

# STUDIES ON THE ECOLOGICAL AND CULTIVATIONAL ASPECTS OF SOLASODINE YIELDING SOLANUMS OF MEGHALAYA

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DEPARTMENT OF BOTANY  
SCHOOL OF LIFE SCIENCES

*SUBMITTED IN FULFILMENT OF THE  
REQUIREMENT OF THE DEGREE OF  
DOCTOR OF PHILOSOPHY*

To



**NORTH - EASTERN HILL UNIVERSITY**  
SHILLONG 793001 (INDIA)

**JULY - 1981**

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Doc. No. 1020557  
Doc. By  
Date  
Title  
Pub. No.  
Class.  
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J. H. S. G. 18/90

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P R E F A C E

The present study is an attempt to understand the biological equipment of an important solasodine yielding plant of north-east India, namely Solanum khasianum. This study also involves preliminary observations on the introduction of two exotic species of Solanum, namely S. aviculare and S. laciniatum.

The thesis starts with a general introduction which also has a review of literature on aspects of weed biology. The thesis has three chapters on S. khasianum dealing with population studies, germination studies and nutritional studies taking into consideration the different natural populations collected from diverse habitats in Meghalaya. The next two chapters pertain to the introduction of S. laciniatum and S. aviculare followed by their nutritional response. All these chapters have been written in a manner suitable for publication, as such some repetitions in presentation could not be avoided. The thesis has at the end a section on literature cited. It is hoped that this study would form the basis for more extensive and intensive studies on S. khasianum in the north-eastern region.

ACKNOWLEDGEMENT

I express my deep sense of gratitude to Professor P.S. Ramakrishnan, Ph.D., F.N.A., F.A.Sc., F.N.A.Sc., Professor of Botany, North-Eastern Hill University, Shillong, for the constant encouragement and dynamic guidance given during the course of the research tenure.

I am grateful to Mr. P.S. Ingty, Director, and other officials of the Soil Conservation Department of Meghalaya, for providing necessary facilities at the Conservation Training Institute, Burnihat. I am also thankful to Mr. S. Roy Chowdhury, the then Silviculturist of the Forest Department of Meghalaya for providing necessary facilities at Umsaw forest nursery. My grati- tudes are also due to Mr. Ashesh Kumar Das, Mr. S. Ravin- dran and other colleagues in the Department, for their help and suggestions during the course of this investiga- tion. My thanks are also due to Mr. Bijoy Das and Mr. Salil Choudhury for photography and drawings respectively.

I owe my deep sense of gratitude to my parents whose constant encouragement and inspiring counsels have helped me in cultivating a deeper sense of interest in the work.

I gratefully acknowledge the financial aid obtained from the C.S.I.R. sponsored research project on "Survey of

medicinal flora of Meghalaya with special emphasis on morphological, ecological and cultivational aspects of solasodine yielding Solanums.

Finally I wish to place on record my gratitude to Mr. Godfrey Pathaw for typing the manuscript with sincere effort.

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CHAPTER I

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## GENERAL INTRODUCTION

The biological equipment of natural populations are related to the germinability of the seeds, seedling establishment and subsequent growth behaviour. The range of distribution over varied environmental situations is also determined by plasticity and possible differences of ecological races at the subspecific level (Bradshaw, 1965; Ramakrishnan, 1971, 1972).

### Population differentiation:

The study of natural populations has gained considerable importance in recent years and the natural populations are being recognized as the fundamental units of species (Turesson, 1922, 1925; Clausen et al., 1940, 1948; McMillan, 1960; Cline and Agatep, 1970; Mott et al., 1975). Species of great ecological amplitude occupy a wide range of environmental situations due to the existence of distinct populations suited to each situation. With the development of a great deal of interest regarding the adaptability of the individuals two distinct view points have emerged (i) that the population is a stable unit, evolved to suit distinct environmental situations, the ecotypes, and (ii) that the individual genotypes assume different characteristics showing both morphological and/or physiological manifestations. These unstable

forms which are due to the plasticity of the same genotypes are variously termed as 'ecads' or 'ecophenes' (Ramakrishnan, 1973). The significance of phenotypic plasticity has been demonstrated by Bradshaw (1965). Turesson (1922) defined ecotypes as the genotypic response of a population to differential factors in the environment.

Turesson (1922) was the first to demonstrate the existence of a large number of climatic races in a number of European plant species based on geographical location or on altitude. Later, extensive studies carried out by Clausen et al. (1940, 1948) have demonstrated the existence of a large number of climatic races in various species along a transect from sea level upto timber line in California. They found that those ecotypes differed with respect to various physiological characters such as pattern of flowering and fruiting, seed and bud dormancy, resistance to cold, etc. Gregor (1930, 1946) working with Plantago maritima came to the conclusion that while certain ecotypes may be characterized by variational discontinuity, often this variation is continuous along an ecological gradient to denote which he coined the term 'ecocline'. Cooper and McWilliam (1966) observed temperature induced differences between Mediterranean populations of Phalaris tuberosa with regard to floral induction, leaf expansion, seed germination, etc. Sheila and Hunter (1962), working with altitudinal populations of Calluna vulgaris reported that variation in growth habit and growth forms

change with change in altitudes. They have also noted that maturity type is related to the length of the growing season at the site of origin of the population. Populations originating from the areas having shorter growing seasons are composed of individuals of an earlier maturity type than from those areas where growing season is longer. David (1976) while studying the temperature response of succinate dehydrogenase reported minimum temperature coefficients at temperatures approximating those of habitats in which they grew and apparent enzyme substrate affinities which were intensive to temperature change in the range. Bjorkman and Holmgren (1963) recorded differential behaviour of the photosynthetic apparatus of Solidago virguarea from exposed and shaded habitats. Kaul (1965) recognized four seasonal populations in Xanthium strumarium, each population suited to different seasons of the year. He also reported variations in morphological as well as physiological features in these seasonal populations. Similarly in a study of seasonal populations of Chenopodium album differences in morphological characters were recorded by Ramakrishnan and Kapoor (1974).

Though the ecotypic studies were initially concerned with the differentiation of a population on climati-geographic basis, the demonstration of edaphic ecotypic differentiation by Kruckeberg (1951) and subsequently by Ramakrishnan (1960a, 1961a, b, 1965a, b) in Euphorbia thymifolia. Population differentiation,

specially from a very narrow area was of great significance in the development of genecological thoughts (Ramakrishnan, 1972). The tolerance of a species to a wider edaphic range may be either due to individuals exhibiting extreme physiological homeostasis (Waddington, 1957) or due to the existence of genetically determined, physiological races within the species, the edaphic ecotypes, each adapted to a narrow range of physical and/or chemical characteristics of the soil. Considerable work has been done on edaphic ecotypes both in India and abroad. Ramakrishnan (1972) has reviewed the work on edaphic ecotypes in relation to physical characteristics of the soil, macro-nutrients and micro-nutrients in the soil.

Kruckeberg (1951) was one of the first to recognize the occurrence of edaphic ecotypes in the case of Achillea borealis in relation to serpentine and non-serpentine soils depending on their adaptability to differential calcium levels in the soil. Ramakrishnan (1961a) noted ecotypic differences in Euphorbia thymifolia over a very short distance. In this species the facultative calcicole and obligate calcifuge populations are distributed in a mosaic of soil situations where the non-calcareous alluvial soil had smaller or longer calcareous patches which determined their restricted distribution pattern. Similarly, Snaydon and Davis (1972) observed sharp change in Anthoxanthum odoratum population at the boundary between plots at the Park Grass experiment, Rothamsted, where environmental conditions

change very sharply. These studies indicate the physiologically and morphologically diverse populations could maintain their identity over very short distances provided environmental conditions change very sharply.

McKell et al. (1960) recognized two races of Dactylis glomerata depending on their adaptability to soil moisture stress. Ramakrishnan (1966) recognized two ecotypes in Euphorbia hirta, erect type and prostrate type; the former growing in moderately moist habitats and the latter on dry hard soil exposed to trampling. Similarly in Echinochloa colona (Ramakrishnan, 1966b) tall form and short form were recognized depending on the soil moisture stress. Jain (1973) demonstrated two ecotypes of Vernonia patula, one being prostrate, was adapted to encounter hard, compact, dry soil and exposed to high illumination and temperature condition and the other one was erect type growing in neutral and base rich soil during favourable season of the year.

Ramakrishnan and his co-workers also reported population differentiation in Tridax procumbens (Ramakrishnan and Jain, 1965a, 1965b), Cynodon dactylon (Ramakrishnan and Singh, 1966), Adhatoda vasica (Ramakrishnan and Baishit, 1968) in relation to exchangeable calcium in the soil. Similar observations in relation to such soil factors were made by Snaydon and Bradshaw (1962) in Trifolium repens, by Jowett (1964) and Bradshaw (1959) in Agrostis tenuis.

In the case of micro differentiation of ecotypic populations,

specially in relation to soil factors, differences are in terms of the dry weight yield of the shoot and the root, the populations being adapted to particular soil type yielding best under more favourable conditions (Ramakrishnan, 1960a, 1965b, 1968a, b, 1969; Snaydon and Bradshaw, 1962; Ramakrishnan and Singh, 1966; Ramakrishnan and Nagpal, 1973; Kapoor and Ramakrishnan, 1974). Such differences as observed in competition free cultures become more marked under the influence of inter ecotypic competition (Snaydon, 1962; Ramakrishnan, 1965b).

With the realization of the fact that the selection pressure could result in population differentiation, it is reasonable to assume that continued biotic pressure would lead to more adapted genotypes. The concept of biotic races was recognized by Stapledon (1928) when he distinguished a number of ecotypes in Dactylis glomerata. Recently, Ramakrishnan (1958) in Euphorbia hirta, Gadgil and Solbrig (1972) in dandelions and Abrahamson and Gadgil (1973) in the case of golden rods showed differences in populations from disturbed sites and from undisturbed mesic sites.

#### Ecological aspect of mineral nutrition:

Calcium:- Since the calcareous and non-calcareous soil types differ from each other primarily with respect to available calcium level, this factor has a great role in the restriction of calcicole and calcifuges to their natural habitats (Ramakrishnan, 1971). This nutrient has been shown to influence plant behaviour and distribu-

tion of contrasting species (Oslen, 1942; Bradshaw, et al., 1958 and Clarkson, 1965) and contrasting populations within the species (Ramakrishnan, 1961a, b; 1965a, b, 1968a, b, 1969, 1970; Ramakrishnan and Jain, 1965a, b; Ramakrishnan and Singh, 1966; Snaydon and Bradshaw, 1961).

Since pH of the soil is directly related to calcium status, a significant interaction between the two and direct influence of pH on the behaviour of contrasting population and species could be expected, as was shown between calcareous and acidic populations in Melilotus alba (Ramakrishnan, 1968a). Thus, whilst the germinability of the seeds of the acidic population decreased with increase in pH at 2.5 level of external calcium concentration that of calcareous population improved with increase in pH at 100 ppm level of external calcium. The dry weight yield of the shoot of the calcareous population was better at pH7 compared to that at pH5.

As a consequent to change in pH associated with calcium status in the soil, the restriction of calcicoles to calcareous soil and calcifuges to non-calcareous soil is not only due to calcium but also due to the availability of phosphorus, iron, aluminium and manganese as was shown in the studies of Melilotus alba and Hypericum perforatum by Ramakrishnan (1968a, b, 1969).

Occurance of the two species of Galium on calcareous and non-calcareous soil types were attributed to their better

germination competitive ability in their respective habitats (Tansely, 1917). Rayner (1921) from his investigation on the calcifuge habit of Calluna vulgaris attributed the absence of this species in calcareous soil as due to delayed and poor seed germination arrested growth and parasitic effect of originally symbiotic fungus.

Ramakrishnan (1961a, b) recognized two ecotypes, the red form and the green form within Euphorbia thymifolia as a direct response to calcium. Differential response to calcium with respect to seed germination, establishment and other growth characteristics of these two ecotypes were observed under competitive conditions. Similar studies have been reported in Cynodon dactylon (Ramakrishnan and Singh, 1966); Tridax procumbens (Ramakrishnan and Jain, 1965a, b) and Adhathoda vasica (Ramakrishnan and Baisht, 1968). The studies on Melilotus alba (Ramakrishnan, 1968a, b) and Hypericum perforatum (Ramakrishnan, 1969) have shown that the calcareous populations in these species exhibit more selectivity than the non-calcareous populations with respect to the uptake of calcium and other cations. Since the selectivity is not so efficient in the case of the calcifuges they are, able to accumulate sufficient calcium even from a calcium poor soil, thus enabling their growth and survival in these soils. But when calcifuges are grown under calcareous situations, accumulate too much calcium, often at the expense of other cations, as conclusion also reached by Jefferies and Willis (1964).

In a comparative study of the response of three species, Sinapsis alba, Dianthus barbatus and Hordeum distichum, Oslen (1942) found that increased calcium levels resulted in diminished amounts of potassium and magnesium in the leaves of these species in contrast to the calcicole, Tussilago farfara. Dixon and Webb (1958) quotes considerable evidence based on invitro studies that calcium can stop the functioning of enzyme system because it competes with other cations for co-factor sites of particular enzymes. Vose and Jones (1963) showed the existence of varietal differences in Trifolium repens and at least in the case of one variety, Szolnok variety, where they have shown a significant interaction between calcium and manganese.

Snaydon and Bradshaw (1961) while working with calcareous and acidic populations in Festuca ovina and Ramakrishnan (1969) working with two such populations in Hypericum perforatum observed a differential ability of these to root at low calcium levels. The poor rooting ability of calcareous population at low calcium levels may influence nutrient absorption ability, thus restricting them from non-calcareous soils.

Phosphorus:- It is well established that phosphorus is an essential plant nutrient, the amount and availability of which varies considerably from one soil to another. Differences in response to phosphate between varieties of several crop species

has been reported by a number of workers (Gregory and Growther, 1928; Smith, 1934; Lyness, 1936, etc.). Snaydon and Bradshaw (1962) reported soil phosphorus as a basis for ecotypic differentiation in the natural populations of Trifolium repens. It was shown that the relatively greater ability of the populations from low phosphate soils to grow at low phosphate levels is due to a more efficient uptake of phosphorus rather than an ability to metabolise at lower internal phosphorus concentration.

In calcareous soil, phosphorus probably remains unavailable due to the formation of comparatively insoluble calcium phosphate. Rossiter (1955) and Bingham et al. (1958) reported that phosphate toxicity under field conditions appear on acidic soils. Rossiter (1952) also showed that phosphate toxicity in Trifolium subterraneum is reduced on acidic soils by the addition of lime. According to Rorison (1968) certain calcicole species make adequate growth for survival on calcareous soils where phosphorus is usually fixed as calcium or magnesium phosphate and that some calcifuges survived in acid soil where mineral phosphorus occurred largely as insoluble aluminium and iron phosphate. He concluded that calcicoles and calcifuges tolerate extreme conditions, partly because they can survive under conditions of very low phosphorus supply.

Ramakrishnan (1968a) in the case of Melilotus alba showed that while the calcareous population was insensitive to wide

variations in the level of phosphorus the acidic ecotype showed a definite improvement at higher phosphorus concentrations. The calcareous population had a higher phosphorus content than the acidic type at low phosphorus level and the reverse was found to be the case at high phosphorus level. A similar differential response was also recorded by Ramakrishnan (1969) in the calcareous and acidic ecotypes in Hypericum perforatum. Snaydon and Bradshaw (1962) also recorded similar behaviour in the case of acidic population of Trifolium repens. These studies indicate that the calcareous populations within these species are more prone to phosphate toxicity than are acidic populations.

Nitrogen:- The importance of nitrogen as a vital plant nutrient and its great effect on the metabolism of the plant has long been recognized. There are considerable evidences that crop species (Russel, 1950; Growth and Yates, 1941; Woodman, 1944) and wild species (Chadwick and Obeid, 1963; Pigott and Taylor, 1964; Bradshaw et al. 1964; and Misra and Ramakrishnan, 1960) differ in response to nitrogen and this nutrient has an important role in plant distribution.

Differential response to nitrogen nutrition by the ecotypic populations of Cynodon dactylon was recorded by Ramakrishnan and Gupta (1973). Results of Bradshaw et al. (1964) also point to the probable importance of nitrogen as a major ecological factor

in determining the distribution of species. Investigation by Chadwick and Obeid (1963) also indicate the importance of nitrogen in the distribution of taxonomically diverse species.

Potassium:- It is well established that potassium is one of the essential elements in plant nutrition. Johansen et al. (1968) while working with Hordeum vulgare have noted a strong depression of calcium absorption by low concentration of potassium. Mattson et al. (1949) have demonstrated an increased absorption of phosphate in the presence of potassium and calcium in the seedlings of barley and pea.

Varietal differences in response to potassium have been extensively reported in the case of crop species. Twelve varieties of perennial rye grass grown on three soils showed variation in potassium and calcium content and also in K/Ca + Mg ratio (Vose, 1963). Very little is known of intraspecific differences in wild species. However, Ramakrishnan and Gupta (1973) indicated that whilst the non-calcareous Chandigarh population of Cynodon dactylon responded more favourably to increase in potassium in the medium, the calcareous population of Shiwalik and Malla showed lesser response.

#### Seed germination:

Germination is an important ecological event and an out-

come of the various ecological factors with the intrinsic capabilities of the seeds (Ramakrishnan, 1971b). The initial step in germination is the reactivation of the system conserved during the seed maturation period and this activation starts with the imbibition of seeds under favourable environmental conditions. Favourable effects of fluctuating temperature was found by Wakhloo (1964) for germination of Solanum xanthocarpum and S. nigrum seeds. Improved germination of S. viarum seeds under suitable alternating temperature regimes was also recorded by Vicente (1972).

Light is an important ecological factor and plays a crucial role during seed germination of many species (Rooden et al., 1970). While, seed germination was totally inhibited in Erigeron linsifolius (Ramakrishnan, 1963) under complete darkness, that in Euphorbia thymifolia was markedly inhibited under continuous light (Ramakrishnan, 1961, a). Rooden et al. (1970) while investigating the nature of seed germination in some tropical weed species, noted that in some seeds which are normally strongly light sensitive and show practically no germination in darkness, the inhibition in germination can be completely alleviated by adding gibberellic acid to the imbibition water (Laha and Basu, 1980).

Dormancy is an important ecological factor that govern the survival and distribution of a population in any habitat (Ramakrishnan, 1963). Literature suggests that both innate and

enforced dormancy are involved in controlling the timing of germination. Under unfavourable conditions it confers a selective advantage on the species and the absence of dormancy may be helpful only under favourable conditions. Thus, Kapoor and Ramakrishnan (1973) noted differential temperature optima for seed germination in the seasonal ecotypes of Chenopodium album, which was related to their distribution in time. Also, Ramakrishnan (1961a) recorded differential germinability of the edaphic ecotypes in Euphorbia thymifolia as related to calcium level in the substratum.

#### Present study :

Solanum is one of the largest genus of the family Solanaceae and consists of more than 1700 species (Willis, 1966) found throughout the temperate and tropical parts of the world. More than 50 species have been recorded in India and a few exotic species of economic importance have been introduced. The genus is economically very important as several species are sources of drugs, food and fodder. Several species of Solanum produce glyco-alkaloids which on hydrolysis and removal of sugar yield steroidal alkaloids. Solanine and solasonine are widely distributed among the members of this genus. The aglycone of these two glycoalkaloids are solanidine and solasodine respectively. With the realization that the glyco-alkaloid solasodine, a nitrogen analogue of diosgenin is a



suitable alternative raw material for the production of steroid hormones, extensive world wide search began for the identification of solasodine rich species of Solanum. With the discovery (Chowdhury and Rao, 1964) that Solanum khasianum Clarke whose fruit yields appreciable quantity of steroidal alkaloid-solasodine, attempts have been made to domesticate and cultivate this species for commercial production of solasodine.

Solanum khasianum was first described from India by C.B. Clarke in the Flora of British India (Hooker, 1883) from a specimen collected from the Khasi Hills. Since then the plant has been recorded from various localities in India.

S. khasianum is an erect or somewhat decumbent branched undershrub upto 1.0 to 1.8 m in height. Spines are present on the stem, petioles, and pedicel of the flowers. Flowers are white and berries are yellow in colour on maturity. This species occurs extensively in the north-eastern region of India and growing in Meghalaya over a wide altitudinal gradient.

A few scattered studies are only available on the biology of this species. Erratic seed germination in this species has been reported by various workers (Chatterjee, 1977; Laha and Basu, 1980; Pingle and Dnyansagar, 1979). Photosensitivity in this species was reported by Laha and Basu (1980); they also observed that Gibberellic acid can remove the photosensitivity

of the seeds and the seeds could consequently germinate in complete darkness. Vicente and Moreas (1974) reported a water soluble inhibitor on the seed surface and which could be removed by thorough washing.

The occurrence, distribution and morphology of this plant has been investigated by Saini (1966). Kaul and Zutshi (1977) described its propagation under conditions prevailing in Jammu area. Agronomic evaluation of S. khasianum has been done for obtaining higher yield of berries (Hazarika and Bora, 1976). Hazarika et al. (1978) have developed an improved strain of S. khasianum which is disease resistant and with less spine intensity on the plant body.

S. khasianum can be cultivated in any kind of soil but too much clayey soil and water logged conditions are injurious to their growth and development (Chakravarty and Raychoudhury, 1974). Experimental cultivation of this plant has been successfully achieved in West Bengal (Saini et al., 1965; Saini, 1966; Saini and Biswas, 1967; Chakravarty and Basu, 1973; and Saini and Sufi, 1974), Bombay (Bakshi and Hamid, 1971), Madhya Pradesh (Dnyansagar, 1976a, b), U.P. (Chandra et al., 1970), Karnataka (Murty and Abraham, 1975; Murty, 1976). Dutta (1971, 1972) introduced and cultivated this plant in Bhubaneswar, and pointed out the great potentiality of starting its cultivation in that region, as well as in the hill regions of India (Kapoor,

1972).

It is evident from the work of Saini and Biswas (1967) and Saini and Sufi (1974) that the time of sowing plays a significant role on the growth development and ultimate yield of fruits. This plant is generally cultivated as annuals but under suitable cultural practices and favourable climatic conditions the plants grow as perennials (Chakraverty and Roychoudhury, 1974).

The stage of fruit maturity for harvest plays a significant role on the ultimate yield of solasodine (Saini et al., 1965; Saini and Biswas, 1967; Saini, 1966; Choudhury and Hazarika, 1966; Khanna and Murty, 1972 and Saini and Sufi, 1974). Saini et al. (1965) and Saini (1966) studied the glycoalkaloid content of the fruits at weekly intervals starting from early stage of fruit development and formed a progressive accumulation of glycoalkaloid, reaching a maximum of 7.6% on their 47 days of growth and then gradually declining to 5.1% on 68 days of maturity. Saini and Sufi (1974) on these observations concluded that the accumulation of glycoalkaloid increased with the physiological age of the fruits and this stage of fruit growth coincided with the change of fruit colour from green to yellow. The glycoalkaloid content of fruits at varying stages of development under Lucknow condition were studied by Chandra et al. (1970). The maximum percentage was recorded when the fruits were exactly 20 weeks old, after which solasodine content gradually declined.

Similar observations were made by Matsunaga et al. (1969) in a strain of S. khasianum grown in Japan, in which glycoalkaloid content varied at different stages of fruit maturity.

A few studies are also available on the fertilization response of this species. Fertilization in newly introduced areas is seldom essential but the plant shows great agronomic promise (White et al., 1971) and respond well to fertilizer application. Nitrogen, phosphorus and potassium have been found to increase the growth of the plant. Excess of nitrogen fertilization reduce the fruit yield. Application of P40, K40, and N60 kg per hectare have been found to be adequate (Saini and Biswas, 1967).

However, not much is known about the ecological equipment of S. khasianum, particularly with respect to natural populations and their adaptive response to different environmental conditions. The present study is an analysis of the natural populations of S. khasianum growing over a wide altitudinal range in Meghalaya.

Further, the possibilities of introduction of two exotic species, Solanum laciniatum and S. aviculare has also been explored in a preliminary fashion. S. laciniatum and S. aviculare are endemic to the Australian region (Randell and Symon, 1976). Despite extensive preliminary tests in many parts of the world (Shreiber, 1968) long term studies seem to have been restricted to Hungary, Russia, and New Zealand. The possibilities of introducing these two species in India has been studied by Kapoor and

Kapoor (1965), Sastry et al. (1973) and Bordoloi et al. (1976). During the present study apart from germination and nutritional requirements of these two species an attempt was made to explore the possibilities of successful introduction and cultivation of these two species, by growing them in the hills of Meghalaya.

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**CHAPTER II**

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STUDIES ON GROWTH YIELD OF SOLANUM KHASIANUM CLARKE AND ITS  
ADAPTATIONAL BEHAVIOUR ALONG AN ALTITUDINAL GRADIENT

INTRODUCTION

Solanum khasianum Clarke, a weed naturally growing in the hills of north-east India, has been recognized as a potential source of solasodine (Choudhury and Rao, 1964; Maiti et al., 1965; Saini, 1966). Practically no published literature is available on the field ecology of indigenous Solanums, although comparative assay of berries collected from different localities has often shown that solasodine content in S. khasianum may vary in different localities situated under diverse agro-climatic conditions. Maiti et al. (1965) reported 5.4% of solasodine in this species from the Nilgiris and 3.2% from Cherrapunjee, in Khasi hills, though Choudhury and Rao (1964), Choudhury and Hazarika (1966) found very low concentration of 0.5% or less. Later, Saini (1966) reported that this species gave 6% of glyco-alkaloids, out of which solasodine was little over 2%. More recently Ram (1978) while growing this species at Jammu from seeds collected from different geographical regions, also noted variation in solasodine content ranging from 0.6 to 2.2%. Very often, the site characteristics are not mentioned in such studies.

Many studies (Turesson, 1922, 1925; Clausen et al., 1940, 1948; Gregor, 1930, 1946; Hunter, 1962; David, 1976) showed that

natural populations growing over an altitudinal gradient differ in their ecological behaviour. The present study on Solanum khasianum Clarke, growing over an altitudinal range, reaching upto an elevation of 1500 m, was undertaken in order to look into possible ecotypic variation within this species.

#### Description of the site:

Burnihat is located at an altitude of 100 m and at 20°N longitude and 90°-50'E latitude. The soil is of lateritic origin and red, sandy loamy in nature. The climate of Burnihat is characterized by seasonality of rainfall. The rainy season extends from May to September, during this period about 90% of the average annual rainfall of 220 mm occurs. This period is also characterized by high humidity. At Burnihat average maximum temperature is 33.5°C and average minimum was 23.3°C. There is a mild winter at Burnihat during December to February. During this period average maximum temperature is 27.8°C and average minimum temperature is 14°C. The temperature begins to rise during March to April and this is mainly a dry period (Fig. 2.1).

Barapani is about 20 km north of Shillong and located at an altitude of 950 m. The soil is of sandy loam type and of lateritic origin. The climatic conditions are similar to that at Shillong, as described below, except that it is slightly warmer.

Cherrapunjee, about 55 km west of Shillong and is located at an altitude of 1300 m. Rainy season at Cherrapunjee extends from April to October; during this period about 90% of the average annual rainfall of about 3850mm occurs. Climatic conditions are similar to Shillong, except that it is slightly warmer.

Shillong is located at an altitude of 1500 m and at 25°-34'N longitude and 91°-56'E latitude. The climate of Shillong is typically monsoonic with rainy season extending from May to September; during this period about 90% of the average annual rainfall of about 2150mm occurs. This period is also characterized by high humidity and average maximum temperature of 22.5°C and average minimum of 16°C. However, winter in Shillong is severe and extends from November to February with an average maximum temperature of 17°C and an average minimum of 11.2°C. The temperature begins to rise during March-April and this period is with frequent stormy wind.(Fig. 2.2).

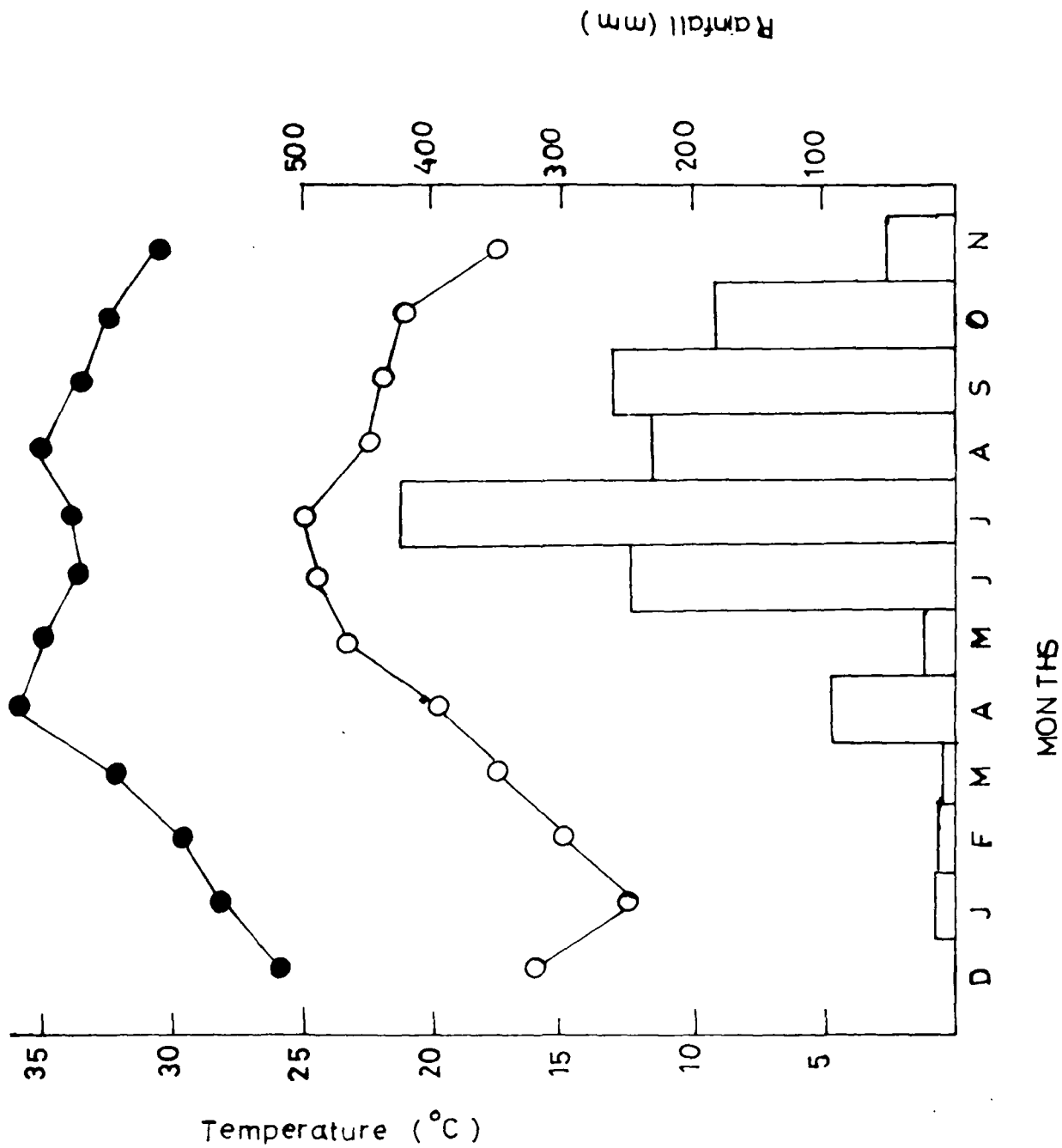
#### METHODS OF STUDY

##### Soil:

Soil analysis was based on the mean of ten soil samples collected from a depth of 15-20 cm (the zone of maximum rooting) from each site, where the species was found to grow. pH of the soil was determined electrometrically. The air dried soil samples were ground and sieved through a 2.54 mm-mesh. Chemical

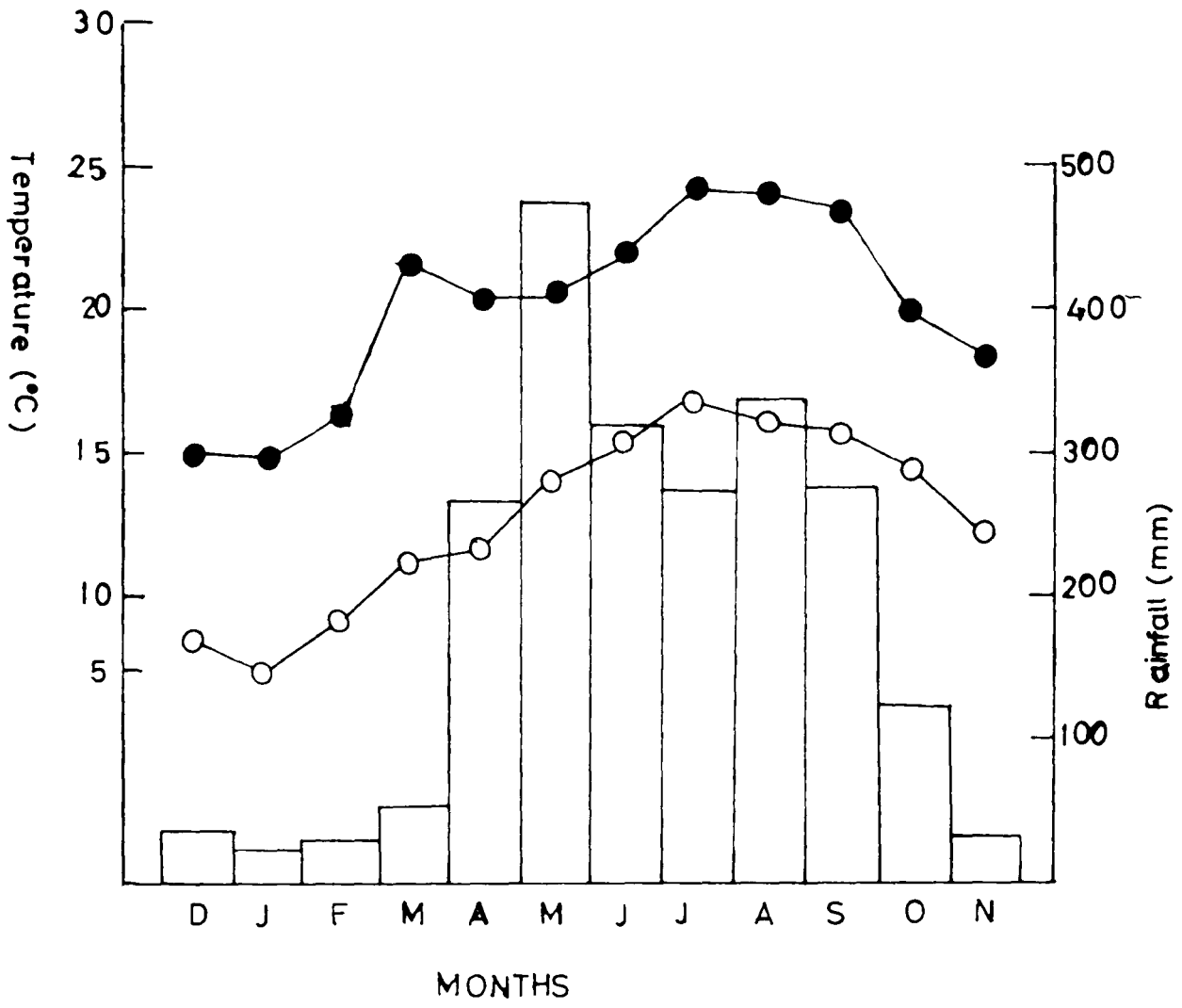
**Fig. 2.1. Ombrothermic diagram for Burnihat (1977-1979)**

Fig. 2-2.



**Fig. 2.2. Ombrothermic diagram for Shillong (1977-1979)**

Fig. 2.2.



analysis of the soil samples were done following the standard procedures as outlined by Jackson (1958) and Allen (1974). Thus the total nitrogen was determined by Kjeldahl method and the available phosphorus was determined colorimetrically using phosphomolybdate blue method. Exchangeable calcium potassium and magnesium were extracted by leaching the soil with 1N ammonium acetate at pH 7. Potassium was estimated flame photometrically, calcium and magnesium were determined by EDTA titration method, using Eriochrome Black-T and Patten and Readers' reagent as two indicators.

Alkaloid concentration in the berries was measured colorimetrically (Crusena et al., 1965), which involved extraction of the dry powdered berries with a mixture of acetic acid, alcohol and water and finally bringing the glycoalkaloid in solution after precipitation and purification.

Field studies were done at four altitudinal sites in the Khasi hills of Meghalaya, at Burnihat (100 m), Barapani (950 m), Cherrapunjee (1300 m) and Shillong (1500 m). Analysis of the vegetation associated with S. khasianum were done at different sites for density, frequency and abundance using quadrats of 4 m<sup>2</sup> (Misra, 1968). Density represents the number of individuals per unit area while frequency and abundance give an idea of the distributional pattern of the species.

Since it is difficult to determine the age of the natural

populations because of their perennial habit, the growth behaviour of the plants at different altitudes were done by marking 25 even aged seedlings at each selected sites, at the beginning of the growing season thus, at Burnihat the seedlings were marked on 26th September 1977, whereas at Barapani, Cherrapunjee and Shillong seedlings were identified on 20th, 14th and 10th March 1977. Growth measurements were taken at maturity, when most of the berries were yellow and fruiting was over.

Seedlings of all the natural populations from different altitudes were raised in two different altitudinal site at Burnihat (100 m) and at Shillong (1500 m) in order to study the possible ecotypic variation in this species. At Burnihat, seeds were sown on 16th September, whereas at Shillong sowing was done on 26th February to coincide with the natural regeneration.

## RESULTS

### Soil characteristics:

The soil was markedly acetic in all the sites except at Cherrapunjee where it was close to neutrality. The nitrogen and phosphorus levels were maximum at Shillong. The soil from Cherrapunjee had a lower nitrogen level. Both potassium and calcium levels were markedly higher at Cherrapunjee, compared to soils from other sites (Table 2.1).

**Table 2.1.** Soil analysis data from four localities where the populations of S. khasianum grow

| Locality     | Exchangeable bases<br>(m.e. %) |               |                |               |               |               |
|--------------|--------------------------------|---------------|----------------|---------------|---------------|---------------|
|              | pH                             | N(%)          | P(ppm)         | Ca            | K             | Mg            |
| Burnihat     | 5.7<br>±0.12                   | 0.15<br>±0.08 | 13.13<br>±8.34 | 2.31<br>±0.86 | 0.29<br>±0.07 | 0.33<br>±0.05 |
| Barapani     | 5.8<br>±0.24                   | 0.18<br>±0.05 | 16.52<br>±9.51 | 2.21<br>±0.38 | 0.23<br>±0.04 | 0.27<br>±0.03 |
| Cherrapunjee | 6.8<br>±0.16                   | 0.13<br>±0.06 | 18.26<br>±7.35 | 5.39<br>±1.21 | 0.87<br>±0.08 | 0.42<br>±0.08 |
| Shillong     | 5.2<br>±0.18                   | 0.21<br>±0.04 | 23.41<br>±5.81 | 2.13<br>±0.36 | 0.26<br>±0.03 | 0.39<br>±0.11 |

#### Associated plants at different sites:

A number of early successional weed species are found to be associated with S. khasianum. The associated species differed in different sites mainly due to the altitudinal differences. At Burnihat and Barapani Sida cordifolia, Mimosa pudica and Paspalum spp. were found to be the associates. At Shillong it was found to grow in association with Eupatorium adenophorum, Lantana camara and Galinsoga parviflora. At Cherrapunjee the most important associates were Desmodium spp., Rubus spp. and Panicum spp. (Table 1.2).

#### Phenology:

Seedling come up in nature at Barapani, Cherrapunjee and Shillong, after the first few showers. Flowering and fruiting occur during July to October and fruiting ceases before the onset of winter. Seedlings come up, however, intermittently throughout the early part of the rainy season, but ultimately end in poor vegetative and reproductive growth and often die with the onset of winter without attaining physiological maturity.

However, at lower altitudes, at Burnihat (100 m) and Nongpoh (540 m) seeds germinate in nature during September-October, comes to reproductive stage during January-February and continues upto March-April. In any case seeds are found to germinate at lower altitude early in the season (April-May) provided the habitat is

Table 2.2. Associates of S. khasianum at different localities. a = abundant, f = frequent o.f = occasionally found, - = absent.

| Species                       | Locality |          |              |          |
|-------------------------------|----------|----------|--------------|----------|
|                               | Burnihat | Barapani | Cherrapunjee | Shillong |
| <u>Eupatorium edenophorum</u> | -        | -        | a            | a        |
| <u>E. odoratum</u>            | f        | -        | -            | -        |
| <u>Galinsoga parviflora</u>   | -        | o.f      | a            | a        |
| <u>Solanum torvum</u>         | f        | f        | o.f          | -        |
| <u>S. sisymbriifolium</u>     | -        | -        | -            | off      |
| <u>Lantana camara</u>         | -        | -        | -            | f        |
| <u>Sida cordifolia</u>        | a        | a        | o.f          | -        |
| <u>Mimosa pudica</u>          | f        | f        | -            | -        |
| <u>Ageratum conyzoides</u>    | f        | o.f      | -            | -        |
| <u>Rubus khasianum</u>        | -        | -        | o.f          | -        |
| <u>Panicum khasianum</u>      | f        | -        | a            | -        |
| <u>Paspalum dilatatum</u>     | -        | f        | f            | f        |

shady and moist, but finally ends up in poor vegetative and reproductive growth (Table 2.3).

Growth behaviour of S. khasianum populations under natural habitats:

Shoot height of the Burnihat population was significantly lower than the other populations. However, differences in shoot height amongst other populations were not statistically significant. The dry weight yield of shoot of Burnihat population was also found to be significantly lower than the other populations. Though comparatively higher shoot yield was observed in the case of the Cherrapunjee and the Barapani population than that of Shillong population, the differences were not statistically significant. Root yield of the Shillong population was significantly higher as compared to the Barapani and the Burnihat populations. However, the Shillong and the Cherrapunjee populations did not differ significantly with respect to root yield. Minimum root yield was observed in the case of Burnihat population (Table 2.4).

The Burnihat population had a significantly smaller berry size as compared to other populations. However, a significantly larger berry size was observed in the Cherrapunjee populations as compared to all others. Significantly lower values for the Burnihat population was also noted with respect to berry weight and number of seeds per berry as compared to others. The Shillong population had a maximum seed number per berry. Solaso-

Table 2.3. Phenological phases of *S. khasianum* populations at different localities at different altitudes.

|                   | Shillong<br>(1500 m)      | Cherrapunjee<br>(1300 m)  | Barapani<br>(950 m)       | Nongpoh<br>(540 m)        | Burnihat<br>(100 m)          |
|-------------------|---------------------------|---------------------------|---------------------------|---------------------------|------------------------------|
| January-February  |                           |                           |                           | Flowering and<br>Fruiting | Flowering<br>and<br>Fruiting |
| March-April       | Germination               | Germination               | Germination               | Flowering and<br>Fruiting | Flowering<br>and<br>Fruiting |
| May-June          | Vegetative                | Vegetative                | Vegetative                |                           |                              |
| July-August       | Flowering and<br>Fruiting | Flowering and<br>Fruiting | Flowering and<br>Fruiting |                           |                              |
| September-October | Flowering and<br>Fruiting | Flowering and<br>Fruiting | Flowering and<br>Fruiting | Germination               | Germination                  |
| November-December |                           |                           |                           | Vegetative                | Vegetative                   |

Table 2.4. Growth performance of S. khasianum at different localities.

| Localities         | Shoot height<br>(cm) | Shoot dry wt.<br>(gm) | Root dry-wt<br>(gm) | Shoot/root<br>ratio |
|--------------------|----------------------|-----------------------|---------------------|---------------------|
| Burnihat           | 65.8                 | 54.61                 | 16.38               | 3.34                |
| Barapani           | 94.2                 | 69.23                 | 18.29               | 3.78                |
| Cherrapunjee       | 82.6                 | 68.85                 | 21.68               | 3.18                |
| Shillong           | 89.3                 | 62.94                 | 25.54               | 2.54                |
| L.S.D.<br>P = 0.05 | 14.325               | 8.021                 | 7.453               |                     |

dine concentration was significantly lower in the Burnihat population and maximum in the case of Cherrapunjee population (Table 2.5).

Cherrapunjee population yielded maximum number of berries per plant and the minimum was for the Burnihat population. Maximum seed output per plant was observed in the Cherrapunjee population followed by the Shillong and the Barapani population. Seed output was minimum in the case of Burnihat population. Highest yield of solasodine was obtained for the Cherrapunjee population. Least yield was in the case of Burnihat population, the other two populations being in between (Table 2.6).

Growth yield of different populations of S. khasianum under reciprocal cultivation:

The results of growth yield of all the populations at Burnihat and Shillong are shown in Table 2.7. Growth in height of all the populations grown at Shillong was found to be more as compared to those grown at Burnihat. However, in either sites differences in height between the populations were not statistically significant. Similar observations were made with regard to shoot dry weight yield. Root dry weight yield of all the populations were higher at Shillong, except for Burnihat population, where root yield was higher at Burnihat as compared to that at Shillong. For all the populations, slightly earlier

Table 1.5. Berry characters of S. khasianum populations at different localities.

| Locality           | Berry size<br>(vol. ml) | Berry fresh<br>weight (g) | Seed number<br>per berry | Solasodine<br>(%) |
|--------------------|-------------------------|---------------------------|--------------------------|-------------------|
| Burnihat           | 8.9                     | 6.8                       | 308                      | 1.02              |
| Barapani           | 10.2                    | 7.8                       | 343                      | 1.12              |
| Cherrapunjee       | 11.5                    | 7.3                       | 351                      | 1.44              |
| Shillong           | 10.4                    | 7.4                       | 369                      | 1.26              |
| L.S.D.<br>P = 0.05 | 1.1                     | 0.8                       | 24                       | 0.20              |

Table 1.6. Seed output and solasodine yield of S. khasianum at different localities.

| Localities             | No. of berry per plant | Seed output per plant | Solasodine yield/ plant (mg) |
|------------------------|------------------------|-----------------------|------------------------------|
| Burnihat               | 16.80                  | 5174.4                | 205.4                        |
| Barapani               | 22.4                   | 7683.2                | 313.6                        |
| Cherrapunjee           | 28.2                   | 9898.2                | 460.8                        |
| Shillong               | 24.5                   | 9040.5                | 359.6                        |
| Significant difference | 5.16                   |                       | 83.57                        |

p = 0.05

flowering and fruit maturity was observed at Burnihat as compared to that at Shillong, as is seen from the number of days taken for 50% of the plants to flower.

No significant differences were discernible among the populations with regard to number of fruits produced per plant. However, at Shillong number of fruits per plant was higher for all the populations as compared to that at Burnihat, though, at Burnihat dry weight yield in fruit of the Burnihat and the Barapani populations were significantly higher than that of the Cherrapunjee and Shillong populations, however fruit yield was not significantly different among different populations grown at Shillong.

At Burnihat significantly smaller number of seeds per fruit were observed in the case of the Shillong and the Cherrapunjee populations, as compared to the other two populations. However, when grown at Shillong, no such differences were observed among the populations with respect to the number of seeds per fruit.

When the plants were grown at Burnihat the Shillong and the Cherrapunjee populations showed significantly lower solasodine concentration, as compared to the Burnihat and the Barapani populations. At Shillong solasodine concentration of the Cherrapunjee population was significantly higher than that of the other populations.

Table 2.7. Growth of S. khasianum populations under reciprocal cultivation at two altitudes

| Exptl. Station | Population   | Shoot height (cm) | Shoot dry-weight (g) | Root dry-weight (g) | Shoot/root ratio |
|----------------|--------------|-------------------|----------------------|---------------------|------------------|
| Burnihat       | Burnihat     | 106.2             | 96.24                | 31.04               | 2.85             |
|                | Barapani     | 111.6             | 98.47                | 26.52               | 3.71             |
|                | Cherrapunjee | 112.3             | 102.36               | 32.26               | 3.16             |
|                | Shillong     | 108.5             | 109.81               | 29.48               | 3.74             |
| L.S.D.         |              | 11.826            | 16.371               | 8.261               |                  |
| P = 0.05       |              |                   |                      |                     |                  |
| Shillong       | Burnihat     | 115.5             | 112.21               | 29.84               | 3.76             |
|                | Barapani     | 118.4             | 101.33               | 34.46               | 2.94             |
|                | Cherrapunjee | 128.6             | 106.58               | 33.39               | 3.19             |
|                | Shillong     | 114.9             | 116.37               | 36.52               | 3.18             |
| L.S.D.         |              | 14.278            | 17.526               | 9.986               |                  |
| P = 0.05       |              |                   |                      |                     |                  |

cont'd

| Exptl. Station | Population         | Fruit dry-weight yield (g) | Time taken for 50% plants to flower(days) | Time taken for first fruit maturity (days) | Fruit No. per plant | Seed No. per fruit | Solaso-dine % | Solaso-dine yield (mg) |
|----------------|--------------------|----------------------------|---|--|---------------------|--------------------|---------------|------------------------|
|                | Burnihat           | 34.06                      | 122                                       | 193  | 22                  | 332                | 0.964         | 328.4                  |
|                | Barapani           | 37.38                      | 124                                       | 195  | 24                  | 315                | 0.953         | 356.2                  |
| Burnihat       | Cherrapunjee       | 29.35                      | 122                                       | 190  | 20                  | 239                | 0.893         | 262.1                  |
|                | Shillong           | 32.17                      | 119                                       | 190  | 25                  | 206                | 0.867         | 278.9                  |
|                | L.S.D.<br>P = 0.05 | 2.16                       |   |  | 7.2                 | 54.26              | 0.034         |                        |
|                | Burnihat           | 39.25                      | 129                                       | 196  | 24                  | 336                | 0.987         | 387.4                  |
|                | Barapani           | 42.38                      | 127                                       | 201  | 29                  | 328                | 0.992         | 420.4                  |
| Shillong       | Cherrapunjee       | 48.14                      | 126                                       | 195  | 34                  | 356                | 1.11          | 534.3                  |
|                | Shillong           | 46.12                      | 129                                       | 198  | 32                  | 348                | 1.03          | 475.0                  |
|                | L.S.D.<br>P = 0.05 | 11.20                      |   |  | 13.5                | 47.32              | 0.061         |                        |

Solasodine yield of the Burnihat and the Barapani populations were found to be significantly higher at Burnihat, as compared to that of the Shillong and the Cherrapunjee populations. However, at Shillong, maximum solasodine yield was obtained for the Cherrapunjee population. The solasodine yield of all the other populations in general, was higher at Shillong than at Burnihat.

#### DISCUSSION

In nature Solanum khasianum grows over a wide altitudinal and climatic gradient and often occupy diverse habitats. Turesson (1922) was first to demonstrate that species of great ecological amplitude occupy a wide range of environmental situations due to the existence of distinct ecological populations suited to each situations. Studies of Clausen et al. (1940) had shown the existence of a large number of climatic races in various species in California, ranging from sea level situation to above timber line.

Although S. khasianum is fairly hardy and does well under diverse ecological conditions, yet it cannot with stand extreme climatic conditions. The differences in the phenological events in this species under natural conditions at lower and higher altitudes could be related to its optimum temperature requirements for proper vegetative and reproductive growth. Saini and

Biswas (1960) have shown best growth performance in this species is obtained at a moderate average temperature regime of 32°C maximum and 25°C minimum. Appearance of the seedlings in nature during September-October at lower altitudes and during February - March at higher altitudes, could possibly be related to its optimum temperature requirement for growth at these altitudes. However, when all the populations under study were brought under reciprocal cultivation, both at lower and higher altitudes no differences were revealed among the populations, with regard to their various phenological events. Thus as stated by Huxly and Vaneck (1974) often, a single species may show quite different patterns of growth and development under different environmental conditions, which is obviously exogenously controlled. Thus the differences in the phenological behaviour of the lower and the higher altitudes populations of S. khasianum is only a plastic adaptation to the local climatic conditions.

The occurrence of a small number of 'out of season' seedlings in the field shows the ability of the species to survive under unfavourable conditions, though in a depauperate state. Onset of winter at higher altitude and that of dry hot summer at lower elevations determine the completion of the life cycle of this species.

In general the poor growth performance of all the populations at Burnihat indicate the greater sensitivity of this

species to higher temperature conditions prevailing there as compared to that at higher altitude situation. In this the better performance of the lower altitude population of Burnihat and Barapani at low altitudes at Burnihat, suggest the close adaptation of these populations to their natural habitats as compared to the higher altitude populations. However the probable requirement of lower temperature for growth of all the populations is seen from more or less uniform performance of all the populations at Shillong. Such a differential behaviour of altitudinal populations indicate some degree of ecotypic variation in this species as also shown by Turesson, 1922, 1925; Clausen et al., 1940, 1948; Gregor, 1930, 1946, Sheila and Hunter, 1962. Differences among the populations to some extent is also seen from the solasodine percentage and yield. Thus at Burnihat both the lower altitude populations of Burnihat and Barapani gave higher solasodine yield compared with the higher altitude populations. Whereas, at Shillong, inspite of the absence of any differences between populations with respect to vegetative and reproductive characteristics, Cherrapunjee population give high solasodine concentration an observation similar to that of Maiti et al. (1965), though, they obtained even higher concentration. However, the present results do not confirm the observations of Chowdhury and Chatterjee (1979), that Solasodine concentration decreases with increase in altitude, as shown at Darjeeling Himalayas. In conclusion it may be noted

that the wide ecological amplitude of S. khasianum is both due to its ecological adaptability within the species and also due to its great plasticity, shown from our nutritional studies.

#### SUMMARY

Growth yield and adaptation behaviour of different altitudinal populations of Solanum khasianum Clarke were studied both under natural conditions and under cultivation. The differences in phenological events in this species under natural conditions at lower and higher altitudes, is related to its optimum temperature requirement for growth. However, under reciprocal cultivation no differences were revealed with regard to its phenology. In general the poor growth performance of all the populations at lower altitude indicate the greater sensitivity of this species to higher temperature conditions and probable requirement of lower temperature for better growth differential behaviour of altitudinal populations indicate some degree of adaptation to the local habitat conditions. Though no correlation was observed between the solasodine content and the altitudinal population, the Cherrapunjee population possessed a comparatively higher solasodine content in the berries.

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**CHAPTER III**

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SEED GERMINATION STUDIES ON SOLANUM KHASIANUM CLARKE.

## INTRODUCTION

Seeds of many weed species do not germinate when freshly harvested, or will do so only within a restricted temperature regime (Roberts and Lockett, 1979). If held in dry storage or kept moist, various changes may occur in the temperature limits for germination (Vegis, 1964). Such changes also occur in seeds in the soil or on soil surface and their relationship with the seasonal temperature cycle governs the period of seedling emergence (Roberts and Lockett, 1979).

Chabot and Billings (1972) working in the Sierra Nevada of California, have investigated ecotypic differentiation in seed germination along altitudinal gradients. They found no significant differences in the rate of seed germination at different temperature regimes among different altitudinal populations of a wide variety of species.

Solanum khasianum Clarke, a wild undershrub grows in the hills of Meghalaya, ascending upto an altitude of 1500 m. Slow and erratic nature of seed germination in S. khasianum have been observed by various workers (Vicente, 1972; Chatterjee, 1977; Chauhan, 1978). Well known methods such as removal of testa, treatments with hormones as well as vitamin (ascorbic acid) were tried but without much success (Pingle and Dnyansagar, 1979).

The present study is an attempt to understand the extent to which the altitudinal populations of S. khasianum differ from each other with respect to their temperature optima for seed germination along an altitudinal gradient.

#### METHODS OF STUDY

Ripe berries of different altitudinal populations of Solanum khasianum Clarke were collected from natural populations at Burnihat (100 m), Cherrapunjee (1300 m) and Shillong (1500 m). Seeds were extracted, washed in running tapwater for about half an hour and dried at room temperature (unless otherwise mentioned). Germination tests were performed in petridishes containing a Whatman filter paper over a thin layer of cotton wool moistened with distilled water. The following experiments were performed using three replicates of 100 seeds in each replicate.

##### a) Storage effect:

Freshly collected seeds were washed, dried and stored in dark bottles at a constant temperature of 25°C and bimonthly germination tests were done at two temperature regimes of 25°C constant and 15°/25°C alternating temperatures.

##### b) Temperature and light effect:

Six months old seeds were tested at a range of constant

temperature regimes of 10°, 15°, 20°, 25°, 30° and 35°C. This experiment was done in unlighted incubators, except for exposure to diffused day light, while watering the petri-dishes and counting the germinated seeds, every day.

In another experiment seeds were kept either in complete darkness or in continuous light at 10°, 15° and 25°C constant temperature regimes.

In a third experiment seeds were put to three alternating temperature regimes of 10°/25°C, 10°/30°C and 15°/25°C; keeping the seeds at lower temperatures for 8 hours and at higher temperatures for 16 hours. The warmer phase of the thermoperiod synchronized with photoperiod.

c) Germination inhibitor:

Seeds were extracted from freshly collected berries and put to germination tests on petri-dishes without clearing at 15°/25°C alternating temperature (light regime coincided with higher temperature). From the same collection another lot of seeds were washed thoroughly in running tap water for 24 hours and subjected to similar temperature regime. Some berries from the same lot were pressed to crack (for easy and proper drying), sun-dried and stored at 25°C and put to bimonthly germination tests at 15°/25°C alternating temperature regimes as before.

## RESULTS

## a) Effect of storage period on germination:

Seed germination at 25°C constant temperature improved with storage, reaching a maximum after six months. Storage duration longer than this resulted in gradual decline in germination. No significant differences were noted between the different populations (Fig. 3.1).

A similar pattern in germination with storage was also observed when tested at 15°/25°C alternating temperature regime, the only difference being that germination was significantly higher at this temperature treatment. Further, maximum germination was obtained after ten months of storage (Fig. 3.2).

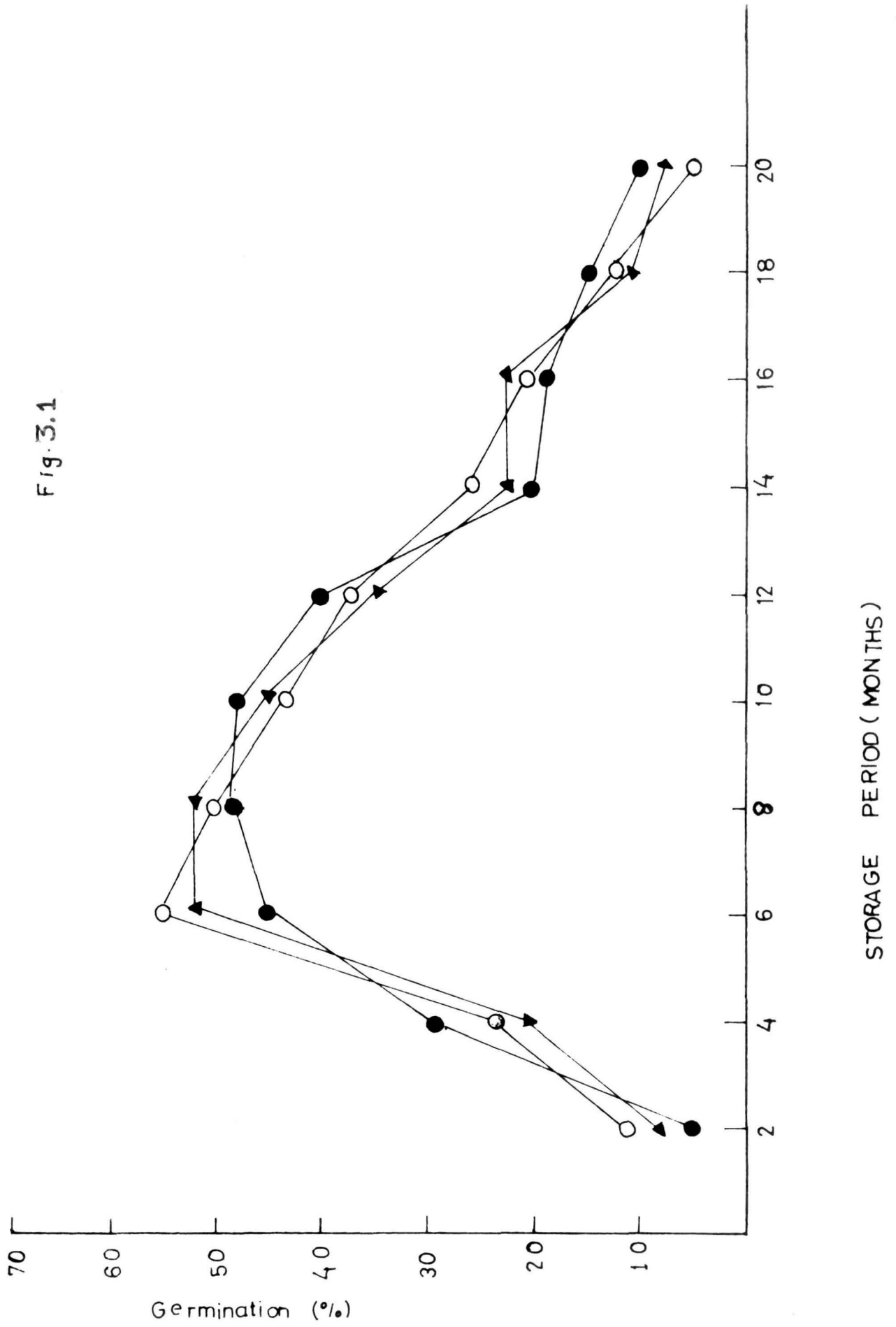
## b) Effect of temperature and light on germination:

In the experiment where germination was tested at different constant temperature, with some diffused light, germinability of the seeds of all the populations improved with increase in temperature, reaching a maximum at 25°C constant temperature after which it declined. Very low germination was obtained at extreme temperature regimes of 10°C and 35°C (Fig. 3.3).

However, when the seeds were exposed to continuous illu-

**Fig. 3.1. Effect of storage period on the germination of three populations of S. khasianum seeds at constant temperature (25°C).  
▲, Burnihat; ●, Cherrapunjee; ○, Shillong.**

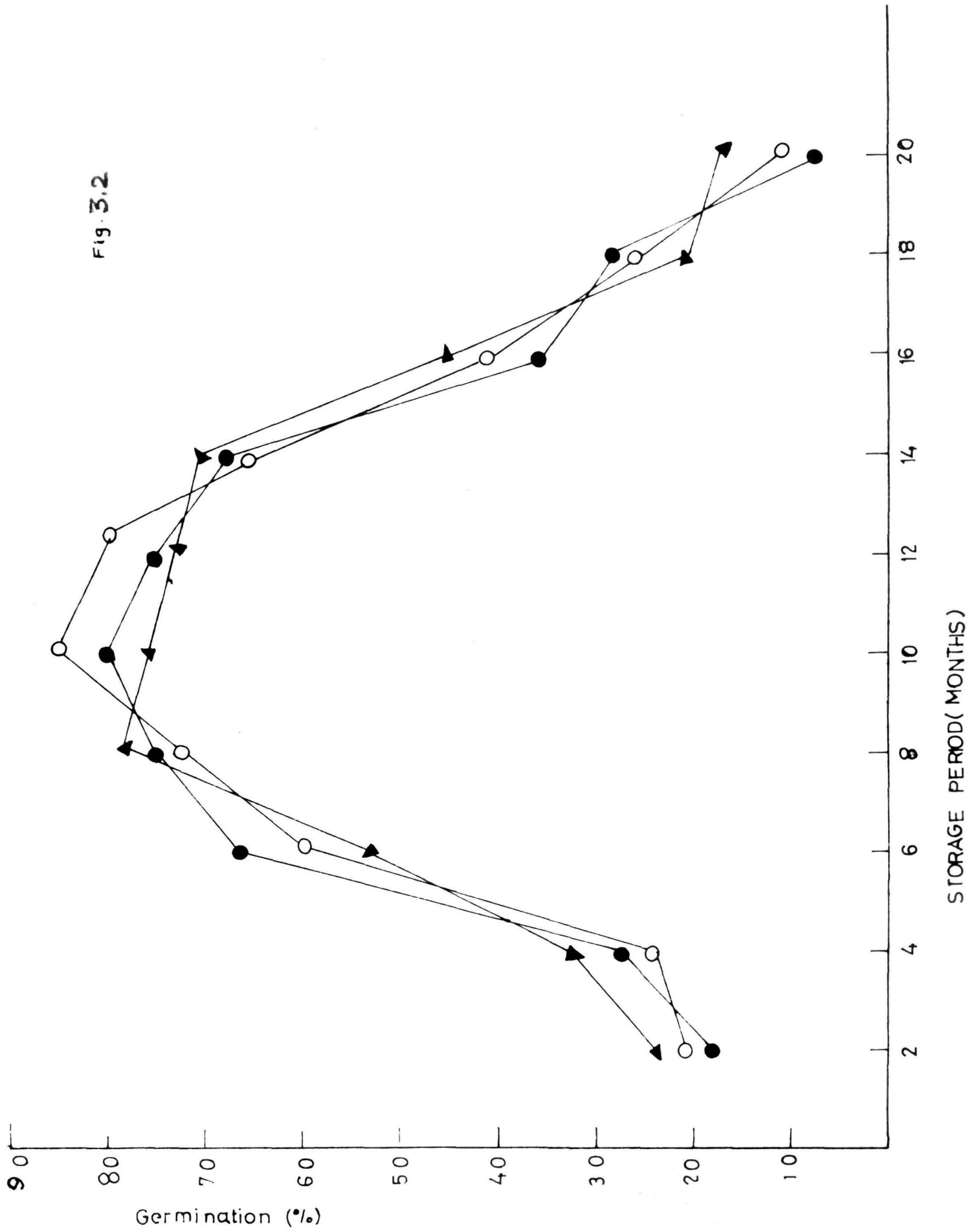
Fig. 3.1



**Fig. 3.2. Effect of storage period on the germination of three populations of *S. khasianum* seeds at alternating temperature (15/25°C).**

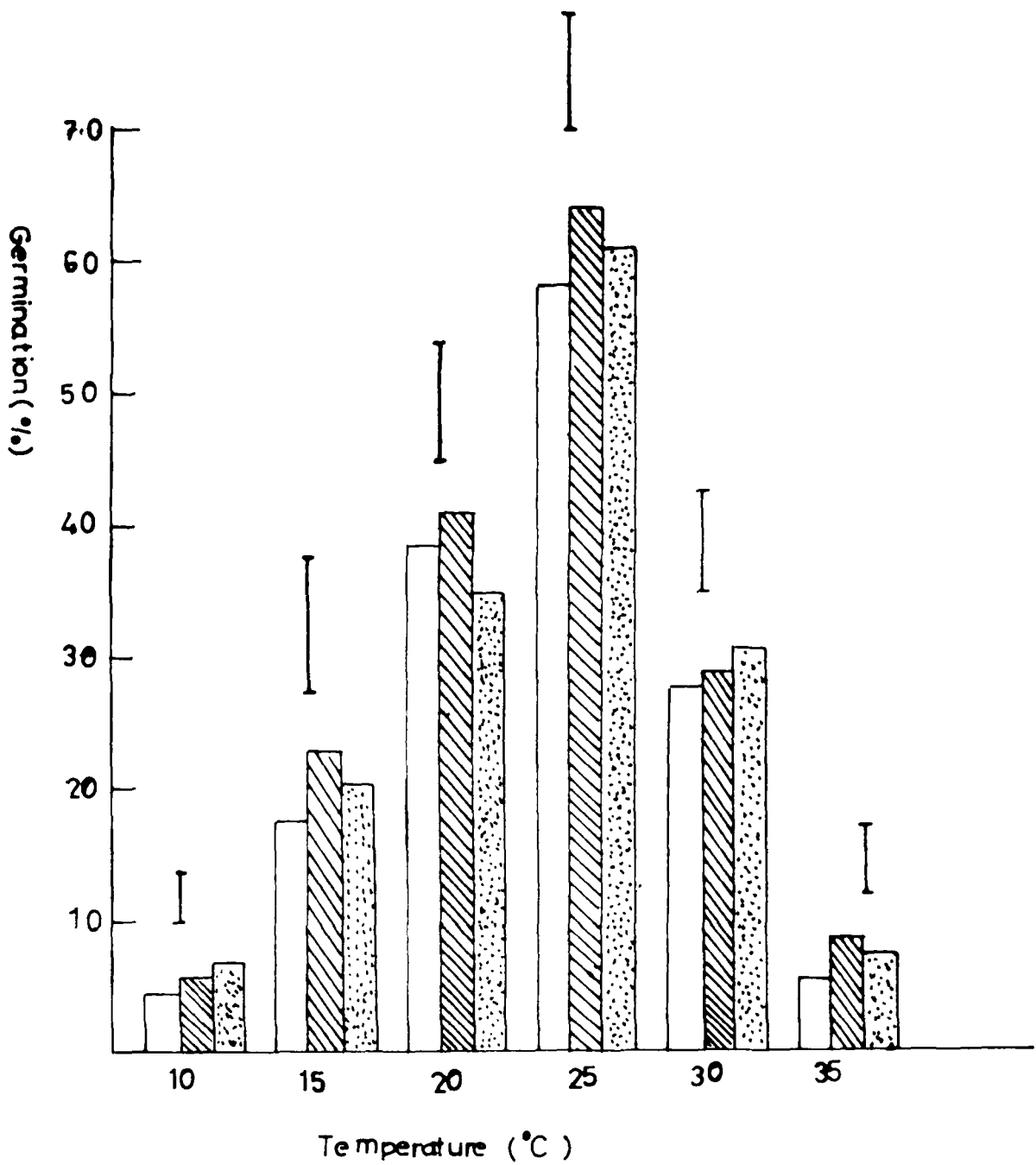
▲, Burnihat, ●, Cherrapunjee, ○, Shillong.

Fig. 3.2



**Fig. 3.3.** Effect of different constant temperature regime on the germination of the three populations of S. khasianum Seeds under diffused light.  
□, Shillong ; ▨, Cherrapunjee ; ▩, Burnihat.

Fig.3.3



mination at constant temperature regimes of 10°, 15° and 25°C, a slight improvement in germination was observed. Over those under partial diffused light. However, the response pattern of the seeds to increase in temperature was not different from the above experiment (Fig. 3.4). Under total darkness seeds failed to germinate both under constant and alternating temperature regimes.

At alternating temperature regimes, where light exposure were given during the high temperature cycle, maximum germination occurred at 15°/25°C temperature regime. Again, no significant differences between the populations with respect to temperature and light requirement for germination were observed (Fig. 3.5).

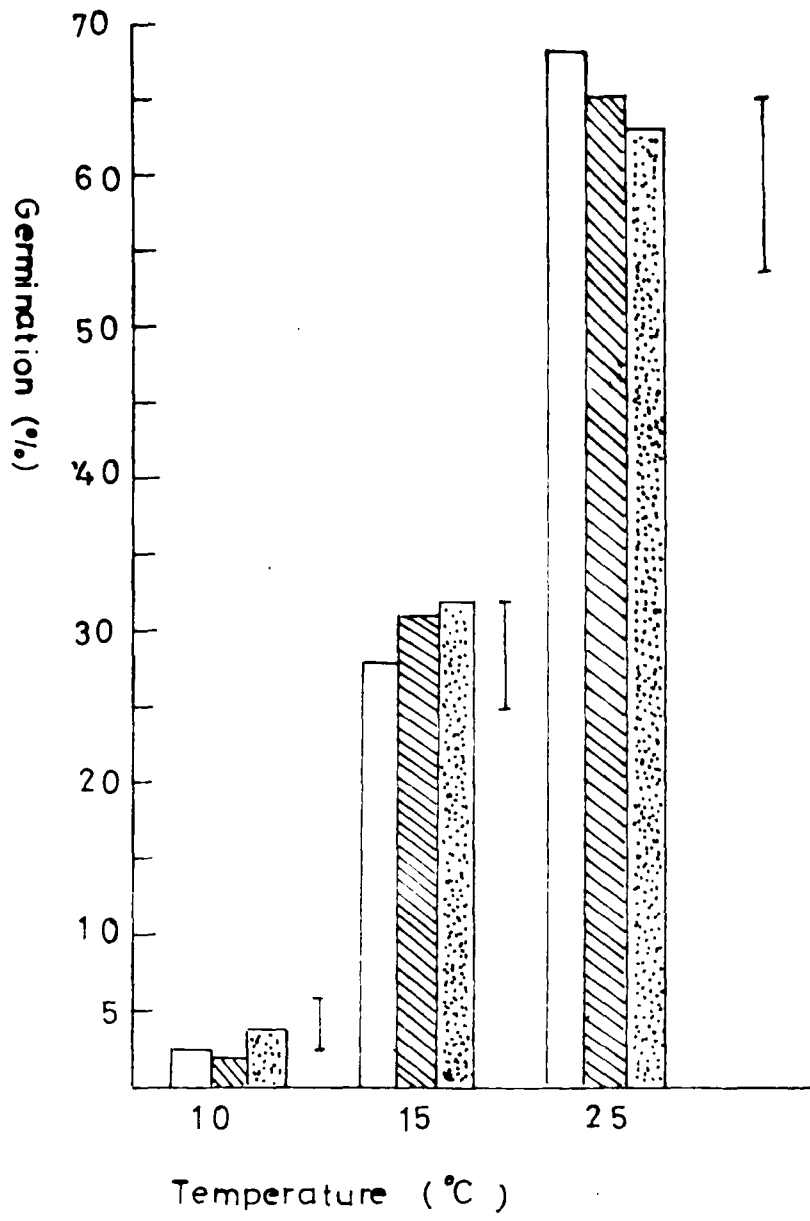
c) Germination inhibitor, washing and storage effect:

When seeds from the fresh berries were directly put to germinate under optimum temperature regime of 15°/25°C no germination occurred, however, this inhibitory effect was removed on washing in running tap water for 24 hours and the seeds subsequently gave 50% germination (Table 3.1). This inhibitory effect was also removed on dry storage of unwashed seeds, and the seeds gave 62% germination after six months of storage period. All the populations behaved in a similar manner and no significant differences between the populations were discernable (Table 3.2).

**Fig. 3.4. Effect of different temperature regimes on the germination of three populations of S. khasianum seeds under continuous light conditions.**

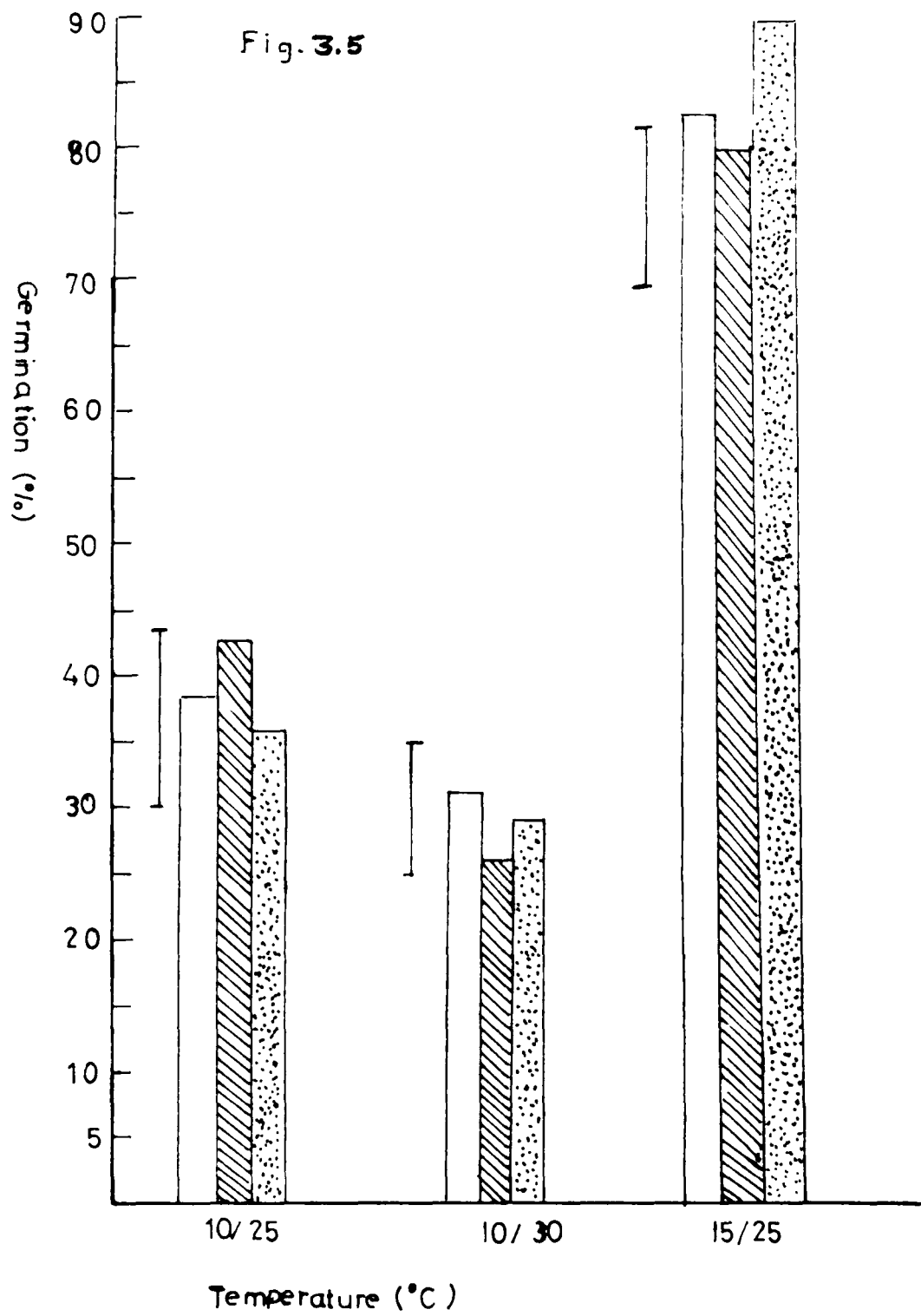
□, Shillong, ▨, Cherrapunjee; ▩, Burnihat

Fig. 3.4



**Fig. 3.5. Effect of alternating temperature and light conditions on the germination of the three populations of S. khasianum.**

□, Shillong; ▨, Cherrapunjee; ◻, Burnihat.



**Table 3.4.** Effect of 24 hours' washing of the seeds under running tap water on the germination of S. khasianum

| Population        | Germination (%) |        |
|-------------------|-----------------|--------|
|                   | Unwashed        | Washed |
| Shillong          | 0               | 55.2   |
| Cherrapunjee      | 0               | 51.6   |
| Burnihat          | 0               | 48.2   |
| L.S.D<br>P = 0.05 |                 | 11.23  |

**Table 3.2.** Effect of storage period on the germination of unwashed seeds of S. khasianum

| Population         | Germination(%) |          |          |
|--------------------|----------------|----------|----------|
|                    | 2 months       | 4 months | 6 months |
| Shillong           | 7.5            | 12.2     | 54.3     |
| Cherrapunjee       | 6.8            | 14.1     | 52.6     |
| Burnihat           | 8.2            | 15.6     | 56.8     |
| L.S.D.<br>P = 0.05 | 3.2            | 5.3      | 8.1      |

## DISCUSSION

Germination is an important ecological event affecting distribution of species population in nature (Ramakrishnan, 1963, 1965). Germination is the outcome of the interaction of various environmental factors with the intrinsic capabilities of the seeds and the initial step in germination is the reactivation of the system conserved during seed maturation (Gupta et al., 1975).

Most of the seeds in this species remain dormant for the first two months and attain maximum germination after six months. Unlike many other species (Pamadasa and Lovell, 1975) S. khasianum seeds showed no widening for the temperature limits for germination. Similar observations were also made by Roberts and Lockett (1977) in the case of S. dulcamara. In all stages of storage period, alternating temperature proved to improve germination percentage. Similar observations were also made by Vicente (1972) in this species and also in the case of Digitaria adscendens (Ramakrishnan and Khosla, 1971).

Seeds of S. khasianum are found to be positively photo-responsive. Similar observation was also made by Laha and Basu (1980). Vicente (1972) also reported stimulation of seed germination at all temperature regimes when light was provided compared to that in diffused light. However, there was no

marked improvement in seed germination in continuous light compared to that at partial diffused light, indicating that the quantity or duration of light required is not critical for seed germination in this species. But at both constant and alternating temperature regimes seeds failed to germinate in complete darkness, though, Laha and Basu (1980) reported that photodormancy in this seed could be overcome by GA<sub>3</sub> application.

The fact that the fresh seeds failed to germinate unless thoroughly washed for at least 24 hours, suggests the presence of a water soluble inhibitor in the mucilaginous coating surrounding the seed. The improvement in germination of the unwashed seeds with storage suggests the degradation of the inhibitory substance with time. Vicente (1974) also recorded the presence of water soluble inhibitor in this species.

Though a close correlation has often been recognized in the germination behaviour of the ecotypic populations as in Euphorbia thymifolia (Ramakrishnan, 1965a) and Erigeron limifolium (Ramakrishnan, 1963), no such differences between the various population were observed with respect to their seed germination in the present case. This is in agreement with a similar study done on altitudinal populations of a variety of plant species by Chabot and Billings (1972), though, they were able to recognise ecotypic differences in the adult plants. This also seem to be the case (c.f. Chapters I and II) in S. khasianum.

## SUMMARY

This study deals with the germination ecology of three altitudinal populations of Solanum khasianum Clarke. No ecotypic differences could be recognized between the different collections. Fresh seeds have dormancy which is due to some chemical inhibitor in the mucilaginous coating on the seed surface and dormancy is overcome by storage. Seed germination was maximum at a constant temperature of 25°C after six months of storage, while a higher maximum was obtained at 15/25°C after ten months of storage. Seeds are photosensitive, with no seed germination occurring in total darkness. The significance of these observations are discussed.

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**CHAPTER IV**

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STUDIES ON THE NUTRITIONAL ECOLOGY OF THE POPULATIONS OF  
SOLANUM KHASIANUM CLARKE

INTRODUCTION

Varietal differences in response to mineral nutrients in crop plants are very well known. Differential response of natural populations to calcium nutrition has received considerable attention mainly due to the interest of ecologists in the calcicole - calcifuge problem in plants (Ramakrishnan, 1961, 1965a, b, 1969, 1971; Ramakrishnan and Singh, 1966; Rorison, 1960a, b; Snaydon and Bradshaw, 1961). Differential response to nitrogen, phosphorus and potassium has also been shown by different workers in a number of species (Vose, 1963; Snaydon and Bradshaw, 1962; Ramakrishnan, 1970; Ramakrishnan and Gupta, 1972, 1973).

Published reports with regard to growth and yield of Solanum khasianum Clarke are restricted to field fertilizer trials (Chowdhury et al., 1979) and Hazarika et al. (1978) indicated the plant has a high demand for major nutrients more particularly for nitrogen. Besides, contradictory reports have appeared with respect to solasodine content in this species collected from different areas. The range varies from as high a value as 5.4% (Maiti et al., 1964). A number of factors like the population characteristics, nutrition, age and vigour

of the plants could be responsible for the differences.

Preliminary observations on the distribution of S. khasianum in Meghalaya suggests that this species occurs on diverse soil types, such as at Cherrapunjee (55 km from Shillong) where the available calcium content in the soil is fairly high as compared to that in the soil at Shillong. Hence, a detailed study of growth yield and nutritional ecology of this species with respect to these two populations were undertaken.

#### METHODS OF STUDY

Sand culture experiments were set up using plastic pots of 12 cm diameter. Sand and pots were prepared using the procedure as suggested by Hewitt (1966). Uniform seedlings of the two populations of S. khasianum from Cherrapunjee and Shillong raised on clean sand were transplanted to the sand culture pots. Plants were grown from April to October, 1978. All experiments were replicated five times.

After the seedlings were transplanted to the pots 100 ml of the appropriate nutrient solution was added to the pots every alternate day. Once in a week the sand in the pot was eluted thoroughly using tap water followed by distilled water. The experiments were performed in a net house covered with transparent polythene sheets; in order to protect the plants

from wind and dust. The plants were exposed to natural diurnal fluctuations of light, temperature and humidity.

The composition of the nutrient solution in ppm was basically the same as given by Hewitt (1966): calcium, 50 (calcium nitrate); sodium, 115 (sodium nitrate); potassium, 78 (potassium nitrate); magnesium, 37 (magnesium sulphate); nitrogen, 133 (in salts); phosphorus 41.3 (sodium dihydrogen orthophosphate); iron, 5 (ferrous sulphate); manganese 0.55 (manganus sulphate); zinc, 0.066 (zinc sulphate); boron, 0.37 (boric acid); copper 0.064 (copper sulphate); molybdenum 0.019 (ammonium molybdate).

In one experiment, six levels (2.5, 5, 10, 25, 50 and 100 ppm) of calcium were obtained by adding appropriate amount of calcium nitrate with compensatory changes in sodium nitrate. The levels of sodium were inversely proportional to calcium within a range of 170-57.5 ppm. pH of the solution in all cases was maintained at 6.5.

In another experiment, plants were grown at three levels of nitrogen, 63, 98 and 133 ppm by altering the amount of sodium nitrate in the nutrient solution, without any compensatory change in any other nutrients. pH of the nutrient solution was maintained at 6.5.

Phosphorus levels were varied in another experiment by

altering the amount of sodium ortho-phosphate without any compensatory changes in any other nutrients. Three levels of phosphorus of 4.13, 41.3 and 123.9 ppm were maintained at pH 5.

In the fourth experiment three potassium levels were maintained at 7.8, 78 and 234 ppm by varying the amount of potassium nitrate. Uniform levels of nitrogen were maintained in all these three treatments by varying the amount of sodium nitrate in the medium. pH was adjusted to 6.5.

After recording the various growth parameters the harvested plant tissue was dried and analysed for different elements. Nitrogen was determined by micro-Kjeldahl method and total phosphorus was determined colorimetrically by phospho-molybdate blue method (Piper, 1944). Calcium and Potassium were determined after dry ashing of the shoot material and following the procedures outlined by Allen (1974), thus potassium was determined flame photo-metrically and calcium by EDTA titration method.

Alkaloid concentration was measured colorimetrically (Crusenna et al., 1965) which involved extraction of the dry powdered berries with a mixture of alcohol, acetic acid and water and finally bringing the glycoalkaloid in solution after precipitation and purification.

Soil samples were collected from Shillong and Cherrapunjee from a depth of 15 - 20 cm. pH of the soil was determined electrometrically using fresh soil samples. The air dried soil samples were ground and sieved through a 2.54 mesh. Chemical analyses of the soil samples were done by standard procedures as outlined by Jackson (1958) and Allen (1974). Total nitrogen was determined by Kjeldahl method and available phosphorus was determined colorimetrically using phospho-molybdate blue-method. Exchangeable potassium and calcium were extracted by leaching the soil with normal ammonium acetate at pH 7. Potassium was estimated flame photometrically and calcium was determined by EDTA titration method, using Eriochrome Black T.

## RESULTS

### Soil:

The soil from the two localities, Shillong and Cherrapunjee differed considerably in their chemical composition. While the pH of Shillong soil was quite acidic, the Cherrapunjee soil was close to neutrality. Nitrogen and available phosphorus levels in the Shillong soil was higher as compared to the Cherrapunjee soil. However, the Cherrapunjee soil had significantly higher levels of exchangeable calcium and potassium than that found in the Shillong soil (Tab. 4.1).

Table 4.1. Analysis of the soil from the two localities where the populations of S. khasianum grow

| Locality     | pH           | N(%)          | P(ppm)         | Exchangeable bases<br>(m.e. %) |               |
|--------------|--------------|---------------|----------------|--------------------------------|---------------|
|              |              |               |                | Ca                             | K             |
| Shillong     | 5.2<br>±0.18 | 0.21<br>±0.04 | 23.42<br>±5.81 | 2.13<br>±0.36                  | 0.26<br>±0.03 |
| Cherrapunjee | 6.8<br>±0.16 | 0.13<br>±0.06 | 18.26<br>±7.35 | 5.39<br>±1.21                  | 0.87<br>±0.08 |

Effect of varied calcium levels on the two populations of  
S. khasianum:

The dry weight increased in both the populations with the increase in calcium content in the medium upto 50 ppm level, beyond which it tended to decline. At 50 ppm calcium level dry weight yield by the Cherrapunjee population was significantly higher as compared to the Shillong population. On the other hand, at lower calcium levels of 5 and 10 ppm, the yield of the Shillong population was significantly higher as compared to that of the Cherrapunjee population.

While the root yield of the Shillong population reached a maximum value at 25 ppm level, that for the Cherrapunjee population was attained at 50 ppm level. Significantly low levels of root yield for the Cherrapunjee population was observed only at 2.5 and 25 ppm levels of calcium.

Shoot/root ratio did not follow any particular pattern for the two populations at different calcium levels. At 50 and 100 ppm levels of calcium the Cherrapunjee population showed significantly higher shoot by root ratio, whereas the reverse was the case at 5 and 10 ppm levels of calcium.

Calcium levels in the plant tissue increased in the Shillong population with increase in calcium concentration in

the medium from 2.5 to 50 ppm, beyond which it tended to decline. However, this was not significantly affected for the Cherrapunjee population at different calcium levels. Calcium levels in the plant tissue was significantly higher in the Shillong population as compared to the Cherrapunjee population only at 25 and 50 ppm calcium level in the medium. (Tab. 4.2).

In the case of the Shillong population fruit yield increased with increase in the calcium level of the medium upto 50 ppm, while at 100 ppm the yield decline. The yield of the Cherrapunjee population was maximum at 100 ppm level of calcium. At all levels it was not significantly affected. Shillong population had a higher fruit yield at 25 and 50 ppm calcium levels as compared to the Cherrapunjee population. However, the Cherrapunjee population had a higher fruit yield at 2.5 and 5 ppm calcium level, as compared to the Shillong population. At 100 ppm level of calcium, fruit yield of the two population was not significantly different.

Solasodine concentration in the case of the Shillong population was not significantly affected though maximum values were obtained at 50 and 100 ppm levels of calcium. For the Cherrapunjee population, solasodine concentration was generally higher at calcium levels beyond 10 ppm. Further, significantly higher concentration of solasodine was obtained for the Cherrapunjee population compared to the Shillong population

Table 4.2. Effect of varied levels of calcium on the growth and calcium content in the two populations of S. khasianum

|                          | Population   | Levels of Calcium (ppm) |       |       |       |       | L.S.D<br>P=0.05 |     |
|--------------------------|--------------|-------------------------|-------|-------|-------|-------|-----------------|-----|
|                          |              | 2.5                     | 5     | 10    | 25    | 50    | 100             |     |
| Shoot yield<br>(g)/plant | Shillong     | 25.57                   | 29.10 | 32.02 | 35.95 | 35.22 | 34.54           | 2.0 |
|                          | Cherrapunjee | 24.85                   | 26.32 | 30.35 | 34.07 | 39.85 | 38.81           |     |
| Root yield<br>(g)/plant  | Shillong     | 7.85                    | 8.07  | 7.81  | 10.65 | 9.75  | 9.43            | 1.1 |
|                          | Cherrapunjee | 5.35                    | 7.83  | 8.41  | 9.62  | 10.60 | 9.39            |     |
| Shoot/root<br>ratio      | Shillong     | 3.51                    | 4.85  | 4.53  | 3.54  | 3.87  | 3.72            | 0.6 |
|                          | Cherrapunjee | 4.84                    | 3.73  | 3.75  | 3.81  | 4.08  | 4.36            |     |
| Calcium<br>%             | Shillong     | 1.26                    | 1.44  | 1.50  | 1.61  | 1.62  | 1.44            | 0.2 |
|                          | Cherrapunjee | 1.32                    | 1.38  | 1.34  | 1.40  | 1.38  | 1.38            |     |

Table 4.3. Effect of Calcium on solasodine percentage and yield in the two populations of S. khasianum

| Population                         | Levels of calcium (ppm) |       |       |       |       |       | L.S.D<br>P = 0.05 |      |
|------------------------------------|-------------------------|-------|-------|-------|-------|-------|-------------------|------|
|                                    | 2.5                     | 5     | 10    | 25    | 50    | 100   |                   |      |
| Fruit yield<br>(g)/plant           | Shillong                | 1.05  | 1.02  | 1.43  | 3.49  | 5.10  | 3.46              | 1.42 |
|                                    | Cherrapunjee            | 3.26  | 3.26  | 3.63  | 3.94  | 3.06  | 4.28              |      |
| Solasodine<br>(%)                  | Shillong                | 0.503 | 0.518 | 0.578 | 0.491 | 0.637 | 0.638             | 0.26 |
|                                    | Cherrapunjee            | 0.660 | 0.563 | 0.833 | 0.832 | 0.900 | 0.835             |      |
| Solasodine<br>yield (mg)/<br>plant | Shillong                | 5.3   | 5.3   | 8.3   | 17.1  | 32.5  | 22.0              | 3.2  |
|                                    | Cherrapunjee            | 21.5  | 18.4  | 10.1  | 15.3  | 27.5  | 35.7              |      |

beyond 10 ppm levels of calcium.

Solasodine yield per plant increased at high calcium levels of 50 and 100 ppm in the case of both the populations. However this increase was more pronounced for the Shillong population compared to the other. At lower calcium levels of 2.5 and 5 ppm and at 100 ppm also, solasodine yield in the Cherrapunjee population was higher compared to the Shillong population (Tab. 4.3).

Effect of varied nitrogen levels on the two populations of S. khasianum:

The dry weight yield of shoot of both the populations increased significantly with increase in the nitrogen level in the medium and this was more pronounced for the Shillong population. A significant difference between the two populations was noted only at 133 ppm level of nitrogen where the Shillong population gave higher yield.

The dry weight yield of root of both the populations increased significantly at the medium nitrogen level of 98 ppm and declined at 133 ppm level. The Shillong population consistently gave higher root yield compared to the Cherrapunjee population at all levels of nitrogen.

The shoot/root ratio was markedly higher for both the populations at 133 ppm level of nitrogen. Further at all

levels of nitrogen the ratio was significantly higher for the Cherrapunjee population compared to the other one.

Nitrogen level in the plant tissue of both the populations increased with increase in nitrogen level in the medium. This increase was more marked in the case of the Shillong population compared to the Cherrapunjee population. A significantly higher level of nitrogen was found in the Cherrapunjee population at 63 and 133 ppm levels of nitrogen (Tab. 4.4.).

Fruit yield of both the populations increased with increase in nitrogen level in the medium. However no significant differences were observed between the two populations with respect to fruit yield at varied levels of nitrogen in the medium.

While solasodine concentration of Shillong population increased with increase in nitrogen level and remained almost at the same level at 98 and 133 ppm levels of nitrogen, that of the Cherrapunjee population increased significantly at 98 ppm level followed by a significant decline at 133 ppm level. A significantly higher solasodine concentration was observed for the Shillong population at 133 ppm level of nitrogen only. At other levels, no significant differences were noted between the two populations.

At 98 ppm level of nitrogen, the Shillong population showed a significant increase in solasodine yield over that at 63 ppm

Table 4.4. Effect of varied levels of nitrogen on the growth and nitrogen content in the two populations of S. khasianum

|                          | Population   | Nitrogen levels (ppm) |       |       | L.S.D<br>P = 0.05 |
|--------------------------|--------------|-----------------------|-------|-------|-------------------|
|                          |              | 63                    | 98    | 133   |                   |
| Shoot yield<br>(g)/plant | Shillong     | 29.39                 | 36.13 | 45.83 | 2.85              |
|                          | Cherrapunjee | 30.24                 | 33.88 | 40.72 |                   |
| Root yield<br>(g)/plant  | Shillong     | 9.24                  | 12.81 | 10.25 | 1.02              |
|                          | Cherrapunjee | 8.12                  | 11.25 | 9.32  |                   |
| Shoot/root<br>ratio      | Shillong     | 3.23                  | 3.0   | 4.51  | 0.14              |
|                          | Cherrapunjee | 3.75                  | 3.20  | 4.71  |                   |
| Nitrogen<br>(%)          | Shillong     | 3.116                 | 3.864 | 4.122 | 0.413             |
|                          | Cherrapunjee | 3.526                 | 3.813 | 4.816 |                   |

Table 4.5. Effect of varied levels of nitrogen in solasodine content and yield in the two populations of S. khasianum

|                                    | Population   | Levels of nitrogen (ppm) |       |        | L.S.D<br>P = 0.05 |
|------------------------------------|--------------|--------------------------|-------|--------|-------------------|
|                                    |              | 63                       | 98    | 133    |                   |
| Fruit yield<br>(g)                 | Shillong     | 1.22                     | 3.57  | 4.24   | 1.08              |
|                                    | Cherrapunjee | 1.51                     | 3.21  | 4.62   |                   |
| Solasodine<br>(%)                  | Shillong     | 0.682                    | 0.843 | 0.849  | 0.17              |
|                                    | Cherrapunjee | 0.623                    | 0.946 | 0.6052 |                   |
| Solasodine<br>yield (mg)/<br>plant | Shillong     | 16.3                     | 31.6  | 35.9   | 12.0              |
|                                    | Cherrapunjee | 24.1                     | 30.3  | 27.9   |                   |

level. At 133 ppm nitrogen level the yield was about the same as at 98 ppm level. The yield of the Cherrapunjee population at varied nitrogen levels was however not significantly affected. (Tab. 4.5).

Effect of varied phosphorus levels on the two populations of S. khasianum :

The dry weight yield of shoot of both the populations increased significantly at 41.3 ppm levels of phosphorus and declined significantly at 123.9 ppm level. No significant differences were observed between the two populations in any of the phosphorus treatments.

Both the Shillong and the Cherrapunjee populations behaved in a similar way with regard to root dry weight yield as that observed for shoot yield.

The shoot/root ratio of both the Shillong and the Cherrapunjee populations decreased with increase in the level of phosphorus in the medium. A significantly higher shoot by root ratio in the Cherrapunjee population was observed only at the highest level of phosphorus (Tab. 4.6).

Solasodine concentration declined significantly at 123.9 ppm level of phosphorus, compared to the lower levels, in both the populations. A significantly higher concentration of sola-

Table 4.6. Effect of varied levels of phosphorus on the growth and phosphorus content in the two populations of S. khasianum

| Population          |              | Levels of phosphorus (ppm) |       |       | L.S.D<br>P = 0.05 |
|---------------------|--------------|----------------------------|-------|-------|-------------------|
|                     |              | 4.13                       | 41.3  | 123.9 |                   |
| Shoot yield<br>(g)  | Shillong     | 32.14                      | 35.96 | 30.26 | 2.7               |
|                     | Cherrapunjee | 31.87                      | 36.17 | 29.85 |                   |
| Root yield<br>(g)   | Shillong     | 9.32                       | 11.80 | 10.21 | 1.2               |
|                     | Cherrapunjee | 8.14                       | 10.36 | 9.25  |                   |
| Shoot/root<br>ratio | Shillong     | 3.6                        | 3.0   | 2.66  | 0.5               |
|                     | Cherrapunjee | 3.91                       | 3.49  | 3.39  |                   |
| Phosphorus<br>(%)   | Shillong     | 0.32                       | 0.34  | 0.39  | 0.1               |
|                     | Cherrapunjee | 0.31                       | 0.36  | 0.35  |                   |

Table 4.7. Effect of various levels of phosphorus on solasodine content and yield in the two populations of S. khasianum

|                                | Population   | Levels of phosphorus (ppm) |       |       | L.S.D    |
|--------------------------------|--------------|----------------------------|-------|-------|----------|
|                                |              | 4.1                        | 41.3  | 123.9 | P = 0.05 |
| Fruit yield<br>(g)/plant       | Shillong     | 4.81                       | 3.44  | 3.12  | 0.1      |
|                                | Cherrapunjee | 1.65                       | 3.18  | 2.06  |          |
| Solasodine<br>%                | Shillong     | 0.815                      | 0.925 | 0.495 | 0.21     |
|                                | Cherrapunjee | 0.621                      | 0.615 | 0.435 |          |
| Solasodine yield<br>(mg)/plant | Shillong     | 14.7                       | 31.8  | 15.5  | 8.0      |
|                                | Cherrapunjee | 10.2                       | 19.5  | 8.9   |          |

sodine was observed at low phosphorus levels only.

Solasodine yield of both the populations improved significantly at 41.3 ppm level of phosphorus compared to 4.13 ppm level of phosphorus. A significantly higher level of solasodine yield was observed in the case of the Shillong population at 41.3 and 123.9 ppm levels of phosphorus (Tab. 4.7).

Effect of varied potassium levels on the two populations of S. khasianum:

The dry weight yield of shoot of both the populations increased with increase in potassium level in the medium. A significantly higher yield for the Shillong population compared to the other was observed at 78 ppm potassium level, while at other levels of potassium, the yield was not significantly different.

The root yield increased with increase in potassium level in the medium in the case of both the populations and this was more pronounced in the case of the Shillong population. While at 78 ppm potassium level the Shillong population showed a higher root yield than that of the Cherrapunjee population, at 234 ppm level the root yield of the Cherrapunjee population was significantly higher as compared to the other.

The shoot by root ratio of both the populations increased with increase in potassium level in the medium. However no

Table 4.8. Effect of varied levels of potassium on the growth and potassium content in the two populations of S. khasianum

|                     | Population   | Levels of potassium (ppm) |       |       | L.S.D<br>P = 0.05 |
|---------------------|--------------|---------------------------|-------|-------|-------------------|
|                     |              | 7.8                       | 78    | 234   |                   |
| Shoot yield<br>(g)  | Shillong     | 27.15                     | 33.97 | 37.59 | 2.31              |
|                     | Cherrapunjee | 25.79                     | 29.76 | 37.19 |                   |
| Root yield<br>(g)   | Shillong     | 6.80                      | 12.38 | 15.15 | 2.41              |
|                     | Cherrapunjee | 6.44                      | 9.57  | 18.55 |                   |
| Shoot/root<br>ratio | Shillong     | 4.09                      | 2.74  | 2.46  | 0.103             |
|                     | Cherrapunjee | 4.06                      | 3.10  | 2.58  |                   |
| Potassium %         | Shillong     | 0.36                      | 0.61  | 0.68  | 0.108             |
|                     | Cherrapunjee | 0.28                      | 0.58  | 0.63  |                   |

Table 4.9. Effect of varied levels of potassium on solasodine content and yield in the two populations of S. khasianum

|                                    | Population   | Levels of potassium (ppm) |        |        | L.S.D<br>P = 0.05 |
|------------------------------------|--------------|---------------------------|--------|--------|-------------------|
|                                    |              | 7.8                       | 78     | 234    |                   |
| Fruit yield<br>(g)                 | Shillong     | 1.26                      | 2.31   | 4.20   | 0.125             |
|                                    | Cherrapunjee | 0.85                      | 4.16   | 4.34   |                   |
| Solasodine<br>%                    | Shillong     | 0.6521                    | 0.8326 | 0.8453 | 0.206             |
|                                    | Cherrapunjee | 0.5684                    | 0.8235 | 0.8326 |                   |
| Solasodine<br>yield (ng)/<br>plant | Shillong     | 16.2                      | 17.7   | 35.4   | 8.0               |
|                                    | Cherrapunjee | 12.8                      | 34.2   | 36.1   |                   |

significant differences were discernible between the two populations (Tab. 4.8).

In general fruit yield of both the populations increased with increase in potassium level in the medium, however, no significant differences were observed between the two populations in any of the treatments.

Solasodine concentration in the case of the Shillong population increased at higher potassium levels, though this was not significant at 5% level of probability. However the concentration in the case of Cherrapunjee population increased significantly at the higher levels of 78 and 234 ppm potassium, compared to 7.8 ppm level. No significant differences could be noted between the two populations in any of the treatments.

Solasodine yield of both the populations increased significantly at 234 ppm level of potassium compared to the lower levels, in the case of the Shillong population whereas such an increase could be noted even at 78 ppm level, in the case of the Cherrapunjee population. A significantly higher solasodine yield for the Cherrapunjee population could be observed only at 78 ppm level of potassium (Tab. 4.9).

#### DISCUSSION

In nature, populations of S. khasianum often occupy very

diverse habitats. One of the main differences between the two soil types is with respect to available calcium in the soil. Cherrapunjee soil being derived from calcareous parent material has a pH close to neutrality and a high available calcium while Shillong soil is quite acidic and with a low available calcium status. Moreover, these two substrates differ not only with respect to available calcium but also on account of other nutrients like nitrogen and potassium and to some extent phosphorus. Thus, the non-calcareous soil at Shillong had higher nitrogen and slightly higher phosphorus status though potassium level was significantly lower. Even otherwise, the availability of these nutrients are likely to be widely different in calcareous and non-calcareous soils as suggested by Ramakrishnan and Gupta (1973) and Kapoor and Ramakrishnan (1974) because of high pH and saturation of exchange complex with calcium, in the former soil type.

Calcium has been implicated as an important factor for population differentiation at subspecific level since long (Ramakrishnan, 1958, 1960, 1961, 1965a, b, 1968a, b, 1969, 1970, 1971; Ramakrishnan and Singh, 1966; Kapoor and Ramakrishnan, 1974). Since the calcareous and non-calcareous soil types differ from each other, primarily with respect to available calcium level this factor has a direct role in the restriction of calcicoles and calcifuges. Thus, the studies of Ramakrishnan and his co-workers (cited above) and Snaydon and Bradshaw (1961) have

shown that response of populations of closely related species from contrasting habitats are related to calcium tolerance. In the present case, the Cherrapunjee population of S. khasianum was found to respond more favourably to increase in calcium level of the soil compared to the Shillong population. In fact, at very high calcium levels the shoot yield of the Cherrapunjee population was significantly higher.

Snaydon and Bradshaw (1961) in the case of Festuca ovina and Ramakrishnan (1969) in the case of Hypericum perforatum showed poor rooting ability of the calcareous populations. Such a behaviour of the calcareous population at low calcium levels may influence nutrient absorptive ability, thus restricting growth of this population in non-calcareous soils. The present results confirm this where the Cherrapunjee population of S. khasianum showed significantly lower rooting at 2.5 ppm level of calcium compared to the other.

Greater selectivity in the absorption of calcium was recorded for the calcareous populations in the case of a number of studies (Ramakrishnan, 1968a, 1969, 1971) and this selectivity was implicated to explain the generally low calcium level in the plant tissue of calcicoles, which became very obvious only at calcium levels between 10 to 50 ppm in the present case. According to this argument, calcifuges are able to accumulate sufficient calcium from even a calcium poor soil while at very high calcium

levels in the medium they accumulate too much of it often at the expense of other cations (Jefferies and Willis, 1964).

There is a close correlation between the behaviour of the two populations and the nitrogen status of the two soil types in which they grow. Thus the Shillong population which naturally occurred in a higher nitrogen status soil, responded better to increased nitrogen level in the medium compared to the other, though both showed increased shoot yield at higher nitrogen levels. In fact, both at 98 and 133 ppm levels of nitrogen the yield of the Shillong population was significantly higher than that of the Cherrapunjee population. This was reflected also with respect to root yield of both the populations where the Shillong population was more responsive than the other. Though fruit yield was not significantly different at different nitrogen levels in the case of two populations, the solasodine concentration showed a differential response in the case of the two in a way that the concentration of the Cherrapunjee population declined sharply at the very high nitrogen level. This, therefore, got reflected in the total solasodine yield of the two populations in response to nitrogen in such a way that the Shillong population gave better response to high nitrogen levels.

A number of workers have reported an increase in shoot/root ratio with increase in nitrogen level in the medium

(Black, 1957; Russel, 1961; Bradshaw et al., 1964), an observation similar to the present one both for the Shillong and the Cherrapunjee populations. However, Ramakrishnan and Gupta (1972, 1973) in the case of two closely related species of Argemone and in the case of the calcareous and non-calcareous populations of Cynodon dactylon have shown differential responses with respect to shoot/root ratio at different nitrogen levels and have concluded that this may not follow the general pattern as reported by other workers and shown during the present study. In fact, Chadwick and Obeid (1963) even suggested that nitrogen level might affect the shoot/root ratio of temperate and tropical plants in different ways.

The two populations showed a similar response to phosphorus levels in the medium with a significant decline in yield at very high phosphorus levels. Such a decline at high phosphorus levels may be indicative of mild phosphorus toxicity, also reported from crop species growing in acid soils (Rossiter, 1952; Bingham et al., 1958). The significantly higher toxicity response of the Cherrapunjee population of S. khasianum compared to the Shillong population is indicative of the lower susceptibility of the former which naturally grows in a soil where phosphorus availability may be limited due to unbalanced chemical nature of the soil. It may be noted that phosphorus in a calcareous soil probably remains unavailable due to the formation of relatively insoluble calcium phosphate. Hence greater

fluctuations in the availability of this nutrient is to be expected in a non-calcareous rather than a calcareous soil (Ramakrishnan and Gupta, 1973). Such a differential response to phosphorus toxicity has also been reported in populations of Cynodon dactylon (Ramakrishnan and Gupta, 1973; Gupta and Ramakrishnan, 1977). This susceptibility of the Cherrapunjee population to phosphorus toxicity is also reflected in the fruit yield of the Cherrapunjee population which was more adversely affected at very high phosphorus level.

The response of the two populations with regard to shoot yield was not very different, though the root yield of the Shillong population tended to be higher at low potassium level (78 ppm) and the reverse being true at 234 ppm level of potassium. Increase in potassium level also favoured fruit production, solasodine concentration of the berries and the consequent yield of solasodine.

In the case of S. khasianum it is evident, on the basis of what is described above, that there are at least two edaphic ecotypes differentiated on the basis of calcium and other related changes in nutrient availability as seen from the behaviour of the two populations from Shillong and Cherrapunjee.

Maiti et al (1965) reported a very high level of solasodine concentration (3.2%) for the population of S. khasianum collected

from Cherrapunjee. The present results do not confirm this but indicate that the concentration in any case does not exceed 0.94% on dry weight basis. This is not very high from the maximum of 0.92% obtained here for the Shillong population. In other words, while definite evidences are available for differences in population from Shillong and Cherrapunjee, the solasodine concentration and yield are dependent upon the nutrient status of the medium which, of course, may result in a differential behaviour.

#### SUMMARY

Differential response of natural populations to calcium nutrition has received considerable attention mainly due to the interest in calcicole-calcifuge problem in plants. A differential response to nitrogen, phosphorus, potassium and calcium was observed for the two populations of Solanum khasianum Clarke naturally occurring at Shillong and Cherrapunjee. The soil nutrient status of these two sites differed considerably specially with respect to calcium content. The Cherrapunjee population of S. khasianum was found to respond more favourably at higher calcium level in the medium as compared to the Shillong population, which could be related to the calcium tolerance of the calcareous population. A close correlation was observed between the behaviour of the two populations and the nitrogen of the two soil types in which they

grow. Thus, the Shillong population which naturally occur in a higher nitrogen status soil responded better to increased nitrogen level as compared to the other. The two populations showed a differential response to phosphorus levels in the medium. The significantly higher toxicity response of the Cherrapunjee population compared to the Shillong population is indicative of the lower susceptibility of the former which naturally grows in a calcareous soil. The growth response of the two populations with regard to potassium nutrition was not very different. The increase in potassium level favoured fruit production, solasodine concentration and yield. The solasodine concentration and yield in this species are dependent upon the nutrient status of the medium, which of course, may result in a differential behaviour.

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**CHAPTER V**

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INTRODUCTION TRIAL AND GROWTH PERFORMANCE OF SOLANUM LACINIATUM AIT. AND S. AVICULARE FORST. AT DIFFERENT ALTITUDES IN MEGHALAYA.

INTRODUCTION

Solanum laciniatum Ait. and S. aviculare Frost. are endemic to the Australian region, confined to the mesic areas of eastern and southern Australia (Randell and Symon, 1976). Both the species had been under investigation for a number of years, in Russia (Sinicin, 1963), in New Zealand (Fryer, 1972), in India (Kapoor and Kapoor, 1965; Sastry, 1973). Besides these two species, many other Solanum species were suggested as commercial sources of solasodine (Schreiber, 1974) but in those species glycoalkaloid mainly occurs in the fruits, often causing practical difficulties in harvesting the crop. In S. laciniatum and S. aviculare, however, a moderately high level of solasodine occurs in the vegetative parts of the plant (Lancaster and Mann, 1975) and could be harvested with minimum efforts.

Germination of the seeds of S. laciniatum and S. aviculare has been reported to be slow and erratic under field condition (Foldesi, 1964; Fryer, 1972; Sudiatso et al., 1974). The slow and erratic nature of germination is a serious obstacle in the cultivation of these crops (Porter and Glimore, 1976).

The possibilities of introducing S. laciniatum in the plains of north-eastern India was studied earlier at Regional Research Laboratory, Jorhat (Bordoloi et al., 1976). During the present study apart from working out the germination requirements of these two species, an attempt was also made to explore the possibilities of successful introduction and cultivation of these two species, by growing them at different altitudes in Meghalaya.

#### CLIMATE

The climate of Burnihat and Umsaw is characterized by seasonality of rainfall. The rainy season extends from May to September, when about 90% of the average annual rainfall occurs. This period is also characterized by high humidity.

At Burnihat during this season the average maximum temperature was 33.5°C and the average minimum was 23.3°C. At Umsaw the average maximum temperature during the season was 32.6°C and the average minimum was 22.4°C. There was a mild winter at these two places during December to February. During this period the average maximum temperature at Burnihat was 27.8°C and average minimum was 14°C and at Umsaw the average maximum temperature during this season was 25°C and the average minimum was 13°C.

Shillong has a monsoonic climate with annual rainfall of

about 2150mm. The rainy season extends from May to September. This period is also characterized by high humidity. At Shillong during this season the average maximum temperature was 22.5°C and the average minimum temperature was 16°C. However, winter in Shillong is severe and extends from November to February with an average maximum temperature of 17°C and average minimum of 11.2°C. March and April are dry and comparatively warm months with an average maximum temperature of 20.2°C and average minimum of 13.5°C (Fig. 5.1.)

#### METHODS OF STUDY

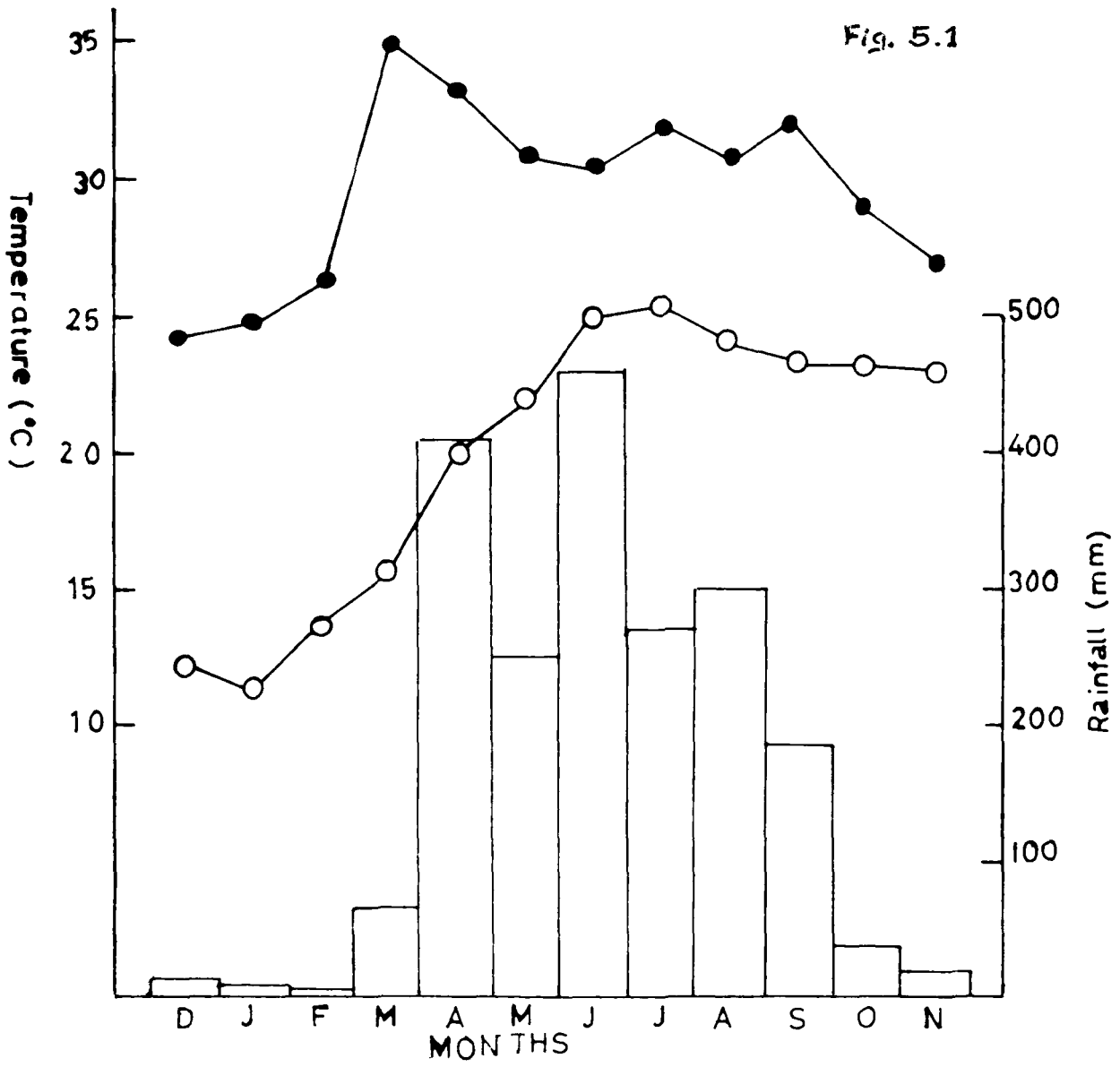
Seeds of S. laciniatum and S. aviculare were tested for germination in petri-dishes on moist Whatman filter paper over a thin layer of cotton wool. Three replicates each with 100 seeds were done for each treatment. Germination tests were concluded after 45 days.

(i) Germination tests at 15°C constant temperature and 15°/25°C alternating temperature were done under two light regimes using four months' old seeds. The seeds were either germinated under total darkness or were subjected to 8 hrs. light and 16 hrs. darkness. In the alternating temperature regime the light period coincided with low temperature treatment.

(ii) In another experiment seeds after different storage period were placed in dark at three constant temperature regimes of 15°C,

**Fig. 5.1. Ombrothermic diagram for Umsaw (1977-1979).**

Fig. 5.1



20°C and 25°C and three alternating temperature regimes of 15°/25°C, 20°/25°C and 20°/30°C. The seeds were kept at higher temperature for 16 hrs. and at lower temperature for 8 hrs.

Individuals of both S. laciniatum and S. aviculare were raised in 1977 at Shillong, using the seeds obtained from New Zealand. Uniform shoots obtained out of the cuttings made from young branches were planted in polythene sleeves (30 x 10 cm) filled with equal portions of soil and farmyard manure. After noting the rooting pattern of these cuttings, after eight weeks under Shillong condition at an average outside temperature regime of 15°/22°C, the rooted shoots were transplanted at three sites over an altitudinal gradient at - (i) Burnihat (100 m), (ii) Umsaw (550 m) and (iii) Shillong (1500 m), during December 1978. Growth measurements were taken at Burnihat and at Umsaw after six weeks of planting as the plants made very poor growth. Only at Shillong observations were made after one year of growth period. All the experiments were replicated 10 times.

Solasodine concentration of the plant material was measured colorimetrically (Crusenna et al., 1965) which involved extraction of the dry powdered leaves with a mixture of alcohol, acetic acid and water and finally bringing the glycoalkaloid into solution after precipitation and purification.

Soil samples from different sites (10 replicates) were collected from a depth of 10 - 20 cm. pH of the soil was determined electrometrically using fresh soil samples. The air dried soil samples were ground and sieved and stored for chemical analysis. The chemical analyses of the soil samples were done by standard procedures as outlined by Jackson (1958) and Allen (1974). Total nitrogen was determined by Kjeldahl method and available phosphorus was determined colorimetrically, using phosphomolybdate blue method. Exchangeable potassium, calcium and magnesium were extracted by leaching the soil with 1N ammonium acetate at pH 7. Potassium was estimated flame-photometrically. Calcium and magnesium were determined by EDTA titration method using Eriochrome Black-T and Patten and Reader's reagent as two indicators.

## RESULTS

### Soil:

The soil in all the sites were acidic in nature, with a pH range of 5.4 to 5.8. Nitrogen, phosphorus and calcium content were significantly higher in Umsaw soil as compared to the other two sites. Soil in Burnihat was in general poor in nutrients, except it had a slightly higher phosphorus content than that from Shillong (Table 5.1).

Table 5.1. Analysis of the soil from different localities  
at different altitudes

| Locality | pH           | N(%)          | P(ppm)         | Exchangeable bases |               |               |
|----------|--------------|---------------|----------------|--------------------|---------------|---------------|
|          |              |               |                | Ca                 | (m.e. %)<br>K | Mg            |
| Shillong | 5.4<br>±0.16 | 0.18<br>±0.05 | 18.61<br>±4.92 | 0.23<br>±0.06      | 0.47<br>±0.04 | 0.31<br>±0.03 |
| Umsaw    | 5.8<br>±0.14 | 0.21<br>±0.07 | 29.52<br>±3.21 | 0.21<br>±0.09      | 0.54<br>±0.07 | 0.26<br>±0.05 |
| Burnihat | 5.7<br>±0.14 | 0.13<br>±0.03 | 21.44<br>±6.05 | 0.16<br>±0.04      | 0.38<br>±0.02 | 0.29<br>±0.06 |

**Seed germination:**

Both the species behaved in a similar manner with respect to light requirements for germination. Thus germination was very poor under total darkness, at a constant temperature of 25°C. Under alternating temperature regime of 15°/25°C, however, germination was somewhat higher under light condition; whereas it improved markedly in total darkness compared to that under constant temperature conditions (Table 5.2).

Germination of the seeds of both the species improved with storage. Further, germinability of the seeds of both the species were higher under alternating temperature regimes than at constant temperature. Of all the three alternating temperature regimes tried a wider fluctuation with lower temperatures was found to be optimum for seed germination (Table 5.3).

**Growth yield:**

The cuttings from young and mature branches raised at Shillong showed after eight weeks that rooting was markedly lower in mature shoots than for young ones (Table 5.4).

Growth performance of both S. laciniatum and S. aviculare were very poor under Burnihat and Umsaw condition. The individual of both the species showed stunted growth, and the leaves became chlorotic within a few weeks of their introduction to the field at these two sites. Therefore, at these two sites plants were

Table 5.2. Seed germination (%) of S. laciniatum and S. aviculare at different temperature regimes under light and dark conditions.

| Species              | Light conditions | Temperature (°C) |             |
|----------------------|------------------|------------------|-------------|
|                      |                  | 25               | 15/25       |
| <b>S. laciniatum</b> | Light/Dark       | 72.3 ± 11.4      | 87.6 ± 9.8  |
|                      | Total dark       | 12.5 ± 2.1       | 63.3 ± 9.2  |
| <b>S. aviculare</b>  | Light/Dark       | 68.6 ± 12.5      | 76.4 ± 13.6 |
|                      | Total dark       | 5.2 ± 2.3        | 64.7 ± 10.4 |

**Table 5.3. Germination (%) of *S. laciniatum* and *S. aviculare* at different temperature regimes after different storage periods.**

| Species              | Storage period (weeks) | Temperature (°C) |              |              |               |               |               |
|----------------------|------------------------|------------------|--------------|--------------|---------------|---------------|---------------|
|                      |                        | 15               | 20           | 25           | 15/25         | 20/25         | 20/30         |
| <i>S. laciniatum</i> | 8                      | 4.8<br>±1.7      | 5.6<br>±2.8  | 8.5<br>±3.2  | 68.5<br>±13.2 | 25.3<br>±3.4  | 22.7<br>±5.1  |
|                      | 24                     | 10.2<br>±2.1     | 8.7<br>±3.2  | 15.7<br>±3.8 | 72.1<br>±9.7  | 41.8<br>±12.3 | 38.2<br>±8.7  |
|                      | 52                     | 18.4<br>±3.5     | 29.3<br>±6.2 | 27.2<br>±4.3 | 86.2<br>±11.0 | 46.5<br>±9.5  | 42.1<br>±12.2 |
| <i>S. aviculare</i>  | 8                      | 0                | 2.8<br>±1.4  | 7.8<br>±2.8  | 34.5<br>±6.7  | 21.3<br>±4.5  | 25.6<br>±5.9  |
|                      | 24                     | 0                | 5.2<br>±2.3  | 13.2<br>±3.5 | 57.1<br>±8.3  | 35.7<br>±10.3 | 27.8<br>±6.5  |
|                      | 52                     | 0                | 18.5<br>±5.1 | 28.4<br>±5.8 | 94.3<br>±13.4 | 64.5<br>±11.2 | 38.2<br>±12.6 |

**Table 5.4.** Effect of stem maturity on rooting of S. laciniatum and S. aviculare cuttings.

| Species              | Rooted cuttings (%) |       |
|----------------------|---------------------|-------|
|                      | Mature              | Young |
| <u>S. laciniatum</u> | 11.2                | 88.6  |
| <u>S. aviculare</u>  | 18.5                | 76.4  |

Table 5.5. Growth yield of *S. laciniatum* and *S. aviculare* at three altitudes in Meghalaya

| Growth parameters          | <i>S. laciniatum</i> |             |            | <i>S. aviculare</i> |            |            |
|----------------------------|----------------------|-------------|------------|---------------------|------------|------------|
|                            | Shillong             | Umsew       | Burnihat   | Shillong            | Umsew      | Burnihat   |
| Shoot height (cm)          | 88.4 ± 18.2          | 38.5 ± 11.2 | 40.2 ± 8.3 | 69.5 ± 9.4          | 42.6 ± 6.8 | 34.3 ± 7.9 |
| Shoot yield (g)/plant      | 154.9 ± 21.3         | 14.5 ± 2.8  | 12.2 ± 3.5 | 143.6 ± 26.3        | 10.6 ± 3.9 | 13.8 ± 5.4 |
| Root yield (g)/plant       | 26.8 ± 9.2           | 4.5 ± 1.3   | 3.9 ± 0.73 | 13.7 ± 8.3          | 4.2 ± 0.78 | 3.9 ± 0.67 |
| Leaf yield (g)/plant       | 34.5 ± 6.2           | 3.8 ± 0.66  | 4.8 ± 0.89 | 29.3 ± 8.5          | 2.7 ± 0.44 | 3.4 ± 0.71 |
| Solasodine (%)             | 0.39                 | -           | -          | 0.45                | -          | -          |
| Solasodine yield (g)/plant | 0.134                | -           | -          | 0.121               | -          | -          |

harvested after five weeks of growth. However, at Shillong both the species gave good growth yield. In general, the growth performance of S. laciniatum was better as compared to that of S. aviculare. However, solasodine concentration was higher in S. aviculare, though solasodine yield was higher in S. laciniatum (Table 5.5).

#### DISCUSSION

Seed germination is a critical phase in the establishment of any species (Clapham, 1956; Ramakrishnan, 1963). Light and temperature are two critical factors often implicated for controlling the germinability of the seeds (Ramakrishnan, 1961). In the present case both Solanum laciniatum Ait. and S. aviculare Frost. seem to be adapted to low alternating temperature regimes, with better germination in light than in darkness. Similar results with alternating temperature regimes were also reported by Wakhloo (1964), while working with germination behaviour of Solanum nigrum and S. xanthocarpum. Similar observation was also made by Ramakrishnan and Khosla (1971) in the case of Digitaria adscendens.

Both S. laciniatum and S. aviculare received similar management at all the three sites. Though the soil nutrient status of the three sites were slightly different, no important nutritional factor could be limiting plant growth. The differences in the

growth yield of both the species at lower and higher altitudes are likely to be related to the climatic differences, with temperature as the determining factor for differences in growth. These two temperate species native to New Zealand (Crush, 1973) obviously require lower temperature condition for their proper growth. The poor growth performance, and chlorotic appearance of the leaves of these two species may be at least partly due to the higher respiration rate as suggested by Cline et al. (1970), while working with altitudinal races of Mimulus lewisii. The present results are in contrast to the findings of Bordoloi et al. (1976) on the growth and yield of S. laciniatum under Jorhat condition, where seedling transplantation during November-December resulted in better growth as compared to that done during January-March. It may also possibly be related to the differences in the climatic conditions at the time when experiments were done at Jorhat. If this be so, then the growth performance of at least S. laciniatum may change from year to year depending upon fluctuations in climatic conditions.

Young stem cuttings of both S. laciniatum and S. aviculare readily produced roots while those from mature stems resulted in poor rooting and this supports the findings of Bordoloi et al. (1976).

Under Shillong condition though solasodine concentration

was slightly higher in the leaf tissue of S. aviculare than in S. laciniatum, the overall yield of solasodine was higher in S. laciniatum. This is due to higher dry matter production by the latter. The present results on solasodine concentration also gave lower values than that reported by Sastry (1973) at Jammu, Bordoloi et al. (1976) at Jorhat. However, it is interesting to note that in S. laciniatum considerable fluctuation in solasodine concentration occurred from year to year ranging anywhere between 0.65 to 1.5% at Jammu (Sastry, 1973) and 0.95 to 1.15% at Jorhat (Bordoloi et al., 1976). It may also be noted that Kapoor and Kapoor (1965) while working with S. aviculare at Jammu, reported 0.86% solasodine in this species. Besides, during the present growth studies at Shillong, the solasodine concentration was found to be not more than 0.40%. These variations may be due to various factors, such as period of cultivation, agro-climatic conditions and differences in cultural practices. Thus though, the growth of both S. laciniatum and S. aviculare were encouraging under Shillong condition, the solasodine yield was fairly low.

#### SUMMARY

Solanum khasianum Ait. and S. aviculare Forst. are two exotic species endemic to the Australian region. During the present study an attempt was made to explore the possibilities of successful introduction and cultivation of these two species,

by growing them at different altitudes in Meghalaya. Both the species seem to be adapted to low alternating temperature regimes, with better germination in light than in darkness. Young stem cuttings of both the species rapidly produced roots, while those from mature stems resulted in poor rooting. At higher altitude both the species gave good growth response while at lower altitudes very poor growth occurred. Though, soil nutrient status of the three altitudes were slightly different, no important nutritional factor could be limiting plant growth. The differences in the growth yield of both the species at lower and higher altitudes are likely to be related to the climatic differences, with temperature as the determining factor for differences in growth. Though, the growth of both the species were encouraging under the Shillong condition, the solasodine yield was fairly low.

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CHAPTER VI

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NITROGEN, PHOSPHORUS AND POTASSIUM NUTRITION OF  
SOLANUM LACINIATUM AIT. AND S. AVICULARE FORST.

INTRODUCTION

Solanum laciniatum Ait. and S. aviculare Forst. are two important solasodine yielding species native to New Zealand. Commercial cultivation of these species have been considered by different workers, in Russia (Sinicin, 1963), in New Zealand (Fryer, 1972) and in India (Kapoor and Kapoor, 1965; Sastry et al., 1973). The alkaloid occurs mainly in the leaves and fruits. The fruit has a higher solasodine content than leaves but constitutes a smaller proportion of the total biomass of the plant. Thus, the leaves of S. laciniatum and S. aviculare are more important from the commercial point of view (Mann and Lancaster, 1976). Further, considerable variation in alkaloid concentration have been reported in the literature. Geographic and climatic strains, cultural practices, all have been shown to affect alkaloid concentration (Mathe et al., 1964).

Published reports on the mineral nutrition of these two species are restricted to field fertilizer trials (Fryer, 1972; Crush, 1973; Bordoloi et al., 1976). In manurial trials in the field done at Jorhat, application of 40 kg of nitrogen per hectare of nitrogen was found to be optimum for growth and

yield of S. laciniatum (Bordoloi et al., 1976). Earlier studies have shown that mineral nutrients seem to influence alkaloid concentration more by influencing growth patterns than through any direct effects (Crush, 1973).

In another study on the nitrogen nutrition of Nicotiana and Solanum, it was shown that in the former species alkaloid concentration increased with the increase in nitrogen level in the medium, whereas that in Solanum it decreased indicating that all the plant species do not react in the same way to increased nitrogen fertilization; i.e. with an increase in alkaloid biosynthesis (Nowacki et al., 1975).

#### METHODS OF STUDY

Sand culture experiments were performed using plastic pots of 12 cm diameter and twenty days' old uniform sized seedlings of S. aviculare and S. laciniatum raised on nutrient free sand beds. Sand and pots were prepared using the procedure as suggested by Hewitt (1966). After the seedlings were transplanted to the pots, 100 ml of the appropriate nutrient solutions were added to the pots every alternate day. Once in a week the sand in the pot was eluted by using tap water followed by 500 ml of distilled water. All the experiments were replicated five times. Plants were allowed to grow for 10 weeks, between January to March 1980. The experiment was

performed in a glass house protected from wind and dust. The plants were exposed to natural diurnal fluctuations of light, temperature and humidity.

The composition of the nutrient solution was basically the same as that given by Hewitt (1966) except for the changes introduced for the levels of nitrogen, phosphorus and potassium (Ramakrishnan and Kumar, 1976). In the first experiment nitrogen was provided at 63, 98 and 133 ppm by varying the amount of  $\text{NaNO}_3$  in the nutrient solution, without any compensatory change in other salts. In the second experiment phosphorus was provided at 4.13, 41.3 and 123.0 ppm without any change in other nutrients. In another experiment three levels of potassium, 7.8, 78 and 234 ppm were obtained by varying the amount of  $\text{KNO}_3$ . In order to keep uniform nitrogen level in this series compensatory changes in the amount of  $\text{NaNO}_3$  was made.

In the nitrogen and potassium series of nutrient solutions pH was adjusted to 6.5, but in the phosphorus series pH was maintained at 5.0 as to avoid precipitation at higher phosphorus level. pH of the nutrient solution was adjusted using normal sulphuric acid and normal sodium hydroxide, and an appropriate amount of sodium sulphate was used to compensate for the addition of sulphuric acid (Ramakrishnan and Kumar, 1976).

Nitrogen in the leaf tissue was determined by the micro-Kjeldahl method and the total phosphorus was determined colorimetrically by the phospho-molybdate blue method, and potassium was determined Flame photometrically following the procedure outlined by Allen (1974). Alkaloid concentration was measured colorimetrically (Crusena et al., 1965) which involved extraction of dry powdered berries with a mixture of alcohol, acetic acid and water and finally bringing the glyco-alkaloid in solution after precipitation and purification.

## RESULTS

Effect of varied levels of nitrogen on S. laciniatum and S. aviculare:

In both S. laciniatum and S. aviculare dry weight yield of shoot and root increased with increase in the level of nitrogen in the medium. However, no significant differences were observed between the two species with respect to these two. Leaf yield also improved with increase in nitrogen level. However, the leaf yield in S. aviculare was significantly higher than that of S. laciniatum at 133 ppm level of nitrogen. In both the species shoot/root ratio increased with the increase in nitrogen level in the medium. Foliar nitrogen level improved with increase in nitrogen level in the medium in both the species. No significant differences were noticed between the

two species regarding the uptake of nitrogen in any of the treatments. While solasodine content in both the species improved slightly with increase in nitrogen level in the medium, this increase was not significant at 5% level of possibility. However, in all the treatments S. aviculare showed significantly higher level of solasodine content compared to the other species, though the differences were more pronounced at the highest level of nitrogen. Maximum solasodine yield was obtained at 98 ppm nitrogen level in S. laciniatum, while in S. aviculare this was obtained at highest level of nitrogen. However, yield was higher in S. aviculare in all the treatments (Table 6.1).

Effect of varied level of phosphorus on S. laciniatum and S. aviculare:

The dry weight yield of shoot and root in both the species increased with increasing phosphorus level in the medium. However, no differences were observable between the two species except for the root yield at 41.3 ppm phosphorus level. Leaf yield also followed a similar trend. Shoot/root ratio in both the species increased with the increase in phosphorus level. However, in both the species differences between the middle and higher treatments of phosphorus were not significant. Foliar phosphorus level was not significantly

Table 6.1. Effect of varied levels of nitrogen on the growth, yield and solasodine contents of S. laciniatum and S. aviculare

|                                    |               | Levels at nitrogen (ppm) |       |       | L.S.D  |
|------------------------------------|---------------|--------------------------|-------|-------|--------|
|                                    |               | 63                       | 98    | 133   | p=0.05 |
| Shoot yield<br>(g)/plant           | S. laciniatum | 2.29                     | 3.47  | 4.45  | 0.36   |
|                                    | S. aviculare  | 2.37                     | 3.35  | 4.83  |        |
| Root yield<br>(g)/plant            | S. laciniatum | 1.35                     | 1.64  | 1.92  | 0.23   |
|                                    | S. aviculare  | 1.43                     | 1.69  | 1.78  |        |
| Shoot/root<br>ratio                | S. laciniatum | 1.696                    | 2.115 | 2.317 | 0.42   |
|                                    | S. aviculare  | 1.656                    | 1.982 | 2.713 |        |
| Leaf yield<br>(g)/plant            | S. laciniatum | 1.17                     | 1.83  | 2.13  | 0.31   |
|                                    | S. aviculare  | 1.31                     | 1.95  | 2.51  |        |
| Foliar Ni-<br>trogen (%)           | S. laciniatum | 3.261                    | 3.863 | 4.235 | 0.89   |
|                                    | S. aviculare  | 3.210                    | 3.735 | 4.249 |        |
| Solasodine<br>%                    | S. laciniatum | 0.28                     | 0.39  | 0.31  | 0.13   |
|                                    | S. aviculare  | 0.41                     | 0.52  | 0.50  |        |
| Solasodine<br>yield (mg)/<br>plant | S. laciniatum | 3.3                      | 7.1   | 6.6   | 2.3    |
|                                    | S. aviculare  | 5.4                      | 10.1  | 13.0  |        |

affected due to the increase in phosphorus level in the medium. Further, this was not significantly different in the two species. Solasodine content in the leaves also followed a similar trend as that of foliar phosphorus content. As regards solasodine yield gradual improvement was observed with the increase in phosphorus level in the medium in both the species. No significant differences were noticed between the two species regarding the yield of solasodine in any of the treatments (Table 6.2).

Effect of varied levels of potassium on S. laciniatum and S. aviculare:

The dry-weight of shoot and root increased in both S. laciniatum and S. aviculare with increasing levels of potassium in the medium. However, no significant differences were noted between the two species in any of the treatments. Leaf yield per plant also followed a similar trend. In both the species shoot/root ratio increased with increase in potassium level in the medium. However, shoot/root ratio was not found to increase at 234 ppm potassium level than that at 78 ppm level. Foliar potassium level increased with increase in potassium concentration in the medium, however, no significant differences were observed between the two species. In both S. laciniatum and S. aviculare solasodine concentration decreased in the leaves with the increase in potassium level in



Table 6.2. Effect of varied levels of phosphorus on growth, yield and solasodine content of S. laciniatum and S. aviculare

|                             |               | Levels of phosphorus (ppm) |       |       | L.S.D    |
|-----------------------------|---------------|----------------------------|-------|-------|----------|
|                             |               | 4.13                       | 41.3  | 123.9 | p = 0.05 |
| Shoot yield (g)/plant       | S. laciniatum | 2.01                       | 4.12  | 4.65  | 0.45     |
|                             | S. aviculare  | 2.23                       | 4.36  | 4.96  |          |
| Root yield (g)/plant        | S. laciniatum | 1.43                       | 1.56  | 1.85  | 0.19     |
|                             | S. aviculare  | 1.60                       | 1.75  | 1.93  |          |
| Shoot/root ratio            | S. laciniatum | 1.405                      | 2.641 | 2.513 | 0.58     |
|                             | S. aviculare  | 1.394                      | 2.491 | 2.569 |          |
| Leaf yield (g)/plant        | S. laciniatum | 1.31                       | 1.63  | 2.82  | 0.51     |
|                             | S. aviculare  | 1.53                       | 2.08  | 2.62  |          |
| Foliar phosphorus (%)       | S. laciniatum | 0.31                       | 0.35  | 0.34  | 0.18     |
|                             | S. aviculare  | 0.27                       | 0.31  | 0.39  |          |
| Solasodine %                | S. laciniatum | 0.36                       | 0.32  | 0.33  | 0.21     |
|                             | S. aviculare  | 0.38                       | 0.41  | 0.41  |          |
| Solasodine yield (mg)/plant | S. laciniatum | 4.7                        | 5.7   | 9.6   | 3.9      |
|                             | S. aviculare  | 4.1                        | 6.4   | 10.2  |          |

Table 6.3. Effect of varied levels of potassium on growth, yield and solasodine content of S. laciniatum and S. aviculare

|                                    |               | Levels of potassium (ppm)L.S.D |       |       |        |
|------------------------------------|---------------|--------------------------------|-------|-------|--------|
|                                    |               | 7.8                            | 78    | 234   | p=0.05 |
| Shoot yield<br>(g)/plant           | S. laciniatum | 2.76                           | 4.42  | 4.81  | 0.54   |
|                                    | S. aviculare  | 2.36                           | 4.28  | 4.59  |        |
| Root yield<br>(g)/plant            | S. laciniatum | 1.45                           | 1.68  | 1.73  |        |
|                                    | S. aviculare  | 1.36                           | 1.81  | 1.89  |        |
| Shoot/root<br>ratio                | S. laciniatum | 1.904                          | 2.631 | 2.780 | 0.34   |
|                                    | S. aviculare  | 1.735                          | 2.364 | 2.426 |        |
| Leaf yield<br>(g)/plant            | S. laciniatum | 1.52                           | 2.69  | 2.82  | 0.59   |
|                                    | S. aviculare  | 1.34                           | 2.81  | 2.89  |        |
| Foliar potas-<br>sium (%)          | S. laciniatum | 0.82                           | 1.04  | 1.08  | 0.11   |
|                                    | S. aviculare  | 0.72                           | 1.11  | 1.19  |        |
| Solasodine<br>%                    | S. laciniatum | 0.42                           | 0.35  | 0.30  | 0.12   |
|                                    | S. aviculare  | 0.45                           | 0.31  | 0.21  |        |
| Solasodine<br>yield (mg)/<br>plant | S. laciniatum | 6.4                            | 9.4   | 8.5   | 1.8    |
|                                    | S. aviculare  | 6.0                            | 8.7   | 6.1   |        |

the medium. In both the species maximum yield of solasodine was obtained at 78 ppm level of potassium and the yield declined at highest potassium level (Table 6.3).

#### DISCUSSION

It is evident from the present results that the two species did not differ significantly in growth yield in response to nitrogen, phosphorus and potassium nutrition. The growth yield of the two species improved with increase in the nutrient status. Thus, two closely related species showed a similar response to nitrogen, phosphorus, and potassium nutrition this is to be expected as the two species are not known to have diverse ecological requirements (Randell and Symon, 1976). This, however, is in contrast to the observations on closely related species but with diverse ecological requirements, such as Argemone maxicana and A. ochro<sup>a</sup>luca (Ramakrishnan and Gupta, 1972).

Foliage production is an important characteristic of S. laciniatum and S. aviculare as this organ is the chief source for solasodine yield. This parameter of these two species also showed a positive relationship with increase in the levels of nitrogen phosphorus and potassium in the medium. However the response of the two species with respect to solasodine concentration in the leaf tissue was found to be different. Solaso-

dine concentration in the leaf tissue of S. aviculare was more than that of S. laciniatum in the nitrogen treatments. Further, nitrogen and phosphorus treatments did not significantly affect solasodine concentration at different levels, whereas solasodine concentration decreased significantly at higher potassium levels. However, solasodine yield per plant increased markedly at high nitrogen and potassium levels. However, the yield tended to decline at the highest potassium level of 234 ppm in the medium, in both the species.

Increasing nitrogen concentration in the medium increased dry-weight yield of shoot, 4.13 ppm level of phosphorus was evidently adequate under the experimental condition and the foliar phosphorus levels varied little between the treatments, and have no apparent influence on alkaloid concentration.

In the experimental work alkaloid yield was always closely related with dry matter production. Thus, any treatment that increases dry matter yield is likely to increase alkaloid yield as well. Present results confirm earlier work of Foldesi (1964) and Crush (1973).

Earlier results of Crush (1973) tends to suggest that the response to phosphorus and potassium by these two species are neither consistent nor marked. In contrast to this, while the response to potassium as far as solasodine yield was concerned

is not so well marked (though leaf yield improved markedly at the high potassium level tried here), the response of the two species to phosphorus nutrition was significant.

#### SUMMARY

The effects of different levels of nitrogen, phosphorus and potassium on the growth and alkaloid accumulation in Solanum laciniatum Ait. and S. aviculare Forst. were investigated under sand culture condition. In both the species dry weight of shoot and root increased with increase in nitrogen level in the medium. Solasodine content in both the species improved slightly with increase in the nitrogen level in the medium. Maximum solasodine yield was obtained at a lower nitrogen level in S. laciniatum while in S. aviculare this was obtained at a higher nitrogen level. However, Solasodine yield was higher in S. aviculare in all the treatments. Both the species gave good responses with increase in phosphorus level in the medium. Foliar phosphorus level was not significantly affected due to the increase in phosphorus level in the medium, solasodine content also followed a similar pattern. However, solasodine yield improved with additional phosphorus level in the medium. The growth yield of both the species improved with increase in the potassium level in the medium. In both the species solasodine concentration decreased with increase in potassium level in the medium. The response of potassium as far as solasodine yield was concerned was not well marked; the response of the two species to nitrogen and phosphorus nutrition was significant.

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