CROP WEATHER RELATIONSHIP IN OKRA

[*Abelmoschus esculentus* (L.) Moench]

By

S. KAVITHA

THESIS

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DEPARTMENT OF AGRICULTURAL METEOROLOGY
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Kerala, India

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DECLARATION

I hereby declare that this thesis entitled "**Crop weather relationship in okra [*Abelmoschus esculentus* (L.) Moench]**" is a bonafide record of research work done by me during the course of research and that the thesis has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
25. 3. 2000

S. KAVITHA

Dr.A.V.R. Kesava Rao
Associate Professor
Department of Agricultural Meteorology
College of Horticulture, Vellanikkara
Presently working as Senior Scientist (Agrometeorology)
Central Research Institute of Dryland Agriculture
Santhosh Nagar, Hyderabad, A.P.

Vellanikkara
25. 3. 2000

CERTIFICATE

Certified that this thesis, entitled "**Crop weather relationship in okra [*Abelmoschus esculentus* (L.) Moench]**" is a record of research work done independently by Smt. S. Kavitha, under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Dr. A.V.R. KESAVA RAO
Chairman, Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Smt.S.Kavitha** a candidate for the degree of **Master of Science in Agriculture** with major in **Agricultural Meteorology**, agree that the thesis entitled **"Crop weather relationship in okra [*Abelmoschus esculentus* (L.) Moench]"** may be submitted by Smt.S. Kavitha, in partial fulfilment of the requirement for the degree.

Dr. A.V.R. Kesava Rao
Associate Professor
Dept. of Agricultural Meteorology
College of Horticulture
Presently working as Senior Scientist, Agrometeorology
Central Research Institute for Dryland Agriculture
Santhosh Nagar, Hyderabad
(Chairman)

28/3/'00

Dr. G.S.L.H.V. Prasada Rao
Professor and Head
Dept. of Agricultural Meteorology
College of Horticulture
Vellanikkara
(Member)

25/3/2000

Dr. E.K.Lalitha Bai
Associate Professor
Dept. of Agricultural Meteorology
College of Horticulture
Vellanikkara
(Member)

Dr. K.V.Suresh Babu
Assistant Professor
Department of Olericulture
College of Horticulture
Vellanikkara
(Member)

25/3/2000

EXTERNAL EXAMINER
(T.N. Balasubramani)

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KAVITHA

Dedicated to

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INTRODUCTION

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench), commonly known as bhindi and 'vendaykka' in Malayalam, is one of the most important warm season fruit vegetables grown in the tropical and subtropical climates. Eventhough India is its center of origin; ancient cultivable varieties were introduced to our country by the western navigators and explorers. The crop is now being cultivated throughout the country in different agroclimatic regions.

Okra occupies an important place among the vegetable crops on account of its tender green fruits, quick growth habit, short duration and easiness in cultivation under wide range of growing conditions. Advances in food technology have given further boost to the cultivation of the crop, with the export of dehydrated pods to foreign countries.

The fruits of okra are rich in protein, fibre, mineral matter and fat. The fruits are also good source of Vitamins A, B and C and minerals like Calcium, Magnesium and Phosphorus and play an important role in balanced human nutrition. Nutritive value of bhindi in hundred g of fresh fruit as reported by Das (1993) is given in the Table 1.

Table 1. Nutritive value of bhindi in 100 g fruits

Protein (g)	Carbo hydrate (g)	Fat (g)	Mineral matter (g)	Fibre (g)	Calcium (g)	Magnesium (g)	Phosphorus (mg)	Iron (mg)	Sodium (mg)
1.8	6.4	0.2	0.7	1.2	66.0	43.0	56.0	1.5	6.9

Apart from the use of fruits as a vegetable, the stem of the plant is used for the extraction of the fibre, which is one of the strongest fibre materials. Mucilaginous extracts of green stems are commonly employed in India for clarifying sugarcane juice in gur manufacture. Seeds are sometimes roasted and grounded as substitute for coffee (Chouhan, 1968). Also bhindi seeds had been identified as a nutritious cattle feed.

Okra is having unique medicinal properties also. A mucilaginous preparation from the pod can be used as a plasma replacement or blood volume expander. The leaves and the immature fruits had been popular in the east for use in poultices to relieve pain (Purseglove, 1968). At the same time 61.5 per cent of okra cultivators were reported to have skin diseases from okra cultivation (Matsushita *et al*, 1981).

In India, the total area under okra cultivation is 0.4 mha and provides four million tonnes of fresh fruits per year. The yield of bhindi per unit of land per unit time has remained very low in our country. A galaxy of reasons - poor genetic potential of the existing genotypes to manufacture and store photosynthate, incidence of many parasitic and non - parasitic insect pests and diseases, and lack of appropriate agronomic package of practice in accordance with the varying environmental conditions during different seasons - have been attributed to the poor performance of Indian bhindi.

The growth and yield of okra and incidence of insect pest and diseases are highly dependent on the prevailing weather conditions during the growth and reproductive stages of the crop. When specially tailored weather support is readily available to the needs of this crop cultivation, it greatly contributes towards making short term adjustment in daily agricultural operations which minimize losses resulting from adverse weather conditions and improve the yield and quality of the product.

Okra can be grown throughout the year. But best results were obtained from sowings in March, April and May when mean temperature and day length were maximum (Thamburaj, 1972). This shows the boundless interrelationship of the crop and prevailing weather conditions during its life span.

In tropical monsoon climates like Kerala, high rainfall (2000 to 3000 mm), low bright sunshine (2 to 4 h/day) and high relative humidity (>90%) during the rainy season (June to September) are the major climatic constraints. Hence successful cultivation of vegetables round the year is very much limited. In this context okra is an under exploited vegetable crop in Kerala and hence for commercialization, efforts are needed to maintain high level productivity through crop management in different agroclimatic zones. By developing crop weather relationships of okra using relevant meteorological skills, crop manipulations could be made efficiently for improving its production both in quality and quantity.

In view of the above, the present investigation was undertaken with the following objectives:

(1) To understand the influence of times of sowing on the yield of okra.

(2) To study the effect of plant characters on the yield of okra and

(3) To understand the crop weather relationships in okra.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Weather, which remained largely outside human control, is one of the most important factors determining the growth and yield of vegetables. Studies on the interrelationship between weather and crop growth are very few in okra and the available literature is reviewed in this chapter.

2.1 Effect of time of sowing on growth and yield of okra

Okra can be grown throughout the year where frost and severe winters are absent. In the plains and frost-free areas, the first, second and third sowings are taken up around January, June-July and September-October respectively. In regions where frost occurs, the crop is not raised in September-October.

Grewal *et al.* (1972) in their study on the effect of date of sowings on okra during 20th June, 10th July and 30th July at Punjab Agricultural University, Ludhiana, found that the seed yield, hundred seed weight and weight of dry mature pod per plant declined with later sowings.

Okra cultivar Pusa Sawani was grown during the winter (October – January), Summer (March – June) and rainy (July – September) seasons by Bisaria and Shamshery (1979) and reported high yield during the rainy season, while low in the winter season at Moradabad, Uttarpradesh.

A two year trial was conducted at Indian Institute of Horticultural Research, Bangalore, with the cultivars Pusa Sawani for 9 dates of sowing between 25th May and 5th November. The highest average yield of 110.8 q per ha was obtained from May 25th sowing (Gupta *et al.*, 1981).

Sureshbabu (1981) tried twenty five genotypes of bhindi at Kerala Agricultural University, Vellanikkara during May to August 1980 and September to January 1980-81, and found that four genotypes - Pusa Sawani, Hybrid Sel.1, Lam selection and Pusa Makhmali- were stable under medium yielding environments

Singh *et al.* (1986) reported a highest seed yield of 19.4 q to 21 q/ha by June 15th sown crop from Hissar.

Two widely grown okra cultivars (Ishan Local I and Ishan Local II) were sown by Inemiren and Okiy (1986) at Nigeria for approximately 14 days interval from 1st April to 1st June during the rainy season. April sowings resulted to vigorous growth in plants and they flowered earlier and had a longer harvest duration. This resulted in an increase in the number of pods per plant, pod length, diameter, volume, weight and thereby yield.

Singh *et al.* (1988) compared four sowing dates at fortnight intervals from 20th June to 4th August and four plant spacings at Jabalpur, Madhya Pradesh. They recorded maximum yield of 18.44 q ha^{-1} when sown on 20th June with a spacing of 45 x 30 cm.

Out of three sowing dates for the kharif season at Akola, Maharashtra viz., 4th July, 19th July and 3rd August during 1989, the plants from early sowing gave highest yield in terms of green pods and seeds (Bhuibhar *et al.*, 1989).

Mondal *et al.* (1989) observed highest plant height (84.5 cm), number of fruits per plant (10.9) and fruit yield (186.9 g per plant) from 20th April sowing at Mohanpur, West Bengal.

Gadakh *et al.* (1990) reported that out of the three cropping seasons viz., autumn, winter and summer, the summer season crop resulted with highest yield of 185 q ha^{-1}. Gupta (1990) got the highest yield of 147.1 q ha^{-1} from Okra cultivar Pusa Sawani during the spring seasons of 1980 and 1981 at Bangalore.

Rukhmani (1990) conducted an experiment to study the effects of physical, chemical and biological agents on fruit characters and yield of okra var. Pusa Sawani. Broadcasting and spaced planting (60 x 60 cm, 60 x 45 cm, 60 x 30 cm and 60 x 15 cm) were the physical treatments. Spacing 60 x 15 cm recorded the highest index to earliness in flowering during spring 1989-90 and summer 1990, whereas spacing 60 x 60 cm produced longest fruits. It was also recorded the superiority of summer season over other growing seasons in terms of yield.

Ghanti *et al.* (1991) in their studies on the effect of different seasons and spacing on yield and quality of bhindi at Rahuri observed that cultivars Pusa Sawani and Sel-2-2 recorded highest yield in the summer season with closest spacing.

Bisen *et al.* (1994) reported highest yield and seed per ha from okra plants sown on 20th June at a spacing of 45 x 30 cm.

Premnath *et al.* (1994) reported an increased yield of 80-92 q ha^{-1} in rainy season and 54-60 q ha^{-1} in summer season. The duration of the crop was also high (90-100 days) in the rainy season.

Kadam *et al.* (1995) reported highest seed yield of 572 kg/ha for Arka Anamika in kharif season with a spacing of 45 x 20 cm from Rahuri.

Cerri and Vilella (1996) had experiments with two dates of sowings viz. 1st December 1991 and 29th January 1992 at Argentina. They observed that photoperiod, temperature and interception of photosynthetically active radiation at floral inception differed and thereby leaf area index at floral initiation and dry matter accumulation varied between the two sowing dates. They found that late sowing resulted in increased rate of production of nodes whereas early sowing resulted in high rate of fruit growth. They also reported that December sowing had a total growth cycle of 93 days with an economic yield of 1171 g m^{-2}

whereas, January sown crop had a growth cycle of 77 days and economic yield of 885.3 g m^{-2}.

Raghav (1996) in his studies at G.B. Pant University of Agriculture and Technology, Nagina observed taller plants with high green pod yield, when okra was sown on March 1st with closest spacing of 15 x 30 cm.

Franco and Ortegon (1997) tested two planting dates during 1994 (15 February and 22 March) and 1995 (21 February and 15 March) at Mexico. The result was in favour of the 15th February planting over other sowing dates in terms of total yield.

Eventhough okra is an all season vegetable crop in tropics, reports indicate that the time of sowing could influence the performance of the crop to a greater extent in different seasons.

2.2 Biometric models

Thamburaj and Kamalanathan (1973) observed a significant positive correlation between the fruit weight, the total number of nodes per plant and yield.

Kirtisingh *et al.* (1974) reported that in bhindi, yield had negative correlation with days to first flower. They also obtained positive correlation between yield per plant and flower number, number of branches, plant height and fruits per plant both at phenotypic and genotypic levels.

According to Swamy and Ramu (1975) an increase in yield of 0.158, 0.0406 and 0.0305 g/plant was associated with unit increase in plant height, node number and pod number. Out of these three yield components, pod numbers per plant had most significant effect.

A significant positive total correlation was obtained for the plant height and the number of fruits, number of shoots and height of main shoot. Also a significant positive correlation was observed between the number of fruits and branches and fruit yield (Roy and Chonkar, 1976).

Mandal and Dana (1994) reported that fruit yield was significantly and positively associated with the number of fruits per plant and fruit length, whereas it was negatively associated with days to 50 per cent flowering.

Mahto (1996) reported a significant and positive correlation between seed yield per plant and plant height.

Yadav (1996) presented positive correlations between the yield per plant and number of pods and seed per pod. Similar correlation was also worked out between plant height and pod length and node at which first pod appeared and number of primary branches.

The above studies revealed that, yield per plant was highly correlated with the biometric characters in case of okra.

2.3 Effect of Environmental factors on growth and yield of okra

Okra or bhindi [*Abelmoscus esculentus* (L.) Moench] had been included as a warm season crop requiring long warm season and higher temperature above 21°C (Mac Gillivray, 1953 and Thomson and Kelly, 1957). Randhawa (1967) found that higher temperature and longer days that prevailed from March to May have caused the plants to grow taller with thick stems. Yawalker (1969) reported that the temperature and day length during various stages of the crop are more important than the sum total of the weather factors in a season.

Der (1972) reported a negative correlation between rainfall and yield of okra. The yield was highly sensitive to the amount of rainfall during the growing season.

Singh and Dhaliwal (1972) studied the effect of soil temperature on seedling emergence in different crops at Ludhiana and came to the conclusion that the optimum temperature range for seedling emergence was narrower for vegetables than for cereals. The seedlings of okra emerged at above 15°C along with bottlegourd and squash.

Thamburaj (1972) made monthly sowings of okra at Coimbatore to determine the effect of different day lengths and temperatures on germination, growth and yield. He observed that sowing from March to May was ideal when mean temperature and day length were maximum. The study revealed that higher maximum temperature of 34.5±1°C, higher minimum temperature of 23.0±0.5°C and longer days of 9.0 to 9.4 hours prevailed during the months were congenial for realizing a higher percentage of germination, imparting earliness in flowering and fruit production, improving vigour of plants, production of large number of flowers and fruits and to get maximum yield both in terms of number and weight of pods. All these plant characters had positive and significant correlations with the weather data studied, except flower initiation period, which alone showed a negative and significant correlation.

At Canada, Arulrajah and Ormrod (1973) studied the response of okra cultivars H-10, Pusa Sawani and Clemson spineless to photoperiod of 10 to 15 h and 25/30, 30/25 and 35/30 deg C day night temperatureswith 12 h thermo periods. The following results were obtained:

i) Initiation and development of floral buds were slow in long photoperiods and at higher temperatures.
ii) Floral buds of H-10 and Clemson spineless developed slowly compared with Pusa Sawani and were classified as facultative short day and day-neutral plants respectively, with varying degrees of response to different photoperiods and temperature.
iii) Carbohydrate content rose with increase in temperature and was low in long photoperiods. This effect varied with the cultivars.

Siedenschnur (1973) reported that in okra the date of start of flowering and length of flowering period depended on several climatic factors particularly temperature. If daily temperature was high, the flowering period was short.

Heat stress of 45°C for 10 h on the day of sowing promoted hypocotyl elongation and accelerated seedling emergence in okra (Onwueme, 1975).

Hesketh *et al.* (1975) noted that cotton cultivars carrying okra and super okra genes grown at 32/29, 32/23, 26/23 and 23/20 °C in a thermal day/night period of 8-16 h and in a 16 h day length showed a reduction in the number of large lobes on the leaf, as the temperature decreased. At 32/33°C the shape of the super okra leaf approached that of the okra leaf.

Jimenez (1976) tested numerous vegetables for their performance in hot, humid tropical conditions and recommended okra cultivars for hot humid tropics.

Oyolu (1977) divided okra cultivars grown outdoor at different times of the year in Nigeria into two groups depending on their response to photoperiod. The dry season or short day group had a critical day length of 12 ¼ h or less and all season or natural group had a critical day length of 12 ¼ h or more. A study of the same cultivars under controlled environment in Newcastle, UK, showed variability in growth and flowering time within the all season cultivars exposed to day length or temperature interaction.

In okra the germination of seeds was accelerated by longer exposure to light. According to Varma and Pujari (1977), imbibed seeds of okra, took 24 to 48 hours at 30°C for germination.

Watanabe and Inayama (1977) in their search for the factors responsible for the occurrence of a physiological disorder in okra named warty pod, noticed that, at low temperature and light intensity the growth of okra plant was poor and this disorder appeared. At high temperature and light intensity, the growth was normal without the disorder.

Bisaria and Shamshery (1979) studied the effects of different seasons on growth and yield attributes in okra at Moradabad, Uttar Pradesh and found that the yield was highest in the rainy season and lowest in the winter season.

Early and late varieties of the short day plant (*Abelmoschus esculentus*) were subjected to various numbers of 10 h short days before transfer to 16 h days. Short day treatments were started at the time of cotyledon release following germination. The early varieties of okra required six short day cycles for the induction of flowering in plants, but the late varieties required 14 short days. Both the varieties required more than 20 short days for flower opening. As the number of short days increased from 2 to 20, the flower bud produced on each plant increased. The total number of seeds per plant also increased as the number of short days increased (Nwoke, 1980).

Sionit *et al.* (1981) made studies on the response of okra cultivars Clemson spineless to six different day or night temperature regimes with a 16 h photoperiod, ambient light and CO_2. They found that at ambient CO_2 concentration, all plants grown at 26/20°C or above, matured and produced fruits. A temperature regime of 32/26°C was optimal and produced 20 fruits per plant at 80 days after planting.

Palanisamy and Ramasamy (1985), from their studies on the influence of environmental factors on production and quality of bhindi seeds conducted at Coimbatore found significant and positive correlation between temperature and day length that prevailed during the growth phase, and the number of flowers and fruits per plant, seeds per fruit, hundred seed weight, seed germination and seed vigour.

Growth chamber experiments with all combinations of 13 h 20 minutes and 12 h photoperiods and 36/27°C and 36/20°C day and night temperatures showed that high night temperature produced taller plants of okra than low night temperature. High temperature delayed floral development in both short and long photo periods (Tenga and Ormrod, 1985).

Ariyo (1987) from his studies on the stability of performance of okra as influenced by planting date showed significant genotype x environment interaction for number of days to flowering and number of branches per plant. Additive environmental effects were significant for all characters.

According to Premnath *et al.* (1994) the optimum temperature for germination of okra seed is 26.7°C to 30°C and it did not germinate below 15.6°C.

Singh (1994) noticed that low light stress reduced shoot growth, economic yield, yield components, harvest index, content of total sugars, starch and nucleic acid and shoot nitrate reductase activity. Plant height and content of chlorophyll b, protein, soluble and total organic nitrogen in shoots were increased under low light.

Singh (1997) reported that shading did not effect the seed yield in okra, whereas shading combined with high temperature produced parthenocarpic fruits in okra.

All the above studies reveal that the growth and development of okra are highly influenced by weather parameters and out of which, rainfall, temperature and photo period occupy the prime position.

2.4 Crop weather studies of vegetables

The crop weather relationship studies of bitter gourd by Sarah Jacob (1986) showed that the maximum temperature during the first ten weeks, the minimum temperature during seven to eleven weeks and relative humidity during six to thirteen weeks after sowing were negatively correlated with both yield and number of fruits per plant. There was a positive correlation between sunshine hours from sixth to 13th weeks and the yield.

Thankamani (1987) worked out the following regression equations for estimating crop yield in snakegourd.

1) $Y = -0.11\ (RH) + 1.010\ (SH) + 4872$, ($R^2 = 0.91$) for fruit yield per plant and

2) $Y = -0.782\ (RH) + 1.447\ (SH) + 66.754$, ($R^2 = 0.86$) for total yield.

Where, RH is the mean relative humidity of 11 to 15 weeks after sowing and SH is the mean sunshine hours during 10 to 15 weeks after sowing.

Neendissery (1993) found that in watermelon, which was raised in rice fallows, the temperature range during flowering and early fruit development, the maximum temperature during fruit development and relative humidity during maturity were negatively correlated with the yield.

Lincy Davis (1996) studied the crop weather relationship of bittergourd using variety MC 84 and developed multiple regression equation for fruit yield with four weather parameters. The regression equation is

$$Y = -1.23\ T\ min + 0.05\ T\ range + 0.68\ SSH + 0.012\ RH\ morning + 23.429,\quad (R^2 = 0.92)$$

where, Y - yield in t ha^{-1}, T min - minimum temperature, T range is temperature range and RH is relative humidity during 45 to 65 days after sowing and SSH is sunshine hours at 45 to 55 days after sowing.

Ajith Kumar (1999) found that in tomato, fruit yield was significantly related to maximum temperature and morning relative humidity at six to eight weeks after planting. Regression equation developed for two different levels of fertilizer application studied were as follows:

1) $Y = -206.44\ NT - 9.77\ RH_1 + 5967.45$, ($R^2 = 0.646$) at 75 kg N ha^{-1} and

2) $Y = -339.27\ NT - 14.64\ RH_1 + 9590.92$, ($R^2 = 658$) at 125kg N ha^{-1}.

Where Y - fruit yield, NT - minimum temperature at 7-8 week state, RH_1 - Morning relative humidity at 6-7 week stage.

2.5 Effect of weather on insect pest and diseases of okra

Like all the other vegetable crops, bhindi is also facing serious threat due to the severe incidence of various pests and diseases. Warm humid tropical climate is highly conducive for the multiplication and spread of insect pest and diseases and their vectors.

a) Weather and disease incidence

According to Verma (1952), the spread of bhindi yellow vein mosaic virus inoculums was favoured at high temperature and humidity. The average yield loss due to yellow vein mosaic disease infection in okra was 93.8 per cent when the plants were infected 35 days after germination and 49.4 per cent when infection occurred 50 and 65 days after germination respectively (Sastry and Singh, 1974). Sharma *et al.* (1987) studied the effect of temperature on the incidence of yellow vein mosaic virus on six varieties of okra over a period of six years. Incidence increased with decreased temperature in September compared to August. A significant negative correlation coefficient between temperature and virus incidence was observed. This was particularly incident in the resistant varieties, which were free of virus in August but showed virus symptoms in September. It was concluded that resistance to Hibiscus yellow vein mosaic virus was influenced by temperature and could then be under the control of a polygenetic system. Nath *et al.* (1992) reported that both the incidence of bhindi yellow vein mosaic disease and its vector '*Bemsia tabaci*' were lowest in crops sown during the period of 10^{th}

February to 10th March. Significant positive associations were recorded between disease incidence and the whitefly population, temperature, relative humidity and rainfall. Singh *et al.* (1994) had experiments with weekly sowings of okra cultivars Pusa Sawani during June and July in 1989 at Nainital and reported that plants from seeds sown later in the year exhibited a higher percentage of yellow vein mosaic virus infection and a lower yield of seed compared with plants from seeds sown earlier in the year. Nath and Saikia (1995) reported that the incidence of bhindi yellow vein mosaic virus disease on okra cultivar Pusa Sawani varied from 75 to 91 per cent in plots sown between early April and end of June. Infection in plots sown during February to the end of March was progressively less. The lowest yield of okra was obtained from the plots sown in May and June. Lower disease incidence and whitefly population were revealed by crops sown between February 25 and March 20 compared with the sowing dates of April 15 to June 25 (Magumder *et al.*, 1996). Sangar (1997) reported that the incidence of yellow vein mosaic virus was higher during the rainy season. He also screened different varieties for mosaic resistance and the variety Arka Anamika was found to be highly resistant. In support to the above work the field trials conducted by Sannigrahi and Choudhary (1998) at Tezpur, Assam during 1991 and 1992 kharif season revealed that Arka Anamika was the most suitable yellow vein mosaic virus resistant okra cultivar for commercial cultivation.

Gupta (1992) studied the influence of sowing date on the development of Cercospora leaf blight of okra caused by *Cercospora abelmoschii*. He found that the lowest disease incidence and the highest yield occurred on crops sown on March 18. Though temperature played an important role in disease development, the influence of relative humidity was less significant. Mild outbreaks occurred when the minimum temperature was less than 18°C.

b) Weather and insect pest incidence

Rawat and Sadu (1973) estimated the losses on the growth and yield of okra due to *Empoasca devastans* Distant and *Earias* sp. during the kharif season. It was observed that the average losses in plant height, the number of leaves per plant and weight of healthy fruits were 49.8, 45.1 and 69 per cent respectively.

Senapati and Khan (1978) studied the population fluctuation in *Amrasca biguttula biguttula* on okra and reported that the population of these cicadellid occurred throughout the year. Maximum infection was from November to February with a peak in December, when temperature and relative humidity were low.

Generally the pest incidence was highest in humid periods after rainfall. A study by Kashyap and Verma (1982) on the seasonal incidence of *Earias* spp. in Haryana showed that the population density of the pest and infested fruits were not correlated with the prevailing temperature, relative humidity or rainfall.

Studies on the occurrence of arthropod pests of okra during the Kharif season of 1980 and summer season of 1981 revealed that the typhlocybid *Amrasca biguttula biguttula* remained active throughout both the seasons and low relative humidity accounted for it. Whereas, the activity of shoot and fruit infestation by *Earias vittella* increased with increased humidity (Dhamdhere *et al.*, 1984).

Risch *et al.* (1987) had the opinion that the insect outbreak plays a greater role in agroecosystems than in natural ecosystems, because the former, especially annual ones are often less buffered against the climatic changes. Wellings *et al.* (1987) reported that the climatic conditions especially temperature and wind were critical to the insect outbreaks. They also reported that prolonged favourable weather conditions allowed aphids to achieve their rapid population increase to epidemic levels.

Kumar and Urs (1988) noted a significant positive correlation between the incidence of *Earias vittella* and prevailing temperature. Relative humidity was found to be negatively correlated with pest incidence, whereas rainfall did not show any such correlation.

Studies on seasonal patterns of the cicacellid *Amrasca biguttula biguttula* on okra revealed that among the various weather parameters studied only minimum temperature showed a significant positive correlation with their population (Srinivasan *et al.*, 1988).

Uthamasamy (1988) observed the highest infestation of *Amrasca biguttula biguttula* on okra crops sown in July, where loss in fruit yield was negatively correlated with the infestation and leaf damage. But *Aphis gossypii* Glover population was most active on okra during September-October and declined from mid May to the end of June due to high temperature (40-45°C) according to Kandoria *et al.* (1989).

Lat *et al.* (1990) reported that continuous heavy rainfall for four days (61.1 mm) during the second half of the fourth week after sowing, a low mean temperature (<29°C), a high RH (>78%) and less sunshine (6.4 h/day) drastically reduced the pest population in the different varieties of okra, irrespective of their level of susceptibility to attack.

Mahmood *et al.* (1990) observed the effect of various environmental factors on the density of leaf hopper *Amrasca devastans* on okra. He reported that among the various environmental factors, the only significant factor was minimum temperature. A positive correlation was found between maximum and minimum temperatures with regard to the density of the pest.

Singh and Brar (1994) suggested that okra sown on May 15th harboured the highest mean population of *Amrasca biguttula biguttula* and *Earias* sp. followed by the crop sown on May 30. Maximum damage due to *Earias* sp. was observed on June 15 sown crop while minimum on July 30.

Kadam and Khaire (1995) reported that *Earias vittella* infestation on okra crop was high from 12th February to 20th May (50.63% in summer season). It was low to moderate from the 21st May to 7th October (24.23% in rainy season).

Thereafter, it increased rapidly and reached its peak, becoming severe (54.56%) from first November to 31st December.

Studies on the effect of sowing dates on the incidence of leaf hopper, mite and fruit borer on okra were conducted at Maharashtra, showed that the crop sown on 15th May and first June had the lowest incidence of leaf hopper and fruit borer, with a good yield of marketable fruits (22.9 and 19.1 q per ha). The mite incidence was nil in the crop sown on first September, 15th September and first October (Pawar *et al.*, 1996).

Patel *et al.* (1997) observed a significant relationship between *Amrasca biguttula biguttula* population level and maximum temperature as well as hours of bright sunshine. The population of *Amrasca biguttula biguttula* increased during the monsoon season when the temperature remained around 37°C along with at least 10 h of bright sunshine per day.

Shukla *et al.* (1997) correlated the weekly mean maximum temperature (°C) and percentage of fruit damage caused by shoot and fruit borer *Earias vittella* using the following regression equations:

1) $Y = -99.46 + 3.121\ x$ for 1993, ($R^2 = 0.91$) and
2) $Y = -62.54 + 2.216\ x$ for 1994 ($R^2 = 0.93$)

where, Y - fruit damage and x - weekly mean maximum temperature.

The major insect pest and diseases in okra under various agroclimatic conditions are fruit and shoot borer, aphids, jassids, whitefly, mites, petiole maggot, bhindi yellow vein mosaic disease and cercospora leaf spot. They were influenced mainly by the surface air temperature both maximum and minimum, rainfall and relative humidity.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment was conducted at the Department of Agricultural Meteorology, College of Horticulture, Kerala Agricultural University, Vellanikkara during 1998-1999 with the objective of studying crop weather relationships of Okra variety 'Arka Anamika'. The details of the materials used and the techniques adopted during the course of this investigation are presented below:

3.1 Experimental materials

3.1.1 Site and climate

The experimental field was situated at 10°32' N latitude and 76°13' E longitude with an altitude of 22.25 m above mean sea level.

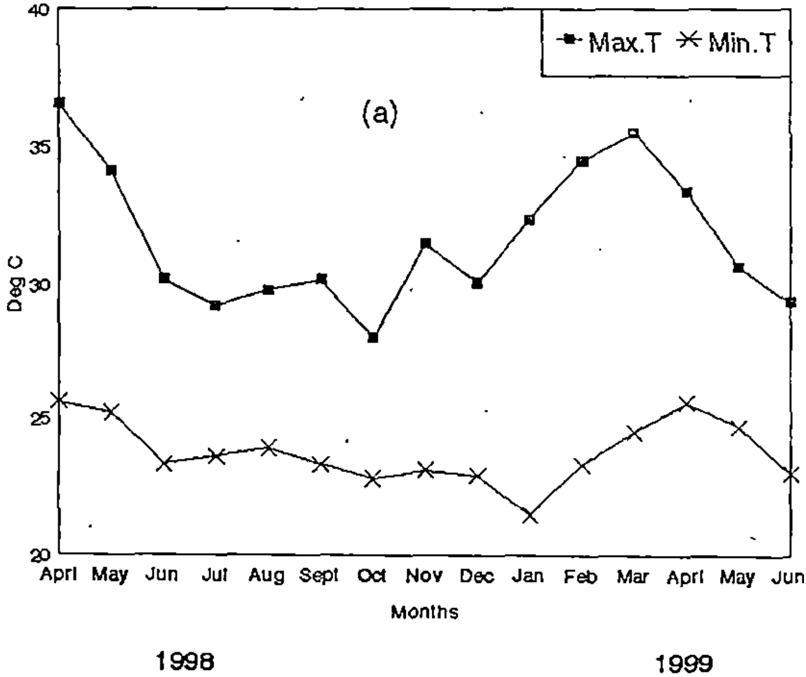
The details of the meteorological observations during the experimental period are presented in Fig. 1 and described in results.

3.1.2 Soil characters

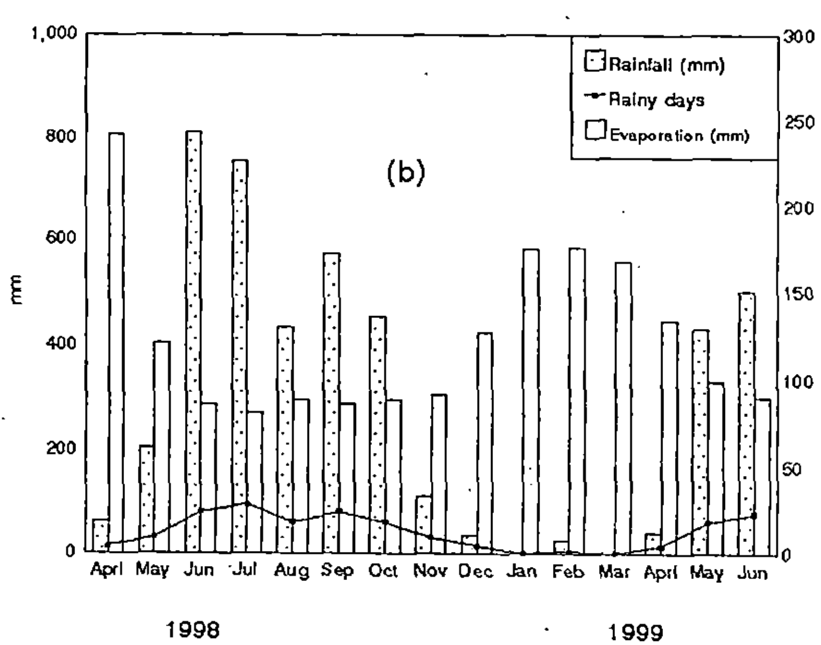
Composite soil samples of 0-30 cm depth were taken before commencement of the experiment and used for the determination of the physio-chemical properties. The soil of the experimental area was deep, well drained sandy loam. The physio-chemical properties and the data are given in Table 2.

3.1.3 Crop variety

The variety Arka Anamika released from I.I.H.R., Bangalore was selected based on its better performance and resistance to yellow vein mosaic virus (Katyal and Chadha, 1987) for the study. Arka Anamika is an interspecific hybrid between *Abelmoschus* esculentus and *Abelmoschus manihot species* Tetraphyllus,

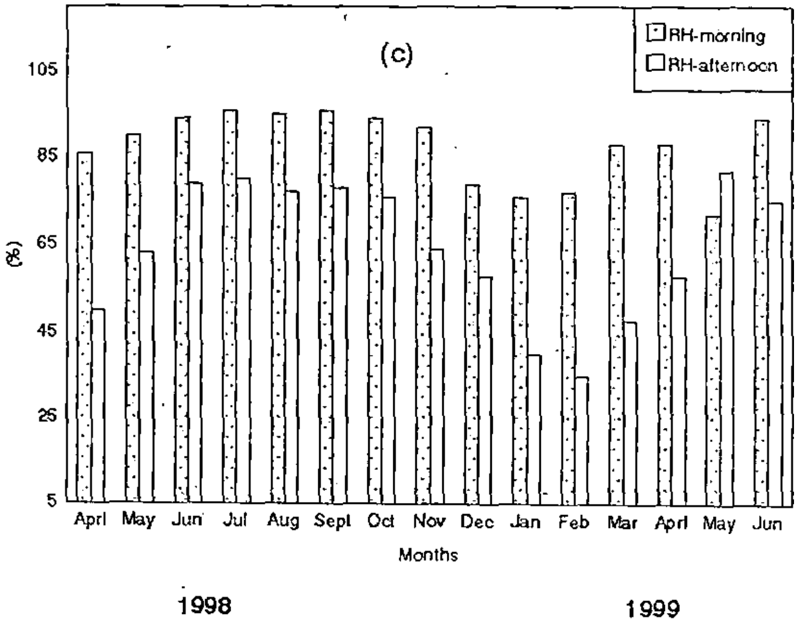


Maximum and Minimum temperature

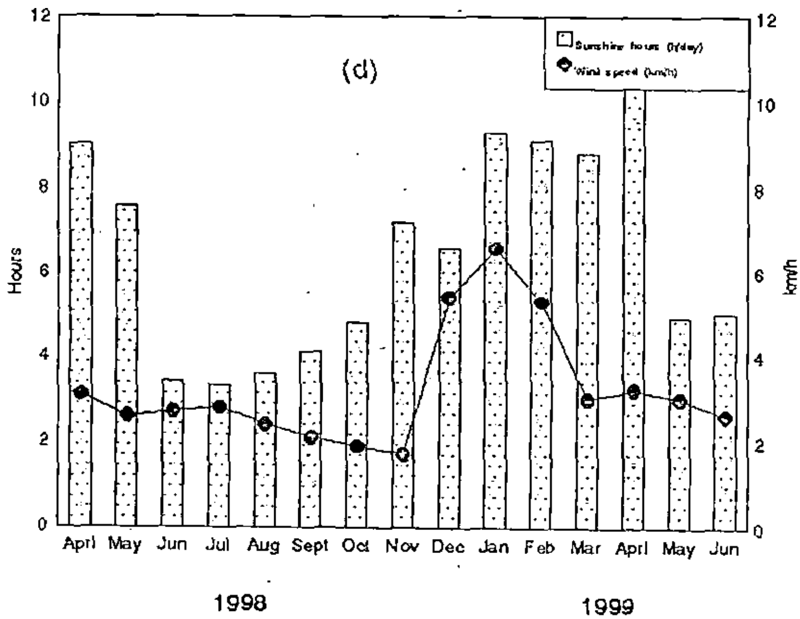


Rainfall, rainy days and evaporation

Fig.1. Weather during the experimental period



Morning and Afternoon relative humidity



Sunshine hours and windspeed

Fig.1 Weather during the experimental period (contd.)

Table 2. Soil characteristics of the experimental site

Fraction	Per cent composition	Procedure adopted
1. Mechanical composition		
Coarse sand	16.18	Robinson international
Fine sand	27.10	pipette method
Silt	10.00	
Clay	36.20	
Textural class	Sandy clay loam	I.S.S.S. System
2. Physical constants of the soil		
Field capacity at 0.3 hrs (%)	19.23	Pressure Plate apparatus
Moisture percentage at 15 bars	10.90	Pressure Plate apparatus
Bulk density (g cm^{-3})	1.41	Core method
Particle density (g cm^{-3})	2.18	Pycno meter method
3. Chemical properties		
Organic carbon (%)	0.47	Walkley and Black rapid titration method
Available Nitrogen (%)	0.008	Alkaline permanganate method
Available Phosphorus (%)	0.0003	Chlorostamnus reduced molybdo-phosphorus blue colour method in hydrochloric acid system
Available Potassium (%)	0.008	Flame photometry, Neutral normal ammonium acetate extraction
Soil reaction (pH)	5.4	Soil water suspension of 1:2.5
Electrical conductivity (mmhos cm^{-1})	0.35	Soil water extract of 1:2.5

released during 1990. The plants are tall, well branched, with a duration of 120 days and having an average yield of 20 t ha^{-1}. (Anon, 1998).

3.2 Methods

3.2.1 Layout

The experiment was laid out in randomised block design with three replications. There were 36 plots in the field with 30 plants in each plot having a spacing of 60 x 45cm. The layout of the experimental field is given in Fig.2.

3.2.2 Treatments

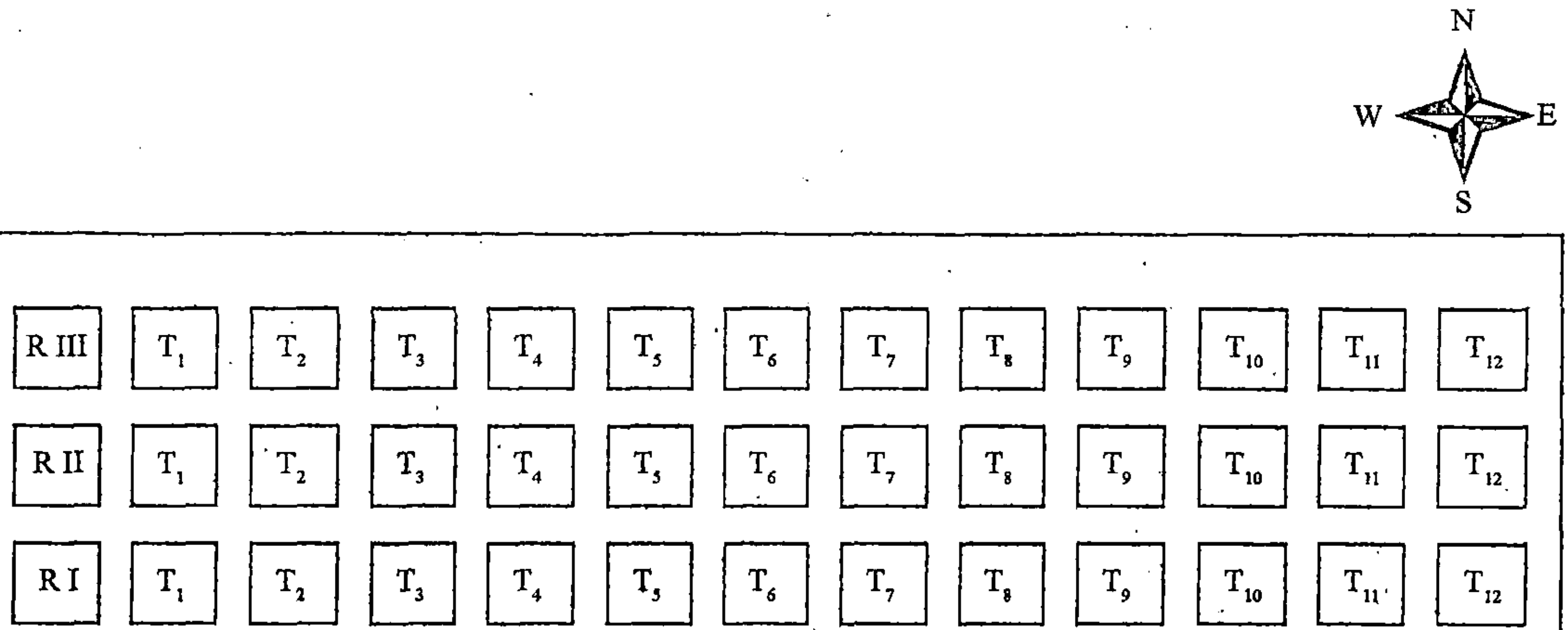
The treatments include 12 times of planting started from 21st April 1998 to 21st March 1999.

3.3 Field operations

All the field operations were followed as per the package of practice recommendations, Crops, 1996, Kerala Agricultural University.

3.3.1 Preparation of field

The area was ploughed and the weeds were removed. The selected area was divided into 12 experimental units. The organic manure 12 t ha^{-1} was uniformly spread. Ridges and furrows were taken keeping a spacing of 60 cm from ridge to ridge and furrow to furrow. The seeds of variety Arka Anamika provided from the Department of Olericulture, College of Horticulture, Vellanikkara were used throughout the period of investigation. Seeds were soaked in water for four hours before sowing. These seeds were taken out, drained and sown at a rate of three seeds per hole with a spacing of 45 cm from plant to plant within the row. Sowings on ridges were carried out during June, July and August to avoid water stagnation in furrows. For the remaining months furrow sowings were followed.



TREATMENTS

T_1 - April 21st
T_2 - May 21st
T_3 - June 21st
T_4 - July 21st
T_5 - August 21st
T_6 - September 21st
T_7 - October 21st
T_8 - November 21st
T_9 - December 21st
T_{10} - January 21st
T_{11} - February 21st
T_{12} - March 21st

Fig.2. LAYOUT PLAN

3.3.2 Fertilizer application

Farm yard manure at a rate of 12 t ha^{-1} was applied prior to the preparation of ridges and furrows as basal dose. The fertilizers viz., Factomphos 20:20:0:15, Urea and Muriate of Potash were used to supply required quantities of N, P and K (NPK @ 50:8:25 kg/ha). P and K were applied basally as single dose. However, N was applied in two split doses, half as basal and the other half at 30 Days after sowing.

3.3.3 Weeding

The plots were hand-weeded frequently to keep them free of weeds.

3.3.4 Thinning

Thinning was done ten days after sowing, retaining only one healthy plant.

3.3.5 Top dressing and earthing up

The top dressing using remaining half of the N dose was done after 30 DAS along with earthing up.

3.3.6 Plant protection

During the course of study, the crop faced several serious threats due to the severe incidence of various pests and diseases. Plant protection measures were taken as and when required using recommended chemicals.

a) Yellow vein mosaic disease scoring

Yellow vein mosaic disease intensity was scored using the rating scale developed by Arumugam *et al.* (1975). Which is given as follows:

Symptom	Grade	Rating scale
1) No visible symptoms characteristic of the disease	Highly resistant	1
2) Very mild symptoms, basal half of the primary veins green, mild yellowing of anterior half of primary veins, secondary veins and veinlets. Infection is also seen late in the season under field condition	Resistant	2
3) Veins and veinlets turn complete yellow	Moderately resistant	3
4) Pronounced yellowing of veins and veinlets, 50 per cent of the leaf lamina turned yellow, fruits exhibit slight yellowing	Susceptible	4
5) Petiole, veins, veinlets and inter-veinal area turn yellow in colour. Leaves started drying from the margin, fruits turn yellow in colour	Highly susceptible	5

The disease rating for each treatment in a replication was calculated as follows:

$$\text{Mean disease rating} = \frac{\text{Sum of disease scores of plants observed}}{\text{Number of plants}}$$

Scoring of shoot and fruit borer

b) Percentage of shoot infestation

The number of shoot infested plants in a plot were counted and averaged and expressed in percentage.

c) Percentage of fruit infestation

The total number of fruits damaged by fruit and shoot borer in a plot was counted, averaged and expressed in percentage.

3.3.7 Harvest

Harvesting was taken up alternatively. The tender fruits were harvested which were of commercially sizeable in growth. The pods were broken by giving a cut from the stalk by bending at the base.

3.4 Observations

The following morphological, phonological and yield observations were taken from five randomly selected plants of each replication excluding border plant and the mean was worked out. Morphological observations like plant height, 5th node leaf's length and width, primary branches per plant, number of nodes on main stem and internodal length were taken at 15, 30, 45, 60, 75 and 90 days after sowing.

3.4.1 Plant height

The plant height from the ground level to the top most bud leaf was measured for each plant.

3.4.2 5th node leaf's length and width

Length and width of 5th node leaf of each plant were measured in cm.

3.4.3 Primary branches/plant

Total number of primary branches produced per plant was counted.

3.4.4 Nodes on main stem

Total number of nodes on the main stem of each observational plant was taken.

3.4.5 Internodal length

The length of internode between 5th and 6th node of the plants were taken and expressed in cm.

3.4.6 Node to first flower

The node at which the first flower appeared was counted from the cotyledon node and recorded.

3.4.7 Duration for first flowering

Number of days taken for first blooming was recorded in all the five observational plants and averaged.

3.4.8 Duration for first fruit set

The duration from sowing to the first fruit set in each observational plant was recorded.

The length was measured from base to the tip of the fruit using measuring scale and expressed in cm at each harvest.

3.4.14 Fruit girth

3.4.16 Seeds per fruit

Fruits from plants maintained as seed plants were used. Seeds of 10 fruits from each replication were counted and worked out the mean.

3.5 Weather data

The daily data on different weather elements viz., maximum and minimum temperatures, morning and afternoon relative humidity, sunshine hours, wind speed, rainfall, rainy days and evaporation were collected from the Principal Agrometeorological Station of the College of Horticulture, Vellanikkara for the crop period from 21st April 1998 to 21st July 1999.

3.6 Statistical analysis

Analysis of variance was done separately for all characters as per the statistical design of RBD (Panse and Sukhatme, 1985).

Correlation and regression analysis were carried out between the growth and yield characters. The weekly mean/total values of rainfall, number of rainy days, maximum temperature, minimum temperature, relative humidity and sunshine hours were taken into account to determine the effect of weather elements on the growth and yield of okra through correlation and regression techniques.

Growing Degree Days (GDD)

The Growing Degree Days (GDD) were worked out during the crop period and attempted to relate the same with crop duration as well as fruit yield. The GDD were calculated using the following formula. The base or threshold temperature is assumed as 10°C for Okra, as its growth may cease if it is below the optimum of 10°C.

$$GDD = \sum_{i=1}^{t} \frac{T\ maximum + T\ minimum}{2} - 10°C$$

where,

$\sum_{i=1}^{t}$ = period from sowing date till the last date of harvesting

GDD = Growing Degree Days

RESULTS

4. RESULTS

4.1 Crop environment during experimental period (April 1998 to June 1999)

4.1.1 Weather during crop growth period

4.1.1.1 Surface air temperature

The maximum temperature during crop period varied between 36.6° and 27.8°C, while the minimum temperature was between 26.8° and 19.5°C (Table 3). A sudden decline was noticed in maximum temperature from third week of June (23rd standard meteorological week) onwards and remained constant (around 29°C) up to third week of October (42^{nd} standard meteorological week). This was due to heavy rain received during the above period. Thereafter, a gradual increase was noticed in maximum temperature from fourth week of October (43rd standard meteorological week) to third week of March (11th standard meteorological week). A similar phenomenon was noticed again from the fourth week of March (12^{th} standard meteorological week) to the first week of June (21^{st} standard meteorological week), as it was cyclic.

In case of minimum temperature, the highest minimum temperature (24-26.8°C) was noticed during summer months (March-May), followed by rainy season (23 to 24.4°C) and the lowest (19.5°C to 22°C) during December and January.

4.1.1.2 Rainfall and its distribution

The weekly rainfall varied between 11.0 mm (21^{st} standard meteorological week) and 368.7 mm (26^{th} standard meteorological week) during the southwest monsoon (June to September). Zero rainfall was noticed during the third week of December to January. A gradual decline in weekly rainfall (Table 3) was noticed since the last week of June, followed by a raise during September (34-37 standard

Table 3. Weekly distribution of weather parameters

Meteorological week	Rainfall (mm)	Rainy days	Evaporation (mm)	Surface temperatures (°C) Max.T.	Min.T.	Mean.T.	Sunshine (h day^{-1})	Relative humidity (%) morning	afternoon	Wind speed (km h^{-1})
16	4.2	1	5.4	36.6	26.8	31.7	8.5	85	53	3.1
17	57.2	3	6.0	35.9	24.6	30.3	8.7	89	54	8.0
18	4.8	1	4.7	35.2	25.5	30.4	8.5	89	61	2.7
19	79.0	2	4.2	35.5	25.3	30.4	6.5	88	59	2.3
20	107.4	4	8.4	32.4	24.1	28.1	4.6	93	72	2.1
21	11.0	2	2.9	33.6	25.7	29.7	8.3	91	62	2.9
22	24.4	1	9.3	34.4	25.2	29.8	8.8	86	63	3.2
23	65.7	5	3.8	32.0	23.9	27.9	6.4	92	71	3.1
24	118.0	5	3.1	30.0	23.1	26.6	2.2	94	81	2.0
25	257.3	7	2.3	29.0	22.4	25.7	3.0	96	79	2.5
26	368.7	7	2.1	27.8	23.2	25.5	0.3	95	89	3.4
27	250.6	7	2.4	29.0	23.8	26.2	2.5	96	81	2.6
28	140.1	6	2.6	29.2	24.0	26.6	2.4	95	81	2.2
29	116.2	5	2.9	29.8	24.1	26.9	4.9	96	77	2.4
30	151.6	7	2.4	29.2	23.4	26.3	3.0	96	84	2.8
31	80.0	6	8.2	30.3	24.4	27.4	4.6	97	76	3.1
32	80.9	6	2.8	29.2	23.8	26.5	2.1	95	80	2.5
33	12.7	2	3.1	30.5	24.5	27.3	4.6	94	73	2.2
34	274.7	5	2.1	28.5	23.5	26.0	2.5	95	84	2.9
35	129.9	3	3.4	30.2	23.6	26.9	5.4	94	72	2.4
36	184.4	6	2.7	30.7	23.7	27.2	3.8	96	82	1.8
37	169.4	7	2.9	28.4	22.9	25.7	3.2	95	80	2.2
38	29.9	4	3.4	30.2	23.3	26.8	6.8	95	72	2.2
39	63.0	5	2.4	28.6	23.1	25.9	2.4	95	77	1.6
40	51.8	6	2.8	29.3	23.1	26.2	3.8	93	79	1.5
41	319.4	6	1.9	27.8	23.0	25.4	1.5	95	91	2.7
42	70.2	5	3.1	29.8	22.6	26.2	4.8	94	73	1.8
43	10.8	1	3.5	31.1	22.5	26.8	8.2	92	66	2.0
44	6.9	1	2.8	31.1	23.2	27.2	5.5	94	68	1.6
45	86.0	5	2.6	30.8	23.6	27.2	4.1	93	70	1.8
46	16.9	3	3.5	31.9	22.8	27.4	8.9	94	63	1.9
47	0.0	0	3.2	31.7	22.8	27.3	9.0	93	58	1.3
48	4.8	1	3.3	32.2	23.0	27.6	7.9	88	58	1.7
49	1.4	0	4.5	31.3	23.8	27.6	6.1	78	60	6.0
50	27.0	3	2.9	29.7	23.4	26.5	3.3	82	71	7.1
51	0.0	0	4.2	31.4	22.4	26.9	8.6	79	57	4.3
52	0.0	0	5.1	31.1	22.0	26.6	8.2	76	40	6.7
1	0.0	0	5.1	31.1	22.0	26.6	8.2	76	40	6.7
2	0.0	0	5.0	32.5	21.9	27.2	9.5	79	43	5.1
3	0.0	0	6.9	32.2	22.8	27.5	10.0	70	40	9.8
4	0.0	0	5.9	32.5	19.5	26.0	7.9	74	32	5.5
5	0.0	0	4.5	33.9	22.1	28.0	10.1	83	39	3.6
6	22.8	1	5.1	34.0	23.4	28.7	9.2	80	44	4.3
7	0.0	0	6.3	34.7	23.2	29.0	10.0	79	39	5.3

Table 3. Continued

Meteorological week	Rainfall (mm)	Rainy days	Evaporation (mm)	Surface temperatures (°C) Max.T.	Min.T.	Mean.T.	Sunshine ($h\ day^{-1}$)	Relative humidity (%) morning	afternoon	Wind speed ($km\ h^{-1}$)
8	0.0	0	7.6	34.2	24.5	29.4	6.9	70	33	7.9
9	0.0	0	7.6	36.4	22.2	29.3	10.4	74	33	5.0
10	0.0	0	5.8	36.5	23.8	30.2	9.9	92	34	3.1
11	0.0	0	4.9	35.2	25.0	30.1	8.4	89	54	2.8
12	0.0	0	4.5	34.8	25.0	29.9	8.4	91	55	2.4
13	0.0	0	4.9	34.9	25.1	30.0	7.5	89	54	2.4
14	26.2	1	5.7	34.9	24.5	29.7	7.8	90	55	3.0
15	0.0	0	4.6	33.2	25.8	29.5	7.4	86	59	3.3
16	7.6	1	3.9	33.1	26.2	29.7	4.6	89	62	3.2
17	5.2	1	3.6	32.0	25.9	29.0	4.2	90	59	3.4
18	35.0	1	4.4	33.6	25.8	29.7	6.3	89	59	3.1
19	37.0	3	3.1	31.0	25.2	28.1	6.4	90	66	3.5
20	51.6	4	3.2	30.4	25.1	27.8	5.5	88	74	3.1
21	221.6	6	2.9	29.0	23.8	26.4	2.6	95	85	2.6
22	143.2	7	3.1	29.8	23.5	26.7	5.0	96	75	3.1

Max. T. – Maximum temperature
Min. T. – Minimum temperature
Mean T. – Mean temperature

meteorological weeks). Thereafter, a sudden raise during October and November (39-45 standard meteorological week) indicated the influence of Northeast monsoon over the region.

4.1.1.3 Sunshine hours

As the rainfall and the number of rainy days increased, there was a reduction in the bright sunshine from third week of June (23rd standard meteorological week) to second week of October (46th standard meteorological week) due to increased cloudiness. From third week of October, a gradual increase in sunshine hours was noticed and reached a maximum of 10.4 hours during first week of March. Thereafter, a decline was noticed in sunshine hours till the end of the experimental period (Table 3). As a whole, the crop experienced heavy cloudiness (0.3 h/day) during the fourth week of June and bright sunshine (around 10 h/day) during January and February.

4.1.1.4 Relative humidity

Both morning as well as afternoon relative humidity remained high during the rainy weeks of pre monsoon and monsoon periods. The morning relative humidity ranged between 85 to 97 per cent and afternoon relative humidity ranged between 53 to 89 per cent during this period (Table 3). Relative humidity remained low during the winter months (December and January), ranging from 32 per cent to 76 per cent.

4.1.1.5 Evaporation

Higher evaporation rate (130-175 mm/week) was recorded during the zero rainfall weeks (December and January). Evaporation remained low and ranged between 2.1 mm and 3.1 mm during June and July.

4.1.1.6 Wind speed

Wind speed started increasing from 2nd week of December (49th standard meteorological week) of 1998 to last week of March (ninth standard meteorological week) of 1999 due to Northeast trade wind from the 'Palakkad Gap'. This is a peculiar phenominon of this region during Mundakan season (November to February).

4.1.2 Soil condition

The soil type of the experimental site was sandy clay loam with moisture at field capacity of 19.23 per cent, permanent wilting point of 10.9 per cent, bulk density 1.41 g/cm3 and pH 5.4 (Table 2). The soil was rich in available phosphorus (0.0003%) whereas available nitrogen was low (0.008%). Available potassium recorded a medium status in the rating scale (0.008%).

4.1.3 Crop performance

Higher maximum yield in terms of weight and number of fruits were recorded by April sown crop. The general vigour of the plants i.e. the height of the plant, number of nodes, leaf area and number of primary branches was also better for this crop. The crop sown during March showed a similar performance pattern as that of April. The crop duration was maximum (110 days) when the crop was sown during March and April.

Lowest yield with stunted appearance was the performance of the crop raised during the cooler months of the year i.e. November, December and January. Interestingly the September sown crop performed very well in terms of yield. Fluctuations in the kind and severity of attack of different pests affected the general performance of the crop during different sowing dates.

4.1.4 Insect pests and diseases

During the course of investigation, the incidence and severity of various insect pests were noticed in accordance with the changing weather conditions. Incidence of the following pest was noticed in different sowings.

1. Fruit and shoot borer : *Earias vittella*
2. Aphids : *Aphis malvae*
3. Jassids : *Amrasca biguttula biguttula*
4. Whitefly : *Bemisia tabaci*
5. Mites : *Tetranychus urticae*
6. Petiole maggot : *Melanagromyza hibisci*

The percentage infestation of *Earias vittella* increased gradually from August up to January and there-after decreased. The severity of the attack was maximum during January (80%), while the crop sown during July was free from the pest attack (Table 4).

Table 4. Time of sowing and incidence of insect pests in okra

Time of sowing (Treatments)		Percentage infestation					
		Fruit and shoot borer	Jassids	Aphids	Whitefly	Mites	Petiole maggot
T_1	April 21	8	85	90	45	0	0
T_2	May 21	5	25	35	30	0	0
T_3	June 21	0	28	35	35	0	0
T_4	July 21	5	15	15	0	0	0
T_5	August 21	15	20	25	10	0	23
T_6	September 21	18	15	20	4	0	18
T_7	October 21	28	20	20	5	0	8
T_8	November 21	45	30	26	8	40	0
T_9	December 21	80	35	30	10	90	0
T_{10}	January 21	48	35	55	10	0	0
T_{11}	February 21	30	85	68	25	0	0
T_{12}	March 21	10	90	90	30	0	0

A similar trend was noticed in case of *Aphis malvae* and *Amrasca biguttula biguttula* population on different sowings. The incidence of these pests was observed in all the treatments and severe in crops sown during March, April and February which showed hopper burn symptoms. The percentage infestation remained low from July to October.

The crop sown during March to June recorded the highest percentage infestation of *Bemisia tabaci*. July sown crop was devoid of this pest infestation.

Mites and petiole maggots are the minor pests of the crop. The mite attack was noticed only during December and January on November and December sown crops. The crops sown during August, September and October showed the presence of petiole maggots. All other treatments were free from its infestation.

The incidence of the following diseases was observed during the crop growth period:

1) Bhindi yellow vein mosaic disease
2) Cercospora leaf spot and
3) Damping off.

From Table 5, it was observed that the maximum infestation of bhindi yellow vein mosaic (3.2) was noticed in June, followed by May (2.8) and April (2.3). There was a decreasing trend in infestation from December to February.

The occurrence of the disease Cercospora leaf spot caused by the fungus *Cercospora abelmoschii* was observed in the crops sown during August, September, December and January. Damping off of the seedlings was noticed only during the rainy months i.e., June and July and was not severe.

Table 5. Times of sowing and incidence of Bhindi Yellow Vein Mosaic disease

Treatments	Mean disease rating
April	2.3
May	2.8
June	3.2
July	1.9
August	1.8
September	1.5
October	1.5
November	1.5
December	1.1
January	1.0
February	1.0
March	1.8

4.2 Biometric observations

4.2.1 Plant height

4.2.1.1 Plant height at 15 days after sowing

The crop sown on 21st March recorded the highest plant height of 12.9 cm, followed by August (11.7cm) and February (11.1cm) at 15 Days after sowing which were on par (Table 6). The lowest plant height (6.4cm) was observed in the case of 21st April sown crop followed by January (6.7cm) and December (6.9cm) sown crop, which were on par. It revealed that the plant height was significantly superior at 15 days after sowing when the crop was sown on 21st March.

4.2.1.2 Plant height at 30 days after sowing

The maximum plant height (30.2cm) was recorded when the crop was sown on 21st March, followed by April (18.0 cm) and July (17.6 cm). The minimum plant height of 12.0 cm was recorded by 21st January and 21st December (12.5cm) sown crops and were on par. It also revealed that the plant height was significantly superior at 30 days after sowing when crop was sown on 21st March (Table 6).

Table 6. Effect of times of sowing on plant height of okra at different intervals.

Time of sowing		Plant height (cm)				
(Treatments)		15 DAS	30 DAS	45 DAS	60 DAS	75DAS
T_1	April 21	6.4^{h}	18.0^{b}	46.97^{b}	101.96^{a}	116.0^{a}
T_2	May 21	7.3^{fg}	16.3^{cde}	40.3^{cd}	66.2^{b}	90.4^{b}
T_3	June 21	7.7^{ef}	17.3^{bcd}	36.8^{def}	53.7^{d}	64.8^{c}
T_4	July 21	8.7^{d}	17.6^{bc}	32.7^{fg}	41.6^{e}	45.6^{e}
T_5	August 21	11.7^{b}	15.6^{e}	37.4^{cde}	44.8^{e}	49.0^{de}
T_6	September 21	8.3^{de}	16.3^{cde}	29.2^{g}	40.5^{e}	44.9^{e}
T_7	October 21	9.9^{c}	15.9^{de}	35.2^{ef}	45.3^{e}	51.8^{d}
T_8	November 21	7.9^{ef}	15.3^{e}	23.5^{h}	31.6^{f}	36.3^{f}
T_9	December 21	6.9^{gh}	12.5^{f}	18.0^{i}	25.4^{g}	28.0^{g}
T_{10}	January 21	6.7^{gh}	12.0^{f}	15.6^{i}	22.6^{g}	24.9^{g}
T_{11}	February 21	11.1^{b}	15.4^{e}	41.3^{c}	45.0^{e}	54.1^{d}
T_{12}	March 21	12.9^{a}	30.2^{a}	53.6^{a}	60.4^{c}	91.9^{b}
SEm ±		0.47	1.12	2.95	3.85	3.69
CD (0.05)		1.37	3.25	8.64	11.29	10.85

4.2.1.3 Plant height at 45 days after sowing

The crop sown on 21st March recorded the highest plant height of 53.6 cm, which was followed by the crop sown on 15th April (46.9 cm), 21st February (41.3 cm) and 21st May (40.3 cm) respectively (Table 6). The lowest plant height at 45 days after sowing was observed in the January sown crop, which was on par with December (18.0cm) sown crop. The plant height of the crop sown on 21st March was superior at 45 days after sowing.

4.2.1.4 Plant height at 60 days after sowing

At 60 days after sowing the crop sown during April recorded the highest plant height of 101.9 cm (Table 6). This was followed by May (66.2cm) and March (60.4cm) sown crops. The lowest plant heights of 22.6cm and 25.4cm were recorded during January and December, respectively. It revealed that the crop sown on 21st April was superior in plant height at 60 days after sowing.

4.2.1.5 Plant height at 75 days after sowing

The highest plant height was recorded in the case of April (116 cm) sown crop, followed by March (91.9cm), May (90.4cm) and June (64.8cm) sown crops. The lowest plant heights were recorded by January (24.9 cm) and December (28 cm) and were on par. Like the plant height at 60 days after sowing, the crop sown on 21st April showed superiority at 75 days after sowing also. It is evident that the plant height was superior (116cm) at 75 days after sowing when planted on 21st April.

It revealed that the plant height was significantly influenced by timesof sowing and April sown crop was superior.

4.2.2 Number of primary branches

At 15 days after sowing, April sown crop recorded the maximum number of primary branches (1.7), followed by March (1.4) sown crop (Table 7). Unlike in plant height, the crop sown on April 21st showed its superiority from the beginning in case of number of primary branches.

A maximum of five primary branches was produced by April sown crop at 30 and 45 days after sowing and significantly superior. Interestingly, no primary branches were produced by crops sown during July and August at 60 days after sowing. The number of primary branches was intermediary at all the days after sowing.

Like in plant height, the crop sown on 21[st] April showed its superiority in case of primary branches also.

Table 7. Effect of time of sowing on number of primary branches at different intervals.

Time of sowing (Treatments)		Number of primary branches				
		15 DAS	30 DAS	45 DAS	60 DAS	75DAS
T_1	April 21	1.7 [a]	5.0 [a]	5.0 [a]	3.0 [a]	4.0 [a]
T_2	May 21	0.0 [d]	0.0 [f]	3.0 [bc]	2.0 [bc]	2.0 [c]
T_3	June 21	0.0 [d]	0.0 [f]	0.0 [ef]	1.0 [ef]	0.0 [f]
T_4	July 21	0.0 [d]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
T_5	August 21	0.0 [d]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
T_6	September 21	0.0 [d]	0.0 [f]	2.0 [cd]	2.3 [cd]	2.7 [b]
T_7	October 21	0.0 [d]	0.0 [f]	1.7 [cd]	1.3 [cd]	1.7 [cd]
T_8	November 21	0.0 [d]	0.6 [e]	1.7 [cd]	2.0 [cd]	1.7 [cd]
T_9	December 21	0.0 [d]	1.0 [d]	2.0 [de]	1.0 [de]	1.0 [e]
T_{10}	January 21	0.0 [d]	0.0 [f]	1.6 [ef]	1.6 [ef]	0.0 [f]
T_{11}	February 21	1.0 [c]	2.0 [c]	2.3 [cd]	2.0 [cd]	2.0 [c]
T_{12}	March 21	1.4 [b]	3.0 [b]	3.0 [b]	3.0 [b]	4.0 [a]
SEm ±		0.07	0.11	0.11	0.11	0.13
CD (0.05)		0.22	0.35	0.32	0.32	0.39

4.2.3 Nodes on main stem

4.2.3.1 Nodes on main stem at 15 days after sowing

The highest number of six nodes per plant was produced in the case of March (5.7), April (6.0), May (5.7) and August (6.0) sown crops and they were on par (Table 8). The lowest number of four nodes on main stem was produced by July, November, December, January and February sown crops.

4.2.3.2 Nodes on main stem at 30 days after sowing

The maximum number of nine nodes on main stem was recorded by March and May sown crops which was followed by April (8.7) and August (8.0) sown crops. Crops sown during January recorded the minimum number (5.3) of nodes, followed by December (6.0) and November (6.7) sown crops (Table 8). It revealed that the crop sown on 21st March and 21st May were statistically superior and on par.

Table 8. Effect of time of sowing on number of nodes on main stem at different intervals

Time of sowing		Number of nodes on main stem				
(Treatments)		15 DAS	30 DAS	45 DAS	60 DAS	75DAS
T_1	April 21	6.0^{a}	8.7^{b}	18.3^{a}	20.3^{a}	24.0^{a}
T_2	May 21	5.7^{a}	9.3^{a}	15.3^{b}	17.0^{c}	19.3^{c}
T_3	June 21	4.7^{b}	7.7^{cd}	10.7^{de}	15.0^{d}	17.0^{d}
T_4	July 21	4.0^{c}	7.7^{cd}	11.7^{cd}	13.7^{e}	15.3^{f}
T_5	August 21	6.0^{a}	8.0^{c}	12.3^{c}	15.0^{d}	17.0^{d}
T_6	September 21	5.0^{b}	6.7^{e}	11.0^{de}	14.3^{de}	16.0^{ef}
T_7	October 21	4.7^{b}	7.7^{cd}	12.7^{c}	14.0^{de}	16.3^{e}
T_8	November 21	4.0^{c}	6.7^{e}	10.3^{e}	12.3^{f}	14.3^{g}
T_9	December 21	4.0^{c}	6.0^{f}	7.7^{f}	10.0^{g}	12.3^{h}
T_{10}	January 21	4.0^{c}	5.3^{g}	8.7^{f}	10.3^{g}	11.3^{i}
T_{11}	February 21	4.0^{c}	7.3^{d}	10.0^{e}	14.3^{de}	16.7^{de}
T_{12}	March 21	5.7^{a}	9.3^{a}	15.7^{b}	19.0^{b}	20.7^{b}
SEm ±		0.36	0.34	0.85	0.74	0.64
CD (0.05)		1.06	1.02	1.51	1.39	1.58

4.2.3.3 Nodes on main stem at 45 days after sowing

The crop sown during April recorded the highest number of nodes (18.3) on main stem and was significantly superior. This was followed by March (15.6) and May (15.3) sown crops and were on par. The lowest number of nodes on main stem was observed in December (7.6), January (8.7) and November (10.3).

4.2.3.4 Nodes on main stem at 60 days after sowing

The highest number of nodes (20.3) on main stem was observed for April sown crop, followed by March (19.0) sown crop. The lowest number of nodes was recorded by December (10.0) and January (10.3) sown crops and were on par (Table 8). April sown crop was significantly superior in case of nodes produced at 60 days after sowing.

4.2.3.5 Nodes on main stem at 75 days after sowing

The crop sown during April recorded the highest number of nodes (24.0) followed by March (20.7) and May (19.3) sown crops at 75 days after sowing (Table 8). The lowest number of nodes of 11 was recorded by January followed by December (12.3) and November (14.3) sown crops. All other treatments were intermediary. It is evident that April sown crop was significantly superior.

As a whole, the crop sown on 21st April was superior when compared to other months of sowing in terms of nodes produced on mainstem also.

4.2.4 Internodal length

4.2.4.1 Internodal length at 15 days after sowing

At 15 days after sowing, March (1.38 cm), April (0.56) and May (1.2 cm) sown crops had the sixth node and hence the internodal length. The internodal length was superior in case of crop sown on 21st March (Table 9).

4.2.4.2 Internodal length at 30 days after sowing

The crop sown on 21st March (2.7cm), 21st April (2.5cm), 21st May (2.2cm), 21st June (2.0cm) and 21st July (1.9cm) showed on par and superior internodal length when compared to other dates of sowing, at 30 days after sowing.

Table 9. Effect of time of sowing on internodal length at different intervals

Time of sowing		Internodal length (cm)				
(Treatments)		15 DAS	30 DAS	45 DAS	60 DAS	75DAS
T_1	April 21	0.56^{a}	2.53^{ab}	3.73^{b}	4.26^{b}	4.26^{b}
T_2	May 21	1.18^{c}	2.20^{bc}	4.06^{a}	4.93^{a}	5.03^{a}
T_3	June 21	0.00^{d}	2.00^{c}	3.60^{bc}	4.26^{b}	4.26^{b}
T_4	July 21	0.00^{d}	1.90^{c}	3.70^{b}	4.03^{b}	4.10^{b}
T_5	August 21	0.10^{cd}	1.43^{e}	2.80^{efg}	3.00^{cde}	3.07^{d}
T_6	September 21	0.00^{d}	0.87^{f}	2.87^{ef}	3.27^{cd}	3.28^{cd}
T_7	October 21	0.00^{d}	1.50^{de}	3.27^{cd}	3.33^{c}	3.50^{c}
T_8	November 21	0.00^{d}	0.80^{f}	2.57^{fgh}	2.90^{e}	3.03^{d}
T_9	December 21	0.00^{d}	0.70^{fg}	1.60^{i}	2.20^{f}	2.40^{e}
T_{10}	January 21	0.00^{d}	0.33^{g}	2.27^{h}	2.67^{e}	2.67^{e}
T_{11}	February 21	0.00^{d}	1.83^{cd}	2.50^{gh}	2.93^{de}	3.10^{de}
T_{12}	March 21	1.38^{a}	2.70^{a}	3.01^{de}	3.33^{c}	3.53^{c}
SEm ±		0.10	0.27	0.25	0.24	0.23
CD (0.05)		0.11	0.80	0.73	0.70	0.69

4.2.4.3 Internodal length at 45 days after sowing

It was showed that the crop sown on 21st May (4.1cm) had significant and superior internodal length at 45 days after sowing (Table 9). This was followed by

21st April (3.7cm), 21st July (3.7cm) and 21st June (3.6cm) sown crops and were on par.

4.2.4.4 Internodal length at 60 days after sowing

April, May, June and July sown crops showed their superiority and produced the internodal lengths varying between 4.93 and 4.03cm. The lowest internodal length was recorded by December (2.4cm) followed by January (2.7cm) sown crop (Table 9).

4.2.4.5 Internodal length at 75 days after sowing

A similar trend was noticed in case of internodal length at 75 days after sowing. The crop raised during 21st May (5.03cm) remained superior at 75 days after sowing.

The internodal length remained high from April 21st to July 21st sown crops. However, May sown crop was significantly superior to other treatments from 45 days after sowing.

4.2.5 Fifth node leaf area

4.2.5.1 Fifth node leaf area at 15 days after sowing

The crop sown during April (7.64 cm^2) showed significantly superior leaf area when compared to other months of sowings.

4.2.5.2 Fifth node leaf area at 30 days after sowing

The largest leaf area was produced by May sown crop (71.8 cm^2) and April (68.1cm^2) sown crops (Table 10). However, they were significantly superior to other treatments, which showed that the leaf area produced by the crops sown on 21st April and 21st May were on par and superior.

4.2.5.3 Fifth node leaf area at 45 days after sowing

The crop raised on 21st April (101.7cm^2), 21st May (95.6cm^2) and 21st August (89.4cm^2) were on par and significantly superior when compared to other dates of sowing (Table 10).

Table 10. Effect of times of sowing on fifth node leaf area at different intervals

Time of sowing (Treatments)		5th node leaf area (cm^2) 15 DAS	30 DAS	45 DAS
T_1	April 21	7.64 ^{a}	68.10 ^{a}	101.70 ^{a}
T_2	May 21	3.72 ^{b}	71.83 ^{a}	95.57 ^{ab}
T_3	June 21	1.18 ^{c}	32.67 ^{cd}	60.50 ^{dc}
T_4	July 21	0.00 ^{c}	38.10 ^{bc}	70.03 ^{cd}
T_5	August 21	1.39 ^{dc}	23.43 ^{ef}	89.37 ^{ab}
T_6	September 21	1.09 ^{c}	20.63 ^{fg}	38.70 ^{g}
T_7	October 21	1.95 ^{cd}	31.07 ^{d}	67.77 ^{cd}
T_8	November 21	0.00 ^{c}	29.03 ^{de}	42.93 ^{fg}
T_9	December 21	0.00 ^{c}	16.53 ^{g}	22.20 ^{h}
T_{10}	January 21	0.00 ^{c}	21.60 ^{fg}	24.70 ^{h}
T_{11}	February 21	0.00 ^{c}	23.70 ^{ef}	51.03 ^{ef}
T_{12}	March 21	2.07 ^{c}	43.23 ^{b}	73.30 ^{c}
SEm ±		0.23	4.03	6.84
CD (0.05)		1.39	11.85	20.12

4.2.6 Duration of vegetative phase (sowing to first flower)

Monthly planting had no significant influence on the duration of vegetative phase of okra. The emergence of first flower was noticed in 45 days when the crop was sown on 21st December and it was on par with other monthly sowings.

Table 11. Effect of times of sowing on crop duration of okra

Time of sowing (Treatments)		Crop durartion in days	
		Sowing to first flower	Sowing to final harvest
T_1	April 21	45^{ab}	111^{a}
T_2	May 21	45^{ab}	91^{cd}
T_3	June 21	48^{a}	81^{ef}
T_4	July 21	50^{a}	78^{fg}
T_5	August 21	46^{ab}	93^{c}
T_6	September 21	53^{d}	106^{a}
T_7	October 21	46^{ab}	101^{ab}
T_8	November 21	52^{a}	91^{cd}
T_9	December 21	45^{ab}	86^{de}
T_{10}	January 21	49^{a}	75^{fg}
T_{11}	February 21	46^{ab}	102^{ab}
T_{12}	March 21	48^{ab}	107^{a}
SEm ±		1.76	2.29
CD		5.18	6.72

4.2.7 Crop duration (sowing to final harvest)

The duration of the crop was maximum and on par when the crops were sown on 21st April (111 days), 21st March (107 days), 21st September (106 days), 21st February (102 days) and 21st October (101 days). The crop during January took least days to final harvest and hence shorter duration (75 days). This was followed by July (78), June (81) and December (86) sowings, which were on par (Table 11).

4.2.8 Fruit length

The longest fruits were produced by March sown crop (18.9 cm) and was superior. This was followed by February (17.4 cm), September (17.4 cm) and August (17.4 cm) sown crops and were on par (Table 12). All other treatments were significantly inferior to the above treatments. The shortest fruits were produced by May (14.3 cm) and June (14.8 cm) sown crop and were on par.

4.2.9 Fruit girth

Fruit girth varied significantly among treatments. The maximum girth of fruit was recorded by May (6.4 cm) sown crop (Table 12), followed by April (6.3 cm) and March (6.2 cm) and were on par. September sown crop recorded the minimum girth (5.5 cm).

Table 12. Seasonal effect on Fruit length, Fruit girth and Fruit weight

Time of sowing (Treatments)		Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
T_1	April 21	15.6^{de}	6.3^{ab}	23.3^{bc}
T_2	May 21	14.3^{f}	6.4^{a}	25.0^{ab}
T_3	June 21	14.8^{f}	6.0^{d}	20.7^{c}
T_4	July 21	15.4^{e}	5.9^{e}	23.3^{bc}
T_5	August 21	17.4^{b}	5.8^{f}	24.3^{bc}
T_6	September 21	17.4^{b}	5.5^{i}	23.3^{bc}
T_7	October 21	16.1^{cd}	5.7^{g}	22.9^{cd}
T_8	November 21	16.9^{b}	6.0^{d}	20.2^{e}
T_9	December 21	16.2^{c}	5.6^{h}	20.8^{c}
T_{10}	January 21	16.1^{cd}	5.7^{g}	20.3^{e}
T_{11}	February 21	17.4^{b}	6.0^{b}	22.8^{d}
T_{12}	March 21	18.9^{a}	6.2^{bc}	25.5^{a}
SEm ±		0.40	0.06	0.79
CD (0.05)		1.16	0.18	2.33

4.2.10 Fruit weight

The weight of fruit was highest in March (25.5 g), which was on par with May (25.0 g) and August (24.3 g) July (23.3 g) and September (23.3 g) sown crops (Table 12). All other treatments were statistically similar and inferior to above treatments.

4.2.11 Number of harvests

The number of harvests was significantly influenced by the time of sowing (Table 13). The crop sown during April recorded the highest number of harvests (10.0), followed by March (9.0), September (8.0) and February (8.0). The lowest number of harvests was recorded by the crop raised during July (3.0) followed by May (4.0), June (4.0) and December (4.0) and were on par.

4.2.12 Fruit yield per plant

The highest yield (250.8 g/plant) was recorded by the April sown crop, followed by March (235.5 g/plant) and September (223.6 g/plant). All the above were on par and significantly superior to other treatments. The remaining treatments were statistically similar and inferior. The lowest yield of 74.7 g was recorded by January (74.7 g) sown crop (Table 13).

Table 13. Seasonal effect on number of harvests and fruit yield per plant.

Time of sowing (Treatments)		Number of harvests	Fruit yield (g $plant^{-1}$)
T_1	April 21	10^{a}	250.8^{a}
T_2	May 21	4^{de}	103.6^{fg}
T_3	June 21	4^{de}	81.7^{g}
T_4	July 21	3^{e}	84.8^{g}
T_5	August 21	5^{d}	137.5^{e}
T_6	September 21	8^{b}	223.6^{ab}
T_7	October 21	7^{bc}	168.2^{cd}
T_8	November 21	6^{cd}	110.5^{e}
T_9	December 21	6^{cd}	112.2^{ef}
T_{10}	January 21	4^{de}	74.7^{gh}
T_{11}	February 21	8^{b}	171.3^{c}
T_{12}	March 21	9^{ab}	235.5^{ab}
SEm ±		0.62	17.02
CD (0.05)		1.82	50.06

4.3 Relationship between plant characters and yield

Simple linear correlation between plant characters and yield revealed that all the plant characters viz., plant height, number of nodes on main stem, number of primary branches, days to final harvest and number of harvests had positive effect on yield (Table 14) and it was significant.

Table 14. Correlation coefficients between various plant characters and yield of okra

Plant characters	Correlation coefficients
1. Plant height at 45 DAS	+0.614*
2. Plant height at 60 DAS	+0.577*
3. Number of nodes on main stem at 45 DAS	+0.603*
4. Number of nodes on main stem at 60 DAS	+0.665*
5. No. of primary branches at 45 DAS	+0.666*
6. No. of primary branches at 60 DAS	+0.832**
7. Days to final harvest	+0.956**
8. Number of harvests	+0.942**

* Significant at 5% level
** Significant at 1% level

Based on this, multiple regressions were worked out to estimate the yield of okra based on plant characters. The equations are as follows:

1) $Y = 23.43\ X_1 - 3.94\ X_2 + 2.65\ X_3 + 13.48\ X_4 - 189.77\ (R^2 = 0.94)$

Where X_1 - Plant height at 60 DAS (cm)

X_2 - Number of primary branches

X_3 - Duration of the crop (days)

X_4 - Number of harvests, and

Y - Yield per plant (g)

From the above equation, it is understood that 94 per cent of the yield variability could be explained due to the plant height, number of primary branches, crop duration and number of harvests. Quite interestingly, the duration of the crop and the number of harvests also could explain the variability in yield by 94 per cent and the multiple regression equation is as follows:

2) $Y = 3.08\ X_1 + 11.15\ X_2 - 210.14$ ($R^2 = 0.94$)

Where X_1 - Duration of the crop(days)

X_2 - Number of harvests and

Y - Yield per plant (g)

It revealed that the crop duration and number of harvests are very important in deciding the final yield as evident from the equation 2). From the above equation, the estimated yield per plant was worked out and given in the Table 15. The percentage deviation between observed and estimated yield varied between 2.7 per cent and 25 per cent, which explain the validity of the equation for estimating the fruit yield of okra based on crop duration and number of harvests.

Table 15. Actual and predicted yield of okra (g plant^{-1})

Time of sowing (treatments)	Yield (g plant^{-1})		
	Observed	Predicted	% deviation from the observed yield
April 21	250.8	243.2	+3.0
May 21	103.6	114.7	-10.7
June 21	81.7	83.9	-2.7
July 21	84.8	63.6	+25.0
August 21	137.5	132.1	+3.9
September 21	223.6	205.5	+8.1
October 21	168.2	179.0	-6.4
November 21	110.5	137.0	+24.0
December 21	112.2	121.6	+8.4
January 21	74.7	65.5	+12.3
February 21	171.3	193.2	-13.4
March 21	235.5	219.8	+6.2

4.4 Crop Weather Relationships of Okra

4.4.1 Plant height

The plant height was positively correlated (correlation coefficient more than 0.9) with minimum air temperature during its vegetative phase and later on, it was negatively correlated (correlation coefficients varied between –0.614 and –0.856) with maximum temperature (Table 16). The plant height was adversely affected whenever the temperature range was high, as both are negatively correlated (correlation coefficients more than –0.8). The positive association with relative humidity might be due to inter-dependency between maximum temperature and relative humidity. A similar association was noticed between rainfall and sunshine. Whenever rainfall was high the number of bright sunshine hours was less and vice versa. As expected, rainfall had a significant positive effect (correlation coefficients variation between 0.602 and 0.843) during its vegetative phase while it was negative (correlation coefficients varied between –0.736 and –0.80) with bright sunshine.

4.4.2 Number of nodes on main stem

The interaction between weather elements and number of nodes on mainstem was similar to that of plant height. Rainfall and minimum temperature had positive association (correlation coefficients +0.843 and +0.938), while maximum temperature and temperature range had negative correlation (Table 16). The similar crop weather relationships with plant height and number of nodes on mainstem could be explained due to the inter-relationship between them. It is likely that the number of nodes on mainstem follows with plant height.

4.4.3 Number of primary branches

Unlike in plant height and number of nodes on mainstem, the number of primary branches responded positively to maximum temperature (correlation coefficient varied between +0.595 and +0.873) during vegetative and reproductive

Table 16. Correlation coefficients between plant and yield characters of okra and weather elements

Plant characters	Weather elements							
	Maximum temperature (°C)	Minimum temperature (°C)	Mean temperature (°C)	Temperature range	RH-1	RH-2	SS hours	RF
1. Plant height at 45 DAS	-0.614* (5-6)	+0.913* (1-6)	+0.563* (1-4)	-0.814** (6)	+0.740** (1-5)	+0.709** (4-6)	-0.736** (4-6)	+0.602* (6)
2. Plant height at 60 DAS	-0.856** (6-9)	+0.938** (1-3)	-0.888** (8-9)	-0.800** (3-9)	+0.682* (1-5)	+0.815** (1-9)	-0.807** (3-9)	+0.843** (3-9)
3. No. of nodes on main stem at 45 DAS	-0.605* (5-6)	+0.941** (2)	+0.594* (1-4)	-0.619* (5-9)	+0.587* (1-5)	+0.655* (5-6)	-0.637* (5-6)	+0.708* (5-6)
4. No. of nodes on main stem at 60 DAS	-0.856** (6-9)	+0.938** (1-3)	-0.888** (8-9)	-0.800** (3-9)	+0.682* (1-5)	+0.815** (1-9)	-0.807** (3-9)	+0.843** (3-9)
5. No. of primary branches at 45 DAS	+0.873** (1-6)	NS	+0.892* (1-6)	+0.597* (1-5)	NS	NS	+0.562* (1-5)	-0.588* (1-4)
6. No. of primary branches at 60 DAS	+0.595* (1-8)	NS	+0.604* (1-9)	NS	NS	NS	NS	-0.596* (1-8)
7. Days to final harvest	NS	+0.658* (1-6)	+0.560* (1-5)	NS	NS	NS	NS	NS
8. No. of harvests	NS	+0.651 (1-6)	+0.687 (1-6)	NS	NS	NS	NS	-0.570* (4-5)

Table.16. Correlation coefficients between plant and yield characters of okra and weather elements (continued)

Plant characters	Weather elements							
	Maximum temperature (°C)	Minimum temperature (°C)	Mean temperature (°C)	Temperature range	RH-1	RH-2	SS hours	RF
1. Fruit length	NS	NS	+0.625* (2-5)	NS	NS	NS	NS	-0.717* (2-5)
2. Fruit girth	-0.655* (7-14)	+0.837** (1-4)	-0.656* (2-12)	-0.758* (1-9)	+0.650* (5-12)	-0.679* (8-9)	-0.792** (2-14)	+0.854** (8-9)
3. Fruit weight	-0.738** (1-12)	+0.585* (1-9)	-0.860** (3-16)	-0.673** (1-11)	+0.667* (1-6)	+0.609* (1-11)	-0.624* (1-7)	+0.623* (3-7)
4. Fruit yield/plant	NS	+0.716** (6-7)	+0.776** (1-6)	NS	NS	NS	NS	NS

* Significant at 5% level
** Significant at 1% level
Figures in parenthesis denote periods in week after planting

RH-1 and RH-2 - Morning and afternoon relative humidities
SS hours - Hours of bright sunshine
RF - Rainfall total in mm

phases and temperature range (Table 16), during early vegetative phase (+0.597). It is quite interesting to note that the minimum temperature neither effected positively nor negatively with the number of primary branches. The negative association with rainfall may be due to inter-relationship between rainfall and maximum temperature. It appeared that the bright sunshine during the early vegetative phase of okra might influence the number of primary branches as it was positively correlated (+0.562).

4.4.4 Crop duration (sowing to final harvest)

The positive association (correlation coefficient +0.658) between crop duration and minimum temperature during its early vegetative phase might indicate that it was the minimum temperature and not the maximum temperature along with other elements, which influenced the crop duration.

4.4.5 Number of harvests

The number of harvests was also associated with minimum temperature (correlation coefficient +0.651) during its early vegetative phase (Table 16). It was similar to that of the observations made in case of crop duration.

4.4.6 Fruit characters

Among fruit length, fruit girth, and fruit weight, the length, and girth are maximum influenced by weather factors. The fruit girth and weight responded to weather elements in the same fashion. As observed in case of plant height and number of nodes the fruit girth and weight were negatively influenced (Table 16) by maximum temperature (correlation coefficient –0.655 and –0.738) and were positively (correlation coefficient +0.837 and +0.585) influenced by minimum temperature and rain fall (correlation coefficient +0.854 and +0.623). The negative correlation with bright sunshine may be due to inter-relationship between rainfall and sunshine.

4.4.7 Yield

It is quite interesting to note that the fruit yield was associated positively (correlation coefficients +0.716 and +0.776) with minimum and mean temperature and not to maximum temperature or any other weather factors (Table 16).

The studies on crop weather relationships of okra revealed that the maximum temperature had a positive correlation with primary branches only. While negative with all other plant characters viz., plant height, number of nodes on main stem, fruit girth and fruit weight. Interestingly, the maximum temperature had no relationship with the crop duration while it was positively related to the minimum temperature. As a whole, okra comes up well if the minimum temperature during its vegetative stage is around 24-25°C, and the maximum is around 33-34°C. The positive relationship with relative humidity on crop may be due to multi-collinearity effect with maximum temperature as they are related inversely. Similar was the case between rainfall and sunshine hours. Rainfall also had positive association with all biometric characters except in case of primary branches. It revealed that the minimum temperature and rainfall had positive association with the crop as a whole while it was negative with maximum temperature and temperature range.

Based on the association between weather elements and crop yield of okra, a multiple regression equation was worked out and given below:

$$Y = 50.7\,X_1 - 28.69\,X_2 + 16.11\,X_3 - 0.058\,X_4 - 456.29 \quad (R^2 = 0.76)$$

Where Y - yield per plant (g)

X_1 - Minimum temperature (°C) during vegetative phase
(6^{th} to 7^{th} week after sowing)

X_2 - Maximum temperature (°C) during reproductive phase
(6^{th} to 9^{th} week after sowing)

X_3 - Bright sunshine (h/day) during vegetative phase
(4^{th} to 6^{th} week after sowing)

X_4 - Rainfall (mm) during vegetative phase
(5^{th} to 6^{th} week after sowing)

From the above, it revealed that the minimum (6^{th} to 7^{th} week) and maximum (6^{th} to 9^{th} week) temperature during the initial reproductive phase, rainfall (5^{th} to 6^{th} week) and sunshine (4^{th} to 6^{th} week) during vegetative phase might explain the variability in fruit yield of okra by 76 per cent. It also revealed that the surface air temperature, rainfall and bright sunshine might be the driving factor for the crop growth and development of okra among different weather factors.

Plate.I. Overall view of the experimental plot

Plate.II. April sown crop at 60 DAS

Plate.III. January sown crop at 60 DAS

Overall view of the experimental plot

April sown crop at 60 DAS (fruit yield per plant-good)

January sown crop at 60DAS (fruit yield per plant-poor)

DISCUSSION

5. DISCUSSION

Growth, development and productivity of plants depend on mainly two major factors, viz., internal factors and external or environmental factors. When other crop production factors remain at the optimum level, aberrations in weather cause variation in crop yield by about 50 per cent (Mavi, 1994). A fuller exploitation of the weather resource, therefore, is the major hope for greater agricultural production to meet the demands of the staggering increase in population.

The present investigation is meant to study the effect of various weather parameters on the growth and yield potentials of okra, using variety 'Arka Anamika'. The various results obtained during the course of investigation are discussed in this chapter.

5.1 Biometric observations

5.1.1 Plant height

A declining trend was noticed in plant height of okra from April to January (Fig.3). The plant height was superior in March sown crop up to 45 days after sowing and thereafter, a sudden increase was noticed in April sown crop and it was significantly superior. This might be due to increase in rainfall (295.0 to 1629.7 mm) and heavy cloudiness (< 4 h/day) during the reproductive phase. The increase in plant height resulted in internodal elongation. An increase in plant height was noticed by Singh (1994) under low light stress. The higher maximum (30.5°C-34°C), minimum (24°C-25°C) temperatures (Table 17) and sunshine hours (6-7 hrs) during vegetative phase and increased amount of rainfall during reproductive phase (as compared to vegetative phase) favoured the incremental plant height of February, March and April sown crops. December and January sown crops enjoyed the same conditions of higher maximum and minimum temperatures and sunshine hours during the vegetative stage. But the lack of rainfall during the reproductive

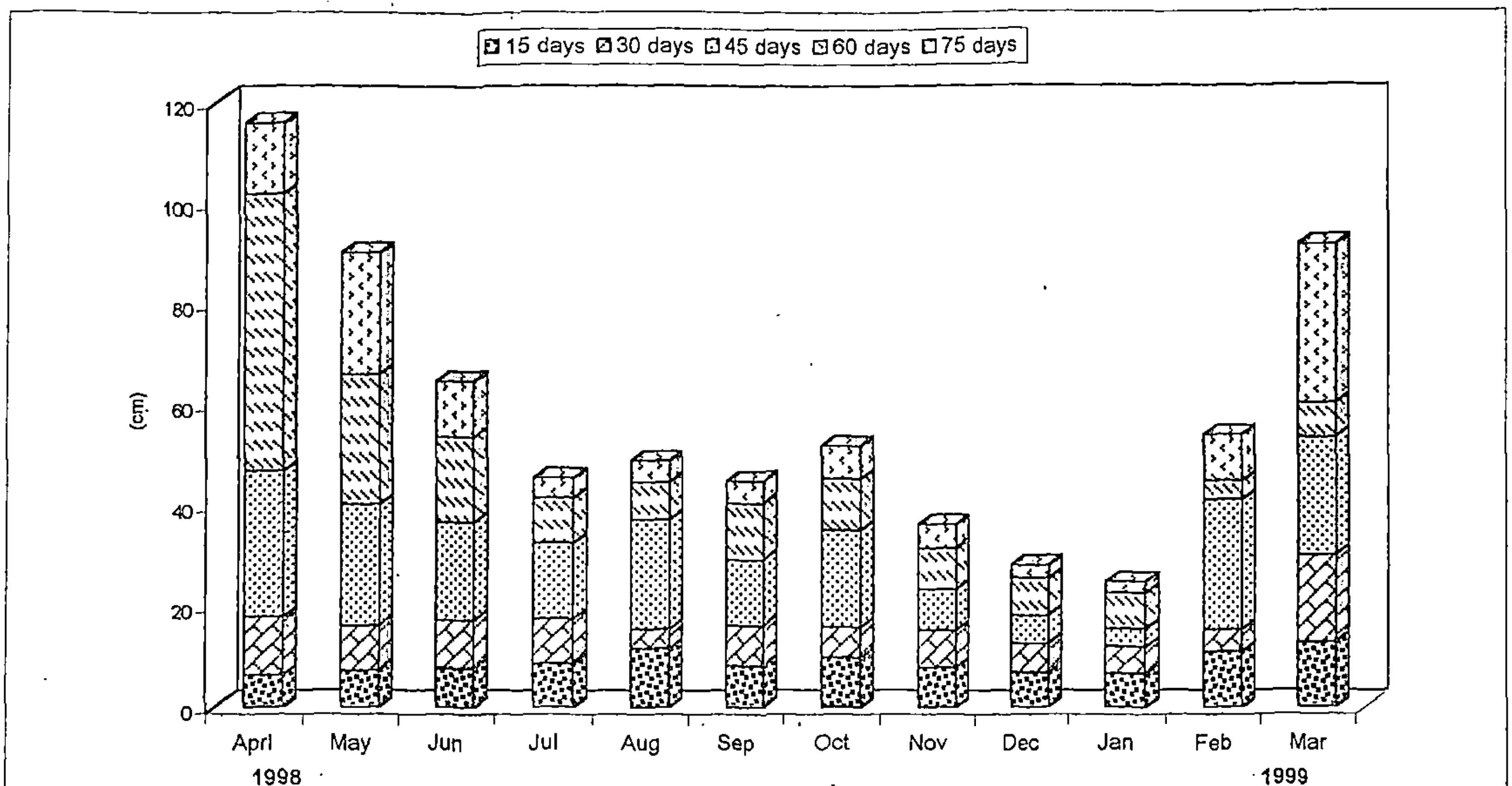


Fig.3. Effect of times of sowing on plant height at 15, 30, 45, 60 and 75 DAS

Table 17. Mean meteorological parameters prevailed during vegetative and reproductive phases of okra

Months	Maximum Temp °C		Minimum Temp °C		Temperature Range °C		Sunshine (hrs)		Relative humidity(%)		Rainfall (mm)	
	Veg.	Rep.	Veg.	Rep.	Veg.	Rep.	Veg.	Rep.	Veg.	Rep.	Veg.	Rep.
April	34.0	29.4	25.2	23.1	9.4	6.0	7.7	2.2	75.5	87.7	295.0	1629.7
May	30.9	29.5	23.3	23.4	7.3	5.6	4.4	3.6	83.5	87.2	1060.0	740.3
June	29.1	28.5	23.1	23.7	5.4	5.7	2.7	3.6	88.5	89.1	1239.2	691.5
July	30.8	28.2	23.8	22.5	6.1	6.0	3.9	3.9	90.5	86.7	823.6	441.3
August	28.7	30.5	22.9	22.4	6.1	7.3	4.0	7.1	86.5	80.4	874.5	443.7
September	28.0	31.3	23.9	22.3	6.7	8.3	4.7	9.0	83.9	82.5	551.7	42.7
October	30.9	31.6	23.0	22.5	8.5	9.5	7.3	8.0	75.5	64.2	125.4	28.4
November	31.4	31.8	22.2	24.2	8.8	11.1	5.6	9.1	68.0	57.5	33.2	22.8
December	32.2	35.2	21.7	24.3	10.5	11.5	9.1	9.2	60.5	58.1	0.0	22.8
January	33.8	31.3	22.2	24.9	11.4	10.3	9.0	8.4	55.0	71.6	22.8	20.4
February	33.8	31.5	24.8	25.1	11.2	6.4	8.7	5.4	66.4	79.3	26.2	520.0
March	30.5	29.7	25.5	24.4	8.1	6.1	6.3	4.9	74.0	85.0	87.4	893.0

Veg. – Vegetative phase
Rep. – Reproductive phase

phase failed to give the boost to the further growth of the plant, which negatively affected the plant height. The severe attack of fruit and shoot borer (Table 4), 80 and 48%, coursed in law plant height by terminating the growth of terminal buds. The fruit and shoot borer (*Earias vitella*) infestation was favoured by higher temperature (30-30°C) prevailed throughout the crop period. Kumar and Urs (1988) noted a significant and positive correlation between temperature and incidence of *Earias vitella*. The influence of higher temperature and longer days on the plant height was reported by Randhawa (1967), Thamburaj (1972) and Inemiren and Okiy (1986). Okra requires a long growing season with warm temperatures as reported by Thompson and Kelly (1957), Wattsand Watts (1939), Knott (1944), Shoemaker (1953), Mac Gillivray (1953), Howthorn and Pollard (1954), Chauhan (1965) and Yawalker (1969).

5.1.2 Primary branches

The crop variety 'Arka Anamika' is known for its branching habit. The maximum number of primary branches was produced by February, March and April sown crops along with the September sown crop, which gave the maximum yield. There was an interrelationship between the number of primary branches and yield (Fig. 4). It was similar to that of the result obtained by Kirtisingh *et al.* (1974), Roy and Chonkar (1976) and Yadav (1996). The length of the day and the maximum temperature during both vegetative and reproductive stages had positive association (correlation coefficients +0.562 and +0.598) with the number of primary branches. Increase in the number of sunshine hours (5.4 and 4.9 hours) and temperature (29.7 to 33.8°C) during vegetative phase favoured the production of primary branches during February and March sowings, while the number of sunshine hours and temperature during reproductive phase enhanced the production of primary branches from September to January sown crops (Table 17).

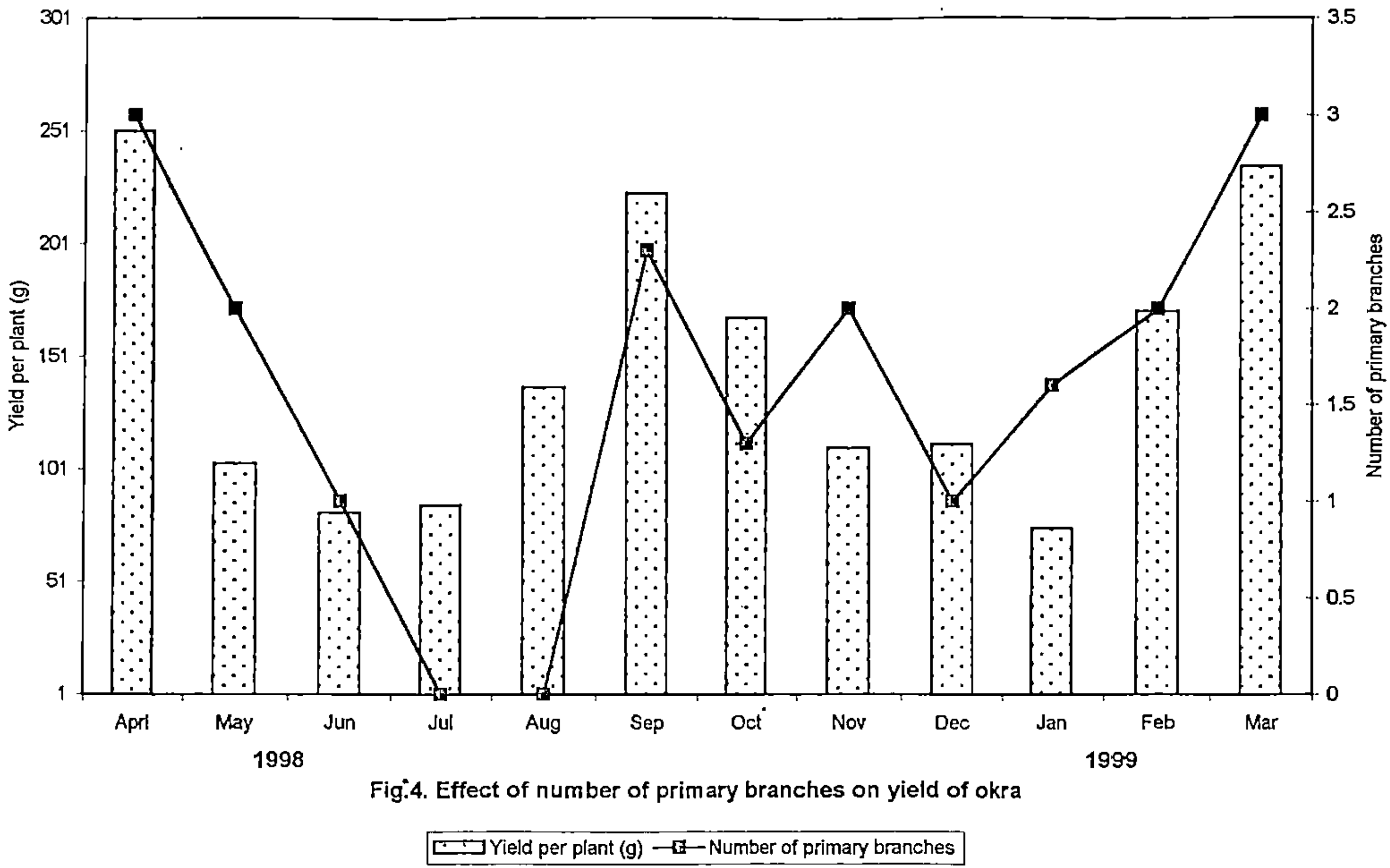


Fig. 4. Effect of number of primary branches on yield of okra

5.2.3 Number of nodes on main stem

Thamburaj and Kamalanathan (1973) and Swamy and Ramu (1978) reported the positive correlation between the number of nodes and yield. The number of nodes produced by the April sown crop showed significant superiority over other treatments (Fig. 5). This may be due to the higher maximum temperature (34°C) and longer days during the vegetative phase along with sufficient rainfall (295 mm and 1629 mm) during both vegetative and reproductive phases (Table 17). As these factors contribute to the production of nodes in okra, they are indirectly contributed to the yield of the crop. The number of nodes produced during November, December and January was significantly inferior to all other treatments. This may mainly because of lower minimum temperature and higher temperature range during both the phases. Lack of adequate soil moisture due to the nonavailability of sufficient amount of rainfall may also be another reason for the low production of nodes during November, December and January.

5.2.4 Internodal length

The superiority in internodal length over other treatments was noticed in March, April and May sown crops (Fig. 6). Heavy cloudiness during the rainy season resulted in less number of bright sunshine hours and tends the plant to elongate without producing new nodes and resulted in increased internodal length. This is in agreement with Singh (1994). Shorter internodal lengths were observed during November, December and January sowing. Low night temperature (21°-22°C) and increased sunshine hours (9.0-9.2 hours) during vegetative phase may be responsible for shorter internodal length. This confirmed the susceptibility of okra plants to lower temperatures as reported by Thompson and Kelly (1957) and Yawalker (1969).

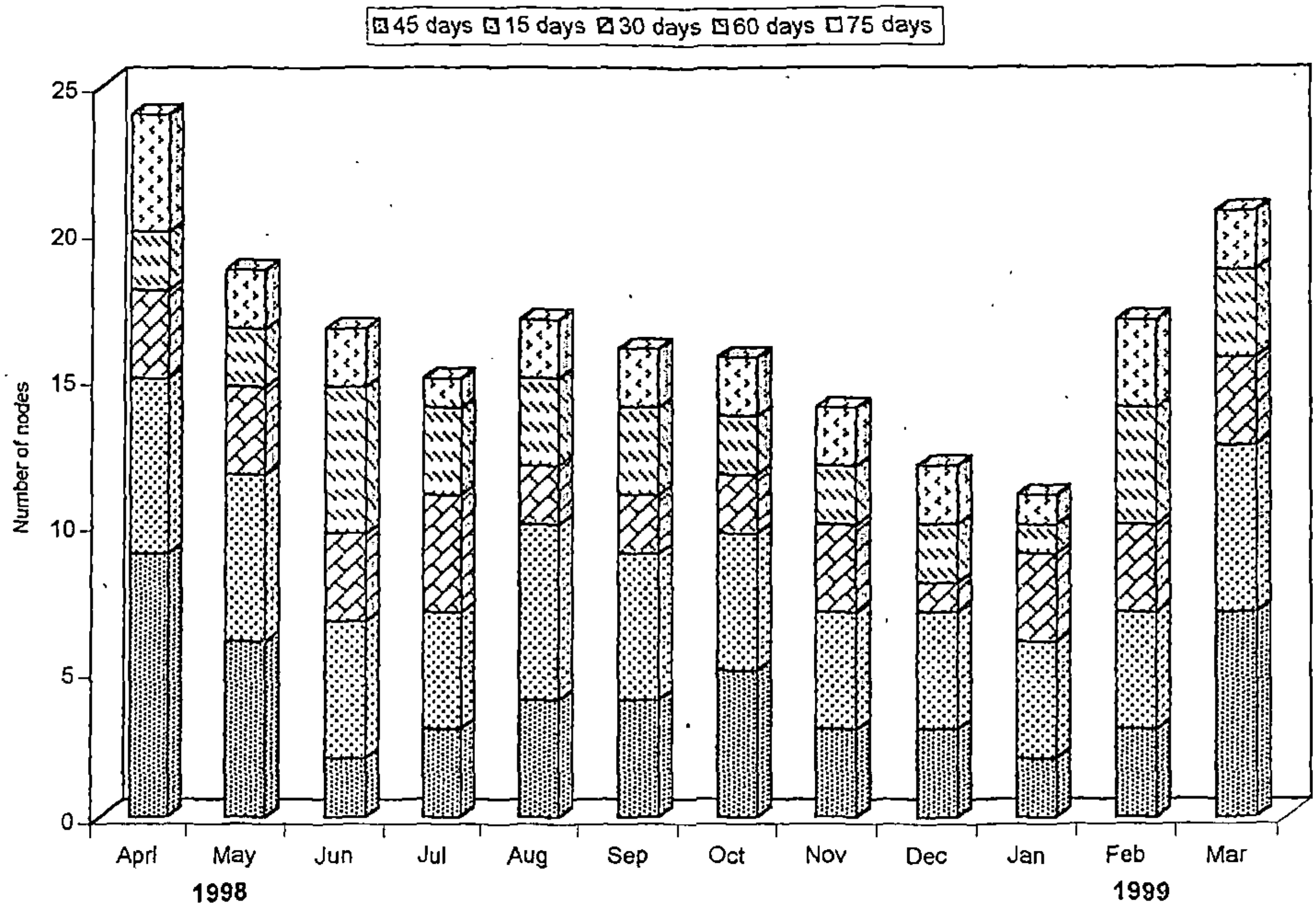


Fig.5. Effect of times of sowing on number of nodes on mainstem at 15, 30, 45, 60 and 75 DAS

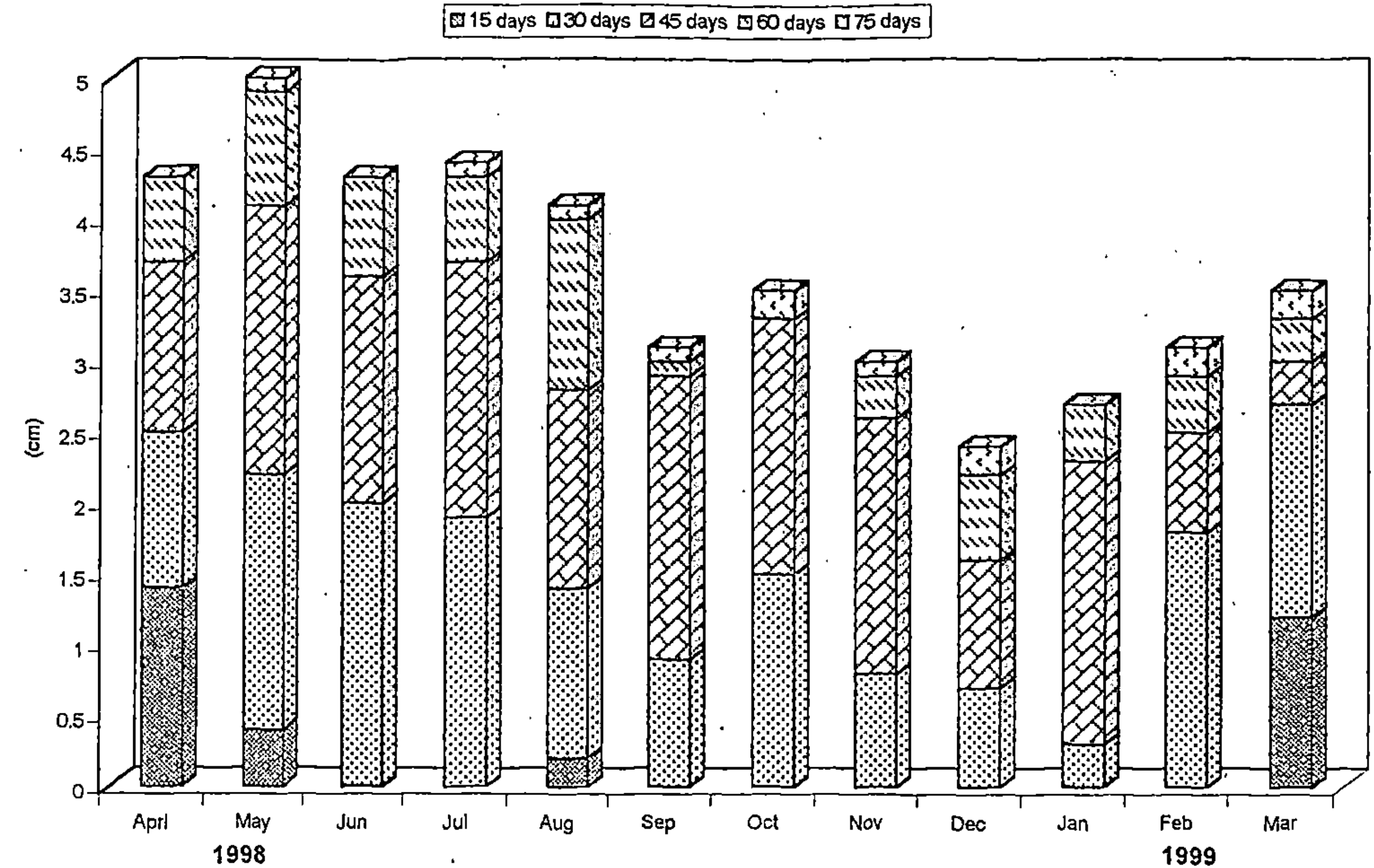


Fig.6. Effect of times of sowing on internodal length at 15, 30, 45, 60 and 75 DAS

5.2.5 Fifth node leaf area

Increased leaf area provides more space for photosynthesis, resulting in greater food production and finally yields. The maximum leaf area was appeared in April sowing (Table 10) and was significantly superior to other treatments except May and August which were on par. Higher temperature (34°C) along with sufficient moisture due to adequate rainfall during the vegetative phase may congenial for the leaf lamina expansion in okra.

5.2.6 Duration to first flower (Vegetative phase)

The period taken for the appearance of the first flower depend on temperature and day length. The plant exposed to longer days (6-9.2 hrs) and higher temperature (both maximum of 30-34°C and minimum of 25-30°C), may produce flowers earlier (Table 17). Similar early initiation of flowering has been recorded by Joshi *et al.* (1960), Randhawa (1967) and Thamburaj (1972). Influence of temperature alone on first floral appearance was reported by Siedenschnur (1973). This was contradictory to the statement made by Tenga and Ormrod (1985). According to him, higher temperature delayed floral development in okra.

5.2.7 Duration to final harvest (Reproductive phase)

Among the different times of sowing, February (102 days), March (107 days), April (111 days) and September (106 days) took more number of days to final harvest. Interestingly, the duration of reproductive phase was higher (53 to 56 days) as compared to the vegetative phase in the above sown crops. This might be one of the reasons why, the yield was much better in Apil, September and March sown crops (Fig.7). Inemiren and Okiy (1986) also reported that the reproductive phase was longer if the crop was sown in April. This may be due to higher minimum temperature and Growing Degree Days experienced during the crop period

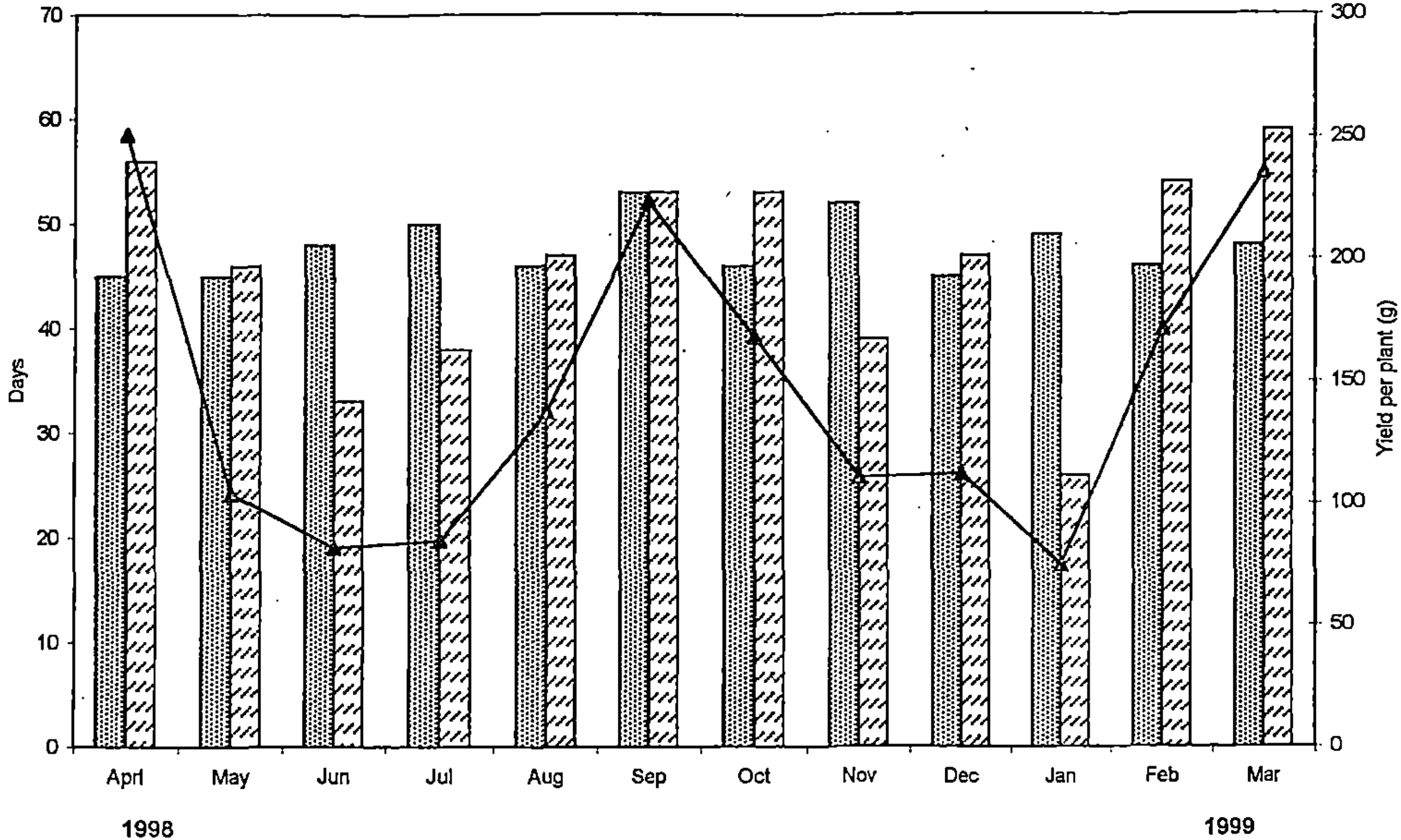


Fig.7. Effect of vegetative phase and reproductive phase on yield of Okra

(Table 18). The April sown crop took 1522.3 GDD for maturity, which was the highest and on par with February (1456.3) and March (1459.9)

5.2.8 Number of harvests

In addition to the better vigour of plants, February to April sown crops have produced more number of fruits along with September sown crop. Significant positive correlation between number of harvests and yield was reported by Kirtisingh *et al*. (1974), Roy and Chonkar (1976), Swamy and Ramu (1978, Mandal and Dana (1994) and Yadav (1996). Higher maximum temperature and longer days prevailed during these months were congenial for the production of more number of fruits, and hence harvests (Table 19). A positive significant correlation between maximum temperature and longer days, with number of harvests was reported by Thamburaj (1972) and Palanisamy and Ramasamy (1985). This is in corroboration with the finding of Mondal *et al.* (1981), also. The number of fruits was less in June, July and December sown crops. Low light availability i.e., lesser sunshine hours during both the vegetative and reproductive phases (2.7 to 3.9 h/day) reduced the number of harvests in July sown crop whereas, soil moisture limitation due to zero rainfall during vegetative phase, reduced the number of harvests in December sown crop (Table 17). The yield was highly sensitive to the amount of rainfall during vegetative phase as reported by Der (1972).

5.2.9 Fruit length, fruit girth and fruit weight

Crops sown during March produced longer fruits (18.9 cm) with higher fruit weight (25.5 g). Higher morning relative humidity (90-96%) and adequate rainfall experienced during the period may cause increase in fruit length and weight. Higher fruit girth (6.4 cm) and weight (25 g) were also recorded by May sown crop. Contribution of more fruits from yellow vein mosaic affected plants to the general mean, reduced the mean length of the fruit in May sown crop. November and

Table 18. Effect of Growing Degree Day on yield and duration of okra

Date of sowing (Treatments)	Growing Degree Days taken	Yield/plant (g)	Duration (days)
April 21	1522.3	250.8	111.0
May 21	1208.1	108.6	90.5
June 21	1052.1	81.7	81.0
July 21	1027.4	84.8	78.0
August 21	1204.6	137.5	92.7
September 21	1387.9	223.6	105.7
October 21	1353.7	168.2	101.0
November 21	1216.2	110.5	91.3
December 21	1206.2	112.2	86.0
January 21	1041.3	74.7	75.3
February 21	1456.3	171.3	102.0
March 21	1459.9	235.5	107.3
CD (0.05%)	72.2	50.06	6.72
SEm (±)	23.5	17.02	2.29

December sown crops produced fruits of lesser weight (20.2 and 20.8 g). The minimum temperature (21-22°C) and the relative humidity (55-60%) persisted during the reproductive phase may be the reason for less fruit weight.

5.2.10 Fruit yield per plant

The fruit yield was high in April (250.8 g), March (235.5 g) and September (223.6 g) sown crops. This was in agreement with the findings of Inemiren and Okiy (1986), Mondal *et al.* (1989) and Raghav (1996). Higher temperature and longer days that prevailed during the crop were congenial for realizing the higher yield in March and April sown crops (Table 19). This was supported by Venkataramani (1945), Randhawa (1967), Thamburaj (1972) and Palanisami and Ramasami (1985). Higher temperature and longer days that prevailed during the crop period were congenial for realising the higher yield in March and April sown crop. At the same time these crops were affected by bhindi yellow vein mosaic virus. High temperature (29-32°C) in combination with high relative humidity (85-90%) favoured the growth and spread of this disease inoculum (Fig.8). The influence of temperature and relative humidity on the spread of bhindi yellow vein mosaic disease was reported by Varma (1952) and Nath *et al.* (1992). This may cause in yield reduction to the same extent in April, September, and March sown crop, eventhough they were superior to other months of sowing. For September sown crop the attack of diseases and insect pests remained below infective level and may be the main reason for superior and on par yield with April and March sown crops. The spread of the disease bhindi yellow vein mosaic was mainly depends on the vector population ie. *Bemisia tabaci*. The continuous rainfall during the previous months of September may wash out the eggs of this insect population and thereby reduced their count on the plants and hence the disease. The lowest yield was recorded by June, July and January sown crop. Somewhat similar weather conditions were prevailed during both the stages of these crops due to different reasons. Both the maximum (28-30°C) and minimum (23°C) temperature

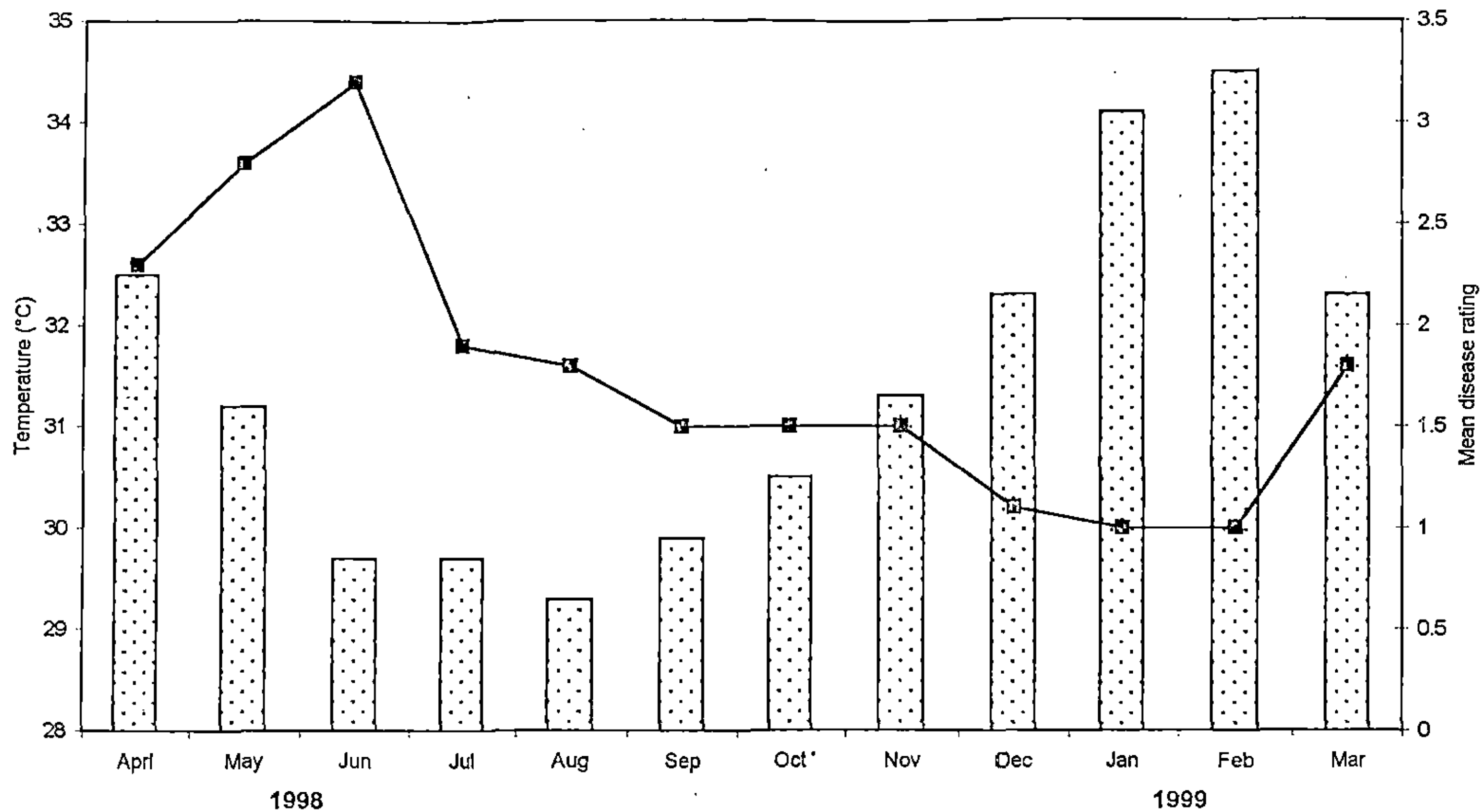


Fig.8. Effect of maximum temperature on bhindi yellow vein mosaic disease

Maximum temperature (°C) — Mean disease rating

Table 19. Maximum and minimum temperatures and sunshine hours during April 1998, September 1998 and March 1999.

Weeks after sowing	April 1998			September 1998			March 1999		
	Max. T. (°C)	Min. T. (°C)	Sunshine (hrs)	Max. T. (°C)	Min. T. (°C)	Sunshine (hrs)	Max. T. (°C)	Min. T. (°C)	Sunshine (hrs)
1	36.6	26.8	8.5	28.6	23.1	2.4	34.8	25.0	8.4
2	35.9	24.6	8.7	29.3	23.1	2.8	34.9	25.1	7.5
3	35.2	25.5	8.5	27.8	23.0	1.5	34.9	24.5	7.8
4	35.5	25.3	6.5	29.8	22.6	4.8	33.2	25.8	7.4
5	32.4	24.1	4.6	31.1	22.5	8.2	33.1	26.2	4.6
6	33.6	25.7	8.3	31.1	23.2	5.5	32.0	25.9	4.2
7	34.4	25.2	8.8	30.8	23.6	4.1	33.6	25.8	6.3
8	32.0	23.9	6.4	31.9	22.8	8.9	31.0	25.2	6.4
9	30.0	23.1	2.2	31.7	22.8	9.0	30.4	25.1	5.5
10	29.0	22.4	3.0	32.2	23.0	7.9	29.0	23.8	2.6
11	27.8	23.2	0.3	31.3	23.8	6.1	29.8	23.5	5.0
12	29.0	23.3	2.5	29.7	23.4	3.3	29.1	22.8	4.8
13	29.2	24.0	2.4	31.4	22.4	8.6	28.4	22.7	1.8
14	29.8	24.1	4.9	31.1	22.0	8.2	29.6	23.2	5.1
15	29.2	23.4	3.0	31.9	21.8	9.4	30.9	23.0	8.9
16	30.3	24.4	4.6	31.0	21.8	9.5	29.6	23.1	3.7

Max. T. – Maximum temperature
Min. T. – Minimum temperature

along with sunshine (2.7-3.6 hours) during vegetative and reproductive phases caused reduction in yield of June and July sown crops. The lowering of maximum temperature was mainly due to the continuous rainfall obtained during the growing period. Inadequate rainfall during vegetative and reproductive phases might be one of the reasons for low fruit yield in December sown crops.

The crop duration and number of harvests alone accounted for 94 per cent variability in fruit yield of okra, though height of the plant and number of primary branches played a significant role in crop health. This might be due to the contribution of plant height and number of branches in keeping the plant vigour, which ultimately led the plant's life to more number of days and thus more number of harvests. Similar reports were published by Roy and Chonkar (1976). It revealed that the critical plant characters, which differ from crop to crop ultimately, decided the final fruit yield. In the case, it is the crop duration and number of harvests, which are very important for final fruit yield of okra.

As literature suggested, it is the environmental factors, which decided the plant characters and final yield for a given genotype. It is presumed that among several environmental factors weather is the resource, which drives the plant husbandry if the crop management practices are strictly adhered to. Under the above situation, all attempts have been made to develop a relationship between various weather elements and crop yield through correlation and regression techniques. Interestingly, the surface air temperature (both maximum and minimum) and rainfall and cloudiness (bright sunshine) played a major role and explained an accountability of 76 per cent in explaining fruit yield of okra. From the review of work done on crop weather relationships of okra, it is the surface air temperature and day length, which contributed for successful growth and yield of bhindi. The results obtained for Thamburaj (1972) strictly support this condition.

In this case, the day length may not be a contributing factor as it does not vary much from season to season and hence, it is the surface air temperature along with sunshine and rainfall influenced the crop yield to a greater extent in humid climate like Kerala. Since these studies if replicated for atleast three to five years, may pin point the best time of sowing and weather cycle, which is conducive for exploitation of okra to her potential on commercial scale.

SUMMARY

6. SUMMARY

The experiment was conducted at the College of Horticulture, Vellanikkara, from April 1998 to June 1999, to study the crop weather relationships of okra (*Abelmoschus esculentus* [L.] Moench) using variety 'Arka Anamika'.

The experiment was laid out in randomised block design with three replications. There were twelve monthly sowings, starting from 21st April 1998 to 21st March 1999. Observations on morphological, phenological and yield characters of the crop were recorded during the course of investigation. The daily weather data recorded at the Principal Agricultural Meteorological Station, College of Horticulture, Vellanikkara were made use of, to work out the crop weather relationships.

The main findings of the study are summarised as follows:

1. April sown crop was superior in respect of both biometric and yield characters. Biometric characters like plant height, number of nodes on main stem, and fifth node leaf area remained significantly superior when crops sown on 21st April. The harvest duration was also high and produced maximum number of fruits with better fruit girth and finally the higher yield per plant.
2. Crop raised during March and September were on par with the April sown crop in harvest duration, number of harvests and yield per plant.
3. Weather parameters prevailed during the above time of sowings were as follows:

Month	Maximum temperature	Minimum temperature	Sunshine
April	29.0-36.6°C	22.4-26.8°C	0.3-8.8 h/day
September	29.7-31.9°C	21.8-23.6°C	1.5-9.5 h/day
March	29.1-34.8°C	22.7-26.2°C	1.8-8.4 h/day

4. May sown crop had the highest internodal length and interestingly no primary branches were produced by July and August sown crops.
5. Significant positive correlations were observed between yield per plant and plant height, number of nodes on main stem, number of primary branches, days to final harvest and number of harvests.
6. The regression equation developed for predicting fruit yield based on plant characters is as follows:

   $Y = 3.08\ X_1 + 11.15\ X_2 - 210.4\ (R^2 = 0.94)$

   Where, Y – yield per plant (g), X_1 – duration of the crop in days and X_2 – number of harvests. The duration of the crop and the number of harvests could explain the variability in yield by 94 per cent.
7. The crop responded in accordance with Growing Degree Days, and yielded maximum when they experienced maximum Growing Degree Days.
8. The fruit yield per plant was positively correlated with minimum temperature of sixth to seventh week after sowing and mean temperature of first to sixth week after sowing.
9. The plant height and number of nodes were positively correlated with minimum temperature, mean temperature and morning and afternoon relative humidity whereas the plant height was negatively correlated with maximum temperature, temperature range and sunshine hours.
10. Number of primary branches showed significant positive correlation with maximum and mean temperatures and negative correlation with rainfall.
11. Days to final harvest and number of harvests had significant positive correlation with mean and minimum temperatures during vegetative phase.
12. The fruit girth and fruit weight were positively correlated with minimum temperature, morning and afternoon relative humidity and rainfall. They were negatively correlated with maximum temperature, temperature range and sunshine hours. The fruit length was positively correlated with mean temperature and negatively correlated with rainfall.

13. The regression equation developed for fruit yield per plant based on weather elements is

$Y = 50.7\ X_1 - 28.69\ X_2 + 16.11\ X_3 - 0.058\ X_4 - 456.29\ (R^2 = 0.76)$

Where, Y = yield per plant (g), X_1 - Minimum temperature (°C) during vegetative phase (6th to 7th week after sowing), X_2 - Maximum temperature (°C) during reproductive phase (6th to 9th week after sowing), X_3 - Bright sunshine (h per day) during vegetative phase (4th to 6th week after sowing) and X_4 – Rainfall (mm) during vegetative phase (5th to 6th week after sowing). This equation explains the variability in fruit yield of okra by 76 per cent due to the above weather parameters.

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CROP WEATHER RELATIONSHIP IN OKRA

[*Abelmoschus esculentus* (L.) Moench]

By

S. KAVITHA

ABSTRACT OF THE THESIS

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DEPARTMENT OF AGRICULTURAL METEOROLOGY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
Kerala, India

2000

ABSTRACT

CROP WEATHER RELATIONSHIP IN OKRA (*Abelmoschus esculentus* [L.] Moench), VARIETY 'ARKA ANAMIKA'

The experiment was conducted during 1998-1999 at the College of Horticulture, Vellanikkara to find out the crop weather relationships of okra, 'Arka Anamika'. The experiment was laid out in randomised block design with three replications. The treatments consisted of twelve monthly sowing, starting from 21st April 1998 to 21st March 1999.

Observations on morphological, phenological and yield attributes were recorded during the course of investigation. The daily values of weather elements viz., rainfall, number of rainy days, maximum and minimum surface air temperatures, bright sunshine, morning and afternoon relative humidity, pan evaporation and wind speed were collected from the Principal Agricultural Meteorological Station, College of Horticulture, Vellanikkara, to work out the crop weather relationships of okra.

March, April and September sown crops were significantly superior in terms of fruit yield per plant, number of harvests and crop duration. April sown crop was also superior in plant height, number of nodes on mainstem, and number of primary branches.

The fruit yield was significantly associated with the plant height, number of nodes on mainstem, number of primary branches, number of harvests and duration of the crop.

A multiple regression equation was worked out for predicting fruit yield based on plant characters and it is as follows:

$$Y = 3.08\ X_1 + 11.15\ X_2 - 210.14\ (R^2 = 0.94)$$

Where, X_1 is the duration of the crop in days, X_2 is the number of harvests and Y is the yield per plant (g).

Based on the association between weather elements and crop yield of okra, a multiple regression equation was worked out and given below:

$$Y = 50.7\ X_1 - 28.69\ X_2 + 16.11\ X_3 - 0.058\ X_4 - 456.29\ (R^2 = 0.76)$$

Where, Y = yield per plant (g), X_1 - Minimum temperature (°C) during vegetative phase (6^{th} to 7^{th} week after sowing), X_2 - Maximum temperature (°C) during reproductive phase (6^{th} to 9^{th} week after sowing), X_3 - Bright sunshine (h per day) during vegetative phase (4^{th} to 6^{th} week after sowing) and X_4 – Rainfall (mm) during vegetative phase (5^{th} to 6^{th} week after sowing).