PHENOLOGY OF MEDICINAL SNAKE GOURD (*Trichosanthes cucumerina* L.) UNDER DIFFERENT SEASONS

By

HARSHA SATHEESH

2010-20-109

THESIS

Submitted in partial fulfilment of the

requirement for the degree of

B.Sc-M.Sc (Integrated) CLIMATE CHANGE ADAPTATION

Kerala Agricultural University

ACADEMY OF CLIMATE CHANGE EDUCATION AND RESEARCH

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

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DECLARATION

I hereby declare that the thesis entitled "**Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons**" is bonafide record of research work done by me during the course of research and that the thesis has not previously formed on the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

Place: Vellanikkara
Date:

HARSHA SATHEESH
2010-20-109

CERTIFICATE

Certified that the thesis entitled "**Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons**" is a record of research work done independently by **Miss. HARSHA SATHEESH (2010-20-109)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Place: Vellanikkara
Date:

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Chairman, Advisory Committee
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CERTIFICATE

We, the undersigned members of the advisory committee of **Miss. Harsha Satheesh (2010-20-109)**, a candidate for the degree of BSc- MSc (Integrated) Climate Change Adaptation agree that the thesis entitled "**Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons**" may be submitted by **Miss. Harsha Satheesh (2010-20-109)**, in partial fulfillment of the requirement for the degree.

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ACKNOWLEDGEMENT

Along the journey of my studies during MSc programme in Kerala Agricultural University, I have been supported and encouraged by many people. Firstly, I would like to express my sincere gratitude to my major advisor ***Dr. M. T. Kanakamany,*** *Professor and Head, AICRP on MAP & B, College of Horticulture, for the continuous encouragement, guidance and support of my MSc study and related research.*

Besides my advisor, I deeply express my whole hearted thanks to ***Dr Kurien E. K,*** *our beloved special officer and member of my advisory committee for his kind concern and expert advice.*

I am privileged to place my deep sense of gratitude to ***Dr. C. Beena,*** *Associate professor (Biotechnology), AICRP on MAP & B, College of Horticulture and member of my advisory committee for her insightful suggestion and support throughout my project work.*

I extend my gratitude to ***Dr. P. V. Sindhu,*** *Assistant professor (Agronomy), AICRP on MAP & B, College of Horticulture and member of my advisory committee for her help and valuable guidance for the successful completion of my research work.*

My sincere thanks to ***Dr .K. M. Sunil,*** *Assistant professor (Agricultural Meteorology), ACCER for his timely support during collection and interpretation of weather data.*

I would like to acknowledge the help extended by ***Dr. S. Krishnan,*** *Professor, Department of Statistics, College of Horticulture for his valuable suggestions and immense help extended during statistical analysis.*

My gratefulness and personal obligation goes to ***Dr. B. Ajithkumar,*** *Assistant professor, Head of the department of Agricultural Meteorology and all other members of the department specially* ***Mr. Paulose*** *and* ***Mr. Gangadhar*** *for the immense help extended during the data collection.*

The help received from ***Mr. Unnikrishnan*** *of Kottakkal Arya vaidya sala and* ***Dr. N. Sasidharan****, Professor of KFRI during my work is also specially acknowledged.*

My heartfelt thanks to ***Dr. C. S. Gopakumar*** *of Administrative block for the wholehearted co-operation, sincere and ever time help rendered by him.*

I sincerely express my obligations to ***Dr. Gavas Rakesh****, Assistant professor, Department of Entomology and* ***Mr. Vipin Rao****, Forest Range Officer, Munnar for their timely help and valuable advice at critical stage of my study.*

With all regards, I sincerely acknowledge the wholehearted co-operation and generous help rendered by all the staffs especially ***Mr. Shaiju. D. Ollekkat*** *(Farm officer),* ***Mrs. Susmitha, Mrs. Gayathri, Mrs. Bini, Mrs. Sheeba*** *and all labours of AICRP on MAP & B.*

My sincere gratitude to K.A.U and I sincerely acknowledge the help and support extended by each and every members of my ACCER family especially ***Mr. Saju*** *and* ***Mrs. Saritha****.*

Help received from ***Dr. A. T. Francis,*** *Librarian, K.AU Central Library and all staff in the library during my thesis work is acknowledged.*

More personally I am thankful to all my loving friends ***Devu, Safi, Gayu, Tou, Rani, Basil, Athira. T.K*** *and* ***Pareeth ikka*** *for the joyous company and help rendered to me.*

I extend my loving gratitude to my juniors ***Shamiya, Abeeshna, Induja, Aleena, Anand, Aneesha*** *and* ***Arya*** *for their help provided during my work.*

I am forever intended and affection to my parents and my sister for their boundless affection, moral support, love and constant prayers.

Above all I submit this achievement before ***God*** *Almighty- the power that had driven me all throughout this journey, protected me in all my difficult times and giving ability to complete my thesis work on time.*

HARSHA SATHEESH

Dedicated to my beloved Grandmother
and to my family

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INTRODUCTION

CHAPTER 1

INTRODUCTION

The uses of plants and plant products as medicine dates back to time immemorial with archeological evidences pointing to the practice of using herbal drugs against diseases to the beginning of human civilization. Several naturally occurring compounds in its pure or extracted forms from plants, fungi and microbes are being used in pharmaceutical preparations. These find wide application in the treatment of several diseases and ailments worldwide. Medicinal plants serve as the richest bio-resource of drugs of traditional system of medicine, modern medicine, nutraceuticals, food supplements, folk medicines, pharmaceutical intermediate and lead compounds in synthetic drugs (Ncube *et al*., 2008). The developing countries are the leading suppliers of medicinal and aromatic plant products in the world market.

With two out of the eighteen biodiversity hot spots of the world being located in the India, about 15 per cent out of the reported 20,000 medicinal plants of the world are reported to be indigenous to our country. The medicinal plant wealth in India is reported to have tremendous therapeutic potentials and finds wide applications in the traditional Indian systems of medicine *viz., Ayurveda, Yunani and Siddha* apart from the Homeopathic systems of treatment. The extensive use of herbal medicine in various traditional systems and coupled with the rich biodiversity, has made India the largest producer of medicinal herbs in the world. The 7800 medicinal drug manufacturing units in India are reported to be consuming an estimated 2000 tonnes of herbs annually belonging to about 300 medicinal plant species (Sivarajan and Balachandran, 1994). Apart from this, the medicinal plants are also strongly associated with folk medicine practiced in different parts of the country for the treatment of many ailments.

Ved and Goraya (2007) reported that the Indian medicinal plants based industries are growing at the rate of seven to fifteen per cent annually. Nearly 9500 registered herbal industries and a multitude of unregistered cottage level herbal units depend upon

the continuous supply of medicinal plants for manufacture of herbal medical formulations based on Indian systems of medicine. Significant quantities of medicinal plant resources are also consumed in the country under traditional health care practices at the household level, by traditional healers and by practitioners of Indian system of medicine. The global trend of increased demand for medicinal plants for pharmaceuticals, phytochemicals, nutraceuticals, cosmetics and other products opens up vast opportunities for Indian trade and commerce (Pushpangadan and Govindarajan, 2005).

Medicinal plants constitute an important plant resource spectrum in Kerala. Over 1500 species of plants are indigenous to Kerala and are used in Indian system of medicine. The rural folk and tribal communities also make use of about 2000 species of wild plants for various medicinal uses. About 60 to 65 per cent of plants that used in *Ayurveda and Sidha* are obtained from the forests of Kerala. Natural plant extracts and chemical derivatives are also used in homeopathy and modern medicine. About 300 million people are dependent on Ayurveda for their health and well being. In Kerala more than 90 per cent of plant species utilized by the user industry are collected from wild that causing immense threat to their genetic pool. So many national policies are there to preserve the endangered medicinal species and promote cultivation of remunerative plants.

The medicinal plant, *Trichosanthes cucumerina* (*kattupatavalam* or *kaipan patavalam*), occupy a prominent place in ayurveda drug industry. It is regarded as a laxative, anti oxidant, anti diabetic, anti inflammatory and a blood purifier. It is used against bronchitis, headache and renal problems. The plant is considered to be beneficial in the treatment of dermatitis and intestinal disorder (Sivarajan and Balachandran, 1999). There is a huge demand for the crop throughout the year by the user industries. Average annual consumption of raw drug in Kerala by the medicine manufacturing units are 133298 tonnes and presently its entire supply is met from the wild, but due to over exploitation it has led to erosion of the genetic resources of this crop (Sasidharan and Muraleedharan, 2009). In addition, climate change is reported to have direct and indirect

effects on growth and development of medicinal plants. The medicinal plant, *Trichosanthes cucumerina* is reported to be extremely sensitive to climate. In Kerala the production of medicinal plants like kaipan patavalam is low during the monsoon period due to heavy rainfall and unfavorable growing condition.

Considering the above, the present study was formulated to assess the influence of different weather parameters on yield and yield attributing characters of *Trichosanthes cucumerina* under different growing environments.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Trichosanthes cucumerina L is used in the traditional medicine and there is a huge demand for the crop throughout the year by the user industries. In Kerala the production is low during the monsoon period due to heavy rainfall and unfavorable growing condition.

2.1. Habitat and distribution of *Trichosanthes cucumerina* and related species

Trichosanthes cucumerina is widely cultivated as a vegetable in tropical and subtropical regions around the globe and another 15 species are commonly used in Asian traditional medicine (Perry and Metzger 1980). *Trichosanthes* belongs to the sub tribe Trichosantheae C. Jeffr., subfamily Cucurbitoideae. The genus includes about 40 species occurring in East, Southeast, South Asia, tropical Australia and Fiji. Two species are cultivated and several other species are used in native medicine. *Trichosanthes cucumerina* L. (Snake gourd) is cultivated widely in South and Southeast Asia. Wild forms of the species occur naturally from India to Australia (Nayar and More, 1998). *Trichosanthes cucumerina* found to be distributed in Bengal, Gujarat, Konkan, Deccan, Kerala, in the plains as well as in the lower hills, Italy, Sri Lanka, tropical Himalaya, Malesia, Polynesia and North Australia (Sivarajan and Balachandran, 1999).

Trichosanthes includes three taxa, *Trichosanthes cucumerina, Trichosanthes anguina* and *Trichosanthes lobata,* crossed readily in pair wise combination in both the direction and hybrids were found to be vigorous with good seed set (Singh and Roy, 1979). In the hybrids the fruit size was intermediate. *Trichosanthes anguina* appear to be closer to *Trichosanthes lobata* than *Trichosanthes cucumerina.* The three taxa were found to be genetically close to each other and separate species status appeared to be not justified. *Trichosanthes lobata* represents a link between *Trichosanthes cucumerina*

and *Trichosanthes anguina* (Sinha *et al.,* 1983). *Trichosanthes cucumerina* is a monoecious, annual, herbaceous climber. The immature fruit is boiled and eaten. The fruits are slender, long tapering and 30-150 cm long. Occasionally, shoots and tender leaves are also used as vegetable. Within the genus Trichosanthes, *Trichosanthes cucumerina* showed highest similarity to *Trichosanthes anguina* and *Trichosanthes palmate. Trichosanthes dioica* clustered further away. Trichosanthes exhibited at least 50 per cent similarity to Gymnopetalum. Sivarajan and Balachandran (1999) reported that ayurvedic texts recognize two kinds of *patola* namely, small fruited bitter variety locally called kaipan patavalam or kattupadavalam and large fruited sweetish variety called swadupadavalam.

2.2 Botany and Floral biology

Tricosanthes cucumerina is a monoecious annual herb climbing by two to three branched tendrils and five to six meters high. The stems are slender, green, four angled, somewhat hairy and faintly disagreeable in odour. The roots are tuberous and white in color. The leaves are alternate, simple and hairy on surfaces, rounded in outline, seven to 14 centimeters long and broad, three or five lobed, the lobes being broad, rounded or obtuse and the sinuses broad or narrow and rounded. The leaf base is broadly heart-shaped (Sandhya *et al*., 2010). DeWilde and Duyfjes (2010) mentioned that in the genus *Trichosanthes* the flowers are white with elongated receptacle-tubes and free filaments.

According to Seshadri and More (2009) anthesis in snake gourd, take place at early hours of the night and anther dehiscence occur simultaneously. Pollen grains remained viable 49 to 59 hours after dehiscence and stigma remains receptive from 10 hours before anthesis to 51 hours after opening. Kritikar and Basu (2006) observed that the male infloresence are axillary racemes on 10 to 30 cm long peduncles. They are with three stamens but the female flowers are solitary and sessile with inferior, single celled ovary, long and with hairy stigmas. Fruits are very slender, long and cylindrical berry, often twisted, greenish-white when immature and dark red when mature. The seeds are half-ellipsoid, somewhat compressed, undulate, hard, nearly one centimeter long,

grayish-brown, sculptured, margin undulate and imbedded in a soft foetid with red pulp. Pollen grains failed to germinate in water in the in-vitro germination studies. High pollen germination percentage and pollen tube growth was obtained in five to twenty per cent sucrose media with highest values observed in 15 per cent sucrose and thereafter a slight decline was noticed which support the findings of Sindhu (2002).

Nayar and Singh (1998) and Chakravarthi (1959) cited that flowers are monecious, white and pollinated by insects. Male flowers are present on axillary racemes and female are axillary and solitary.

Pal *et al.* (1972) pointed out that floral biology in *Momordica charantia* L. of the cucurbitaceae family showed that bittergourd plants started flowering 40 days after sowing and blooming period varied from 68 to 76 days. The male flower buds took on an average 17 to 19 days, whereas female buds took 21 to 22 days for their complete development. The anthesis started from 4.00 A.M. to 7.30 A.M. and flowers became fully open from 6.00 A.M. to 9.55 A.M. The dehiscence of anthers happened longitudinally within 6.10 A.M. to 8.55 A.M. The male flowers dropped off on the same day at 6.00 P.M. to 7.00 P.M., while female flowers withered away next morning. Pollen grains of bitter gourd were round in shape with three distinct germpores. Their size varied from 42.69 to 46.95 microns within the varieties. The maximum pollen germination was observed in 20 per cent sucrose solution. The stigma receptivity was found maximum at the time of anthesis, beginning from eight hours before anthesis and continuing up to twelve hours after anthesis.

Mcgregor (1976) observed that pollination also increased the quality and efficiency of crop production. Incomplete pollination of crops may result in less yield and inferior quality of fruit. In cucumber, Miller and Quesenberry (1976) reported that genetic variance was addictive for early flowering. They found that a day to opening of 1st female flower was controlled by relatively few genes and heritability was moderately high. In bitter gourd, Srivastava and Srivastava (1976) obtained the highest genotypic coefficient of variation, heritability and genetic gain for number of fruits per plant. They reported that characters like weight of fruit, yield per plant and length of fruit might be

controlled by addictive gene where as number of lateral branches per plant, numbers of female flowers per plant and days taken for the first female flower to appear were controlled by non-addictive gene effect.

Grimstad (1995) indicated that low temperature delayed flowering in tomato. Ho (1996) observed that under low light conditions, initiation of first inflorescence delayed in tomato, as more leaves are initiated prior to the inflorescence. In an indeterminate plant, temperature affected floral initiation, floral development and fruit set and fruit growth simultaneously.

2.3. Medicinal properties of *Trichosanthes* Genera

Duvey *et al.* (2012) reported that the *Trichosanthes palmate* (Roxb) used by tribals traditionally to treat intestinal worm infections showed significant anthelmintic activity. *Trichosanthes tricaspidata* (Roxb) showed more significant action when compared with standard drug albendazole in concentration of 20 mg /ml. But when ethanolic extract and aqueous extract of *Trichosanthes tricaspidata* (Roxb) were compared it was found that ethanolic extract showed more potent action than aqueous extract. Gill and Bali (2012) cited that the whole fruit of *Cucumis melo* (musk melon) is useful in chronic eczema. The fruit is tonic, laxative, galactagogue, diuretic and diaphoretic. The fruit extract has a high Superoxide Dismutase Activity (SOD). The SOD activity is responsible for the *in vitro* and *in vivo* antioxidant and anti-inflammatory properties of the extract.

Sandhya *et al.* (2010) reported that *T. cucumerina* is a rich source of protein, fat, fibre, vitamins A, C & E and some of the elements such as potassium, phosphorus, cucurbitacin B, cucurbitacin E, Isocucurbitacin B and 23-24-dihydroisocucurbitacin. The aqueous extract of root exhibited significant anti-inflammatory activity. Shivhare *et al.* (2010) advised scientific evaluation for the wound healing potential of methanolic (MeOH) extract of *T. dioica* fruits. He also studied methanolic extract of the plant *T. dioica* for assessment of healing potential in the form of simple ointment using full thickness burn wound model in rats. The effect produced by the extract ointment

provided significant healing when compared with the control and standard groups. Rai *et al*. (2010) reported the *in vitro* assessment of anti microbial activity of different concentrations of extract of different parts of *Trichosanthes dioica*. Five clinical isolates of different bacterial strains were used and the disc diffusion method was opted. The results revealed that leaves, fruits and seeds of *T. dioica* plant may be used as anti bacterial agents. Though the leaves extract was active against all five strains, the highest inhibition was observed against *Mycobacterium smegmatis*. The leaves extract could be used for tuberculosis treatment.

Kongtun *et al.* (1999) cited that the whole plant used for antifertility activity and also used in prevent to infections and malignancies. (Xanthopoulou *et al.* (2009) cited that phytochemical investigations on *Cucurbita andreana* species have yielded cucurbitacins as feeding stimulants for diabrotica and *C. andreana* exhibited potent anticancer and cyclooxygenase-2 (COX-2) inhibitory activities. *T. dioica* leaves have good hypoglycemic potential along with a high anti diabetic profile (Rai *et al*., 2008). *T. dioica* fruits dose of 1000 mg / kg body weight daily once for 28 days reduced the levels of fasting blood glucose, postprandial glucose, aspirate amino transferase, alanine amino transferase, alkaline phosphatase, creatinine, urine sugar and urine protein whereas total protein and body weight was increased. Ghaisas *et al*. (2008) suggested that *T. dioica* extracts showed profound histopathological protection to liver cells as evident from histopathological studies and it can be concluded that it has significant hepatoprotective activity. Ghaisas *et al.* (2008) stated that *Trichosanthes dioica* extracts showed profound histopathological protection to liver cells.

According to Sharmilabanu *et al.* (2007) *Trichosanthes dioica* treatment caused significant decrease of plasma cholesterol levels after a single administration and after repeated oral administrations. Significant increase of triglyceride levels was observed six hours after a single oral administration of the *T. dioica* aqueous fruit extract. On the other hand, repeated oral administration of *T. dioica* aqueous fruit extract caused significant decrease of body weight after two weeks of treatment in both normal and

diabetic rats. The study indicated that the aqueous fruit extract of *T. dioica* exhibits cholesterol and body weight-lowering activities in both normal and hyper glycemic rats. Leaves and fruits used for treating alcoholism and jaundice. Leaves are used in odema and alopecia. It is also used as anti pyretic, diuretic, cardiotonic and laxative (Khare 2007).

Sharmilabanu et *al.* (2007) observed cholesterol lowering activity of the aqueous fruit extract of *Trichosanthes dioica* Roxb. in normal and streptozotocin diabetic rats. Seeds were useful in management of benign prostatic hyperplasia capacity (Winkler *et al.,* 2005). Fruits of *Cucumis sativus* (cucumber) help in removing constipation and aid indigestion. The fruits are used during summer as a cooling food. Fruit is demulcent. Seeds are cooling, tonic, diuretic and anthelmintic (Jayaprakasam *et al.,* 2003).The seed extracts of *Cucurbita pepo* modulate immune biochemical pathways induced by interferons.

Dhiman *et al.* (2002) observed that the seeds of *Trichosanthes kirilowii* (Chinese cucumber) have been used in Chinese medicine as a cough medicine and an expectorant. Kirtikar and Basu (2001) reported that the bark of *Trichosanthes kirilowii* is acrid, sweet, cooling, cardiotonic, alexipharmic and stomachic, anthelmintic, astringent, cure biliousness also used in fever, ulcers, diseases of the gums and teeth. Acosta *et al.* (2001) confirmed that the fruit of *Cucurbita pepo* (pumpkin) increased appetite, cures leprosy and purifies the blood. Seeds cure sore chests, haemoptysis, bronchitis and fever.

Bhujbal (1999) showed that polyherbal formulation including *T. dioica* is useful in skin disorder. Fifty cases of various skin diseases were treated with decoction of a mixture of *Trichosanthes* and other herbal crude drugs in a dose of 20 ml to 40 ml in empty stomach with hot water and honey for four to six weeks. The drug was found to be useful and no side effect was observed. Gaur (1999) has reported the use of this plant in curing bronchitis and the application of seed paste for hoof and mouth disease in cattle.

Hariti and Rathee *et al.* (1996) stated that the fixed oil of seeds of *Trichosanthes* species including *T. dioica* have anti fungal property and anti bacterial activity of the

unsaponifiable fraction of the fixed oil of *T. dioica* seeds against *Bacillus anthracis* and *Xanthomonas malracearum.* Sherma and Pant *et al.* (1992) mentioned the influence of alcoholic extract of whole fruit of *T. dioica* on lowering the blood sugar, total cholesterol, low density lipoprotein cholesterol, triglyceride levels, increased the high density lipoprotein cholesterol, phospholipid, serum lipids, lipoproteins and faecal sterols in normal albino rabbits. Sherma and Pant (1992) observed that extract of whole fruit of *Trichosanthes dioica* lowered the blood sugar, total cholesterol, low density lipoprotein cholesterol and triglyceride levels and increased the high density lipoprotein cholesterol, phospholipid and faecal sterol levels.

According to Sing and Sing (1985) crude drug *T. dioica* is known to have anti ulcerous effect in polyherbal preparation. It was found that Patoladi kasaya a polyherbal formulation, consisted of 10 herbs *viz., T.dioica, Haritaki, Bibhitaka, Amalaki, Kutaki, Cirayata, Amrta, Pittapapada, Sunthi and Bhrngaraja* exhibited complete improvement in 50 per cent cases and partial improvement in 40 per cent cases with peptic ulcer and also studied the efficacy of single herb *patola* in 20 patients with duodenal ulcer. Effectiveness of *patola* in duodenal ulcer was found as 45 per cent excellent response out of 20 cases. Juice of leaves of *T. dioica* is used as tonic, febrifuge and in sub acute cases of enlargement of liver and spleen (Nadkarni 1982). According to Chopra *et al.* (1956) the roots of *T. tricuspidata* are used to treat lung diseases in cattle and for the treatment of diabetic carbuncles and headaches.

2.4. Medicinal properties of *Trichosanthes cucumerina*

Aiyer and Kolammal (1960) reported that the *Trichosanthes* plant as a whole, along with roots are used medicinally. *Trichosanthes cucumerina* is used in tridosha and that cures bronchitis by Blatter *et al.* (1975). Jayaweera (1980) stated that *Trichosanthes cucumerina* L. is one of the medicinal plants that are often used in Sri Lankan traditional system of medicine for the preparation of formulations used to treat a variety of disease conditions. Jeffrey *et al*. (1984) reported that fruits of *Trichosanthes cucumerina* are regarded as purgative and vomitive.

According to Patil and Bhole (1993) the methanol extract of *Trichosanthes cucumerina* showed appreciable inhibitory effect on *Salmonella paratyphi*. The positive effects of the plant are due to the carotenoids, flavonoids, lycopene, phenolics and ß-carotene present in it. A novel isoflavone glucoside, 5, 6, 6'- trimethoxy-3', 4'-methylene dioxyisoflavone 7-O-beta-D- (2"-O-p- coumaroyl glucopyranoside) has been characterized from the seeds of *Trichosanthes* (Yadava and Syeda 1994). It is useful for treatment of wounds including boils, sores, skin eruptions such as eczema and dermatitis. It has long been used as appetizer, laxative, aphrodisiac and blood purifier (Shivarajan and Indira, 1994). Hot aqueous extract of root tubers of *Trichosanthes cucumerina* exhibited significant anti-inflammatory activity (Kolte *et al.,* 1997).

Nadkani (1998) cited that *Trichosanthes cucumerina* is used in the treatment of headache, alopecia, fever, abdominal tumors, bilious, acute colic, diarrhoea, haematuria and skin allergy and also used as an abortifacient, vermifuge, refrigerant, purgative, malaria, laxative, agglutinant, emetic, cathartic, bronchitis and anthelmintic. Kongtun *et al.* (1999) reported that the root extract and the fruit juice tested cytotoxicity against four human breast cancer cell lines and lung cancer cell lines and one colon cancer cell line. The root extract inhibited more strongly than the fruit juice.

Dhiman *et al.* (2000) pointed that the seeds are used for stomach disorders and are also considered as antifebrile and anthelmintic. Leaf is cardiotonic, anti pyretic and anti periodic, useful for intestinal worms and its juice rubbed over the liver in remittent fever (Kirtikar and Basu, 2001). Jian-Hua Wang *et al.* (2002) observed that the plant material has potent action against HIV because of its ribosome inactivating activity. Studies on the pharmacological profile have shown the presence of anti-inflammatory activity in the roots and tubers and anti diabetic activity in seeds. Chemically galactose specific lectin has been isolated from the seeds. The hot aqueous extract of *Trichosanthes cucumerina* exerted a significant protection against ethanol or indomethacin induced gastric damage. Increasing the protective mucus layer, as well as decreasing the acidity of the gastric juice and antihistamine activity are probable

mechanisms by which the hot water extract mediates its gastroprotective actions. It is also used to treat cardiac failure (Pullaiah, 2006).

Madhava *et al*. (2008) mentioned that the seed is said to be cooling and the dried seeds are used for its anthelmintic and anti diarrhoeal properties. Seeds have anti-bacterial, anti-spasmodic and insecticidal properties. It is used as abortifacient, acrid, aphrodisiac, astringent, bitter, febrifuge, purgative and trichogenous. Crude ethanolic extract of *Trichosanthes cucumerina* showed significant blood glucose lowering activity in diabetic albino rats. The acetone extract of leaves of *Trichosanthes cucumerina* showed moderate larvicidal effects (Rahuman *et al*., 2008). Hot water extract of aerial parts of *Trichosanthes cucurmerina* has noted to improve glucose tolerance and tissue glycogen in non-insulin dependent diabetes mellitus induced rats. Study showed the drug possess anti diabetic activity with volume improvement in oral glucose tolerance and glucose uptake in peripheral tissues (Kirana and Srinivasan 2008).

Trichosanthes cucumerina shown to have anti diabetic, gastro protective, anti-inflammatory, antioxidant, lipid lowering, activities and non toxicity in rodents (Arawwawala *et al*., 2009). Snake gourd is one of the leading summer vegetable. It has got tremendous export potentiality because of its excellent keeping quality (Podder *et al.,* 2010). Out of the eight herbal extracts examined for anti bacterial activity, leaf chloroform extract of *Trichosanthes cucumerina* exhibited remarkable activity against *Bacillus cereus* whereas it did not inhibit *Staphylococcus aureus* and *Pseudomonas aeruginosa.* The leaf choloroform extract was found to be effective on *Enterobacter faecalis, Salmonella paratyphi, Escherichia coli, Streptococcus faecalis, Proteus vulgaris, Klebsiella pneumoniae* and *Serratia marcescens* (Joji *et al*., 2010). Reddy *et al.,* (2010) mentioned that diabetic patients are advised to consume young fruits as it having low sugar and excellent source of fibres, vitamins, minerals and proteins. Ethonolic extract of this plant show an anti ovulatory activity in female albino rats, while methanolic extract showed anti bacterial activity.

Joji *et al*. (2010) confirmed that *Trichosanthes cucumerina* showed inhibitory effect against *Enterobacter faecalis* comparable with that of the standard antibiotic tobramycin. Fruits examined for anti bacterial activity showed a significant activity against the different strains of bacteria. The activities of these extracts are found to be quiet comparable with the standard antibiotics screened under similar conditions. These extracts can be used as an external antiseptic in prevention and treatment of bacterial infections. The incorporation of these extracts into the drug formulations is also recommended. *Trichosanthes cucumerina* extracts exhibited anti bacterial activity against both gram (+) ve bacterial strains such as *Staphylococcus aureus*, *Staphylococcus pyogenes* and gram (-) ve bacterial strains such as *Escherichia coli* and *Pseudomonas aeroginosa* mediating the presence of a broad spectrum of anti bacterial compounds in the plant (Arawwawala *et al.*, 2011).

2.5. Biochemical constituents in cucurbitaceous plants

Biochemically the cucurbits are characterized by bitter principles called cucurbitacin. Cucurbitacin are the rich oxygen containing compounds of *Citrullus*, *Cucurbita luffa* and *Cucumis* (Lavie and Glotter (1971). The distribution of bitter principle known as cucurbitacin was studied in a total of 45 species belonging to 18 genera (Gibbs, 1974). Guha and Sen (1975) and Jeffrey (1984) stated that cucurbitacins are produced in at least some tissues of all members of the Cucurbitaceae and a few species in other plant families. In most species cucurbitacin compounds are concentrated in aerial parts, because of their extreme bitterness, cucurbitacins are thought to be involved in plant protection against herbivores (Pohlman (1975), Dryer and Trousdale (1978), Thorne (1981), Metcalf (1985) and Tallamy and Krischik (1989). Chemically, cucurbitacins are tetracyclic triterpenes having extensive oxidation level. They occur in nature, free as glycosides or in complicated mixtures (Ramachandran and Seshadri, 1986). Musza *et al.* (1994) and Attard *et al.* (1999) mentioned that most common cucurbitacin found in Cucurbitaceous species is cucurbitacin E (CuE).

Occurrence of many cucurbitacin as glycoside was reported by Enslin and Rivatte (1957) in cucurbitaceous plants. Whittaker and Davis (1962) reported that highest concentration of bitter principles was usually found in aerial parts of trichosanthes. Chambliss *et al.* (1968) did not find Cucurbitacin E glycoside in watermelon fruits of the non bitter cultivar. Murty *et al.* (1970) isolated several triterpenoids from cucurbitaceae family.

Mohamed (1974) isolated a tetrahydroxy pentacyclic triterpene "trichotetrol" from the root extract of *Trichosanthes tricuspidata*. The roots of *T. tricuspidata* contain more than six times cucurbitacin than the roots of *T. kirilowii* Maxim. Var. *japonicum* (Kitajima 1989). Toyokawa *et al.* (1991) isolated an abortifacient protein called karasurin, from fresh root tubers of the plant. It was found to express protein polymorphism separated by ion-exchange chromatography. Mai *et al*. (1994) isolated 14 cucurbitane glycosides from the fruits of *Trichosanthes tricuspidata*. An extract of the fruits of this plant was found to be cytotoxic in KB cells and two new cucurbitacins were tricuspidatin and 2-O-glucocucurbitacin J. also reported a protease from the sarcocarp of the fruits of this plant. The root contains methyl palmitate, palmitic acid, suberic acid, spinasterol, stigmast-7-en-3-beta-ol, spinasterol 3-obeta- D-glucopyranoside, stigmast 7-en-3-beta-ol-3-O-beta- D-glucopyranoside, glyceryl 1-palmitate, glyceryl 1-stearate, bryonolic acid, cucurbitacin B, isocucurbitacin B, 3-epiisocucurbitacin B, 23,24-dihydrocucurbitacin D, isocucurbitacin D and D-glucose as reported by Kaneda and Uchikoba (1994). Kasai *et al.* (1999) isolated three new cycloartane glycosides, named cyclotricuspidosides A, B and C, from the leaf and stem parts.

About 19 cucurbitacins (A-S) have been isolated and characterized so far. Out of this 19 cucurbitacins (A-S); Cucurbitacin B and E constitute the primary component. Cucurbitacin A is found only in *cucumis* and generally in association with Cucurbitacin B. Biogenetically Cucurbitacin B may be precursor of Cucurbitacin A, C, D and E. Cucurbitacin E may give rise to cucurbitacins C, D, E, G, H, I, J and L. All the 19 cucurbitacins have been reported from the sub family cucurbitoidae. In the sub tribe

Luffineal Cucurbitacin B alone occured in four to six species investigated so far. Cucurbitacin B is of rare occurrences in the tribe Trichosantheae (Pash and Sen, 1998).

Casellas *et al.* (1998) reported that a peptide trypsin inhibitor isolated from *T. kirilowii* roots may be the smallest naturally occurring protein inhibitor. The roots of *T. kirilowii* contain trichosanthin, an abortifacient protein which was found recently to be a ribosome-inactivating protein. Yeung *et al*. (1987) reported that the most studied component of *Trichosanthes kirilowii* is the protein trichosanthin. Two trichosanthins have been identified: Alpha from *T. kirilowii* and beta from *T. cucumeroides*. A highly purified form of trichosanthin has been investigated under the name GLQ-223. A second protein, trichokirin, was isolated and found to possess ribosome-inactivating activity. Another ribosome-inactivating protein, beta-kirilowin, has recently been isolated from *T. kirilowii* seeds and exhibits strong abortifacient activity.

2.6. Medicinal properties of cucurbitacin

Chugh *et al.* (2005) reported that cucurbitacin E inhibited the depolymerisation of actin filaments in HeLa cell. Natural and semi-synthetic cucurbitacins showed promising anticancer activities ranging from growth inhibition and cell cycle arrest, to induction of apoptosis (Bairagi *et al*., 2012, Borden *et al.,* 1999, Cragg and Newman, 2013, Orlikova *et al*., 2014 and Altieri, 2010).

Metcalf *et al.* (1980) reported that cucurbitacins function primarily as a plant defense mechanism in the bitter cucurbits. Miro (1995) mentioned that cucurbitacin has been investigated for their cytotoxic, hepatoprotective, antiinflammatory, cardiovascular effects and as diabroticites. Jayaprakasam *et al.* (2002) reported that cucurbitacins B, D, E and I exhibited potent anticancer activity as well as specific COX-2 enzyme inhibition. Cucurbitacin derivatives have been shown to be promising anticancer drug candidates against various types of cancer (Guo *et al.* (2014), Zheng *et al.* (2014), Hung *et al.* (2013), Lan *et al*. (2013), Kong *et al.* (2014).

The crude extract of a bitter Hawkesbury watermelon containing cucurbitacin E-glycoside significantly inhibited germination of watermelon, squash and tomato seeds

(Martin and Blackburn, 2003). Cucurbitacin I showed cytotoxic effects against four human cancer cell lines and significant activity against HIV replication in H9 lymphocyte cells (Wu *et al.,* 2004). Cucurbitacin E tested on peripheral human lymphocytes and showed an immunodulatory activity (Attard *et al*., 2005). Cucurbitacin B has a potent anti proliferative effect on breast cancer (Wakimoto *et al*., 2008). The most significant mechanisms with regard to the apoptotic effects of cucurbitacins are their ability to modify mitochondrial trans-membrane potential and transcriptional activities via nuclear factors or genes and their capability to activate or inhibit pro- or anti-apoptotic proteins.

2.7. Influence of weather on growth and yield of crops

Miller and Ries (1958) observed that low temperature increased the length of diameter ratio of cucumber. Hussey (1963) mentioned that leaf formation was accelerated by both temperature and light intensity. Increase in light intensity accelerated the formation and growth of leaves and harvested the enlargement of the vegetative apex. On other hand increase in temperature accelerated the formation and growth of leaves but delayed the enlargement of vegetative apex. Papadopoulos and Ormrod (1991) observed that in tomato that the highest leaf area per plant recorded under shade net house during summer and winter seasons.

Surlekov and Laanov (1969) reported that cucumber sown in April produced plants with the largest number of fruits, the highest mean fruit weight, the greatest seed number and weight. Kartalov (1970) conducted some tests to establish appropriate dates for sowing and planting cucumber cultivars for hot bed production and found that the highest yield was obtained with the earliest sowing and planting dates through 17th January and 22nd February, respectively. Pumphrey (1980) mentioned that mean temperature showed a positive significant correlation with the herbage yield of pine wood land in north eastern Oregon.

Kmiecik and Coska (1981) from a three year trial with cucumber, sown in field in early or late May or early June observed that the average yield of commercial and

processing cucumbers were the highest with the earliest date of sowing. In cucumber Schrosde and Drews (1982) recommended economic planting dates as January end to mid-February. Desai and Patil (1985) studied the effect of date of sowing on the expression of sex ratio and yield contributing parameters of watermelon and reported that the male female sex ratio was the lowest in plants sown on the earliest date (3.86) and highest (8.48) in those sown on the latest date 20th the yield was the highest in plants sown on December 30th and January 20th.

Kalloo, (1986) reported that the mean fruit weight of tomato was significantly affected by date of planting and growing environment. Alvarez (1989) showed that muskmelon sown in January, February, March and April achieved higher feminization rate than plants sown in May, June and July. Plants sown in September, October and November did not produce any pistillate flowers, whereas in plants sown in December, the reminization rate was intermediate. Nandapuri *et al.* (1976) observed highest plant height (84.5cm), number of fruits per plant (10.9) and fruit yield (186.9 g/plant) from 20th April sowing at Mohanpur, West Bengal. Alvarez (1989) planted musk melons in the field on 15th May (very early), 24th May (early) and 4th June in 1990 and 1991. It was found that early planting was best in no cover treatments. Gadakh *et al.* (1990) reported that out of three cropping seasons *viz* autumn, winter and summer, the summer season crop resulted with highest yield of 185 q/ ha.

Mcglashan and Fielding (1990) carried out three experiments on muskmelon cultivars planted at monthly intervals from 15th November 1986 to 15th January 1987, 5th January 1988 to 5th March 1988 and on 12th March 1989. Highest yield was obtained with November planting in the first trial and the January planting in the second trial. Palumbo *et al.,* (1991) investigated the effect of summer squash **(***Curcurbita pepo***)** planting dates on fruit yield, significantly larger plants containing higher number of yields than on younger plants with fewer leaves. Huyskens *et al.* (1992) mentioned that the flowering pattern in bitter gourd was affected by planting season. More female flowers were produced in spring summer under long day and high temperature than in autumn winter under short day and low temperature.

Huyskens *et al.* (1993) also reported that planting season significantly influenced the flowering pattern with more female flowers under long day and high temperature conditions. The yield of snake gourd is very poor and its production is also restricted to only to three to four months in Bangladesh .There are number of cultivars with wide range of variability in size shape and color of fruits available in this country (Rashid 1993). It is monoecious and highly cross pollinated crop. Sunil *et al.* (2011) reported that fruit yield of arecanut was affected by temperature and relative humidity. Mulkey and Talbot (1993) reported that April sowing produced Zucehini summer squash with highest yield. Vezhavendran (2003) reported that growth of capsicum was largely influenced by growing condition and seasons.

Production of cucurbitacin is temperature dependent. As the temperature increases cucurbitacins production increased; decrease in the temperature, production of cucurbitacins was found decrease (Devendra *et al.*, 2011).

MATERIALS AND METHOD

CHAPTER 3
MATERIALS AND METHODS

The study reported herein on the "Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons" was carried out at Academy of Climate Change Education and Research (ACCER), Vellanikkara during the period 2014-2015. Field experiments were conducted at All India Coordinated Research Project on Medicinal, Aromatic plants and Betel vines (AICRP on MAP & B), College of Horticulture, Vellanikkara. The place is situated at 10˚ 32" N latitude and 76˚ 10" E longitude and 15m above mean sea level. The soil was acidic with pH of 5.2, laterite with clay loam texture.

3.1. Seasons

Experiment was conducted during winter (December-February), summer (March-May) and rainy (June –July) seasons of 2014-2015.

3.2 Materials

Seeds of *Trichosanthes cucumerina* (kaippan patavalam) obtained from the AICRP on MAP & B, College of Horticulture, Vellanikkara was used for the study.

3.3. Experiment details

Experiment was laid out in randomized block design (RBD) with six treatments and four replications (in rain shelter and open condition for three seasons). Seeds of *Trichosanthes cucumerina* were sown in pro trays containing vermi compost and the seedlings of one week old were transplanted to the main fields during December 2014 for the winter crop, February 2015 for the summer crop and May 2015 for the rainy season crop. Three pits and each containing four plants constituted a single replication. The spacing given was 30 cm between the plants within the pits and 2m between the pits. Ten kilogram of farm yard manure and 2.5 g pseudomonas was applied in each pit. Irrigation was given once in two days and weeding once in three weeks. Plants were provided with trellies for support (Plate 1 and 2). Observations on morphological, yield and quality parameters were recorded from 12 plants from each replication.

3.4. Observations recorded

3.4.1. Vine length (cm)

Vine length was measured at the time of final harvest of the plant. Length was measured in centimeter using a tape from root tip to tip of the plant.

3.4.2. Number of branches

Number of branches produced by the plant was observed and recorded at weekly intervals. The branches were counted separately for 12 plants and the average number of branches produced was determined for each replication.

3.4.3. Leaf area (cm^2)

Leaf area was measured on 45^{th} day after planting when the plants attain their maximum vegetative phase. Twelve plants were randomly selected per replication and leaf area recorded using graphical method.

3.4.4. Days to flowering

Number of days taken from planting to first male and first female flower opening was observed separately for all the plants.

3.4.5. Number of flowers per plant

Number of flowers opened per day per plant was counted from the date of opening of the first flower to the day after which no flowering was observed. This was recorded for both male and female flowers and average of each replication was taken.

3.4.6. Time of anthesis

Flower opening was closely observed at five minutes interval from 7 PM to 10 PM in five plants in each replication and the opening time of male and female flower was recorded.

3.4.7. Pollen size (µm)

Pollen grains dispersed in a drop of acetocarmine- glycerin medium mounted on a clean microscopic slide and it is covered with cover slip and kept for 30 minutes Pollen grains were observed under microscope and the diameter of the pollen was recorded from 50 pollen grains of each replication and average value was calculated.

3.4.8. Pollen fertility (%)

Pollen grains collected on the day of anther dehiscence were stained with one per cent acetocarmine on slides under microscope. Pollen fertility was estimated by counting fertile and sterile pollen grains separately. Pollen grains stained well, looked plumpy and well-shaped was considered as fertile and those unstained, small or shriveled as sterile or non viable pollens (Marks, 1954). Five hundred pollen grains were studied from each replication. Fertility percentage was estimated as the percentage of stained pollen grains over the total number of pollen grains.

3.4.9. Pollen viability (%)

Pollen grains from all the replications were collected and kept for germination in a medium containing one per cent sucrose solution + 60 ppm Boric acid (Sulusoglu and Cavusoglu, 2014). The germinated grains were counted from 10 different fields per replication and the percentage germination was calculated as

$$\text{Percentage of germination} = \frac{\text{Number of pollen grains germinated}}{\text{Total number of pollen grains}} \times 100$$

3.4.10. Pollination studies

Hand pollination was carried out using pointed pick or needle. The pollens were collected and dusted on the stigmatic surface of the female flower of the same plant and on different plants at ten hours after anthesis. Twenty flowers from each replication were randomly selected for pollination and the percentage of fruit set was recorded.

3.4.11. Number of fruits per plant

Number of fruits from each plant was recorded separately when they attain physiological maturity. Average of each replication was recorded.

3.4.12. Fruit characters

The length, breadth and weight of the fruit were measured. Length and breadth of the fruit measured in centimeters and the weight measured in grams using an

electronic balance. Ten fruits per plant were taken for the observation and average was recorded.

3.4.13. Fruit yield (g/plant)

Weight of fruits from each plant at each harvest was taken using a top loading balance and added to get the total and average of each replication was recorded.

3.4.14. Seeds per fruit

Ten fruits were randomly selected from each plant and seeds were counted. Average of each replication was recorded.

3.4.15. Herbage yield (g/plant)

Herbage yield of each plant was taken separately by uprooting the whole plant after the final harvest of fruits and average of each replication was taken for the study.

3.4.16. Dry weight (g/plant)

The plant samples were uprooted, cleaned, air dried and oven dried at 80±5˚C and dry weight was recorded as g/plant.

3.4.17. Total yield (g/plant)

Sum of herbage yield and fruit yield gave the total yield. Yield of all plants from all the replication was calculated and total yield was recorded.

3.4.18. Cucurbitacin content (g)

Cucurbitacin content of the whole plant sample was estimated using HPTLC method. (Devendra *et al.,* 2011). HPTLC plate of silica gel 60 F 254. Cucurbitacin standard was purchased from Sigma. Sample constant was prepared in methanol (1g/ 50 ml) and applied along with cucurbitacin standard (1mg/ ml). Mobile phase used was chloroform: methanol (9.5:1). The profile generated was scanned by CAMAG Linomat 5 scanner at 250 nm and 360 nm.

3.5. Meteorological observations

3.5.1. Rainfall data (mm)

The open field rainfall data at monthly interval were collected from Department of Meteorology, College of Horticulture, Vellanikkara.

3.5.2. Canopy temperature (ºC)

Canopy temperature of the plant was recorded using infrared thermometer, at weekly interval. Temperature at the leaf surface was recorded and average values were taken. Observations were taking at 11: 00 AM.

3.5.3. Soil moisture

Soil moisture content recorded at weekly interval by using thermo gravimetric method before irrigation using the formula,

$$Pw = \frac{Wm-Wd}{Wd} \times 100$$

Pw – per cent soil moisture by weight

Wm – weight of moist sample

Wd - weight of oven dried sample

3.5.4. Soil temperature (ºC)

Soil temperature was recorded using a soil thermometer at five cm depth and observations were recorded at 8:30 UST.

3.5.5. Maximum and minimum temperature (ºC)

Daily maximum and minimum temperature was recorded using sensors installed in both rain shelter and open field.

3.5.6. Relative humidity (%)

Daily relative humidity was recorded in both open field and rain shelter using sensors installed inside each growing environment.

3.6. Statistical analysis

The data were subjected to analysis of variance using statistical package MSTAT– C' (Freed-2006). Simple correlations and regression between plant characters with the weekly mean values of maximum temperature, minimum temperature, relative humidity, soil moisture, soil temperature, canopy air temperature and monthly rainfall during the crop period to determine the effect of weather parameters on growth and

yield of kaipan patavalam (*Trichosanthes cucumerina*). Data on vine length, number of fruits, total herbage yield, fruit yield and total yield which showed wide variation were subjected to square root ($\sqrt{X}$ +0.5) transformation to make the analysis of variance valied (Gomez and Gomez, 1984).

Plate 1: Field view of *Trichosanthes cucumerina* (open)

Plate 2: Field view of *Trichosanthes cucumerina* (rain shelter)

RESULTS

CHAPTER 4

RESULT

Kaipan patavalam (*Trichosanthes cucumerina* L.) evaluated under rain shelter and open condition during winter, summer and rainy seasons and the results of the studies are given below.

4.1. Vine length

Growing conditions and seasons have no significant influence on vine length of *Trichosanthes cucumerina* (Table 1). The highest vine length of 484.12 cm was observed when plants were grown in summer under rain shelter. Plants under open condition grown during rainy season recorded the lowest vine length of 130.37cm. In general, plants grown in summer exhibited higher vine length both under open and rain shelter. Compared to open condition the vine length was higher under rain shelter condition.

4.2. Number of branches

From the table (2) it was observed that there was no significant difference between number of branches grown under open and rain shelter. However higher number of mean branches (1.40) was obtained for the plants that grown under rain shelter during summer and lower value of (1.07) were found under open condition during winter. Number of branches was found to be more in summer season as compared to winter and rainy season.

4.3. Leaf area

Leaf area at maximum vegetative phase represented in table 3. It showed that there was significant variation in leaf area for the plants grown under open and rain shelter during three seasons. Maximum leaf area was obtained on 45^{th} day after planting. The highest value of 211.9 cm^2 was obtained under summer in rain shelter and a lowest of 154.8 cm^2 during winter season in open condition. The rain shelter grown plants exhibited more leaf area as compared to open environment.

Table 1: Vine length (cm) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	189.91 * (13.79)	241.47 * (15.54)
Summer	442.30 * (21.04)	484.12 * (22.01)
Rainy	130.37 * (11.42)	204.79 * (14.30)

CD (0.05) =1.056

Table 2: Number of branches under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	1.00	1.17
Summer	1.33	1.40
Rainy	1.02	1.21

CD (0.05) = 0.304

* Orginal value
Transformed value in paranthesis

Table 3: Leaf area (cm^2) at maximum vegetative phase under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	154.8 * (12.41)	201.6 * (14.21)
Summer	187.3 * (13.67)	211.9 * (14.56)
Rainy	165.2 * (12.86)	194.5 * (13.96)

CD (0.05) = 0.35

* Orginal value
Transformed value in paranthesis

4.4. Days to 1st flower opening

Tables 4 and 5 represented the number of days to first male and female flower opening respectively (Plate 3 and 4). Number of days taken for first male flower opening showed no significant variation under different growing environments. The higher number of days taken for male flower opening was found to be 48.00 days under rain shelter during winter season. The lowest of 40.25 days was recorded for the plants grown under open condition during summer season. Number of days taken for first male flower opening was found to be lower under open condition as compared to rain shelter. (Table 4).

Number of days to first female flower opening did not show any significant variation with seasons and growing environments. The higher mean numbers of days to first female flower opening was 63.25 days under rain shelter during winter season and the lower number of 47.75 days were found during summer season. Plants grown in summer season exhibited lower number of days to first female flowering as compared to winter and rainy season (Table 5).

4.5. Number of flowers per plant

Total number of male and female flowers per plant is presented in tables 6 and 7. Growing conditions and seasons significantly influenced the mean number of male flowers. Number of male flowers was found to be highest (85.75) under the rain shelter during summer season and lowest (38.75) was found under open condition during the winter season. Number of male flowers was found to be high during summer season, followed by rainy and winter seasons (Table 6).

Number of female flowers showed significant effect under different growing conditions and seasons. Highest numbers of female flowers was obtained under rain shelter during winter season (63.25) and the lowest numbers of 40.25 were observed under open environment during summer season. Female flowers were found to be more during winter season (Table 7).

Plate 3: Male flower of *Trichosanthes cucumerina*

Plate 4: Female flower of *Trichosanthes cucumerina*

Table 4: Number of days to 1st male flower opening under open and rain shelter during winter, summer and rainy seasons

.

Seasons	Conditions	
	Open	Rain shelter
Winter	45.75 * (6.79)	48.00 * (6.96)
Summer	40.25 * (6.38)	45.00 * (6.74)
Rainy	44.25 * (6.68)	46.25 * (6.83)

CD (0.05) = 0.13

Table 5: Number of days to 1st female flower opening under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	57.00	63.25
Summer	47.75	51.75
Rainy	53.75	57.25

CD (0.05) =1.846

* Orginal value
Transformed value in paranthesis

Table 6: Number of male flowers under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	68.25	82.50
Summer	82.50	85.75
Rainy	38.75	65.00

CD (0.05) = 0.411

Table 7: Number of female flowers under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	40.25	48.25
Summer	57.00	63.25
Rainy	50.75	55.00

CD (0.05) = 0.092

4.6. Time of anthesis

Time of anthesis of both male and female flowers (Table 8) showed that anthesis occurred during night time. For male flowers anthesis occurred between 19: 30 hours during summer to 20:23 hours during rainy seasons. Early anthesis of male flower occurred for the plants that grown under open condition during summer, whereas delayed anthesis occurred under rain shelter between 20:10 hours (summer) to 20:50 hours (rainy) under rain shelter condition. In case of female flower anthesis occurred between 20.43 hours (summer) to 21:31 hours (rainy) under open condition whereas delayed anthesis occurred between 21:14 hours (summer) to 21:44 hours (winter). Early anthesis occurred during summer season for both male and female flowers under open condition (Plate 5 and 6).

4.7. Pollen size (µm)

The size of the pollen grain is presented in table 9. From the data it is observed that the highest vertical distance of the pollen grain observed was 77.96 µm (rainy) and the horizontal distance recorded was 78.96 µm (rainy) under the rain shelter compared to the open field. The lowest vertical and horizontal value obtained was 72.7 µm (winter) and 74.42 µm (rainy) respectively in open condition.

4.8. Pollen fertility (percentage)

Growing environments and seasons had a significant effect on pollen fertility (Table10). Pollen fertility was recorded to be highest (95.77 %) under open condition during summer season and lowest (63.87 %) obtained under open condition during winter. Pollen fertility was found to be more during summer season (Plate 7).

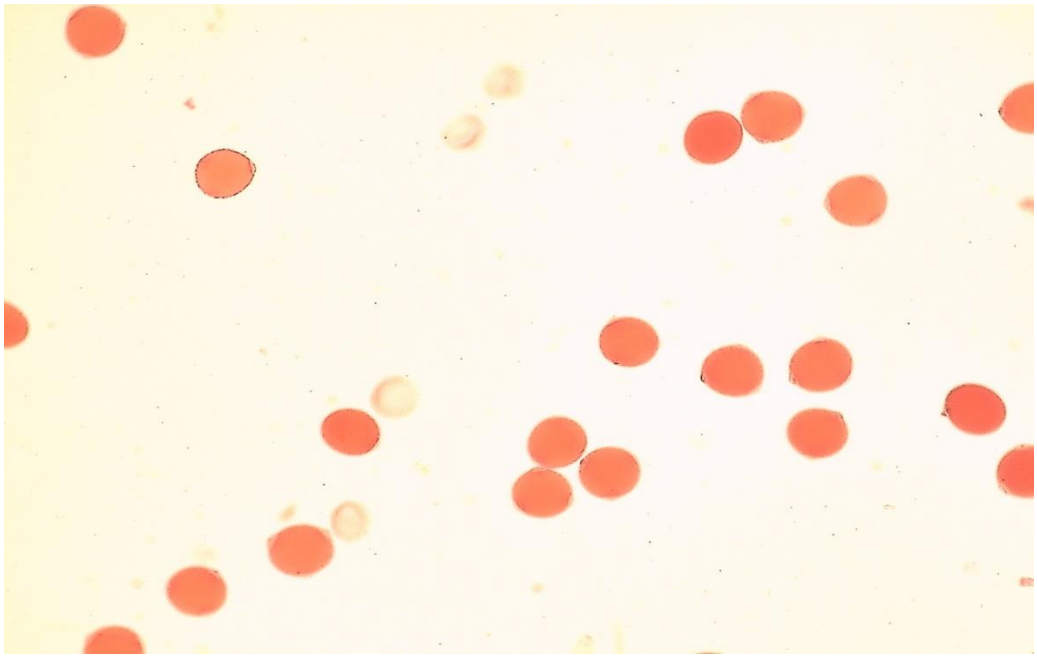

Plate 7: Pollen fertility of *Trichosanthes cucumerina*

Table 8: Time of anthesis under open and rain shelter during winter, summer and rainy seasons

Seasons	Conditions			
	Open		Rain shelter	
	Male (hours)	Female (hours)	Male (hours)	Female (hours)
Winter	20:10	21:26	20:39	21:39
Summer	19:30	20:43	20:10	21:14
Rainy	20:23	21:31	20:50	21:44

Table 9: Pollen size (µm) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions			
	Open		Rain shelter	
	Vertical	Horizontal	Vertical	Horizontal
Winter	72.7	74.64	75.27	74.65
Summer	77.03	78.12	75.88	73.69
Rainy	76.09	74.42	77.96	78.96

Table 10: Pollen fertility (%) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	88.15	65.93
Summer	95.77	81.32
Rainy	63.87	70.71

CD (0.05) = 9.615

4.9. Pollen viability (percentage)

Viability of the pollen grains were observed by growing the pollen grains in a medium containing one per cent sucrose solution + 60 ppm Boric acid and percentage of pollen viability was recorded. The highest percent of viable pollen were recorded as 49% under open condition during summer and lowest of 19 % under rain shelter during winter season (Table 11 and Plate 8).

4.10. Pollination studies

Pollination was done using pollen grains collected from same plant and also from different plants and dusted on the stigmatic surface. The number of fruit set was counted in all the seasons under open and rain shelter condition.

4.11. Number of fruits per plant

Number of fruits obtained from the *Trichosanthes cucumerina* plant showed a significant difference with growing environments (Table 12). From the table it was observed that highest number of fruits (42.0) was recorded under open condition during summer and lowest (15.7) was obtained under open condition during rainy season. Number of fruits obtained were higher under open and rain shelter during summer season. Fruits obtained were found to be lowest during the rainy season (Plate 9).

4.12. Fruit characters

Fruit length exhibited significant difference under growing environment (Table 13). Maximum length was recorded for the fruits that obtained under rain shelter (9.02 cm) during summer and a lower value was recorded for the fruits that obtained under open condition during rainy season (5.70 cm). Comparing to open condition the length of fruit were found to be higher under rain shelter.

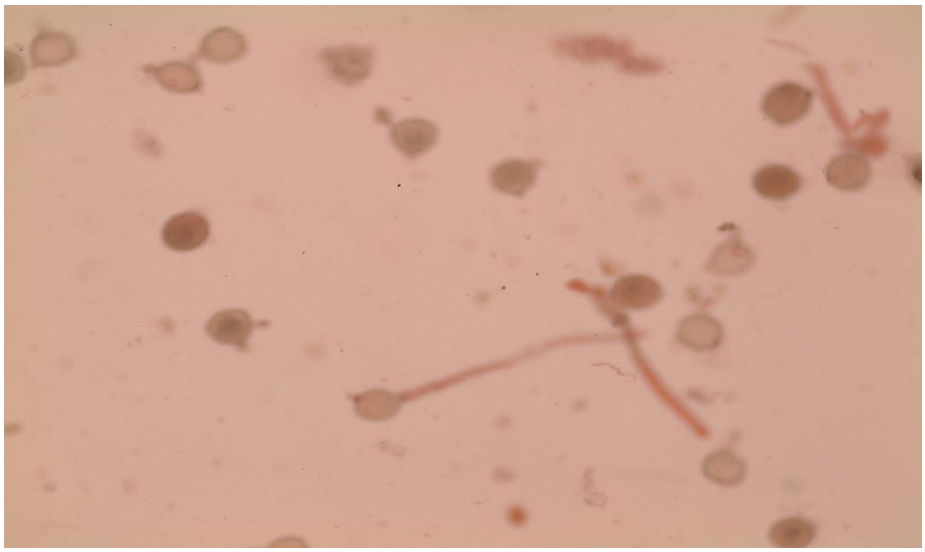

Plate 8: Pollen viability of *Trichosanthes cucumerina*

Plate 9: Fully matured fruit of *Trichosanthes cucumerina*

Table 11: Pollen viability (%) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions							
	Open				Rain shelter			
	Fertile pollens	Sterile pollens	Total number of pollen	Viability (%)	Fertile pollens	Sterile pollens	Total number of pollen	Viability (%)
Winter	140	360	500	28%	95	405	500	19%
Summer	245	255	500	49%	220	280	500	44%
Rainy	225	275	500	45%	205	295	500	41%

Table 12: Number of fruits per plant under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	23.50	26.00
Summer	42.00	35.00
Rainy	15.55	17.75

CD (0.05) = 0.292

Table 13: Length of fruit (cm) under open and rain shelter during winter, summer and rainy season

Seasons	Conditions	
	Open	Rain shelter
Winter	6.45	8.42
Summer	7.07	9.02
Rainy	5.70	7.47

CD (0.05) = 0.90

Girth of fruit showed a significant difference under the different growing conditions. Highest fruit girth (9.92 cm) was observed for the fruits that obtained under the open field during summer where as lowest fruit girth (7.32 cm) was recorded for the fruits that obtained under rain shelter during summer season. The fruit girth recorded was more under open than under the rain shelter (Table 14).

Growing environment and season had significant effect on the weight of the fruit (Table 15). The highest mean fruit weight was recorded for the fruits that obtained from open field under summer season (39.06 g) and a lowest fruit weight of 21.47 g was recorded for the fruits that obtained under rain shelter during winter season.

4.13. Fruit yield (g / plant)

Fruit yield of the plant was significantly influenced by growing environment. (Table 16). Highest fruit yield of 1655.10 g was obtained for the plants that grown under open field during summer season and lowest yield of 359.52 g was recorded for the plants in open field during winter season.

4.14. Seeds per fruit

Number of seeds obtained per fruit did not show any significant variation under open and rain shelter during winter, summer and rainy seasons (Table 17). Number of seeds found to be higher (10.89) for the fruits that grown under rain shelter during summer and a lower (8.22) for the fruits grown during rainy season under open condition.

4.15. Herbage yield (Fresh) (g /plant)

Total herbage yield (Fresh) showed a significant variation within the growing environment and seasons. Plants grown under rain shelter during summer season produced highest herbage yield of 501.25 g and lowest of 201.68 g obtained for the plants that grown under open field during rainy season (Table 18).

Table 14: Girth of fruit (cm) under open and rain shelter during winter, summer and rainy season

Seasons	Conditions	
	Open	Rain shelter
Winter	9.22	8.42
Summer	9.92	7.32
Rainy	9.62	6.95

CD (0.05) = 0.92

Table 15: Weight of fruit (g) under open and rain shelter during winter, summer and rainy seasons

Seasons	Conditions	
	Open	Rain shelter
Winter	32.60	21.47
Summer	39.06	28.63
Rainy	23.31	22.27

CD (0.05) = 3.187

Table 16: Fruit yield (g/plant) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	634.47* (25.14)	498.81* (22.34)
Summer	1655.52* (40.59)	1004.05* (31.66)
Rainy	359.52* (18.93)	396.55* (19.88)

CD (0.05) = 2.72

Table 17: Seeds per fruit under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	9.06	9.77
Summer	10.77	10.89
Rainy	8.82	8.98

CD (0.05) =1.125

* Orginal value
Transformed value in paranthesis

4.16. Herbage yield (Dry) (g/plant)

Dry yield of the pants represented in table 19. Dry yield showed no significant influence under the growing environment and seasons. Highest dry yields (73.5 g) were recorded under rain shelter during summer season and lowest yield (36.7 g) recorded under open condition during rainy season.

4.17. Total yield (g/plant)

Total yield of the plants represented under table 20. It showed that the total yield of the plant was significantly influenced by the growing environment and seasons. Highest yield of 2126.35 g was obtained from the plant that grown under open condition during summer season and lowest yield of 561.21 g was obtained under open field during rainy season. Summer season recorded highest yield than other two seasons.

4.18. Cucurbitacin content of the plant (g)

Cucurbitacin content of plant was influenced by growing condition and seasons significantly. The highest quantity of cucurbitacin was found under open condition during summer season (3.0 g) and lowest quantity was obtained under open condition during rainy season (0.78 g). Cucurbitacin was found to be highest in summer season followed by winter and rainy season (Table 21).

Table 18: Herbage yield (Fresh g/plant) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	203.7* (2.84)	312.77* (2.91)
Summer	471.25* (2.72)	501.25* (2.78)
Rainy	201.68* (2.80)	254.47* (2.84)

CD (0.05) = 0.030

Table 19: Herbage yield (Dry g/plant) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	36.98	55.5
Summer	68.5	73.5
Rainy	36.7	56.2

CD (0.05) = 7.01

* Orginal value
Transformed value in paranthesis

Table 20: Total yield (g/plant) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Conditions	
	Open	Rain shelter
Winter	838.17* (28.9)	754.24* (28.49)
Summer	2126.35* (46.04)	1505.58* (38.78)
Rainy	561.21* (23.67)	650.73* (25.49)

CD (0.05) = 2.431

Table 21: Per plant cucurbitacin content (g) under open and rain shelter during winter, summer and rainy seasons.

Seasons	Condition	
	Open	Rain shelter
Winter	1.34	1.12
Summer	3.00	2.50
Rainy	0.78	0.84

CD (0.05) = 0.025

* Orginal value
Transformed value in paranthesis

4.2. Meteorological observations

4.2.1. Rainfall data (mm)

Monthly rainfall (Figure 1) obtained during the cropping period of monsoon (June –July) was 1355.2 mm, during summer (March –May) was 472.1mm and lowest of 80.8 mm were recorded during the winter (December- February) season.

4.2.2. Canopy temperature (°C)

Canopy air temperature (CAT) was observed to be highest under rain shelter than in open field in all the three seasons. The highest CAT of 36.2 °C (rain shelter) and lowest of 24.8 °C (open) were recorded during the 2nd week after planting in the winter season (Table 22). In the case of summer season the highest CAT of 44.5 °C (rain shelter) and lowest of 30.2 °C (open) was recorded during the week 12 and 8 (Table 23). Canopy temperature showed a great variation in open and rain shelter during rainy season. Regarding rainy season, highest CAT of 35.3 °C during the 2nd week and lowest of 30.3 °C during the week five was recorded under rain shelter and open condition respectively (Table 24).

4.2.3. Soil moisture

Soil moisture was found to be higher under the rain shelter during winter and summer seasons (Table 22). In winter season, highest soil moisture of 46.4 per cent were recorded under rain shelter (4th week after planting) and lowest of 30.4 per cent was recorded under open condition (3rd week after planting).

During summer season, highest soil moisture recorded (42.4%) under the rain shelter during the 4th week after planting and lowest (29.0%) under open condition during the 6th week after planting (Table 23). Highest soil moisture (48.3%) under open and lowest (30.2%) under rain shelter were recorded during 6th and 10th week after planting during rainy season (Table 24).

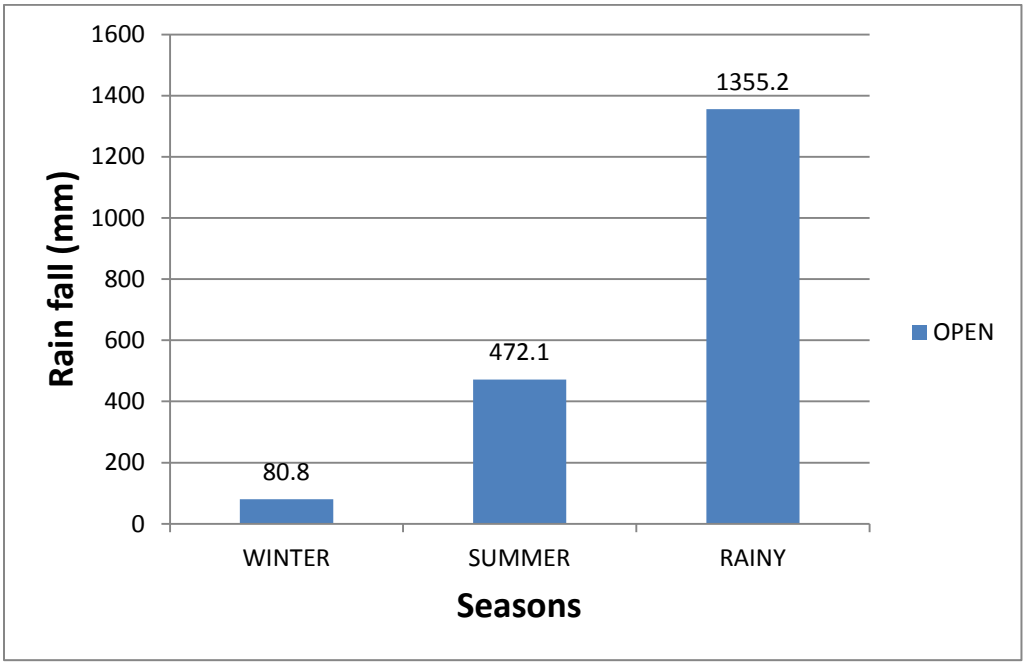

Figure 1: Monthly rainfall (mm) during winter, summer and rainy seasons

4.2.4. Soil temperature (ºC)

Soil temperature recorded was highest under open condition during winter and summer seasons whereas, lowest during rainy season. During winter season highest soil temperature of 30.6 ºC recorded under open and lowest of 25.3 ºC was found under rain shelter during 6th and 8th week of planting (Table 22). In summer season highest of 35.1 ºC and lowest of 26.2 ºC were recorded during 4th and 1st week after planting under the open and rain shelter condition respectively (Table 23). In rainy season highest soil temperature recorded was 31.3 ºC and lowest of 24.3 ºC under rain shelter and open condition during the 1st and 11th week after planting (Table 24).

4.2.5. Maximum and minimum temperature (ºC)

In general maximum temperature was highest inside the rain shelter in all seasons as compared to open condition. During winter season maximum temperature found to increase from week one to week twelve (Table 22). Highest maximum temperature of 37.4 ºC (rain shelter) and lowest maximum temperature of 30.4ºC (open) were recorded. In summer season maximum temperature from week one to week five showed an increase in temperature followed by a decrease in temperature (Table 23). Highest maximum of 39.6ºC and lowest of 35.3 ºC was recorded during 5th and 12th week after planting under rain shelter and open. Maximum temperature showed a decrease from week one to week nine. Highest maximum temperature of 37.8^{o}C (rain shelter) and a lowest maximum of 30.4ºC (open) were recorded during rainy season (Table 24).

Minimum temperature was found to be higher in rain shelter than in open during three seasons. In winter season (Table 22) the minimum temperature was found to be increased from week one to week thirteen. Lowest minimum temperature of 24.1°C was recorded under open condition and a highest minimum temperature of 31.5°C recorded under rain shelter during week one and week thirteen. Highest minimum temperature of 31.2°C and lowest minimum temperature of 24.1°C were recorded during week ten and week one under the rain shelter and open condition during summer season (Table 23). During rainy season minimum temperature found to

increase from week one to week thirteen and highest minimum temperature of 31.5 °C (rain shelter) and lowest minimum of 24.1 °C (open) were recorded during the 1st and 13th week after planting (Table 24).

4.2.6. Relative humidity (%)

During winter and summer seasons average relative humidity was recorded to be highest under rain shelter. In winter season highest relative humidity of 81 per cent and lowest of 35.2 per cent was recorded under open field during the 13th and 2nd week after planting (Table 22). During summer season highest relative humidity of 65.4 per cent under rain shelter and lowest of 39.2 per cent under open condition were recorded during the 11th and 3rd week after planting (Table 23). Highest of 80.4 per cent and lowest of 66.3 per cent were recorded under open condition during the 13th and 1st week after planting during the rainy season (Table 24).

4.3. Crop weather relationships

4.3.1. Rainfall

Number of male flowers produced showed significantly strong negative correlation with rainfall during the week six to nine (-0.910, -0.882, -0.882 and -0.769) and from week eleven and twelve (-0.551 and -0.618) and found to be non significant during week ten (Table 25). Pollen fertility showed significant strong negative correlation with rainfall during week one to twelve (-0.968, -0.948, -0.955, -0.593, -0.948, -0.935, -0.913, -0.913, -0.818, -0.620 and -0.682) except week ten (Table 26). Rainfall and number of female flowers showed no significant relationship from week six to nine and found to be negatively correlated (Table 27) from week ten to twelve (-0.692, -0.480 and -0.404). Significant negative correlation was observed between rainfall and total number of fruits obtained from plants from week six to nine (-0.680, -0.627,-0.629,-0.450) and found to be non significant from week ten to twelve (Table 28).

Significant negative correlation was obtained between fruit yield and rainfall from week six to eight (-0.606, -0.549 and -0.549) and found to be non significant from

week nine to twelve (Table 29). Herbage yield showed significant negative correlation from week one to three (-0.605,-0.502 and -0.531) and from week five to six (-0.502 and-0.458) and showed a strong positive correlation during week five (0.987), rest of the cropping period found to be non significant (Table 30). Total yield and rainfall (Table 31) showed a negative correlation from week one to eight (-0.712, -0.623, -0.648, -0.623,-0.584, -0.525 and -0.524) and from week nine to twelve found to be non significant (Table 30). Cucurbitacin content of the plant (Table 32) showed strong negative correlation with rainfall from week one to nine (0.776, -0.692,-0.717, -0.938, -0.692, -0.655, -0.598, -0.598 and -0.411).

4.3.2. Soil temperature

Number of male flowers showed a significant positive correlation with soil temperature only during week seven, ten and eleven (0.595, 0.412 and 0.582) and found to be non significant during rest of the cropping period (Table 25). Correlation of soil temperature with pollen fertility was (Table 26) found to be non significant from week one to week twelve. However showed a negative correlation (-0.417) during week three. Number of female flowers was found to have significant negative correlation with soil temperature during week eight (- 0.417) and rest of the period found to be non significant (Table 27). No significant correlation was observed between soil temperature and total number of fruits obtained from vine (Table 28) and fruit yield (Table 29). Total herbage yield (Table 30) showed a significant positive correlation with soil temperature from week seven to ten (0.697, 0.526, 0.674 and 0.679) and found to be non significant from week one to six and eleven to twelve. Cucurbitacin had a negative correlation with soil temperature during week three (0.429) and positive correlation during week ten (0.417) and all other period found to non-significant (Table 32).

4.3.3. Canopy temperature

Canopy temperature showed a significant positive correlation with number of male flowers from week nine to eleven (0.550, 0.514 and 0.547) and found to be non-significant from week six to eight and twelve (Table 25). Pollen fertility showed a

significant positive correlation from week three to six (0.674, 0.648, 0.639 and 0.625), week eight (0.505), week eleven and twelve (0.761 and 0.661) with canopy temperature Table 26). Number of female flowers showed significantly strong negative correlation from week six to seven (-0.823 and -0.672) and from week ten to eleven (-0.430 and -0.506) and showed no correlation during week eight, nine and twelve (Table 27). Canopy temperature and number of fruits (Table 28) found to have no significant correlation from week six to eight and showed a significant positive correlation from week nine to twelve (0.478, 0.689, 0.831 and 0.569). Fruit yield (Table 29) showed a positive correlation from week six to eight (0.562, 0.497 and 0.712) and found to be non significant fro week nine to twelve.

Herbage yield recorded a significant positive correlation from week one to five (0.569, 0.542, 0.636, 0.691 and 0.645) and from week nine to eleven (0.470, 0.572 and 0.553) and correlation with week six to eight and twelve (Table 30). Positive correlation was exhibited between total yield and canopy temperature on week one (0.532), week three to six (0.877, 0.785, 0.717 and 0.547), week nine to twelve (0.407, 0.708, 0.822 and 0.682) and no significant correlation on week two, seven and eight (Table 31). Canopy temperature and cucurbitacin content (Table 32) of the plant showed a strong positive correlation with canopy temperature from week one to six (0.451, 0.820, 0.798, 0.733 and 0.581) except week two and from week ten to twelve (0.591, 0.783 and 0.582).

4.3.4. Minimum temperature

Number of male flowers showed a positive correlation with minimum temperature during week eight (0.678) and negative correlation during week nine (0.535) and found to be non-significant during other weeks (Table 25). Significant negative correlation observed with pollen fertility during week one, two and four (-0.531, -0.467 and -0.449), observed a positive correlation in week eight and eleven (0.631 and 0.620) and no correlation during week three, five, six, seven, nine and ten (Table 26). Minimum temperature showed a significant negative correlation with female flower (Table 27) from week eight to twelve (-0.404, -0.818, -0.577, -0.717 and -0.921). Number of fruits showed a negative correlation during week seven (-0.435)

and positive correlation during week eight and nine (0.670 and 0.483) and found to be non-significant during rest of the period (Table 28). Fruit yield (Table 29) showed a significant positive correlation from week six to seven (0.562, 0.497, 0.712, 0.856 and 0.753) except week seven and nine. Herbage yield (Table 30) showed no significant correlation from week one to seven and from week ten to eleven and showed strong positive correlation during week eight, nine and twelve (0.717, 0.707 and 0.474). Total yield showed a significant negative correlation during week one and two (-0.468 and -0.454) and showed a positive correlation during week eight, nine and twelve (0.630, 0.601 and 0.599) and found to be non significant from week three to seven and from week ten to eleven (Table 31). Minimum temperature and cucurbitacin content (Table 31) showed a negative correlation during week one and two (-0.461 and -0.443) and showed a positive correlation during week eight, nine and twelve (0.722, 0.6287 and 0.537).

4.3.5. Maximum temperature

Significantly strong positive correlation was observed with number of male flowers produced during the week seven to eleven and week twelve (0.863, 0.813, 0.854, 0.756 and 0.810) except week seven and eleven (Table 25). Pollen fertility (Table 26) had a significant negative correlation during week one (-0.575) and showed a positive correlation from week seven to week ten (0.587, 0.556, 0.569 and 0.453) and week twelve (0.590). Maximum temperature showed a strong significant negative correlation with number of female flowers during the week eight to week ten (-0.823, -0.672 and -0.330) and rest of the period correlation was non-significant (Table 27). Number of fruits showed a significant negative correlation (Table 28) from week seven to ten (0.721, 0.776, 0.692 and 0.426) and during week twelve (0.750). Significant positive correlation between maximum temperature and fruit yield (Table 29) from week seven to nine (0.538, 0.594 and 0.508) and week twelve (0.588). Herbage yield showed a significant negative correlation (Table 30) during week one and six (-0.558 and -0.435) and showed positive correlation during week five, seven, eight and twelve (0.492, 0.610, 0.715, 0.546 and 0.562). Total yield (Table 31) showed significant

negative correlation during week one (-0.674) and showed positive correlation from week seven to nine (0.573, 0.642 and 0.535) and in week twelve (0.604). Significantly strong positive correlation was observed with cucurbitacin content from week seven to nine (0.640, 0.721 and 0.592) and week twelve (0.643), negative correlation during week one (-0.681) and no correlation was observed on week two to six and ten to eleven (Table 32).

4.3.6. Relative humidity

Relative humidity (Table 25) showed a strong negative correlation with number of male flowers from week six to week twelve (-0.901, -0.726, -0.706, -0.661, -0.661, -0.515 and -0.625). Pollen fertility showed a significant negative correlation with relative humidity from week one to week eight (-0.499, -0.687, -0.685, -0.602, -0.656, -0.641, -0.495 and -0.450) and found to be non significant from week nine to twelve (Table 26). Significant negative correlation from week nine to twelve (-0.410, -0.431, -0.600 and -0.509) was observed for number of female flowers produced and showed no significant correlation from week six to eight (Table 27). Relative humidity and number of fruits showed significant negative correlation during week six, seven and twelve (-0.468, -0.418 and -0.531) and no correlation from week eight to eleven (Table 28). Fruit yield (Table 29) had significant negative correlation during week seven (-0.445) and showed a positive correlation during week eight to nine (0.580, 0.547) and from week eleven to twelve (0.451 and 0.605). Herbage yield showed strong negative correlation from week one to six (-0.832, -0.881, -0.917, -0.858, -0.599 and -0.610) and found to be non significant from week seven to week twelve (Table 30). Total yield showed a strong significant negative correlation with relative humidity only from week one to six (-0.778, -0.865, -0.918, -0.827, -0.613 and -0.617) and found to have no significant correlation from week seven to twelve (Table 31). Cucurbitacin content also showed strong negative correlation from week one to six (-0.807, -0.874, -0.917, -0.818, -0.638 and -0.632) and no significant influence during rest of the cropping period (Table 32).

4.3.7. Soil moisture

Number of male flowers produced during week six to week twelve showed strong significant negative correlation with soil moisture (-0.907, -0.863, -0.898, -0.924, -0.865, -0.880 and -0.870) (Table 25). Pollen fertility also showed significant negative correlation with soil moisture from week one to week nine (-0.498, -0.500, -0.514, -0.500, -0.487, -0.523, -0.505, -0.479 and -0.447), week eleven and twelve (-0.471 and -0.459) except week eleven (Table 26). Number of female flowers obtained during the cropping period and soil moisture had no significant correlation (Table 27). Significant negative correlation was found with number of fruits and soil moisture from week six to week twelve (-0.651, -0.548, -0.581, -0.598, -0.478, -0.551 and -0.532) (Table 29). Fruit yield (Table 30) showed significant negative correlation from week six to week eight (-0.484, -0.407 and -0.423). Negative correlation was obtained between soil moisture and herbage yield (Table 30) from week one to week nine (-0.568, -0.571, -0.548, -0.593, -0.575, -0.650, -0.485, -0.502, -0.545) and from week 11 to 12 (-0.444 and -0.441). Soil moisture had significant negative correlation with total yield (Table 31). From week one to week nine (-0.471, -0.467, -0.449, -0.491, -0.463, -0.538, -0.439,-0.456, and -0.450) and from week eleven to twelve (-0.419 and -0.407). Cucurbitacin content (Table 32) showed a significant negative correlation from week one to nine (-0.511, -0.514, -0.506, -0.532, -0.504, -0.586, -0.458, -0.465 and -0.481) and from week eleven to twelve (-0.425 and -0.411).

4.4. Multiple regression models developed

Stepwise regression analysis was carried out to select the critical variables, which contributed to yield and phenological variables and multiple regression equations were developed.

4.4.1 Number of male flowers

Number of male flowers = 91.086 - 1.760 SM_9 + 0.137 RF_9 +1.977 $TMin_9$

(R^2 = 0.935)

Where,

SM_9 = Soil moisture for ninth week

RF_9 = Rainfall for ninth week

$TMin_9$ = Minimum temperature for ninth week

4.4.2 Number of female flowers

Number of female flowers = 156.17 - 2.201 $TMin_{12}$ - 1.417 $TMax_8$ - 0.013 RF_{12}

(R^2 = 0.957)

Where,

$TMin_{12}$ = Minimum temperature for 12^{th} week

$TMax_8$ = Maximum temperature for eighth week

RF_{12} = Rainfall for 12^{th} week

4.4.3 Pollen fertility

Pollen fertility = -175.89 +1.29 CT_{11} + 4.069 $TMin_{11}$ + 2.880 $TMax_9$

(R^2 = 0.810)

Where,

CT_{11} = Canopy air temperature for 11^{th} week

$TMin_{11}$ = Minimum temperature for 11^{th} week

$TMax_9$ = Maximum temperature for ninth week

4.4.4 Number of fruits

Number of fruits = -3.680 + 0.849 CT_{11} + 1.673 $TMin_9$ - 1.079 SM_9 + 0.166 RF_9

(R^2= 0.939)

Where,

CT_{11} = Canopy air temperature for 11^{th} week

$TMin_9$ = Minimum temperature for ninth week

SM_9 = Soil moisture for ninth week

RF_9 = Rainfall for ninth week

4.4.5 Fruit yield

Fruit yield = $-7136.57 + 130.454\ TMin_{12} + 136.310\ TMax_{12}$

(R^2=0.931)

Where,

$TMin_{12}$ = Minimum temperature for 12^{th} week

$TMax_{12}$ = Maximum temperature for 12^{th} week

4.4.6 Herbage yield

Herbage yield= $-280.60 - 5.639\ RH_3 + 36.605\ TMin_9$

(R^2= 0.942)

Where,

RH_3 = Relative Humidity for third week

$TMin_9$ = Minimum temperature for ninth week

4.4.7 Total yield

Total yield = $-7781.56 -7.076\ RH_3 + 121.483\ CT_3 + 201.877\ TMin_8$

(R^2= 0.952)

Where,

RH_3 = Relative Humidity for third week

CT_3 = Canopy temperature for third week

$TMin_8$ = Minimum temperature for eighth week

4.4.8 Cucurbitacin content

Cucurbitacin content = $1.747 – 0.106\ RH_3 + 0.071\ RH_4 + 0.052\ CT_4$

(R^2 = 0.935)

Where,

RH_3 = Relative Humidity for third week

RH_4 = Relative humidity for fourth week

CT_4 = Canopy air temperature for fourth week

DISCUSSION

CHAPTER 5
DISCUSSION

The results of the study entitled "Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different season" are discussed in this chapter.

5.1. Vegetative parameters

Trichosanthes cucumerina plants exhibited an increase in vine length under rain shelter in all the seasons. The highest vine length of 484.12 cm was observed when plants were grown in summer under rain shelter. Plants under open condition grown in rainy season recorded the lowest vine length of 130.37cm. (Table 1 and Figure 2).

Increase in vine length during winter, summer and rainy season under the rain shelter may be due to higher temperature and relative humidity in rain shelter as compared to open field condition which also favour the increase in vine length of the plant under rain shelter (Table 22 to 24).

Similar result was reported by Vezhavendran (2003) in capsicum and according to him the growth was largely influenced by growing condition and seasons.

Numbers of branches were found to be more in summer season. No Significant influence was observed on the number of branches of plants when grown under opens and rain shelter (Table 2). The higher number of mean branches (1.40) was obtained for the plant that grown under rain shelter during summer and lowest value of (1.07) was found under open condition during winter.

Increase in number of branches may be due to high canopy temperature and maximum temperature inside the rain shelter (Table 22 to 24).

Rylski (1986) cited similar result in pepper that the numbers of branches per plant were higher under shade net house than open field.

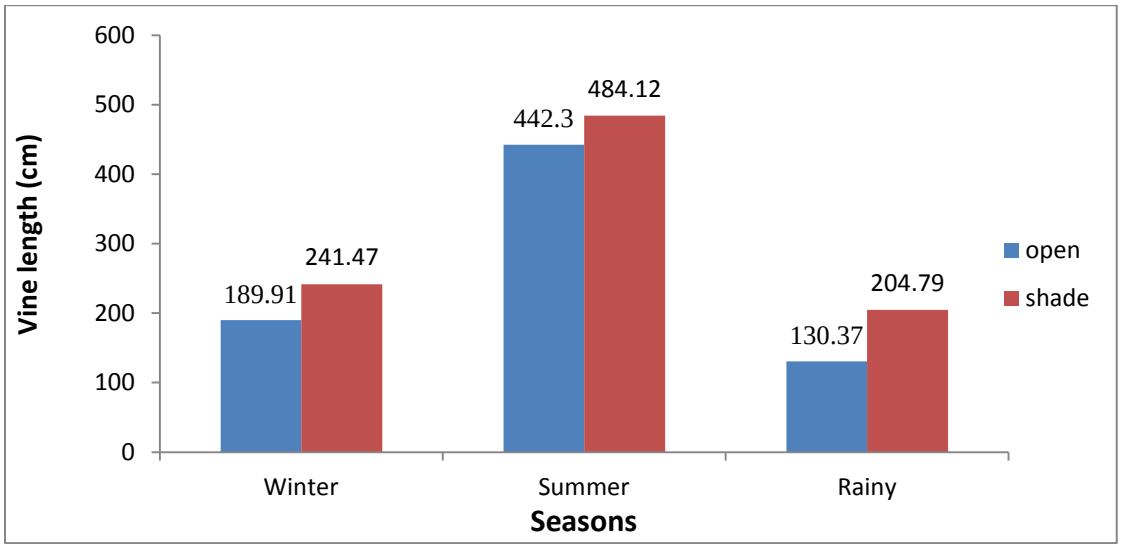

Figure 2: Vine length of *Trichosanthes cucumerina* under open and rain shelter during winter, summer and rainy seasons.

Leaf area at maximum vegetative stage showed a significant influence for plants grown under open and rain shelter during three seasons (Table 3). The highest value of 211.9 cm^2 (rain shelter) was recorded under summer and a minimum of 154.8 cm^2 (open) during winter season (Figure 3).

Increase in leaf area may be due to lower light intensity under shade condition than in open and may also be due to increase in maximum and minimum temperature under the rain shelter (Table 22 to 24). High temperature may favors in increasing the photosynthesis, cell division and increases the number of stomata.

Similar result was reported by Srikrishnan *et al.* (2012) in three varieties of *Dracaena sanderiana L*. in the Dry Zone of Sri Lanka that leaf area was higher at 50 and 70 per cent shade. These results agree with Papadopoulos and Ormrod (1991) in tomato that the highest leaf area per plant recorded under shade net house during summer and winter seasons.

5.2. Floral biology

Number of days took for opening of first male and female flowers showed no significant variation under growing environment. The highest number of days taken for male flower opening was found to be 48.00 days under rain shelter during winter season (Figure 4). The lowest of 40.25 days was recorded for the plants grown under open condition during summer season (Table 4). In the case of female flower, the highest mean numbers of days to first female flower opening was 63.25 days under rain shelter during winter season and a lowest number of 47.75 days were found during summer season (Table 5).

The number of days took for first flower opening varies and this may be due to high temperature under rain shelter (Table 22 to 24). Increase in temperature delayed the flower opening.

Observation by Bustamante and Burquez (2008) that onset of flowering of Organ Pipe Cactus (*Stenocereus thurberi*) is related to the variance in minimum temperatures and maximum temperature

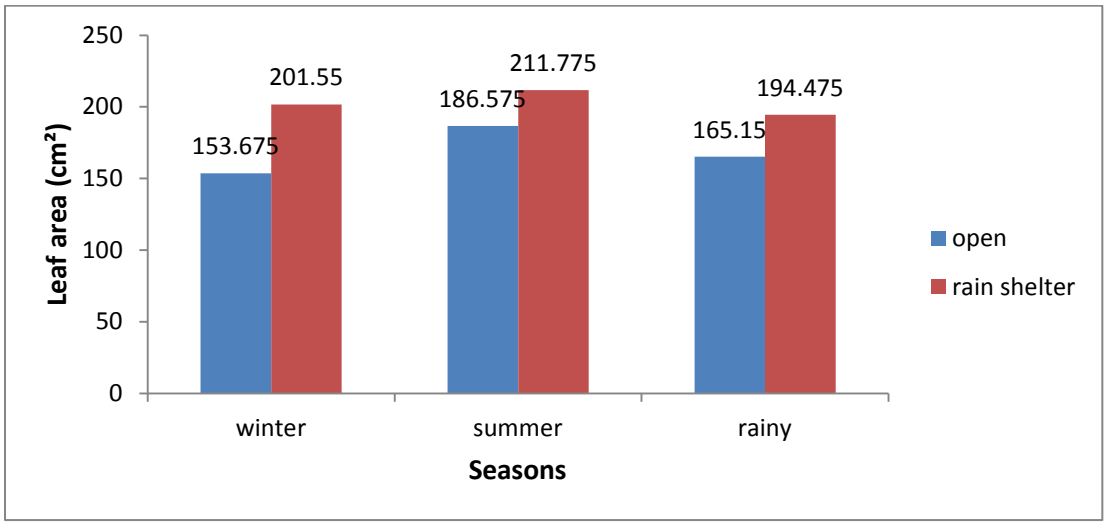

Figure 3: Leaf area of *Trichosanthes cucumerina* under open and rain shelter during winter, summer and rainy seasons

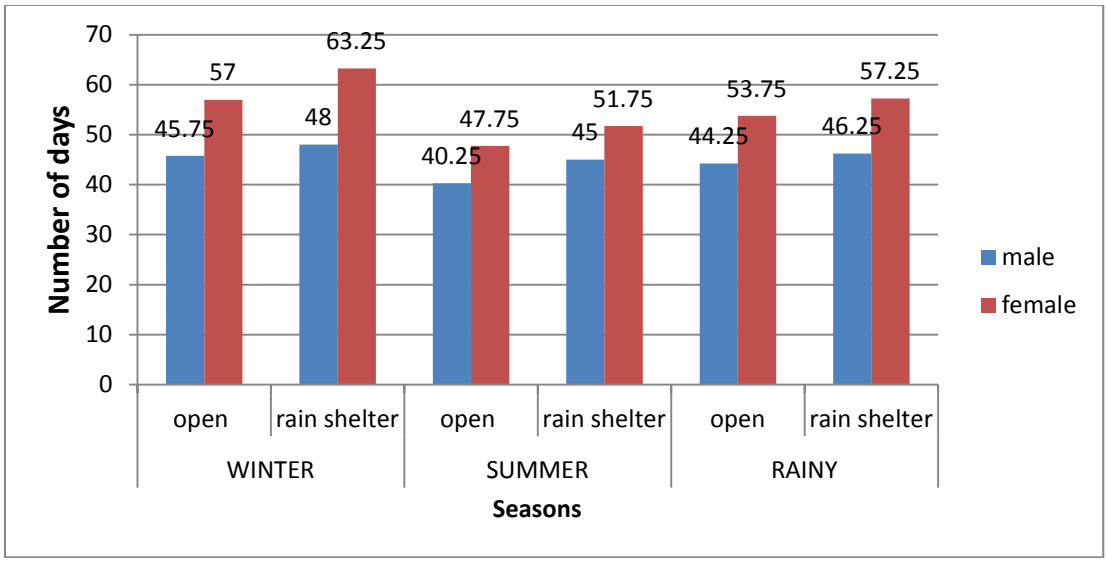

Figure 4: Number of days to first flower opening under open and rain shelter during winter, summer and rainy seasons.

Number of male flowers of *Trichosanthes cucumerina* was significantly influenced by the growing conditions and seasons. The highest number of male flowers 85.75 (Table 6) was observed during summer season under rain shelter and lowest of 38.75 in open condition during winter (Figure 5). Male flowers are recorded to be more during summer season then followed by winter and rainy season. This may be due to increase in temperature under rain shelter (Table 33). There was an increase of 0.71 ˚C under rain shelter when compared to open condition during summer whereas the temperature was less by 0.6 ºC during winter season. In this study, maximum temperature showed a positive correlation with the number of male flowers (Table 26). Thus increase in maximum temperature increased the number of male flowers and relative humidity showed a strong negative correlation with the number of male flowers (Table 27).

Growing environments and seasons had a significant influence on number of female flowers produced. The highest numbers of 63.25 female flowers were obtained under rain shelter during winter and lowest of 40.25 female flowers were observed under open condition during summer (Table 7). Sawn (2014) cited that a significant influence of temperature and relative humidity on number of flowers of cotton.

Male flower anthesis (Table 8) occurred between 19: 30 hours under open (summer) to 20:50 hours under rain shelter (rainy). In case of female flower, anthesis occur between 20.43 hours under open (summer) to 21:44 hours under rain shelter (rainy). This may be due to varying minimum temperature and relative humidity. Due to high humidity under rain shelter might have delay anthesis of both male and female flowers.

Van Doorn and Van Meeteren (2003) reported that opening and closure of flower is regulated by changes in light intensity and with increase in relative humidity.

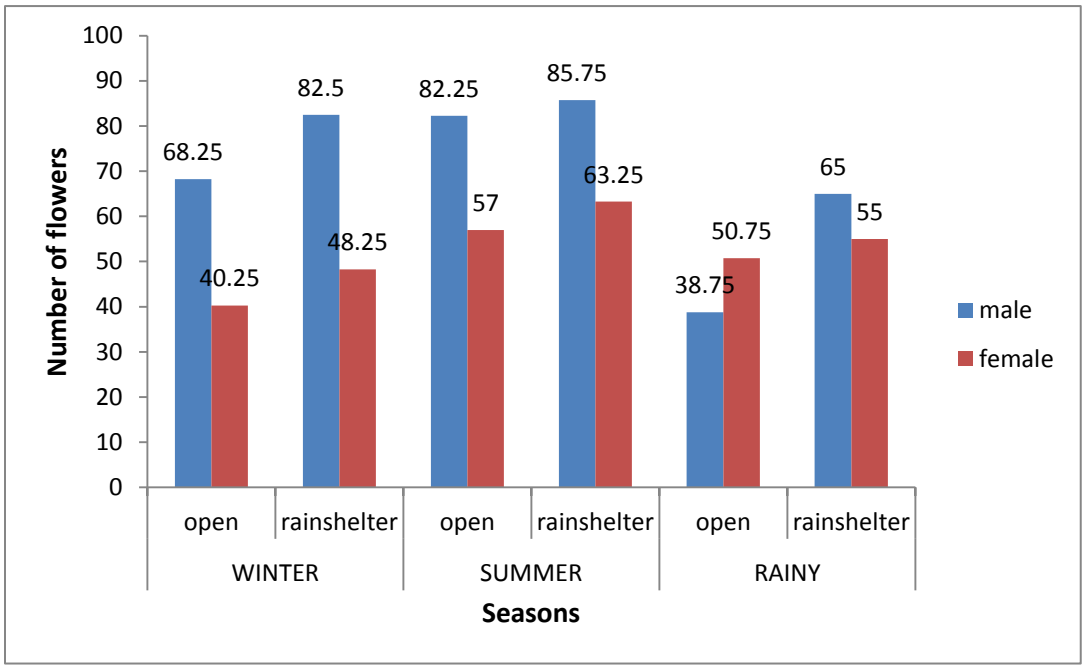

Figure 5: Number of male and female flowers under open and rain shelter during winter, summer and rainy seasons.

Growing environment and seasons had a significant influence on pollen fertility (Table 10). Highest of 95.7 per cent was recorded during summer season and lowest of 63.8 per cent during winter season under the open condition (Figure 6). In this study, relative humidity showed negative correlation with the pollen fertility (Table 25). Relative humidity was low under open condition as compared to rain shelter during summer season. A decrease of 2.7 per cent of relative humidity under open condition was noticed as compared to rain shelter (Table 36).

Significant negative correlation of relative humidity on pollen fertility of *Oryza sativa.* L was reported by Latha and Thiyagarajan (2010).

Quantitative character

Number of fruits (Table 12) had significant variation by the growing condition and seasons. Highest number of fruits of 42 was observed during summer and lowest of 15.5 were recorded during winter under the open condition (Figure 7).This may be due to maximum temperature, rainfall and canopy air temperature, which showed a strong positive correlation with number of fruits and negative correlation with the rainfall (Table 28).

Canopy temperature was found to be higher under the rain shelter during all the seasons, an increase of 3.29°c under rain shelter during winter resulted in highest number of fruits (Table 35). Whereas temperature difference was less during rainy season.

Length of the fruit (Table 13) of *Trichosanthes cucumerina* exhibited no significant difference under growing environment. The highest length was recorded for the fruits obtained under rain shelter (9.02cm) during summer and a lowest value was recorded for the fruits obtained under open condition during rainy season (5.70cm). Girth of fruit showed a significant difference under the growing condition. Highest girth (9.92cm) recorded under the open field during summer whereas lowest girth (7.32cm) was noticed under rain shelter during summer season (Table 14). Growing environment and season had significant effect on weight of the fruit. The highest mean fruit weight

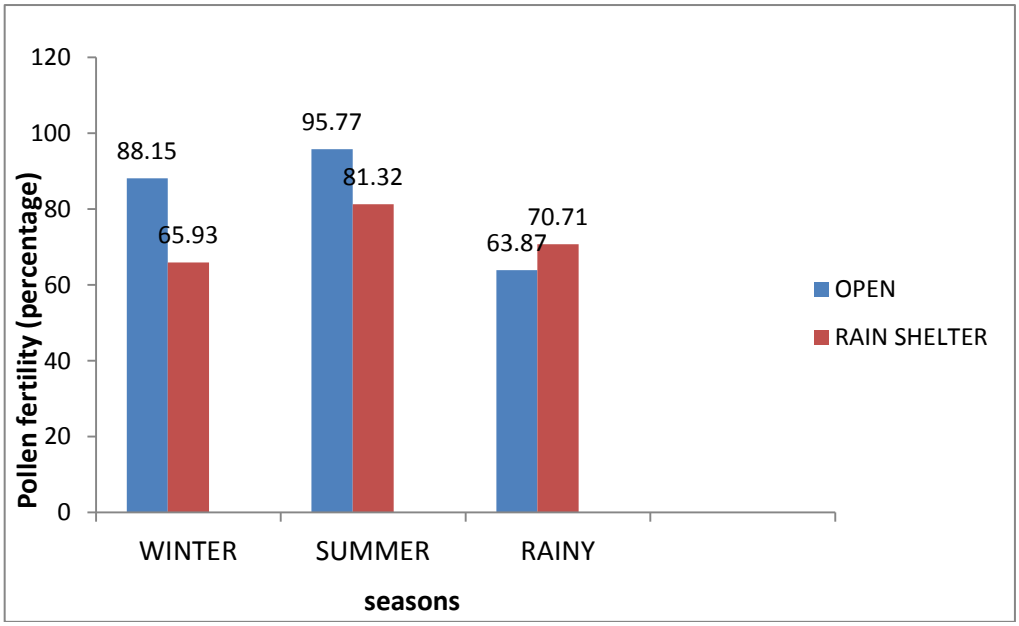

Figure 6: Pollen fertility under open and rain shelter during winter, summer and rainy seasons.

(Table 15) was recorded for the fruits that obtained from open field during summer (39.06g) and lowest fruit weight was recorded for the fruits that obtained under rain shelter during winter (21.47 g).

Change in fruit character may be due to mean minimum and maximum temperature variation. These findings agree with the results in tomato by Kalloo, (1986) who found that mean fruit weight of tomato was significantly affected by date of planting and growing environment.

Fruit yield (Table 16) showed a significant influence under growing environment and seasons. Highest of 1655.5 g (summer) and lowest of 359.5 g (rainy) were recorded under open condition (Figure 7). In the present study rainfall had a negative correlated that resulted in low fruit yield during rainy season (Table 29) whereas maximum temperature and relative humidity had a positive correlation with fruit yield that resulted in higher yield. Similar study was reported by Sunil *et al.* (2011) that there was a significant positive influence of temperature and relative humidity on fruit yield of arecanut.

Significant differences were observed for total herbage yield (Table 18) under different season and growing environment. Highest herbage yield of 501.3g per plant was recorded under rain shelter during summer and lowest of 201.7g under open condition during winter (Figure 9). Higher herbage yield under rain shelter may be due to high maximum temperature, minimum temperature and canopy temperature (Table 33 to 35) under rain shelter than open condition. Lowest herbage yield may be due to negative correlation of the rainfall under the open condition during rainy season (Table 30).

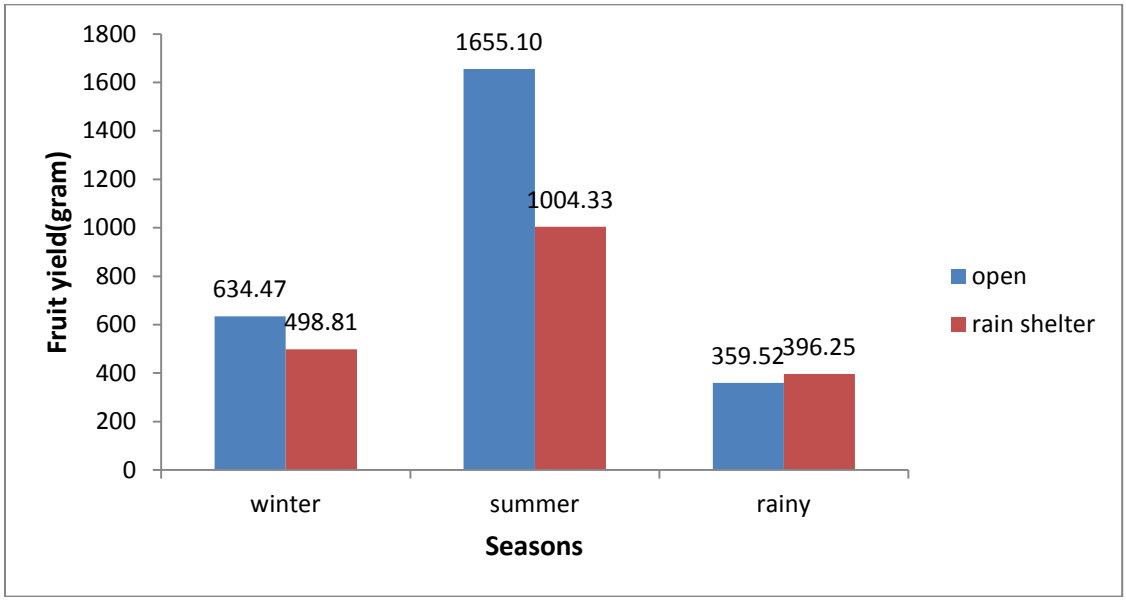

Figure 7: Fruit yield under open and rain shelter during winter, summer and rainy seasons.

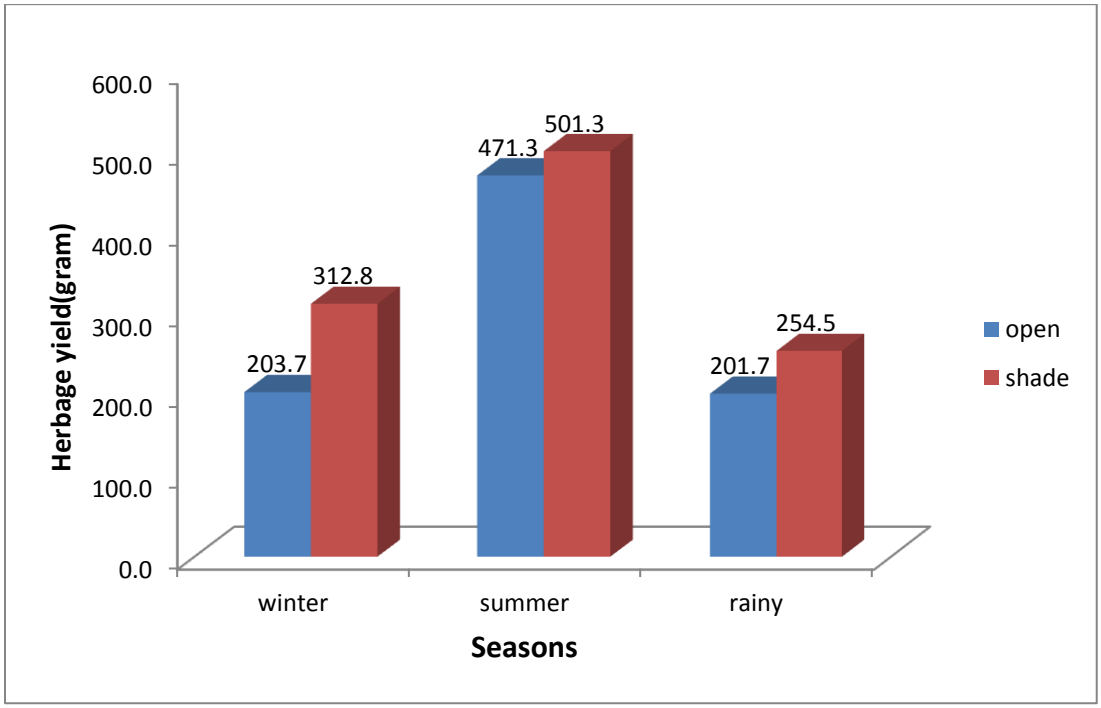

Figure 8: Herbage yield under open and rain shelter during winter, summer and rainy seasons.

Quality parameter

Cucurbitacin (g)

Cucurbitacin content of the plant was influenced by growing condition and seasons significantly. The highest quantity of cucurbitacin was found under open condition during summer season (3.0 g) and lowest quantity was obtained under open condition during rainy season (0.78 g). Among different seasons cucurbitacin was found to be highest in summer season followed by winter and rainy season (Table 21). In the present study, maximum temperature and canopy temperature was positively correlated with cucurbitacin content. Result are in agreement with the findings of Devendra *et al*. (2011), they reported that temperature has a positive influence on cucurbitacin content of the *Trichosanthes cucumerina* plant.

Table 33: Mean maximum temperature data under different growing seasons and growing conditions.

	Max Temp(°C)		
	Open	Rain shelter	Difference
Winter	33.78	34.38	0.61
Summer	37.2	37.9	0.71
Rainy	33.8	34.4	0.64
CD	1.42	1.4	

Table 34: Mean minimum temperature data under different growing seasons and growing conditions.

	Min Temp(°C)		
	Open	Rain shelter	Difference
Winter	26.39	27.55	1.15
Summer	26.9	28.8	1.87
Rainy	26.4	27.5	1.16
CD	0.25	0.759	

Table 35: Mean canopy temperature data under different growing seasons and growing conditions.

	Canopy Temp(°C)		
	Open	Rain shelter	Difference
Winter	31.06	34.35	3.29
Summer	33.9	37.0	3.02
Rainy	32.2	32.7	0.48
CD	2.11	2.102	

Table 36: Mean Relative Humidity data under different growing seasons and growing conditions.

	RH (%)		
	Open	Rain shelter	Difference
Winter	54.36	56.68	2.32
Summer	51.3	54.1	2.7
Rainy	73.7	71.8	1.8
CD	2.88	4.237	

SUMMARY AND CONCLUSIONS

CHAPTER 6
SUMMARY

A study entitled "Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons" was conducted at ACCER and at the fields of All India Coordinated Research Project on Medicinal, Aromatic Plants and Betel Vines (AICRP on MAP & B)), College of Horticulture, Vellanikkara during the period 2014-2015.

The objective of the study was to assess the influence of weather parameters on yield and yield attributing characters of medicinal snake gourd (*Trichosanthes cucumerina* L.) under open and rain shelter during winter, summer and rainy seasons.

Vine length was found to be highest (484.12 cm) under rain shelter during summer seasons. No significant difference was noticed in open and rain shelter during three seasons. Numbers of branches were recorded to be higher during summer season under rain shelter. No significant influence was recorded on number of branches produced during winter, summer and rainy seasons. Leaf area at maximum vegetative phase was found significantly influenced under open and rain shelter during winter and rainy season. Highest leaf area (211.9 cm^2) was recorded under rain shelter during summer season.

Growing environment and seasons have no significant influence on number of days taken to first male and female flowers. Lowest number (40.25) of days to first female flowers occurred under rain shelter during summer and lowest number of days took first female flowers opening (47.75) under rain shelter during the summer season.

Growing environment and seasons showed significant influence with number of male and female flowers produced in the plant. Highest number of male flowers (82.50) and female flowers (63.25) were recorded during summer season under open condition.

Time of anthesis was early during summer season. In male flowers it ranged from 19.30 hours (summer) to 20.50 hours (rainy) and in female flower it ranged from 20.43 hours (summer) to 21.44 hours (winter).

Vertical distance of the pollen grain ranges from 77.03µ (summer) to 77.76 (rainy) and horizontal distance ranges from 73.69 (summer) to 78.96 (rainy).

Highest pollen fertility (95.7%) was recorded during summer season under the open condition. Pollen viability recorded highest (49%) under open condition during summer season.

Highest number of fruits (42.0) was obtained from the plants that grown under open condition during summer. Significant difference was observed for the number of fruits obtained under open and rain shelter during their seasons.

Length and weight of the fruit varied significantly under different growing environments and seasons. Maximum length (9.02 cm) was recorded under rain shelter and highest girth (9.92 cm) and weight (39.06 g) were recorded under open condition during summer.

Fruit yield showed significant difference under different growing environments. Plants grown during summer season under open condition gave highest fruit yield of 1655g per plant.

Highest numbers of seeds (10.89) were obtained during summer under rain shelter and showed no significant influence under open and rain shelter.

With respect to herbage yield, significant difference was noticed with the growing environment and seasons. Highest yield of 501.25g was recorded during summer season under the rain shelter. Highest dry weight (73.5g) was recorded for the plants grown under rain shelter during summer.

Significant difference was exhibited in the case of total yield within the growing environment and seasons. Maximum yield (2126.35 g) was recorded under open condition during summer season.

Quality parameter cucurbitacin content showed significant influence under different seasons. Maximum (3.0 g) was recorded during summer season under open condition.

From this study it is investigated that summer season is the best suitable season for *Trichosanthes cucumerina*. It performs well under open condition. Combination of summer planting under open situation gave the highest fruit yield and total yield. Planting in winter under open condition is the next best alternative for growing *Trichosanthes cucumerina*. Rainy season is not ideal for *Trichosanthes cucumerina*. Rain shelter can be recommended for planting the crop under rainy season.

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PHENOLOGY OF MEDICINAL SNAKE GOURD (*Trichosanthes cucumerina* L.) UNDER DIFFERENT SEASONS

By

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ABSTRACT

Submitted in partial fulfilment of the
requirements for the degree of

B.Sc-M.Sc (Integrated) CLIMATE CHANGE ADAPTATION

Faculty of Agriculture

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VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2015

ABSTRACT

The present study entitled "Phenology of medicinal snake gourd (*Trichosanthes cucumerina* L.) under different seasons" was carried out at Academy of Climate Change Education and Research (ACCER), Vellanikkara during the period 2014-2015. Field experiments were conducted at All India Coordinated Research Project on Medicinal, Aromatic Plants and Betel Vine (AICRP on MAP & B), College of Horticulture, Vellanikkara. The objective of the study was to assess the influence of weather parameters on yield and yield attributing characters of medicinal snake gourd (*Trichosanthes cucumerina* L.) under open and rain shelter during winter, summer and rainy seasons.

The experiment was laid out in a randomized block design with six treatments and four replications each in open and rain shelter during winter, summer and rainy seasons. Observations on meteorological, growth characters, floral biology, yield and quality parameters were recorded under open and rain shelter in all the three seasons.

Significant difference was observed in number of flowers, number of fruits produced, pollen fertility, fruit yield per plant, herbage yield per plant, total yield per plant and per plant cucurbitacin content for plants grown under rain shelter as well as in open condition during the three seasons.

During winter, summer and rainy seasons crops grown under rain shelter recorded highest vine length, number of branches, maximum leaf area and number of male and female flowers produced, herbage yield per plant and dry yield per plant than open condition. Whereas pollen fertility, pollen viability and fruit weight were found to be highest in open condition than in rain shelter during summer season and found more in rain shelter during winter and rainy seasons. Earlier anthesis of both male and female flower was recorded during summer season under open condition. Highest herbage yield per plant, fruit yield per plant and total yield per plant were recorded under open condition during summer season. But during rainy season it is higher under rain shelter when compared to open field.

Per plant cucurbitacin content was highest for the plants that grown under open environment than in rain shelter. It was found to be maximum during summer season followed by winter and rainy season.

Weather parameters such as canopy air temperature, daily minimum and maximum temperature were high under rain shelter during the three cropping seasons. Relative humidity and soil moisture were high under rain shelter during winter and summer and low during rainy season.

Correlation analysis with the weather parameters and crop was studied. Relative humidity and soil moisture had a significant negative correlation with the number of male flowers produced, pollen fertility, herbage yield per plant, total yield per plant and per plant cucurbitacin content. Canopy air temperature, minimum and maximum temperature showed positive correlation with the number of male flowers, produced pollen fertility, number of fruits, fruit yield per plant, herbage yield per plant, total yield per plant and per plant cucurbitacin content whereas rainfall had a negative correlation.