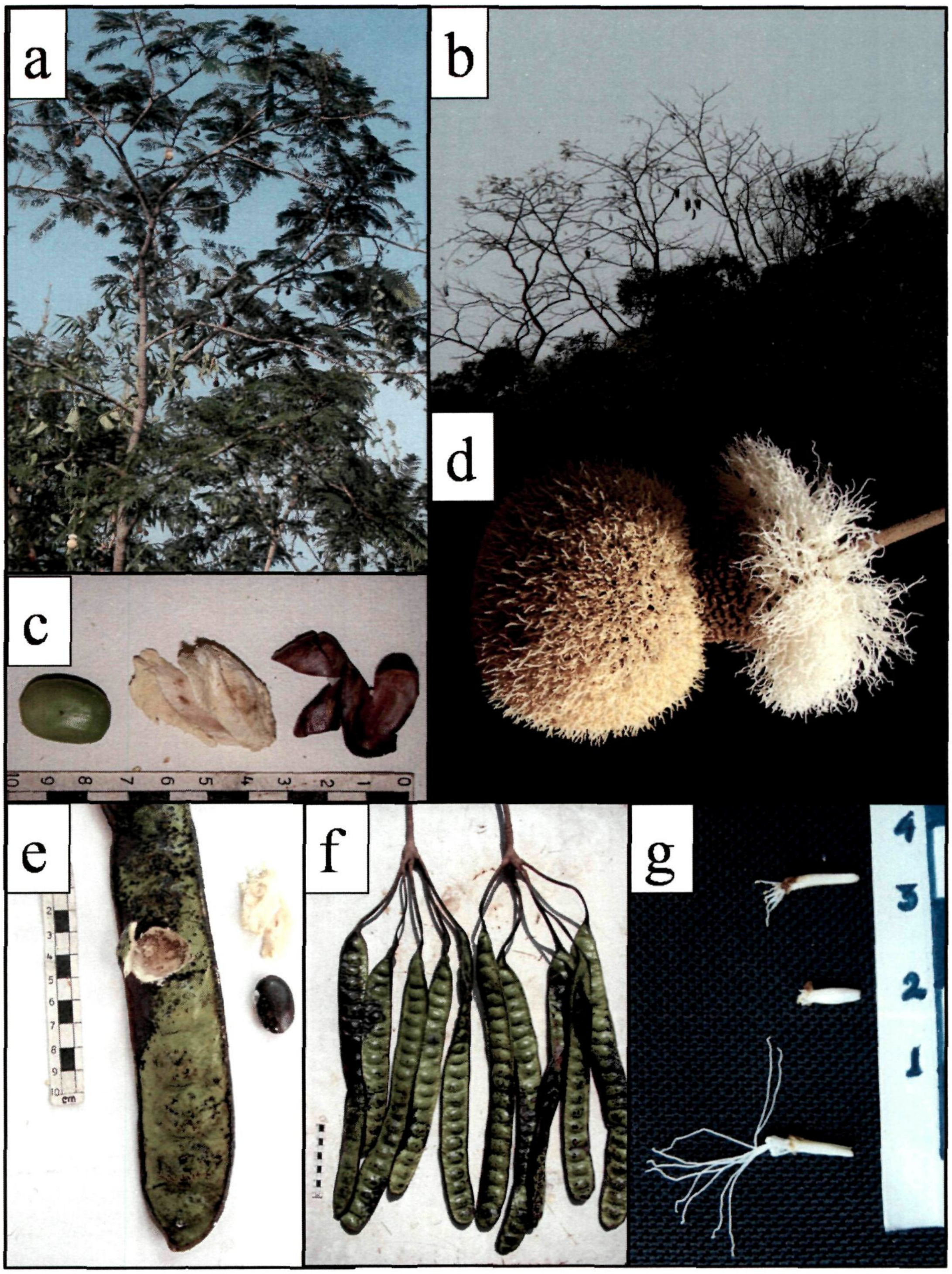


Fig. 3.3. A photographic illustration of plant parts of *Parkia roxburghii*; (a) a flowering tree, (b) a fruiting tree, (c) cotyledon with seed cover and pulp (d) capitulum bearing flowers at anthesis, (e) exposed seed and pulp (f) tender, strap-shaped pods, and (g) flowers and staminode.

P. roxburghii has ornamental value owing to its showy capitulum at flowering stage and chime-like drooping pods at fruiting stage (Figs. 3.2, 3.3). Hence, the tree is planted in the homegardens, *jhum* fallows and marginal land along roads in northeastern India (Kanjilal *et al.* 1938, Sharma *et al.* 1993, Thangjam *et al.* 2003, Rocky *et al.* 2004). The bark and leaves of *P. roxburghii* are used in lotions for skin diseases and ulcers (Bose et al. 1998). Pods and seeds are widely utilized, especially in the villages for curing toothache (Usher, 1954), and diarrhoea (Lewis and Lewis 1977, Bose et al. 1998). The pungent smell in the species is due to the presence of thiazolidine-4-carboxylic acid (TCA, thioproline), a cyclic sulphur-containing amino acid known to be anti-carcinogenic and inhibits the formation of squamous cell carcinomas in the fore-stomach (Suvachittanont *et al.* 1996, Tahira *et al.* 1984, 1988). A number of workers have reported the biochemical and nutritional values of the plant, including various medicinal uses (Quisumbing 1951, Burkill 1966, Sharma *et al.* 1993, Mohan and Janardhanan 1993, Salam 1995 and Longvah and Deosthale 1998). The tender pod is eaten either raw or cooked and has a potential source of protein and fat (Bose et al. 1998, Longvah and Deosthale 1998). The seeds are used as flavouring and nutritive additives to soups/stews and contain about 54% fat and 30% protein obesides vitamins and minerals (Aliero 2004, Longvah and Deosthale 1998).

3.2. *Study sites*

P. roxburghii occurs mainly at lower elevations of the lowland and hill forests, evergreen rainforests, moist-mixed deciduous forests and dry evergreen forests usually between 0 and 600 m elevation. It may grow rarely to 1,300 m of the upper limit Dipterocarp forest in northeast India, Bangladesh and Borneo (Hopkins 1994). In the present study, we encountered *P. roxburghii* in the wild along tropical semi-evergreen and subtropical broadleaved hill forests of the northeastern India where *Schima wallichii, Areca catechu, Tectona grandis, Artocarpus macrophylla, Pinus kesiya, Duabanga grandiflora, Gmelina arborea, Quercus serrata* occur.

The present study was carried out in four States of northeastern region of India, viz., Manipur, Meghalaya, Mizoram and Nagaland (Fig. 3.3). A reconnaissance survey for exploration of natural populations of *P. roxburghii* was carried out in September, 2004. The 23 surveyed populations of *P. roxburghii* belonged to modified communities and only few trees were found growing in the wild with signs of poor or no regeneration (Table 3.2). The most occurrences were in homegardens and jhum fallows.

Of these, seven provenances (populations) were selected that contained higher concentration of *P. roxburghii* individuals. The selection of site was also due to the presence of healthy trees, accessibility of trees to climb on, accessibility of the sites in all weather conditions round-the-year and known history of the sites. Selection of a site in Manipur was based on 'palatability preference' of edible parts by local people. In Nagaland, *P. roxburghii* was found to be growing profusely in homegardens of Peren and Dimapur districts. In Meghalaya, *P. roxburghii* grows naturally in the tropical forests bordering Bangladesh. However, the final selection of study sites or provenances was made after comparing their distance apart with not less than 10 km and their variation in altitudes of a minimum 100 m within a State. A reconnaissance survey revealed many naturally growing pockets of *P. roxburghii* where only seven best provenances have been selected for further studies (Fig. 3.4).

Table 3.2. A list of 23 populations of *P. roxburghii* surveyed for selection of provenances for further study in northeastern India.

State	District	Population	Habitat	Latitude	Longitude	Altitude (m)
Meghalaya	E. Khasi Hills	Mawshamok	Wild, *jhum*	25°13'	91°43'	700
Meghalaya	E. Khasi Hills	Tyrna	Wild, *jhum*	25°14'	91°43'	680
Meghalaya	E. Khasi Hills	Mawriang	Wild, homegarden	25°12'	91°59'	780
Meghalaya	E. Khasi Hills	Nonglait	Wild, *jhum*	25°12'	91°34'	440
Meghalaya	E. Khasi Hills	Dawki	Wild	25°10'	91°01'	260
Meghalaya	E. Khasi Hills	Mawlynnong	Wild	25°12'	91°53'	538
Meghalaya	Jaintia Hills	Umlari	Wild, *jhum*	25°14'	92°05'	500
Meghalaya	Jaintia Hills	Tamabil	Homegarden	25°10'	92°04'	270
Meghalaya	W. Khasi Hills	Pomblang	Wild, *jhum*	25°12'	91°19'	380
Meghalaya	W. Khasi Hills	Ranikor	Wild, *jhum*	25°12'	91°19'	170
Mizoram	Kolasib	Bilkhawthlir	Wild, *jhum*	24°13'	92°40'	680
Mizoram	Kolasib	Kolasib	Homegarden	24°21'	92°43'	643
Mizoram	Kolasib	Kawnpui	Wild, *jhum*	24°09'	92°41'	570
Mizoram	Kolasib	Tatow	Wild, *jhum*	-	-	400
Mizoram	Aizawl	Serkhan	Wild, *jhum*	-	-	980
Mizoram	Aizawl	Khamrang	Wild, *jhum*	-	-	240
Manipur	Imphal	Imphal	Homegarden	24°48'	93°56'	790
Manipur	Senapati	Moirang	Homegarden	24°30'	93°46'	794
Manipur	Senapati	Kangpokpi	Wild, homegarden	25°13'	94°00'	900
Manipur	Churachandpur	Thingkhangphai	Homegarden	24°20'	93°41'	810
Nagaland	Dimapur	Khaibung	Wild, homegarden	25°42'	93°52'	400
Nagaland	Peren	Samziuram	Homegarden	25°32'	93°43'	225
Nagaland	Peren	Kezanglwa	Wild, *jhum*	25°30'	93°42'	600

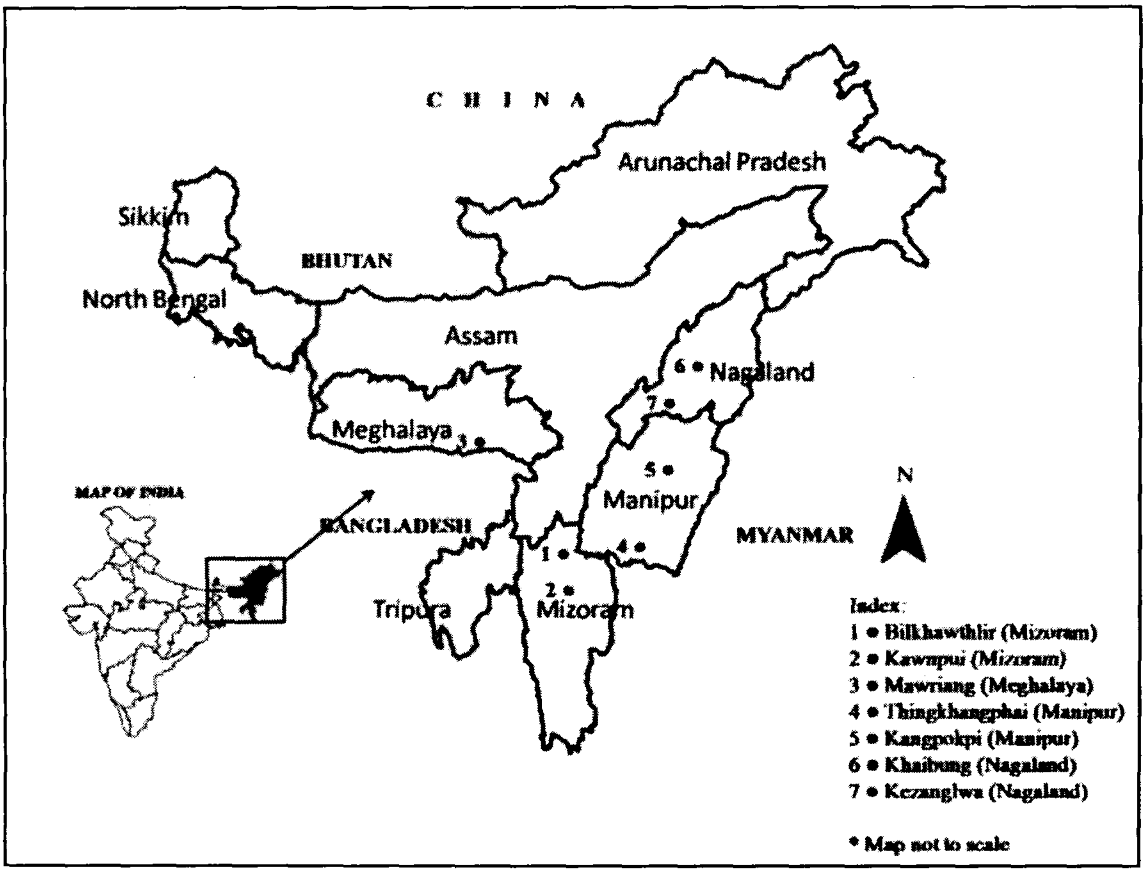


Fig. 3.4. Location map of the study sites of *Parkia roxburghii* in northeastern India

3.3. *Soil characteristics*

Soil samples were collected from surface (0-10 cm depth) and a sub-surface (10-20 cm depth) following monolith excavation technique from three randomly selected locations in each population. Air-dried soil samples passed through a 2 mm sieve were used for chemical analysis. A 1:2.5 suspension of soil-water was used to determine the pH. Organic carbon was determined by Walkley and Black's rapid titration method (Ref) and available nitrogen was determined by alkaline permanganate method (Subbiah and Asija 1956) and available phosphorus by Bray I method (Bray and Kurtz 1945). Available potassium and exchangeable cations (Ca and Mg) were determined using ammonium acetate (pH =7) as an extractant (Allen *et al.* 1974). The physicochemical properties of the soil are presented in Table 3.3.

Table 3.3. Physicochemical properties of soils of seven provenances of *P. roxburghii.*

Provenance	pH	Org. C (%)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Exc. Ca (meg/100g)	Exc. Mg (meg/100g)
			0-10 cm				
Bilkhawthlir	4.19	1.86	187.97	9.97	168.53	3.46	2.51
	±0.12	±0.18	±10.56	±0.14	±17.05	±0.25	±0.17
Kawnpui	4.62	1.68	194.30	10.10	184.53	3.07	2.38
	±0.39	±0.14	±14.55	±0.32	±4.85	±0.24	±0.08
Mawriang	4.73	1.93	227.77	11.82	157.70	3.14	1.79
	±0.24	±0.18	±0.72	±0.71	±6.99	±0.22	±0.03
Thingkhangphai	4.50	1.96	237.33	13.43	322.83	2.68	1.35
	±0.16	±0.08	±5.80	±0.87	±24.90	±0.03	±0.07
Kangpokpi	4.94	2.30	253.47	11.52	431.23	3.44	2.18
	±0.23	±0.17	±11.00	±0.54	±8.45	±0.10	±0.12
Khaibung	3.84	1.78	226.30	11.28	273.03	3.17	1.71
	±0.16	±0.05	±14.38	±0.22	±14.30	±0.28	±0.12
Kezanglwa	4.17	1.76	193.07	12.91	300.73	3.67	1.78
	±0.40	±0.22	±25.69	±1.30	±11.76	±0.35	±0.40
			10-20 cm				
Bilkhawthlir	3.94	1.65	212.20	9.09	182.53	2.64	2.43
	±0.09	±0.12	±3.12	±0.20	±3.42	±0.17	±0.24
Kawnpui	4.01	1.51	201.13	8.32	164.07	2.25	2.13
	±0.11	±0.10	±2.59	±0.58	±9.09	±0.08	±0.06
Mawriang	4.86	1.69	218.73	10.38	160.67	4.64	2.36
	±0.23	±0.13	±12.49	±0.60	±4.38	±0.08	±0.09
Thingkhangphai	5.11	2.00	226.60	10.26	242.07	3.56	2.20
	±0.22	±0.14	±4.97	±0.24	±12.68	±0.25	±0.19
Kangpokpi	5.12	2.01	239.97	11.83	316.83	3.87	2.61
	±0.23	±0.15	±4.65	±0.22	±6.03	±0.23	±0.14
Khaibung	2.69	1.90	172.63	9.32	227.47	3.38	1.82
	±0.53	±0.15	±3.91	±0.45	±8.18	±0.09	±0.05
Kezanglwa	4.33	1.71	183.77	9.69	280.40	3.18	1.93
	±0.58	±0.06	±8.44	±0.21	±3.69	±0.07	±0.22

3.4. *Selection of plus trees of P. roxburghii*

In each provenance, three random quadrats of 50 x 50 m (0.25 ha^2 area) were laid down at a distance of at least 10 m from each other. All individuals of *P. roxburghii* were enumerated and measured for girth, height, crown width, crown length and number of brances within each quadrat (Table 3.4). Five trees of superior phenotypic characters and bearing prolific pods were selected and marked in each population following standard procedures (FAO 1985, Khullar *et al.* 1991, ISTA 1999).

Table 3.4. Growth parameters of trees of *P. roxburghii* measured in seven provenances in four States of northeastern India for selection of plus trees for further study.

Provenance	DBH (cm)	Height (m)	Crown length (m)	Crown width (m)	Number of branches
Bilkhawthlir	12.20±4.36	24.36±3.88	14.68±2.87	16.11±2.72	14.09±1.37
Kawnpui	10.19±2.13	24.07±4.11	15.00±6.25	14.92±2.28	15.92±1.55
Mawriang	11.29±4.32	21.20±5.97	13.46±4.40	13.05±2.94	14.00±1.38
Thingkhangphai	12.45±3.20	21.26±5.63	14.52±5.01	13.53±1.85	13.81±1.91
Kangpokpi	13.36±3.75	26.80±2.09	14.38±1.73	11.88±1.56	11.80±2.04
Khaibung	15.87±3.55	22.30±7.54	11.50±3.08	10.23±3.18	13.40±3.26
Kezanglwa	14.72±1.11	24.25±3.58	11.70±1.45	11.84±1.46	12.20±1.98
Total	**12.86**	**23.46**	**13.60**	**13.08**	**13.60**

The DBH was measured at 1.37 m from the ground. The height was measured using a multimeter (Make and model: Ravi) at a distance of 20 m from axis of the trunk. If the tree canopy was invisible, the height was measured by climbing up to an accessible height and driving a bamboo stick into the crown. The crown width was measured in two directions perpendicular to each other running through the trunk. The crown length was measured between the first green branch and the tip of the tree. Five candidate plus trees with a distance of at least 100 m from each other were selected in each provenance for fruit and seed collection. The locality parameters were recorded in terms of latitude, longitude and altitude.

COMMUNITY STRUCTURE OF *Parkia roxburghii* HABITATS

4.1. Introduction

The information on the structure of the habitats of *Parkia roxburghii* is not available despite studies conducted on the nutritional aspects of this species (Longvah and Deosthale 1998, Meitei and Singh 1990). In northeastern region of India, *P. roxburghii* is distributed over a large geographical area spanning the States of Manipur, Meghalaya, Mizoram and Nagaland. However, the wild populations of *P. roxburghii* are not known. A few presumably wild trees may occur, but populations are not available. In fact, studies from other geographies have highlighted a severe decline in natural populations of *Parkia* species. Generally, seedlings of *Parkia* are scarcely available in the wild and the existing trees are ageing and fast disappearing (Aliero 2004). A similar species, *P. biglobosa* in Africa has a threat to regeneration and establishment in the parklands as well as in the wild (Aliero 2004, Odebiyi et al. 2004). Odebiyi et al. (2004) recorded an overall density of only 6.6 plants ha^{-1} with virtually no regeneration.

P. roxburghii grows in humid tropical environment, mostly dispersed in evergreen rainforests, moist-mixed deciduous forests and dry evergreen forests between 400 and 1,200 m. It can grow on nutrient poor (Luckow and Hopkins, 1995) to moderately rich soils in fallow lands of shifting agriculture, homegardens and tea plantations. In northeastern region, it occurs on slopes in lowland valleys with ample humidity, warmth and precipitation and also planted by people on marginal lands and homegardens (Kanjilal et al. 1938, Sharma et al. 1993, Rocky et al. 2004).

The objectives of this study were to: a) ascertain floristic composition of different habitats of *P. roxburghii*, b) determine the associates of *P. roxburghii*, and c) assess the regeneration status of *P. roxburghii*.

4.2. Material and methods

In each of the seven provenances selected for this study (see Chapter III), community structure of *P. roxburghii* habitats was studied at two levels: woody layer and herbaceous layer. The woody layer was analysed by laying transects of 500 m length and 10 m width (Sukumar et al. 1992, Uma Shankar 2001). In these transects, all stems ≥10 cm girth at breast height (gbh) at 1.37 m from the ground level were enumerated. The gbh, height (m) and phenophase (flowering, fruiting, leaf flush etc.) of all individuals were recorded. The herbaceous layer was analysed by placing three quadrats of 1 m x 1 m at three locations within each transect: one quadrat within first 100 m, one in the middle and one in the last 100 m. The individuals of each species (<10 cm gbh) occurring in quadrats were counted and their phenophases recorded. Specimens of all plant species encountered within transects were collected to aid identification.

The phytosociological analysis was done following standard methods (Mueller-Dombois *et al.* 1974, Greigh-Smith 1983, Uma Shankar 2001) and frequency, density, dominance and importance value index of all species were determined. Whitford's index (abundance-to-frequency ratio) was used as a measure of dispersion (Whitford 1949). The dispersion is considered regular for A/F ratio <0.025, random for 0.025 to 0.05 and contagious (clumped) for >0.05 (Singh et al. 2006). Species richness index was estimated following Whittaker (1972). Shannon's diversity index (H'), Simpson's dominance index (λ) and Pielou's evenness index (Pielou 1966) were calculated following Magurran (1988). The similarity between two sites was calculated following

Sorensen's similarity index (Sorensen 1948). The 2 x 2 contingency table was prepared to calculate index of association between two species, phi-coefficient of association and Pearson's chi-sqaure test of association (Sokal and Sneath 1963). STATISTICA 6.0 was used for most statistical analysis and plotting of graphs (StatSoft, Inc. 1995). The formulae are given below:

Whitford's index:

A/F ratio = abundance of the species / per cent frequency of the species

where, abundance is the number of individuals divided by the number of quadrats in which species occurred, and frequency is the ratio of the number of quadrats in which species occurred divided by the number of all quadrats in which species was studied.

Index of association:

$$IA = c + d / (a + b + c + d)$$

where, a = number of plots having both the species A and B

b = number of plots having only species A

c = number of plots having only species B

d = number of plots having both the species absent

Phi coefficient of association:

$$\phi = ad - bc / \sqrt{}(ab \cdot cd \cdot \ ac \cdot bd)$$

where, a = number of plots having both the species A and B

b = number of plots having only species A

c = number of plots having only species B

d = number of plots having both the species absent

Chi-square value:

$$\chi^2 = \phi^2 \cdot (a + b + c + d)$$

Sørensen's similarity index:

$= 2\ C \times 100 / (A+B)$

where, A = number of species in stand A

B = number of species in stand B

C = number of species common to both stands, A and B

Species richness index:

$= S\text{-}1 / \log_{10} N$

where, S = number of species

N = number of individuals

Shannon's diversity index:

$H' = -\Sigma \{(n_i)/N \times \log_{10} (n_i)/N\}$

where, n_i = importance value or number of individuals of i^{th} species

N = sum of importance values or number of individuals of all species

Simpson's dominance Index (λ):

$Cd = \Sigma(n_i / N) \times (n_i / N)$

where, n_i = importance value or number of individuals of i^{th} species

N = sum of importance values or number of individuals of all species

Pielou's evenness index:

$e = -\Sigma \{(n_i)/N \times \log (n_i)/N\} / \log S$

Where, n_i = importance value or number of individuals of i^{th} species

N = sum of importance values or number of individuals of all species

S = number of species

4.3. Results

4.3.1. *Woody layer*

The floristic composition of woody layer of *P. roxburghii* habitats (provenances) is given in Tables 4.1 through Table 4.7 individually for seven provenances. The provenances varied greatly in floristic composition, species richness and diversity. Mawriang was dominated by *Areca catechu* (IVI = 98.0, Table 4.1), Bilkhawthlir by *Tectona grandis* (IVI = 74.9, Table 4.2), Kawnpui by *Artocarpus heterophyllus* (IVI = 30.8, Table 4.3), Thingkhangphai by *Pinus kesiya* (IVI = 154.1, Table 4.4), Kangpokpi by *Quercus serrata* (IVI = 69.4, Table 4.5), Kezanglwa by *Tectona grandis* (IVI = 52.6, Table 4.6) and Khaibung by *Schima wallichii* (IVI = 44.6, Table 4.7). Only two provenances were dominated by naturally occurring (native) species, i.e., Kangpokpi by *Quercus serrata* and Khaibung by *Schima wallichii.* All other provenances were dominated by the planted species.

The identification of the species was a challenge as the flowers and fruits of several individuals could not be collected during the survey period. In some cases, only the families of the species could be determined with certainty and in a few cases only the generic name could be determined. They have been indicated wherever applicable. The original tag number of the species whose identity could not be determined is shown in the tables under the head 'species name'.

Table 4.1. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Mawriang provenance in Meghalaya.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Areca catechu*	Arecaceae	100.0	484.0	17678	98.0	8.3	0.242
2	*Artocarpus heterophyllus*	Moraceae	70.0	70.0	10147	32.9	8.7	0.071
3	*Cinnamomum tamala*	Lauraceae	70.0	26.0	5219	19.5	9.5	0.027
4	*Schima wallichii*	Theaceae	50.0	36.0	3337	15.4	5.8	0.072
5	MawT43	Unidentified	20.0	6.0	5453	12.0	8.2	0.075
6	*Musa* sp.	Musaceae	50.0	30.0	772	10.4	2.9	0.060
7	MawT40	Unidentified	20.0	12.0	3173	8.9	8.7	0.150
8	*Parkia roxburghii*	Fabaceae	20.0	10.0	3157	8.6	15.2	0.125
9	*Saurauia* sp.2	Actinidiaceae	30.0	24.0	852	7.6	4.8	0.133
10	*Syzygium formosum*	Myrtaceae	10.0	2.0	3677	7.4	14.0	0.100
11	*Maesa indica*	Myrsinaceae	40.0	8.0	658	6.5	8.5	0.025
12	*Itea macrophylla*	Iteaceae	10.0	12.0	1824	5.6	6.0	0.600
13	*Litsea monopetala*	Lauraceae	30.0	10.0	515	5.4	5.4	0.056
14	*Chukrasia* sp.	Meliaceae	30.0	6.0	750	5.3	8.3	0.033
15	*Syzygium* sp.	Myrtaceae	30.0	8.0	606	5.3	3.8	0.044
16	*Bambusa* sp.	Poaceae	30.0	8.0	44	4.4	10.8	0.044
17	*Ficus hirta*	Moraceae	30.0	6.0	40	4.1	3.3	0.033
18	*Ligustrum robustum*	Oleaceae	20.0	6.0	679	4.1	7.0	0.075
19	*Dracaena spicata*	Asparagaceae	20.0	10.0	91	3.6	3.8	0.125
20	*Aporosa oblonga*	Phyllanthaceae	20.0	4.0	172	3.0	3.0	0.050
21	*Phyllanthus emblica*	Phyllanthaceae	20.0	4.0	78	2.8	4.0	0.050
22	*Garcinia* sp.	Clusiaceae	20.0	4.0	54	2.8	4.0	0.050
23	*Citrus* sp.1	Rutaceae	10.0	6.0	343	2.4	4.7	0.300
24	MawT29	Unidentified	10.0	4.0	313	2.1	10.5	0.200
25	*Zanthoxylum ovalifolium*	Rutaceae	10.0	6.0	165	2.1	5.3	0.300
26	*Morinda angustifolia*	Rubiaceae	10.0	6.0	163	2.1	3.3	0.300
27	*Callicarpa arborea*	Lamiaceae	10.0	6.0	58	1.9	4.0	0.300
28	*Macaranga denticulata*	Euphorbiaceae	10.0	4.0	31	1.6	3.0	0.200
29	*Sapindus* sp.	Sapindaceae	10.0	4.0	25	1.6	3.0	0.200
30	*Alstonia scholaris*	Apocynaceae	10.0	2.0	58	1.4	4.0	0.100
31	*Ehretia* sp.	Boraginaceae	10.0	2.0	54	1.4	5.0	0.100
32	*Bauhinia variegata*	Fabaceae	10.0	2.0	39	1.4	5.0	0.100
33	*Trigonostemon semperflorens*	Euphorbiaceae	10.0	2.0	29	1.4	3.0	0.100
34	MawT35	Unidentified	10.0	2.0	20	1.4	10.0	0.100
35	*Artocarpus chaplasha*	Moraceae	10.0	2.0	13	1.4	5.0	0.100
36	*Ficus hispida*	Moraceae	10.0	2.0	13	1.4	5.0	0.100
37	*Mallotus roxburghianus*	Euphorbiaceae	10.0	2.0	10	1.4	3.0	0.100
38	*Psidium guajava*	Myrtaceae	10.0	2.0	8	1.4	3.0	0.100
	Total		900.0	840.0	60318	300.0	7.6	

Table 4.2. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Bilkhawthlir provenance in Mizoram.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Tectona grandis*	Lamiaceae	100.0	98.3	22846	74.9	13.5	0.049
2	*Duabanga grandiflora*	Lythraceae	100.0	43.3	8134	35.8	10.8	0.022
3	*Callicarpa arborea*	Lamiaceae	66.7	40.0	3822	23.9	7.4	0.045
4	*Areca catechu*	Arecaceae	58.3	40.0	1947	19.7	11.1	0.059
5	*Parkia roxburghii*	Fabaceae	58.3	16.7	4294	18.0	12.6	0.024
6	*Schima wallichii*	Theaceae	50.0	23.3	2860	16.2	7.4	0.047
7	*Artocarpus heterophyllus*	Moraceae	58.3	16.7	2431	14.8	9.6	0.024
8	*Erythrina stricta*	Fabaceae	41.7	15.0	1529	11.0	7.7	0.043
9	*Phyllanthus emblica*	Phyllanthaceae	50.0	13.3	820	10.2	6.4	0.027
10	*Ficus* sp.1	Moraceae	41.7	11.7	1361	9.8	8.0	0.034
11	BilT4	Unidentified	41.7	10.0	1113	9.0	8.5	0.029
12	*Robinia* sp.	Fabaceae	33.3	8.3	518	6.6	5.6	0.038
13	*Jatropha curcas*	Euphorbiaceae	33.3	6.7	242	5.7	5.5	0.030
14	*Macaranga denticulata*	Euphorbiaceae	16.7	8.3	871	5.4	6.8	0.150
15	*Ceiba pentandra*	Malvaceae	16.7	6.7	881	5.0	9.0	0.120
16	BilT11	Vitaceae	25.0	5.0	581	5.0	7.7	0.040
17	*Bauhinia variegata*	Fabaceae	25.0	6.7	327	5.0	5.8	0.053
18	*Heptapleurum* sp.	Araliaceae	25.0	5.0	518	4.9	6.7	0.040
19	*Derris* sp.	Fabaceae	8.3	5.0	815	3.6	9.0	0.360
20	*Sterculia villosa*	Malvaceae	8.3	5.0	739	3.4	8.7	0.360
21	BilT24	Unidentified	16.7	5.0	107	3.3	3.7	0.090
22	*Ficus semicordata*	Moraceae	8.3	6.7	95	2.7	3.3	0.480
23	*Gmelina arborea*	Lamiaceae	8.3	3.3	500	2.6	8.5	0.240
24	*Delonix regia*	Fabaceae	8.3	1.7	368	2.0	14.0	0.120
25	*Litsea sebifera*	Lauraceae	8.3	1.7	109	1.5	6.0	0.120
	Total		908.3	403.3	57825	300.0	9.8	

Table 4.3. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Kawnpui provenance in Mizoram.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Artocarpus heterophyllus*	Moraceae	70.0	44.0	5618	30.8	9.1	0.045
2	*Sterculia villosa*	Malvaceae	80.0	50.0	3835	28.3	8.6	0.039
3	*Duabanga grandiflora*	Lythraceae	70.0	52.0	3724	27.5	11.8	0.053
4	*Derris* sp.	Fabaceae	90.0	40.0	2332	23.0	9.3	0.025
5	*Mallotus* sp.	Euphorbiaceae	50.0	48.0	3011	22.9	8.8	0.096
6	*Parkia roxburghii*	Fabaceae	70.0	18.0	3611	19.9	12.8	0.018
7	*Schima wallichii*	Theaceae	70.0	30.0	2429	19.3	8.9	0.031
8	*Gmelina arborea*	Lamiaceae	50.0	30.0	2666	18.1	9.1	0.060
9	*Erythrina* sp.	Fabaceae	60.0	22.0	1782	14.9	8.5	0.031
10	*Stereospermum* sp.	Bignoniaceae	60.0	18.0	1143	12.4	8.2	0.025
11	KawT10	Unidentified	50.0	16.0	948	10.5	8.5	0.032
12	*Melia azedarach*	Meliaceae	40.0	10.0	915	8.2	9.6	0.031
13	*Premna* sp.	Lamiaceae	40.0	10.0	658	7.5	8.6	0.031
14	*Ceiba pentandra*	Malvaceae	30.0	12.0	678	7.1	8.3	0.067
15	*Ficus hispida*	Moraceae	40.0	8.0	557	6.8	9.3	0.025
16	*Bridelia* sp.	Euphorbiaceae	40.0	8.0	510	6.7	8.8	0.025
17	*Macaranga denticulata*	Euphorbiaceae	30.0	10.0	676	6.7	8.8	0.056
18	KawT06	Unidentified	40.0	8.0	454	6.6	8.3	0.025
19	*Dalbergia* sp.1	Fabaceae	30.0	8.0	443	5.6	8.0	0.044
20	*Albizia stipulata*	Fabaceae	20.0	8.0	608	5.2	10.0	0.100
21	KawT14	Unidentified	30.0	6.0	370	5.0	9.0	0.033
22	*Mangifera indica*	Anacardiaceae	10.0	2.0	252	2.0	8.0	0.100
23	*Litchi chinensis*	Sapindaceae	10.0	2.0	180	1.8	8.0	0.100
24	*Citrus* sp.2	Rutaceae	10.0	2.0	136	1.7	7.0	0.100
25	*Manihot esculenta*	Euphorbiaceae	10.0	2.0	22	1.4	9.0	0.100
	Total		1100.0	464.0	37556	300.0	9.3	

Table 4.4. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Thingkhangphai provenance in Manipur.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Pinus kesiya*	Pinaceae	50.0	140.0	18251	154.1	10.2	0.280
2	*Lithocarpus dealbatus*	Fagaceae	30.0	28.0	552	24.1	5.4	0.156
3	*Schima wallichii*	Theaceae	40.0	14.0	956	23.7	8.1	0.044
4	*Quercus serrata*	Fagaceae	20.0	30.0	587	21.7	5.5	0.375
5	*Mangifera indica*	Anacardiaceae	30.0	8.0	631	16.4	7.5	0.044
6	*Parkia roxburghii*	Fabaceae	30.0	6.0	720	15.9	9.7	0.033
7	*Phyllanthus emblica*	Phyllanthaceae	30.0	8.0	45	13.8	4.3	0.044
8	*Dalbergia* sp.2	Fabaceae	20.0	4.0	978	12.8	8.0	0.050
9	*Eucalyptus* sp.	Myrtaceae	20.0	4.0	71	8.8	5.5	0.050
10	ThingT6	Poaceae	10.0	2.0	18	4.3	13.8	0.100
11	*Albizia stipulata*	Fabaceae	10.0	2.0	16	4.3	6.0	0.100
	Total		290.0	246.0	22825	300.0	8.5	

Table 4.5. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Kangpokpi provenance in Manipur.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Quercus serrata*	Fagaceae	80.0	46.0	12315	69.4	10.6	0.036
2	*Schima wallichii*	Theaceae	80.0	48.0	7018	53.5	10.3	0.038
3	*Pinus kesiya*	Pinaceae	60.0	30.0	657	23.2	7.5	0.042
4	*Phyllanthus emblica*	Phyllanthaceae	70.0	20.0	1168	22.3	6.4	0.020
5	*Lithocarpus dealbatus*	Fagaceae	50.0	20.0	562	17.3	6.6	0.040
6	*Castanopsis tribuloides*	Fagaceae	30.0	8.0	2755	16.4	14.0	0.044
7	*Quercus* sp.	Fagaceae	30.0	12.0	2017	15.7	10.5	0.067
8	*Parkia roxburghii*	Fabaceae	40.0	8.0	973	12.3	9.3	0.025
9	*Flacourtia jangomas*	Salicaceae	30.0	8.0	740	10.1	8.5	0.044
10	*Wendlandia wallichii*	Rubiaceae	30.0	8.0	389	9.0	4.3	0.044
11	*Engelhardtia roxburghiana*	Juglandaceae	20.0	6.0	955	8.4	11.7	0.075
12	*Albizia stipulata*	Fabaceae	30.0	6.0	237	7.7	6.0	0.033
13	*Myrica esculenta*	Myricaceae	20.0	6.0	490	7.0	8.0	0.075
14	*Ficus* sp.2	Moraceae	10.0	6.0	828	6.5	5.7	0.300
15	*Lindera* sp.	Lauraceae	20.0	6.0	270	6.3	7.7	0.075
16	*Engelhardtia spicata*	Juglandaceae	10.0	2.0	134	2.7	11.0	0.100
17	*Albizia* sp.	Fabaceae	10.0	2.0	68	2.5	10.0	0.100
18	*Helicia erratica*	Proteaceae	10.0	2.0	64	2.5	9.0	0.100
19	KangT06	Lauraceae	10.0	2.0	11	2.4	9.0	0.100
20	*Wendlandia tinctoria*	Rubiaceae	10.0	2.0	11	2.4	5.0	0.100
21	*Rhus chinensis*	Anacardiaceae	10.0	2.0	10	2.3	5.0	0.100
	Total		660.0	250.0	31674	300.00	8.8	

Table 4.6. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Kezanglwa provenance in Nagaland.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Tectona grandis*	Lamiaceae	60.0	90.0	7283	52.6	11.6	0.125
2	*Gmelina arborea*	Lamiaceae	90.0	76.0	5132	45.7	9.0	0.047
3	*Schima wallichii*	Theaceae	90.0	60.0	4944	41.3	10.3	0.037
4	*Holarrhena pubescens*	Apocynaceae	90.0	42.0	3013	30.6	7.7	0.026
5	*Lagerstroemia parviflora*	Lythraceae	80.0	36.0	1960	24.5	8.4	0.028
6	*Kydia calycina*	Malvaceae	40.0	20.0	2204	16.8	13.1	0.063
7	*Careya arborea*	Lecythidaceae	50.0	14.0	727	11.7	7.3	0.028
8	*Litsea monopetala*	Lauraceae	50.0	12.0	641	10.9	8.8	0.024
9	*Derris robusta*	Fabaceae	50.0	12.0	624	10.9	7.9	0.024
10	*Parkia roxburghii*	Fabaceae	30.0	6.0	1470	9.9	16.3	0.033
11	*Antidesma* sp.	Euphorbiaceae	50.0	10.0	388	9.6	7.6	0.020
12	Acer	Sapindaceae	40.0	12.0	590	9.6	7.3	0.038
13	KezT10	Unidentified	40.0	12.0	537	9.4	8.7	0.038
14	*Phyllanthus emblica*	Phyllanthaceae	40.0	12.0	253	8.4	5.8	0.038
15	*Dillenia scabrella*	Dilleniaceae	40.0	10.0	297	8.1	6.6	0.031
	Total		840.0	424	30062	300.0	9.5	

Table 4.7. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of Khaibung provenance in Nagaland.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Schima wallichii*	Theaceae	50.0	46.0	13984	44.6	16.9	0.092
2	KhaiT01	Unidentified	70.0	32.0	4960	28.1	13.8	0.033
3	*Holarrhena pubescens*	Apocynaceae	50.0	22.0	4075	20.7	14.9	0.044
4	*Lagerstroemia parviflora*	Lythraceae	30.0	28.0	4498	20.5	14.4	0.156
5	*Tectona grandis*	Lamiaceae	40.0	18.0	3468	17.0	13.3	0.056
6	KhaiT17	Unidentified	40.0	14.0	3330	15.5	17.7	0.044
7	*Albizia lebbeck*	Fabaceae	20.0	12.0	4235	13.6	24.8	0.150
8	*Parkia roxburghii*	Fabaceae	40.0	10.0	2012	12.1	12.4	0.031
9	*Saurauia* sp.1	Actinidiaceae	20.0	12.0	3007	11.6	15.2	0.150
10	*Castanopsis* sp.	Fagaceae	30.0	12.0	2130	11.5	12.3	0.067
11	*Mallotus roxburghianus*	Euphorbiaceae	20.0	18.0	1637	11.2	10.9	0.225
12	*Derris* sp.	Fabaceae	40.0	10.0	1243	10.8	13.6	0.031
13	KhaiT50	Apocynaceae	20.0	12.0	1163	8.5	11.2	0.150
14	*Sterculia villosa*	Malvaceae	20.0	8.0	1168	7.3	20.8	0.100
15	*Litsea* sp.	Lauraceae	20.0	6.0	905	6.2	17.3	0.075
16	*Melia* sp.	Meliaceae	10.0	6.0	1306	5.5	16.0	0.300
17	*Castanopsis indica*	Fagaceae	20.0	4.0	831	5.4	14.0	0.050
18	*Gmelina arborea*	Lamiaceae	20.0	4.0	532	4.9	12.5	0.050
19	KhaiT31	Malvaceae	20.0	4.0	486	4.9	13.0	0.050
20	*Spondias pinnata*	Anacardiaceae	20.0	4.0	237	4.4	9.0	0.050
21	*Erythrina stricta*	Fabaceae	10.0	4.0	918	4.2	18.0	0.200
22	*Macaranga denti*culata	Euphorbiaceae	10.0	4.0	773	3.9	14.0	0.200
23	*Artocarpus lakoocha*	Moraceae	10.0	2.0	964	3.6	30.0	0.100
24	*Elaeocarpus prunifolius*	Elaeocarpaceae	10.0	4.0	267	3.1	17.5	0.200
25	*Toona ciliata*	Meliaceae	10.0	2.0	577	3.0	28.0	0.100
26	*Anthocephalus cadamba*	Rubiaceae	10.0	2.0	517	2.9	25.0	0.100
27	*Artocarpus chaplasha*	Moraceae	10.0	2.0	513	2.9	13.0	0.100
28	KhaiT19	Unidentified	10.0	2.0	437	2.7	18.0	0.100
29	*Callicarpa arborea*	Lamiaceae	10.0	2.0	279	2.5	15.0	0.100
30	*Moringa indica*	Moringaceae	10.0	2.0	207	2.4	7.0	0.100
31	*Phyllanthus emblica*	Phyllanthaceae	10.0	2.0	147	2.3	5.0	0.100
32	*Cassia fistula*	Fabaceae	10.0	2.0	100	2.2	13.0	0.100
	Total		720.0	312.0	60905	300.0	15.1	

A pooled analysis of provenances yielded a total of 1510 individuals representing 117 species, 75 genera and 44 identified families. The basal area was 30.12 m^2 in 3.6 ha sample area of all provenances and its mean was 8.37 m^2 ha^{-1} (Table 4.8).

Table 4.8. Floristic composition, frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), mean height (m) and abundance-to-frequency ratio (A/F) of a pooled community of seven provenances in northeastern region of India.

Sl. #	Species	Family	Freq-ency	Den-sity	Basal area	IVI	Mean height	A/F ratio
1	*Schima wallichii*	Theaceae	61.1	36.4	35527	28.3	10.3	0.049
2	*Areca catechu*	Arecaceae	23.6	73.9	19626	27.2	8.5	0.663
3	*Tectona grandis*	Lamiaceae	30.6	31.4	33597	22.6	12.7	0.168
4	*Artocarpus heterophyllus*	Moraceae	29.2	18.6	18196	14.2	8.9	0.109
5	*Pinus kesiya*	Pinaceae	15.3	23.6	18909	13.9	9.7	0.506
6	*Parkia roxburghii*	Fabaceae	41.7	10.8	16237	13.3	12.7	0.031
7	*Duabanga grandiflora*	Lythraceae	26.4	14.4	11857	10.8	11.3	0.104
8	*Gmelina arborea*	Lamiaceae	23.6	15.8	8829	9.7	9.1	0.142
9	*Quercus serrata*	Fagaceae	13.9	10.6	12902	8.6	8.6	0.274
10	*Phyllanthus emblica*	Phyllanthaceae	31.9	8.6	2511	7.0	5.8	0.042
11	*Holarrhena pubescens*	Apocynaceae	19.4	8.9	7088	7.0	10.2	0.118
12	*Lagerstroemia parviflora*	Lythraceae	15.3	8.9	6458	6.2	11.1	0.190
13	*Sterculia villosa*	Malvaceae	15.3	8.9	5742	6.0	10.1	0.190
14	*Derris* sp.	Fabaceae	19.4	7.8	4390	5.8	10.0	0.103
15	*Callicarpa arborea*	Lamiaceae	13.9	7.8	4159	5.0	7.3	0.202
16	KhaiT01	Unidentified	9.7	4.4	4960	4.0	13.8	0.235
17	*Cinnamomum tamala*	Lauraceae	9.7	3.6	5219	3.8	9.5	0.191
18	*Mallotus* sp.	Euphorbiaceae	6.9	6.7	3011	3.5	8.8	0.691
19	*Lithocarpus dealbatus*	Fagaceae	11.1	6.7	1114	3.4	5.9	0.270
20	*Macaranga denticulata*	Euphorbiaceae	9.7	3.9	2350	3.0	8.0	0.206
21	*Erythrina stricta*	Fabaceae	8.3	3.1	2447	2.6	9.5	0.220
22	*Litsea monopetala*	Lauraceae	11.1	3.1	1156	2.5	7.3	0.124
23	*Erythrina* sp.	Fabaceae	8.3	3.1	1782	2.4	8.5	0.220
24	MawT43	Unidentified	2.8	0.8	5453	2.4	8.2	0.540
25	KhaiT17	Unidentified	5.6	1.9	3330	2.3	17.7	0.315
26	*Albizia lebbeck*	Fabaceae	2.8	1.7	4235	2.2	24.8	1.080
27	*Musa* sp.	Musaceae	6.9	4.2	772	2.1	2.9	0.432
28	*Kydia calycina*	Malvaceae	5.6	2.8	2204	2.1	13.1	0.450
29	*Ceiba pentandra*	Malvaceae	6.9	2.8	1558	2.1	8.6	0.288
30	*Stereospermum* sp.	Bignoniaceae	8.3	2.5	1143	2.0	8.2	0.180
31	*Albizia stipulata*	Fabaceae	8.3	2.2	860	1.9	8.0	0.160
32	*Ficus* sp.1	Moraceae	6.9	1.9	1361	1.8	8.0	0.202
33	MawT40	Unidentified	2.8	1.7	3173	1.8	8.7	1.080
34	*Saurauia* sp.1	Actinidiaceae	2.8	1.7	3007	1.8	15.2	1.080
35	*Mallotus roxburghianus*	Euphorbiaceae	4.2	2.8	1647	1.7	10.1	0.800
36	KawT10	Unidentified	6.9	2.2	948	1.7	8.5	0.230
37	*Castanopsis tribuloides*	Fagaceae	4.2	1.1	2755	1.7	14.0	0.320
38	BilT4	Unidentified	6.9	1.7	1113	1.7	8.5	0.173
39	*Castanopsis* sp.	Fagaceae	4.2	1.7	2130	1.6	12.3	0.480
40	*Saurauia* sp.2	Actinidiaceae	4.2	3.3	852	1.6	4.8	0.960
41	*Quercus* sp.	Fagaceae	4.2	1.7	2017	1.6	10.5	0.480
42	*Careya arborea*	Lecythidaceae	6.9	1.9	727	1.6	7.3	0.202
43	*Derris robusta*	Fabaceae	6.9	1.7	624	1.5	7.9	0.173
44	*Syzygium formosum*	Myrtaceae	1.4	0.3	3677	1.5	14.0	0.720
45	*Ficus hispida*	Moraceae	6.9	1.4	570	1.4	8.4	0.144
46	*Antidesma* sp.	Euphorbiaceae	6.9	1.4	388	1.4	7.6	0.144
47	*Melia azedarach*	Meliaceae	5.6	1.4	915	1.3	9.6	0.225
48	*Mangifera indica*	Anacardiaceae	5.6	1.4	883	1.3	7.6	0.225
49	*Acer* sp.	Sapindaceae	5.6	1.7	590	1.3	7.3	0.270

50	KezT10	Unidentified	5.6	1.7	537	1.3	8.7	0.270
51	*Premna* sp.	Lamiaceae	5.6	1.4	658	1.3	8.6	0.225
52	*Robinia* sp.	Fabaceae	5.6	1.4	518	1.2	5.6	0.225
53	*Maesa indica*	Myrsinaceae	5.6	1.1	658	1.2	8.5	0.180
54	*Itea macrophylla*	Iteaceae	1.4	1.7	1824	1.2	6.0	4.320
55	*Bauhinia variegata*	Fabaceae	5.6	1.4	365	1.2	5.6	0.225
56	*Bridelia* sp.	Euphorbiaceae	5.6	1.1	510	1.1	8.8	0.180
57	*Dillenia scabrella*	Dilleniaceae	5.6	1.4	297	1.1	6.6	0.225
58	KhaiT50	Apocynaceae	2.8	1.7	1163	1.1	11.2	1.080
59	KawT06	Unidentified	5.6	1.1	454	1.1	8.3	0.180
60	*Jatropha curcas*	Euphorbiaceae	5.6	1.1	242	1.1	5.5	0.180
61	*Flacourtia jangomas*	Salicaceae	4.2	1.1	740	1.0	8.5	0.320
62	*Syzygium* sp.	Myrtaceae	4.2	1.1	606	1.0	3.8	0.320
63	*Chukrasia* sp.	Meliaceae	4.2	0.8	750	1.0	8.3	0.240
64	*Dalbergia* sp.1	Fabaceae	4.2	1.1	443	0.9	8.0	0.320
65	*Wendlandia wallichii*	Rubiaceae	4.2	1.1	389	0.9	4.3	0.320
66	BilT11	Bignoniaceae	4.2	0.8	581	0.9	7.7	0.240
67	*Heptapleurum* sp.	Araliaceae	4.2	0.8	518	0.9	6.7	0.240
68	*Engelhardtia roxburghiana*	Juglandaceae	2.8	0.8	955	0.9	11.7	0.540
69	KawT14	Unidentified	4.2	0.8	370	0.9	9.0	0.240
70	*Litsea* sp.	Lauraceae	2.8	0.8	905	0.9	17.3	0.540
71	*Bambusa* sp.	Poaceae	4.2	1.1	44	0.8	10.8	0.320
72	*Dalbergia* sp.2	Fabaceae	2.8	0.6	978	0.8	8.0	0.360
73	*Melia* sp.	Meliaceae	1.4	0.8	1306	0.8	16.0	2.160
74	*Ligustrum robustum*	Oleaceae	2.8	0.8	679	0.8	7.0	0.540
75	*Castanopsis indica*	Fagaceae	2.8	0.6	831	0.8	14.0	0.360
76	*Ficus hirta*	Moraceae	4.2	0.8	40	0.7	3.3	0.240
77	*Myrica esculenta*	Myricaceae	2.8	0.8	490	0.7	8.0	0.540
78	*Dracaena spicata*	Asparagaceae	2.8	1.4	91	0.7	3.8	0.900
79	*Artocarpus chaplasha*	Moraceae	2.8	0.6	526	0.7	9.0	0.360
80	Ficus sp.2	Moraceae	1.4	0.8	828	0.7	5.7	2.160
81	KhaiT31	Malvaceae	2.8	0.6	486	0.7	13.0	0.360
82	*Lindera* sp.	Lauraceae	2.8	0.8	270	0.6	7.7	0.540
83	BilT24	Unidentified	2.8	0.8	107	0.6	3.7	0.540
84	*Spondias pinnata*	Anacardiaceae	2.8	0.6	237	0.6	9.0	0.360
85	*Artocarpus lakoocha*	Moraceae	1.4	0.3	964	0.6	30.0	0.720
86	*Aporosa oblonga*	Phyllanthaceae	2.8	0.6	172	0.5	3.0	0.360
87	*Eucalyptus* sp.	Myrtaceae	2.8	0.6	71	0.5	5.5	0.360
88	*Garcinia* sp.	Clusiaceae	2.8	0.6	54	0.5	4.0	0.360
89	*Citrus* sp.1	Rutaceae	1.4	0.8	343	0.5	4.7	2.160
90	*Ficus semicordata*	Moraceae	1.4	1.1	95	0.5	3.3	2.880
91	*Toona ciliata*	Meliaceae	1.4	0.3	577	0.4	28.0	0.720
92	*Zanthoxylum ovalifolium*	Rutaceae	1.4	0.8	165	0.4	5.3	2.160
93	*Morinda angustifolia*	Rubiaceae	1.4	0.8	163	0.4	3.3	2.160
94	*Anthocephalus cadamba*	Rubiaceae	1.4	0.3	517	0.4	25.0	0.720
95	MawT29	Unidentified	1.4	0.6	313	0.4	10.5	1.440
96	*Elaeocarpus prunifolius*	Elaeocarpaceae	1.4	0.6	267	0.4	17.5	1.440
97	KhaiT19	Unidentified	1.4	0.3	437	0.4	18.0	0.720
98	*Delonix regia*	Fabaceae	1.4	0.3	368	0.4	14.0	0.720
99	*Sapindus* sp.	Sapindaceae	1.4	0.6	25	0.3	3.0	1.440
100	*Moringa indica*	Moringaceae	1.4	0.3	207	0.3	7.0	0.720
101	*Litchi chinensis*	Sapindaceae	1.4	0.3	180	0.3	8.0	0.720
102	*Citrus* sp.2	Rutaceae	1.4	0.3	136	0.3	7.0	0.720
103	*Engelhardtia spicata*	Juglandaceae	1.4	0.3	134	0.3	11.0	0.720
104	*Litsea sebifera*	Lauraceae	1.4	0.3	109	0.3	6.0	0.720

105	*Cassia fistula*	Fabaceae	1.4	0.3	100	0.3	13.0	0.720
106	*Albizia* sp.	Fabaceae	1.4	0.3	68	0.3	10.0	0.720
107	*Helicia erratica*	Proteaceae	1.4	0.3	64	0.3	9.0	0.720
108	*Alstonia scholaris*	Apocynaceae	1.4	0.3	58	0.3	4.0	0.720
109	*Ehretia* sp.	Boraginaceae	1.4	0.3	54	0.3	5.0	0.720
110	*Trigonostemon semperflorens*	Euphorbiaceae	1.4	0.3	29	0.3	3.0	0.720
111	*Manihot esculenta*	Euphorbiaceae	1.4	0.3	22	0.3	9.0	0.720
112	MawT35	Unidentified	1.4	0.3	20	0.3	10.0	0.720
113	ThingT6	Poaceae	1.4	0.3	18	0.3	13.8	0.720
114	KangT06	Lauraceae	1.4	0.3	11	0.2	9.0	0.720
115	*Wendlandia tinctoria*	Rubiaceae	1.4	0.3	11	0.2	5.0	0.720
116	*Rhus chinensis*	Anacardiaceae	1.4	0.3	10	0.2	5.0	0.720
117	*Psidium guajava*	Myrtaceae	1.4	0.3	8	0.2	3.0	0.720
	Grand Total		777.8	419.4	301165	300.0	9.4	

Only seven species had IVI >10. Among these, *Areca catechu*, *Artocarpus heterophyllus* and *Tectona grandis* are planted species, whereas *Schima wallichii*, *Pinus kesiya* and *Duabanga grandiflora* are naturally occurring species. *P. roxburghii* is native to all provenances. Among native species, *Schima wallichii* occurred in all provenances and emerged on the top in a pooled analysis with highest values of frequency, density (except after Areca catechu), basal area and IVI (Table 4.8). It showed a random dispersion with an abundance-to-frequency ratio of 0.049. The other native species, *Duabanga grandiflora*, occurred in only two provenances (Bilkhawthlir and Kawnpui) and was at the bottom in the list of top seven species with an IVI of 10.77 (Table 4.8). About one-half of the species (57 species) were rare as they exhibited an IVI of 1 or less (Table 4.8). A large number of species (45 species) exhibited an IVI between >1 and <5 (Table 4.8). Only 8 species exhibited an IVI $\geq$ 5 and <10.

Among provenances, most phytosociological attributes varied nearly three-fold or more: number of species ranged from 11 to 38, stand density from 246 to 840 ha^{-1}, basal area from 4.57 to 12.18 m^2 ha^{-1} and mean basal area from 142 to 390 cm^2 $individual^{-1}$ (Table 4.9). Species richness index ranged from 4.8 to 14.9, Shannon's index from 0.76 to 1.35, Pielou's index from 0.73 to 0.92, and Simpson's index from 0.06 to 0.29 (Table 4.10).

Table 4.9: Phytosociological attributes of seven provenances of *P. roxburghii*.

Sl #	Provenance	Number of species	Density (ha^{-1})	Basal area (m^2 ha^{-1})	Mean basal area (cm^2 $individual^{-1}$)
1	Mawriang, ML	38	840.0	12.06	144
2	Bilkhawthlir, MZ	25	403.3	9.64	239
3	Kawnpui, MZ	25	464.0	7.51	162
4	Thingkhangphai, MN	11	246.0	4.57	186
5	Kangpokpi, MN	21	250.0	6.33	253
6	Kezanglwa, NL	15	424.0	6.01	142
7	Khaibung, NL	32	312.0	12.18	390
	All provenances	117	419.4	8.37	199

Table 4.10: Community indices of seven provenances of *P. roxburghii*.

Sl #	Provenance	Species richness index	Shannon's diversity by		Pielou's evenness by		Simpson's dominance by	
			Density	IVI	Density	IVI	Density	IVI
1	Mawriang	14.1	0.86	1.20	0.54	0.76	0.345	0.134
2	Bilkhawthlir	10.1	1.17	1.18	0.84	0.84	0.104	0.104
3	Kawnpui	10.1	1.24	1.28	0.89	0.91	0.070	0.062
4	Thingkhangphai	4.8	0.66	0.76	0.63	0.73	0.358	0.293
5	Kangpokpi	9.5	1.11	1.11	0.84	0.84	0.107	0.113
6	Kezanglwa	6.0	1.02	1.07	0.87	0.91	0.123	0.103
7	Khaibung	14.1	1.32	1.35	0.88	0.90	0.065	0.060
	All provenances	36.5	1.58	1.70	0.76	0.82	0.057	0.037

Khaibung represented the most natural vegetation with high species richness, Shannon's diversity and Pielou's evenness index (Table 4.10). This provenance was dominated by the most regularly occurring species, *Schima wallichii*, and was characterised by the presence of most individuals with higher girth. Mawriang was a merge of natural vegetation and plantation of *Areca catechu*. It exhibited highest number of species and density, but most individuals were with low girth (Table 4.9). Kangpokpi was a degraded natural forest with second highest value of basal area individual^{-1} and was dominated by a native species, *Quercus serrata* (Table 4.9). Kawnpui is a jhum fallow enriched with *Artocarpus heterophyllus*. Bilkhawthlir and Kezanglwa were modified provenances for plantation of *Tectona grandis*. Between these two sites, Bilkhawthlir exhibited more species richness and higher value of basal area individual^{-1} (Table 4.9). Thingkhangphai represents a late-successional vegetation in a jhum fallow with predominance of pine and oak. It is characterised by low species diversity and basal area (Table 4.10).

The importance value index (IVI) exhibited a significant linear relationship with all three constituent measures, viz., frequency ($r = 0.884$), density ($r = 0.928$) and basal area ($r = 0.956$) and scatter diagrams showed *Areca catechu* as an outlier (Fig. 4.1a,b,c). *Areca catechu* is characterised by the highest density (73.9 stems ha^{-1}), low frequency (23.6%), clumped dispersion (A/F ratio = 0.663) and low variability (coefficient of variation 23.4%) in mean girth of individuals (Table 4.8). The scatter diagrams showed a middle-of-the-range location of *P. roxburghii* (Fig. 4.1). A scatter diagram between A/F ratio and IVI showed a non-linear 'L' shaped pattern (Fig. 4.1d). The species falling on the y-axis may follow regular dispersion (no such species in this study), those on the vertical streak of 'L' may follow random dispersion (3 species in this study) and those on the horizontal tail may follow increasingly clumped dispersion with increasing distance. *P. roxburghii* follows a random dispersion and *Areca catechu* a clumped dispersion.

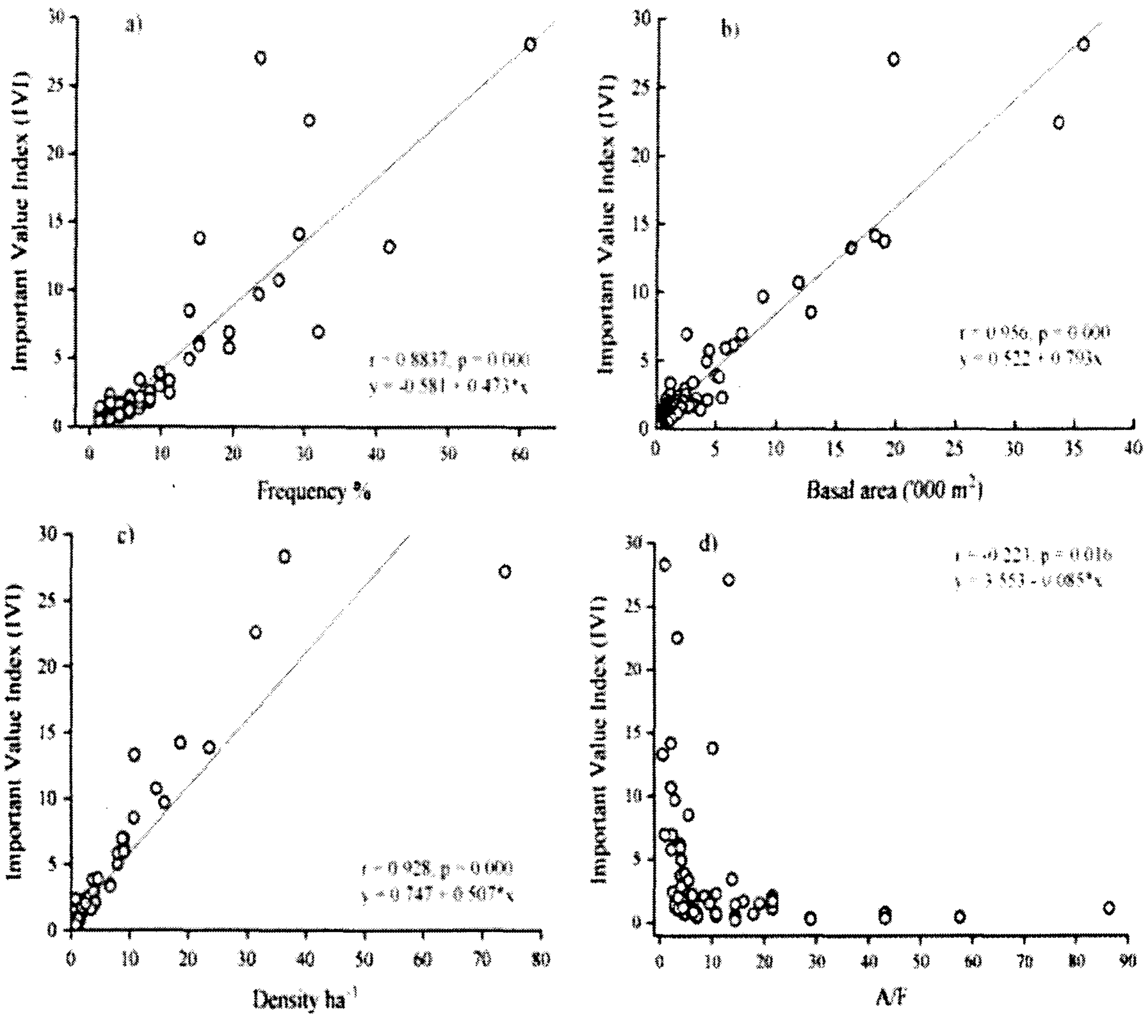


Fig. 4.1. Interrelationships between IVI and frequency (a), basal area (b), density (c) and A/F ratio (d).

The provenances were more dissimilar than similar from each other based on the floristic composition (species presence-absence data). The maximum similarity was observed between Kangpokpi and Thingkhangphai provenances (Table 4.11).

The provenances clustered according to their location within the States in northeastern region of India (Fig. 4.2). Bilkhawthlir and Kawnpui in Mizoram, Kangpokpi and Thingkhangphai in Manipur and Mawriang in Meghalaya formed clearly in separate clusters. The provenances from Nagaland (Kezanglwa and Khaibung) did not form a single cluster.

Table 4.11. A symmetrical matrix of index of dissimilarity for seven provenances computed by SIMINT module of NTSYSpc 2.2.

Provenance	Bilkhaw-thlir	Kang-pokpi	Kawnpui	Kezan-glwa	Khaibung	Maw-riang	Thingkh-angphai
Bilkhawthlir	0						
Kangpokpi	0.585	0					
Kawnpui	0.523	0.585	0				
Kezanglwa	0.506	0.506	0.539	0			
Khaibung	0.562	0.634	0.620	0.531	0		
Mawriang	0.634	0.673	0.673	0.620	0.692	0	
Thingkhangphai	0.506	0.392	0.489	0.413	0.562	0.606	0

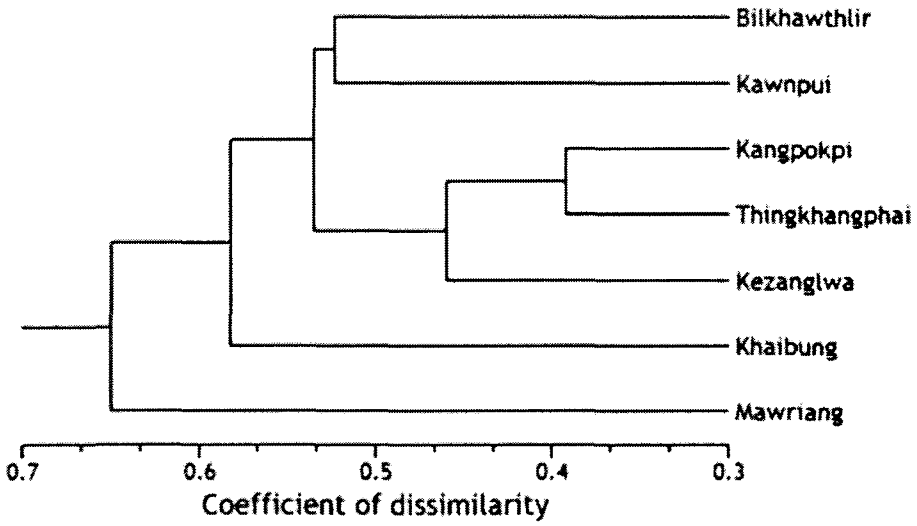


Fig. 4.2. A cluster analysis of seven provenances of *P. roxburghii* in northeastern region of India using SAHN module in NTSYSpc 2.2.

The dominance-diversity curves followed Preston's lognormal hypothesis at Khaibung and niche pre-emption hypothesis as revealed by geometric model at all other sites (Fig. 4.3).

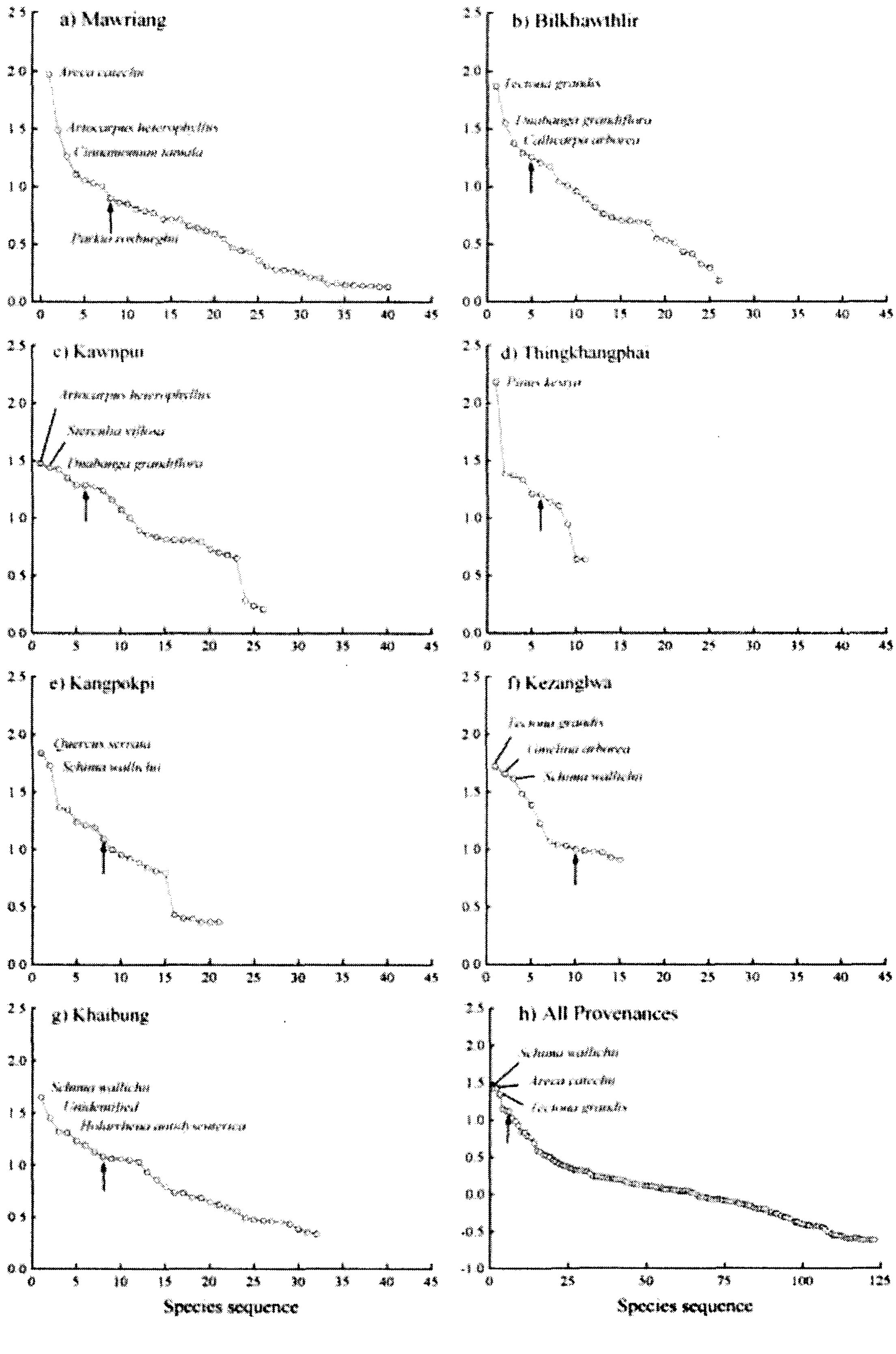


Fig. 4.3. Dominance-diversity curves based on Log_{10} of IVI for woody layer in seven provenances (a through g) and for a pool of all provenances (h). Position of *P. roxburghii* is indicated by an arrow.

P. roxburghii ouccrred in all seven provenances, but was not dominant in any provenance (Tables 4.1 through 4.7). It ranked sixth with an IVI of 13.33 in a pooled analysis and showed random dispersion with an abundance-to-frequency ratio of 0.031 (Table 4.8). Besides *P. roxburghii* (Table 4.12), the only species with random dispersion were *Schima wallichii* and *Phyllanthus emblica*. Among the three randomly dispersed species, *Phyllanthus emblica* was not dominant at any site. The index of association between *P. roxburghii* and *Schima wallichii* was 0.5 which is a high value for tropical forest species. A chi-square test based on 2 x 2 contingency table led to the conclusion that these two species are associated with each other and they do not occur independently in the plots (χ^2 = 5.08, $p<0.05$). The phytosociological attributes (frequency, density, basal area, IVI and mean height) of *P. roxburghii* (Table 4.12) and *Schima wallichii* (Table 4.13) were regressed and a significant correlation (r = 0.657) was found (Fig. 4.4).

Table 4.12. Phytosociological attributes of *P. roxburghii* in seven provenances.

Sl #	Provenance	Frequency (%)	Density (ha^{-1})	Basal area (m^2 ha^{-1})	IVI	Mean height (m)
1	Mawriang	20.0	10.0	0.316	8.65	15.2
2	Bilkhawthlir	58.3	16.7	0.429	17.98	12.6
3	Kawnpui	70.0	18.0	0.361	19.86	12.8
4	Thingkhangphai	30.0	6.0	0.072	15.94	9.7
5	Kangpokpi	40.0	8.0	0.097	12.33	9.3
6	Kezanglwa	30.0	6.0	0.147	9.88	16.3
7	Khaibung	40.0	10.0	0.201	12.06	12.4
	All provenances	41.7	10.8	1.624	13.33	12.7

Table 4.13. Phytosociological attributes of *Schima wallichii* in seven provenances.

Sl #	Provenance	Frequency (%)	Density (ha^{-1})	Basal area (m^2 ha^{-1})	IVI	Mean height (m)
1	Mawriang	50.0	36.0	0.334	15.37	5.8
2	Bilkhawthlir	50.0	23.3	0.286	16.24	7.4
3	Kawnpui	70.0	30.0	0.243	19.30	8.9
4	Thingkhangphai	40.0	14.0	0.096	23.67	8.1
5	Kangpokpi	80.0	48.0	0.702	53.48	10.3
6	Kezanglwa	90.0	60.0	0.494	41.31	10.3
7	Khaibung	50.0	46.0	1.398	44.65	16.9
	All provenances	61.1	36.4	3.553	28.33	10.3

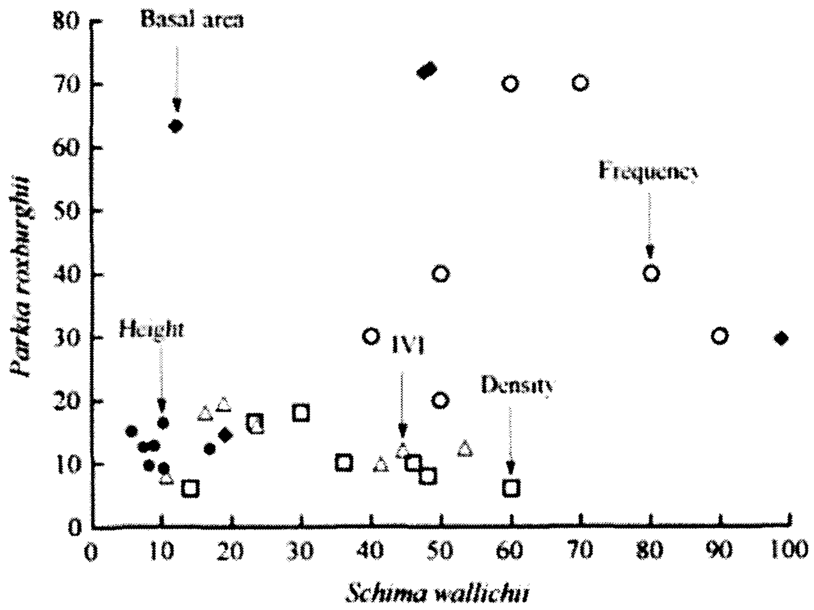


Fig. 4.4. A simple linear relationship between phytosociological attributes of *Schima wallichii* and *P. roxburghii*.

The population structure of individuals (>30 cm gbh) showed a successive decline in number of individuals from a lower to the next higher class in all provenances (Fig. 4.5a,c,e,f,g) except Bilkhawthlir and Thingkhangphai (Fig. 4.5b,d). Both these sites were characterised by young individuals and the individuals >70 cm gbh were absent.

The regeneration of species was poor in all provenances as density of individuals <30 gbh was low. At Mawriang, high density is because of the plantation of *Areca catechu*.

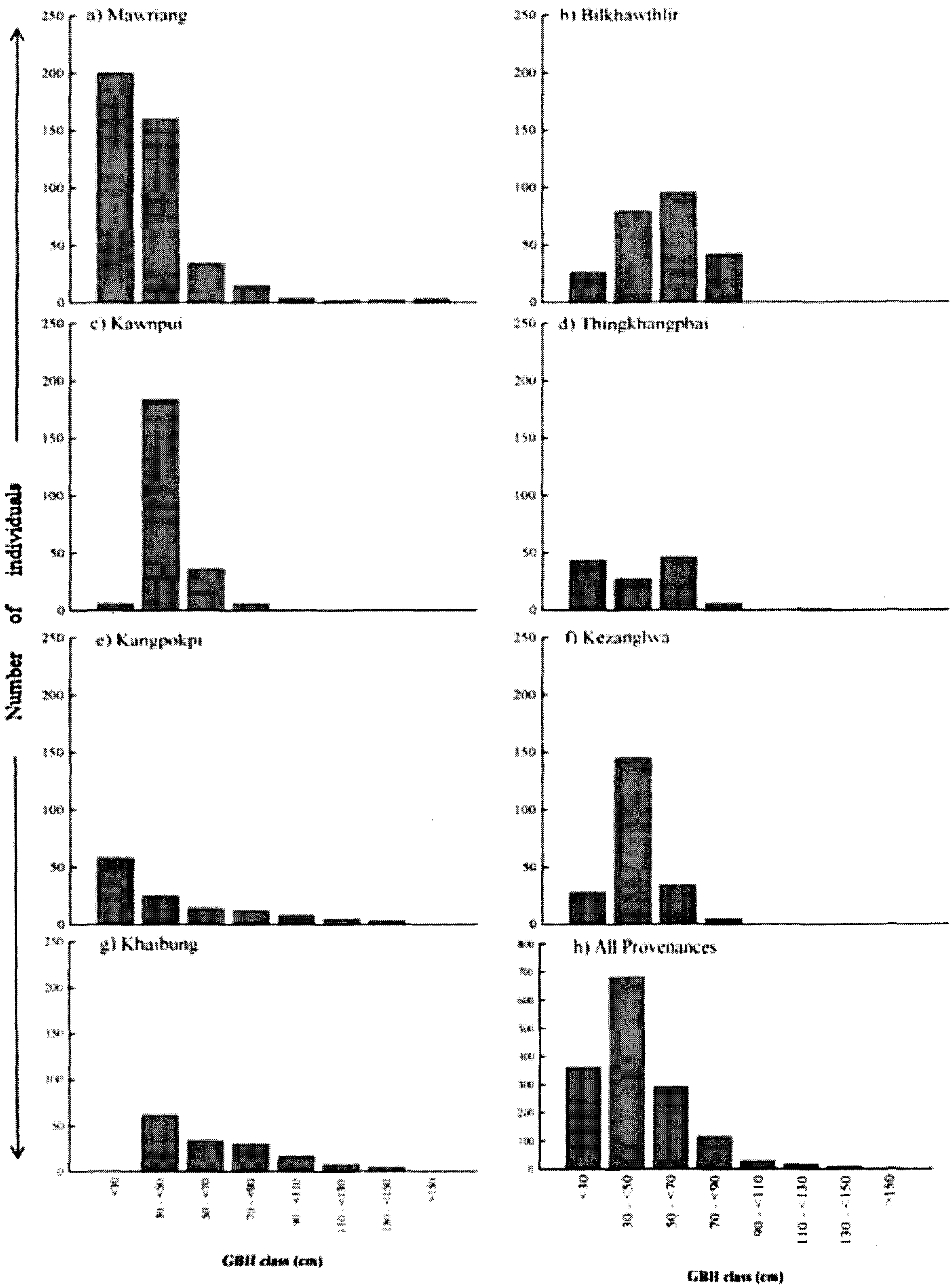


Fig. 4.5. Population structure of individuals (>30 cm gbh) in *Parkia* habitats.

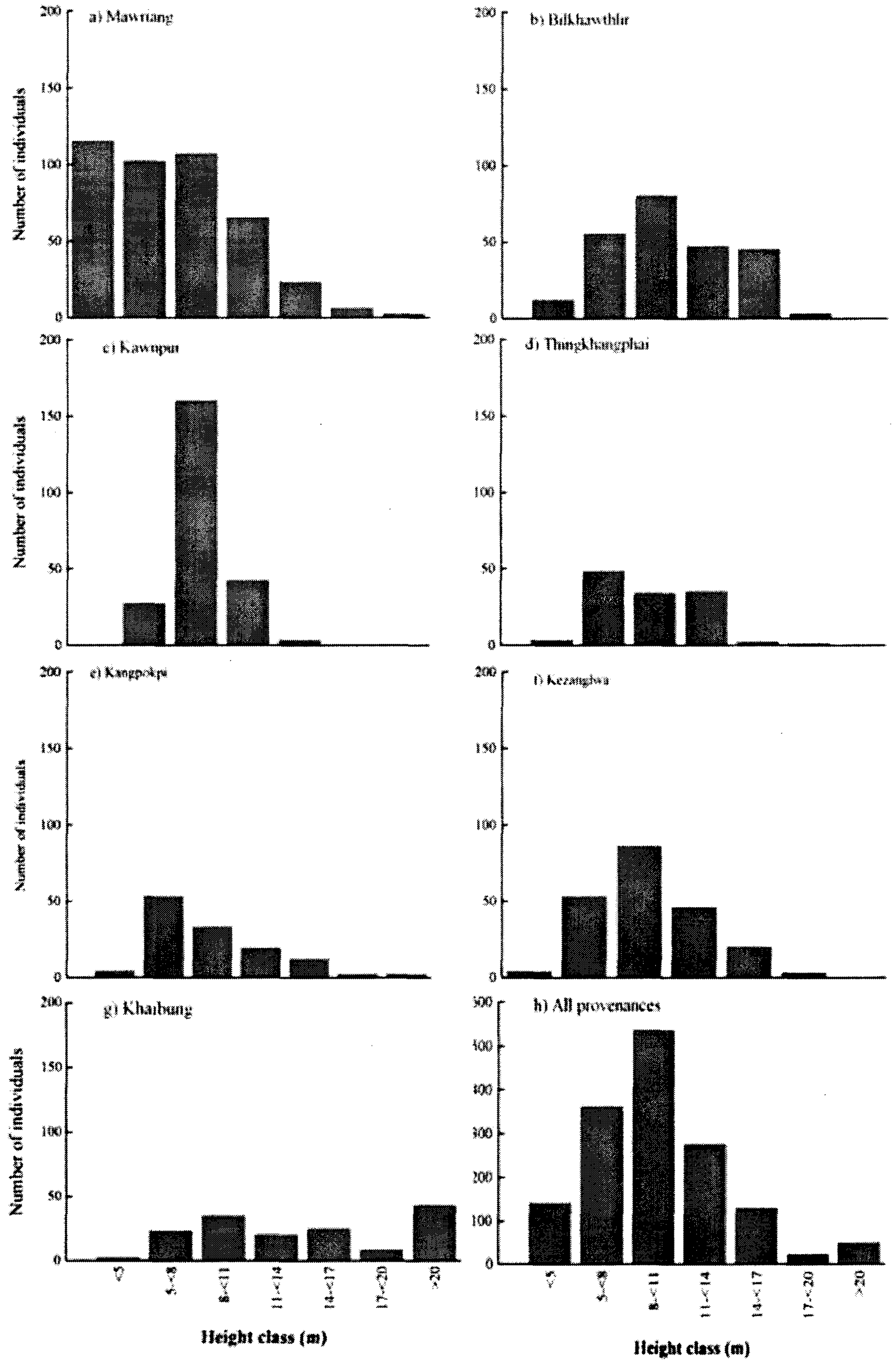


Fig. 4.6. Height structure of trees in *Parkia* habitats.

The height class distribution of individuals showed a peak in 8-11 m class for most provenances as well as for the pool of all provenances (Fig. 4.6). All provenances were characterised by low height trees. Very few individuals (0.9%) exhibited a height >30 m and another 2.25% individuals were between 20 and 30 m height. Tallest individuals (>20 m) belonged to the less frequent species (IVI <10). Only two individuals of each *P. roxburghii* and *Tectona grandis* were taller than 20 m.

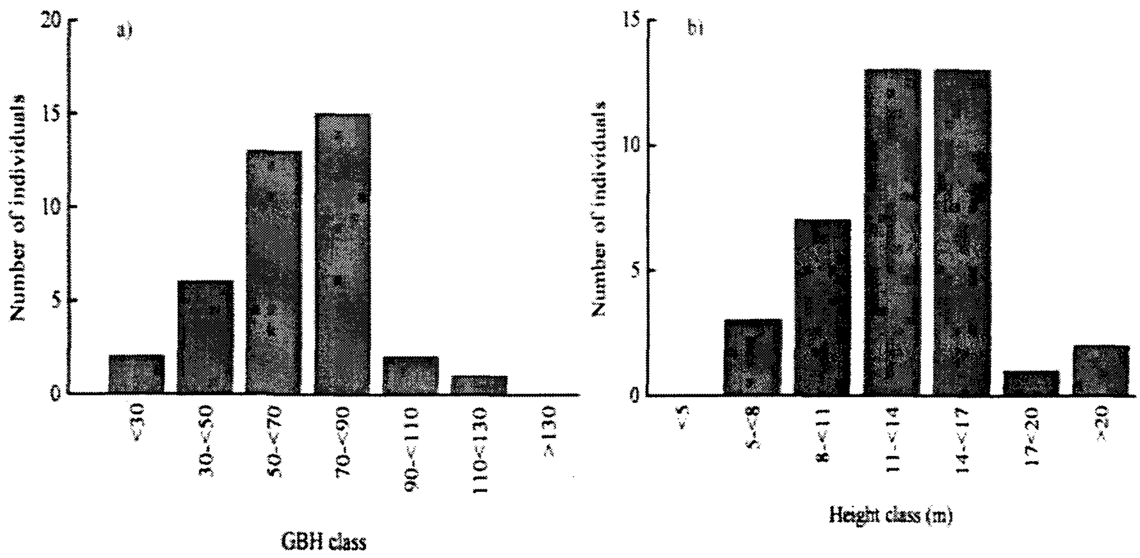


Fig. 4.7. A pooled population structure (a) and height structure (b) of *P. roxburghii* in northeastern India.

The population structure of *P. roxburghii* exhibited a successive increase in number of individuals from a lower to the next higher class which is an indicator of the paucity of regeneration (Fig. 4.7a). The height structure of *P. roxburghii* also followed a similar trend, i.e., a paucity of individuals in low height classes due to lack of regeneration (Fig. 4.7b).

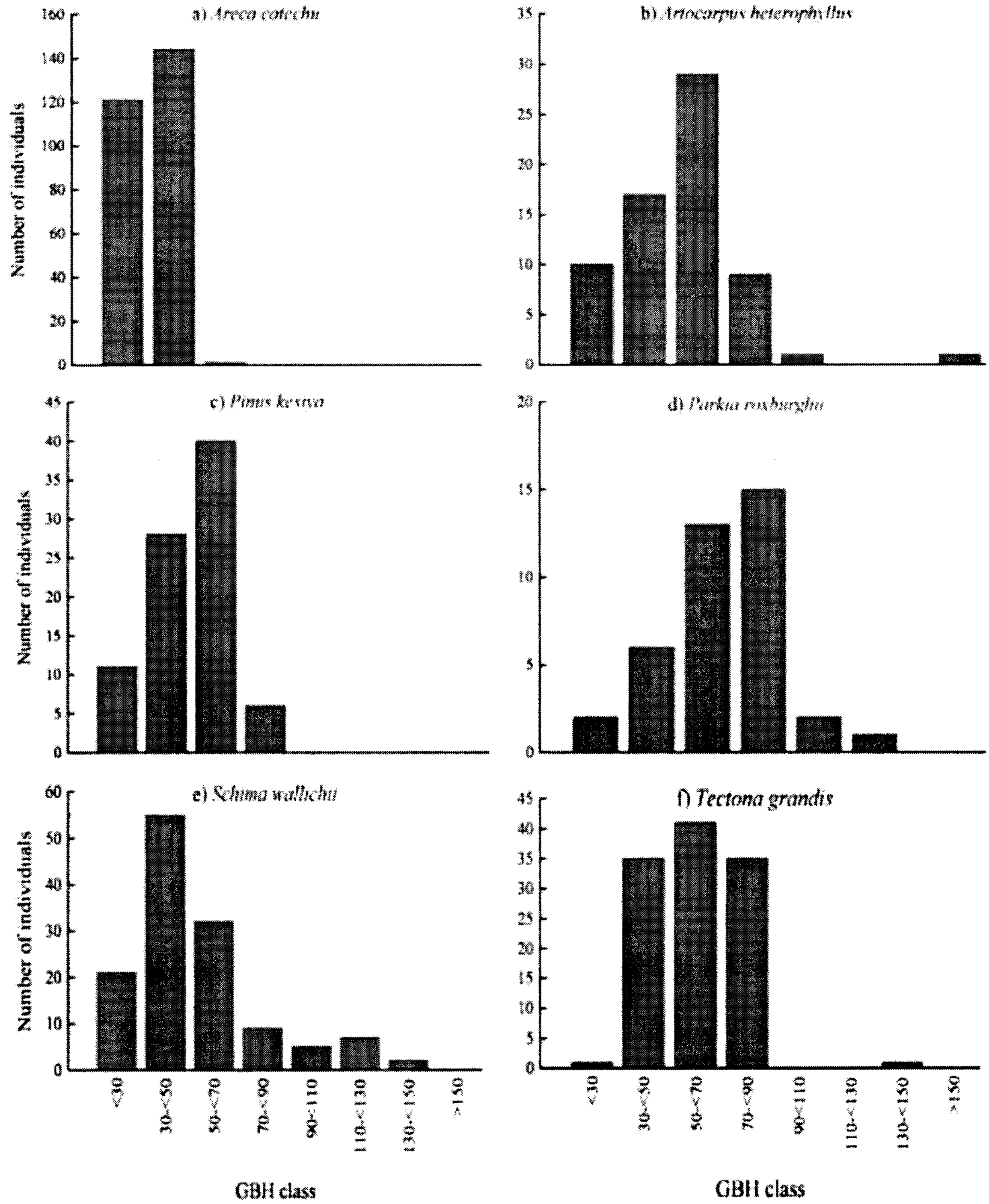


Fig. 4.8. Population structure of six tree species dominant in *P. roxburghii* habitats.

4.3.2. *Ground layer*

The floristic composition of ground layer of *P. roxburghii* habitats (provenances) is given in Tables 4.14 through Table 4.20 individually for seven provenances. A total of 739 individuals comprising 79 species belonging to 39 genera were recorded in a pooled ground layer of seven provenances (Table 4.21). The five dominant species in pooled gound layer were *Eupatorium odoratum*, *Eupatorium adenophorum*, *Imperata cylindrica*, *Bambusa* sp. and *Oplismenus* sp2 with an IVI of 13.5, 10.2, 8.8, 7.9 and 7.7, respectively.

The provenances varied greatly in terms of density of individuals. Almost 25% individuals were recorded from Kangpokpi and only 5% individuals from each of Bilkhawthlir and Kawnpui (Table 4.22). All other provenances occurred in the middle of this range. *Eupatorium odoratum* dominated ground layer followed by *Eupatorium adenophorum* and *I. cylindrica* (Fig. 4.9). The figure also suggests that *Eupatorium odoratum* in Bilkhawthlir provenance, *I. cylindrica* and *Borreria* sp.2 in Thingkhangphai provenance, *Bambusa* sp. in Kezanglwa provenance and *Eupatorium adenophorum* in Khaibung provenance had a clear distinction of dominance in ground layer.

On the basis of IVI, Mawriang represented *Hedyotis ulmifolia – Justicia procumbens –* a Poaceae member community (Table 4.10), Bilkhawthlir a *Eupatorium odoratum –* BILH05 – *Mimosa pudica* community (Table 4.11), Kawnpui a *Eupatorium odoratum – Oxalis corniculata – Ageratum conyzoides* community (Table 4.12), Thingkhangphai a *Imperata cylindrica – Borreria* sp.2 – *Eupatorium odoratum* community (Table 4.13), Kangpokpi a *Oplismenus* sp.2 – KangH05 (a member of Poaceae) – *Desmodium* sp. community (Table 4.14), Kezanglwa a *Bambusa* sp. - *Ageratum houstonianum – Eupatorium odoratum* community (Table 4.15) and Khaibung a *E. adenophorum – Ficus* sp./*Solanum torvum – Eupatorium odoratum* community (Table 4.16).

Table 4.14. Floristic composition of ground layer in Mawriang, Meghalaya.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum houstonianum*	Asteraceae	1	10	14.3
2	*Areca catechu*	Arecaceae	2	2	12.9
3	*Cinnamomum tamala*	Lauraceae	2	3	13.7
4	*Dalbergia* sp.	Fabaceae	1	4	9.1
5	*Hedyotis* sp.	Rubiaceae	1	2	7.3
6	*Hedyotis ulmifolia*	Rubiaceae	1	25	27.5
7	*Justicia procumbens*	Acanthaceae	1	20	23.1
8	*Mallotus roxburghianus*	Euphorbiaceae	1	6	10.8
9	*Melastoma* sp.1	Melastomataceae	1	4	9.1
10	*Oplismenus* sp.1	Poaceae	1	7	11.7
11	*Pteris semipinnata*	Pteridaceae	1	5	9.9
12	*Trigonostemon semperflorens*	Euphorbiaceae	1	2	7.3
13	*Zanthoxylum ovalifolium*	Rutaceae	1	1	6.4
14	MawH14	Poaceae	1	15	18.7
15	MawH15		1	7	11.7
16	MawH06		1	1	6.4

Table 4.15. Floristic composition of ground layer in Bilkhawthlir, Mizoram.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum conyzoides*	Asteraceae	1	3	12.7
2	*Areca catechu*	Arecaceae	1	2	10.4
3	*Euphorbia hirta*	Euphorbiaceae	1	5	17.2
4	*Eupatorium odoratum*	Asteraceae	3	12	44.9
5	*Lantana camara*	Verbenaceae	3	3	24.5
6	*Manihot esculenta*	Euphorbiaceae	1	1	8.2
7	*Mimosa pudica*	Fabaceae	3	3	24.5
8	*Mucuna exserta*	Fabaceae	1	1	8.2
9	*Spilanthes paniculata*	Asteraceae	1	6	19.5
10	BilH05		2	7	27.7
11	BilH07		1	4	15.0

Table 4.16. Floristic composition of ground layer in Kawnpui, Mizoram.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum conyzoides*	Asteraceae	3	5	22.5
2	*Arisaema* sp.	Araceae	1	1	5.8
3	*Borreria* sp.1	Rubiaceae	2	2	11.7
4	*Boehmeria* sp.	Urticaceae	1	1	5.8
5	*Eupatorium odoratum*	Asteraceae	3	9	32.5
6	*Heptapleurum* sp.	Araliaceae	1	1	5.8
7	*Mikania micrantha*	Asteraceae	3	4	20.0
8	*Mimosa pudica*	Fabaceae	2	2	11.7
9	*Mussaenda* sp.	Rubiaceae	1	1	5.8
10	*Oxalis corniculata*	Oxalidaceae	7	7	40.8
11	*Polygonum* sp.	Polygonaceae	1	1	5.8
12	*Stereospermum* sp.	Bignoniaceae	1	1	5.8
13	KawH03	Asteraceae	3	4	20.0
14	KawH12		1	1	5.8

Table 4.17. Floristic composition of ground layer in Thingkhangphai, Manipur.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Albizia stipulata*	Fabaceae	1	1	5.6
2	*Borreria* sp.2	Rubiaceae	2	35	38.7
3	*Callicarpa arborea*	Lamiaceae	1	1	5.6
4	*Clerodendrum serratum*	Lamiaceae	1	1	5.6
5	*Eupatorium odoratum*	Asteraceae	2	5	13.7
6	*Glochidion* sp.	Euphorbiaceae	1	1	5.6
7	*Glochidion multiloculare*	Euphorbiaceae	1	2	6.4
8	*Imperata cylindrica*	Poaceae	1	60	54.8
9	*Lantana camara*	Verbenaceae	2	3	12.0
10	*Lygodium* sp.	Lygodiaceae	1	4	8.1
11	*Melastoma* sp.2	Melastomataceae	2	2	11.2
12	*Rhus chinensis*	Anacardiaceae	2	1	10.4
13	*Urena lobata*	Malvaceae	1	1	5.6
14	ThingH03		2	1	10.4
15	ThingH09		1	2	6.4

Table 4.18. Floristic composition of ground layer in Kangpokpi, Manipur.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum conyzoides*	Asteraceae	1	7	9.6
2	*Ageratum houstonianum*	Asteraceae	1	6	9.1
3	*Bidens pilosa*	Asteraceae	2	12	18.1
4	*Desmodium* sp.	Fabaceae	2	22	23.5
5	*Eupatorium adenophorum*	Asteraceae	2	15	19.7
6	*Oplismenus* sp.2	Poaceae	1	52	33.5
7	*Oplismenus* sp.3	Poaceae	2	18	21.3
8	*Rhus chinensis*	Anacardiaceae	1	3	7.5
9	KangH05	Poaceae	2	23	24.0
10	KangH04	Poaceae	2	21	22.9
11	KangH06	Malvaceae	1	9	10.7

Table 4.19. Floristic composition of ground layer in Kezanglwa, Nagaland.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum houstonianum*	Asteraceae	3	8	25.3
2	*Bambusa* sp.	Poaceae	3	43	67.0
3	*Bidens pilosa*	Asteraceae	1	3	8.8
4	*Borreria articularis*	Rubiaceae	2	6	17.7
5	*Cyperus* sp.1	Cyperaceae	1	1	6.5
6	*Desmodium latifolium*	Fabaceae	2	4	15.3
7	*Eupatorium odoratum*	Asteraceae	2	7	18.9
8	*Mikania micrantha*	Asteraceae	2	3	14.1
9	*Spilanthes paniculata*	Asteraceae	1	3	8.8
10	*Triumfetta rhomboidea*	Malvaceae	2	6	17.7

Table 4.20. Floristic composition of ground layer in Khaibung, Nagaland.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Bidens pilosa*	Asteraceae	1	6	8.9
2	*Cyperus* sp.2	Cyperaceae	1	7	9.6
3	*Dioscorea bulbifera*	Dioscoreaceae	1	8	10.2
4	*Dioscorea* sp.2	Dioscoreaceae	1	5	8.2
5	*Dioscorea* sp.3	Dioscoreaceae	1	5	8.2
6	*Erythrina* sp.	Fabaceae	1	1	5.4
7	*Eupatorium adenophorum*	Asteraceae	2	40	36.9
8	*Eupatorium odoratum*	Asteraceae	1	10	11.6
9	*Ficus* sp.	Moraceae	1	12	13.0
10	*Gnetum gnemone*	Gnetaceae	1	6	8.9
11	*Lantana camara*	Verbenaceae	1	6	8.9
12	*Paederia foetida*	Rubiaceae	1	3	6.8
13	*Panicum* sp.	Poaceae	1	9	10.9
14	*Smilax* sp.	Smilicaceae	1	3	6.8
15	*Solanum torvum*	Solanaceae	1	12	13.0
16	KhaiH04	Menispermaceae	1	1	5.4
17	KhaiH03		1	4	7.5
18	KhaiH05		1	3	6.8
19	KhaiH16		1	3	6.8
20	KhaiH02		1	2	6.1

Table 4.21. Floristic composition of ground layer in a pooled community of seven *P. roxburghii* provenances.

Sl. #	Species	Family	Occurrence	Number of individuals	IVI
1	*Ageratum conyzoides*	Asteraceae	5	15	5.5
2	*Ageratum houstonianum*	Asteraceae	5	24	6.7
3	*Albizia stipulata*	Fabaceae	1	1	0.8
4	*Areca catechu*	Arecaceae	3	4	2.6
5	*Arisaema* sp.	Araceae	1	1	0.8
6	*Bambusa* sp.	Poaceae	3	43	7.9
7	*Bidens pilosa*	Asteraceae	4	21	5.6
8	*Borreria articularis*	Rubiaceae	2	6	2.2
10	*Borreria* sp.1	Rubiaceae	2	2	1.7
9	*Borreria* sp.2	Rubiaceae	2	35	6.1
11	*Callicarpa arborea*	Lamiaceae	1	1	0.8
12	*Cinnamomum tamala*	Lauraceae	2	3	1.8
13	*Clerodendrum serratum*	Lamiaceae	1	1	0.8
14	*Cyperus* sp.1	Cyperaceae	1	1	0.8
15	*Cyperus* sp.2	Cyperaceae	1	7	1.6
16	*Dalbergia* sp.	Fabaceae	1	4	1.2
17	*Debregeasia* sp.	Urticaceae	1	1	0.8
18	*Desmodium latifolium*	Fabaceae	2	4	1.9
19	*Desmodium* sp.	Fabaceae	2	22	4.4
20	*Dioscorea bulbifera*	Dioscoreaceae	1	8	1.8
21	*Dioscorea* sp.1	Dioscoreaceae	1	5	1.4
22	*Dioscorea* sp.2	Dioscoreaceae	1	5	1.4
23	*Erythrina* sp.	Fabaceae	1	1	0.8
24	*Eupatorium adenophorum*	Asteraceae	4	55	10.2
25	*Eupatorium odoratum*	Asteraceae	11	43	13.5
26	*Euphorbia hirta*	Euphorbiaceae	1	5	1.4
27	*Ficus* sp.	Moraceae	1	12	2.3
28	*Glochidion* multiloculare	Euphorbiaceae	1	2	1.0
29	*Glochidion* sp.	Euphorbiaceae	1	1	0.8
30	*Gnetum gnemone*	Gnetaceae	1	6	1.5
31	*Hedyotis* sp.	Rubiaceae	1	2	1.0
32	*Hedyotis ulmifolia*	Rubiaceae	1	25	4.1
33	*Heptapleurum* sp.	Araliaceae	1	1	0.8
34	*Imperata cylindrica*	Poaceae	1	60	8.8
35	*Justicia procumbens*	Acanthaceae	1	20	3.4
36	*Lantana camara*	Verbenaceae	6	12	5.8
37	*Lygodium* sp.	Lygodiaceae	1	4	1.2
38	*Mallotus roxburghianus*	Euphorbiaceae	1	6	1.5
39	*Manihot esculenta*	Euphorbiaceae	1	1	0.8
41	*Melastoma* sp.1	Melastomataceae	1	4	1.2
40	*Melastoma* sp.2	Melastomataceae	2	2	1.7
42	*Mikania micrantha*	Asteraceae	5	7	4.4
43	*Mimosa pudica*	Fabaceae	5	5	4.1
44	*Mucuna exserta*	Fabaceae	1	1	0.8
45	*Mussaenda* sp.	Rubiaceae	1	1	0.8
48	*Oplismenus* sp.1	Poaceae	1	7	1.6
46	*Oplismenus* sp.2	Poaceae	1	52	7.7
47	*Oplismenus* sp.3	Poaceae	2	18	3.8
49	*Oxalis corniculata*	Oxalidaceae	7	7	5.8
50	*Paederia foetida*	Rubiaceae	1	3	1.1

51	*Panicum* sp.	Poaceae	1	9	1.9
52	*Polygonum* sp.	Polygonaceae	1	1	0.8
53	*Pteris semipinnata*	Pteridaceae	1	5	1.4
54	*Rhus chinensis*	Anacardiaceae	3	4	2.6
55	*Smilax* sp.	Smilacaceae	1	3	1.1
56	*Solanum torvum*	Solanaceae	1	12	2.3
57	*Spilanthes paniculata*	Asteraceae	2	9	2.6
58	*Stereospermum* sp.	Bignoniaceae	1	1	0.8
59	*Trigonostemon semperflorens*	Euphorbiaceae	1	2	1.0
60	*Triumfetta* sp.	Malvaceae	2	6	2.2
61	*Urena lobata*	Malvaceae	1	1	0.8
62	*Zanthoxylum ovalifolium*	Rutaceae	1	1	0.8
63	KawH03	Asteraceae	3	4	2.6
64	KhaiH04	Menispermaceae	1	1	0.8
65	MawH14	Poaceae	1	15	2.7
66	KangH04	Poaceae	2	21	4.2
67	KangH05	Poaceae	2	23	4.5
68	KangH06	Malvaceae	1	9	1.9
69	BilH05		2	7	2.3
70	BilH07		1	4	1.2
71	KawH12		1	1	0.8
72	KhaiH02		1	2	1.0
73	KhaiH03		1	4	1.2
74	KhaiH05		1	3	1.1
75	KhaiH16		1	3	1.1
76	MawH06		1	1	0.8
77	MawH15		1	7	1.6
78	ThingH03		2	1	1.5
79	ThingH09		1	2	1.0
				739	**200**

Table 4.22: Phytosociological attributes of ground layer of seven provenances of *P. roxburghii.*

Sl #	Provenance	Number of species	Density (m^{-2})	Shannon's diversity index	Pielou's evenness index	Simpson's dominance index
1	Mawriang	16	38.0	0.89	0.74	0.03
2	Bilkhawthlir	11	14.7	0.80	0.77	0.06
3	Kawnpui	14	13.3	0.81	0.70	0.05
4	Thingkhangphai	15	40.0	0.80	0.68	0.06
5	Kangpokpi	11	62.7	0.78	0.75	0.05
6	Kezanglwa	10	28.0	0.71	0.71	0.07
7	Khaibung	20	48.7	0.94	0.72	0.03
	All provenances	79	35.2			

The dominance-diversity curves followed Preston's lognormal hypothesis at all sites (Fig. 4.9).

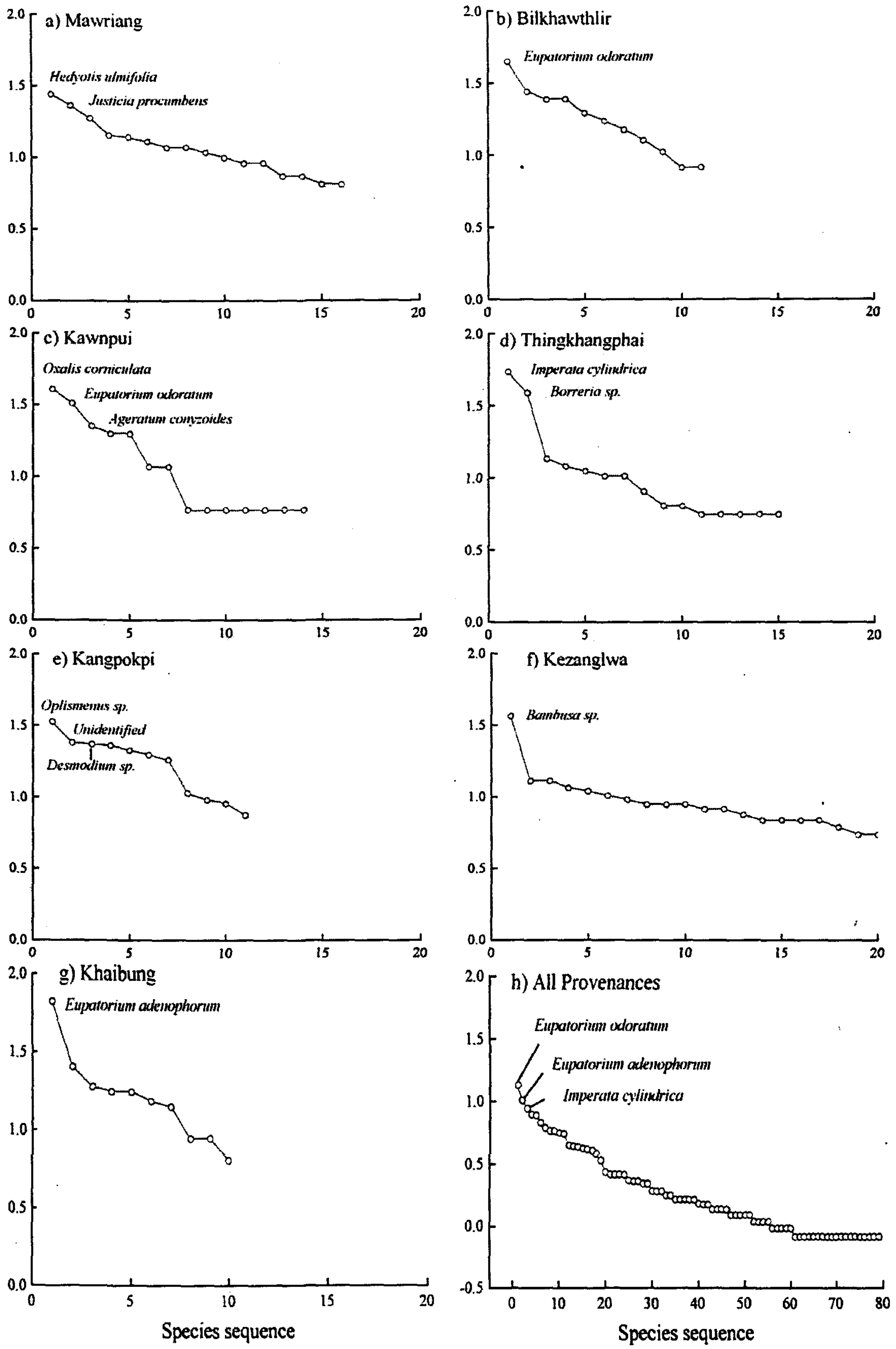


Fig. 4.9. Dominance-diversity curves based on Log_{10} of IVI for ground layer in seven provenances (a through g) and for a pool of all provenances (h).

4.4. Discussion

The phytosociological analysis of seven habitats in the four states of northeastern region of India revealed that: 1) *P. roxburghii* is widely distributed in northeastern region of India, (2) *P. roxburghii* inhabits ecosystems varying from plantations through *jhum* fallows to natural habitats, (3) *P. roxburghii* is not a dominant species at any of the sites, (4) *P. roxburghii* is randomly dispersed, (5) *P. roxburghii* reveals an association with *Schima wallichi* and (6) the natural regeneration of *P. roxburghii* is very poor.

The provenances showed variation in floristic composition, species richness and diversity. Only two provenances were dominated by the naturally occurring species, i.e., Kangpokpi by *Quercus serrata* and Khaibung by *Schima wallichi.* All other provenances were dominated by the planted species. From all seven provenances, 1,510 individuals of >10 cm gbh were recorded which belong to 117 species, 75 genera and 44 identified families. The maximum numbers of species (38 species) were recorded from Mawriang provenance in Meghalaya, despite the fact that this site is dominated by a planted species, *Areca catechu.* The least number of species were recorded from Thingkhangphai provenance in Manipur where *Pinus kesiya* is the most dominant species.

In all seven provenances, the most dominant species was characterized by a high value of IVI. When the data from all seven provenances were pooled, the IVI of the most dominant species, *Schima wallichii*, declined below 30 (Table 4.8). In all, only seven species showed IVI >10. Among these species *Schima wallichii* occurred in all provenances and showed a random dispersion. In these provenances, more than one-half of the species richness was contributed by the rare species with an IVI <1. This is a general trend in most tropical forest in India where the species richness is mostly due to the rare species, as observed in native *sal* forests (Uma Shankar 2001, Uma Shankar *et al.* 1998, Pandey and Shukla 1999, Pandey 1999, Kushwaha and Nandy 2012), dry-deciduous forests (Sukumar *et al.* 1992, Murali *et al.* 1996, Sagar *et al.* 2003), moist-deciduous forests (Sundarapandian and Swami 2000), evergreen forests (Nath *et al.* 2005, Deb and Sundriyal 2011, Ayyappan and Parthasarthy 2004, Parthasarathy and Karthikeyen 1997) montane forests (Sundriyal *et al.* 1994, Rikhari *et al.* 1997) and scrub forests (Uma Shankar *et al.* 1998).

The provenance Khaibung was characterized by the most natural vegetation and high value of species richness, Shannon diversity index and evenness index, and was dominated by *Schima wallichii*. Here, the dominance-diversity curve followed log normal pattern indicating more equitable sharing of resources within the community. In all other sites dominance-diversity curve followed a geometric model indicating the high dominance of one or a few species.

Only three species were characterized by the random dispersion pattern. These are *P. roxburghii*, *Schima wallichii* and *Phyllanthus emblica*. *P. roxburghii* and *Schima wallichii* showed a high value of index of association (0.5) and a Chi square test confirmed that these two species are associated with each other and do not occur independently in studied plots. The phytosociological attributes of *P. roxburghii* and *Schima wallichii* showed a significant correlation.

Evidently, *P. roxburghii* is not a dominant element in any of the communities, which is in conformity with other studies from *P. roxburghii* habitats (Don and Singh 1986, Hopkins 1994, Rocky and Sahoo 2002, Amzu *et al.* 2007). The IVI value of *P. roxburghii* ranged from 8.65 to 19.86 with a mean value of 13.33 in the present study. The density of *P. roxburghii* was between 6 and 18 individuals per hectares. The low dominance of *P. roxburghii* in the present studies indicates is because of the poor regeneration. The population structure of *P. roxburghii* clearly reveled paucity of newly requiring individuals in smaller girth classes. Similarly there was a paucity of individuals of *P. roxburghii* in smaller height classes. In fact, not even a single individual of *P. roxburghii* was recorded in the ground layer in any the seven provenances. The poor regeneration of *P. roxburghii* is presumably because of the harvest of tender as well as mature fruits for consumption as vegetable by the local people. The poor regeneration of a tree species may also be due to failure of seed set, prolonged dormancy, pest attack, poor viability of seeds and germination failure. Some of these aspects are studied and being presented in the next chapters.

PROVENANCE VARIABILITY IN FRUIT AND SEED CHARACTERISTICS OF *Parkia roxburghii*

5.1. Introduction

An idea of the available variation in fruit and seed characteristics and germination behaviour of a species is helpful in selecting the best available geographic source of seeds (Kertadikara and Prat 1995, Uma Shankar and Synrem 2012, Wright 1976). The vigorous growth of the seedlings and subsequent survival in the field depends mainly on the quality of seeds (Abideen *et al.* 1993, Khan *et al.* 1999, Uma Shankar 2006). Variation in weight and dimensions of seeds may result from the diversity in edapho-climatic conditions of the habitats combined with genetic variability (Friis 1992, Willan 1985). While several species exhibit little variability (stenospermous), others reveal large variability (euryspermous). Although studies on germination and seedling growth have been carried out in many species, those on variation in fruit and seed characteristics and their implication on germination and seedling growth are few (Jayasankar *et al.* 1999, Khan *et al.* 1999, Kundu and Tigerstedt 1997, Loha *et al.* 2006, Uma Shankar 2006 and 2012, Uma Shankar and Synrem 2012, Wulff 1986).

The fruit of *P. roxburghii* is the most important part of the tree. A *P. roxburghii* tree bears fruits nearly eight years after planting. Mostly, 12 to 20 fruits are borne in a single capitulum. Each fruit contains 5-20 seeds embedded in spongy yellow endocarp. The tender green fruits are eaten raw. During lean period, the kernels are consumed. There is a visible variation in the color of the fruit from one provenance to the other. On maturity, fruit color turns brown or blackish and the hulls of the fruits become hardened, smooth, and woody. The fruit is also a favored food of chimpanzees, baboons, and other primates (Hopkins 1983) who contribute to dispersal and natural regeneration of this species. Variation in fruit and seed traits of *Parkia* species is poorly studied (Salam *et al.* 1992, Hopkins 1983, Hopkins 1994, Singh *et al.* 2000a, Olorunmaiye *et al.* 2011). Most *Parkia* species including *P. roxburghii* are cross-pollinated resulting into wide variation in fruit and seed traits. Luckow and Hopkins (1995) found considerable variation in pod size, seed size and flavor of *Parkia speciosa* in Thailand.

Although fruit and seed characteristics play an important role in seed germination and seedling growth, there is no information on variation in morphometric traits of *P. roxburghii*. This study focuses on documenting variability and inter-relationships in morphometric traits of fruits and seeds in *P. roxburghii* to select the best provenance and trees for wide multiplication in homesteads.

5.2. Materials and methods

In each of the seven provenances, five phenotypically robust mother trees were selected and tagged for fruit collection. Ten healthy developing fruits on each tree were marked and followed until maturity. When fully ripened, the fruits were collected in spring season (April-May) and transported to the laboratory. Among ten fruits collected from each tree, only five fruits that were free from any disease and were most developed were drawn for further study. Thus, a total of 25 fruits (5 fruits each from 5 trees) were available from each provenance for further analysis.

Fruit length (between peduncular end and stylar end) and pedicel length (between first seed within the fruit and the point of pedicel joining the branch) were measured using a flexible plastic meter-tape bending along curvature of the fruit (Fig. 5.1). A digital calliper was used to measure fruit width (through widest portion of the fruit). The fruits were surface-cleaned with a dry cloth and their weight was recorded on an electronic balance. The seeds within a fruit were counted in two categories: developed and aborted, and their positions were recorded by assigning a serial number beginning as first from the peduncular end (Fig. 5.1). The seeds were manually extracted from the fruits and seed characteristics (seed weight, seed diameter, seed length and seed thickness) were measured (Fig. 5.1). Each seed was labelled and stored in polythene bags until further use. The seeds were used for germination studies as detailed out in the next Chapter.

The data on fruit characteristics were averaged for 25 fruits in each provenance. The variability of mean values is presented in terms of standard deviation and coefficient of variation. The differences between provenances and the years of study, 2006 and 2007, were detected by one-way analysis of variance (F-test) followed by post-hoc Tukey's test. Similarly, the seed characteristics were worked out across the number of seeds recovered from 25 fruits in each provenance. The interrelationships between fruit and seed characteristics were analysed by using linear regression model. The statistical analyses were performed using PAST ver. 2.11 and STATISTICA ver. 6.0 software.

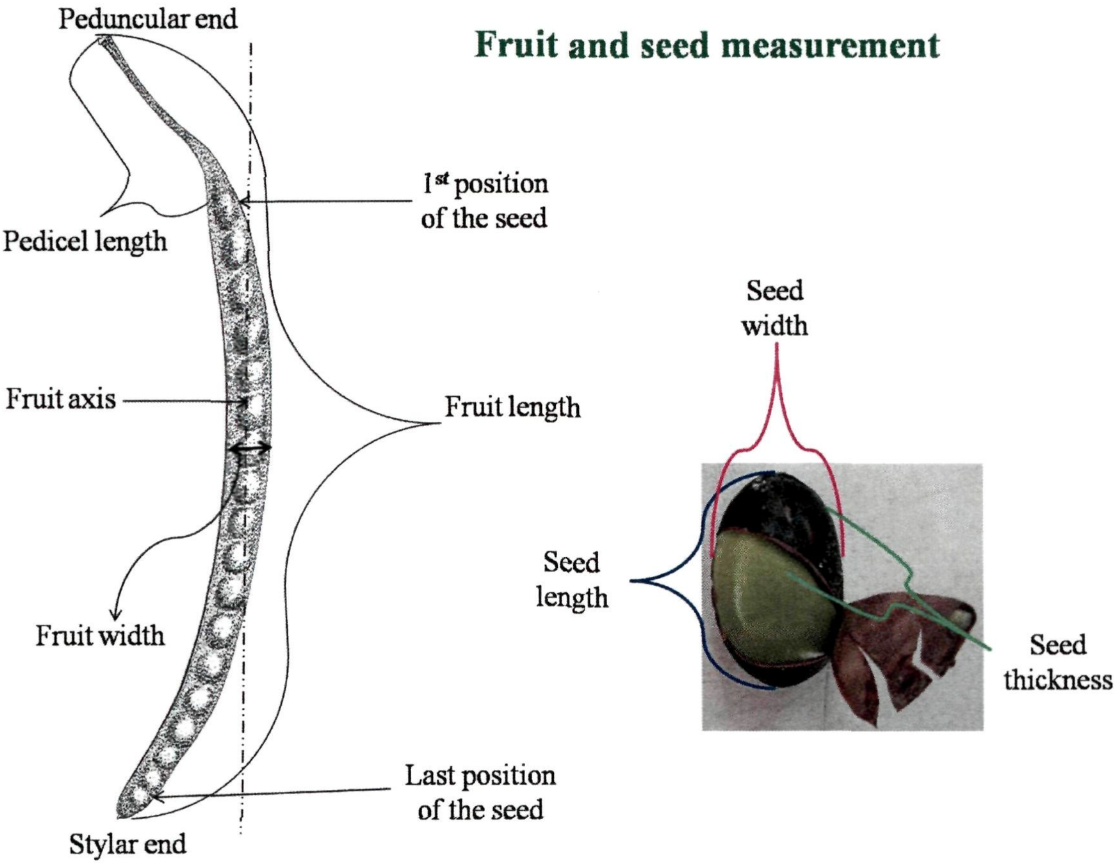


Fig. 5.1. A diagrammatic representation of the measurements of the dimensions of fruit and seed of *Parkia roxburghii.*

5.3. Results

5.3.1. *Fruit characteristics*

Seven fruit traits were considered, viz., fruit weight, fruit length, fruit width, pedicel length, developed seeds per fruit, aborted seeds per fruit, and total seeds per fruit (Fig. 5.2). The data on angle of twist of fruit along its axis and on the angle of pedicel from the capitulum are not considered here. The data on fruit traits are presented for two consecutive years, i.e., 2006 and 2007. The phenotypic traits of fruits vary visually among provenances (Fig. 5.2).

Fig. 5.2. Variation in phenotypic traits of fruits among provenances in northeast India.

5.3.2. *Provenance variation among fruit traits*

The mean fruit weight varied from 23.98 g (Bilkhawthlir) to 39.28 g (Kangpokpi) in 2006 and from 23.51 g (Bilkhawthlir) to 40.61 g (Kawnpui) in 2007 (Tables 5.1, 5.2). The minimum weight of a single fruit was 13.72 g in 2006 and 12.14 g in 2007. The maximum weight of a single fruit was 60.39 g in 2006 and 64.30 g in 2007. Hence, fruit weight varied nearly 5-fold across all provenances. The coefficient of variation ranged from 9.3% to 33.6% in 2006 and from 11.8% to 25.9% in 2007 among provenances.

The mean fruit length varied from 27.00 cm (Bilkhawthlir) to 43.78 cm (Mawriang) in 2006 and from 30.67 cm (Kezanglwa) to 51.57 cm (Mawriang) in 2007 (Tables 5.1, 5.2). The minimum length of a single fruit was 19.5 cm in 2006 and 14.1 cm in 2007. The maximum length of a single fruit was 51.00 cm in 2006 and 58.60 cm in 2007. Hence, fruit length varied nearly 3-fold across all provenances. The coefficient of variation ranged from 4% to 23% in 2006 and from 7.9% to 30.6% in 2007 among provenances.

The mean fruit width varied from 1.70 cm (Bilkhawthlir) to 3.61 cm (Kezanglwa) in 2006 and from 5.80 cm (Bilkhawthlir) to 14.4 cm (Kezanglwa) in 2007 (Tables 5.1, 5.2). The minimum width of a single fruit was 1.3 cm in 2006 and 2.5 cm in 2007. The maximum width of a single fruit was 4.5 cm in 2006 and 4.5 cm in 2007. Hence, fruit width varied nearly 3-fold across all provenances. The coefficient of variation ranged from 5.3% to 12.8% in 2006 and from 3.6% to 14.4% in 2007 among provenances.

The mean pedicel length varied from 6.75 cm (Thingkhangphai) to 11.68 cm (Mawriang) in 2006 and from 8.74 cm (Bilkhawthlir) to 13.40 cm (Kawnpui) in 2007 (Tables 5.1, 5.2). The minimum pedicel length of a single fruit was 4 cm in 2006 and 4.5 cm in 2007. The maximum pedicel length of a single fruit was 19 cm in 2006 and 21 cm in 2007. Hence, pedicel length varied nearly 5-fold across all provenances. The coefficient of variation ranged from 7.7% to 35.5% in 2006 and 16.8% to 28.5% in 2007.

The mean number of seeds developed per fruit varied from 12.08 (Kezanglwa) to 16.64 (Mawriang) in 2006 and from 13.04 (Kezanglwa) to 16.36 (Mawriang) in 2007 (Tables 5.1, 5.2). The minimum number of seeds developed in a single fruit was 8 in 2006 and 7 in 2007. The maximum number of seeds developed in a single fruit was 20 in 2006 and 21 in 2007. Hence, number of seeds developed per fruit varied nearly 3-fold across all provenances. The coefficient of variation ranged from 11.8% to 21.2% in 2006 and from 11.7% to 24.5% in 2007 among provenances.

The mean number of aborted seeds per fruit varied from 0.88 (Thingkhangphai) to 3.28 (Kawnpui) in 2006 and from 0.28 (Kangpokpi) to 3.76 (Kawnpui) in 2007 (Tables 5.1, 5.2). The minimum number of aborted seeds in a single fruit was nil in 2006 as well as 2007. The maximum number of aborted seeds in a single fruit was 7 in 2006 and 9 in

2007. Hence, number of aborted seeds per fruit varied many-fold across all provenances. The coefficient of variation ranged from 35.8% to 144.2% in 2006 and from 73% to 152.8% in 2007 among provenances.

The mean number of total seeds per fruit varied from 13.84 (Kezanglwa) to 19.28 (Kawnpui) in 2006 and from 14.32 (Kezanglwa) to 18.20 (Kawnpui) in 2007 (Tables 5.1, 5.2). The minimum number of total seeds in a single fruit was 8 in 2006 and 9 in 2007. The maximum number of total seeds in a single fruit was 23 in 2006 as well as 2007. Hence, the number of total seeds per fruit varied nearly 3-fold across all provenances. The coefficient of variation ranged from 9.05% to 15.8% in 2006 and from 12.7% to 16.0% in 2007 among provenances.

The analysis of variance yielded significant F values for each of the seven fruit traits both in 2006 (Table 5.1) and 2007 (Table 5.2). The results of Tukey's pairwise comparisons between two provenances at a time signify that most pairs of provenances were significantly different with respect to a single trait (Table 5.3, read column wise). The traits, fruit weight, fruit length, fruit width and pedicel length were significantly different for most of the provenance pairs in at least one year (2006 or 2007) or in both the years. With respect to these traits, Kangpokpi, Kezanglwa and Khaibung were not different from each other. The number of developed seeds per fruit did not vary significantly among many provenance pairs. The number of aborted seeds per fruit was significantly different between pairs of Kawnpui indicating that seed abortion was more at Kawnpui than other sites. The total seeds per fruit did not vary significantly in many cases.

Table 5.1. Provenance variation in morphometric traits of fruits of *P. roxburghii* in 2006.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's post-hoc test)
Fruit weight (g)						
1. Bilkhawthlir	25	17.50	27.30	23.98 ± 2.23	9.3	2,3,5,6,7
2. Kawnpui	25	23.80	40.10	32.98 ± 4.75	14.4	1,4,5
3. Mawriang	25	24.13	39.51	32.09 ± 4.39	13.7	1,5
4. Thingkhangphai	25	15.17	35.08	26.91 ± 5.28	19.6	2,6
5. Kangpokpi	25	21.09	60.39	39.28 ±10.97	27.9	1,2,3,4,66
6. Kezanglwa	25	18.19	40.20	32.67 ± 6.15	18.8	1,5
7. Khaibung	25	13.72	59.74	33.65 ±11.32	33.6	1,4
ANOVA						$F=11.85$, $p<0.001$
Fruit length (cm)						
1. Bilkhawthlir	25	24.50	28.00	27.00 ± 1.07	4.0	1,3,5,6,7
2. Kawnpui	25	20.00	35.70	28.87 ± 4.60	15.9	3,5,6,7
3. Mawriang	25	34.20	50.30	43.78 ± 4.07	9.3	1,2,4,5,6
4. Thingkhangphai	25	23.00	33.00	29.49 ± 2.95	10.0	3,5,6,7
5. Kangpokpi	25	25.70	50.50	36.95 ± 6.60	17.8	1,2,3,4
6. Kezanglwa	25	21.00	50.00	38.03 ± 6.88	18.1	1,2,3,4
7. Khaibung	25	19.50	51.00	39.43 ± 9.05	23.0	1,2,4
ANOVA						$F=31.92$, $p<0.001$
Fruit width (cm)						
1. Bilkhawthlir	25	1.30	2.00	1.70 ± 0.26	15.1	2,3,4,5,6,7
2. Kawnpui	25	2.30	3.70	2.90 ± 0.40	13.7	1,3,5,6,7
3. Mawriang	25	3.10	3.70	3.40 ± 0.18	5.3	1,2,4
4. Thingkhangphai	25	2.30	3.70	3.04 ± 0.38	12.5	1,3,5,6
5. Kangpokpi	25	2.50	4.20	3.42 ± 0.44	12.8	1,2,4
6. Kezanglwa	25	3.20	4.50	3.61 ± 0.36	9.9	1,2,4,7
7. Khaibung	25	2.50	4.00	3.30 ± 0.35	10.8	1,2,6
ANOVA						$F=85.23$, $p<0.001$
Pedicel length (cm)						
1. Bilkhawthlir	25	7.00	9.00	7.60 ± 0.82	10.7	2,3,6,7
2. Kawnpui	25	9.00	12.10	10.55 ± 0.81	7.7	1,4,5
3. Mawriang	25	6.50	16.50	11.68 ± 2.34	20.1	1,4,5,7
4. Thingkhangphai	25	5.00	11.00	6.75 ± 1.55	23.0	2,3,6,7
5. Kangpokpi	25	4.60	13.00	8.62 ± 2.19	25.4	2,3

6. Kezanglwa	25	4.90	19.00	10.45 ± 3.71	35.5	1,4
7. Khaibung	25	4.00	16.50	9.64 ± 3.02	31.3	1,3,4
ANOVA						F=14.63, p<0.001
Seeds developed per fruit						
1. Bilkhawthlir	25	12.00	19.00	15.20 ± 2.02	13.3	6
2. Kawnpui	25	10.00	20.00	16.00 ± 1.89	11.8	5,6,7
3. Mawriang	25	13.00	20.00	16.64 ± 2.56	15.4	4,5,6,7
4. Thingkhangphai	25	10.00	20.00	14.36 ± 2.75	19.2	3,6
5. Kangpokpi	25	9.00	17.00	14.00 ± 2.00	14.3	2,3
6. Kezanglwa	25	8.00	17.00	12.08 ± 2.56	21.2	1,2,3,4
7. Khaibung	25	10.00	19.00	13.84 ± 2.21	16.0	2,3
ANOVA						F=10.82, p<0.001
Seeds aborted per fruit						
1. Bilkhawthlir	25	0.00	6.00	2.08 ± 1.68	80.8	NS
2. Kawnpui	25	1.00	6.00	3.28 ± 1.17	35.8	3,4,5,6
3. Mawriang	25	0.00	5.00	1.68 ± 1.52	90.5	2
4. Thingkhangphai	25	0.00	5.00	0.88 ± 1.27	144.2	2,7
5. Kangpokpi	25	0.00	6.00	1.28 ± 1.43	111.7	2
6. Kezanglwa	25	0.00	5.00	1.76 ± 1.42	80.8	2
7. Khaibung	25	0.00	7.00	2.28 ± 2.07	90.9	4
ANOVA						F=6.32, p<0.001
Total seeds per fruit						
1. Bilkhawthlir	25	13.00	21.00	17.28 ± 2.09	12.1	2,4,5,6
2. Kawnpui	25	12.00	21.00	19.28 ±1.74	9.05	1,4,5,6,7
3. Mawriang	25	14.00	23.00	18.32 ± 2.23	12.2	4,5,6,7
4. Thingkhangphai	25	11.00	20.00	15.24 ± 2.37	15.5	1,2,3
5. Kangpokpi	25	11.00	18.00	15.28 ± 1.72	11.3	1,2,3
6. Kezanglwa	25	8.00	17.00	13.84 ± 2.19	15.8	1,2,3,7
7. Khaibung	25	11.00	20.00	16.12 ± 2.33	14.5	2,3,6
ANOVA						F=20.5, p<0.001

Table 5.2. Provenance variation in morphometric traits of fruits of *P. roxburghii* in 2007.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's post-hoc test)
Fruit weight (g)						
1. Bilkhawthlir	25	16.93	40.89	23.51 ± 5.44	23. 2	2,3,4,5,7
2. Kawnpui	25	29.13	64.30	40.61 ± 9.56	23.5	1,3,4,5,6,7
3. Mawriang	25	13.93	58.34	32.36 ± 8.06	24.9	1,2,6,7
4. Thingkhangphai	25	18.91	42.76	34.29 ± 6.82	19.9	1,2,6,7
5. Kangpokpi	25	23.12	38.71	31.14 ± 4.44	14.2	1,2,6,7
6. Kezanglwa	25	22.32	32.13	25.32 ± 3.00	11.8	2,3,4,57
7. Khaibung	25	12.14	26.21	16.58 ± 4.30	25.9	1,2,3,4,5,6
ANOVA						F=39.25, p<0.001
Fruit length (cm)						
1. Bilkhawthlir	25	28.00	44.50	35.44 ± 4.45	12.5	2,3
2. Kawnpui	25	34.00	58.60	45.70 ± 5.86	12.8	1,3,4,5,6,7
3. Mawriang	25	40.24	58.00	51.57 ± 4.10	7.9	1,2,4,5,6,7
4. Thingkhangphai	25	30.00	48.50	39.84 ± 5.52	13.9	2,3,5,6,7
5. Kangpokpi	25	25.00	42.46	32.83 ± 4.16	12.7	2,3,4
6. Kezanglwa	25	18.52	37.52	30.67 ± 4.61	15.0	2,3,4
7. Khaibung	25	14.10	54.02	33.52 ±10.26	30.6	2,3,4
ANOVA						F=41.84, p<0.001
Fruit width (cm)						
1. Bilkhawthlir	25	2.50	3.20	2.87 ± 0.17	5.8	2,3,4,6
2. Kawnpui	25	3.20	4.50	3.64 ± 0.38	10.4	1,5,6,7
3. Mawriang	25	3.20	3.80	3.50 ± 0.13	3.6	1,5,7
4. Thingkhangphai	25	3.00	4.00	3.42 ± 0.24	7.0	1,5,7
5. Kangpokpi	25	2.66	3.91	3.07 ± 0.30	9.9	2,3,4,6
6. Kezanglwa	25	2.52	4.21	3.38 ± 0.49	14.4	1,2,5,7
7. Khaibung	25	2.72	3.43	3.06 ± 0.20	6.7	2,3,4,6
ANOVA						F=22.25, p<0.001
Pedicel length (cm)						
1. Bilkhawthlir	25	5.50	13.00	8.92 ± 2.16	24.2	2,3,4
2. Kawnpui	25	5.50	20.30	14.34 ± 3.90	27.2	1,5,6,7
3. Mawriang	25	9.00	17.00	12.80 ± 2.18	17.9	1,5,6,7
4. Thingkhangphai	25	5.50	21.00	13.40 ± 3.82	28.5	1,5,6,7
5. Kangpokpi	25	5.50	12.40	9.45 ± 1.73	18.3	2,3,4
6. Kezanglwa	25	4.50	12.50	8.74 ± 2.06	25.6	2,3,4

7. Khaibung	25	6.20	12.10	8.84 ± 1.49	16.8	2,3,4
ANOVA						F=20.74, p<0.001
Seeds developed per fruit						
1. Bilkhawthlir	25	9.00	21.00	16.20 ± 2.93	18.1	4,6
2. Kawnpui	25	8.00	19.00	14.44 ± 3.54	24.5	NS
3. Mawriang	25	10.00	20.00	16.36 ± 2.46	15.1	4,6
4. Thingkhangphai	25	9.00	17.00	13.84 ± 2.19	15.8	1,3
5. Kangpokpi	25	12.00	19.00	15.48 ± 1.81	11.7	6
6. Kezanglwa	25	8.00	17.00	13.04 ± 2.68	20.6	1,3,5
7. Khaibung	25	7.00	20.00	14.16 ± 3.10	21.9	NS
ANOVA						F=5.27, p<0.001
Seeds aborted per fruit						
1. Bilkhawthlir	25	0.00	3.00	0.76 ± 1.01	133.1	2
2. Kawnpui	25	0.00	9.00	3.76 ± 2.74	73.0	1,3,4,5,6,7
3. Mawriang	25	0.00	5.00	1.68 ± 1.52	90.5	2,5
4. Thingkhangphai	25	0.00	5.00	0.72 ± 1.10	152.8	2
5. Kangpokpi	25	0.00	2.00	0.28 ± 0.54	193.4	2,3,7
6. Kezanglwa	25	0.00	4.00	1.28 ± 1.06	82.9	2
7. Khaibung	25	0.00	6.00	1.88 ± 1.62	85.9	2,5
ANOVA						F=14.45, p<0.001
Total seeds per fruit						
1. Bilkhawthlir	25	11.00	21.00	16.96 ± 2.54	15.0	4,6
2. Kawnpui	25	13.00	22.00	18.20 ± 2.48	13.6	4,5,6
3. Mawriang	25	12.00	23.00	18.04 ± 2.89	16.0	4,5,6
4. Thingkhangphai	25	9.00	18.00	14.56 ± 2.10	14.4	1,2,3
5. Kangpokpi	25	12.00	20.00	15.76 ± 2.01	12.7	2,3
6. Kezanglwa	25	9.00	19.00	14.32 ± 2.82	19.7	1,2,3
7. Khaibung	25	8.00	22.00	16.04 ± 3.32	20.7	-
ANOVA						F=8.65, p<0.001

Similarly, a single pair of provenance showed significant differences mostly with respect to fruit weight, fruit length, fruit width and pedicel length (Table 5.3, read row wise). The differences with respect to number of developed, aborted and total seeds were only in fewcases and were mostly present in pairs of Kawnpui with other provenances.

Table 5.3. Tukey's post-hoc test of significant differences between pairs of provenances following one-way analysis of variance for seven fruit traits for 2006 (first digit) and 2007 (second digit). The digit 'Y' means significantly different and 'N' means not different at p=0.05. The digits in red color highlight 'differences not significant in both the years', in green colour highlight 'differences significant in only one of the years' and in black colour highlight 'differences significant in both the years'.

Provenance pair	Fruit weight	Fruit length	Fruit width	Pedicel length	Developed seeds	Aborted seeds	Total seeds
1. Bilkhawthlir - Kawnpui	Y Y	N Y	Y Y	Y Y	N N	N Y	Y N
2. Bilkhawthlir - Mawriang	Y Y	Y Y	Y Y	Y Y	N N	N N	N N
3. Bilkhawthlir-Thingkhangphai	N Y	N N	Y N	N Y	N Y	N N	Y Y
4. Bilkhawthlir - Kangpokpi	Y Y	Y N	Y N	N N	N N	N N	Y N
5. Bilkhawthlir - Kezanglwa	Y N	Y N	Y Y	Y N	Y Y	N N	Y Y
6. Bilkhawthlir - Khaibung	Y Y	Y N	Y N	Y N	N N	N N	N N
7. Kawnpui - Mawriang	N Y	Y Y	Y N	N N	N N	Y Y	N N
8. Kawnpui - Thingkhangphai	Y Y	N Y	N N	Y N	N N	Y Y	Y Y
9. Kawnpui - Kangpokpi	Y Y	Y Y	Y Y	Y Y	Y N	Y Y	Y Y
10. Kawnpui - Kezanglwa	N Y	Y Y	Y Y	N Y	Y N	Y Y	Y Y
11. Kawnpui - Khaibung	N Y	Y Y	Y Y	N Y	Y N	N Y	Y N
12. Mawriang-Thingkhangphai	N N	Y Y	Y N	Y N	Y Y	N N	Y Y
13. Mawriang - Kangpokpi	Y N	Y Y	N Y	Y Y	Y N	N Y	Y Y
14. Mawriang - Kezanglwa	N Y	Y Y	N N	N Y	Y Y	N N	Y Y
15. Mawriang - Khaibung	N Y	N Y	N Y	Y Y	Y N	N N	Y N
16. Thingkhangphai-Kangpokpi	Y N	Y Y	Y Y	Y Y	N N	N N	N N
17. Thingkhangphai-Kezanglwa	N Y	Y Y	Y N	Y Y	Y N	N N	N N
18. Thingkhangphai - Khaibung	Y Y	Y Y	N Y	Y Y	N N	Y N	N N
19. Kangpokpi - Kezanglwa	Y Y	N N	N Y	N N	N Y	N N	N N
20. Kangpokpi - Khaibung	N Y	N N	N N	N N	N N	N Y	N N
21. Kezanglwa - Khaibung	N Y	N N	Y Y	N N	N N	N N	Y N

5.3.3. *Relationships among fruit traits*

The relationships among fruit traits are shown in Figs. 5.3 and 5.4. Fruit weight showed a positive linear correlation with fruit length, fruit width, pedicel length and the number of seeds per fruit both in 2006 and 2007 (Table 5.4). The scatter diagrams showed that the relationship of fruit weight was strongest with fruit length and weakest with number of seeds per fruit in 2006 (Fig. 5.3) and 2007 (Fig. 5.4). Fruit length showed a stronger relationship with pedicel length and weaker relationship with number of seeds per fruit in 2006 (Fig. 5.3) and 2007 (Fig. 5.4).

Table 5.4. Relationships among morphometric traits of fruits of *P. roxburghii* in 2006 and 2007.

Provenance (year)	Sample size (n)	Dependent variable (Y)	Independent variable (X)	Regression model	r	*p*
All	175	Fruit weight	Fruit length	y = 9.56 + 0.64x	0.61	0.001
(2006)	175	Fruit weight	Fruit width	y = 10.50 + 6.93x	0.57	0.001
	175	Fruit weight	Pedicel length	y = 21.01 + 1.14x	0.38	0.001
	175	Fruit weight	Seeds per fruit	y = 23.22 + 0.58x	0.18	0.020
	175	Fruit length	Pedicel length	y = 18.88 + 1.71x	0.59	0.001
	175	Fruit length	Seeds per fruit	y = 28.72 + 0.42x	0.14	0.070
All	175	Fruit weight	Fruit length	y = 6.64 + 0.58x	0.56	0.001
(2007)	175	Fruit weight	Fruit width	y = -3.94 + 10.09x	0.41	0.001
	175	Fruit weight	Pedicel length	y = 10.53 + 1.72x	0.63	0.001
	175	Fruit weight	Seeds per fruit	y = 19.91 + 0.62x	0.19	0.010
	175	Fruit length	Pedicel length	y = 21.93 + 1.54x	0.59	0.001
	175	Fruit length	Seeds per fruit	y = 25.44 + 0.88x	0.28	0.001
Mawriang	25	Fruit weight	Fruit length	y = -0.84 + 0.75x	0.70	0.010
(2006)	25	Fruit weight	Fruit width	y = 32.36 - 0.08x	0.00	0.990
	25	Fruit weight	Pedicel length	y = 26.31 + 0.50x	0.26	0.200
	25	Fruit weight	Seeds per fruit	y = 21.63 + 0.63x	0.37	0.070
	25	Fruit length	Pedicel length	y = 30.87 + 1.11x	0.64	0.001
	25	Fruit length	Seeds per fruit	y = 39.16 + 0.28x	0.18	0.400
Mawriang	25	Fruit weight	Fruit length	y = 29.12 + 0.06x	0.03	0.880
(2007)	25	Fruit weight	Fruit width	y = 20.42 + 3.41x	0.05	0.800
	25	Fruit weight	Pedicel length	y = 19.67 + 1.04x	0.28	0.170
	25	Fruit weight	Seeds per fruit	y = -3.10 + 2.17x	0.66	0.001
	25	Fruit length	Pedicel length	y = 48.50 + 0.25x	0.13	0.520
	25	Fruit length	Seeds per fruit	y = 60.31 - 0.53x	-0.32	0.120
Bilkhawthlir	25	Fruit weight	Fruit length	y = 21.10 + 0.11x	0.05	0.810
(2006)	25	Fruit weight	Fruit width	y = 18.34 + 3.31x	0.38	0.060
	25	Fruit weight	Pedicel length	y = 22.65 + 0.18x	0.06	0.760
	25	Fruit weight	Seeds per fruit	y = 24.07 - 0.01x	-0.01	0.980

	25	Fruit length	Pedicel length	y = 28.90 - 0.25x	-0.19	0.360
	25	Fruit length	Seeds per fruit	y = 31.54 - 0.30x	-0.56	0.001
Bilkhawthlir	25	Fruit weight	Fruit length	y = -6.18 + 0.84x	0.68	0.001
(2007)	25	Fruit weight	Fruit width	y = 35.94 - 4.33x	-0.13	0.520
	25	Fruit weight	Pedicel length	y = 11.34 + 1.36x	0.54	0.010
	25	Fruit weight	Seeds per fruit	y = 20.97 + 0.16x	0.08	0.690
	25	Fruit length	Pedicel length	y = 20.57 + 1.67x	0.81	0.001
	25	Fruit length	Seeds per fruit	y = 34.67 + 0.05x	0.03	0.880
Kawnpui	25	Fruit weight	Fruit length	y = 43.46 - 0.36x	-0.35	0.080
(2006)	25	Fruit weight	Fruit width	y = 33.94 - 0.33x	-0.03	0.900
	25	Fruit weight	Pedicel length	y = 22.51 + 0.99x	0.17	0.420
	25	Fruit weight	Seeds per fruit	y = 35.08 - 0.13x	-0.05	0.800
	25	Fruit length	Pedicel length	y = 43.29 - 1.37x	-0.24	0.250
	25	Fruit length	Seeds per fruit	y = 16.63 + 0.77x	0.31	0.130
Kawnpui	25	Fruit weight	Fruit length	y = -11.85 + 1.15x	0.70	0.001
(2007)	25	Fruit weight	Fruit width	y = -3.87 + 12.22x	0.49	0.010
	25	Fruit weight	Pedicel length	y = 25.84 + 1.03x	0.42	0.040
	25	Fruit weight	Seeds per fruit	y = 39.27 + 0.09x	0.03	0.870
	25	Fruit length	Pedicel length	y = 34.60 + 0.77x	0.21	0.010
	25	Fruit length	Seeds per fruit	y = 43.75 + 0.13x	0.08	0.700
Thingkhangphai	25	Fruit weight	Fruit length	y = -14.95 + 1.42x	0.79	0.001
(2006)	25	Fruit weight	Fruit width	y = -9.12 + 11.84x	0.85	0.001
	25	Fruit weight	Pedicel length	y = 19.09 + 1.16x	0.34	0.100
	25	Fruit weight	Seeds per fruit	y = 12.62 + 0.995x	.0.52	0.010
	25	Fruit length	Pedicel length	y = 23.92 + 0.83x	0.43	0.030
	25	Fruit length	Seeds per fruit	y = 20.05 + 0.66x	0.61	0.001
Thingkhangphai	25	Fruit weight	Fruit length	y = -6.47 + 1.02x	0.83	0.001
(2007)	25	Fruit weight	Fruit width	y = 10.21 + 7.05x	0.25	0.240
	25	Fruit weight	Pedicel length	y = 19.17 + 1.13x	0.63	0.001
	25	Fruit weight	Seeds per fruit	y = 2.42 + 2.30x	0.74	0.001
	25	Fruit length	Pedicel length	y = 29.23 + 0.79x	0.55	0.001
	25	Fruit length	Seeds per fruit	y = 16.96 + 1.65x	0.66	0.001
Kangpokpi	25	Fruit weight	Fruit length	y = -18.22 + 1.56x	0.94	0.001
(2006)	25	Fruit weight	Fruit width	y = -40.08 + 23.23x	0.93	0.001
	25	Fruit weight	Pedicel length	y = 27.84 + 1.33x	0.27	0.200
	25	Fruit weight	Seeds per fruit	y = 14.32 + 1.78x	0.33	0.110
	25	Fruit length	Pedicel length	y = 25.61 + 1.32x	0.44	0.030
	25	Fruit length	Seeds per fruit	y = 25.18 + 0.84x	0.25	0.220
Kangpokpi	25	Fruit weight	Fruit length	y = 36.18 - 0.15x	-0.14	0.490
(2007)	25	Fruit weight	Fruit width	y = 50.30 - 6.23x	-0.43	0.030
	25	Fruit weight	Pedicel length	y = 29.89 + 0.13x	0.05	0.810
	25	Fruit weight	Seeds per fruit	y = 42.90 - 0.76x	-0.31	0.130
	25	Fruit length	Pedicel length	y = 16.01 + 1.78x	0.74	0.001
	25	Fruit length	Seeds per fruit	y = 20.91 + 0.77x	0.33	0.100

Kezanglwa	25	Fruit weight	Fruit length	y = 8.51 + 0.64x	0.71	0.001
(2006)	25	Fruit weight	Fruit width	y = 54.72 - 6.10x	-0.35	0.080
	25	Fruit weight	Pedicel length	y = 29.33 + 0.32x	0.19	0.360
	25	Fruit weight	Seeds per fruit	y = 13.28 + 1.61x	0.67	0.001
	25	Fruit length	Pedicel length	y = 27.82 + 0.98x	0.53	0.010
	25	Fruit length	Seeds per fruit	y = 17.06 + 1.74x	0.65	0.001
Kezanglwa	25	Fruit weight	Fruit length	y = 21.29 + 0.13x	0.20	0.330
(2007)	25	Fruit weight	Fruit width	y = 32.16 - 2.02x	-0.33	0.110
	25	Fruit weight	Pedicel length	y = 24.14 + 0.14x	0.09	0.660
	25	Fruit weight	Seeds per fruit	y = 14.58 + 0.82x	0.74	0.001
	25	Fruit length	Pedicel length	y = 21.35 + 1.07x	0.48	0.020
	25	Fruit length	Seeds per fruit	y = 22.57 + 0.62x	0.36	0.080
Khaibung	25	Fruit weight	Fruit length	y = 0.03 + 0.85x	0.68	0.001
(2006)	25	Fruit weight	Fruit width	y = -54.99 + 26.86x	0.84	0.001
	25	Fruit weight	Pedicel length	y = 10.87 + 2.36x	0.63	0.001
	25	Fruit weight	Seeds per fruit	y = 3.08 + 2.21x	0.43	0.030
	25	Fruit length	Pedicel length	y = 15.39 + 2.49x	0.83	0.001
	25	Fruit length	Seeds per fruit	y = 25.31 + 1.02x	0.25	0.230
Khaibung	25	Fruit weight	Fruit length	y = 7.25 + 0.28x	0.66	0.001
(2007)	25	Fruit weight	Fruit width	y = 28.71 - 3.96x	-0.19	0.370
	25	Fruit weight	Pedicel length	y = 1.7 + 1.68x	0.58	0.001
	25	Fruit weight	Seeds per fruit	y = 10.73 + 0.41x	0.30	0.150
	25	Fruit length	Pedicel length	y = 3.91 + 3.35x	0.49	0.010
	25	Fruit length	Seeds per fruit	y = 12.23 + 1.50x	0.45	0.020

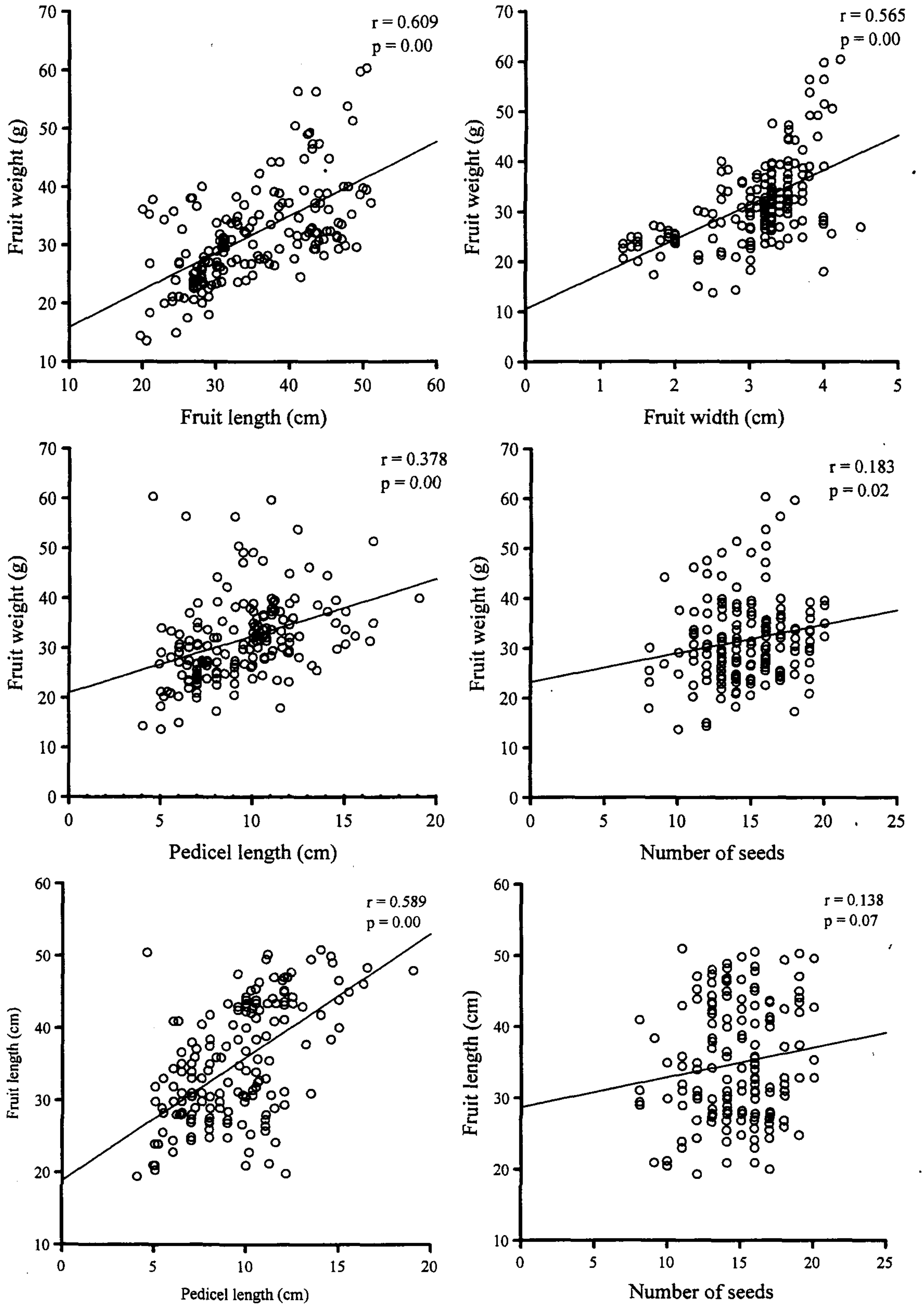


Fig. 5.3. Relationships among morphometric traits of fruits in the year 2006.

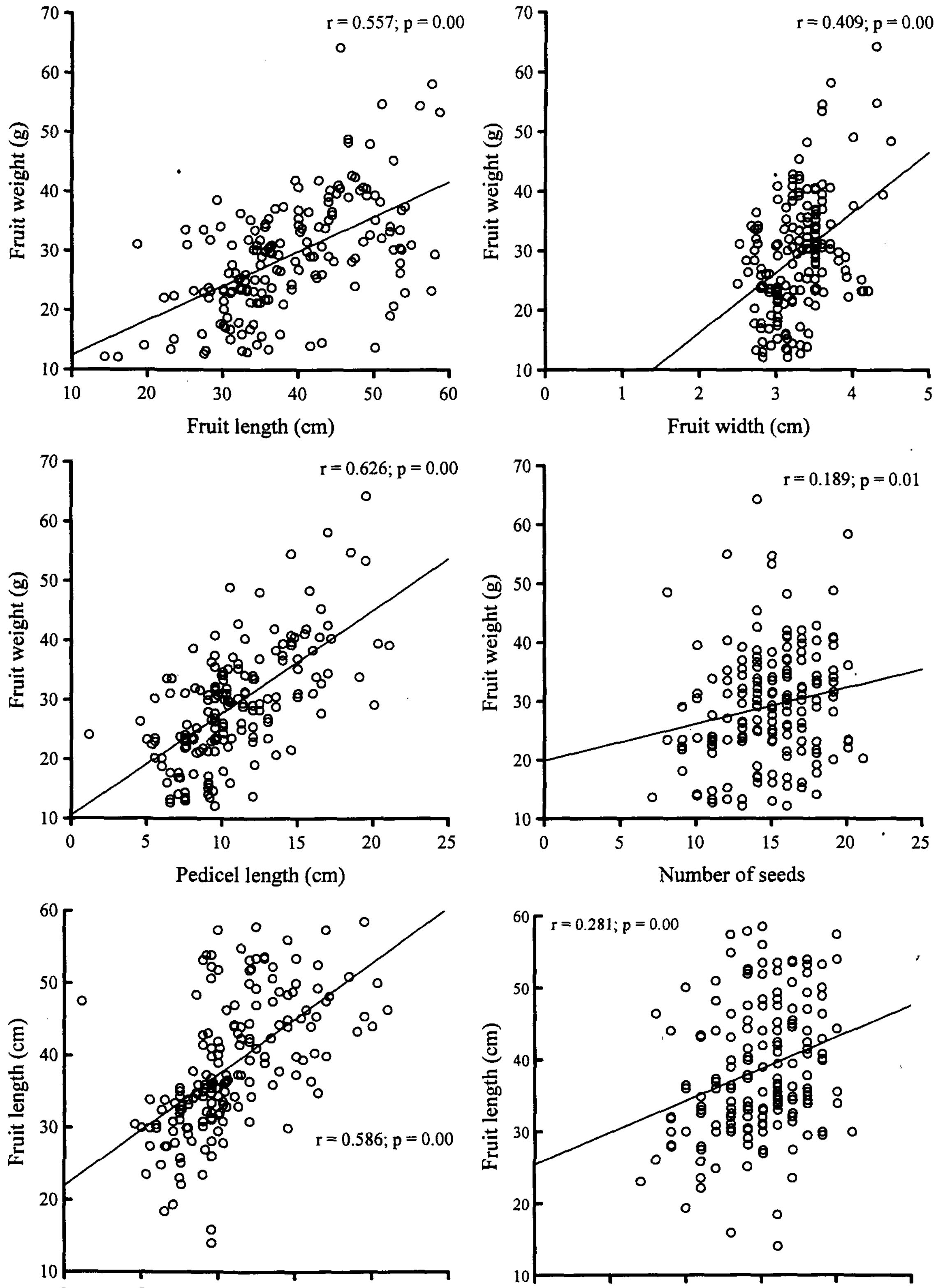


Fig. 5.4. Relationships among morphometric traits of fruits in the year 2007

5.3.4. *Seed characteristics*

Five seed traits were considered, viz., seed weight, seed length, seed width, seed thickness and seeds volume (Fig. 5.2). The data on seed traits are presented for two consecutive years, i.e., 2006 and 2007. The phenotypic traits of seeds vary among provenances (Fig. 5.5). The external appearance of seeds varied in texture, smoothness, color and turgidity. However, all these qualitative traits are not considered in further analysis.

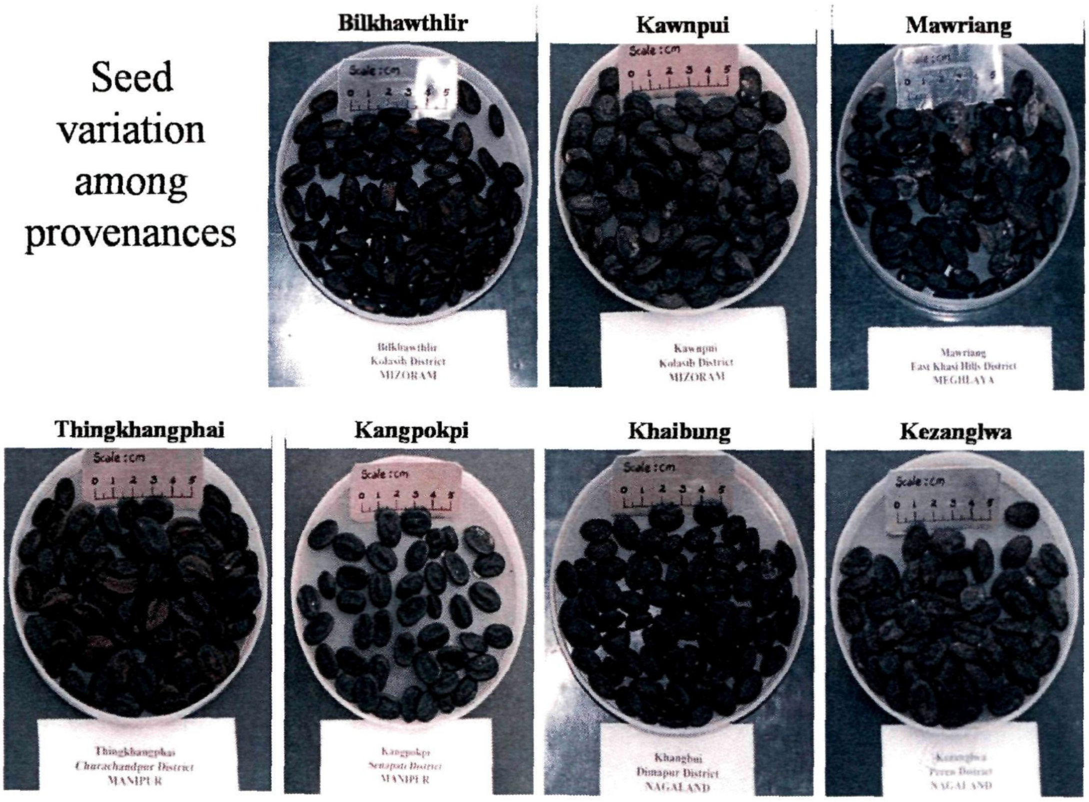


Fig. 5.5. Variation in phenotypic traits of fruits among provenances in northeast India.

5.3.5. *Provenance variation among seed traits*

The mean seed weight varied from 0.42 g (Mawriang) to 1.02 g (Kangpokpi) in 2006 and from 0.45 g (Kezanglwa) to 0.90 g (Bilkhawthlir) in 2007 (Tables 5.5, 5.6). The minimum weight of a single seed was 0.1 g in 2006 and 0.08 g in 2007. The maximum weight of a single seed was 1.88 g in 2006 and 1.40 g in 2007. Hence, seed weight varied nearly 18-fold across all provenances. The coefficient of variation ranged from 5% to 34.1% in 2006 and from 5.1% to 27.9% in 2007 among provenances.

The mean seed length varied from 1.5 cm (Mawriang) to 1.9 cm (Kezanglwa) in 2006 and from 1.35 cm (Thingkhangphai) to 1.8 cm (Bilkhawthlir) in 2007 (Tables 5.5, 5.6). The minimum length of a single seed was 0.89 cm in 2006 and 0.36 cm in 2007. The maximum length of a single seed was 2.81 cm in 2006 and 2.3 cm in 2007. Hence, seed length varied nearly 8-fold across all provenances. The coefficient of variation ranged from 2.1% to 13% in 2006 and from 2% to 10% in 2007 among provenances.

The mean seed width varied from 1.16 cm (Mawriang) to 1.39 cm (Kangpokpi) in 2006 and from 1.16 cm (Bilkhawthlir) to 1.98 cm (Kezanglwa) in 2007 (Tables 5.5, 5.6). The minimum width of a single seed was 0.31 cm in 2006 and 0.12 cm in 2007. The maximum width of a single seed was 1.8 cm in 2006 and 2.3 cm in 2007. Hence, seed width varied nearly 7-fold across all provenances. The coefficient of variation ranged from 2.5% to 9.8% in 2006 and from 2.3% to 25.5% in 2007 among provenances.

The mean seed thickness varied from 0.48 cm (Mawriang) to 0.7 cm (Bilkhawthlir) in 2006 and from 0.42 cm (Khaibung) to 0.63 cm (Kawnpui) in 2007 (Tables 5.5, 5.6). The minimum seed thickness of a single seed was 0.19 cm in 2006 and 0.19 cm in 2007. The maximum seed thickness of a single seed was 1.11 cm in 2006 and 1.53 cm in 2007. Hence, seed thickness varied nearly 7-fold across all provenances. The coefficient of variation ranged from 3.5% to 26.3% in 2006 and 3% to 22.7% in 2007 among provenances.

The mean seed volume varied from 0.84 cm (Mawriang) to 1.86 cm (Kangpokpi) in 2006 and from 0.78 cm (Khaibung) to 2.23 cm (Kawnpui) in 2007 (Tables 5.5, 5.6). The minimum seed volume of a single seed was 0.27 cm in 2006 and 0.1 cm in 2007. The maximum seed volume of a single seed was 3.13 cm in 2006 and 3.61 cm in 2007. Hence, seed volume varied nearly 7-fold across all provenances. The coefficient of variation ranged from 5.1% to 37.2% in 2006 and 4.9% to 40.2% in 2007 among provenances.

The analysis of variance yielded significant F values for each of the five seed traits both in 2006 (Table 5.5) and 2007 (Table 5.6). The results of Tukey's pairwise comparisons between two provenances at a time signify that most pairs of provenances were significantly different with respect to a single trait (Table 5.7, read column wise). The traits, seed weight, seed length, seed width, seed thickness and seed volume were significantly different for most of the provenance pairs in at least one year (2006 or 2007) or in both the years. With respect to these traits, Bilkhawthlir and Kawnpui were not different from each other.

Table 5.5. Provenance variation in morphometric traits of seeds of *P. roxburghii* in 2006.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's test)
Seed weight (g)						
1. Bilkhawthlir	25	0.59	1.40	0.92 ± 0.06	6.3	3,4,5,6,7
2. Kawnpui	25	0.50	1.88	0.93 ± 0.05	5.0	3,4,5,6,7
3. Mawriang	25	0.10	0.66	0.42 ± 0.08	19.2	1,2,4,5,6,7
4. Thingkhangphai	25	0.17	1.35	0.67 ± 0.15	21.6	1,2,3,5,6,7
5. Kangpokpi	25	0.31	1.56	1.02 ± 0.18	17.8	1,2,3,4,6,7
6. Kezanglwa	25	0.13	1.71	0.74 ± 0.25	34.1	1,2,3,4,5
7. Khaibung	25	0.25	1.85	0.72 ± 0.24	33.4	1,2,3,4,5
ANOVA						$F=403.8$, $p<0.001$
Seed length (cm)						
1. Bilkhawthlir	25	1.44	2.30	1.84 ± 0.05	2.8	3,4,5,6,7
2. Kawnpui	25	1.40	2.17	1.82 ± 0.04	2.1	3,4,5,6,7
3. Mawriang	25	0.91	1.80	1.50 ± 0.08	5.2	1,2,4,5,6,7
4. Thingkhangphai	25	1.15	2.30	1.64 ± 0.14	8.5	1,2,3,5,6,7
5. Kangpokpi	25	0.89	2.81	1.89 ± 0.19	9.9	1,2,3,4,6
6. Kezanglwa	25	1.23	2.50	1.90 ± 0.11	6.0	1,2,3,4,5,7
7. Khaibung	25	1.00	2.30	1.70 ± 0.22	13.0	1,2,3,4,6
ANOVA						$F=249.5$, $p<0.001$
Seed width (cm)						
1. Bilkhawthlir	25	1.00	1.68	1.28 ± 0.04	3.1	3,4,5,7
2. Kawnpui	25	1.00	1.74	1.28 ± 0.03	2.5	3,4,5,7
3. Mawriang	25	0.70	1.43	1.16 ± 0.06	5.1	1,2,5,6,7
4. Thingkhangphai	25	0.59	1.80	1.16 ± 0.11	9.6	1,2,5,6,7
5. Kangpokpi	25	0.31	1.80	1.39 ± 0.12	8.5	1,2,3,4,6,7
6. Kezanglwa	25	0.79	1.68	1.30 ± 0.11	8.3	3,4,5,7
7. Khaibung	25	0.81	1.74	1.25 ± 0.12	9.8	1,2,3,4,5,6
ANOVA						$F=155.7$, $p<0.001$
Seed thickness (cm)						
1. Bilkhawthlir	25	0.49	0.93	0.70 ± 0.03	3.8	3,4,6,7
2. Kawnpui	25	0.45	0.93	0.68 ± 0.02	3.5	3,4,6,7
3. Mawriang	25	0.28	1.11	0.48 ± 0.05	10.7	1,2,4,5,6,7
4. Thingkhangphai	25	0.28	0.91	0.61 ± 0.07	10.9	1,2,3,5,6,7
5. Kangpokpi	25	0.31	1.00	0.70 ± 0.05	7.0	3,4,6,7
6. Kezanglwa	25	0.28	1.00	0.58 ± 0.15	26.3	1,2,3,4,5
7. Khaibung	25	0.19	1.00	0.58 ± 0.13	21.7	1,2,3,4,5
ANOVA						$F=204.1$, $p<0.001$
Seed volume (cm^3)						
1. Bilkhawthlir	25	0.85	2.80	1.66 ± 0.14	8.2	3,4,5,6,7
2. Kawnpui	25	0.93	2.79	1.61 ± 0.08	5.1	3,4,5,6,7
3. Mawriang	25	0.20	2.16	0.84 ± 0.13	15.7	1,2,4,5,6,7
4. Thingkhangphai	25	0.27	3.13	1.18 ± 0.30	25.7	1,2,3,5,6,7
5. Kangpokpi	25	0.30	3.01	1.86 ± 0.34	18.5	1,2,3,4,6,7
6. Kezanglwa	25	0.37	3.02	1.45 ± 0.45	30.8	1,2,3,4,5,7
7. Khaibung	25	0.38	2.77	1.27 ± 0.47	37.2	1,2,3,4,5,6
ANOVA						$F=305.8$, $p<0.001$

Table 5.6. Provenance variation in morphometric traits of seeds of *P. roxburghii* in 2007.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's test)
Seed weight (g)						
1. Bilkhawthlir	25	0.59	1.40	0.90 ± 0.10	11.2	2,3,4,5,6,7
2. Kawnpui	25	0.56	1.00	0.70 ± 0.04	5.1	1,3,4,5,6,7
3. Mawriang	25	0.08	0.87	0.46 ± 0.09	19.2	1,2,4,5,7
4. Thingkhangphai	25	0.54	1.36	0.82 ± 0.05	5.7	1,2,3,5,6,7
5. Kangpokpi	25	0.12	1.37	0.61 ± 0.25	14.9	1,2,3,4,6,7
6. Kezanglwa	25	0.11	0.78	0.45 ± 0.13	27.9	1,2,4,5,7
7. Khaibung	25	0.12	0.96	0.40 ± 0.09	21.9	1,2,3,4,5,6
ANOVA						F=475.3, p<0.001
Seed length (cm)						
1. Bilkhawthlir	25	1.30	2.30	1.80 ± 0.07	3.8	3,4,5,6,7
2. Kawnpui	25	1.30	2.15	1.79 ± 0.05	2.8	3,4,5,6,7
3. Mawriang	25	0.36	2.03	1.53 ± 0.12	8.1	1,2,4,5,6
4. Thingkhangphai	25	1.10	1.60	1.35 ± 0.03	2.0	1,2,3,5,6,7
5. Kangpokpi	25	1.00	1.99	1.44 ± 0.14	10.0	1,2,3,4,6,7
6. Kezanglwa	25	1.12	2.06	1.61 ± 0.13	8.2	1,2,3,4,5,7
7. Khaibung	25	0.36	1.92	1.57 ± 0.10	6.3	1,2,4,5,6
ANOVA						F=345.1, p<0.001
Seed width (cm)						
1. Bilkhawthlir	25	1.37	2.26	1.74 ± 0.07	3.8	2,3,4,5,6,7
2. Kawnpui	25	1.37	2.30	1.98 ± 0.06	3.1	1,3,5,6,7
3. Mawriang	25	0.74	1.73	1.19 ± 0.07	5.7	1,2,4,5
4. Thingkhangphai	25	1.65	2.26	1.97 ± 0.04	2.3	1,3,5,6,7
5. Kangpokpi	25	0.70	2.30	1.47 ± 0.38	25.5	1,2,3,4,6,7
6. Kezanglwa	25	0.71	1.63	1.20 ± 0.12	9.7	1,2,4,5,7
7. Khaibung	25	0.12	1.53	1.16 ± 0.06	4.9	1,2,4,5,6
ANOVA						F=999.7, p<0.001
Seed thickness (cm)						
1. Bilkhawthlir	25	0.35	0.90	0.62 ± 0.04	5.7	3,5,6,7
2. Kawnpui	25	0.45	0.81	0.63 ± 0.01	3	3,4,5,6,7
3. Mawriang	25	0.20	1.11	0.50 ± 0.05	10.9	1,2,4,6,7
4. Thingkhangphai	25	0.45	0.81	0.60 ± 0.02	2.5	2,3,5,6,7
5. Kangpokpi	25	0.23	0.90	0.49 ± 0.10	20.9	1,2,4,6,7
6. Kezanglwa	25	0.23	1.53	0.53 ± 0.10	19.6	1,2,3,4,5,7
7. Khaibung	25	0.19	0.90	0.42 ± 0.10	22.7	1,2,3,4,5,6,
ANOVA						F=145.4, p<0.001
Seed volume (cm^3)						
1. Bilkhawthlir	25	0.73	3.61	1.95 ± 0.18	9.3	2,3,4,5,6,7,
2. Kawnpui	25	1.13	3.56	2.23 ± 0.11	4.9	1,3,4,5,6,7
3. Mawriang	25	0.18	2.32	0.92 ± 0.18	20.1	1,2,4,5,6,7
4. Thingkhangphai	25	0.97	2.59	1.59 ± 0.08	4.9	1,2,3,5,6,7
5. Kangpokpi	25	0.27	2.95	1.08 ± 0.44	40.2	1,2,3,4,7
6. Kezanglwa	25	0.30	3.15	1.06 ± 0.32	30.6	1,2,3,4,7
7. Khaibung	25	0.01	1.97	0.78 ± 0.22	27.8	1,2,3,4,5,6
ANOVA						F=603.9, p<0.001

Table 5.7. Tukey's post-hoc test of significant differences between pairs of provenances following one-way analysis of variance for seven seed traits for 2006 (first digit) and 2007 (second digit). The digit 'Y' means significantly different and 'N' means not different at p=0.05. The digits in red color highlight 'differences not significant in both the years', in green colour highlight 'differences significant in only one of the years' and in black colour highlight 'differences significant in both the years'.

Provenance pair	Seed weight	Seed length	Seed width	Seed thickness	Seed volume
1. Bilkhawthlir - Kawnpui	N Y	N N	N Y	N N	N Y
2. Bilkhawthlir - Mawriang	Y Y	Y Y	Y Y	Y Y	Y Y
3. Bilkhawthlir-Thingkhangphai	Y Y	Y Y	Y Y	Y N	Y Y
4. Bilkhawthlir - Kangpokpi	Y Y	Y Y	Y Y	N Y	Y Y
5. Bilkhawthlir - Kezanglwa	Y Y	Y Y	N Y	Y Y	Y Y
6. Bilkhawthlir - Khaibung	Y Y	Y Y	Y Y	Y Y	Y Y
7. Kawnpui - Mawriang	Y Y	Y Y	Y Y	Y Y	Y Y
8. Kawnpui - Thingkhangphai	Y Y	Y Y	Y N	Y Y	Y Y
9. Kawnpui - Kangpokpi	Y Y	Y Y	Y Y	N Y	Y Y
10. Kawnpui - Kezanglwa	Y Y	Y Y	N Y	Y Y	Y Y
11. Kawnpui - Khaibung	Y Y	Y Y	Y Y	Y Y	Y Y
12. Mawriang-Thingkhangphai	Y Y	Y Y	N Y	Y Y	Y Y
13. Mawriang - Kangpokpi	Y Y	Y Y	Y Y	Y N	Y Y
14. Mawriang - Kezanglwa	Y N	Y Y	Y N	Y Y	Y Y
15. Mawriang - Khaibung	Y Y	Y N	Y N	Y Y	Y Y
16. Thingkhangphai-Kangpokpi	Y Y	Y Y	Y Y	Y Y	Y Y
17. Thingkhangphai-Kezanglwa	Y Y	Y Y	Y Y	Y Y	Y Y
18. Thingkhangphai - Khaibung	Y Y	Y Y	Y Y	Y Y	Y Y
19. Kangpokpi - Kezanglwa	Y Y	Y Y	Y Y	Y Y	Y N
20. Kangpokpi - Khaibung	Y Y	N Y	Y Y	Y Y	Y Y
21. Kezanglwa - Khaibung	N Y	Y Y	Y Y	N Y	Y Y

5.3.6. *Relationships among seed traits*

The relationships among all five seed traits were worked out individually for seven provenances and for pooled data. For pooled data, seed weight showed a positive linear correlation with seed length, seed width, seed thickness and the seed volume both in 2006 and 2007 (Table 5.8). The scatter diagrams showed that the relationship of seed weight was strongest with seed volume and seed length in 2006 (Fig. 5.6) and 2007 (Fig. 5.7). Seed volume showed a stronger relationship with seed thickness in 2006 (Fig. 5.6) and 2007 (Fig. 5.7).

Table 5.8. Relationships among morphometric traits of germinated seed of *P. roxburghii*.

Provenance	Sample size (n)	Dependent variables (Y)	Independent variables (X)	Regression model	r	*P* level
All provenance (2006)	2543	Seed weight	Seed length	y = -1.080 + 1.064x	0.80	0.001
		Seed weight	Seed width	y = -0.991 + 1.417x	0.70	0.001
		Seed weight	Seed thickness	y = -0.123 + 1.523x	0.69	0.001
		Seed weight	Seed volume	y = 0.104 + 0.488x	0.87	0.001
		Seed volume	Seed length	y = -1.695 + 1.763x	0.79	0.001
		Seed volume	Seed width	y = -2.016 + 2.725x	0.76	0.001
		Seed volume	Seed thickness	y = -0.599 + 3.334x	0.84	0.001
		Seed length	Seed width	y = 0.559 + 0.404x	0.62	0.001
		Seed length	Seed thickness	y = 1.280 + 0.823x	0.49	0.001
		Seed width	Seed thickness	y = 1.012 + 0.437x	0.40	0.001
All provenance (2007)	2526	Seed weight	Seed length	y = 0.192 + 0.277x	0.26	0.001
		Seed weight	Seed width	y = -0.928 + 0.462x	0.75	0.001
		Seed weight	Seed thickness	y = 0.119 + 0.937x	0.52	0.001
		Seed weight	Seed volume	y = 0.282 + 0.250x	0.68	0.001
		Seed volume	Seed length	y = -0.948 + 1.476x	0.51	0.001
		Seed volume	Seed width	y = -0.349 + 1.175x	0.84	0.001
		Seed volume	Seed thickness	y = -0.852 + 3.965x	0.75	0.001
		Seed length	Seed width	y = 1.461 + 0.075x	0.13	0.001
		Seed length	Seed thickness	y = 1.343 + 0.430x	0.26	0.001
		Seed width	Seed thickness	y = 0.670 + 1.552x	0.53	0.001
Bilkhawthlir (2006)	380	Seed weight	Seed length	y = -0.167 + 0.603x	0.56	0.001
		Seed weight	Seed width	y = 0.185 + 0.596x	0.50	0.001
		Seed weight	Seed thickness	y = 0.495 + 0.656x	0.43	0.001
		Seed weight	Seed volume	y = 0.458 + 0.294x	0.71	0.001
		Seed volume	Seed length	y = -1.248 + 1.572x	0.61	0.001
		Seed volume	Seed width	y = -0.667 + 1.824x	0.63	0.001

		Seed volume	Seed thickness	y = -0.324 + 2.873x	0.77	0.001
		Seed length	Seed width	y = 0.907 + 0.206x	0.23	0.007
		Seed length	Seed thickness	y = 1.694 + 0.239x	0.17	0.052
		Seed width	Seed thickness	y = 1.182 + 0.155x	0.12	0.160
Bilkhawthlir (2007)	367	Seed weight	Seed length	y = 0.243 + 0.373x	0.41	0.001
		Seed weight	Seed width	y = 0.509 + 0.233x	0.29	0.001
		Seed weight	Seed thickness	y = 0.811 + 0.173x	0.16	0.072
		Seed weight	Seed volume	y = 0.768 + 0.076x	0.32	0.001
		Seed volume	Seed length	y = 0.017 + 1.077x	0.29	0.001
		Seed volume	Seed width	y = -1.998 + 2.266x	0.68	0.001
		Seed volume	Seed thickness	y = -0.523 + 4.068x	0.92	0.001
		Seed length	Seed width	y = 1.776 + 0.019x	0.02	0.815
		Seed length	Seed thickness	y = 1.711 + 0.160x	0.14	0.134
		Seed width	Seed thickness	y = 1.372 + 0.621x	0.47	0.001
Kawnpui (2006)	400	Seed weight	Seed length	y = -0.533 + 0.804x	0.61	0.001
		Seed weight	Seed width	y = -0.146 + 0.842x	0.47	0.001
		Seed weight	Seed thickness	y = 0.339 + 0.900x	0.45	0.001
		Seed weight	Seed volume	y = 0.286 + 0.420x	0.73	0.001
		Seed volume	Seed length	y = -0.910 + 1.373x	0.56	0.001
		Seed volume	Seed width	y = -0.963 + 1.952x	0.63	0.001
		Seed volume	Seed thickness	y = -0.235 + 2.695x	0.77	0.001
		Seed length	Seed width	y = 0.919 + 0.198x	0.27	0.002
		Seed length	Seed thickness	y = 1.741 + 0.121x	0.08	0.377
		Seed width	Seed thickness	y = 1.135 + 0.219x	0.20	0.028
Kawnpui (2007)	376	Seed weight	Seed length	y = 0.534 + 0.1167x	0.18	0.475
		Seed weight	Seed width	y = 0.614 + 0.066x	0.12	0.204
		Seed weight	Seed thickness	y = 0.858 - 0.178x	-0.13	0.161
		Seed weight	Seed volume	y = 0.707 + 0.016x	0.07	0.467
		Seed volume	Seed length	y = -0.465 + 1.511x	0.56	0.001
		Seed volume	Seed width	y = -0.267 + 1.294x	0.55	0.001
		Seed volume	Seed thickness	y = -0.478 + 4.313x	0.75	0.001
		Seed length	Seed width	y = 1.862 - 0.031x	-0.04	0.705
		Seed length	Seed thickness	y = 1.595 + 0.322x	0.15	0.104
		Seed width	Seed thickness	y = 1.760 + 0.337x	0.14	0.136
Mawriang (2006)	408	Seed weight	Seed length	y = -0.452 + 0.573x	0.66	0.001
		Seed weight	Seed width	y = -0.405 + 0.714x	0.61	0.001
		Seed weight	Seed thickness	y = 0.251 + 0.349x	0.31	0.001
		Seed weight	Seed volume	y = 0.187 + 0.273x	0.59	0.001
		Seed length	Seed width	y = 0.589 + 0.371x	0.50	0.001
		Seed volume	Seed length	y = -0.830 + 1.106x	0.60	0.001
		Seed volume	Seed width	y = -0.943 + 1.550x	0.61	0.001
		Seed volume	Seed thickness	y = -0.180 + 2.146x	0.87	0.001
		Seed length	Seed thickness	y = 1.353 + 0.346x	0.26	0.001
		Seed width	Seed thickness	y = 1.036 + 0.247x	0.25	0.001
Mawriang (2007)	391	Seed weight	Seed length	y = -0.029 + 0.314x	0.60	0.001
		Seed weight	Seed width	y = -0.196 + 0.546x	0.61	0.001
		Seed weight	Seed thickness	y = 0.315 + 0.273x	0.32	0.001

		Seed weight	Seed volume	y = 0.250 + 0.218x	0.64	0.001
		Seed volume	Seed length	y = -0.793 + 1.118x	0.70	0.001
		Seed volume	Seed width	y = -0.793 + 1.451x	0.56	0.001
		Seed volume	Seed thickness	y = -0.096 + 2.029x	0.83	0.001
		Seed width	Seed thickness	y = 1.133 + 0.109x	0.12	0.163
		Seed length	Seed width	y = 0.474 + 0.893x	0.52	0.001
		Seed length	Seed thickness	y = 1.460 + 0.147x	0.09	0.270
		Seed volume	Seed thickness	y = 0.056 + 2.606x	0.62	0.001
Thing-khangphai (2006)	354	Seed weight	Seed length	y = -0.796 + 0.905x	0.86	0.001
		Seed weight	Seed width	y = -0.183 + 0.793x	0.70	0.001
		Seed weight	Seed thickness	y = 0.317 + 0.747x	0.42	0.001
		Seed weight	Seed volume	y = 0.318 + 0.347x	0.87	0.001
		Seed volume	Seed length	y = -1.165 + 1.416x	0.69	0.001
		Seed volume	Seed width	y = -1.141 + 2.035x	0.72	0.001
		Seed volume	Seed thickness	y = -0.673 + 3.233x	0.73	0.001
		Seed length	Seed width	y = 0.401 + 0.468x	0.51	0.001
		Seed length	Seed thickness	y = 1.387 + 0.572x	0.34	0.001
		Seed width	Seed thickness	y = 1.053 + 0.264x	0.17	0.108
Thing-khangphai (2007)	353	Seed weight	Seed length	y = 1.179 - 0.270x	-0.22	0.021
		Seed weight	Seed width	y = 0.665 + 0.074x	0.08	0.400
		Seed weight	Seed thickness	y = 0.767 + 0.075x	0.03	0.742
		Seed weight	Seed volume	y = 0.856 - 0.028x	0.05	0.606
		Seed volume	Seed length	y = -0.087 + 1.250x	0.59	0.001
		Seed volume	Seed width	y = -0.214 + 0.917x	0.56	0.001
		Seed volume	Seed thickness	y = 0.056 + 2.606x	0.62	0.001
		Seed length	Seed width	y = 1.096 + 0.132x	0.18	0.059
		Seed length	Seed thickness	y = 1.337 + 0.034x	0.02	0.849
		Seed width	Seed thickness	y = 2.070 - 0.141x	-0.06	0.560
Kangpokpi (2006)	351	Seed weight	Seed length	y = -0.501 + 0.789x	0.78	0.001
		Seed weight	Seed width	y = -0.290 + 0.927x	0.74	0.001
		Seed weight	Seed thickness	y = 0.451 + 0.750x	0.28	0.001
		Seed weight	Seed volume	y = 0.272 + 0.399x	0.79	0.001
		Seed volume	Seed length	y = -1.165 + 1.416x	0.694	0.001
		Seed volume	Seed width	y = -0.933 + 1.972x	0.79	0.001
		Seed volume	Seed thickness	y = -0.294 + 2.976x	0.57	0.001
		Seed length	Seed width	y = 0.361 + 0.533x	0.66	0.001
		Seed length	Seed thickness	y = 2.001 - 0.102x	-0.04	0.595
		Seed width	Seed thickness	y = 1.369 + 0.093x	0.06	0.448
Kangpokpi (2007)	377	Seed weight	Seed length	y = 0.714 + 0.067x	0.07	0.350
		Seed weight	Seed width	y = 1.063 - 0.139x	-0.20	0.011
		Seed weight	Seed thickness	y = 0.745 + 0.119x	0.08	0.289
		Seed weight	Seed volume	y = 0.809 + 0.001x	0.00	0.809
		Seed volume	Seed length	y = 0.268 + 0.572x	0.22	0.001
		Seed volume	Seed width	y = -0.421 + 1.029x	0.79	0.001
		Seed volume	Seed thickness	y = -0.559 + 3.286x	0.88	0.001
		Seed length	Seed width	y = 2.470 - 0.451x	-0.35	0.001

		Seed length	Seed thickness	y = 1.392 + 0.074x	0.05	0.507
		Seed width	Seed thickness	y = 0.752 + 1.551x	0.54	0.001
Kezanglwa (2006)	304	Seed weight	Seed length	y = -0.529 + 0.665x	0.43	0.001
		Seed weight	Seed width	y = -0.827 + 1.199x	0.62	0.001
		Seed weight	Seed thickness	y = 0.194 + 0.934x	0.50	0.001
		Seed weight	Seed volume	y = 0.133 + 0.424x	0.70	0.001
		Seed volume	Seed length	y = -1.783 + 1.705x	0.67	0.001
		Seed volume	Seed width	y = -0.753 + 1.657x	0.52	0.001
		Seed volume	Seed thickness	y = -0.085 + 2.604x	0.84	0.001
		Seed length	Seed width	y = 0.544 + 0.397x	0.50	0.001
		Seed length	Seed thickness	y = 1.631 + 0.482x	0.40	0.001
		Seed width	Seed thickness	y = 1.248 + 0.125x	0.14	0.144
Kezanglwa (2007)	324	Seed weight	Seed length	y = -0.663 + 0.695x	0.77	0.001
		Seed weight	Seed width	y = -0.552 + 0.838x	0.89	0.001
		Seed weight	Seed thickness	y = 0.116 + 0.644x	0.57	0.001
		Seed weight	Seed volume	y = 0.116 + 0.326x	0.86	0.001
		Seed volume	Seed length	y = -1.689 + 1.711x	0.71	0.001
		Seed volume	Seed width	y = -1.381 + 2.010x	0.81	0.001
		Seed volume	Seed thickness	y = -0.282 + 2.527x	0.85	0.001
		Seed length	Seed width	y = 0.121 + 0.672x	0.71	0.001
		Seed length	Seed thickness	y = 1.374 + 0.435x	0.35	0.001
		Seed width	Seed thickness	y = 0.906 + 0.561x	0.47	0.001
Khaibung (2006)	346	Seed weight	Seed length	y = -0.773 + 0.904x	0.76	0.001
		Seed weight	Seed width	y = -0.240 + 0.879x	0.32	0.001
		Seed weight	Seed thickness	y = 0.125 + 1.210x	0.62	0.001
		Seed weight	Seed volume	y = 0.211 + 0.448x	0.80	0.001
		Seed volume	Seed length	y = -1.147 + 1.409x	0.77	0.001
		Seed volume	Seed width	y = -1.571 + 2.401x	0.50	0.001
		Seed volume	Seed thickness	y = -0.355 + 2.957x	0.84	0.001
		Seed length	Seed width	y = 0.942 + 0.186x	0.43	0.001
		Seed length	Seed thickness	y = 1.480 + 0.567x	0.34	0.001
		Seed width	Seed thickness	y = 1.245 + 0.061x	0.09	0.371
Khaibung (2007)	338	Seed weight	Seed length	y = 0.138 + 0.171x	0.22	0.025
		Seed weight	Seed width	y = 0.226 + 0.153x	0.17	0.075
		Seed weight	Seed thickness	y = 0.224 + 0.413x	0.48	0.001
		Seed weight	Seed volume	y = 0.248 + 0.197x	0.51	0.001
		Seed volume	Seed length	y = -0.596 + 0.886x	0.54	0.001
		Seed volume	Seed width	y = -0.356 + 0.993x	0.43	0.001
		Seed volume	Seed thickness	y = -0.098 + 2.044x	0.92	0.001
		Seed length	Seed width	y = 0.706 + 0.288x	0.33	0.001
		Seed length	Seed thickness	y = 1.443 + 0.255x	0.23	0.016
		Seed width	Seed thickness	y = 1.090 + 0.144x	0.15	0.128

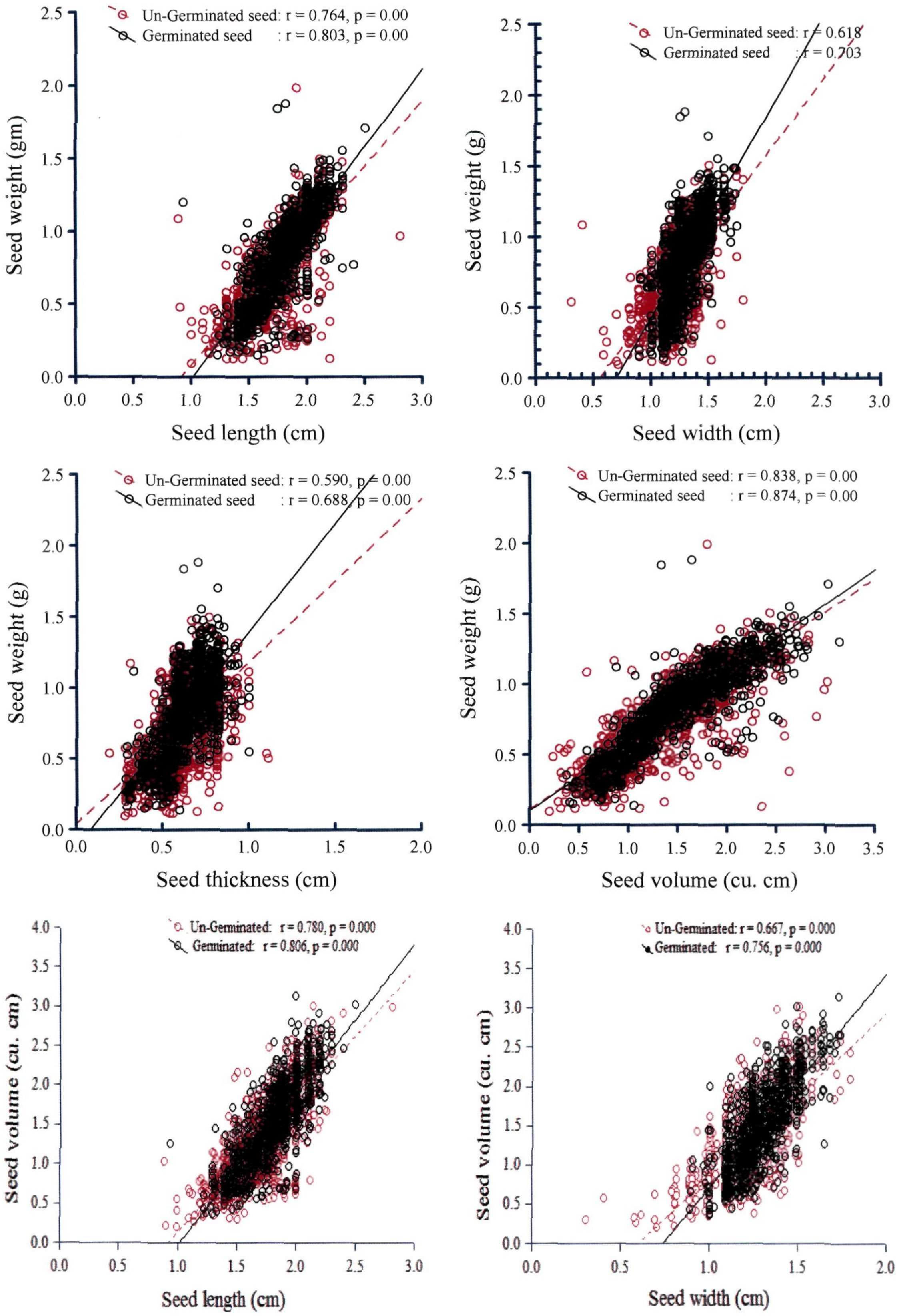


Fig. 5.6. Relationships among morphometric traits of seeds in the year 2006. (cont…)

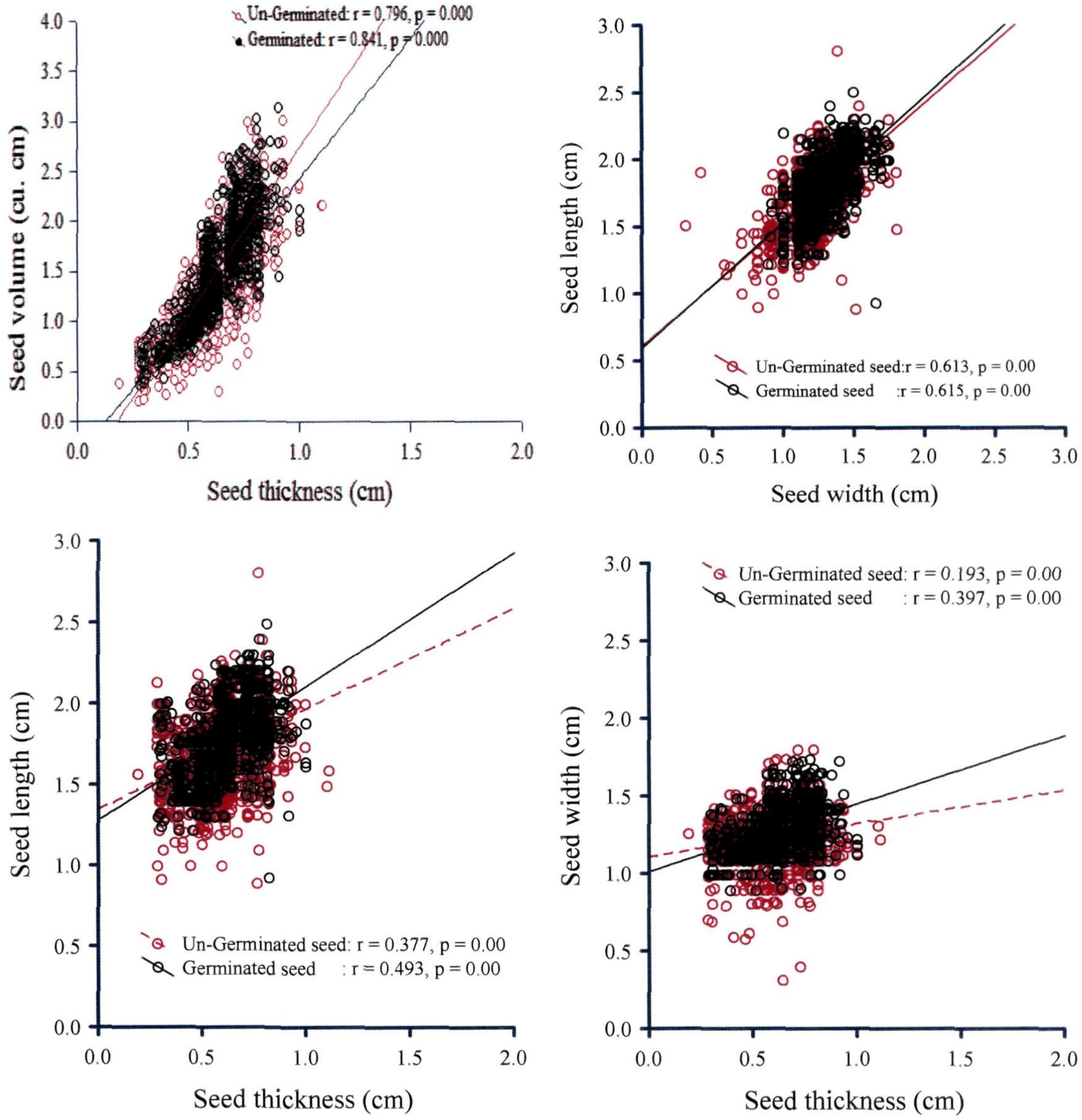


Fig. 5.6. Relationships among morphometric traits of seeds in the year 2006.

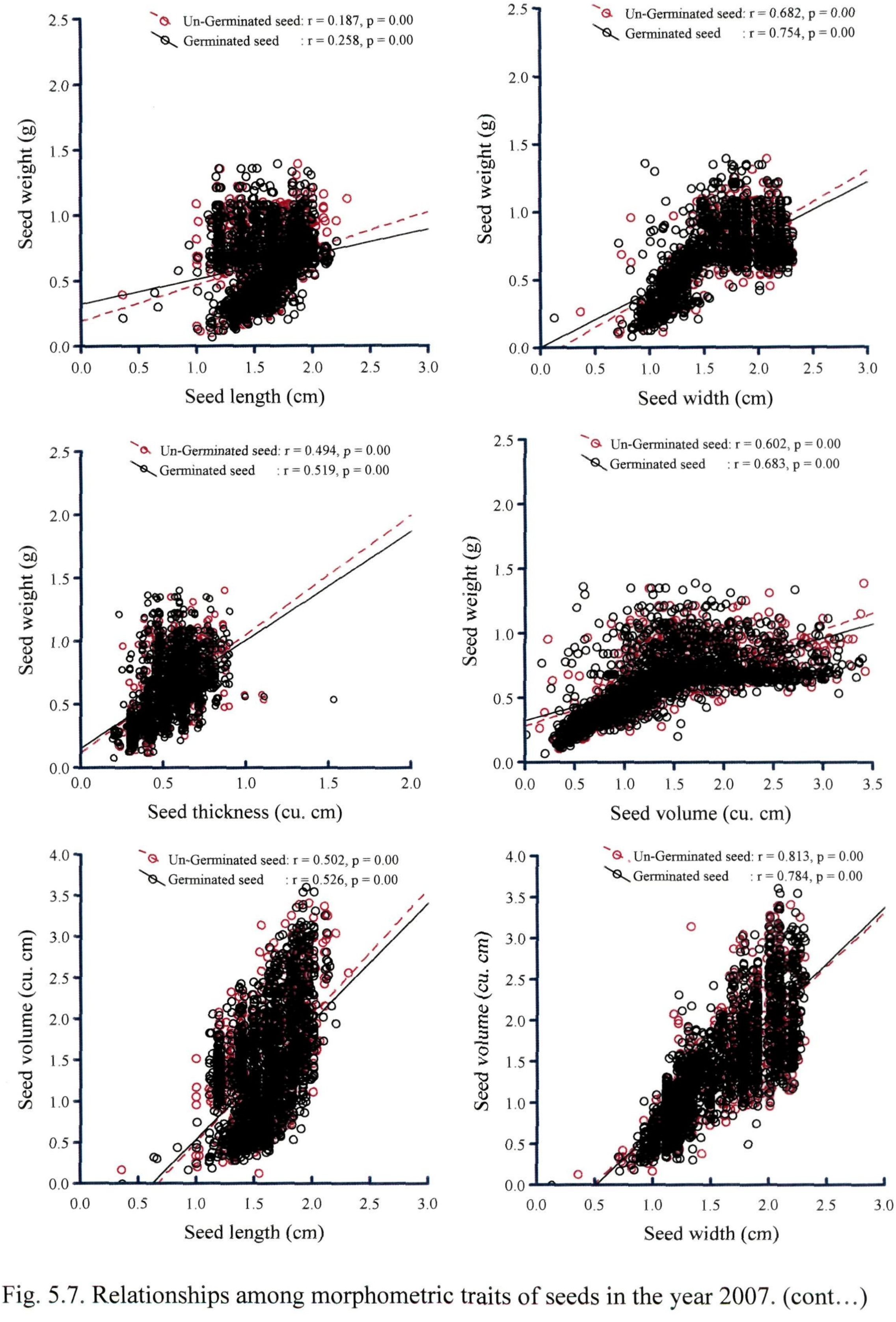


Fig. 5.7. Relationships among morphometric traits of seeds in the year 2007. (cont…)

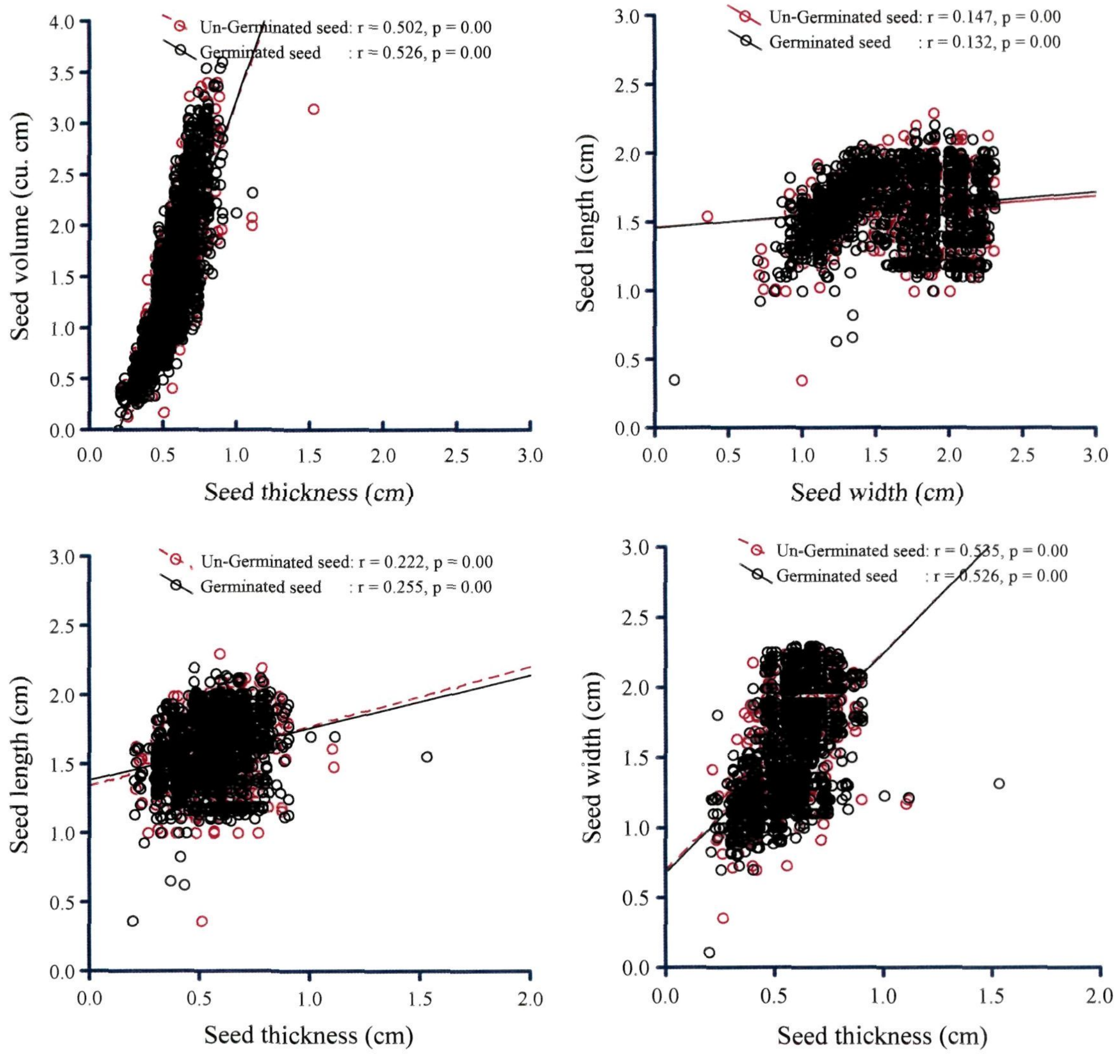


Fig. 5.7. Relationships among morphometric traits of seeds in the year 2007.

5.3.7. *Between year differences in fruit and seed traits*

The differences in fruit and seed traits (seven fruit traits and five seed traits) between years 2006 and 2007 were tested by one-way analysis of variance (Table 5.9). The data on each trait from all seven provenances were pooled and mean values were calculated. Mean values of seeds developed per fruit, total seeds per fruit (developed + aborted seeds) and seed volume did not vary significantly between the years. However, mean fruit weight, mean seed weight and dimensions of fruits and seeds showed significant variation between the years. Between years differences in mean values of fruit and seed traits of individual provenances were followed a similar trend (data not presented here).

Table 5.9. Between year differences in morphometric traits of fruits and seeds of *P. roxburghii*.

Traits	2006	2007	F	*p* value
Fruit weight (g)	31.65 ± 8.42	29.11 ± 9.63	6.88	0.009
Fruit length (cm)	34.79 ± 8.07	38.51 ± 9.19	16.17	0.001
Fruit width (cm)	3.05 ± 0.69	3.28 ± 0.39	13.96	0.001
Pedicel length (cm)	9.33 ± 2.78	10.84 ± 3.42	20.53	0.001
Seeds developed per fruit	14.59 ± 2.67	14.79 ± 2.92	0.45	0.504
Seeds aborted per fruit	1.89 ± 1.67	1.48 ± 1.83	4.81	0.028
Total seeds per fruit	16.48 ± 2.73	16.27 ± 2.96	0.48	0.487
Seed weight (g)	0.77 ± 0.28	0.62 ± 0.24	400.78	0.001
Seed length (cm)	1.75 ± 0.23	1.58 ± 0.23	662.10	0.001
Seed width (cm)	1.25 ± 0.15	1.54 ± 0.40	1088.00	0.001
Seed thickness (cm)	0.62 ± 0.14	0.54 ± 0.14	341.08	0.001
Seed volume (cm^3)	1.39 ± 0.50	1.39 ± 0.67	0.01	0.956

The variability of mean values of fruit and seed traits in terms of coefficient of variation was more or less similar between the years for many traits such as fruit weight, fruit length, pedicel length, seeds developed per fruit, total seeds per fruit, seed weight, seed length and seed thickness (Table 5.10). The variability was more in 2006 than in 2007 for fruit width. Conversely, the variability was more in 2007 than in 2006 for number of aborted seeds per fruit, seed width and seed volume. Between years differences in mean values of fruit and seed traits of individual provenances were followed a similar trend (data not presented here).

Table 5.10. Between year differences in coefficient of variation of morphometric traits of fruits and seeds of *P. roxburghii.*

Traits	**2006 (CV)**	**2007 (CV)**
Fruit weight (g)	26.59	33.06
Fruit length (cm)	23.18	23.86
Fruit width (cm)	22.49	11.90
Pedicel length (cm)	29.85	31.54
Seeds developed per fruit	18.30	19.76
Seeds aborted per fruit	88.26	123.96
Total seeds per fruit	16.57	18.18
Seed weight (g)	36.27	38.58
Seed length (cm)	12.92	14.72
Seed width (cm)	12.09	26.17
Seed thickness (cm)	22.02	25.17
Seed volume (cm^3)	36.14	48.41

In 2006, Kangpokpi emerged as the best provenance since most traits of fruits and seeds showed highest mean values for this provenance (Table 5.11). However, in 2007, Kawnpui emerged the best provenance based on same considerations.

Table 5.11. Determination of best provenances of *P. roxburghii* in 2006 and 2007.

Year of study	Trait	Best provenance
2006	Fruit weight (g)	Kangpokpi
	Fruit length (cm)	Mawriang
	Fruit width (cm)	Kangpokpi, Mawriang and Khaibung
	Pedicel length (cm)	Mawriang, Kawnpui and Kezanglwa
	Seeds developed per fruit	Kangpokpi
	Seeds aborted per fruit	Kangpokpi
	Total seeds per fruit	Kangpokpi
	Seed weight (g)	Kangpokpi
	Seed length (cm)	Kangpokpi and Kezanglwa
	Seed width (cm)	Kangpokpi
	Seed thickness (cm)	Kangpokpi, Bilkhawthlir and Kawnpui
	Seed volume (cm^3)	Kangpokpi
2007	Fruit weight (g)	Kawnpui
	Fruit length (cm)	Mawriang
	Fruit width (cm)	Kawnpui and Mawriang
	Pedicel length (cm)	Kawnpui and Thingkhangphai
	Seeds developed per fruit	Kawnpui
	Seeds aborted per fruit	Kawnpui
	Total seeds per fruit	Kawnpui
	Seed weight (g)	Bilkhawthlir
	Seed length (cm)	Kawnpui and Bilkhawthlir
	Seed width (cm)	Kawnpui and Thingkhangphai
	Seed thickness (cm)	Kawnpui and Bilkhawthlir
	Seed volume (cm^3)	Kawnpui

5.4. Discussion

During the study, we observed that neither the entirely capitula nor the self-pollinated capitula containing 3000 to 4000 flowers of *Parkia roxburghii* set fruit. Thus, variation in fruit and seedling characteristics is more prominent compared to other plant species. The present study found all fruit parameters to be significantly different ($p < 0.01$) among provenances (Table 5.1 and 5.2) where Kawnpui replaced Kangpokpi in *recording highest fruit weight and fruit width and Mawriang in pedicel length in 2007. In* both the years, Mawriang retained highest mean fruit length. The changes in recording higher means in different years studied is not well understood and literature supporting the above finding is scarce or not available. However, different date of collections of both fruits each year may not be ruled out of having an impact on such variations in fruit characteristics. Such incidences have been reported in many plant species. The genus *Parkia* has been reported to have variations in fruit width and length among provenances and sometimes such variations are also observed among trees (Olorunmaiye *et al.* 2011).

As expected, the relationships among fruit parameters of *Parkia* from all provenances showed positive linearly significant trends with stronger relationships between fruit weight and other parameters in both the years of study. A vague picture of the scatter plot among fruit parameters when compared among the years (Fig. 5.2 and 5.3) is an issue of further research. Irrespective of years, there was a strong relationship between fruit weight and fruit length in all provenances. Fewer provenances recorded significant relationship between fruit weight and fruit width with a negative relationship in Kangpokpi during the year 2007. This study observed that the length of a fruit pedicel affected the overall weight of a fruit significantly in Mawriang, Bilkhawthlir, Kawnpui, Thingkhangphai and Khaibung in either or both years. Nonetheless, seeds developed in a fruit had a linear significant impact in Thingkhangphai, Kezanglwa and Khaibung.

The seeds across the genus *Parkia* have been observed to display different colour, smoothness of the coat and variation in weight, length, width, thickness and volume among provenances (Hopkins 1983 and 1994, Olorunmaiye *et al.* 2011). This investigation revealed similar results (Fig. 5.5 and Table 5.3 and 5.4) suggesting an inbreeding effect across its distribution. Irrespective of years, number of seeds developed from a fruit varied from one provenance to the other. Replacing Kangpokpi and Kezanglwa of 2006 data, Bilkhawthlir had the heaviest and longest mean seed values, respectively. However, Kawnpui replaced both in recording higher mean values of seed width, thickness and volume during the year of 2007 (Table 5.3 and 5.4).

As assumed, the weight of germinated seed was affected by its length, width, thickness and volume (Table 5.6). The study revealed a strong relationship between seed weight in (*y*-axis) to other seed parameters in *x*-axis (width and volume) in the previous year and to length and thickness during 2007. In 2007, a negative relationship was observed when seed weight in *y*-axis was analysed against seed width in *x*-axis. The germinated seeds also showed significant relationship during the years of study when plotted among seed length, width, thickness and volume.

The scatter plot of both the germinated and ungerminated seeds revealed a more visible distinct population in the year 2006 suggesting the effect of seed parameters especially the seed weight as an indicator on the germination behaviour of seeds (Fig. 5.6). Uma Shankar (2006) recommended seed weight as an indicator of choosing a seed for better success in germination and seedlings establishment of Hollong (*Dipterocarpus macrocarpus*). However, the vague picture of the subsequent year (2007) contradicts the decision on predicting germination on the basis of seed weight only in the case of *P. roxburghii* (Fig. 5.7). The present study struggled to understand the clear cut edges of the relationships between seed parameters of *Parkia* when we also observed similar strong significant relationships among parameters of the ungerminated seeds. The graph depicts a large chunk of the germinated seeds in the upper part of the plot and the ungerminated seeds distributed along the lower end of *y*-axis. However, the distribution of populations appeared fussy with many seeds both germinated and ungerminated overlapping across the middle section.

Provenances varied significantly in most traits of fruit and seed. A single best provenance based on morphometric traits of fruits and seeds was Kongpokpi in 2006 and Kawnpui in 2007. The differences in morphometric traits of fruits and seeds between the years were significant for most of the mean values of the measured parameters. However, the Coefficient of Variation (CV) did not show differences in the variability of the mean. The coefficient of variation was more for weight (of fruit and seed) as compared to the dimensions of fruits and seeds. Such a trend has been worked out in other tropical species such as *Prunus nepaulensis* (Sohiong) and *Dipterocarpus macrocarpus* (Hollong).

SEED GERMINATION AND SEEDLING SURVIVAL AND GROWTH OF *Parkia roxburghii*

6.1. Introduction

The germination of seeds and early survival and growth of seedlings is often determined by the weight of seeds in many species. Seed size has been shown to influence emergence rate and competitive ability of seedlings (Gross 1984, Grime and Jeffery 1965, Piper 1986, Uma Shankar 2006, 2012). Seeds may vary in shape and size widely due to differential genetic superiority and/or environmental variations across provenances (Uma Shaanker et al. 1988). Hence, the competitive ability of the seedlings to survive and grow and produce better-quality adults will vary from provenance to provenance. Hence, determination of superior quality of populations for collection of seeds for raising plantations is of paramount importance. In NTFP species such as *P. roxburghii*, augmenting populations through plantations is necessary as it has a direct bearing on the supply of the economic product and on revenue generation to the people (Hegde *et al.* 1996).

The species which yield fruits and seeds that are harvested by the people for consumption and trade often suffer paucity of regeneration in nature (Uma Shankar et al. 1996). The degree of failure of regeneration may vary from species to species depending on the quantum of the removal of fruits and seeds, viability of seeds, success of germination and early survival and growth of seedlings (Uma Shankar et al. 2006). *P. roxburghii* is one such species which faces removal of tender fruits for consumption as vegetable and of mature pods for consumption of seeds in various ways (Chapter 2). The removal of fruits and seeds has severely affected the regeneration of *P. roxburghii* which is evident by the lack of seedlings in populations which was found in all provenances in this study (Chapter 4). In other species of genus *Parkia*, seedlings are reported scarce in the wild (Aliero 2004). The seeds of African species of *Parkia* are reported to be intolerant to fire in slash and burn cultivation (Sambe *et al.* 2010), which is also a common practice in northeastern region. In most *Parkia* species, seedling raising is the main method of propagation.

Here, a study was undertaken to determine 1) viability of seeds, 2) germination pattern and percentages, 3) seedling growth pattern, and 4) effect of seed weight on germination in *P. roxburghii*. The study was aimed to find out the best geographic source of seeds from the point-of-view of germination and survival success.

6.2. Materials and methods

6.2.1. *Seed viability test*

Seed viability test was performed for hundred healthy seeds from each provenance after removing the seed coat and leaving the cotyledons exposed. The seed coat was removed manually by rupturing it with a sharp blade very carefully so that no harm is done to the cotyledons. The seeds were immersed in 1% solution of 2, 3, 5-triphenyl tetrazolium chloride (TTC) for 9 h at 35 °C (Moore 1985).

6.2.2. *Seed sowing and germination*

The seeds were sown in root trainers containing a 1:1 mixture of loam and sand and were placed in a mist chamber at 25°C temperature and 80-90% relative humidity. A regular misting of one minute at 3 h interval was programmed. Germination was examined daily until no further germination occurred. Seed germination characteristics and leaf emergence time were observed following standard methods (ISTA 1976, Jayashankar et al. 1999, Uma Shankar 2006, 2012, Uma Shankar and Synrem 2012). Seeds were considered germinated when radicle emerged from the seed coat. The time between germination and expansion of first pair of leaves was recorded as 'leaf emergence time'. The seeds that failed to germinate were retrieved from the root trainers to confirm death.

The germination capacity (GC), peak value (PV),. and germination value (GV) were calculated (Czabator, 1962, Jayashankar et al. 1999). GC was calculated from the percentage of seeds that had germinated at the end of the year from the date of sowing. PV was the maximum quotient derived by dividing daily the accumulated number of germinants by the corresponding number of days. GV is the combination of both the speed and completeness of germination into a single value and is the product of PV and mean daily germination. This represents the mean daily germination of the most vigorous component of the seed lot, which is a mathematical expression of the tangent drawn through the origin of the sigmoid curve representing a typical course of germination.

6.2.3. *Seedling survival and growth*

One month old seedlings were regularly transferred from a root trainer to a polythene bag in the open nursery to allow greater space for spreading roots. Shoot height, collar diameter, leaf number and leaf fall of seedlings was measured at 7, 14, 21, 30, 90, 180, 270 and 365 days since sowing. Shoot height was measured between the shoot tip and placental joint and collar diameter immediately above the placental joint using a digital caliper (Jayashankar *et al.* 1999, Khan *et al.* 1999, Uma Shankar 2006, 2012).

6.2.4. *Seedling biomass*

At one year of age, twelve seedlings from each provenance were randomly harvested for biomass estimation. Each seedling was separated into root, stem and leaf components and their fresh weights were determined. Each component was placed in a paper bag in an oven at 72 °C until constant weight to measure biomass.

6.2.5. *Statistical analyses*

The data were analyzed statistically for mean, standard deviation and coefficient of variation. One-way analysis of variance was used to test the differences between group means. Pair-wise comparisons were made using Tukey's post-hoc test.

6.3. Results

6.3.1. *Seed viability*

The viability of seeds was high in all provenances and ranged between 94 and 100% (Table 6.1, Fig. 6.1).

Table 6.1. Results of viability test of seeds of *P. roxburghii* from seven provenances.

Provenance	Viability (%)
Bilkhawthlir	98.0
Kawnpui	97.0
Mawriang	100.0
Thingkhangphai	98.0
Kangpokpi	98.0
Kezanglwa	94.0
Khaibung	100.0
All provenances mean	97.9

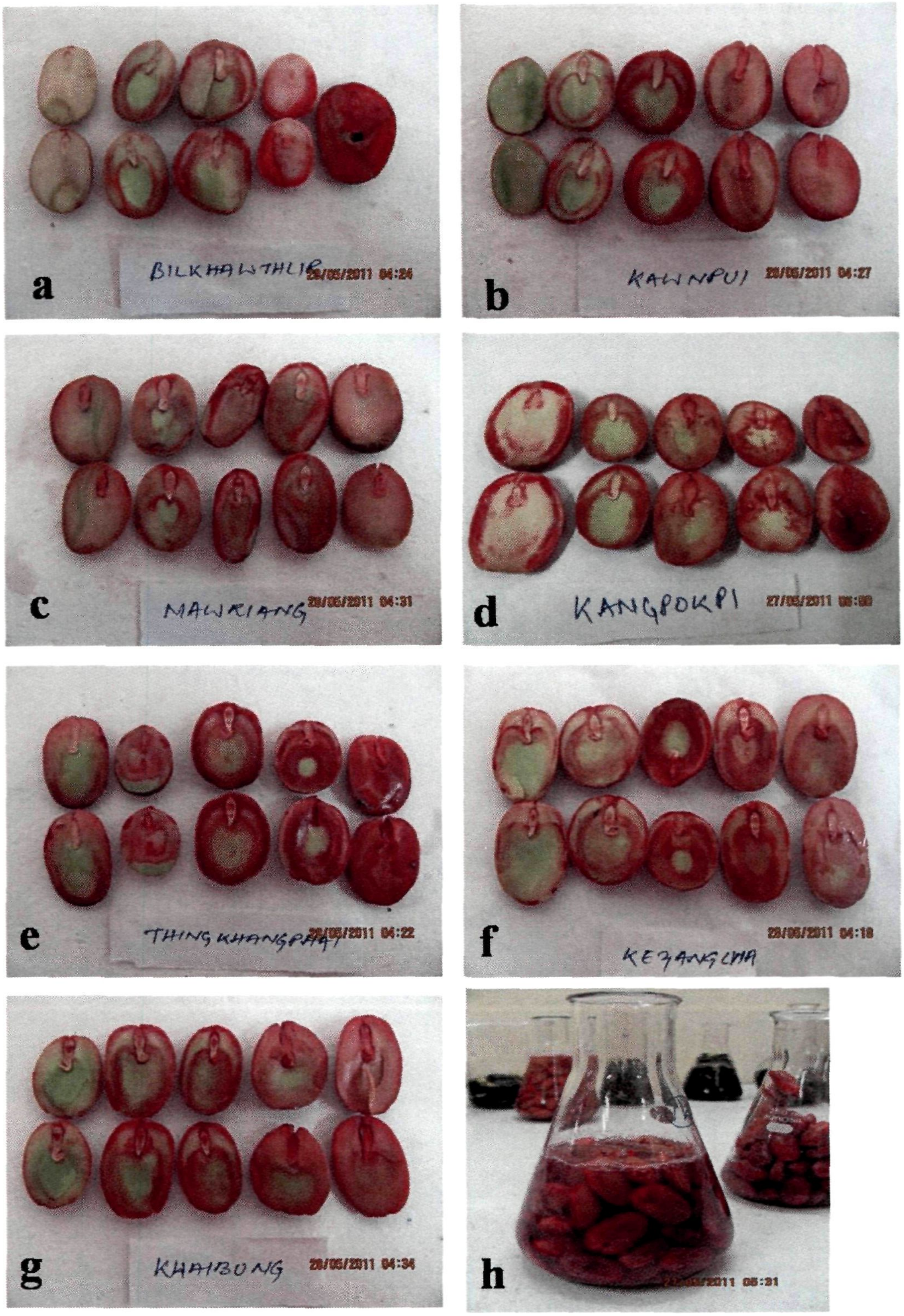


Fig. 6.1. Seed viability test in *P. roxburghii*: seeds without seed coat from (a) Bilkhawthlir, (b) Kawnpui, (c) Mawriang, (d) Kangpokpi, (e) Thingkhangphai, (f) Kezanglwa, and (g) Khaibung provenances and (h) seeds with coat.

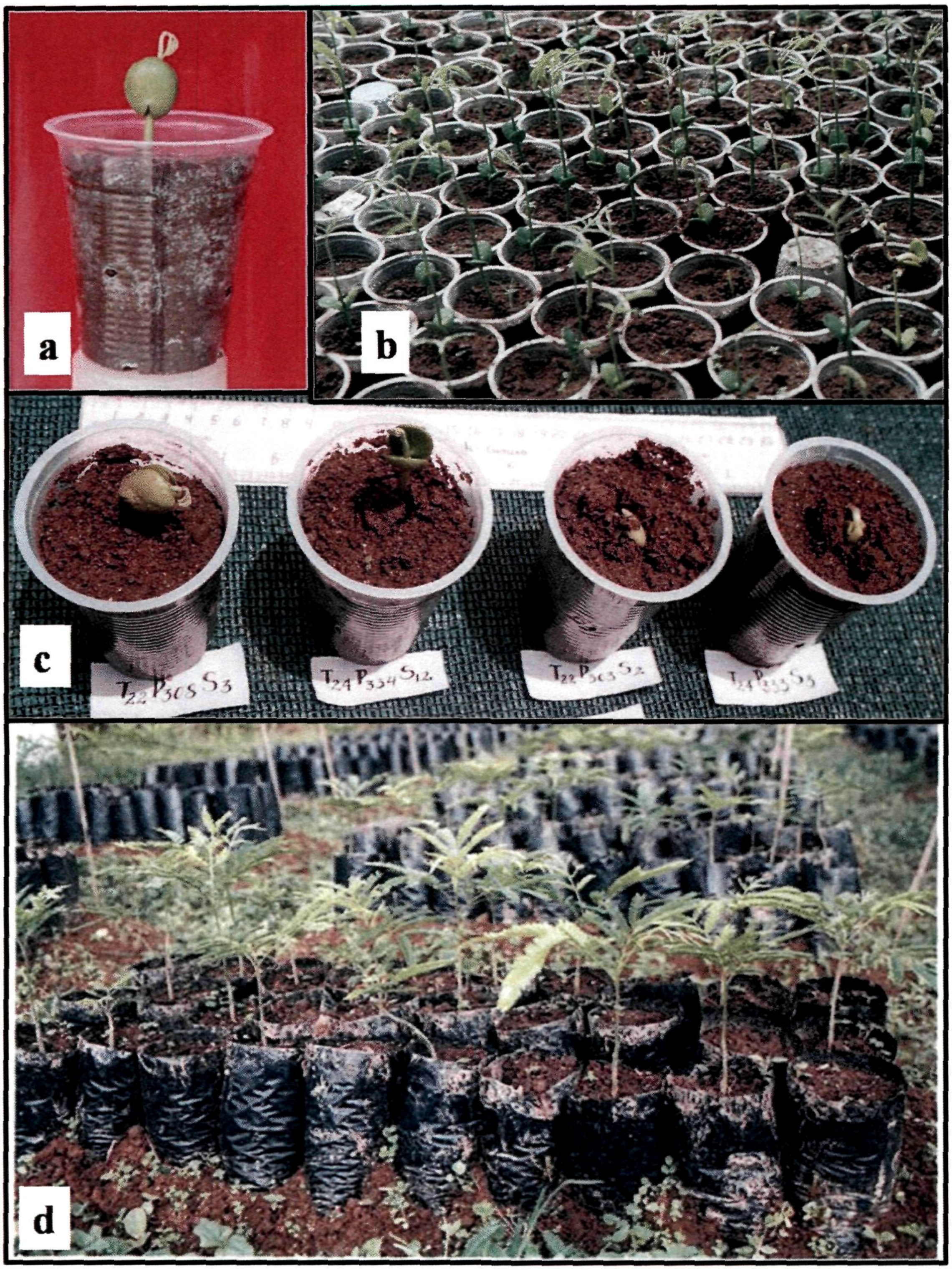


Fig. 6.2. Seed germination in *P. roxburghii*; (a) epigeous type germination (b) emergence of cotyledonary leaves (c) stages of germination (d) seedlings after transplant.

6.3.2. *Seed germination*

Germination of seeds is of epigeous type in *P. roxburghii* (Fig. 6.2). The radicle emerges from the side of the seed and curves downwards (Fig. 2c). After the radical is firmly rooted in the soil, the cotyledons take up moisture, expand emerge from the soil surface upward. The fleshy cotyledons nourish the seedling. The shoot grows upright from the cotyledonary leaves and first pair of leaves emerges. These leaves take the charge of conducting photosynthesis and subsequently cotyledons detach from the seedling.

A total of 2,543 seeds were sown in 2006 and 2,526 in 2007 from all provenances together. Of these, 36.43% seeds germinated in 2006 and 34.50% seeds in 2007 (Table 6.2). The provenance variation in seed germination percentage is not remarkable. Among provenances, the seeds from Kangpokpi showed significantly higher germination than other provenances, 48.15% in 2006 and 42.44% in 2007). All other sites did not vary significantly with respect to germination percentage (Table 6.2).

Table 6.2. Germination of seeds of *P. roxburghii* collected from seven provenances in northeast India in 2006 and 2007.

Provenance	2006			2007		
	Seeds sown	Seeds germi-nated	Germi-nation (%)	Seeds sown	Seeds germi-nated	Germi-nation (%)
1. Bilkhawthlir	380	137	36.05	367	124	33.79
2. Kawnpui	400	127	31.75	376	119	31.65
3. Mawriang	408	179	43.87	391	147	37.60
4. Thingkhangphai	354	90	25.42	353	115	32.58
5. Kangpokpi	351	169	48.15	377	160	42.44
6. Kezanglwa	304	112	36.84	324	102	31.48
7. Khaibung	346	114	32.95	338	107	31.66
All provenances	2,543	928	36.49	2,526	874	34.60

Seed germination started on day-3 and ceased by day-20 in 2006 and started on day-2 and ceased by day-22 2007. Among provenances, mean seed germination time ranged between 6.48 and 8.49 days in 2006 and between 7.29 and 9.49 days in 2007 (Table 6.3). Similarly, among provenances, mean leaf emergence time ranged between 3.48 and 3.83 days in 2006 and between 3.34 and 3.93 days in 2007 (Table 6.3). The leaf emergence was recorded in all germinated seedlings both in 2006 and 2007 (Table 6.3).

Table 6.3. Seed germination time, leaf emergence time and leaf emergence success of *P. roxburghii* collected from seven provenances in northeast India in 2006 and 2007.

Provenance	2006			2007		
	Germination time (days)	Leaf emergence time (days)	Leaf emergence (%)	Germination time (days)	Leaf emergence time (days)	Leaf emergence (%)
1. Bilkhawthlir	6.97±2.17	3.50±0.75	100	8.69±3.05	3.35±2.19	100
2. Kawnpui	6.99±1.52	3.83±0.58	100	8.07±2.72	3.74±1.50	100
3. Mawriang	8.49±2.51	3.75±0.77	100	8.63±2.47	3.93±0.93	100
4. Thingkhangphai	7.32±2.03	3.68±0.80	100	9.49±3.31	3.58±1.68	100
5. Kangpokpi	6.48±2.24	3.48±0.89	100	7.29±2.75	3.34±1.15	100
6. Kezanglwa	7.09±1.73	3.79±0.68	100	8.69±3.00	3.53±3.11	100
7. Khaibung	6.94±2.14	3.69±0.90	100	7.82±2.68	3.52±1.15	100
All provenances	7.22±2.21	3.66±0.79	100	8.34±2.92	3.57±1.76	100

6.3.3. *Seedling growth*

Seedling growth of *P. roxburghii* was recorded after 7, 14, and 21 days and then after 1, 3, 6, 9 and 12 months of germination of seeds from all seven provenances collected in 2006 and 2007 (Tables 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11). The growth of seedlings was consistent except in month-6 when leaf fall caused a decline in number (Figs. 6.3).

Table 6.4. Seedling growth of *P. roxburghii* after 7 days of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	1.01±1.68	0.08±0.11	0.01±0.12	0.64±1.44	0.05±0.09	0.02±0.13
2. Kawnpui	0.38±0.77	0.02±0.07	0.00±0.00	0.34±0.87	0.03±0.08	0.00±0.00
3. Mawriang	0.24±0.64	0.03±0.08	0.00±0.00	0.09±0.32	0.01±0.05	0.00±0.00
4. Thingkhangphai	0.92±1.48	0.10±0.11	0.03±0.23	0.38±0.90	0.05±0.09	0.01±0.09
5. Kangpokpi	1.59±1.94	0.30±0.14	0.20±0.48	1.42±2.09	0.11±0.12	0.17±0.47
6. Kezanglwa	0.36±0.61	0.03±0.08	0.00±0.00	0.51±1.01	0.07±0.10	0.00±0.00
7. Khaibung	0.98±1.30	0.12±0.11	0.01±0.09	0.42±0.93	0.05±0.09	0.00±0.00
All provenances	0.79±1.40	0.08±0.11	0.04±0.24	0.57±1.31	0.05±0.10	0.03±0.22

Table 6.5. Seedling growth of *P. roxburghii* after 14 days of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	5.81±2.56	0.38±0.09	0.97±0.45	4.80±2.85	0.36±0.09	0.94±0.65
2. Kawnpui	5.60±2.42	0.43±0.06	0.84±0.37	5.09±2.72	0.40±0.08	0.87±0.55
3. Mawriang	5.78±2.33	0.41±0.07	0.96±0.31	5.87±2.28	0.40±0.09	0.90±0.38
4. Thingkhangphai	5.86±2.20	0.41±0.09	0.89±0.32	5.07±2.44	0.41±0.07	0.83±0.56
5. Kangpokpi	7.27±2.67	0.42±0.06	0.98±0.52	6.95±2.91	0.41±0.08	0.87±0.58
6. Kezanglwa	5.19±2.01	0.43±0.07	0.88±0.33	5.88±2.61	0.40±0.08	0.81±0.42
7. Khaibung	6.22±2.40	0.39±0.08	0.89±0.36	5.26±2.37	0.41±0.08	0.83±0.42
All provenances	6.02±2.48	0.41±0.08	0.92±0.40	5.61±2.70	0.40±0.08	0.87±0.52

Table 6.6. Seedling growth of *P. roxburghii* after 21 days of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	11.08±3.10	0.49±0.07	1.94±0.55	9.57±3.99	0.48±0.08	1.98±0.62
2. Kawnpui	10.12±3.52	0.53±0.07	1.69±0.54	9.68±3.80	0.51±0.07	1.83±0.56
3. Mawriang	9.84±3.01	0.52±0.07	1.66±0.47	9.91±3.24	0.52±0.07	1.68±0.47
4. Thingkhangphai	10.67±3.09	0.51±0.07	1.84±0.56	10.50±3.39	0.52±0.06	1.83±0.61
5. Kangpokpi	13.13±3.31	0.53±0.07	1.91±0.55	12.90±3.37	0.53±0.07	1.85±0.65
6. Kezanglwa	9.61±3.11	0.53±0.07	1.75±0.49	11.17±3.62	0.51±0.07	1.77±0.56
7. Khaibung	11.21±3.12	0.51±0.07	1.91±0.56	9.93±3.14	0.52±0.07	1.64±0.56
All provenances	10.88±3.39	0.52±0.07	1.81±0.54	10.56±3.69	0.51±0.07	1.80±0.58

Table 6.7. Seedling growth of *P. roxburghii* after 1 month of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	16.29±3.84	0.61±0.07	7.09±1.59	15.58±4.78	0.61±0.09	6.71±2.12
2. Kawnpui	13.38±4.40	0.65±0.05	7.27±1.43	12.69±4.82	0.64±0.07	6.97±1.89
3. Mawriang	11.39±3.17	0.65±0.05	7.47±1.32	11.57±3.39	0.65±0.06	7.32±1.49
4. Thingkhangphai	15.51±4.15	0.63±0.05	7.32±2.44	14.81±5.13	0.64±0.08	7.35±1.77
5. Kangpokpi	18.77±4.11	0.65±0.05	6.92±1.58	18.68±3.98	0.64±0.06	6.94±1.58
6. Kezanglwa	13.58±3.94	0.65±0.05	7.99±0.80	16.54±5.43	0.63±0.07	6.94±1.97
7. Khaibung	16.16±4.13	0.63±0.08	6.38±2.22	13.33±4.09	0.64±0.05	7.40±1.60
All provenances	15.00±4.64	0.64±0.06	7.20±1.70	14.74±5.08	0.64±0.07	7.09±1.79

Table 6.8. Seedling growth of *P. roxburghii* after 3 months of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	22.29±3.94	0.73±0.07	6.61±2.24	31.28±13.10	0.77±0.11	7.44±2.75
2. Kawnpui	18.42±5.41	0.77±0.05	7.76±2.70	20.03±6.35	0.77±0.06	7.71±2.60
3. Mawriang	15.58±5.01	0.76±0.05	7.33±2.30	15.49±4.37	0.76±0.06	7.21±2.48
4. Thingkhangphai	21.28±4.25	0.76±0.06	7.11±2.37	22.47±9.18	0.76±0.06	7.45±2.56
5. Kangpokpi	24.46±4.60	0.77±0.06	7.28±2.2	25.49±5.02	0.78±0.09	7.68±2.45
6. Kezanglwa	19.13±4.46	0.77±0.04	7.31±2.32	26.71±9.17	0.77±0.07	7.76±2.15
7. Khaibung	21.57±4.53	0.76±0.06	7.39±1.98	18.67±5.15	0.76±0.05	7.18±2.59
All provenances	20.34±5.52	0.76±0.06	7.31±2.34	22.77±9.42	0.77±0.07	7.48±2.52

Table 6.9. Seedling growth of *P. roxburghii* after 6 months of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	27.69±4.66	0.81±0.07	5.15±2.25	36.34±12.55	0.87±0.13	5.32±2.42
2. Kawnpui	24.91±6.75	0.87±0.06	5.04±1.71	26.00±7.16	0.86±0.07	5.09±1.61
3. Mawriang	22.48±7.04	0.85±0.06	4.96±1.68	21.21±6.24	0.85±0.07	5.06±1.57
4. Thingkhangphai	26.19±5.02	0.83±0.06	5.74±1.60	29.93±11.10	0.87±0.11	5.26±1.74
5. Kangpokpi	30.17±4.58	0.84±0.06	4.81±1.71	31.44±6.54	0.84±0.07	4.81±1.80
6. Kezanglwa	25.05±5.54	0.88±0.06	4.79±1.84	31.77±8.76	0.83±0.06	5.42±2.05
7. Khaibung	26.81±5.17	0.82±0.07	5.40±1.93	24.54±6.40	0.85±0.07	4.96±1.76
All provenances	26.22±6.18	0.84±0.07	5.08±1.84	28.63±9.92	0.85±0.09	5.12±1.87

Table 6.10. Seedling growth of *P. roxburghii* after 9 months of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	32.88±5.39	0.91±0.13	9.49±2.69	41.42±12.38	0.98±0.15	9.64±2.83
2. Kawnpui	31.44±7.63	1.02±0.12	9.46±1.95	32.04±7.67	1.00±0.12	9.40±2.38
3. Mawriang	28.62±8.17	1.01±0.11	9.48±2.22	26.81±7.79	0.99±0.12	9.38±2.41
4. Thingkhangphai	31.13±5.51	0.97±0.10	9.13±2.28	35.28±11.33	1.02±0.13	9.82±2.72
5. Kangpokpi	35.51±5.00	0.98±0.10	9.16±2.05	36.63±6.60	0.98±0.11	9.12±2.40
6. Kezanglwa	30.88±6.55	1.04±0.10	9.48±2.11	36.47±8.64	0.97±0.12	9.43±2.44
7. Khaibung	31.90±5.71	0.95±0.12	9.14±2.75	30.44±7.40	1.01±0.12	9.77±2.36
All provenances	31.84±6.79	0.98±0.12	9.34±2.30	34.03±10.10	0.99±0.13	9.49±2.51

Table 6.11. Seedling growth of *P. roxburghii* after one year of germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	2006			2007		
	Seedling height (cm)	Collar diameter (mm)	Number of leaves	Seedling height (cm)	Collar diameter (mm)	Number of leaves
1. Bilkhawthlir	38.39±5.93	1.04±0.19	10.89±3.0	46.98±12.79	1.12±0.23	10.04±3.37
2. Kawnpui	37.38±8.08	1.22±0.13	11.23±2.8	37.67±7.97	1.20±0.15	10.85±3.38
3. Mawriang	35.11±8.74	1.23±0.12	12.18±2.6	32.37±9.09	1.19±0.14	11.85±2.82
4. Thingkhangphai	35.83±5.71	1.16±0.13	12.89±3.4	41.29±11.94	1.21±0.14	11.57±3.54
5. Kangpokpi	41.45±5.52	1.19±0.12	11.64±3.0	42.41±6.67	1.17±0.13	11.48±3.15
6. Kezanglwa	36.00±7.11	1.23±0.10	11.40±2.4	42.04±9.95	1.16±0.16	10.91±2.96
7. Khaibung	36.80±6.40	1.14±0.16	10.34±3.3	35.84±8.13	1.21±0.15	11.70±2.48
All provenances	37.48±7.27	1.17±0.15	11.51±3.0	39.68±10.71	1.18±0.16	11.22±3.17

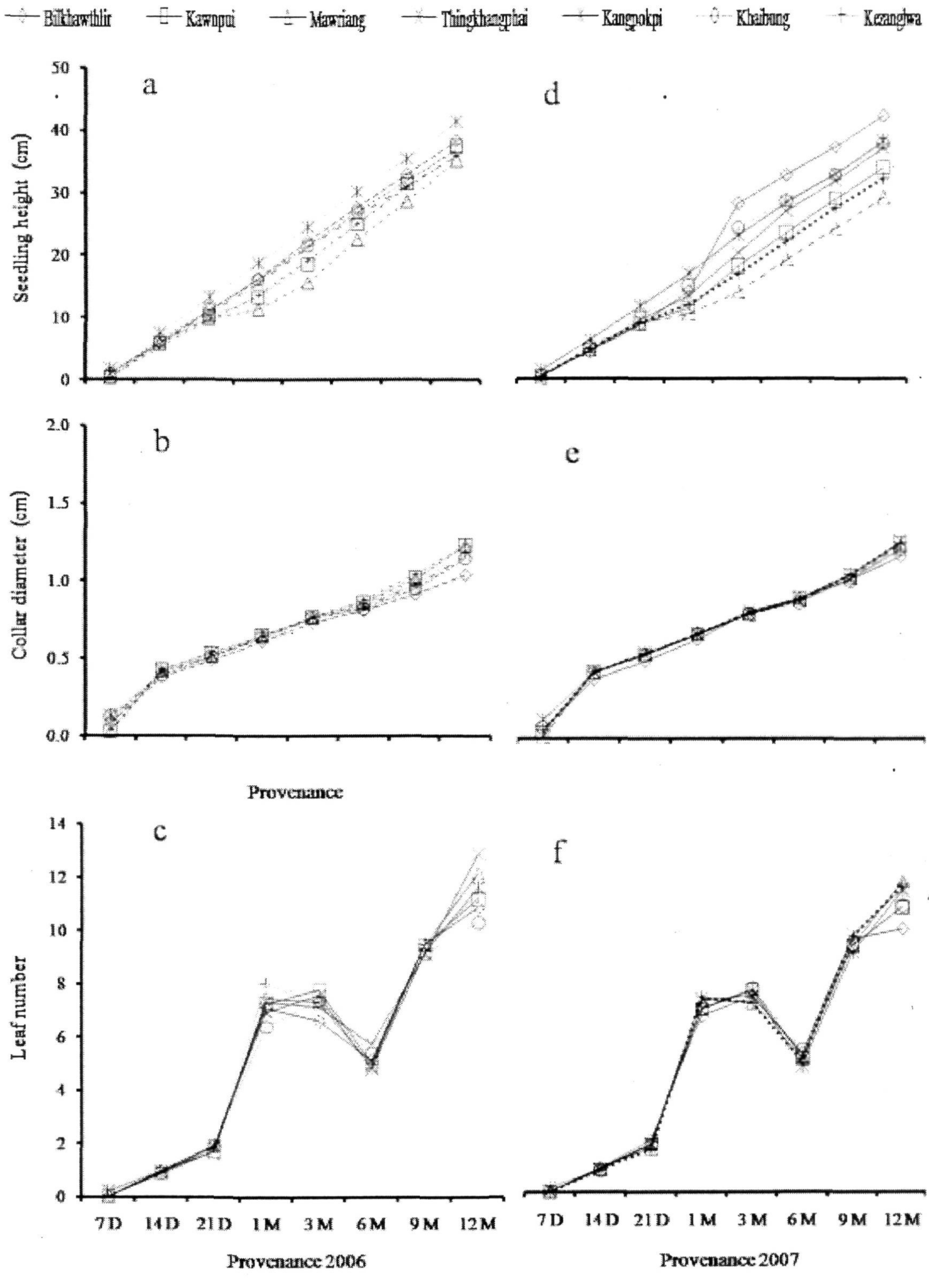


Fig. 6.3. Growth of seedlings of *P. roxburghii* in terms of seedling height ('a' in 2006 and 'd' in 2007), collar diameter ('b' in 2006 and 'e' in 2007), number of leaves ('c' in 2006 and 'f' in 2007) from seeds of seven provenances in northeast India.

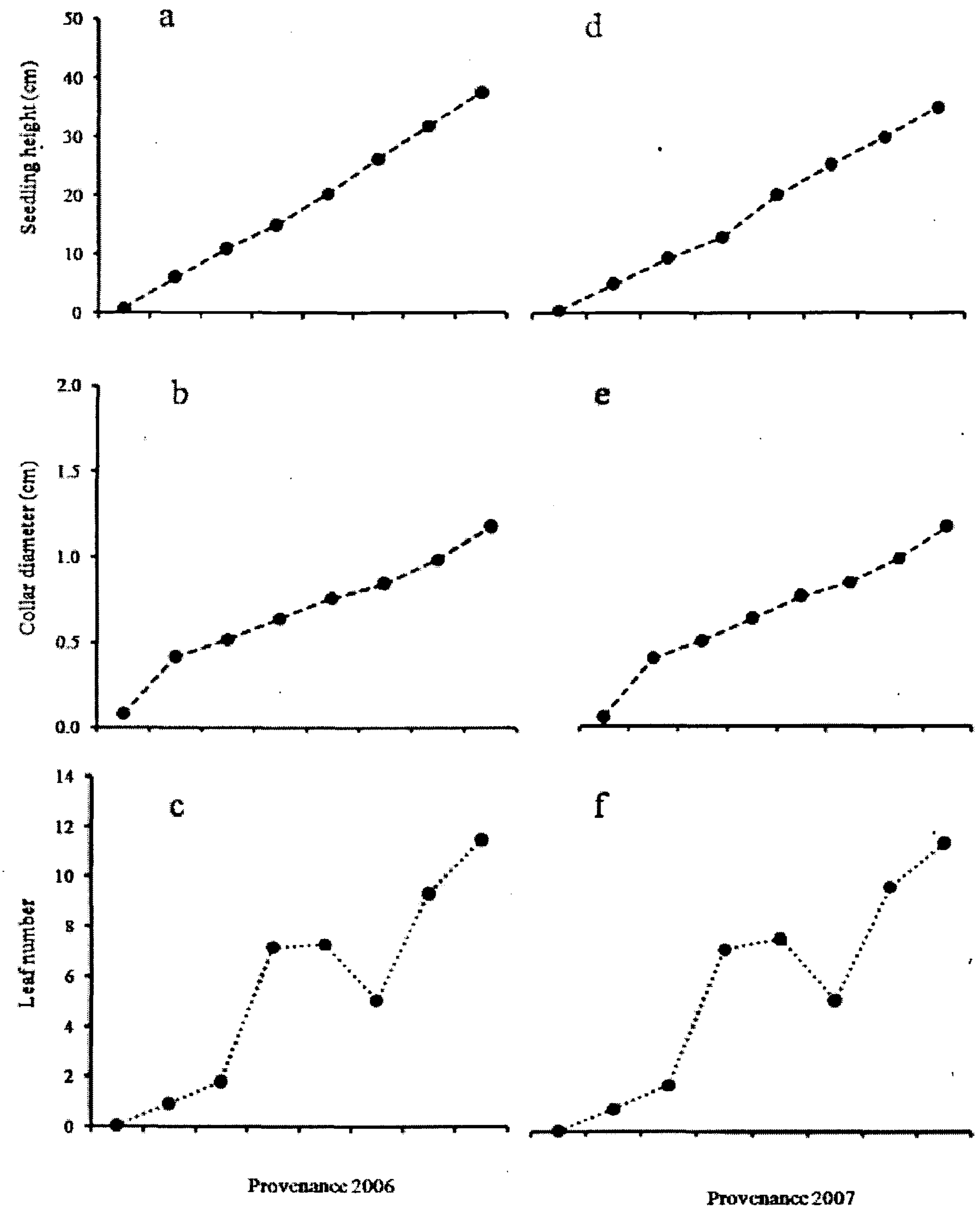


Fig. 6.4. Growth of seedlings of *P. roxburghii* in terms of seedling height ('a' in 2006 and 'd' in 2007), collar diameter ('b' in 2006 and 'e' in 2007), number of leaves ('c' in 2006 and 'f' in 2007) after pooling data for seven provenances in northeast India.

The differences between years 2006 and 2007 in the pattern of growth of seedlings were minimal (Fig. 6.4). An overlay of the time-series data showed a nearly-perfect similarity between the growth of seedling height, collar diameter and leaf number (Fig. 6.5). After growth for 12 months, the seedlings grew to 37 cm mean height in 2006 and 39 cm in 2007, 1.17 mm mean collar diameter in 2006 and 2007, and 11.5 mean number of leaves per seedling in 2006 and 2007.

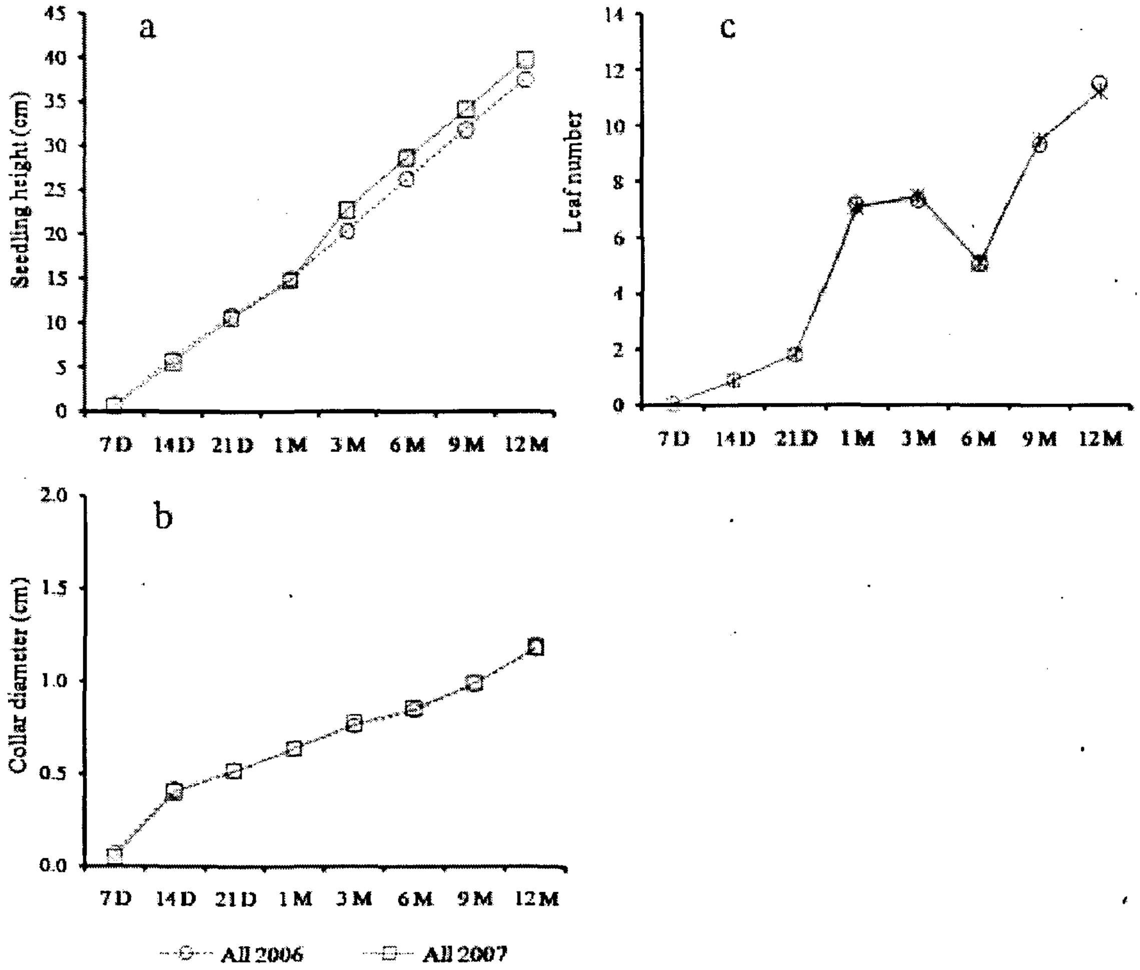


Fig. 6.5. An overlay comparison of growth of seedlings of *P. roxburghii* in 2006 and 2007 in terms of seedling height, collar diameter, number of leaves after pooling data for seven provenances in northeast India.

6.3.4. *Seedling survival*

Although germination of seeds of P. roxburghii was mediocre, the survival of seedlings was good (Table 6.12). Across provenances, 80-100% seedlings survived by the end of one year of observations both for the seedlings raised from seeds of 2006 and 2007.

Table 6.12. Seedling survival of *P. roxburghii* up to one year after germination of seeds from seven provenances in northeast India collected in 2006 and 2007.

Provenance	Seeds sown	Seeds germi-nated	Seedling survival after (D=days/M=months)							
			7D	14D	21D	1M	3M	6M	9M	12M
					2006					
1. Bilkhawthlir	380	137	137	137	137	137	136	136	136	136
2. Kawnpui	400	127	127	127	127	127	126	124	124	124
3. Mawriang	408	179	179	179	179	174	169	169	169	168
4. Thingkhangphai	354	90	90	90	90	90	87	87	87	87
5. Kangpokpi	351	169	169	169	169	169	169	167	167	167
6. Kezanglwa	304	112	112	112	112	111	107	106	106	106
7. Khaibung	346	114	114	113	112	111	109	108	108	108
All provenances	2,543	928	928	927	926	919	903	897	897	896
					2007					
8. Bilkhawthlir	367	124	124	124	123	121	121	120	119	119
9. Kawnpui	376	119	119	119	119	119	113	112	112	112
10. Mawriang	391	147	147	142	142	142	141	141	141	141
11. Thingkhangphai	353	115	115	115	114	114	111	109	109	109
12. Kangpokpi	377	160	160	142	139	136	134	134	134	134
13. Kezanglwa	324	102	102	102	102	102	100	99	99	99
14. Khaibung	338	107	107	106	106	106	98	97	95	95
All provenances	2,526	874	874	850	845	840	818	812	809	809

6.3.5. *Comparison of seed traits of germinated and failed seeds*

The differences in the mean values values of the traits of seeds germinated and seeds failed to germinated were analyzed separately and are presented for the following traits: seed weight (Table 6.13), seed length (Table 6.1), seed width (Table 6.15), seed thickness (Table 6.16) and seed volume (Table 6.17). The seed traits considerably among provenances both for germinated and failed seed categories both in 2006 and 2007. However, the variations between the traits of germinated and failed seeds were minimal and not significant in most cases.

Table 6.13. Comparison of mean seed weight (g) of germinated and failed seeds of *P. roxburghii* in 2006 and 2007 individually for seven provenances and for all provenances together. The differences between mean values were tested using one-way analysis of variance (F test) and respective p values are shown.

Provenance	2006		2007	
	Germinated	Failed	Germinated	Failed
Bilkhawthlir	0.95 ± 0.13	0.90 ± 0.13	0.92 ± 0.15	0.88 ± 0.15
Kawnpui	0.93 ± 0.18	0.92 ± 0.14	0.74 ± 0.10	0.68 ± 0.06
Mawriang	0.42 ± 0.10	0.40 ± 0.11	0.45 ± 0.09	0.46 ± 0.13
Thingkhangphai	0.78 ± 0.16	0.63 ± 0.14	0.81 ± 0.17	0.82 ± 0.17
Kangpokpi	1.08 ± 0.20	0.96 ± 0.26	0.61 ± 0.28	0.61 ± 0.29
Kezanglwa	0.82 ± 0.29	0.72 ± 0.29	0.45 ± 0.15	0.48 ± 0.15
Khaibung	0.89 ± 0.28	0.64 ± 0.23	0.40 ± 0.12	0.41 ± 0.11
All provenances	0.83 ± 0.29	0.74 ± 0.27	0.63 ± 0.25	0.62 ± 0.24
	F=199.10, p<0.001	F=251.69, p<0.001	F=169.77, p<0.001	F=309.50, p<0.001

Table 6.14. Comparison of mean seed length (cm) of germinated and failed seeds of *P. roxburghii* in 2006 and 2007 individually for seven provenances and for all provenances together. The differences between mean values were tested using one-way analysis of variance (F test) and respective p values are shown.

Provenance	2006		2007	
	Germinated	Failed	Germinated	Failed
Bilkhawthlir	1.86 ± 0.12	1.82 ± 0.12	1.81 ± 0.17	1.79 ± 0.16
Kawnpui	1.82 ± 0.14	1.83 ± 0.13	1.80 ± 0.16	1.78 ± 0.17
Mawriang	1.52 ± 0.12	1.49 ± 0.14	1.53 ± 0.17	1.52 ± 0.18
Thingkhangphai	1.74 ± 0.16	1.61 ± 0.16	1.36 ± 0.14	1.34 ± 0.15
Kangpokpi	1.93 ± 0.21	1.85 ± 0.26	1.43 ± 0.21	1.45 ± 0.19
Kezanglwa	1. 29 ± 0.19	1.85 ± 0.19	1.60 ± 0.17	1.63 ± 0.18
Khaibung	1.84 ± 0.23	1.63 ± 0.24	1.55 ± 0.15	1.56 ± 0.20
All provenances	1.79 ± 0.22	1.72 ± 0.22	1.58 ± 0.23	1.59 ± 0.23
	F=115.00, p<0.001	F=165.30, p<0.001	F=128.65, p<0.001	F=218.20, p<0.001

Table 6.15. Comparison of mean seed width (cm) of germinated and failed seeds of *P. roxburghii* in 2006 and 2007 individually for seven provenances and for all provenances together. The differences between mean values were tested using one-way analysis of variance.(F test) and respective p values are shown.

Provenance	2006		2007	
	Germinated	Failed	Germinated	Failed
Bilkhawthlir	1.29 ± 0.11	1.28 ± 0.10	1.75 ± 0.19	1.73 ± 0.21
Kawnpui	1.28 ± 0.10	1.28 ± 0.11	1.98 ± 0.18	1.97 ± 0.20
Mawriang	1.15 ± 0.09	1.15 ± 0.11	1.19 ± 0.10	1.18 ± 0.11
Thingkhangphai	1.22 ± 0.14	1.13 ± 0.15	1.99 ± 0.19	1.96 ± 0.20
Kangpokpi	1.49 ± 0.13	1.35 ± 0.21	1.54 ± 0.42	1.43 ± 0.38
Kezanglwa	1.32 ± 0.14	1.29 ± 0.15	1.20 ± 0.16	1.22 ± 0.16
Khaibung	1.28 ± 0.10	1.22 ± 0.11	1.15 ± 0.14	1.15 ± 0.14
All provenances	1.28 ± 0.15	1.24 ± 0.15	1.54 ± 0.41	1.53 ± 0.40
	$F=93.70$, $p<0.001$	$F=79.10$, $p<0.001$	$F=304.95$, $p<0.001$	$F=714.97$, $p<0.001$

Table 6.16. Comparison of mean seed thickness (cm) of germinated and failed seeds of *P. roxburghii* in 2006 and 2007 individually for seven provenances and for all provenances together. The differences between mean values were tested using one-way analysis of variance (F test) and respective p values are shown.

Provenance	2006		2007	
	Germinated	Failed	Germinated	Failed
Bilkhawthlir	0.70 ± 0.08	0.69 ± 0.09	0.61 ± 0.14	0.62 ± 0.14
Kawnpui	0.66 ± 0.09	0.69 ± 0.10	0.64 ± 0.07	0.63 ± 0.08
Mawriang	0.48 ± 0.09	0.47 ± 0.11	0.51 ± 0.10	0.49 ± 0.10
Thingkhangphai	0.62 ± 0.09	0.60 ± 0.10	0.60 ± 0.07	0.61 ± 0.08
Kangpokpi	0.71 ± 0.08	0.68 ± 0.10	0.51 ± 0.15	0.49 ± 0.13
Kezanglwa	0.60 ± 0.16	0.56 ± 0.15	0.52 ± 0.14	0.54 ± 0.15
Khaibung	0.63 ± 0.14	0.55 ± 0.14	0.43 ± 0.14	0.43 ± 0.17
All provenances	0.63 ± 0.13	0.61 ± 0.14	0.54 ± 0.14	0.55 ± 0.14
	$F=92.96$, $p<0.001$	$F=126.26$, $p<0.001$	$F=44.11$, $p<0.001$	$F=103.48$, $p<0.001$

Table 6.17. Comparison of mean seed volume (cm^3) of germinated and failed seeds of *P. roxburghii* in 2006 and 2007 individually for seven provenances and for all provenances together. The differences between mean values were tested using one-way analysis of variance (F test) and respective p values are shown.

Provenance	2006		2007	
	Germinated	Failed	Germinated	Failed
Bilkhawthlir	1.69 ± 0.32	1.61 ± 0.30	1.97 ± 0.63	1.94 ± 0.60
Kawnpui	1.53 ± 0.31	1.63 ± 0.32	2.29 ± 0.41	2.21 ± 0.47
Mawriang	1.85 ± 0.22	0.82 ± 0.25	0.93 ± 0.25	0.91 ± 0.29
Thingkhangphai	1.34 ± 0.41	1.10 ± 0.30	1.61. ± 0.31	1.59 ± 0.31
Kangpokpi	1.98 ± 0.41	1.72 ± 0.52	1.15 ± 0.56	1.05 ± 0.49
Kezanglwa	1.55 ± 0.50	1.38 ± 0.47	1.02 ± 0.41	1.12 ± 0.42
Khaibung	1.51 ± 0.49	1.12 ± 0.40	0.79 ± 0.31	0.78 ± 0.30
All provenances	1.49 ± 0.53	1.33 ± 0.48	1.39 ± 0.68	1.39 ± 0.67
	F=143.31, p<0.001	F=194.78, p<0.001	F=204.50, p<0.001	F=402.96, p<0.001

Table 6.18. Comparison of mean germinated and failed seeds of *P. roxburghii* in 2006 and 2007 for all provenances together.

Provenance	Sample size (n)	Minimum	Maximum	Mean (± sd)	CV (%)
		Seed weight (gm)			
Germinated (2006)	928	0.15	1.88	0.83 ± 0.29	35.44
Failed (2006)	1615	0.10	1.51	0.74 ± 0.27	36.00
Germinated (2007)	874	0.11	1.40	0.63 ± 0.25	39.51
Failed (2007)	1652	0.08	1.40	0.62 ± 0.24	38.08
All seeds (2006)	2543	0.10	1.88	0.77 ± 0.28	36.27
All seeds (2007)	2526	0.08	1.40	0.62 ± 0.24	38.58
Seed length (cm)					
Germinated (2006)	928	0.93	2.50	1.79 ± 0.22	12.36
Failed (2006)	1615	0.89	2.81	1.72 ± 0.22	13.03
Germinated (2007)	874	0.36	2.30	1.58 ± 0.23	14.68
Failed (2007)	1652	0.36	2.20	1.59 ± 0.23	14.74
All seeds (2006)	2543	0.89	2.81	1.75 ± 0.23	12.92
All seeds (2007)	2526	0.36	2.30	1.58 ± 0.23	14.72
Seed width (cm)					
Germinated (2006)	928	0.89	1.74	1.28 ± 0.15	11.36
Failed (2006)	1615	0.31	1.80	1.24 ± 0.15	12.30
Germinated (2007)	874	0.36	2.30	1.54 ± 0.41	26.35
Failed (2007)	1652	0.12	2.30	1.53 ± 0.40	26.07
All seeds (2006)	2543	0.31	1.80	1.25 ± 0.15	12.09
All seeds (2007)	2526	0.12	2.30	1.54 ± 0.40	26.17
Seed thickness (cm)					
Germinated (2006)	928	0.28	1.00	0.63 ± 0.13	21.23
Failed (2006)	1615	0.19	1.11	0.61 ± 0.14	22.44
Germinated (2007)	874	0.21	1.11	0.54 ± 0.14	25.27
Failed (2007)	1652	0.19	1.53	0.54 ± 0.14	25.12
All seeds (2006)	2543	0.19	1.11	0.62 ± 0.14	22.02
All seeds (2007)	2526	0.19	1.53	0.54 ± 0.14	25.17
		Seed volume (cu. cm)			
Germinated (2006)	928	0.36	3.13	1.49 ± 0.53	35.42
Failed (2006)	1615	0.20	3.01	1.33 ± 0.48	35.93
Germinated (2007)	874	0.14	3.42	1.39 ± 0.68	49.02
Failed (2007)	1652	0.01	3.61	1.39 ± 0.67	48.10
All seeds (2006)	2543	0.20	3.13	1.39 ± 0.50	36.14
All seeds (2007)	2526	0.01	3.61	1.39 ± 0.67	48.41

6.4. Discussion

The fruit is indehiscent with seeds embedded in a thick hard coat bounded by strong sutures. Seeds may have to remain in the fruit long after it is ripened and rely on other mechanisms such as decay or predation to release the contents. Moreover, the seed may not escape from predation when its size may not be determined from the fruit cover (Uma Shankar 2006). This character of the fruit may have been the factor of low regeneration in the wild. Detaching from the branch the chime-like pendent fruits are also seen entangled on the lower branches till they naturally rots. How viable the seed must be, the species will face natural stress of regenerating itself when very few fruits are developing from a capitulum that are further withheld by the stout indehiscent fruit cover.

Seeds are viable with 94 to 100 percent seeds thoroughly stained with tetrazolium (Table 6.1 and Fig. 6.2). Luckow and Hopkins (1995) termed *P. roxburghii* as the most complex species across the genus that produce only 9 to 17 fruits from thousands of its fertile flowers in a capitulum. This study also observed another contrasting feature in context to germination when only 35 percent of seeds germinated in spite of producing huge lump of seeds per fruit. Provenances differed significantly among themselves but are not remarkable to convince any environment or genetic influence. Does the species follow a self-suicide trend right from developing less fruits from numerous fertile flowers, embedding its seeds within an indehiscent fruit and to producing huge viable but non-germinating seeds? Literature search yielded scarce information to explain the question hence needs further investigation.

Leaves appeared within the sixth day of germination in 2006 and extended to the ninth day in 2007 across provenances that are significantly different from each other (Table 6.2). Once the seed germinate they developed into a seedling and showed strong establishment with more than 90 percent of seedling survival during its early growth (Table 6.3), and is in tune with hollong (Uma Shankar 2006). There was no strong correlation among seeds germinated and that developed to seedlings to seed dimensions. Seedling growth behaviour of *P. roxburghii* followed almost a similar trend in both the years (Fig. 6.3, 6.4 and 6.5). The seeds that germinated and those that did not germinate showed no significant differences among morphometric traits (Table 6.4 and 6.6). It is assumed that seeds having large diameter and heavier weight will assure high germination (Khan and Uma Shankar 2001, Uma Shankar 2006). The study also witnessed higher values in the germinated seeds that differed significantly (p=0.05) among provenances (Table 6.4 through 6.14). Interestingly, all seeds from 2006 collection are larger, heavier and thicker as compared to those collected during 2007 (Table 6.14). However, fuzzy distribution of the seeds germinated and those failed across dimensions thoroughly discussed in the previous chapter don not guarantee a definite success when heavier, larger and thicker seeds are considered for sowing. Therefore, the seeds that will be successful in germination may not be predicted easily in the case of *P.roxburghii*.

Germination is epigeous and starts on the second day of sowing and ceased at day-22 across provenances (Table 6.2). For unknown reasons, 23 seedlings died in 2006 and increased to 34 deaths in the following year. Seedling characteristics do vary from one provenance to the other in height and collar diameter but follow a same trend of growth. Seedling height showed wider differences among provenances with Thingkhangphai and Bilkhawthlir in the front in either year, respectively. The study observed mild differences in seed dimension affecting the growth of the seedling across provenances. Hence, the study cannot conclude whether heavier, larger and thicker seeds will assure healthier seedlings. A seedling vigour was influenced by the seed dimensions within provenance especially those with heavier weight where the growth was comparative better with the passage of time. The present study was conducted at relatively same type of elevation (980) with its natural habitats which ranged from 400 to 1200 m above mean sea level and similar climate of ICAR campus, Umiam (Meghalaya). Hence, the result obtained during the study may bear resemblance with seedlings if grown within respective provenances. With no specific trend of correlation among seed dimensions to germination as well as seedling growth behaviour, *P. roxburghii* may not be an easy species to judge on its success of sorting seeds for future multiplication. The seed that would germinate and finally developed in to a healthy seedling is influenced by provenance and not merely of the fruit and seed dimensions.

The overall germination percentage across all provenances averages 36.4% in 2006 and 34.5% in 2007. The provenance variation in seed germination percentage is not remarkable. However, the mean seed germination time and the mean leaf emergence time showed little variation among provenances. The overall survival of seedlings after one year of growth is good (>80%) in all provenances and in both the years. All the provenances followed a similar pattern of seedling growth. The seeds that germinated and the seeds that did not germinate (failed) showed no significant differences among morphometric traits. Hence, the seeds that will be successful in germination may not be predicted easily.

CHAPTER VII

NUTRITITIVE VALUE AND ETHNOBOTANICAL IMPORTANCE OF *Parkia roxburghii*

7.1. Introduction

Many of bean varieties popularly called the 'poor man's meat' that are being consumed worldwide today are a recent discovery for their rich nutritional value that they offered. At present its consumption is decreasing in many developed nations but it is difficult for many developing cuisines without them in their diet (Messina 1999). India is in the midst of a paradoxical situation where approximately 200 million people are underfed and 50 million on the brink of starvation. However, people in northeastern region of India have from ages developed ingenious uses of wild plants to meet nutritional requirements (Singh and Arora 1978, Longvah and Deosthale 1998, Sundriyal and Sundriyal.2001, Murugkar and Subbulakshmi 2005). Among the numerous non-conventional foods used by the local communities is a tree legume, a member of Mimosoidae, *Parkia roxburghii* G. Don. (Syn. *Parkia timoriana* (DC.) Merr.), popularly known as the 'tree bean'. The northeastern region is the primary and secondary source of origin of *Parkia roxburghii* (Singh *et al.* 2000a) extending to Irian Jaya. It grows in humid tropical plains extending to subtropical climate in the hills between 400 and 1,200 MSL. Owing to the multipurpose nature, *P. roxburghii* is extensively planted in the homegardens (Kanjilal *et al.* 1938, Sharma *et al.* 1993, Rocky *et al.* 2004) and road sides.

Parkia roxburghii is a potential source of protein and fat (Don and Singh 1986, Longvah and Deosthale 1998) and is believed to have some medicinal remedies. The fruit is a legume, hanging in bunch of 8 - 20 numbers from a biglobose capitulum at the end of a peduncle and is highly preferred by many tribes for its taste (Meitei and Singh 1990). At lean period, seeds are also consumed. The nutrient composition and food potentiality of genus *Parkia* have been carried out by various workers since a few decades, however we failed to identify a document fully dealing with the evaluation of nutritional properties from various geographical source of north eastern India. The objective of this correspondence is to highlight the nutritional and anti-nutritional properties of *Parkia roxburghii* from seven rich growing pockets of northeastern India to meet the nutritional requirement.

7.2. Materials and methods

7.2.1. *Sample collection and preparation*

The tender fruits of *P. roxburghii* were collected during November-December, 2005and brought to the laboratory. Tender fruits as well as seeds for nutritive analysis were collected from the same trees that were marked for fruits and seeds collection meant for germination trials. One bunch of healthy fruits was selected from each tree irrespective of the number of fruits developed in a capitulum. All fruits were processed for nutritive analysis. Seeds were extracted manually from healthy fruits that are left out after the germination trial. However, the address of fruits and seeds were not traced for this analysis. The fruits were washed in tap water, air-dried, crushed into small pieces, andoven dried at 72 °C till constant weight.

The seeds after removing seed coat (called kernel here) were also analyzed for nutritional parameters. The seeds were collected from mature fruits during April-May in 2006. The maturity of the fruits is known when they are totally dried hanging on trees or are just fallen on the ground.

The oven-dried samples of tender fruits and kernels were ground to a fine powder enough to pass through a 2 mm sieve. The powdered samples were stored in air tight plastic bottles in a refrigerator until further use.

7.2.2. *Determination of biochemical properties*

The gross energy was determined after burning the oven-dried samples in a bomb calorie meter (Make: Rajdhani–RSB digital). The ash content was determined by combusting the plant material in silica crucibles in a muffle furnace at 600 ^{0}C for 3 h. The protein content (nitrogen x 6.25) was estimated by the copper catalyst Kjeldahl method. Crude fiber was determined by acid and alkaline digestion methods in a Kjeldahl fibraplus fiber tech apparatus (Allen, 1989). Crude fat content was estimated through petroleum ether extract method (AOAC 1990). Calcium and magnesium were determined by EDTA (disodium salt of ethylene diamine-tetra-acetic acid) titration methodand potassium was determined by wet-digestion method by a flame photometer (Anderson and Ingram, 1993). Phosphorus was determined following the ammonium molybvanadate method (AOAC, 1990). Manganese, zinc, iron, copper, cobalt and sulphur were determined at required wavelength in a Varian Techtron atomic absorption spectrophotometer (AAS). Antinutritional factors viz. phenolics, tannins and oxalates were examined by following standard procedures of AOAC (1990). The coefficient of variation (CV) of all parameters was also calculated for all parameters. Analysis of variance (ANOVA) is employed for all parameters to test the significance level among provenances. Comparison among provenances for different parameters was done using Tukey's post hoc test analysis.

7.3. Results

The proximate analysis of the edible parts of *Parkia roxburghii* is depicted in table 7.1 and table 7.2. Ash content differed significantly (P=0.05) among provenances with fruits from Kawnpui (4.08%) and seeds from Kangpokpi (5.95%) registering maximum residues after complete combustion. On complete combustion, the mean ash content ranged between 3.39% in fruit to 5.06% in seed. Crude fiber of immature fruits and seeds showed significant difference (P=0.05) among provenances where Kezanglwa and Khaibung accumulated the maximum, respectively. The result is in tune with the findings of Longvah *and* Doesthale in *P. roxburghii* and Oladunmoye 2007 in *P. biglobosa*. Provenances differed significantly (P=0.01) in the fat content of kernels but found non-significant in fruits. Seeds of *P. roxburghii* from Bilkhawthlir (31.97%), Mawriang (30.17%) and Kawnpui (28.53%) having higher fat contents may therefore have an ample scope for edible oil production in northeastern India.

Crude protein percent ranged between 11 to 15 in fruits and 25 to 30 percent in seeds (Table 7.1 and 7.2). A significant difference (P=0.05) among provenances was observed in this study with Bilkhawthlir dominating the protein content both in fruits (15%) and seeds (29%). The study revealed an optimum mean content of protein (14% in fruits & 28% in seeds) that matches the findings of Longvah and Deosthale (1998) in *P. roxburghii* and Okpala (1990), Obizoba (1998), Alabi *et al* (2005) and Oladunmoye (2007) in the seeds of *P. biglobosa.*

Table 7.1. Provenance variation in nutritive traits of tender fruits of *P. roxburghii*.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's post-hoc test)
Energy (cal. g^{-1})						
1. Bilkhawthlir	3	11.64	12.03	11.83 ± 0.20	1.6	2,5,6,7
2. Kawnpui	3	13.01	13.40	13.20 ± 0.20	1.5	1,5,6,7
3. Mawriang	3	11.49	13.40	12.50 ± 0.96	7.7	5,6,7
4. Thingkhangphai	3	12.81	13.20	15.33 ± 0.25	1.5	5,6,7
5. Kangpokpi	3	15.07	15.56	13.01 ± 0.20	1.6	1,2,3,4,6
6. Kezanglwa	3	17.12	17.61	17.29 ± 0.27	1.6	1,2,3,4,5,7
7. Khaibung	3	14.09	14.77	14.41 ± 0.34	2.4	1,2,3,4
ANOVA					F=57.89, p<0.001	
Ash content (%)						
1. Bilkhawthlir	3	3.47	4.10	3.75 ± 0.32	8.6	5
2. Kawnpui	3	3.92	4.19	4.08 ± 0.15	3.5	5,7
3. Mawriang	3	3.23	3.68	3.50 ± 0.24	6.8	5
4. Thingkhangphai	3	3.32	3.42	3.38 ± 0.05	1.5	NS
5. Kangpokpi	3	1.87	3.11	2.62 ± 0.66	25.2	1,2,3,6
6. Kezanglwa	3	3.40	3.52	3.47 ± 0.06	1.8	5
7. Khaibung	3	2.86	3.06	2.93 ± 0.11	3.8	2
ANOVA					F=7.84, p<0.0011	
Crude fiber (%)						
1. Bilkhawthlir	3	8.24	8.50	8.37 ± 0.13	1.6	2,4,5,6,7
2. Kawnpui	3	9.28	9.76	9.52 ± 0.24	2.5	1,3,6,7
3. Mawriang	3	8.48	8.50	8.49 ± 0.01	0.1	2,5,6,7
4. Thingkhangphai	3	8.96	10.02	9.65 ± 0.46	4.8	1,6,7
5. Kangpokpi	3	9.19	10.11	9.49 ± 0.53	5.6	1,3,6
6. Kezanglwa	3	10.88	10.96	10.56 ± 0.59	5.6	1,2,3,4,5,
7. Khaibung	3	9.97	11.15	10.92 ± 0.04	0.4	1,2,3,4
ANOVA					F=20.71, p<0.001	

Fat (%)						
1. Bilkhawthlir	3	7.92	8.32	8.13 ± 0.20	2.5	NS
2. Kawnpui	3	6.82	8.12	7.46 ± 0.65	8.7	NS
3. Mawriang	3	6.98	8.30	7.70 ± 0.67	8.7	NS
4. Thingkhangphai	3	8.19	8.52	8.34 ± 0.17	2.0	NS
5. Kangpokpi	3	7.67	8.20	7.91 ± 0.27	3.4	NS
6. Kezanglwa	3	7.87	8.06	7.97 ± 0.10	1.2	NS
7. Khaibung	3	7.48	7.98	7.78 ± 0.26	3.4	NS
ANOVA					F=1.60, p<0.215	
Protein (%)						
1. Bilkhawthlir	3	15.27	15.29	15.28 ± 0.01	0.1	2,3,4,5,6,7
2. Kawnpui	3	13.73	13.77	13.75 ± 0.02	0.2	1,7
3. Mawriang	3	13.31	13.80	13.64 ± 0.28	2.1	1,7
4. Thingkhangphai	3	13.88	14.19	14.02 ± 0.16	1.1	1,7
5. Kangpokpi	3	13.55	14.30	13.95 ± 0.38	2.7	1,7
6. Kezanglwa	3	13.80	13.93	13.86 ± 0.07	0.5	1,7
7. Khaibung	3	11.27	11.67	11.53 ± 0.23	2.0	1,2,3,4,5,5
ANOVA					F=85.50, p<0.001	
P (%)						
1. Bilkhawthlir	3	0.402	0.422	0.41 ± 0.01	2.6	2,3,4,5,6,7
2. Kawnpui	3	0.181	0.201	0.19 ± 0.01	5.2	1,3,7
3. Mawriang	3	0.322	0.386	0.35 ± 0.03	9.4	1,2,4,5,6,7
4. Thingkhangphai	3	0.213	0.214	0.21 ± 0.00	0.2	1,3,7
5. Kangpokpi	3	0.172	0.197	0.19 ± 0.01	7.0	1,3,7
6. Kezanglwa	3	0.140	0.140	0.17 ± 0.02	10.3	1,3
7. Khaibung	3	0.152	0.187	0.14 ± 0.00	0.1	1,2,3,4,5
ANOVA					F=125.00, p<0.001	
K (%)						
1. Bilkhawthlir	3	0.202	0.212	0.207 ± 0.00	2.4	3,4,5,6,7
2. Kawnpui	3	0.209	0.213	0.211 ± 0.00	0.9	3,4,7
3. Mawriang	3	0.181	0.184	0.182 ± 0.00	0.8	1,2,4,5,6,7
4. Thingkhangphai	3	0.220	0.227	0.219 ± 0.00	0.3	12,3
5. Kangpokpi	3	0.220	0.219	0.223 ± 0.00	1.6	1,3
6. Kezanglwa	3	0.213	0.224	0.223 ± 0.01	2.0	1,3
7. Khaibung	3	0.219	0.228	0.218 ± 0.00	2.5	1,2,3
ANOVA					F=46.50, p<0.001	

Ca (%)						
1. Bilkhawthlir	3	0.195	0.201	0.20 ± 0.00	1.5	2,3,4,5,6,7
2. Kawnpui	3	0.163	0.165	0.16 ± 0.00	0.7	1
3. Mawriang	3	0.158	0.170	0.16 ± 0.01	3.7	1
4. Thingkhangphai	3	0.159	0.162	0.16 ± 0.00	1.0	1,5,7
5. Kangpokpi	3	0.169	0.171	0.17 ± 0.00	0.6	1,4,6
6. Kezanglwa	3	0.155	0.161	0.16 ± 0.00	1.9	1,5,7
7. Khaibung	3	0.167	0.174	0.17 ± 0.00	2.1	1,4,6
ANOVA					F=52.80, p<0.001	
Mg (%)						
1. Bilkhawthlir	3	0.489	0.508	0.50 ± 0.01	1.9	2,3,4,5,6,7
2. Kawnpui	3	0.428	0.436	0.43 ± 0.00	1.0	1
3. Mawriang	3	0.415	0.442	0.43 ± 0.01	3.2	1
4. Thingkhangphai	3	0.418	0.426	0.42 ± 0.01	1.0	1
5. Kangpokpi	3	0.429	0.446	0.44 ± 0.00	2.0	1,6
6. Kezanglwa	3	0.394	0.408	0.40 ± 0.01	1.8	1,5
7. Khaibung	3	0.405	0.462	0.44 ± 0.03	6.6	1
ANOVA					F=14.80, p<0.001	
Mn (%)						
1. Bilkhawthlir	3	44.70	51.00	47.83 ± 3.15	6.6	3,4,5,7
2. Kawnpui	3	44.30	53.20	47.87 ± 4.71	9.8	3,4,5,7
3. Mawriang	3	29.10	29.40	29.23 ± 0.15	0.5	1,2,5,6,7
4. Thingkhangphai	3	24.90	26.00	25.37 ± 0.57	2.2	1,2,5,6,7
5. Kangpokpi	3	7.20	8.60	7.90 ± 0.70	8.9	1,2,3,4,6,7
6. Kezanglwa	3	45.40	46.40	45.80 ± 0.53	1.2	3,4,5,7
7. Khaibung	3	16.0	18.10	17.03 ± 1.05	6.2	1,2,3,4,5,6
ANOVA					F=158.00, p<0.001	
Zn (%)						
1. Bilkhawthlir	3	3.20	3.90	3.60 ± 0.36	10.0	2,3,4,5,6,7
2. Kawnpui	3	2.00	3.10	2.40 ± 0.61	25.3	1,3,4,5,6,7
3. Mawriang	3	1.20	1.48	1.33 ± 0.14	10.7	1,2
4. Thingkhangphai	3	1.20	1.40	1.30 ± 0.10	7.7	1,2
5. Kangpokpi	3	0.90	1.10	1.00 ± 0.10	10.0	1,2
6. Kezanglwa	3	1.20	1.50	1.37 ± 0.15	11.2	1,2
7. Khaibung	3	0.90	1.00	0.93 ± 0.06	6.2	1,2
ANOVA					F=34.50, p<0.001	

Fe (%)						
1. Bilkhawthlir	3	20.30	28.20	25.27 ± 4.32	17.1	2,6
2. Kawnpui	3	57.60	66.50	61.07 ± 4.76	7.8	1,3,4,5,6,7
3. Mawriang	3	24.20	26.10	25.30 ± 0.98	3.9	2,6
4. Thingkhangphai	3	28.50	46.70	37.3 ± 9.10	24.2	2,7
5. Kangpokpi	3	29.80	32.90	31.33 ± 1.55	4.9	2,7
6. Kezanglwa	3	38.70	45.30	42.20 ± 3.32	7.9	1,2,3,
7. Khaibung	3	14.20	20.40	18.10 ± 3.40	18.8	2,4,5,6
ANOVA					F=28.50, p<0.001	
Cu (%)						
1. Bilkhawthlir	3	0.40	0.50	0.47 ± 0.06	12.4	2,4,6
2. Kawnpui	3	20.30	27.50	23.40 ± 3.70	15.8	1,3,5,6,7
3. Mawriang	3	0.80	0.90	0.83 ± 0.06	6.9	2,4,6
4. Thingkhangphai	3	13.40	29.0	21.33 ± 7.80	36.6	1,3,5,6,7
5. Kangpokpi	3	0.60	0.80	0.70 ± 0.10	14.3	2,4,6
6. Kezanglwa	3	31.70	47.60	37.57 ± 8.73	23.2	1,2,3,4,5,7
7. Khaibung	3	0.50	0.80	0.67 ± 0.15	22.9	2,4,6
ANOVA					F=32.10, p<0.001	
S (%)						
1. Bilkhawthlir	3	0.010	0.020	0.02 ± 0.01	34.6	2,4,6
2. Kawnpui	3	0.070	0.095	0.08 ± 0.01	16.5	1,3,5,7
3. Mawriang	3	0.030	0.045	0.04 ± 0.01	21.7	2,4,6
4. Thingkhangphai	3	0.080	0.100	0.09 ± 0.01	13.3	1,3,5,7
5. Kangpokpi	3	0.035	0.045	0.04 ± 0.01	13.9	2,4,6
6. Kezanglwa	3	0.070	0.085	0.08 ± 0.01	9.8	1,3,5,7
7. Khaibung	3	0.030	0.050	0.04 ± 0.01	25.0	2,4,6
ANOVA					F=24.60, p<0.001	
Oxalic acid (%)						
1. Bilkhawthlir	3	1.90	2.00	1.95 ± 0.05	2.6	3,7
2. Kawnpui	3	1.62	1.84	1.73 ± 0.11	6.4	5
3. Mawriang	3	1.42	1.50	1.46 ± 0.04	2.7	1,4,5
4. Thingkhangphai	3	1.99	2.01	2.00 ± 0.01	0.5	3,7
5. Kangpokpi	3	2.01	2.11	2.06 ± 0.05	2.4	2,3,7
6. Kezanglwa	3	1.36	1.68	1.78 ± 0.22	12.4	NS
7. Khaibung	3	1.56	2.00	1.52 ± 0.16	10.5	1,4,5
ANOVA					F=12.40, p<0.001	

Tannins (%)						
1. Bilkhawthlir	3	2.21	2.81	2.51 ± 0.30	12.0	NS
2. Kawnpui	3	1.79	3.03	2.41 ± 0.62	25.7	NS
3. Mawriang	3	1.99	2.11	2.05 ± 0.06	2.9	4,5,7
4. Thingkhangphai	3	2.80	3.00	2.90 ± 0.10	3.4	3
5. Kangpokpi	3	2.81	2.93	2.87 ± 0.06	2.1	3
6. Kezanglwa	3	2.58	2.84	2.71 ± 0.13	4.8	NS
7. Khaibung	3	2.92	3.00	2.96 ± 0.04	1.4	3
ANOVA					F=4.40, p<0.010	
Phenols (%)						
1. Bilkhawthlir	3	0.88	1.70	1.29 ± 0.41	31.8	NS
2. Kawnpui	3	0.96	1.90	1.43 ± 0.47	32.9	NS
3. Mawriang	3	1.19	1.69	1.44 ± 0.25	17.4	NS
4. Thingkhangphai	3	1.29	1.41	1.35 ± 0.06	4.4	NS
5. Kangpokpi	3	0.74	2.06	1.40 ± 0.66	47.1	NS
6. Kezanglwa	3	1.81	1.93	1.87 ± 0.06	3.2	NS
7. Khaibung	3	1.28	1.52	1.40 ± 0.12	8.57	NS
ANOVA					F=0.84, p<0.561	

The seeds accumulated higher phosphorus content (Table 7.1 and 7.2) compared to fruits (0.26 & 0.24%, respectively). Provenances varied significantly (P=0.01) with Bilkhawthlir dominating over other provenances. This study confirms the findings of Longvah and Deosthale (1998) that *P. roxburghii* has more calcium contents than *P. biglobosa* as presented in the work of Oladunmoye (2007) and also higher than that of some selected beans, as evident from the data presented by Messina (1999). Magnesium content in the present study is in agreement with the earlier findings of Longvah and Deosthale 1998. Fruits from Kangpokpi revealed higher contents of both calcium and magnesium whereas, Bilkhawthlir proves better in seeds. Calcium and magnesium contents has significant variation (P=0.01) among provenances with calcium content in seeds as an exception. Provenances studied were found to have varied significantly (P=0.01) in potassium content of both seeds and fruits. The mean potassium content was observed to have diminished with the advancement of fruits (0.212 %) towards the formation of seeds (0.194 %).

Table 7.2. Provenance variation in nutritive traits of kernels of *P. roxburghii*.

Trait / provenance	Sample size (n)	Minimum	Maximum	Mean ± SD	CV (%)	Provenance is different from (Tukey's post-hoc test)
A	B	C	D	E	F	G
Energy (cal. g^{-1})						
1. Bilkhawthlir	3	16.92	17.82	17.41 ± 0.45	2.6	6
2. Kawnpui	3	16.92	17.84	17.24 ± 0.52	3.0	6
3. Mawriang	3	15.36	17.15	16.54 ± 1.02	6.2	5,6
4. Thingkhangphai	3	16.97	17.82	17.42 ± 0.43	2.4	6
5. Kangpokpi	3	17.98	18.71	18.46 ± 0.41	2.2	3
6. Kezanglwa	3	18.96	19.56	19.34 ± 0.33	1.7	1,2,3,4,7
7. Khaibung	3	16.94	17.56	17.14 ± 0.36	2.1	6
ANOVA					F=8.70, p<0.001	
Ash content (%)						
1. Bilkhawthlir	3	5.50	6.02	5.85 ± 0.30	5.1	4
2. Kawnpui	3	3.96	5.47	4.80 ± 0.77	16.0	NS
3. Mawriang	3	4.46	5.94	5.44 ± 0.85	15.6	NS
4. Thingkhangphai	3	3.48	4.50	3.83 ± 0.58	15.2	1,5
5. Kangpokpi	3	5.94	5.97	5.95 ± 0.02	0.3	4
6. Kezanglwa	3	4.95	5.47	5.13 ± 0.29	5.7	NS
7. Khaibung	3	3.90	5.37	4.40 ± 0.84	19.2	NS
ANOVA					F=4.95, p<0.006	
Crude fiber (%)						
1. Bilkhawthlir	3	5.97	5.99	5.98 ± 0.01	0.2	NS
2. Kawnpui	3	5.38	6.08	5.73 ± 0.35	6.1	7
3. Mawriang	3	5.97	5.99	5.98 ± 0.01	0.2	NS
4. Thingkhangphai	3	5.16	6.1	5.63 ± 0.47	8.3	7
5. Kangpokpi	3	5.6	5.72	5.66 ± 0.06	1.1	7
6. Kezanglwa	3	5.97	6.57	6.27 ± 0.30	4.8	NS
7. Khaibung	3	6.34	7.08	6.71 ± 0.37	5.5	2,4,5
ANOVA					F=5.51, p<0.004	

Fat (%)						
1. Bilkhawthlir	3	30.40	34.30	31.97 ± 2.06	6.4	4,5,6,7
2. Kawnpui	3	28.00	29.20	28.53 ± 0.61	2.1	NS
3. Mawriang	3	28.70	31.60	30.17 ± 1.45	4.8	4,5,6,7
4. Thingkhangphai	3	23.80	27.20	25.47 ± 1.70	6.7	1,3
5. Kangpokpi	3	24.90	28.30	26.13 ± 1.88	7.2	1,3
6. Kezanglwa	3	24.90	26.20	25.43 ± 0.68	2.7	1,3
7. Khaibung	3	25.70	26.20	25.90 ± 0.26	1.0	1,3
ANOVA					F=10.40, p<0.001	
Protein (%)						
1. Bilkhawthlir	3	28.30	30.20	29.40 ± 0.98	3.3	4
2. Kawnpui	3	27.80	28.30	28.10 ± 0.26	0.9	NS
3. Mawriang	3	27.20	29.30	28.37 ± 1.07	3.8	NS
4. Thingkhangphai	3	24.90	27.60	26.50 ± 1.42	5.3	1
5. Kangpokpi	3	26.80	29.20	28.33 ± 1.33	4.7	NS
6. Kezanglwa	3	26.90	27.60	27.23 ± 0.35	1.3	NS
7. Khaibung	3	25.90	28.20	27.23 ± 1.19	4.4	NS
ANOVA					F=2.60, p<0.067	
P (%)						
1. Bilkhawthlir	3	0.269	0.273	0.27 ± 0.00	0.7	7
2. Kawnpui	3	0.249	0.258	0.25 ± 0.00	1.8	NS
3. Mawriang	3	0.251	0.268	0.26 ± 0.01	3.3	NS
4. Thingkhangphai	3	0.253	0.281	0.27 ± 0.01	5.4	7
5. Kangpokpi	3	0.259	0.272	0.27 ± 0.01	2.6	7
6. Kezanglwa	3	0.253	0.271	0.26 ± 0.01	3.7	7
7. Khaibung	3	0.238	0.243	0.24 ± 0.00	1.0	1,4,5,6
ANOVA					F=4.90, p<0.007	
K (%)						
1. Bilkhawthlir	3	0.177	0.181	0.18 ± 0.00	1.1	3,4,5,6,7
2. Kawnpui	3	0.180	0.190	0.19 ± 0.01	2.7	3,4,5,6,7
3. Mawriang	3	0.161	0.167	0.16 ± 0.00	1.8	1,2,4,5,6,7
4. Thingkhangphai	3	0.213	0.217	0.22 ± 0.00	0.9	1,2,3,7
5. Kangpokpi	3	0.208	0.209	0.21 ± 0.00	0.3	1,2,3,7
6. Kezanglwa	3	0.208	0.21	0.21 ± 0.00	0.5	1,2,3,7
7. Khaibung	3	0.199	0.202	0.20 ± 0.00	0.7	1,2,3,4,5,6,
ANOVA					F=163.40, p<0.001	

Ca (%)						
1. Bilkhawthlir	3	0.161	0.177	0.17 ± 0.01	5.1	NS
2. Kawnpui	3	0.146	0.179	0.16 ± 0.02	11.7	NS
3. Mawriang	3	0.150	0.162	0.16 ± 0.01	4.1	NS
4. Thingkhangphai	3	0.165	0.193	0.18 ± 0.02	8.7	NS
5. Kangpokpi	3	0.116	0.222	0.18 ± 0.05	31.0	NS
6. Kezanglwa	3	0.119	0.193	0.16 ± 0.04	23.7	NS
7. Khaibung	3	0.130	0.172	0.15 ± 0.02	14.0	NS
ANOVA					F=0.50, p<0.826	
Mg (%)						
1. Bilkhawthlir	3	0.387	0.422	0.41 ± 0.02	4.9	4,6,7
2. Kawnpui	3	0.370	0.381	0.37 ± 0.01	1.6	3,5
3. Mawriang	3	0.395	0.423	0.41 ± 0.02	3.8	2,4,6,7
4. Thingkhangphai	3	0.356	0.362	0.36 ± 0.00	1.0	1,3,5
5. Kangpokpi	3	0.398	0.423	0.41 ± 0.01	3.3	2,4,6,7
6. Kezanglwa	3	0.371	0.379	0.37 ± 0.00	1.2	1,3,5
7. Khaibung	3	0.342	0.373	0.36 ± 0.02	4.6	1,3,5
ANOVA					F=11.30, p<0.001	
Mn (%)						
1. Bilkhawthlir	3	21.70	29.70	25.63 ± 4.00	15.6	3
2. Kawnpui	3	20.60	26.20	22.57 ± 3.15	14.0	NS
3. Mawriang	3	10.90	11.80	11.43 ± 0.47	4.1	1,5,7
4. Thingkhangphai	3	13.90	22.90	27.23 ± 8.47	24.2	NS
5. Kangpokpi	3	17.80	34.20	18.90 ± 4.58	31.1	3
6. Kezanglwa	3	14.70	18.90	23.60 ± 0.89	3.8	NS
7. Khaibung	3	22.60	24.30	16.27 ± 2.29	14.1	3
ANOVA					F=5.30, p<0.005	
Zn (%)						
1. Bilkhawthlir	3	1.60	2.40	1.90 ± 0.44	22.9	NS
2. Kawnpui	3	1.80	2.80	2.17 ± 0.55	25.4	NS
3. Mawriang	3	1.90	2.60	2.23 ± 0.35	15.7	NS
4. Thingkhangphai	3	1.40	2.20	2.23 ± 0.40	22.9	NS
5. Kangpokpi	3	2.00	2.40	1.77 ± 0.21	9.3	NS
6. Kezanglwa	3	1.70	3.60	2.30 ± 0.35	15.1	NS
7. Khaibung	3	2.10	2.70	2.37 ± 1.07	45.2	NS
ANOVA					F=0.50, p<0.805	

Fe (%)						
1. Bilkhawthlir	3	81.10	95.00	88.60 ± 7.01	7.9	2,5
2. Kawnpui	3	17.90	30.00	22.43 ± 6.60	29.4	1,6
3. Mawriang	3	43.90	83.70	58.03 ± 22.27	38.4	NS
4. Thingkhangphai	3	36.70	65.00	44.33 ± 15.19	31.9	NS
5. Kangpokpi	3	23.00	69.00	47.67 ± 23.18	52.3	1
6. Kezanglwa	3	82.70	92.10	54.97 ±18.87	34.3	2
7. Khaibung	3	35.00	72.50	87.17 ± 4.72	5.4	NS
ANOVA					F=6.80, p<0.002	
Cu (%)						
1. Bilkhawthlir	3	24.10	45.70	34.90 ± 10.8	30.9	2,3,4,5,6
2. Kawnpui	3	1.30	2.00	1.73 ± 0.38	21.8	1,7
3. Mawriang	3	10.60	16.80	10.57 ± 6.25	59.1	1,7
4. Thingkhangphai	3	0.80	0.90	3.77 ± 0.06	6.9	1,7
5. Kangpokpi	3	3.00	4.80	0.83 ± 0.93	24.7	1,7
6. Kezanglwa	3	12.30	15.40	30.47 ± 6.85	22.5	1,7
7. Khaibung	3	23.60	37.30	13.60 ± 1.61	11.8	2,3,4,5,6
ANOVA					F=22.50, p<0.001	
S (%)						
1. Bilkhawthlir	3	0.110	0.125	0.12 ± 0.01	7.5	NS
2. Kawnpui	3	0.095	0.120	0.11 ± 0.01	11.8	NS
3. Mawriang	3	0.080	0.115	0.10 ± 0.02	18.0	NS
4. Thingkhangphai	3	0.130	0.140	0.12 ± 0.01	4.2	NS
5. Kangpokpi	3	0.105	0.130	0.14 ± 0.01	11.5	NS
6. Kezanglwa	3	0.095	0.145	0.10 ± 0.01	14.7	NS
7. Khaibung	3	0.090	0.115	0.12 ± 0.03	20.8	NS
ANOVA					F=2.40, p<0.088	
Oxalic acid (%)						
1. Bilkhawthlir	3	1.64	1.74	1.69 ± 0.05	3.0	3,7
2. Kawnpui	3	1.36	1.58	1.47 ± 0.11	7.5	5
3. Mawriang	3	1.20	1.24	1.21 ± 0.02	1.9	1,4,5
4. Thingkhangphai	3	1.73	1.75	1.74 ± 0.01	0.6	3,7
5. Kangpokpi	3	1.75	1.85	1.80 ± 0.05	2.8	2,3,7
6. Kezanglwa	3	1.30	1.74	1.52 ± 0.22	14.5	NS
7. Khaibung	3	1.10	1.42	1.26 ± 0.16	12.7	1,4,5
ANOVA					F=12.20, p<0.001	

Tannins (%)						
1. Bilkhawthlir	3	1.95	2.55	2.25 ± 0.30	13.3	3
2. Kawnpui	3	2.61	2.77	2.69 ± 0.08	3.0	3,4,5
3. Mawriang	3	1.73	1.85	1.79 ± 0.06	3.4	1,2,6,7
4. Thingkhangphai	3	2.01	2.13	2.07 ± 0.06	2.9	2,7
5. Kangpokpi	3	1.99	2.03	2.01 ± 0.02	1.0	2,7
6. Kezanglwa	3	2.04	2.62	2.33 ± 0.29	12.4	3
7. Khaibung	3	2.66	2.74	2.70 ± 0.04	1.5	3,4,5
ANOVA					F=13.00, p<0.001	
Phenols (%)						
1. Bilkhawthlir	3	1.31	1.33	1.32 ± 0.01	0.8	NS
2. Kawnpui	3	1.14	2.06	1.60 ± 0.46	28.8	NS
3. Mawriang	3	0.95	1.27	1.11 ± 0.16	14.4	NS
4. Thingkhangphai	3	1.57	1.87	1.72 ± 0.15	8.7	NS
5. Kangpokpi	3	0.96	1.86	1.41 ± 0.45	31.9	NS
6. Kezanglwa	3	0.76	2.10	1.66 ± 0.06	3.6	NS
7. Khaibung	3	1.60	1.72	1.43 ± 0.67	46.9	NS
ANOVA					F=1.04, p<0.439	

Micronutrients of *P. roxburghii* were analyzed in the study to evaluate the variability of their contents among different provenances of the region. Minerals composition of both fruits and seeds of *Parkia* are presented in table 3. The table revealed that mineral contents differed significantly (P=0.05) among provenances of northeast India. Cobalt was also analyzed but not presentable as the values are meager or absent in the sample taken. All six minerals determined from Kanpokpi provenance are more related to that reported by Longvah and Deosthale (1998). Provenances differed significantly (P=0.05) in all the minerals with zinc and sulphur content in fruits as an exception. Kawnpui provenance registered maximum values for minerals in fruits and of comparable amount against FAO (1985) recommendation.

P. roxburghii like many other plant yielding foods was found to have been affected by some anti-nutritional factors. This study concentrates on phenolic (phytates) compounds, tannins and oxalates (Table 7.1). This study noticed that oxalic acid content in the cotyledons of P. *roxburghii* was slightly higher than that reported by Alabi *et al.* (2005) in *P. biglobosa.* Fruit tissues having more mean oxalates (1.79%) than that of kernel (1.53%) or in other words cotyledon, may have been due to inclusion of cotyledon, pulp and seed testa in the sample. Oxalates, tannins and phenolic compounds differed significantly (P=0.05) between provenances of both fruit and kernel with the least content in Mawriang. Fruit samples of *P. roxburghii* registered lower values of nutritional parameters than those in seeds which may be due to higher accumulations of antinutritional components.

Table 7.3. Differences in nutritive traits of tender fruits and kernels of *P. roxburghii* based pooled data from all provenances

Traits	Tender fruits	Kernels	F	*p* value
Energy	31.65 ± 8.42	29.11 ± 9.63	6.88	0.009
Ash (%)	34.79 ± 8.07	38.51 ± 9.19	16.17	0.001
Crude fiber (%)	3.05 ± 0.69	3.28 ± 0.39	13.96	0.001
Fat (%)	9.33 ± 2.78	10.84 ± 3.42	20.53	0.001
Protein (%)	14.59 ± 2.67	14.79 ± 2.92	0.45	0.504
P (%)	1.89 ± 1.67	1.48 ± 1.83	4.81	0.028
K (%)	16.48 ± 2.73	16.27 ± 2.96	0.48	0.487
Ca (%)	0.77 ± 0.28	0.62 ± 0.24	400.78	0.001
Mg (%)	1.75 ± 0.23	1.58 ± 0.23	662.10	0.001
Mn (%)	1.25 ± 0.15	1.54 ± 0.40	1088.00	0.001
Zn (%)	1.89 ± 1.67	1.48 ± 1.83	4.81	0.028
Fe (%)	16.48 ± 2.73	16.27 ± 2.96	0.48	0.487
Cu (%)	0.77 ± 0.28	0.62 ± 0.24	400.78	0.001
S (%)	1.75 ± 0.23	1.58 ± 0.23	662.10	0.001
Oxalic acid (%)	1.25 ± 0.15	1.54 ± 0.40	1088.00	0.001
Tannins (%)	0.62 ± 0.14	0.54 ± 0.14	341.08	0.001
Phenols (%)	1.39 ± 0.50	1.39 ± 0.67	0.01	0.956

The coefficient of variation of data collected suggests low deviation of mean values in almost all parameters except for iron in the seed data. Among all nutrients, Tukey's post hoc test revealed provenances to have significantly (p=0.05) differed from each other with an exception in fat contents in fruit (Table 7.1), and protein content, calcium, zinc and sulphur availability in seeds (Table 7.2). However, phenolics content in both the edible parts did not show any significant relationships across provenances. The analysis of variance (ANOVA) between fruit and seed revealed significant (p=0.05) difference from each other except for protein, potassium and iron among nutrients, and phenolics among antinutrients (Table 7.3). The mean value of studied components is comparatively higher in fruits from that of the seeds.

Table 7.4. Best provenances of *P. roxburghii* based on traits of tender fruits and kernels.

Nutrition parameter	Tender fruits	Kernels
1. Energy	Kangpokpi	Kangpokpi
2. Ash	Bilkhawthlir	Bilkhawthlir
3. Crude fiber	Kezanglwa	Kezanglwa
4. Fat	Bilkhawthlir	Bilkhawthlir
5. Protein	Bilkhawthlir	Bilkhawthlir
6. P	Bilkhawthlir	Bilkhawthlir
7. Ca	Bilkhawthlir	Bilkhawthlir
8. Mg	Bilkhawthlir	Bilkhawthlir
9. K	Thingkhangphai	Thingkhangphai
10. Mn	Bilkhawthlir	Bilkhawthlir
11. Zn	Bilkhawthlir	Bilkhawthlir
12. Fe	Kawnpui	Bilkhawthlir
13. Cu	Kezanglwa	Bilkhawthlir
14. S	Kawnpui	Bilkhawthlir
15. Oxalic acid	Mawriang	Mawriang
16. Tannins	Mawriang	Mawriang
17. Phenols	Mawriang	Mawriang

7.4. Discussion

Beans are the excellent source of dietary fiber that lowers serum cholesterol in hypercholestrolemic individuals and controls diabetic risks (Anderson *et al* 1984, Messina 1999). Immature fruit (9.57%) of *P. roxburghii* recorded a higher mean fiber percent to that of the seeds (5.99%), which may be attributed to high content of non-degradable fibers (Messina 1999) as well as reduction in carbohydrate content (Esenwah and Ikenebomeh 2008) approaching its maturity. High ash residue may have been due to high fiber content resulting from the tough texture and presence of high waxy substances, especially in seed (Alabi *et al* 2005). The study revealed that mean fat content in kernels was 28.52 % higher than that of the fruits which is in confirmatory with the findings of Longvah and Deosthale 1998. However, the fat content in seeds was recorded 5.84% less than the findings of Longvah and Deosthale (1998) in *P. roxburghii* and 6.7% more than that reported by Oladunmoye (2007) in *P. biglobosa.* Screening and extraction of edible oils from *Parkia* may be as important (Longvah and Deosthale 1998) as many other vegetable oils that will increase the energy density and act as a transport vehicle for fat soluble vitamins if included in foods meant for infants and children (Mariam 2005). Seeds of *P. roxburghii* from Bilkhawthlir, Mawriang and Kawnpui may be collected for edible oil production in northeastern India. Higher protein content in seeds than that of the fruits may however been affected by lower non-degradable fiber contents (Messina 1999 and Oladunmoye 2007) supplemented by reduction of carbohydrates (Esenwah and Ikenebomeh 2008 and Oladunmoye 2007). Nonetheless, maturity advancement of the fruits that led to higher accumulation of protein and fat contents (Longvah and Deosthale 1998) may have continued till the seeds are fully ripened. Messina (1999) reported that proteins from beans improve the calcium retention that subsequently reduces the urinary calcium excretion and also improves bone health in human. A decreasing trend of mean calcium content in *P. roxburghii* was recorded with maturity ranging between 0.169 in fruits to 0.165 percent in seeds. The depletion will however be compensated in the diet with beans having more or less than 20 per cent calcium bioavailability (Messina 1999).

Among micronutrient of *P. roxburghii*, all six minerals determined from Kangpokpi provenance are more related to that reported by Longvah and Deosthale (1998) because both Kangpokpi and Imphal belongs to the same state, Manipur. Moreover, Kangpokpi variety of *P. roxburghii* is among those highly demanded in the local markets of the state. However, mineral contents in seeds of Khaibung provenance may be compared with similar constituent of other beans (Messina 1999, Oladunmoye 2007, Longvah and Deosthale 1998). The result from the study is convincing that *P. roxburghii* can somehow contribute towards eliminating micronutrients malnutrition in the region.

Higher percentage of tannins is recorded in fruit (2.63) than in seed (2.26); affecting the level of iron and protein content accordingly (Gopalan *et al.* 1998). Tannins and phenolic compounds can be eliminated from pulses by decortications, soaking, cooking and simultaneous process of soaking and cooking before consumption (Pugalenthi *et al.* 2004). However, the phenolic percent may have inhibited the activity of digestive enzymes (Pugalenthi *et al.* 2004), formed insoluble complexes with iron (in the presence of calcium and magnesium) leading to a decrease in iron availability (Gopalan *et al.* 1998) and reduced the digestibility of proteins and carbohydrates (Pugalenthi *et al.* 2004). This study provides an ample scope of screening some genotypes from the selected high nutrient provenances for further mass production and introduction into the *jhum* affected areas, road plantation, agroforestry systems and also degraded forest areas of the region. Targeting the food security in the region, *Parkia roxburghii* from Bilkhawthlir may be an important source of planting material accumulating maximum important nutrients both in fruit and seeds (Table 7.4). However, fruits and seeds from Mawriang may prove beneficial to the health of consumers due to low accumulations of antinutrients both in seed and fruit.

GENERAL DISCUSSION

Research on forest management, the role of trees and other forest products on food security, and rural household development welfare in general can help to identify ways for allowing local people to grow more trees, thus bringing about economic, environmental, and social benefits. These benefits can come, apart from marketable products, also from environmental protection provided by the trees and increased biodiversity. The important element is the involvement of the local people in growing trees for their own use on sustainable basis (Willan 1985). This involves local knowledge and local resources, including the physical resources as well as institutions to organise the means of production and to distribute any increased production fairly. The second common element is technological innovation to generate and sustain increase in land productivity. Germination and seedling establishment of tree species are expected to be rapid under optimum conditions when seeds are physiologically ready. However, the co-incidence of germinable seeds and optimum conditions in the field is unpredictable and random that may affect the seedling recruitment. Regardless, the variability of weather and biological systems make optimum field conditions hard to predict and unlikely to be arranged.

The phytosociological analysis of seven habitats in the four states of northeastern region of India revealed that: 1) *P. roxburghii* is widely distributed in northeastern region of India, (2) *P. roxburghii* inhabits ecosystems varying from plantations through *jhum* fallows to natural habitats, (3) *P. roxburghii* is not a dominant species at any of the sites, (4) *P. roxburghii* is randomly dispersed, (5) *P. roxburghii* reveals an association with *Schima wallichi* and (6) the natural regeneration of *P. roxburghii* is very poor.

The provenances showed variation in floristic composition, species richness and diversity. Kangpokpi by *Quercus serrata* and Khaibung by *Schima wallichi* were the only provenance dominated by the naturally occurring species. All other provenances were dominated by the planted species. A total of 1,510 individuals of >10 cm gbh were recorded during the study which belong to 117 species, 75 genera and 44 identified families. Mawriang recorded maximum numbers of species (38 species), despite the fact that this site is dominated by a planted species, *Areca catechu* and the least number of species were recorded from Thingkhangphai where *Pinus kesiya* is dominant.

The pooled data from all seven provenances projected *Schima wallichii* the most dominant species and occurred in all provenances with a random dispersion. In these provenances, more than one-half of the species richness was contributed by the rare species with an IVI <1. This is a general trend in most tropical forest in India where the species richness is mostly due to the rare species, as observed in native *sal* forests (Uma Shankar 2001, Uma Shankar *et al.* 1998, Pandey and Shukla 1999, Pandey 1999, Kushwaha, Nandy 2012), dry-deciduous forests (Sukumar *et al.* 1992, Murali *et al.* 1996, Sagar *et al.* 2003), moist-deciduous forests (Sundarapandian and Swami 2000), evergreen forests (Nath *et al.* 2005, Deb and Sundriyal 2011, Ayyappan and Parthasarthy 2004, Parthasarathy and Karthikeyen 1997) montane forests (Sundriyal *et al.* 1994, Rikhari *et al.* 1997) and scrub forests (Uma Shankar *et al.* 1998).

The provenance Khaibung was characterized by the most natural vegetation and high value of species richness, Shannon diversity index and evenness index, and was dominated by *Schima wallichii.* The study found that only three species viz. *P. roxburghii*, *Schima wallichii* and *Phyllanthus emblica* were characterized by the random dispersion pattern. *P. roxburghii* and *Schima wallichii* showed a high value of index of association (0.5) and a Chi square test confirmed that these two species are associated with each other and do not occur independently in studied plots. The phytosociological attributes of *P. roxburghii* and *Schima wallichii* showed a significant correlation. Evidently, *P. roxburghii* is not a dominant element in any of the communities, which is in conformity with other studies from *P. roxburghii* habitats (Don and Singh 1986, Hopkins 1994, Rocky and Sahoo 2002, Amzu *et al.* 2007).

The population structure of *P. roxburghii* clearly revealed paucity of newly requiring individuals in smaller girth classes. The poor regeneration of *P. roxburghii* is presumably because of the harvest of tender as well as mature fruits for consumption as vegetable by the local people. The poor regeneration of a tree species may also be due to failure of seed set, prolonged dormancy, pest attack, poor viability of seeds and germination failure.

The genus *Parkia* has been reported to have variations in fruit width and length among provenances and sometimes such variations are also observed among trees (Olorunmaiye *et al.* 2011). The relationships fruit weight with other parameters is strong in both the years of study. We observed different colour, smoothness of the coat and variation in weight, length, width, thickness and volume in fruit and seeds across provenances which is in tune with other African species (Hopkins 1983 and 1994, Olorunmaiye *et al.* 2011). This study contradicts the recommendation by Uma Shankar (2006) of choosing seed weight as an indicator for better success in germination and seedlings establishment of Hollong (*Dipterocarpus macrocarpus*).

High seeding rates is consistent with *Parkia* ecology. As with this species good management requires an understanding of specific seedbed ecologies and innovation in adapting methods of seed distribution and fixation that will complement diaspore functions most critical to seed success. Success with *Parkia roxburghii* depends on good seed vigor, and rapid seedling development. These characteristics are influenced by harvesting, processing, storing, and sowing. In this manuscript we discuss research findings related to those activities and it appears that *Parkia roxburghii* growing in the Kangpokpi provenance of Manipur might hold viable seed longer, and might have greater seed dormancy than do other habitat types. *Parkia* seeds in storage often show unexpected and seemingly random viability losses. We need research to define the interactions of seed physiology and storage conditions and to predict seed shelf-life. Heavy and larger seeds do not guarantee the species to germinate better. Lower seeding rates reduce stand density but heavier rates do not give a corresponding density increase. High seeding rates are consistent with *Parkia roxburghii* ecology across its distribution but with comparatively low germination capacity. The species is expected to follow a self-suicide trend right from less indehiscent fruits developed from numerous fertile flowers to producing huge viable but non-germinating seeds.

Several factors are responsible for low regeneration *Parkia roxburghii* in the wild. Firstly, *Parkia roxburghii* fruit is indehiscent and seeds may have to rely on other mechanisms such as decay or predation to germinate in natural condition. Moreover, the seed may not escape from predation when its size may not be determined from the fruit cover (Uma Shankar 2006). The detached fruit are often seen entangled on the lower branches till it naturally rots. The species develops few fruits from a capitulum and that are not necessarily to germinate.

The study did not observe strong correlation among seeds germinated and that developed to seedlings to seed dimensions. *P. roxburghii* did not showed fuzzy trend of germination and not as assumed that seeds having large diameter and heavier weight will assure high germination (Khan and Uma Shankar 2001, Uma Shankar 2006). Therefore, the seeds that will be successful in germination may not be predicted easily in the case of *P.roxburghii*. Germination is epigeous and starts as early as on the second day of sowing and ceased at day-22 across provenances. Seedling characteristics varied among provenances in growth characteristics with no signs of seed dimension affecting the growth of the seedling. The study cannot conclude whether heavier, larger and thicker seeds will assure healthier seedlings. Hence, *P. roxburghii* may not be an easy species to judge on its success of sorting seeds for future multiplication. The danger of overexploitation and depleting a resource is high and improving material wealth alone cannot ensure the survival of *Parkia roxburghii*. An integrated system of reducing demands on depleting resources and improving beneficial farming practices will be the solution for preserving *Parkia roxburghii*.

The study of nutritive value of fruit and seeds of *P. roxburghii* revealed confirmatory findings with that of Longvah and Deosthale 1998. Higher fiber percent in immature fruit of *P. roxburghii* to that of the seeds may be attributed to high content of non-degradable fibers (Messina 1999) as well as reduction in carbohydrate content (Esenwah and Ikenebomeh 2008) approaching its maturity also resulting to high ash residue, especially in seed. The fat content in seeds was 5.84% less than the findings of Longvah and Deosthale (1998) in *P. roxburghii* and 6.7% more than that reported by Oladunmoye (2007) in *P. biglobosa*. *P. roxburghii* can be screened for extraction of edible oils (Longvah and Deosthale 1998) that will increase the energy density and act as a transport vehicle for fat soluble vitamins (Mariam 2005). Higher protein content in seeds than that of the fruits may however been affected by lower non-degradable fiber contents (Messina 1999 and Oladunmoye 2007) supplemented by reduction of carbohydrates (Esenwah and Ikenebomeh 2008, Oladunmoye 2007). Nonetheless, maturity advancement of the fruits that led to higher accumulation of protein and fat contents (Longvah and Deosthale 1998) may have continued till the seeds are fully ripened. A decreasing trend of mean calcium content in *P. roxburghii* was recorded with maturity ranging between 0.169 in fruits to 0.165 percent in seeds. The depletion will however be compensated in the diet with beans having more or less than 20 per cent calcium bioavailability (Messina 1999).

Among micronutrient of *P. roxburghii*, all six minerals determined from Kangpokpi provenance are more related to that reported by Longvah and Deosthale (1998) because both Kangpokpi and Imphal belongs to the same state, Manipur. Moreover, Kangpokpi variety of *P. roxburghii* is among those highly demanded in the local markets of the state. However, mineral contents in seeds of Khaibung provenance may be compared with similar constituent of other beans (Messina 1999, Oladunmoye 2007, Longvah and Deosthale 1998). *P. roxburghii* can be a substitute towards eliminating micronutrients malnutrition in the region.

SUMMARY

The northeastern region is regarded as the primary and secondary source of origin of *Parkia roxburghii* (Singh *et al.* 2000b). *P. Roxburghii* is the most widespread species of *Parkia* in the Indo-Pacific region, and the only one to occur on both sides of Wallace's line (Thangjam *et al.* 2003b, Hopkins 1994). In India, it is distributed in Arunachal Pradesh, Cachar hills of Assam, Garo and Khasi Hills of Meghalaya, Lushai Hills, Kolasib – Bukpui and Sialsuk road in Upper Thenzawl area of Mizoram and Imphal, Kangpokpi and Pachao of Manipur (Hajra *et al.* 1996, Singh *et al.* 2000b). The species is also reported from Chittagong and Sylhet of Bangladesh, Myanmar and Malay Peninsula (Hooker 1973). A tree legume, *Parkia roxburghii* G. Don. (Syn. *Parkia timoriana* (DC.) Merr.), is a popular non-conventional source of nutritional, medicinal and recreational values. The genus *Parkia* has 31 species distributed through the rainforests of the Amazon Basin, Africa & Madagascar and Indo-Pacific region (Luckow and Hopkins 1995). Ten species occur in the Indo-Pacific region (Luckow and Hopkins 1995) and four of these are indigenous to India, viz., *Parkia roxburghii* G. Don., *P. biglandulosa* W. & A., *P. leiophylla* Kurz. and *P. insignis* Kurz. (Don and Singh 1986). The pod is edible and available from November till April and is a potential source of protein and fat (Longvah and Dosthale 1998). It is consumed in all developmental stages starting from the green tender pods to mature seeds.

P. roxburghii shows a wide range of variation in phenotypic traits among provenances. Although morphological characters and agronomic traits have been used traditionally to characterise levels and patterns of diversity, these traits alone represent only a small portion of the plant genome and are also influenced by environmental factors, thereby limiting their utility in describing the potentially complex genetic structures which may exist within and between taxa (Avise, 1976). The knowledge of the origin of genetic variation within and between plant populations is also important for the effective utilisation and conservation of species (Thangjam *et al.* 2003a, Hamrick, 1987). The observations show that *Parkia roxburghii* trees are dwindling in wild as well as in homegardens due to harvest of fruits and seeds and due to loss of habitats. Besides seeds being lost to rodents and primates in the wild, Almond moth (*Cadra cautella*) also causes serious damage to the pod as well as seeds (Thangjam *et al.* 2003a). The information on the provenance variation and regeneration ecology of *P. roxburghii* is lacking. Hence, the present study is has been undertaken with the following objectives:

- to assess population structure of *Parkia roxburgii* in different provenances in northeastern India, and
- to study provenance variability in fruit and seed traits, seed germination and seedling growth.

In the present study, we encountered *P. roxburghii* in the wild along tropical semi-evergreen and subtropical broadleaved hill forests of the northeastern India where *Schima wallichii, Areca catechu, Tectona grandis, Artocarpus macrophylla, Pinus kesiya, Duabanga grandiflora, Gmelina arborea, Quercus serrata* occur. The present study was carried out in four States of northeastern region of India, viz., Manipur, Meghalaya, Mizoram and Nagaland (Fig. 3.3). A reconnaissance survey for exploration of natural populations of *P. roxburghii* was carried out in September, 2004. The 23 surveyed populations of *P. roxburghii* belonged to modified communities and only few trees were found growing in the wild with signs of poor or no regeneration (Table 3.2). The most occurrences were in homegardens and *jhum* fallows.

Of these, seven provenances (populations) were selected that contained higher concentration of *P. roxburghii* individuals. The selection of site was also due to the presence of healthy trees, accessibility of trees to climb on, and accessibility of the sites in all weather conditions round-the-year and known history of the sites. The study sites or provenances was made after comparing their distance apart with not less than 10 km and their variation in altitudes of a minimum 100 m within a State.

The phytosociological analysis was done following standard methods (Mueller-Dombois *et al.* 1974, Greigh-Smith 1983, Uma Shankar 2001) and frequency, density, dominance and importance value index of all species were determined. Whitford's index (abundance-to-frequency ratio) was used as a measure of dispersion (Whitford 1949). The dispersion is considered regular for A/F ratio <0.025, random for 0.025 to 0.05 and contagious (clumped) for >0.05 (Singh *et al.* 2006). Species richness index was estimated following Whittaker (1972). Shannon's diversity index (H'), Simpson's dominance index (λ) and Pielou's evenness index (Pielou 1966) were calculated following Magurran (1988). The similarity between two sites was calculated following Sorensen's similarity index (Sorensen 1948). The 2 x 2 contingency table was prepared to calculate index of association between two species, phi-coefficient of association and Pearson's chi-sqaure test of association (Sokal and Sneath 1963).

The data on fruit characteristics were averaged for 25 fruits in each provenance. The variability of mean values is presented in terms of standard deviation and coefficient of variation. Similarly, the seed characteristics were worked out across the number of seeds recovered from 25 fruits in each provenance. The interrelationships between fruit and seed characteristics were analysed by using linear regression model. Seed viability test was performed for hundred healthy seeds from each provenance after removing the seed coat. The seeds were immersed in 1% solution of 2, 3, 5-triphenyl tetrazolium chloride

(TTC) for 9 h at 35 °C (Moore 1985). For germination the seeds were sown in root trainers containing a 1:1 mixture of loam and sand and were placed in a mist chamber at 25°C temperature and 80-90% relative humidity. Germination was examined daily until no further germination occurred. Seed germination characteristics and leaf emergence time were observed following standard methods (ISTA 1976, Jayashankar *et al.* 1999, Uma Shankar 2006, 2012, Uma Shankar and Synrem 2012). Seeds were considered germinated when radicle emerged from the seed coat. The time between germination and expansion of first pair of leaves was recorded as 'leaf emergence time'. The seeds that failed to germinate were retrieved from the root trainers to confirm death. One month old seedlings were regularly transferred from a root trainer to a polythene bag in the open nursery to allow greater space for spreading roots. Shoot height, collar diameter, leaf number and leaf fall of seedlings was measured at regular intervals (Jayashankar *et al.* 1999, Khan *et al.* 1999, Uma Shankar 2006, 2012). The data were analyzed statistically for mean, standard deviation and coefficient of variation. One-way analysis of variance was used to test the differences between group means. Pair-wise comparisons were made using Tukey's post-hoc test.

The phytosociological analysis of seven habitats in the four states of northeastern region of India revealed that: 1) *P. roxburghii* is widely distributed in northeastern region of India, (2) *P. roxburghii* inhabits ecosystems varying from plantations through *jhum* fallows to natural habitats, (3) *P. roxburghii* is not a dominant species at any of the sites, (4) *P. roxburghii* is randomly dispersed, (5) *P. roxburghii* reveals an association with *Schima wallichi* and (6) the natural regeneration of *P. roxburghii* is very poor.

The provenances showed variation in floristic composition, species richness and diversity. Only two provenances were dominated by the naturally occurring species, i.e., Kangpokpi by *Quercus serrata* and Khaibung by *Schima wallichi*. All other provenances were dominated by the planted species. From all seven provenances, 1,510 individuals of

>10 cm gbh were recorded which belong to 117 species, 75 genera and 44 identified families. The maximum numbers of species (38 species) were recorded from Mawriang provenance in Meghalaya, despite the fact that this site is dominated by a planted species, *Areca catechu*. The least number of species were recorded from Thingkhangphai provenance in Manipur where *Pinus kesiya* is the most dominant species.

In all seven provenances, the most dominant species was characterized by a high value of IVI. When the data from all seven provenances were pooled, the IVI of the most dominant species, *Schima wallichii*, declined below 30 (Table 4.8). In all, only seven species showed IVI >10. Among these species *Schima wallichii* occurred in all provenances and showed a random dispersion. In these provenances, more than one-half of the species richness was contributed by the rare species with an IVI <1. This is a general trend in most tropical forest in India where the species richness is mostly due to the rare species, as observed in native *sal* forests (Uma Shankar 2001, Uma Shankar *et al.* 1998, Pandey and Shukla 1999, Pandey 1999, Kushwaha and Nandy 2012), dry-deciduous forests (Sukumar *et al.* 1992, Murali *et al.* 1996, Sagar *et al.* 2003), moist-deciduous forests (Sundarapandian and Swami 2000), evergreen forests (Nath *et al.* 2005, Deb and Sundriyal 2011, Ayyappan and Parthasarthy 2004, Parthasarathy and Karthikeyen 1997) montane forests (Sundriyal *et al.* 1994, Rikhari *et al.* 1997) and scrub forests (Uma Shankar *et al.* 1998).

The provenance Khaibung was characterized by the most natural vegetation and high value of species richness, Shannon diversity index and evenness index, and was dominated by *Schima wallichii*. Only three species were characterized by the random dispersion pattern. These are *P. roxburghii*, *Schima wallichii* and *Phyllanthus emblica*. *P. roxburghii* and *Schima wallichii* showed a high value of index of association (0.5) and a Chi square test confirmed that these two species are associated with each other and do not occur independently in studied plots. The phytosociological attributes of *P. roxburghii* and *Schima wallichii* showed a significant correlation.

Evidently, *P. roxburghii* is not a dominant element in any of the communities, which is in conformity with other studies from *P. roxburghii* habitats (Don and Singh 1986, Hopkins 1994, Rocky and Sahoo 2002, Amzu *et al.* 2007). The density of *P. roxburghii* was between 6 and 18 individuals per hectares. The low dominance of *P. roxburghii* in the present studies indicates is because of the poor regeneration. The population structure of *P. roxburghii* clearly reveled paucity of newly requiring individuals in smaller girth classes. Similarly there was a paucity of individuals of *P. roxburghii* in smaller height classes. In fact, not even a single individual of *P. roxburghii* was recorded in the ground layer in any the seven provenances. The poor regeneration of *P. roxburghii* is presumably because of the harvest of tender as well as mature fruits for consumption as vegetable by the local people.

During the study, we observed that neither the entirely capitula nor the self-pollinated capitula containing 3000 to 4000 flowers of *Parkia roxburghii* set fruit. Thus, variation in fruit and seedling characteristics is more prominent compared to other plant species. The genus *Parkia* has been reported to have variations in fruit width and length among provenances and sometimes such variations are also observed among trees (Olorunmaiye *et al.* 2011).

As expected, the relationships among fruit parameters of *Parkia* from all provenances showed positive linearly significant trends with stronger relationships between fruit weight and other parameters in both the years of study.

The seeds across the genus *Parkia* have been observed to display different colour, smoothness of the coat and variation in weight, length, width, thickness and volume among provenances (Hopkins 1983 and 1994, Olorunmaiye *et al.* 2011). This investigation revealed similar results suggesting an inbreeding effect across its distribution. As assumed, the weight of germinated seed was affected by its length, width, thickness and volume. The study revealed a strong relationship between seed weight in (y-axis) to other seed parameters in x-axis (width and volume). The scatter plot of both the germinated and ungerminated seeds revealed a more visible distinct population in the year 2006 suggesting the effect of seed parameters especially the seed weight as an indicator on the germination behaviour of seeds. Uma Shankar (2006) recommended seed weight as an indicator of choosing a seed for better success in germination and seedlings establishment of Hollong (*Dipterocarpus macrocarpus*). However, the vague picture of the subsequent year (2007) contradicts the decision on predicting germination on the basis of seed weight only in the case of *P. roxburghii*. The distribution of populations appeared fussy with many seeds both germinated and ungerminated overlapping across the middle section.

Provenances varied significantly in most traits of fruit and seed. A single best provenance based on morphometric traits of fruits and seed was Kongpokpi in 2006 and Kawnpui in 2007.

The fruit is indehiscent with seeds embedded in a thick hard coat bounded by strong sutures. Seeds may have to remain in the fruit long after it is ripened and rely on other mechanisms such as decay or predation to release the contents. Moreover, the seed may not escape from predation when its size may not be determined from the fruit cover (Uma Shankar 2006). This character of the fruit may have been the factor of low regeneration in the wild. Detaching from the branch the chime-like pendent fruits are also seen entangled on the lower branches till they naturally rots. How viable the seed must be, the species will face natural stress of regenerating itself when very few fruits are developing from a capitulum that are further withheld by the stout indehiscent fruit cover. Luckow and Hopkins (1995) termed *P. roxburghii* as the most complex species across the genus that produce only 9 to 17 fruits from thousands of its fertile flowers in a capitulum. This study also observed another contrasting feature in context to germination when only 35 percent of seeds germinated in spite of producing huge lump of seeds per fruit. Provenances differed significantly among themselves but are not remarkable to convince any environment or genetic influence. The present study wondered if the species follow a self-suicide trend when a few portion of fruits are developed from numerous fertile flowers, also embedding its seeds within an indehiscent fruit, but producing huge non-germinating viable seeds. Literature search yielded scarce information to explain the question hence needs further investigation.

It is assumed that seeds having large diameter and heavier weight will assure high germination (Khan and Uma Shankar 2001, Uma Shankar 2006). The study also followed the same trend. Interestingly, all seeds from 2006 collection are larger, heavier and thicker as compared to those collected during 2007. However, fuzzy distribution of the seeds germinated and those failed across dimensions will not guarantee a definite success when heavier, larger and thicker seeds are considered for sowing. The seeds of *P.roxburghii* that will be successful in germination may not be predicted easily. The study observed mild differences in seed dimension affecting the growth of the seedling across provenances. Hence, the study cannot conclude whether heavier, larger and thicker seeds will assure healthier seedlings. The seed that would germinate and finally developed in to a healthy seedling is influenced by provenance and not merely of the fruit and seed dimensions.

The study revealed confirmatory results with the findings of Longvah and Deosthale 1998. However, the fat content in seeds was recorded 5.84% less than the findings of Longvah and Deosthale (1998) in *P. roxburghii* and 6.7% more than that reported by

Oladunmoye (2007) in *P. biglobosa.* Immature fruit of *P. roxburghii* recorded a higher mean fiber percent to that of the seeds, depicting to high content of non-degradable fibers (Messina 1999) as well as reduction in carbohydrate content (Esenwah and Ikenebomeh 2008) approaching its maturity. Screening and extraction of edible oils from *Parkia* may be as important (Longvah and Deosthale 1998) as many other vegetable oils that will increase the energy density and act as a transport vehicle for fat soluble vitamins if included in foods meant for infants and children (Mariam 2005). Seeds of *P. roxburghii* from Bilkhawthlir, Mawriang and Kawnpui may be collected for edible oil production in northeastern India. Nonetheless, maturity advancement of the fruits that led to higher accumulation of protein and fat contents (Longvah and Deosthale 1998) may have continued till the seeds are fully ripened.

Among micronutrient of *P. roxburghii,* all six minerals determined from Kangpokpi provenance are more related to that reported by Longvah and Deosthale (1998) because both Kangpokpi and Imphal belongs to the same state, Manipur. However, mineral contents in seeds of Khaibung provenance may be compared with similar constituent of other beans (Messina 1999, Oladunmoye 2007, Longvah and Deosthale 1998).

This study provides an ample scope of screening some genotypes from the selected high nutrient provenances for further mass production and introduction into the *jhum* affected areas, road plantation, agroforestry systems and also degraded forest areas of the region. Targeting the food security in the region, *Parkia roxburghii* from Bilkhawthlir may be an important source of planting material accumulating maximum important nutrients both in fruit and seeds. However, fruits and seeds from Mawriang may prove beneficial to the health of consumers due to low accumulations of antinutrients both in seed and fruit.

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