CROP WEATHER RELATIONSHIP IN TOMATO

(*Lycopersicon esculentum* Mill.)

By

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THESIS

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requirements for the degree of

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DECLARATION

I hereby declare that the thesis entitled **Crop weather relationship in tomato (*Lycopersicon esculentum* Mill)'** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title of any other University or Society.

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Certified that the thesis entitled **'Crop weather relationship in tomato (*Lycopersicon esculentum* Mill)'** is a record of research work done independently by **Mr.B. Ajithkumar** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Mr.B.Ajithkumar,** 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 tomato (*Lycopersicon esculentum* Mill)'** may be submitted by Mr.B.Ajithkumar in partial fulfilment of the requirement for the degree.

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Dedicated to my

beloved Parents

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Introduction

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most important vegetable crops grown throughout the world. The fruits are consumed either as raw or cooked or processed.

Tomato is an important 'protective food' because of its nutritive value. It is the world's largest vegetable crop after potato and sweet potato. The main tomato growing countries in the world are U.S.A., Netherlands, China, Italy, Egypt, Turkey and India. The crop is cultivated in 28.76 lakh hectare in the world producing 78 million tonnes. In India, the annual production of tomato is 4.8 million tonnes from an area of 3.2 lakh hectares (FAO, 1996).

The crop does well under an average monthly temperature of 21°C to 23°C but it may be grown commercially at temperatures ranging from 18°C to 27°C. Fruit set in tomato is restricted to a very narrow range of temperature regimes and is affected when the day/night temperatures are 34/20°C (Stevens and Rick, 1986). Temperature and light intensity affect fruit set, pigmentation and nutritive value. The agroecological conditions largely comprising of edaphic and environmental factors can have more than one effect on the performance of tomato crop. There will be severe problems of fruit set and the incidence of viral disease during summer seasons. commercially

Tomato plant is very much influenced by the supply and availability of nutrients. The effect of fertilizers and weather parameters on the growth and yield of tomato are found to vary according to varieties and soil . Growth and yield of the crop can be enhanced without any extra effort on the part of the farmer, by sowing the crop at the right time. As in many crops, optimum time of sowing is a non-monetary input in enhancing the yield of the crop.

The main limitation of tomato cultivation in Kerala is the incidence of bacterial wilt caused by *Ralstonia solanacearum*. The warm humid tropical climate and acidic soil condition of Kerala favour the incidence of bacterial wilt. By the release of "Sakthi" a bacterial wilt resistant variety of tomato, cultivation of the crop has become a reality in Kerala. Crop weather relationship studies in tomato are very few in India and almost nil in Kerala. Hence the present investigation was proposed with the following objectives.

1. To study the effect of weather on the growth and yield of tomato.
2. To study the effect of varying levels of nitrogen on the growth and yield of tomato.
3. To study the effect of date of planting on the growth and yield of tomato.
4. To find out the interaction, if any, between date of planting and varying levels of nitrogen on the growth and yield of tomato.
5. To find out correlation between weather parameters and growth and yield of tomato and to develop regression equation.
6. To generate the "Minimum Data Set" for soil,weather and crop to validate the tomato model developed by International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT).

Review of Literature

REVIEW OF LITERATURE

Over the past few decades, research on crop weather relationships has received considerable attention. Simulating, analysing and assessing crop responses to weather and climate have found an important place in research and operational field assessment. A considerable effort has been made in recent years towards the practical application of crop weather models on a regional scale, to increase agricultural production. A number of publications on specific aspects of weather and climate in relation to crop yields particularly cereals have appeared in recent times. However, not much work has been reported on the crop weather relationship of tomato in the State. The relevant literature available on the effect of weather on growth and yield of tomato are reviewed in this chapter.

2.1 Influence of weather parameter on growth and yield of tomato

2.1.1 Air temperature

In Canada Charles and Harris (1972) found low fruit set in tomato at 10°C and 12.8°C, which was primarily due to poor pollen viability and germination and to a lesser extent to a high stigma position in the antheridial cone. At 26.7°C, stigma height was the main factor reducing fruitset but low stigma receptivity was a factor in some selections. Shvebs and Grudev (1972) revealed that during fruit formation the optimum day and night temperatures were above 16°C and 13°C respectively. In their study at Russia, a relationship between the sum of mean daily temperature and the duration of flowering was observed .

Rudich *et al.* (1977) observed that the higher temperature condition (39°C ± 2°C day and 22°C ± 2°C night) at Israel caused deficient fruitset in tomatoes. The impaired fruitset of Roma VF was found to be associated with pollen viability, style elongation, and lack of formation of the endothecium, which is essential to stamen and pollen thecae opening. Takahashi (1977) in a studiy with the tomato cv. Fukuju No.2, the highest number of flower buds/plant was obtained from plants receiving high NPK and grown at day/night temperature of 22/12°C.

Longvenesse (1978) grew tomtoe cv. Montfavet 63.5 in a glass house with a day temperature of 20°C and night temperature of 15°C or 11°C and he reported that, with the lower night temperature, flowering, fruit development and maturity were later but did not effect the number of flowers and fruits resulting in higher fruit yield.

The best fruitset and development for tomato at Israel were at 22°C day temperature. A high positive correlation (r=0.9) between the number of seeds/fruit and fruit size at a day temperature of 27°C was reported by Rylski (1979). Kuo *et al.* (1979) observed that the differences in the ability to produce viable pollen and ovules and normal stamens, styles and hormonal activity under high temperature accounted for differences in fruit setting ability under high temperature in the heat-tolerant and heat-sensitive cultivars tested.

Papadopoulos and Tiessen (1983) reported that a low greenhouse air temperature of 19°C (day)/14°C (night) during the autumn, caused no reduction in yield when compared with the standard 22°C/17°C. An air temperature of 13°C/08°C during the spring markedly reduced yield compared with 19°C/14°C. Flowering of Ohio MR-13 in growth chambers was delayed significantly at 24°C/08°C compared with 24°C/17°C but the flowering of Vendor was unaffected. Marketable yield of Vendor was significantly higher at 24°C/08°C than at 24°C/17°C while that of Ohio MR-13 was unaffected. At a constant day air temperature of 24°C, the amount of small fruits decreased as night air temperature was lowered from 14°C to 08°C.

Khayat *et al.* (1985) opined that the fruit production in the cv. Moneymaker was not reduced by interruption of the optimal night temperature regime (18°C) by short intervals (2 h) of lower temperature. The same treatment increased the yield on the cv. Cherry by 82 per cent compared with a constant night temperature of 18°C. The yield increase in this cultivar was due to a larger number of fruits per plant.

Alberton and Rudich (1986) reported that the development of the root system differ among tomato cultivars and the day temperature of 26.5°C and night temperature 16-22°C resulted in the heavier root system.

In an experiment with four cultivars Precodor, Vemone and Marmande Raf, Noto and Malfa (1986) observed that the shortest number of days from sowing to flowering was noted in plants treated with the lowest temperature and exposed to it for the longest time.

In another experiment by Cholette and Lord (1989) the seeds of the cv. Carmello was sown on 16 January and the plants were grown under night temperatures of 17°C, 12°C or 7°C for 2 months after the 6th leaf had expanded and the first cluster was visible (eg. 24 February to 15 April). Total and marketable yields were significantly higher on Nutrient Film Technique (NFT) than in soils, but there was no advantage for the early yield. The date on which half of the flowers of the first cluster opened was 2 weeks earlier for the 17°C treatment than for the 7°C treatment indicating that low night temperature reduced the rate of development.

Heuvelink (1989) found that an increased temperature regime reduced plant growth and development, number of leaves and number of trusses. Growth reduction was caused by a lowering in leaf area ratio (LAR). The decrease in LAR at an inversed temperature regime was caused mainly by a decrease in specific leaf area (SLA). For young, widely spaced plants a lower SLA (thicker leaves) results in less light interception and thus in growth reduction.

Rao *et al.* (1992) studied the rate of net photosynthesis, growth and dry matter(DM) production in tomato cultivars IIHR 1224 and Arka Saurabh that had been grown in the chambers at day/night temperatures of 35°C/20°C and 35°C/27°C. Measurements were began when plants were 30 days old. Significant cultivar differences were observed at both temperatures. Photosynthesis was lower in both cultivars at a night temperature of 27°C. Leaf area and total DM for IIHR 1224 were lower with a night temperature of 27°C. When plants were prehardened by exposure to 40°C for 2 h during the night period at the 3-leaf stage, plants of IIHR 1224 receiving 35°C/27° treatment had a higher relative growth rate and net assimilation rate than those receiving 35°C/20°C.

Ercan *et al.* (1994) studied the effect of low temperature on fruitset and yield of the tomato cultivars Dario F_1 and Amfora F_1 and established that low temperatures reduced the pollen count and thus reduced fruit set and yield. The minimum temperature below which pollen degeneration in the flower began was 5°C for Amphura and 10°C for Dario.

Wang-XiaoXuan (1996) conducted experiment on 6 tomato cultivars at China and found that germination of seeds and pollen, pollen tube growth, growth of the hypocotyledonary axis and fruit set decreased with decreasing temperatures. Under temperatures of 8°C and 12°C, all the above parameters showed a positive correlation with the cold tolerance of the cultivars. Under low temperature in the field, plant growth, flowering, fruiting, pollination and fertilization were inhibited to different degrees and cold tolerant cultivars performing better than cold sensitive ones.

2.1.2 Soil temperature

Abdelhafeez (1971) reported that growth of tomato plants was reduced at soil temperature below 20°C and air temperature of 17°C.

Saito and Ito (1971a) found that exposure of the plants at 9°C for 20 days produced fascinated flowers which might be due to the surplus nutrient supply to the young flower buds just on pre or post differential stage. They remarked that at low temperature vegetative growth is restricted which is due to the supply of more nutrients for flower development. Saito and Ito (1971b) studied the combined effects of low temperature and nutritional conditions and found that poorly manured flowers showed slow growth.

Hisatomi (1972) found that an increase in leaf area and stem thickness were markedly enhanced by the higher soil temperature. Fruit number per unit area and total yield, however, were greater at lower soil temperatures. The adverse effect of high temperature on the yield of winter crop flowering during December to February was due to the excessive vegetative growth produced.

In a study in tomato cultivar Extase grown in containers and soil kept at constant temperatures of 15°C, 20°C, 25°C, 30°C and 35°C, Stanev and Angelov (1978) reported that a reduction of soil temperature from 30°C to 15°C decreased the leaf area by 50 to 70 per cent and an increase in soil temperature to 35°C decreased it by 20 to 40 per cent. Net phosynthetic productivity was the highest at 15°C, the peak at 25-30°C and decreased by 60-70 per cent at 50°C and by 22 to 38 per cent at 35°C.

2.1.3 Light intensity

Nagaoka *et al.* (1979) observed that higher light intensities increased the number of leaves, total leaf area and plant dry weight. Plants grown in lower light intensities were taller with thinner stems particularly at higher night temperatures. Time of flowering and fruit maturation were earlier for higher night temperature, but lower night temperatures increased fruit set (%) when combined with high light intensity.

Picken (1984) stated that poor fruit set in the low light conditions of winter and early spring is caused probably more frequently by failure of pollen production or pollination than by failure of pollen germination, pollen tube growth, ovule production, fertilization and fruit swelling, etc.

Rylski *et al.* (1994) discussed the effects of environmental factors on tomato flower and fruit development. These crops are best suited to a mild stable climate with high solar radiation. The mediterranean climate fits these criteria during the spring and autumn, but in the winter, the temperature and light are sub optimal. The winter conditions can seriously affect the flowering, with malformed ovaries and flower being formed and nonviable pollen produced. In tomato, low temperature prevents pollination and reduces fruit set and in combination with low light, the fruits can be puffy and suffer blotchy ripening.. The reducing sugar content of the tomato fruits is also lower,makaing them less palatable.

2.1.4 Wind velocity

Kalloo (1986) reported that efficient pollination is affected by environmental factors like temperature, humidity and wind velocity. He stated that wind velocity reduces the efficiency of fruit set. The receptivity of the stigma and the nutritional status of the plants are some of the other factors.

2.2 Effect of planting date on growth and yield of tomato

Tongova and Zhelev (1975) reported that tomato cv. Moneymaker was sown on 20 September, 10 October or 1 November and seedlings from each sowing were planted out at the 4-5 leaf or 1st flower truss stage. Both early sowing and early planting increased yields. The highest early and total yields were produced by plants sown on 20 September and transplanted at the 4-5 leaf stage.

Kumanov and Kovachev (1976) conducted the experiment on the determinate tomato cv. Hebrus, which was sown on 15 or 30 March or 20 April and found that sowing on 20 April produced the lowest yield. A direct correlation was found between fruit drymatter content and mean daily temperature during ripening.

Belichki (1977) observed that Pioneer 2 gave the highest yield in Bulgaria during 1972-74, except with the earlier sowing date (25 May), when Khebros gave the best yield.

Trials conducted over several years in Gojvoclina north east Yugoslavia (Popovic, 1977) with the tomato cvs. New Yorker, VF-145-21-4, Heinz 1370 and Roma VF sown in the field in early to mid April, mid to late April, early to mid May or mid to late May and grown once-over harvesting. In general, mid April was the optimum time for sowing. The mid April sown crop produced high net yields and marketable yields which were decreased progressively with delayed sowing.

El-Shevbini *et al.* (1982) used seeds of four tomato cultivars sown in seed beds on 12 dates between first Jaunary and first December and found that the best results with regard to fruit and seed yields were obtained with January sowing. Sowing in January, the cultivars Pritehard, Ace, Moneymaker and Pearl Harbour gave 109.6, 152.8, 28.6 and 21.9 per cent more seed yield respectively, than the February sown plants.

The studies conducted at Coimbatore (Muthukrishnan *et al.*, 1982) on the performance of tomato cultivars at different periods of planting revealed that wide variations in yield were recorded in tomato among the different months of planting.

The variations were attributed to weather conditions prevailed during different growth periods. The months of May, June, July and November are ideal for planting to get more yield.

In a study with seeds of several tomato cvs. were sown directly in the field and in nursery on 4 dates between 15 December and 1st February, Ravikumar *et al.* (1983), observed that nutrient uptake increased with delay in the sowing date and it was higher in direct sown plants.

Seeds of four tomato cultivars were sown directly in the field and in the nursery on four dates between December and February. The nursery raised plants were later transplanted in the field. Although direct sown plants flowered 9-10 days earlier than the transplants, the two method had no appreciable effect on fruit size and weight, the number of fruits per plant and mean yield per plant. Estimated per hectare yield decreased with the delay in sowing dates (Ravikumar and Shanmugavelu, 1983).

Lipuri and Paratore (1986) conducted experimets on the seeds of the tomato cv. Vemone which were sown on 20 November, 20 December or 20 January and the seedlings were transplanted at 60, 90 or 120 days after sowing. They observed that the highest yields were obtained by sowing and transplanting earlier. Delayed sowing from 20 December to 20 January reduced the yield.

Rao (1986) conducted an when experiment on five tomato cultivars (Sel-4, Sel-22, Pusa Raly, Sioux and Roma) and were planted in February, July and November to provide summer, rainy and winter cultural condition, respectively. During February and July planting there was 30-42 per cent flower and fruit drop, coinciding with high temperature and rainfall during flowering and fruiting. Yields were reduced by 29 and 35 per cent in February and July plantings, respectivley, compared with November planting.

The studies conducted at Ludhiana (Saimbi and Gill, 1988) on the performance of tomatoes at different periods of planting revealed wide variations in yield and the highest yield per hectare was recorded in December planting followed by January planting. But transplanting done in February and March decreased the yield by more than 50 per cent over December planting.

Vadivelu and Srimathi (1986) reported that the tomato crop raised in May-June season produced maximum quantity of good quality seed. Rajan (1989) found that October planting of tomato was the best in getting higher yield under Vellanikkara conditions.

Reddy *et al.* (1989) sown 35 tomato genotypes on 3 and 23 March and observed that the performance of all the varieties sown on 23 March date was poor due to high temperature during the development.

In experiments on ostemo sandy loam (Drust and Price, 1991), tomato cv. VC 82 seedlings were planted on 7 or 19 May or 2 June on conventionally tilled plots following rye, or on untilled plots into a rye or wheat mulch. Results showed that tillage system had no effect on plant height. Planting on 2 June led to fewer trusses than planting on 7 May. Later planting reduced the yields of ripe fruits but increased individual fruit weight compared with earlier planting dates. Kadam *et al.* (1991) observed in an experiment on thirty day old tomato seedlings (cv. Pusa Ruby) transplanted on 15 November, 15 December 1986, 14 January, 13 February or 15 March, 1987. Samples were collected at 60, 80 and 100 days after transplanting for assessment of drymatter accumulation and distribution. Highest dry weight of fruits and total dry weight per plant at all crop growth stages were obtained with transplanting on 15th November. He also observed that yields were highest for the first planting date, decreased with delay in planting. Staking resulted in a 34 per cent increase in yield over no staking. Fruit size declined as planting was delayed and fruits were larger when plants were staked.

Pardossi *et al.* (1992) grown tomato cv. Candela with Nutrient Film Technique (NFT) during the autumn or spring season of a mediterranean climate in a cold green house. In the spring crop, better climatic conditions induced abundant fruit set and this was inturn responsible for the higher rates of growth and macronutrient uptake in comparison with the autumn crop. The macronutrient contents of leaves, axillary shoots and fruits were lower in spring than in autumn plants.

Vadivel and Arumugam (1993) sown tomato seeds at (cultivars PKM-1 and CO-3) bimonthly intervals from December 1990 to October 1991. In CO-3, the highest seed yields as well as fruit yields were obtained from the June and December sowing. While the lowest was obtained from the April sowing date. In PKM-1, fruit yields were highest for the June sowing date but seed yield were highest for the December.

Sam and Iglesias (1994) sown the seeds of 4 tomato cultivars-Campbell-28, HC-78-80, INCA 3(a) and INCA 17 on 11 January (optimum sowing date) or 11 May. The period of bud emergence and flower opening began earlier and lasted longer for the second sowing date than for the optimum one. The maximum number of fruits per plant (on the first 3 racemes) was greater in the optimum season than the later season for all 4 cultivars.

Singh and Tripathy (1995) observed the growth and yields of four cultivars (Pusa Ruby, LE-79, BT_1 and Arka Alok) of tomato and showed that significant genotypic variation for vegetative growth, fruit characters and yield when sown on different dates (20 June, 5 and 20 July and 5 and 20 August). Line LE 79 gave the highest fruit yield (12.2 t/ha) and Arka Alok produced significantly larger (20.3 cm) and heaviest fruits (136.7 g). Sowing on 20 June was significantly favourable for plant height, branches per plant, compound leaves per plant and fruit yield as well as its contributing characters like fruit weight, length and girth.

2.3 Effect of fertilizers on the growth and yield of tomato

2.3.1 Nitrogen

Hisatomi (1972) found that greater Nitrogen supply promote the vegetative growth. Fruit number/unit area and total yield were greater with high N supply. Average individual fruit weights was increased by low temperature and high N. Locascio and Roa (1972) carried out NPK trials on summer and winter tomato crops.They found that in tomato crops the total yields increased from 2 to 3.6 t/acre with an increase in applied N from 40 to 80 or 160 lb/acre. In the winter crop yields were 5.7, 7.4 and 13.1 ton/acre, respectively, with these 3 Nitrogen levels. Fruit size increased with increasing N in both seasons.

From the studies on the effects of nitrogen, potassium and sub irrigation on yield and quality of single truss tomato. Adams *et al.* (1973) found that plant height and leaf length increased markedly with N concentration, as also did the number of flowers and unmarketable fruits per plant, the mean weight per fruit and the total yield. Low N levels delayed the harvesting.

A nutritional and spacing trial with tomato cv. Pusy Ruby grown in light soil from December to March showed that the best results were obtained with NPK at 80-60-40 kg/ha and higher rates led to a lower yield (Sulkeri *et al.*, 1975).

Kuskal (1977), from his experiment with different levels of nitrogen and phosphorus on fruit and seed yield of tomato cv. Chaubattia Red reported that plant height, fruit and seed yields were enhanced by N at the higher application rates. P either alone or with N hastened maturity and increased early yields.

Rastogi *et al.* (1978) in trials with the tomato cv. Solan Gola found that 60 kg N/ha rate is considered adequate for tomatoes grown in soil of average fertility. Sharma *et al.* (1978) found that tomato (cv. Angoorlata) yield rose with N and P rates, being highest (3.025 kg/plant) at 60:80 kg/ha.

Praseeda and Sulladmath (1979) found that the hybrid tomato Karnataka gave the highest yield/plant and yield/ha and average fruit weight with N at 230 or 345 kg/ha.

Byari (1981) tested the effect of nitrogen on tomatoes at different temperature and relative humidity levels and found that fruit number, size, cluster number and flower number were increased at high levels of nitrogen.

Varis and George (1985) found that the high N-level increased flower number, fruit and seed yields and gave early flowering and ripening. The results showed that the most favourable combination for high fruit and seed yield, percentage of fruit setting and a high seed weight was N 100, P 243.6 g, K 2166 g/m^2.

Ahmed and Saha (1986) opined that, all the tomato cultivars (Bikash, Tushti, Roma V.I. and Asha-4) gave the highest yield at the highest NPK rate.

Martinez and Cerda (1987) in an experiment of the effect of nitrogen fertilization under saline conditions on tomato observed that with increasing N rates from 5 to 20 mM increased leaf, stem and root DM by 61, 25 and 55 per cent, respectively and also found that N rate of 5 mM was sufficient for maximum yield at low salinity.

Dimri and Gulshanlal (1988) got the highest fruit yield and the best quality on raised beds receiving the highest N rate.

In a trial with cvs. Pusa Baby and NTDR-1 at different spacing (75 x 60, 90 x 50, 75 x 50 or 90 x 41.6 cm) and under different levels of nitrogen (60, 120 or 180 kg/ha), Srinivasa *et al.* (1988) showed that the highest yield in both cultivars were obtained from plants spaced at 90 x 50 cm and receiving 120 kg N/ha.

Begal *et al.* (1989) conducted an experiment on tomato cv. Pusa Ruby and observed that application of increasing rates of N, P and K fertilizers significantly increased the yield, juice content and juice TSS. The optimum fertilizer combination was 200 kg N, 100 kg P_2O_5 and 100 kg K_2O/ha which gave the highest yield of 309 q/ha and good quality fruits.

Huett (1989) observed that tomato yields responded to N application which plateaued at the two highest N levels (10 and 32 mmol/litre). For tomatoes, high N levels produced the firmest fruits with the highest TSS and dry matter contents.

Suniaga-quijada (1990) studied the initial growth of tomato seedlings on various conditions of nitrogen availability. Earlymech (UC 82), which was seeded in pots were daily watered with four nutrient solutions as treatments, a complete blanced one (N), a nitrogen poor one (N/3), a nitrogen rich one (3 N) and a complete one except nitrogen (0N). Plant growth and development were quantified from emergence till the beginning of fruit set. Until emergence tomato didn't need external N, and the supply from seed being enough. At the first 2 true leaves appearance an effect of nitrogen was observed. On and after the 3rd leaf appearance growth rate and N requirements increased. At the beginning of flowering, treatments 3N, N and 0N soil gave far better results than N deficient treatments. 3N rate supply surpassing plant requirements dramatically reduced root growth and increased shoot growth with numerous small trusses which mostly aborted. 0N soil treatment gave a shoot growth and development very similar to 3N rate until early flower set. Then it was behaved more like N/3, and N supply would have been necessary in order to satisfy plant requirements.

Root growth of transplanted tomatoes in the field was directly related to N level supplied to the transplants as seedlings in the green house. Root growth in the field increased exponentially when N was applied at 50 to 350 mg $liter^{-1}$.

Strength of the seedling stem increased with N level curvilinearly.(Lipay and Nicholas,1993).

On the basis of the experiment conducted on the tomato cv. Pusa Ruby under different N (100 or 150 kg N/ha), P (0, 50 or 100 kg P_2O_5/ha) and K (0, 50, 100 or 150 kg K_2O/ha), Pansare *et al.* (1994) reported that yield were highest with a 3:1:3 NPK ratio while TSS was highest with 3:1:2 ratio.

Nwadukwe and Chude (1995), after conducting an experiment on the effect of different irrigation frequencies (5, 7 and 9 day intervals) and N rates (0, 50, 100 and 150 kg N/ha) on the tomato cv. Roma VFN during 3 growing season reported that fruit yield and water use efficiency were highest with 100 and 150 kg N/ha and irrigation at 7 day intervals.

In trials conducted on a sandy loam soil during the spring-summer seasons and the autum-winter season, Baruha *et al.* (1995) treated plants of tomato cv., Pusa Ruby with aqueous solution of 0, 100 or 150 ppm paclobutrazol at 20 and 40 days after planting. Plots also received N at 0, 30, 60, 90, 120 or 180 kg/ha.They demonstrated that plant height increased with increasing rate of N and decreased with increasing rate of paclobutrazol. Flowering was earliest and fruit set was highest with highest rates of N and paclobutrazol application.

In a pot culture study with varying levels of N over a common dose of P, K and Mg to tomato cultivars *Beta* 11 and *Kujawski*, Morrzeckha (1995) found that N rate had no significant effect on yield which ranged from 1.57 kg per plant in *Beta* 11 and from 2.40 to 2.46 in *Kujawski*. In Himachal Pradesh, Sharma (1995) conducted the experiment on the effects of N (30, 60, 90 or 120 kg/ha), P (30 or 60 kg P_2O_5 /ha) and K (30 or 60 kg K_2O/ha) on seed production by tomato (cv. Solan Gola) and found that plant height, fruit number, seed yield/plant and seed yield/ha increased with increasing rates of N and P.

Suresh *et al.* (1995) conducted the experiment on two tomato cultivars Hisar Lalima (Sel-18), Hisar Aron (Sel-7), Sel-30, Antey, Ace, Walter and Flora-dade under optimum and high nitrogen fertilization (100 and 150 kg/ha respectively) at Hisar during 1989-91.They showed that at both fertility levels Hisar Lalima followed by Flora-dade produced large sized fruits and recorded the highest yields and was stated best overall among the varieties tested during the years.

Ragab (1996) conducted the experiment on the effects of 0, 48, 80 or 112 mg S/kg in combination with 0, 80 or 200 mg N/kg on yield of tomato cv. Balca 7 The experiment was conducted on the sandy soil (pH 7.85) in plastic tunnels. He concluded that sulphur had a positive effect on yield and also intracted positively with Nitrogen. Nitrogen had a linear effect of yield.

2.3.2 Nitrogen and Air temperature

Watanabe *et al.* (1977) found that with high NPK seedling growth and flower bud differentiation were promoted by 22/12°C day and night temperatures and with low NPK by 29/19°C. With high NPK, the development of flower buds was earliest with 29/19°C day and night temperatures but the number of flower buds/plant was highest at 22/12°C day-night temperatures.

Byari (1981) tested the effect of Nitrogen on tomato at different temperatures and relative humidity levels and found that fruit yield was increased under both low humidity and high and low temperature regimes. High humidity reduced yield by an estimated 31 per cent and induced fruit cracking and dullness of fruit surface. Yield of tomatoes was greater at 28-35°C than at 18.3-23.8°C.

2.4 Models related to tomato

Kurata and Takakura (1991) developed a numerical simulation model on the performance of solar energy, storage systems which utilise the soil layer under a greenhouse as a thermal storage medium.They investigated several modes of system operation, including seasonal and daily storages and in almost every case it showed seasonal storage operation mode did not give a positive net energy savings.But on the other hand, daily storage modes always gave positive net energy savings.

A highly modular structure was developed by Hodges *et al.* (1992) for crop growth simulation models and implemented in the SIMPOTATO model based on the standards of the IBSNAT project.

Tijsken (1993) developed a Mathematical model which describes changes in tomato fruit colour at different temperatures during storage and at different stages of harvest maturity. The mathematical description used in the model is logistic (Sigmoid) function with a correlation for the biological age of the fruit.

Heuvelink and Bertin (1994) discussed the strong and weak points of two dynamic model TOMSIM (1.0) and TOMGROW (1.0). In both models the simulated drymatter distribution is regulated by the relative sink strengths of the plant organs.

Heuvelink (1996) validated a model for dynamic simulation of dry matter distribution between reproductive and vegetative plant parts and the distribution among individual fruit trusses in glasshouse tomato. This model is part of the crop growth model TOMSIM and is based on the hypothesis that drymatter distribution is regulated by the sink strengths of the plant organs, quantified by their potential growth rates i.e., the growth at non-limiting assimilate supply.

Pachepsky *et al.* (1996) proposed models for photosynthesis. The models were the rectangular hyperbola, Furguhar's model and Harley's interpretation of Furguhar's model. The models were fitted to experimental data for tomato cv. Rutgens Large Red plants by an optimization procedure. The data set consisted of leaf light response curve measured at 18°C, 25°C and 32°C and CO_2 concentration of 100, 300, 700 and 1000 ppm. They have also quoted that the two interpretations of Farquhar's model were quantitatively and qualitatively adequate and can be used for research purpose. With the same variety, Pachepsky and Acock (1996) reported that light utilization efficiency proved to be constant at ambient and elevated CO_2 concentration. Leaf conductance for CO_2 transfer depends on temperature as well as CO_2 concentration. The two other parameters connected with re$piration and Farquhar's curvature factor were linearly dependent on temperature.

Materials and Methods

MATERIALS AND METHODS

Investigations were carried out in the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara during 1996-1998 to study the crop weather relationship in tomato (*Lycoperiscon esculentum* Mill).

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 Crop variety

The bacterial wilt resistant of tomato variety (Sakthi) developed in the Department of Olericulture, College of Horticulture, Vellanikkara and released for the state level was used for the study.

3.1.2 Site and climate

The experimental site was located at 10°31'N latitude and 76°13'E longitude at an elevation of 22.25 m above mean sea level in the central zone of Kerala. The area enjoys a typical warm humid tropical climate.

3.1.3 Soil characteristics

The soil of the experimental site belongs to the textural class sandy clay loam. Physico-chemical properties of the soil are presented in Table 1.

3.2 Methods

3.2.1 Layout

The field experiment was laid out in a split plot design and replicated thrice. There were 54 plots in the field. The subplot size was 4.2 x 4.2 m^2 and each

Table 1. Physicochemical properties of the experimental site

Fraction	Content	Procedure adopted
1. Mechanical composition		
Coarse sand	26.00%	Robinson international pipette method
Fine sand	23.10%	
Clay	29.70%	
Silt	21.20%	
Textural class	Sandy clay loam	I.S.S.S. System
2. Physical constants of the soil		
Field capacity(0.3 bars)	17.9%	Pressure plate apparatus
Permanent writing point(15 bars)	13.2%	,,
Bulk density(g cm^{-3})	1.07	Core method
Particle density(g cm^{-3})	2.05	Pycnometer method
3. Chemical properties		
Available Nitrogen (kg / ha)	222	Alkaline Permanganate method
Available Phosphorus (kg / ha)	40	Chlorostannous reduced molybdo phospheric blue colour method in hydrochloric acid system
Available Potassium (kg / ha)	14	Flame phometry, neutral normal ammonium acetate extraction
Soil reaction (pH) 1:2.5 soil:water ratio	5.2	pH meter
Organic carbon	0.55	Walkley and Black rapid titration method
Electrical conductivity (1:2.5 soil:water ratio) (mmhos/cm^3)	0.54	Soil water suspension

Replication									
R_3	T_2N_2	T_8N_2	T_1N_1	T_3N_1	T_4N_1	T_9N_2	T_7N_1	T_5N_1	T_6N_2
	T_2N_1	T_8N_1	T_1N_2	T_3N_2	T_4N_2	T_9N_1	T_7N_2	T_5N_2	T_6N_1
R_2	T_9N_2	T_8N_1	T_5N_1	T_7N_1	T_6N_1	T_1N_2	T_4N_2	T_2N_1	T_3N_1
	T_9N_1	T_8N_2	T_5N_2	T_7N_2	T_6N_2	T_1N_1	T_4N_1	T_2N_2	T_3N_2
R_1	T_3N_1	T_7N_2	T_6N_2	T_4N_2	T_2N_1	T_5N_2	T_9N_1	T_1N_1	T_8N_2
	T_3N_2	T_7N_1	T_6N_1	T_4N_1	T_2N_2	T_5N_1	T_9N_2	T_1N_2	T_8N_1

TREATMENTS

Date of planting (15th of every month)

T_1 June 1997
T_2 July 1997
T_3 August 1997
T_4 September 1997
T_5 October 1997
T_6 November 1997
T_7 December 1997
T_8 January 1998
T_9 February 1998

Nitrogen levels

N_1 - 75 kg/ha
N_2 - 125 kg/ha
Plot size - 4.2 x 4.2m

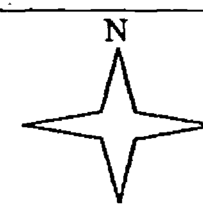


Fig.1 Layout of the experiment

accommodating fourty nine plants. The layout of the experimental field is given in Fig.2. The main plot treatments consisted of nine planting dates at monthly intervals starting from 15th June 1997 to 15th February 1998. The sub plot treatments consisted of two levels of nitrogen (75 and 125 kg N ha^{-1}). The details of plot size used for the experiment along with the notations used to represent the treatments are given below:

A. Main plot treatments	: 9
B. Number of subplots	: 2
Total number of treatments	: 18
Replication	: 3
Plot size	
Subplot	: 4.2 x 4.2 m
Spacing	: 60 x 60 cm
Number of plants in subplot	: 49
Number of plants in net plot	: 25
Net plot size	: 3.0 x 3.0 m^2

Main plot treatments

Date of planting	Notations
15th Jun 1997	T_1
15th Jul 1997	T_2
15th Aug 1997	T_3
15th Sep 1997	T_4
15th Oct 1997	T_5
15th Nov 1997	T_6
15th Dec 1997	T_7
15th Jan 1998	T_8
15th Feb 1998	T_9

Sub plot treatments

Two levels of nitrogen as	Notation
75 kg/ha	N_1
125 kg/ha	N_2

All the treatments received P_2O_5 and K_2O @ 40 and 25 kg/ha, respectively as per the package of Practices Recommendations Crops 1996 of the Kerala Agricultural University. There were eighteen treatment combination as listed below.

Treatment combinations

$T_1 N_1$	$T_4 N_1$	$T_7 N_1$
$T_1 N_2$	$T_4 N_2$	$T_7 N_2$
$T_2 N_1$	$T_5 N_1$	$T_8 N_1$
$T_2 N_2$	$T_5 N_2$	$T_8 N_2$
$T_3 N_1$	$T_6 N_1$	$T_9 N_1$
$T_3 N_2$	$T_6 N_2$	$T_9 N_2$

3.3 Cultural operations

The seedlings were raised in the nursery as described below:

3.3.1. Nursery

The nursery bed was prepared by mixing sand, soil and farm yard manure in the ratio 1:1:1 which was sterilised by fumigating for 10-15 days prior to sowing using formaldehyde (0.5%). This may reduce the mortality of seedlings in the nursery. Adequate moisture, drainage and plant protection measures as and when necessary were provided in the nursery so as to produce healthy seedlings and one month old seedling were sown used for transplanting in the mainfield.

3.3.2 Preparation of main field

The experimental field was cleared off all the stubbles and weeds. Plots were prepared as per the layout.

3.3.3 Manures of fertilizers and their application

Farm yard manure was applied to the experimental plots @ 25 t ha^{-1} at the time of land preparation uniformly to all plots as basal dose. Urea, factomphos and muriate of potash were used as fertilizers to supply nitrogen, phosphorus and potassium respectively as per the treatment.

The application of fertilizers were carried out as follows:

Half of nitrogen, whole of phosphorus and half of potash were applied as basal dose first before transplanting, one fourth of nitrogen and half of potash was applied 30 days after transplanting. The remaining one fourth of N applied 30 days later.

3.3.4 Transplanting

Ridges and furrows were prepared at 60 cm apart in the field and one month old healthy vigorous seedlings were used for transplanting in the main field. The seedlings were planted on ridges during wet months and in the furrows during dry months at a spacing of 60 x 60 cm. To avoid any injury to the root system of the plant, the nursery beds were irrigated one day prior to pulling out of the seedlings. The plot were also irrigated immediately after transplanting. During dry months the transplanted seedlings were provided shade using green leaves. Gap filling was done within one week of transplanting, using the seedlings of equal maturity.

3.3.5 After cultivation

Two intercultural operations were carried out to control weeds. Plant protection measures were followed as per requirement so as to ensure a healthy crop stand.

Earthing up was done after the application of fertilizers. During non-rainy periods, irrigation was given on alternate days. Individual plants were provided with a support to keep erect and to facilitates cultural operations and for precise data collection.

3.3.6 Harvesting

Fruits were harvested at ripe stages as indicated by colour change from green to red. Fruits from the inner twenty five plants (net plot) were collected for the data collection.

3.4 Observations

Plant height, flowering characters and fruit characters were recorded from net plots.

3.4.1 Plant height (cm)

Plant height was measured at fortnightly intervals starting 15 days of transplanting onwards. This was measured from the base of the plant to the tip of the terminal bud of longest branch in centimetre and expressed as the plant height.

3.4.2 Days to first flower emergence

Days to first flower emergence after transplanting recorded for each treatment and the mean was worked out.

3.4.3 Days to 50 per cent flowering

By fifty per cent flowering it was mean that the day on which 50 per cent of the plants in the treatments bear flowers. This was recorded for each treatment and the number of days required for the event was worked out from transplanting.

3.4.4 Time taken for first fruit set

The day on which the first fruit appeared was recorded and the time taken for first fruit set in each treatment was worked out.

3.4.5 Days to first harvest

Days to first harvest from transplanting for each treatment were recorded and the mean worked out.

3.4.6 Days to last harvest

Days to last harvest from transplanting for each treatment were recorded and the mean worked out.

3.4.7 Number of fruits per plant

The total number of fruits per plant was counted for all the plants and the mean number worked out.

3.4.8 Fruit yield per plant

Fruit yield per plant was calculated by adding yields of individual harvest and expressed in grams.

3.4.9 Mean fruit weight

Average weight of a fruit in a treatment was worked out from the total fruit yield per plant and the number of fruits produced by the plant.

3.5 Meteorological observations

The meterological data were collected from the Agromet Observatory of the College of Horticulture, Vellanikkara. The daily data on the maximum temperature, minimum temperature, sun shine hours, rainfall, relative humidity, wind speed and evaporation were recorded for the period of investigation. The details of the meteorological observations for this period are presented in Appendix-1.

3.6 Statistical analysis

The data recorded on growth and yield characters were statistically analysed by applying the analysis of variance techniques for split plot design (Panse and Sukhatme, 1985). Simple correlations were computed between the growth and the yield character with the weekly mean values of maximum temperature, minimum temperature, relativehumidity during morning and afternoon and hours of bright sunshine to determine the effect of weather elements on the growth and yield of tomato. Regression equations were worked out from these observations.

3.7 Validating IBSNAT model

For validating the IBSNAT model, thermal days for various phenological events were worked out for the October planting.

A thermal day or degree day or a heat unit, is the departure from the mean daily temperature above the minimum threshold temperature.

Thermal days for each phenological events was worked from the following:

$$\text{Thermal day} = \sum_{i=1}^{n} \left[\frac{T\,max + T\,min}{2} - T\,base \right]$$

T max = Maximum temperature of the day (°C)
T min = Minimum temperature of the day (°C)
$\sum_{i=1}^{n}$ = Summation for day 1 to day 'n' within which the event occurred.

Results

RESULTS

For the studies on the crop weather relationship in tomato data on various morphological, phenological and yield characters of the crop and the weather parameters recorded during the crop period were recorded. The data collected were subjected to statistical analysis and the results are presented below.

4.1 Weather conditions during the crop period

The total duration of the crop for the different planting times was about four months. The experiment consisted of planting the crop at monthly intervals starting from 15th June 1997 to 15th February 1998. The data on the weather conditions during this period are given in the Appendix-1 presented in Fig.2.

4.2 Plant height

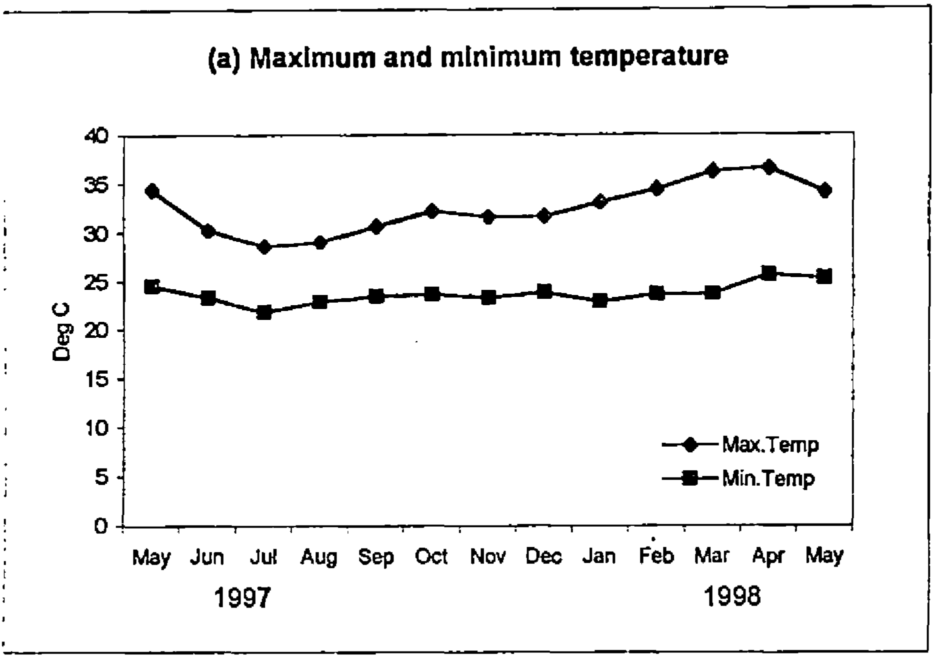
The mean height of the plant at 15, 30, 45 and 60 day stage are given in Table 2 and Fig.3. It could be seen that the date of planting had a significant influence on plant height at all thes stages in tomato.

The different levels of nitrogen did not influence the plant height of tomato. So also the combined effect of planting time x Nitrogen levels.

4.2.1 At 15 days after planting

The December planted crop was taller (28.3 cm) than September planted one, which in turn were statistically similar. July planted ones were the shortest (12.3 cm). November planted crop was also statistically similar in plant height to that of June planted crop.

Fig.2. Weather during the crop growth period



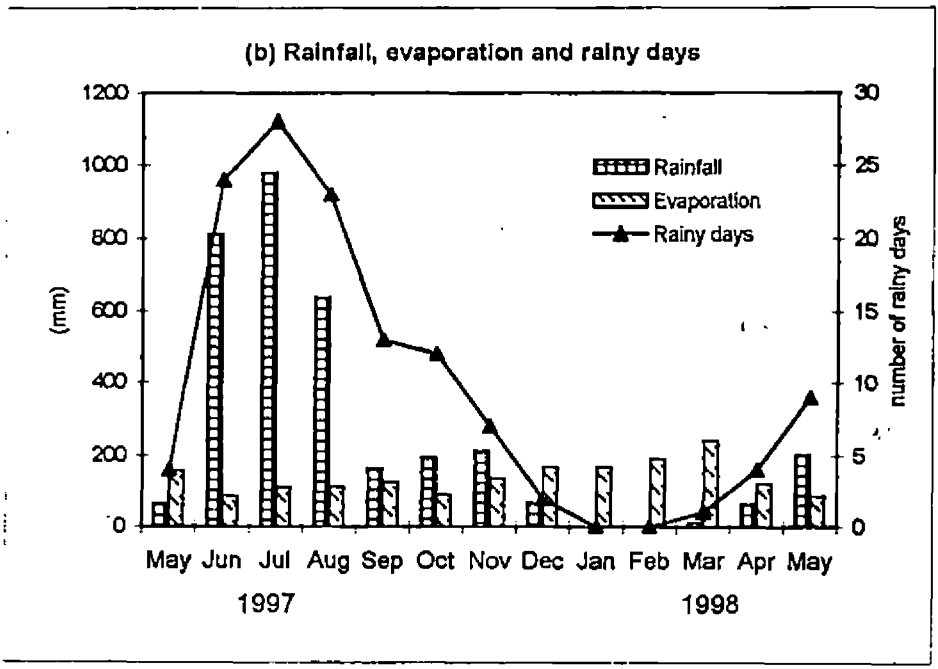
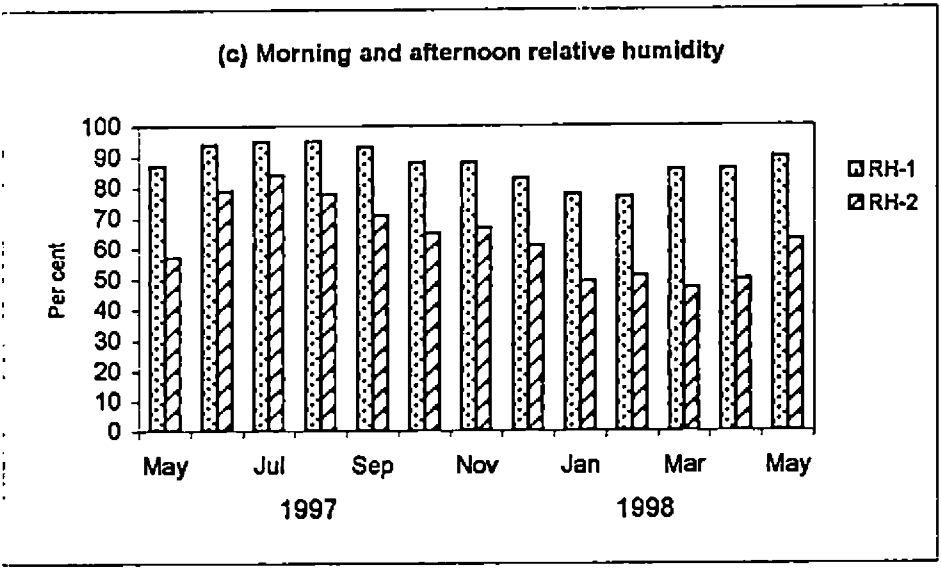


Fig.2. Weather during the crop growth period (contd.)



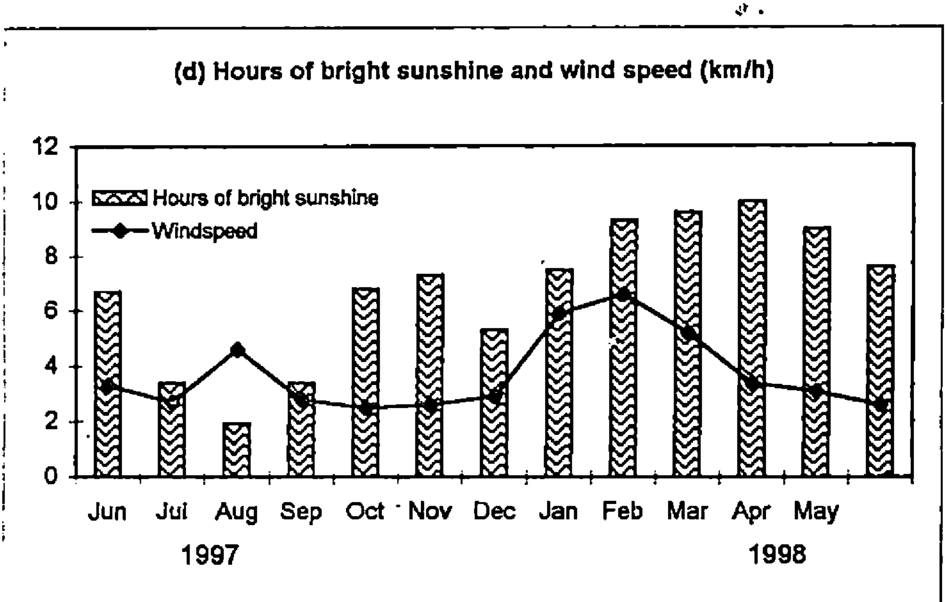


Table 2. Effect of planting date and nitrogen application on plant height (cm) of tomato

Date of planting	Days after transplanting			
	15	30	45	60
1. 15th Jun 1997	13.3	44.0	63.0	63.7
2. 15th Jul 1997	12.3	24.8	37.0	48.0
3. 15th Aug 1997	15.8	45.0	54.5	63.8
4. 15th Sep 1997	26.3	38.2	48.8	55.7
5. 15th Oct 1997	16.8	29.0	40.2	50.8
6. 15th Nov 1997	13.2	33.8	43.3	49.7
7. 15th Dec 1997	28.3	56.3	57.5	59.2
8. 15th Jan 1998	18.2	35.7	45.2	52.5
9. 15th Feb 1998	20.5	40.5	49.2	53.6
SEm±	0.89	1.58	2.05	2.20
CD(0.05)	2.68	4.74	7.52	6.61
Nitrogen (kg/ha)				
1. 75	18.7	38.1	48.5	54.3
2. 125	17.9	39.0	49.0	56.1
SEm±	0.45	0.99	0.98	1.16
CD(0.05)	NS	NS	NS	NS
Planting time x Nitrogen level	NS	NS	NS	NS

NS - Not significant

4.2.2 At 30 days after planting

At 30 days of planting, the tallest plants were observed in the case of December planted crop (56.3 cm) which was significantly superior to that of the other planting dates. This was followed by August and June treatments. February planting resulted in shorter plants which in turn were statistically similar from September, June and November planted ones. The shortest plant was noted in July planting (24.8 cm) which was statistically similar to that of October planting.

4.2.3 At 45 days after planting

At 45 days of planting, June planted crop was the tallest (63.0 cm) which was significantly superior to that of the other treatments except December planted ones. This was followed by August, February and September planting which in turn were on par. July planted crop was the shortest (37.0 cm) and was statistically similar to that in October and November plantings.

4.2.4 At 60 days after planting

At 60 days of planting, tallest plants (63.8 cm) were observed in the case of August and June planting which were on par with December planted crop. This was followed by September, January, October and November planted ones, which in turn were statistically similar. July planting resulted in shortest plants of 48.0 cm which in turn was on par with November, October, January and February planted crops.

4.3 Phenological observations

4.3.1 Days to first flower emergence

The data on the number of days to first flower emergence and days to fifty per cent flowering and time taken to first fruit set are presented in Table 3 and Fig.4.

Table 3. Effect of planting date and nitrogen application on number of days for first flower emergence, 50 per cent flowering and first fruit set in tomato

Date of planting	Days taken for		
	1st flower emergence	50 per cent flowering	1st fruit set
1. 15th Jun 1997	18.2	30.0	38.0
2. 15th Jul 1997	18.0	27.5	45.7
3. 15th Aug 1997	17.2	27.7	45.5
4. 15th Sep 1997	17.2	27.2	44.5
5. 15th Oct 1997	16.5	27.2	46.2
6. 15th Nov 1997	14.2	24.2	45.3
7. 15th Dec 1997	14.3	26.5	47.5
8. 15th Jan 1998	13.8	24.3	46.5
9. 15th Feb 1998	11.8	22.7	46.2
SEm±	0.28	0.22	0.34
CD(0.05)	0.85	0.66	1.03
Nitrogen (kg/ha)			
1. 75	15.6	26.4	45.5
2. 125	15.7	26.3	44.6
SEm±	0.14	0.15	0.11
CD(0.05)	NS	NS	0.33

NS - Not significant

The date of planting showed a significant influence on the days to first flower emergence in tomato. February planting resulted in earlier flowering (11.8 days) which was significantly superior to all the other planting times. This was followed by January, November and December planting which in turn were on par. October planting took 16.5 days for the emergence of 1st flower followed by August and September plantings. These in turn were on par. June planting took the maximum number of days for the first flower to emerge (18.2 days), followed by July planting, which in turn were statistically similar to that of August and September plantings.

Application of different doses of Nitrogen did not influence the character. So also the time of planting x Nitrogen treatment.

4.3.2 Days to 50 per cent flowering

Planting date had a significant effect on days to 50 per cent flowering in tomato. The days taken for 50 per cent flowering showed a similar trend as that of the days taken to first flower emergence.

February planting resulted in earlier flowering and it took only 22.7 days to reach 50 per cent of the plants in the treatment to come to flower. This was significantly superior to that in all the other treatments. November planting was the second in order (24.2 days) immediately followed by January planting which in turn were on par and was significantly superior to that of other treatments viz., October, September, July and August, which themselves were on par. The treatment June planting reached the stage very late which took 30 days for the expression of the character.

Application of different levels of nitrogen did not affect the character. So also the effect of time of planting x N levels on the character.

4.3.3 Time taken for first fruit set

Date of planting significantly influenced the time taken for the first fruit set in tomato. June planting resulted in earlier fruitset (38.0 days) which was significantly superior to that of the other treatments, which took 6-8 days more than this treatment for the first fruit to set. This was followed by September planting which took 44.5 days for the event which in turn was on par with that in November and August plantings. This was followed by July, February, October, January plantings, which in turn were statistically similar to that of August planting. December planting resulted in late fruit set (47.5 days) which was on par with that in January plantings.

Application of different levels of nitrogen significantly influenced the character. Application of 125 Kg N per hectare resulted in earlier fruit set (44.6 days) as compared to that of 75 kg N per hectare.

The data on the effect of date of planting x Nitrogen levels on the days to first fruit set in tomato has been presented in the Table 4.

The data showed that the treatment significantly influenced the character in tomato. June planting along with the application of 125 kg N ha^{-1} resulted in earliest fruit set in tomato as compared to all the other treatments combinations which was significantly superior to that in all the other treatments excepting the treatment June planting x 75 kg N ha^{-1}. This was followed by the treatments September planting x 75 kg N ha^{-1} and September planting x 125 kg N ha^{-1}, February planting x 125 kg N ha^{-1} and November planting x 125 kg N ha^{-1}. These treatments were statistically similar also. December planting x 75 kg N ha^{-1} took the maximum number of days to reach first fruit set (48.0 days) which was on par with that in February planting x 75 kg N ha^{-1}, January planting x 75 kg N ha^{-1} and December planting x 125 kg N ha^{-1} treatments.

Table 4. Effect of treatments on number of days to first fruit set in tomato

Date of planting	Nitrogen (kg / ha)	
	75	125
1. 15th Jun 1997	38.3	37.7
2. 15th Jul 1997	46.0	45.3
3. 15th Aug 1997	46.0	45.0
4. 15th Sep 1997	44.3	44.7
5. 15th Oct 1997	46.0	46.3
6. 15th Nov 1997	45.7	45.0
7. 15th Dec 1997	48.0	47.0
8. 15th Jan 1998	47.3	45.7
9. 15th Feb 1998	47.7	44.7
SEm±	0.33	
CD(0.05)	0.99	

4.3.4 Days to first harvest

The data on mean number of days taken to first harvest and last harvest are presented in Table 5 and Fig.5.

The date of planting had a significant influence on the days taken to first harvest. February planting resulted in earlier harvest (58.5 days) which was significantly different from that in all the other treatments. June and August planting followed this and these three treatments in turn were on par. This was followed by September planting which took 63 days for planting to the first harvest and was significantly superior to the rest of the treatments. December, October and July plantings followed this and these in turn were statistically similar. January planting took another 5-7 days whereas November planting resulted in maximum number of days for the crop to harvest for the first time (75.0 days).

Application of different rates of nitrogen did not affect the character in Tomato

The treatment date of planting x N levels significantly influenced the days to first harvest in tomato (Table 6). The treatment combination February planting x 125 kg N ha^{-1} resulated in earlier harvest (55.7 days) in tomato which was significantly different from that in all the other treatments excepting June planting x 125 kg N ha^{-1} and December planting x 75 kg N ha^{-1}. These three treatments were statistically similar. The treatment November planting x 75 kg N ha^{-1} took the maximum number of days (77.0 days) for the crop to be harvested first.

4.3.5 Days to final harvest

Planting date is significantly influenced the number of days taken by the crop to produce fruits and its maturity time and in turn the duration of the crop (Table 5).

Table 5. Effect of planting date and nitrogen application on days taken to first and last harvest in tomato

Date of planting	Days taken for 1st harvest	Days taken for Final harvest
1. 15th Jun 1997	60.2	84.0
2. 15th Jul 1997	67.0	89.7
3. 15th Aug 1997	60.3	84.8
4. 15th Sep 1997	63.0	82.0
5. 15th Oct 1997	65.8	118.0
6. 15th Nov 1997	75.0	104.5
7. 15th Dec 1997	65.5	94.2
8. 15th Jan 1998	72.5	92.5
9. 15th Feb 1998	58.5	72.0
SEm±	0.63	0.31
CD(0.05)	1.89	0.89
Nitrogen (kg/ha)		
1. 75	64.9	90.4
2. 125	65.7	92.1
SEm±	0.40	0.18
CD(0.05)	NS	0.561

NS - Not significant

Table 6. Effect of treatments on number of days to first harvest in tomato

Date of planting	Nitrogen (kg / ha)	
	75	125
1. 15th Jun 1997	61.3	59.0
2. 15th Jul 1997	67.0	67.0
3. 15th Aug 1997	61.0	59.7
4. 15th Sep 1997	61.0	65.0
5. 15th Oct 1997	65.7	66.0
6. 15th Nov 1997	77.0	73.0
7. 15th Dec 1997	58.0	73.0
8. 15th Jan 1998	72.0	73.0
9. 15th Feb 1998	61.3	55.7
SEm±	1.19	
CD(0.05)	3.53	

February planting resulted in shortest crop duration of 72 days which was significantly different from that in all the other treatments. This was followed by September planting which took 82 days for final harvest which in turn was significantly different from that of the other treatments. This was followed by June and August plantings which statistically similar. Other treatments in order were July, January, December, November and October plantings in which the crop duration increased. October planting crop recorded the maximum crop duration of 118.0 days.

Application of different doses of nitrogen significantly influenced the crop duration in tomato. Nitrogen applied @ 75 kg N ha^{-1} resulted in reducing crop duration (90.4 days) as compared to the crop which received in 125 kg N ha^{-1}.

The treatment combination date of planting x N levels significantly influenced the crop duration in tomato (Table 7). The tomato crop transplanted during February along with the application of 75 kg N ha^{-1} resulted as shortest crop duration which took only 71.0 days from planting to final harvest. This was significantly different from all the other treatment combinations. The treatment combination February planting x 125 kg N ha^{-1} came next with 73.0 day crop duration. The treatments October planting along with 75 and 125 kg N ha^{-1}, recorded maximum crop duration of 118.0 days.

4.4 Yield characters

4.4.1 Number of fruits per plant

The data on the effect of date of planting and application of different levels of Nitrogen in the number of fruits produced in a tomato plant are presented in Table 8 and Fig.6.

Table 7. Effect of treatments on number of days to final harvest in tomato

Date of planting	Nitrogen (kg / ha)	
	75	125
1. 15th Jun 1997	82.3	85.7
2. 15th Jul 1997	88.0	91.3
3. 15th Aug 1997	83.7	86.0
4. 15th Sep 1997	82.0	82.0
5. 15th Oct 1997	118.0	118.0
6. 15th Nov 1997	103.0	106.0
7. 15th Dec 1997	94.0	94.3
8. 15th Jan 1998	92.0	93.0
9. 15th Feb 1998	71.0	73.0
SEm±	0.57	
CD(0.05)	1.68	

Table 8. Effect of planting date and nitrogen application on number of fruits per plant, mean fruit weight (g) and fruit yield per plant (g) in tomato

Date of planting	No. of fruits per plant	Mean fruit weight (g)	Fruit yield/ plant(g)
1. 15th Jun 1997	10.7	18.6	196.1
2. 15th Jul 1997	16.1	20.4	322.5
3. 15th Aug 1997	12.1	18.0	216.7
4. 15th Sep 1997	9.0	21.3	190.0
5. 15th Oct 1997	14.6	24.6	355.6
6. 15th Nov 1997	15.6	21.4	327.8
7. 15th Dec 1997	33.1	25.7	835.6
8. 15th Jan 1998	10.8	25.7	262.2
9. 15th Feb 1998	2.6	25.8	67.0
SEm±	1.0	1.46	4.89
CD(0.05)	3.1	4.38	14.65
Nitrogen (kg/ha)			
1. 75	12.2	22.5	269.6
2. 125	15.5	22.2	346.7
SEm±	0.54	0.63	2.07
CD(0.05)	1.60	NS	6.14

NS - Not significant

The date of planting had a significant influence on the number of fruits per plant. The crop transplanted during December recorded the largest number of fruits per plant (33.1) which was significantly superior to that in the other treatments. The treatment July, October and November planting followed this and these in turn was statistically similar. February planted crop recorded the lowest number of fruits per plant (2.6).

The varying levels of Nitrogen showed a significant influence on the number of fruits per plant. Application of 125 kg N ha^{-1} recorded significantly higher numhber of fruits per plant (15.5) as compared to that in with lower nitrogen level (75 kg N ha^{-1}).

The effect of the treatment combination time of planting x N levels did not show any significant effect on the number of fruits produced in tomato.

4.4.2 Mean fruit weight

The data on the effect of date of planting and nitrogen application on mean fruit weight in tomato are presented in Table 8 and Fig.6.

It can be seen that the date of planting significantly affected the mean fruit weight in tomato. February planted crops gave the largest fruits in terms of mean fruit weight (25.8 g) which was on par with that in January, December and October plantings. August planting resulted in smallest mean fruit weight of 18.0 g which in turn was on par with June, July, September and November planted crops.

Application of different doses of nitrogen did not effect the mean fruit weight in tomato and the values varied from 22.2 to 22.5 g per fruit. So also, the time of planting x N level treatment combinations did not show any effect on the mean fruit weight in tomato.

4.4.3 Fruit yield per plant

The data on the effect of date of planting and nitrogen application in tomato are given in Table 8 and Fig.6.

Date of planting significantly influenced the fruit yield in tomato. December planting recorded the maximum fruit yield per plant (835.6g) which was significantly superior to that in all the other treatments. October and November plantings followed this where the yield was 355.3 g and 327.8 g per plant, respectively and statistically different from each other. The treatment July planting was on par with that in November planting which in turn were statistically superior to that in January planting which was significantly superior to that in August planting. This was followed by June and September planting which recorded 196.1 and 190.0 g per plant respectively and are statistically similar. February planting recorded the lowest yield of 67.0 g per plant.

The fruit yield per plant was also significantly altered by varying nitrogen levels. Application of 125 kg N ha^{-1} resulted in higher yield of 346.7 g per plant which was significantly higher than that in the treatment 75 kg N ha^{-1}

The treatment combination date of planting x N levels affected significantly the fruit yield in tomato (Table 9). The treatment December planting x 125 kg N ha^{-1} recorded the maximum yield of 1006.1 g per plant which was significantly much superior to that in all the other treatment combinations. The combination December planting x 75 kg N ha^{-1} rank record with 665.0 g per plant. The treatment February planting x 75 kg N ha^{-1} had the lowest fruit yield of 42.2 g per plant. Most of the treatments combinations were significantly differnt from other in this character.

Table 9. Effect of treatments on the fruit yield per plant in tomato (g)

Date of planting	Nitrogen (kg / ha)	
	75	125
1. 15th Jun 1997	181.0	211.1
2. 15th Jul 1997	312.2	332.8
3. 15th Aug 1997	148.4	285.0
4. 15th Sep 1997	237.2	142.8
5. 15th Oct 1997	324.4	386.7
6. 15th Nov 1997	276.6	378.9
7. 15th Dec 1997	665.0	1006.1
8. 15th Jan 1998	238.9	285.6
9. 15th Feb 1998	42.2	91.7
SEm±	6.2017	
CD(0.05)	18.43	

4.5 Crop weather relationship

Simple linear correlation between important phenological and yield characters viz. days to first flowering, days to 50 per cent flowering, time taken to first fruit set, number of fruits per plant, mean weight of a fruit, fruit yield per plant to each of the weather elements like maximum temperature, minimum temperature, hours of bright sunshine, temperature range, morning relative humidity and afternoon relative humidity for both the levels of nitrogen (75 and 125 kg N ha^{-1}) were correlation carried out using the grand mean data (Table 10 and 11) and the coefficient have been presented in the Table 12 and 13.

4.5.1 Application of 75 kg N ha^{-1}

The average fruit weight was affected by the maximum temperature between 5 to 9th week after planting and significant positive correlation was obtained between the two. It can be seen from the Table 12 that days to first flowering was negatively related to maximum temperature during the first two weeks of planting. Strong negative correlation was obtained between days to 50 per cent flowering and maximum temperature during 2nd to 4th week after transplanting (r = -0.846). Maximum temperature did not show any influence with the number of fruits per plant and fruit yield in tomato.

Time taken to first fruit set was positively correlated with the minimum temperature between 2nd to 3rd week after planting. Whereas significant negative correlation were obtained between minimum temperature during Ist-2nd weeks and days to first flowering. Fruit yield was influenced much by the minimum temperature during 8th week after planting (r = -0.726). Minimum temperature during 7th and 8th week after planting significant negative correlations were obtained between minimum temperature and number of fruits per plant and fruit yield at 75 kg N application. Days to 50 per cent flowering and average fruit weight was not influenced by the minimum temperature.

Table 10. Effect of planting date on various plant character of tomato at 75 kg of applied N/ha

Date of planting	Plant height (cm)				Days taken to					Yield characters		
	15 DAP	30 DAP	45 DAP	60 DAP	1st flowering	50% flowering	1st Fruit set	1st harvest	Last harvest	No. of fruits	Mean fruit weight(g)	Yield per plant(g)
15th Jun 1997	13.0	37.4	59.8	60.2	18.2	29.9	38.8	61.2	82.3	9.2	19.7	181.1
15th Jul 1997	12.2	24.7	38.7	49.0	18.0	26.9	46.1	67.0	88.0	15.2	20.9	312.2
15th Aug 1997	18.8	47.2	52.9	60.6	17.3	27.8	45.9	61.0	83.7	9.1	16.5	148.3
15th Sep 1997	26.8	41.2	50.8	54.9	17.2	27.2	44.6	61.0	81.8	11.0	21.8	237.2
15th Oct 1997	16.9	27.0	37.9	46.6	16.3	26.9	45.5	65.7	118.0	12.1	26.8	324.4
15th Nov 1997	13.4	33.0	42.0	48.0	14.6	24.1	45.7	77.0	103.0	12.9	21.6	276.7
15th Dec 1997	31.1	58.8	59.6	59.2	13.9	27.0	47.7	58.0	94.0	29.8	23.4	665.0
15th Jan 1998	17.0	36.4	46.1	54.0	14.0	24.2	47.3	72.0	92.0	8.4	28.7	238.9
15th Feb 1998	19.7	38.3	49.8	56.4	11.8	23.3	52.9	61.5	71.0	1.9	24.0	42.2

DAP: Days after planting

Table 11. Effect of planting date on various plant character of tomato at 125 kg of applied N/ha

Date of planting	Plant height (cm)				Days taken to					Yield characters		
	15 DAP	30 DAP	45 DAP	60 DAP	1st flowering	50% flowering	1st Fruit set	1st harvest	Last harvest	No. of fruits	Mean fruit weight(g)	Yield per plant(g)
15th Jun 1997	13.7	50.6	66.4	66.8	18.1	29.9	37.7	59.0	85.8	12.1	17.4	211.1
15th Jul 1997	12.6	25.1	35.4	47.4	17.9	27.9	45.2	67.0	91.1	16.9	19.8	332.8
15th Aug 1997	12.9	42.9	56.1	66.9	17.0	27.8	45.0	59.7	86.0	15.1	19.5	285.0
15th Sep 1997	25.9	35.4	47.2	56.0	17.2	27.1	44.4	65.0	81.8	6.9	20.7	142.8
15th Oct 1997	16.6	31.1	42.7	54.9	16.6	27.3	46.3	56.1	118.0	17.1	22.8	386.7
15th Nov 1997	13.0	35.2	45.0	51.6	14.2	24.6	45.0	73.0	106.0	18.3	21.1	378.9
15th Dec 1997	25.8	53.4	55.7	58.9	14.9	26.0	47.0	73.0	94.2	36.3	27.8	1006.1
15th Jan 1998	19.4	35.1	44.2	50.9	13.3	24.2	45.7	73.0	93.3	13.1	22.7	285.6
15th Feb 1998	21.1	42.9	48.3	50.6	11.9	22.0	44.9	55.6	7.3	3.3	22.7	91.7

DAP: Days after planting

Table 12. Correlation coefficients between various plant characters of tomato and weather elements at 75kg of applied N /ha

Plant character	Weather parameters					
	Max.Temp	Min.Temp	Temp.Range	SSHours	RH-1	RH-2
Days to 1st flowering	-0.687** (1-2)	-0.849** (1-2)	-0.778* (1-2)	-0.842** (1-2)	0.905** (1-2)	0.836** (1-2)
Days to 50% flowering	-0.846** (2-4)	NS	-0.851** (3-5)	-0.726* (4-5)	0.713* (3-4)	0.782* (2-5)
Time taken to first fruit set	0.723* (5-7)	0.687* (2-3)	NS	0.767* (6-7)	-0.708* (4-5)	NS
Number of fruits per plant	NS	-0.728* (7-8)	NS	NS	NS	NS
Average fruit weight (g)	0.741* (5-9)	NS	0.724* (4-7)	0.706* (3-4)	-0.809** (3-5)	0.739* (1-7)
Fruit yield per plant (g)	NS	-0.726* (7-8)	NS	NS	-0.669* (6-7)	NS

* Significant at 5% level
** Significant at 1% level
Figures in parenthesis denote periods in week after planting
Max.Temp: Maximum temperature
Min.Temp: Minimum temperature
Temp.Range: Temperature range
SSHours: Hours of bright sunshine
RH-1 : Relativehumidity at 0700 h LMT
RH-2 : Relativehumidity at 1400 h LMT

Table 13. Correlation coefficients between various plant characters of tomato and weather elements at 125 kg of applied N /ha

Plant character	Weather parameters					
	Max.Temp	Min.Temp	Temp.range	SSHours	RH-1	RH-2
Days to 1st flowering	-0.684* (1-2)	-0.762* (1-2)	-0.761* (1-2)	-0.826** (1-2)	0.921** (1-2)	0.813** (1-2)
Days to 50% flowering	-0.884** (4-5)	-0.746* (3-4)	NS	-0.884** (2-3)	0.827** (2-4)	0.864** (2-5)
Time taken to first fruit set	NS	NS	NS	NS	NS	NS
Number of fruits per plant	NS	NS	NS	NS	NS	NS
Average fruit weight (g)	NS	NS	0.684* (4-7)	0.736* (4-7)	-0.923** (4-7)	NS
Fruit yield per plant (g)	NS	-0.716* (7-8)	NS	NS	-0.681* (6-7)	NS

* Significant at 5% level
** Significant at 1% level
Figures in parenthesis denote weeks after planting
Max.Temp: Maximum temperature
Min.Temp: Minimum temperature
Temp.Range: Temperature range
SSHours: Hours of bright sunshine
RH-1 : Relativehumidity at 0700 h LMT
RH-2 : Relativehumidity at 1400 h LMT

Significant positive correlations were obtained between average fruit weight and range of temperature from 4 and 7th week after planting (r = 0.724) whereas significant negative correlations were noticied in the case of days to first flowering and fifty per cent flowering. Range of temperature did not show any relationship to, number of fruits per plant and fruit yield per plant.

Significant positive correlations were noticed between the house of bright sunshine and time taken to first fruit set (6-7) and average fruit weight (3-4) whereas days taken for first flowering (1-2) and fifty per cent flowering were negatively correlated with bright sunshine hours from 1st-2 weeks and 4 to 5 weeks, respective. Number of fruits per plant and fruit yield per plant was not found to be related to the bright sunshine hours.

Significant positive correlation were obtained respectively at 1-2 weeks and 3-4 weeks between relative humidity during morning hours and days taken to first flowering (0.905) and 50 per cent flowering (0.713). Whereas significant negative correlation between time taken to first fruit set, average fruit weight and fruit yield and the morning relative humdity during 3rd to 7th week growth. Number of fruits per plant was not influenced by the morning relative humidity.

Significant positive correlation were obtained respectively at 1-2, 2-5 and 1-7 weeks between afternoon relative humidity and days taken to first flowering (0.836) and 50 per cent flowering (0.782) and average fruit weight (0.739). Whereas time taken to first fruit set, number of fruits per plant and fruit yield per plant was not found to be related to the afternoon relative humidity.

4.5.2 Application of 125 kg N ha^{-1}

From the Table 8, it can be seen that the days to first flowering (-0.684) and 50 per cent flowering (-0.884) was negatively related to maximum temperature during the first two week and fourth to fifth weeks respectively after planting. Time taken to first fruit set, number of fruits per plant, average fruit weight and fruit yield in tomato were not found to be affected by maximum temperature during the crop growth period.

Significant negative correlations were obtained between minimum temperature between the days to first flowering (-0.762), days to 50 per cent flowering (-0.746) and fruit yield per plant (-0.716) during the first two weeks, third to fourth week and seventh to eighth were respectively, after planting. Time taken to first fruit set, number of fruits per plant and average fruit weight were not influenced by the minimum temperature during the cropping period.

Significant positive correlation were obtained between average fruit weight and range of temperature from 4 and 7th week after planting (r = 0.684). Whereas significant negative correlation was noticed in the case of days to first flowering and temperature range during the first two week after planting. Whereas days to 50 per cent flowering, number of fruits per plant and fruit yield were not found to be related to the temperature range during any period.

Significant positive correlation were noticed between the hours of bright sunshine between 4th to 7th week and average fruit weight. Whereas days to first flowering (-0.826) and fifty per cent flowering (-0.884) were negatively correlated with bright sunshine hours respectively from 1st-2 weeks and 2-3 weeks after planting. Time taken to first fruit set, number fruits per plant and fruit yield per plant was not found to be related to the bright sunshine hours during crop period.

Morning relative humidity at 1-4 weeks and days taken to first flowering and 50 per cent flowering were positively related (r = 0.921 and 0.827, respectively). Whereas significant negative correlation were noticed between average fruit weight (-0.923) and fruit yield (-0.681) and the morning relative humidity during 4th-7th week after planting. Time taken to first fruit set and number of fruits per plant was not influenced by the morning relative humidity.

Significant positive correlation were obtained between afternoon relative humidity from 1-5 week and days to first flowering (0.813) and 50 per cent flowering (0.864). Whereas other characters studied were not found to be related to the afternoon relative humidity.

4.6 Regression analysis

In tomato, fruit yield was significantly related to maximum temperature and morning relative humidity at 6-8 weeks after planting. There two weather parameters were negatively correlated with yield at both the levels of nitrogen applied. Regression equations were developed crop yield and minimum temperature (NT) at 7-8 week stage and morning relative humidity (RH I) at 6-7 weeks of planting which are presented below:

a) The 75 kg N ha^{-1}

$$Y = -206.44\ NT - 9.77\ RH\ I + 5967.45$$

$$R^2 = 0.646$$

Y = Fruit yield in tomato (g/plant)

NT = Minimum temperature at 7-8 week state

RH I = Morning relative humidity 6-7 week stage

b) The 125 kg N ha^{-1}

$$Y = -339.27\ NT - 14.64\ RH\ I + 9590.92$$

$$R^2 = 0.658$$

Y = Fruit yield in tomato (g/plant)

NT = Minimum temperature at 7-8 week state

RH I = Morning relative humidity 6-7 week stage

Table 14. Actual and predicted tomato yield per plant (g)

Date of planting	75 kg N ha^{-1}		125 kg N ha^{-1}	
	Actual	Predicted	Actual	Predicted
15th Jun 1997	181.1	95.7	211.1	76.9
15th Jul 1997	312.2	270.6	332.8	338.6
15th Aug 1997	148.3	207.6	285.0	512.3
15th Sep 1997	237.2	255.3	142.8	342.0
15th Oct 1997	324.4	224.9	386.7	286.1
15th Nov 1997	276.7	202.1	378.9	233.2
15th Dec 1997	665.0	577.9	1006.1	835.3
15th Jan 1998	238.9	385.6	285.6	512.3
15th Feb 1998	42.2	205.3	91.7	247.2

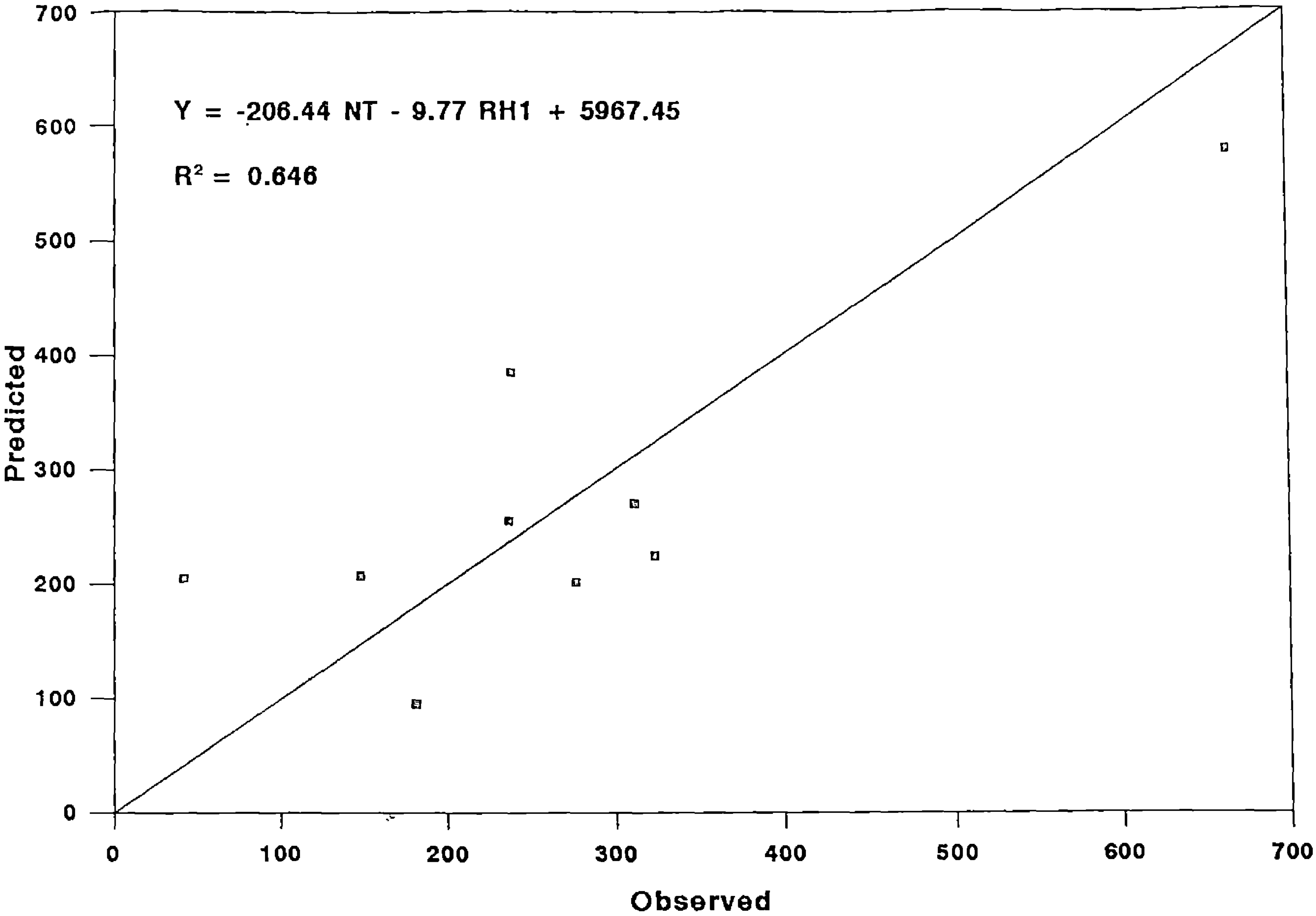


Fig. 7 Observed and predicted yield (g/plant) of tomato at 75 kg N/ha

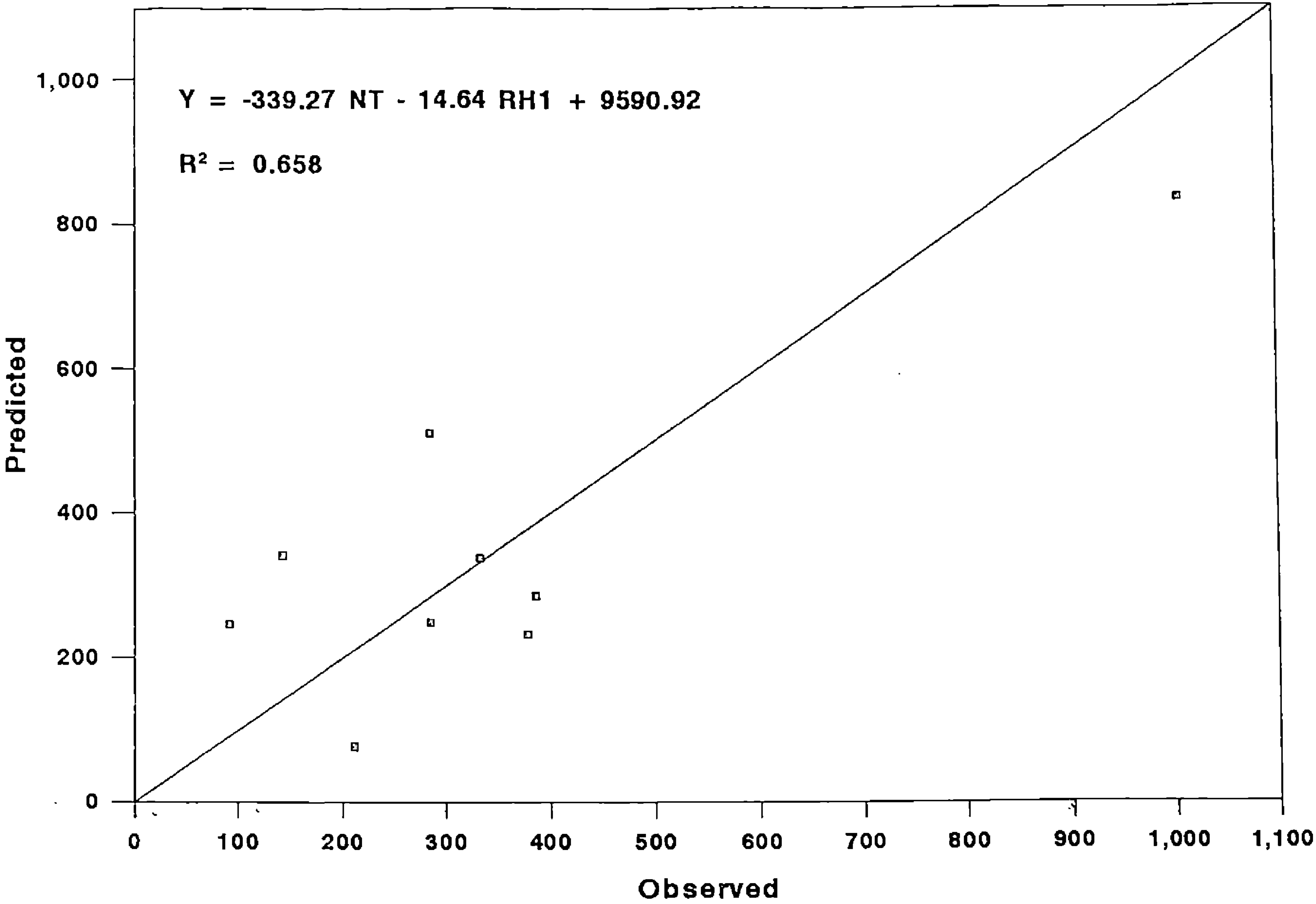


Fig. 8 Observed and predicted yield (g/plant) of tomato at 125 kg N/ha

The predicted yields as determined from the regression equations and the actual yield obtained are given in Table 14 and Figures 7 and 8.

4.7 Validating IBSNAT model

For validating the IBSNAT model thermal days for various phenological events were worked out for the October planting and the results obtained has been presented in Table 15.

The data shows that the tomato seeds took 51.9 thermal days from sowing to emergence and 80.7 thermal days from emergence to first true leaf.

From the first true leaf to juvenile phase, application of 75 kg N ha^{-1} reached the stage earlier (729.7) as compared to that in 125 kg N ha^{-1} (764.9). Application of different levels of nitrogen did not influence the crop in term of time taken from first flower to harvest maturity.

From fruit set to fruit maturity, application of 125 kg N ha^{-1} reached the stage early (230.8) as compared to that in 75 kg N ha^{-1}. Irrespective of the levels of nitrogen applied the crop took 1198.5 thermal days from first flower to last leaf formation. Maximum size of leaf was more in 125 kg N ha^{-1} (52.6 cm^2) as compared to that in 75 kg N ha^{-1}.

Table 15. Thermal days required for various phenological events in October planted tomato crop

Phenological event	Nitrogen (kg/ha)	
	75	125
1. Sowing to emergence	51.9	51.9
2. Emergence to first true leaf	80.7	80.7
3. First true leaf to juvenile phase	729.7	764.9
4. First flower to harvest maturity	697.8	697.8
5. Fruit set to fruit maturity	249.1	230.8
6. First flower to last leaf on main stem	1198.5	1198.5
7. Maximum size of the leaf (cm^2)	50.4	52.6

Plate 1. 15th January 1998 planted crop at 15 day after planting

Plate 2. 15^{th} January 1998 planted crop when flowering just started


T1


Plate 3. 15th December 1997 planted crop at 45 days stage

Plate 4. Single plant in field at 60 days stage


R3
T1

Discussion

DISCUSSION

The present investigation was taken up to study the crop weather relationship in tomato (*Lycopersicon esculentum* Mill) under different times of planting and different levels of nitrogen. The results are discussed below on cause and effect basis.

The December planting resulted in tallest plants during vegetative phase as compaired to the other plantings (Fig.3). This may be due to the fact that the maximum temperature range of (31.0-32.3°C), minimum temperature range of (23.7-24.1°C), bright sunshine hours (5.2-8.7), morning relative humidity of (80-87 %) and afternoon relative humidity of (53-67%) favoured the increase in height during the vegetative phase.

The June planted crop also showed significant increase in plant height during the reproductive stage. This may be due to the fact that the weather condition prevailed viz. maximum temperature of 29.2-30.3°C, minimum temperature of 23.4-24.4 0°C, bright sunshine hours of 2.4-4.9, morning relative humidity of 95-97 per cent, afternoon relative humidity of 78-90 per cent was confirmed for increasing the plant height during this planting. The results are is in agreement with the findings of Singh and Tripathy (1995).

The date of planting showed a significant influence on the number of days to first flower emergence in tomato (Fig.4). Earlier flowering was observed in February planted tomato crop (11.8 days) and this was followed by January, November and December plantings. The maximum .number of days for first flowering was taken by June planting (18.2) followed by July, August, September and October planted crops. The high rainfall and lower minimum temperature during July to September and the maximum temperature of (31.6-32.1) and minimum temperature of (24.1-24.3) during February were attributed to these

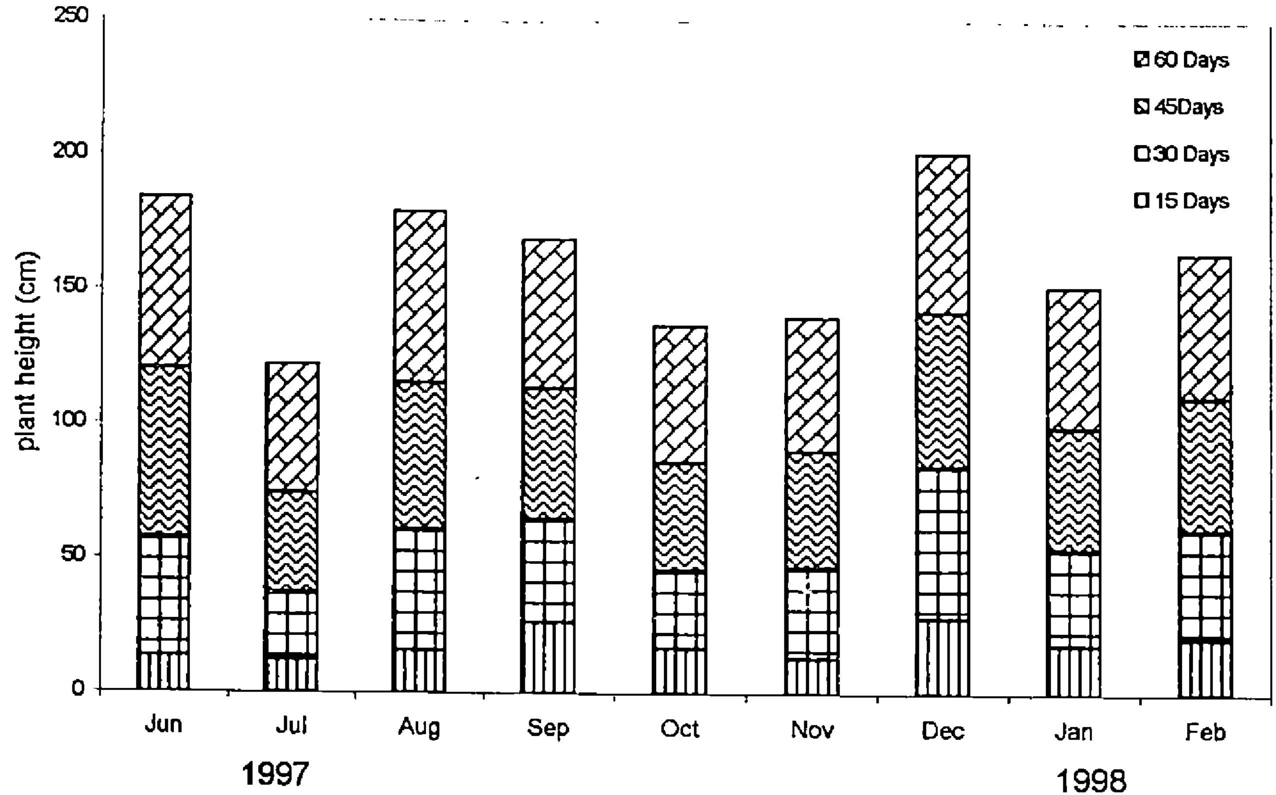


Fig.3 Effect of date of planting on the plant height in tomato

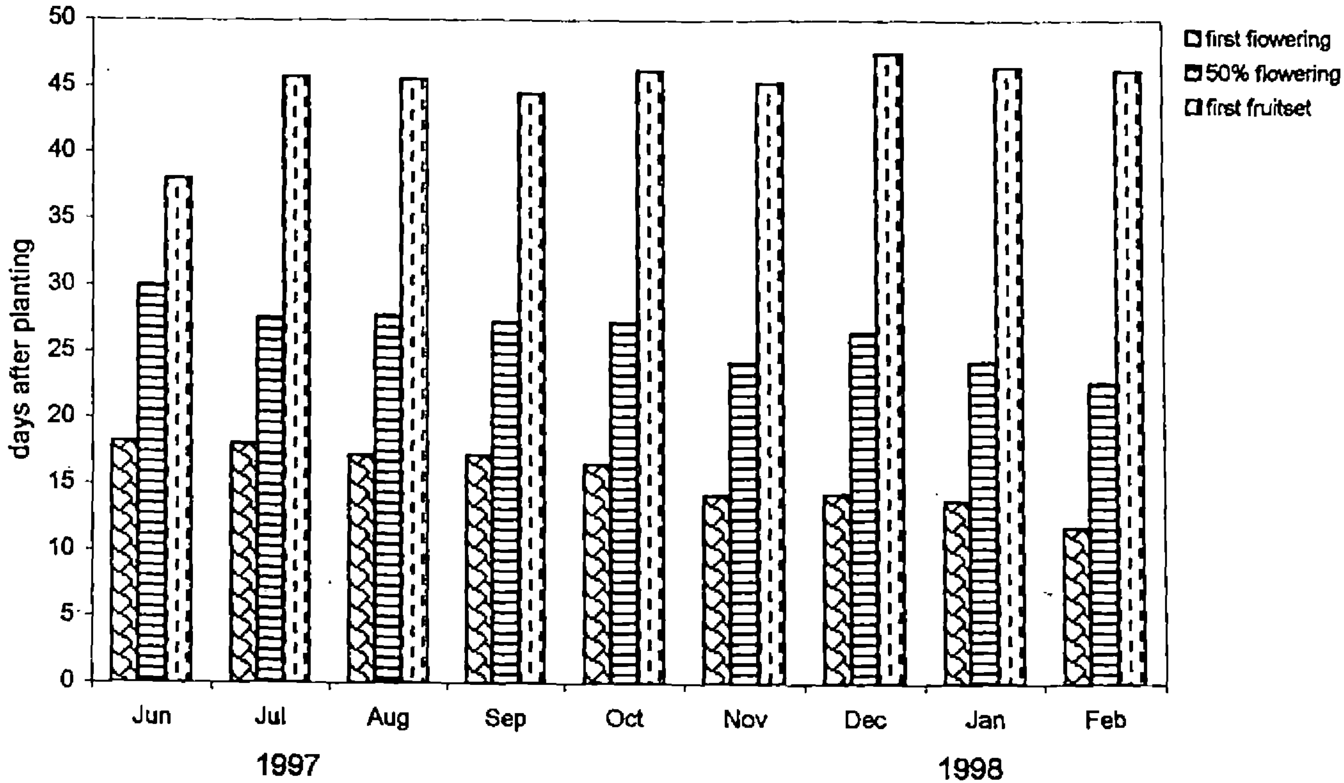


Fig. 4. Effect of date of planting on number of days to first flower emergence, 50% flowering and first fruitset in tomato

differences. Effect of high temperature on early flowering was reported by Kalloo (1986). Effect of lower night temperature on delayed flowering was reported by Longueness (1978).

Planting date had a significant effect on days to 50 per cent flowering in tomato (Fig.4). Days to 50 per cent flowering was higher in June planting and it decreased slowly as the date of planting progressed from July to February. Thus the 50 per cent flowering showed the same trend as that of the days taken to first flower emergence. The earliness in February planting was due to high temperatures and more hours of bright sunshine during February to March. The high rainfall and the high relative humidity from June to September may be the reason for the delay in 50 per cent flowering. Similar observations were made by Kalloo (1986).

Application of different levels of nitrogen did not affect the days to 50 per cent flowering. The effect of time of planting on N levels on the character is null and void.

Early fruit set was observed in June planting and was significantly superior to that of the other planting (Fig.4). December and January plantings took more number of days to set fruits. The maximum temperature of 30.6-32.1°C, minimum temperature of 22.7-32.1°C, bright sunshine hours of 9.3-10.0 may be the reason for the delayed fruit set in December planting.

Application of 125 kg N per hectare resulted in earlier fruit set as compared to that of 75 kg N per hectare (Table 4). A similar study was conducted by Baruah *et al.* (1995) and Varis and George (1985), June planting along with the application of 125 kg N ha^{-1} resulted in the earliest fruit set in tomato as compared to all other treatment combination. December planting with 75 kg N ha^{-1} took the maximum number of days to reach first fruit set.

Earliness in tomato crop increased with increase in the temperature. During higher temperatures, most of the biochemical reactions proceed faster and thus the plant growth is quicker. The higher temperature help in better uptake of nutrients, early completion of vegetative phase, earlier bud differentiation and development. This is in conformity to the reports of Saito and Ito (1971) in tomato.

The date of planting had a significant influence on the days taken to first harvest (Table 5). February planting resulted in earliest harvest which was significantly different from that in all other treatments. November planting took maximum number of days for the crop to harvest for the first time. Dimitrove *et al.* (1973) indicated that in tomato, earliness in harvest was strongly affected by the planting dates. Longuenesse (1978) showed that the lower night temperature during the plant growth stages delayed the fruit development and maturity. February planted crop experienced higher maximum temperature of (34.4-34.8) and hours of bright sun shine (9.6-10.3) which may have resulted in earlier maturity.

Application of different rates of nitrogen did not affect the days taken to first harvest in tomato. The treatment combination February planting with 125 kg N ha^{-1} resulted in earlier harvest in tomato (Table 6). The treatment November planting x 75 kg N ha^{-1} took the maximum number of days for the first harvest. The high temperature and the high dose of Nitrogen may be the reason for the earliness in harvest in February planting. Adams *et al.* (1973) reported that lower nitrogen levels delayed harvesting.

Days taken to final harvest was significantly influenced by the date of planting (Table 5). February planting resulted in the shortest crop duration of 72 days which was significantly different from that in all the other treatments. The high temperature (33.4-35.9) during February may be the reason for the shortest crop duration. October planting crop recorded the maximum crop duration of 118.0 days. With increase in day and night temperatures, the crop duration decreased.

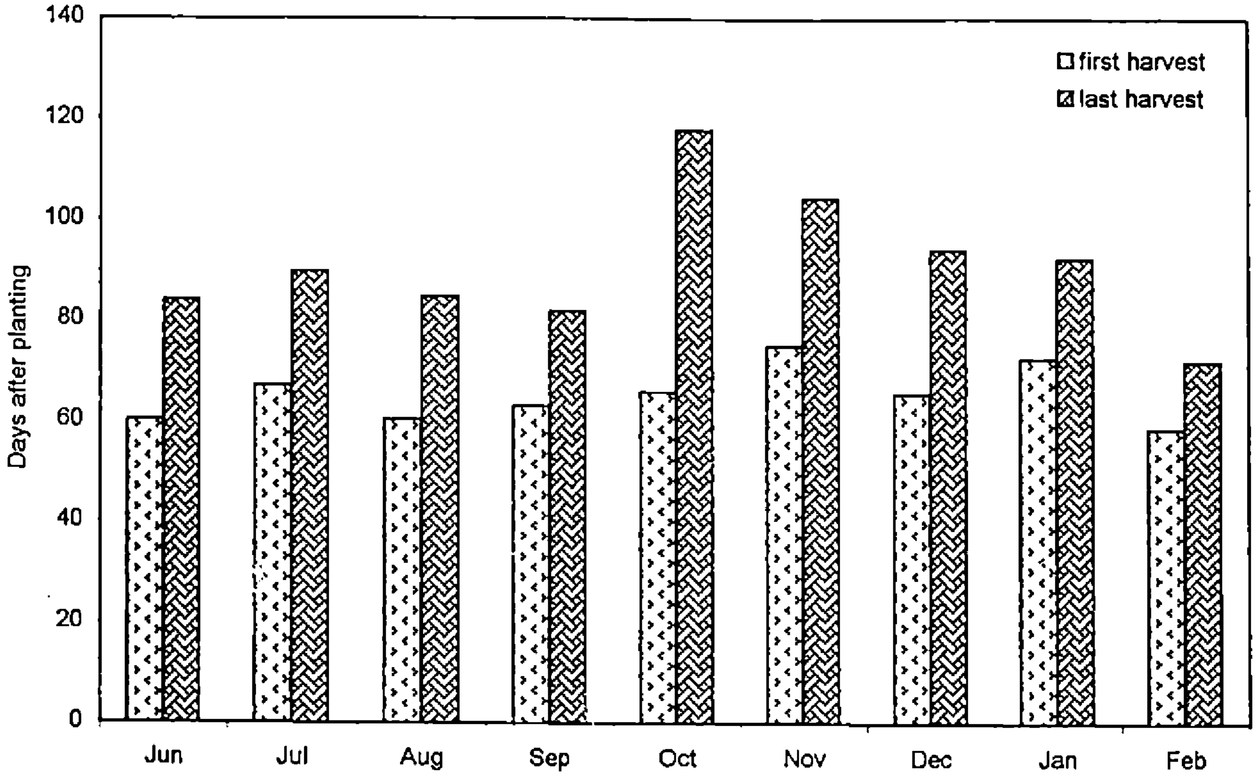


Fig.5. Effect of date of planting on the days taken to first and last harvest in tomato

Higher dose of nitrogen significantly influenced the crop duration in tomato. Nitrogen applied at 75 kg ha^{-1} resulted in reducing crop duration. The tomato crop transplanted during February along with the application of 75 kg N ha^{-1} resulted in shortest crop duration (Table 7). The treatment combination October planting along with 75 and 125 kg N ha^{-1} recorded the maximum crop duration. Higher level of fertilizer was found to lengthen the crop duration significantly in comparison with lower level.

Date of planting had a significant influence on the number of fruits per plant (Fig.6). The crop transplanted during December recorded the largest number fruits per plant. The treatments namely July, October and November plantings followed a decreasing trend in the yield of fruits with the lowest yield in February planted crop. The decrease in fruit number per plant decreases with the increase in temperature during the periods. Blossom and fruit drops were common with high temperatures. Flower and fruit drop coinciding with high temperature have been reported by Rao (1986).

Number of fruits per plant was significantly influenced by the higher dose of nitrogen application (125 kg ha^{-1}) than the lower levels of nitrogen. The treatment combination of time of planting and N levels did not show any significant effect on the number of fruits produced in tomato. The high levels of nitrogen increases the number of fruits per plant was reported by Baruah *et al.* (1993), Byari (1981), Varis and George (1985) and Sharma (1995).

Mean fruit weight in tomato was significantly affected by the date of planting (Fig.6). February planted crops gave the biggest fruits in terms of mean fruit weight and was followed by January, December and October plantings. August planting resulted in the smallest mean fruit weight. The highest fruit weight for February planted crop may be due to the lower number of fruits produced per

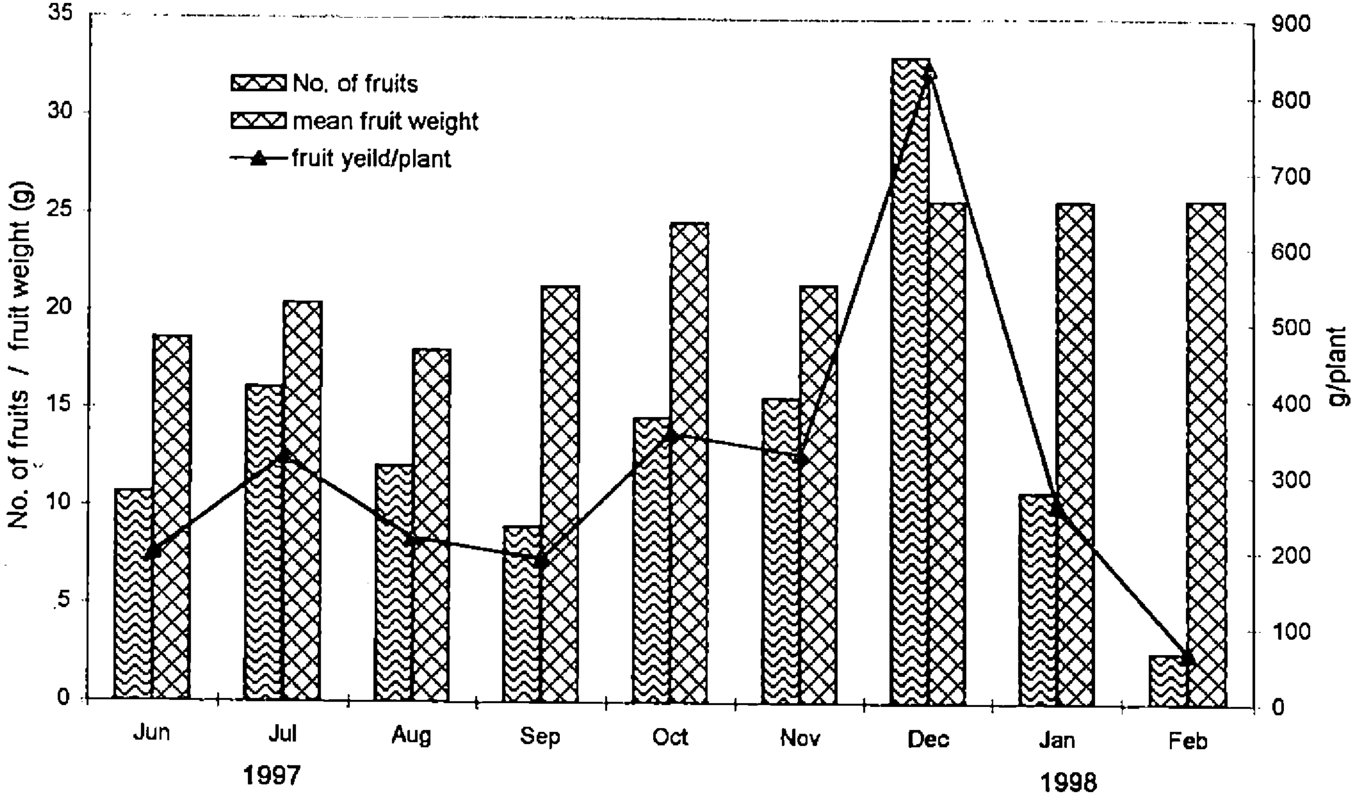


Fig.6. Effect of date of planting on number of fruits, mean fruit weight and fruit yield/plant in tomato

plant. The highest mean fruit weight for December and October planting may be due to the congenial weather conditions during the plant growth period. The Smallest fruit during August may be due to the heavy rainfall during the growth period and also may be due to the disease 'Buck eye rot' caused by *Phytophthora parasitica*.

Date of planting significantly influenced the fruit yield in tomato (Fig.6). December planting recorded the maximum fruit yield per plant and followed by October and November plantings. February planting recorded the lowest yield. The months December, October and November considered as the optimum time for planting tomato. This is in agreement with the studies conducted by Lipure and Paratore (1986), Rao (1986), Saimbi and Gill (1988), Rajan (1989), Kaolam *et al.* (1991) and Vadivel and Arumugam (1993). The lowest fruit yield during February may be due to the higher temperatures prevailing during the growth period. At high temperature the fruit set is impaired and there will be great reduction in the fruit yield per plant Kalloo (1986). The variation in performance of tomato under different situations are attributed to differences in weather conditions prevailing in the locality. Similar observations were recorded from the work done by Muthukrishnan *et al.* (1982).

The fruit yield per plant was also significantly affected by varying levels of nitrogen levels. Higher dose of nitrogen (125 kg ha^{-1}) resulted in higher yield (Table 8). The treatment combination, date of planting and N levels affected the fruit yield significantly (Table 9). Application of higher dose of nitrogen enhanced the fruit yield in tomato has also been reported by many workers (Hisatomy, 1972; Locascis and Rao, 1972; Kuskal, 1977; Sharma *et al.*, 1978; Varis and George, 1985; Ahmed and Saha, 1986 and Rajan, 1986).

Crop weather relationship

Tomato crop is much influenced by the temperature during germination, plant growth, flowering, fruit set, photosynthesis and yield. The crop will have a threshold level of optimum temperature requirement, below and above which in the metabolic processes may be disturbed. At high temperature the fruitset is impaired. The failure of fruitset at high temperature is due to certain disturbed mechanism involved in the male and female parts of the flower was reported by many workers (Rudich *et al*, 1977; Kuo *et al*, 1979 ; Kalloo, 1986).

The maximum temperature during the days to 1st flower emergence and 50 per cent flowering is negatively correlated during 1st -2nd weeks after planting (Table 12 and 13). But the maximum temperature during 5th–9th week has a strong positive effect on the average fruit weight. This was supported by Rylski (1979). Whereas minimum temperature at 1st -2nd week also correlate negatively with the days to first and 50 per cent flowering. This was in agreement with the finding of Nagoka *et al.* (1979). Fruit yield per plant has a strong negative influence with the minimum temperature. The minimum temperature during 7th to 8th week after planting is more important for the crop. But the minimum temperature during 2nd and 3rd week after planting had a strong positive influence on time taken to first fruit set in the crop.

Sunshine hours and temperature range during 1st and 2nd week after planting showed a negative correlation with the days to first flowering and 50 per cent flowering. These two were significant during the 1st-5th week after planting. Sunshine hours and temperature range were positively correlated with the average fruit weight of the plant.

Relative humidity during morning and afternoon also affected the days to first flowering and 50 per cent flowering positively during 1st and 2nd week after planting. The morning relative humidity has a negative influence on the fruit yield per plant during the 6th-7th week after planting.

The minimum temperature and morning relative humidity during the 6th - 8th week after planting plays an important role in the tomato prodution . The minimum temperature of (22.1°C-23.3°C) and morning relative humidity of (70-74%) are congenial for the optimum plant growth.

The regression equations were developed to predict the crop yield from minimum temperature during the 7th-8th week after planting and morning relative humidity during 6th-7th week after planting. Which can predict the yield with 65% accuracy.

Based on the experimental data, minimum data set (MDS) for the validation of tomato model of the IBSNAT has been generated.

Several other models were used by many workers Kurata and Takakava (1991) and Hodges (1992) developed simulation models. Tijeskeni (1993) developed a mathematical model. Pachepsky *et al.* (1996) proposed models for photosynthesis.

To sum up, it can be seen that the fruit production in tomato is largely decided by the seasonal and environmental conditions. At Vellanikkara conditions, December planting crop is more ideal for getting good tomato yield. That is the crop required maximum temperature of 30.6°C-33.7°C, minimum temperature of 22.1°C-24.3 0°C, bright sunshine hours of 5.2-10.0, morning relative humidity of 70-86 per cent, afternoon relative humidity of 45-59 per cent. Planting during October and November is also found to be satisfactory. The higher dose of nitrogen is found to be better than the lower doses of nitrogen. The combination effect of fertilizer application to seasonal influences was evident from the study.

Summary

SUMMARY

An experiment was conducted at the College of Horticulture, Vellanikkara, Thrisur during the period May 1997 to May 1998 to study the crop weather relationship in tomato (*Lycopersicon esculentum* Mill) variety Sakthi.

The experiment was laid out in split plot design with three replications. There were nine dates of sowing and two levels of nitrogen. Observations on morphological, phenological and yield attributes were recorded during the course of investigation. The daily weather elements recorded at the meteorological observatory were used to work out the crop weather relationship.

The main findings of the study are summarised below:

1. In tomato, planting date influenced the height of the plants at 15th, 30th, 40th and 60th days after planting. December planted crop was the tallest at 15th and 30th day stage.
2. June planting had the tallest plant at 45th and 60th day after planting .
3. The date of planting showed a significant influence on the days to first flower emergence in tomato. February planting resulted in earlier flowering (11.8 days) where as June planting took the maximum number of days (18.2 days) for first flower emergence.
4. Levels at 75 and 125 kg/ ha nitrogen did not affect the days taken to first flower emergence.
5. Planting date had a significant effect on days to 50 per cent flowering in tomato. February planting resulted in earlier flowering (22.7 days). The treatment June planting reached the stage very late which took 30 days for 50 per cent flowering.
6. The maximum temperature of (31.6°C-32.1°C) and minimum temperature (24.1 °C -24.3 °C) is optium for early flowering in tomato.

7. Application of different doses of nitrogen did not influence the days to attain 50 per cent of flowering.
8. Time taken for first fruit set varied with the planting date. June planting resulted in earlier fruit set (38.0 days), whereas December planting in late setting of fruit (47.5 days).
9. Of the two levels of nitrogen, the higher dose (125 kg N ha^{-1}) resulted in earlier fruit set (44.6 days) in tomato.
10. Days to first harvest was altered by the planting dates. February planting resulted in earlier harvest (58.5 days), whereas November planting took maximum number of days.(75.0 days)
11. Application of different rates of nitrogen did not affect the days taken for first harvest in tomato.
12. The treatment combination, February planting and application of N at 125 kg ha^{-1} resulted in earlier harvest (55.7 days). and the combination November planting with 75 kg N ha^{-1} the maximum number of days (77.0 days) for first harvest.
13. The date of planting significantly affected the days to final harvest. February planting resulted in shortest crop duration of 72 days, whereas October planted crop recorded the maximum crop duration of 118.0 days.
14. Out of the two nitrogen levels, 75 kg N ha^{-1} resulted in reducing crop duration. Among the treatment combinations, February planting with 75 kg N ha^{-1} resulted the shortest crop duration (72.0 days).
15. The date of planting had a significant influence on the number of fruits per plant. The crop transplanted during December recorded the largest number of fruits per plant (33.1) while February planting recorded the lowest number (2.6).
16. Application of 125 kg N ha^{-1} recorded larger number of fruits per plant as compared to that in the treatment receving 75 kg N ha^{-1}.

17. Date of planting significantly affected the mean fruit weight in tomato. February planted crop gave the highest fruit weight (25.8g) and was on par with that in January, December and October plantings. While August planting resulted in smallest mean fruit weight (18.0 g).
18. Application of different doses of nitrogen did not affect the mean fruit weight in tomato.
19. Date of planting significantly influenced the fruit yield in tomato. December planting recorded the maximum fruit yield per plant (835.6 g). which was followed by October and November planting. February planting recorded the lowest fruit yield in tomato.
20. The fruit yield was also altered by varying levels of nitrogen. Application of 125 kg N ha^{-1} resulted in higher yield as compared to that in 75 kg N ha^{-1}.
21. The treatment combination of December planting x 125 kg N ha^{-1} recorded the maximum yield of 1006.1 g per plant.
22. Crop weather relationship studies showed that days to first flowering was positively correlated with morning and afternoon relative humidity at first two weeks of planting.
23. The fruit yield and number of fruits per plant were negatively correlated with minimum temperature during the 7th and 8th week after planting.
24. Morning relative humidity at sixth to seventh week of planting had a negatieve correlation with the yield of tomato.
25. Maximum temperature, minimum temperature, temperature range and hours of bright sunshine during the 1st two week stage correlated with the days to first flowering in tomato.
26. Minimum temperature of (22.1-23.3 °C) and relative humidity during morning hours (70-74%) during 6th and 8th week after planting are optimum for the increase yield.
27. For optimum growth, crop required maximum temperature of 30.6-33.7°C, minimum temperature of 22.1-24.3 0°C, bright sunshine hours of 5.2-10.0,

morning relative humidity of 70-86 per cent and afternoon relative humidity of 45-59 per cent under Vellanikkara codition.

28. Based on the experimental data, minimum data set for the validation of tomato model of the IBSNAT has been generated.

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Appendices

APPENDIX-I

Weather during crop growth period

Standard week	Max. temp.	Min. temp.	Sunhine hours	Morning relative humidity	Afternoon relative humidity	Wind speed (km/hr)	Rainfall (mm)	Evaporation (mm)
24	31.1	23.2	6.9	93	67	3.2	50.0	4.5
25	31.3	23.2	6.4	94	76	2.4	99.2	4.4
26	26.6	21.8	0.0	97	93	0.8	492.2	2.7
27	27.7	22.1	0.6	95	81	2.6	239.5	2.7
28	28.8	22.3	1.8	96	90	2.3	192.9	2.3
29	29.8	22.8	2.9	94	78	3.7	207.0	3.5
30	29.0	22.7	2.7	96	87	3.2	252.1	3.3
31	29.1	23.3	2.6	95	78	3.9	143.6	3.8
32	27.7	21.9	2.9	96	82	2.2	280.5	3.1
33	29.6	23.1	4.6	95	72	2.9	24.3	3.8
34	29.6	22.9	4.9	96	78	3.0	151.8	3.1
35	28.9	23.4	3.2	93	76	2.5	71.2	4.0
36	30.4	23.0	6.1	92	74	2.7	5.4	3.8
37	31.4	23.1	7.5	91	67	2.5	55.2	3.6
38	29.5	22.7	5.3	96	77	2.8	76.1	3.7
39	30.8	24.3	7.6	93	70	2.2	26.1	3.6
40	31.7	24.7	8.3	91	60	2.0	13.2	4.3
41	33.3	23.1	7.8	87	58	2.9	84.3	4.4
42	32.4	23.6	7.4	85	63	3.8	53.1	4.3
43	31.7	23.5	5.9	88	68	1.8	28.9	3.4
44	31.7	23.1	7.2	86	70	2.7	45.5	3.3
45	31.0	23.6	5.5	86	70	3.2	74.6	3.2
46	32.3	22.8	7.7	89	66	2.5	30.4	3.3
47	31.2	24.5	5.2	95	66	1.9	74.4	2.2
48	31.9	24.7	8.7	87	64	5.9	1.6	4.0
49	30.6	24.0	5.2	80	67	6.2	23.1	3.3
50	32.1	23.9	7.7	86	62	4.0	43.6	4.0
51	32.1	24.1	7.3	85	63	4.7	0	3.5
52	32.1	22.7	9.3	81	53	7.8	0	6.1
1	31.6	24.2	8.6	70	49	9.9	0	6.2
2	32.0	23.3	10.0	74	48	8.1	0	6.4
3	33.7	22.1	8.3	87	52	2.3	0	3.8
4	34.2	24.3	9.7	83	47	5.1	0	4.5
5	34.6	24.3	10.5	76	45	8.8	0	7.1
6	34.8	23.3	9.9	82	51	6.4	0	6.9
7	34.4	23.4	9.9	80	48	5.5	0	6.3
8	33.4	23.6	8.7	88	59	2.9	0	4.7
9	35.3	24.3	9.6	89	50	2.8	0	5.3
10	35.9	23.6	10.3	89	49	3.5	0	6.2
11	35.5	23.8	10.3	83	46	4.1	0	6.6
12	37.5	23.7	10.5	84	44	3.6	0	6.5
13	36.2	22.9	9.0	88	50	2.8	11.0	5.9
14	37.5	25.1	9.6	83	40	3.6	0	6.5
15	36.4	26.1	9.1	86	52	2.8	0	5.5
16	36.6	26.8	8.5	85	53	3.1	4.2	5.4
17	35.9	24.6	8.7	89	54	3.0	57.2	6.0
18	35.2	25.5	8.5	89	61	2.7	4.8	4.7

APPENDIX-II

Analysis of variance for plant height at 15 DAP, 30 DAP, 45 DAP and 60 DAP

Source	Degrees of freedom	Mean square			
		15 DAP	30 DAP	45 DAP	60 DAP
Replication	2	12.57	130.30	48.46	5.24
Date of planting	8	198.69*	526.05*	425.09*	205.41*
Error (a)	16	4.78	15.01	25.23	29.16
Varying levels of Nitrogen	1	9.80	10.67	2.67	40.91
Interaction	8	11.88	54.25	24.63	34.24
Error (b)	18	5.65	26.30	26.30	36.43

*Significant at 5% level

APPENDIX-III

Analysis of variance for the number of days to first flower emergence, days to 50 per cent flowering and time taken to first fruit set

Source	Degrees of freedom	Mean square		
		Days to first flower emergence	Days to 50% flowering	Time taken to first fruit set
Replication	2	0.30	0.13	0.02
Date of planting	8	29.23*	30.10	45.95*
Error (a)	16	0.48	0.30	0.71
Varying levels of Nitrogen	1	0.17	0.17	10.67*
Interaction	8	0.46	0.80	1.54*
Error (b)	18	0.54	0.57	0.33

*Significant at 5% level

APPENDIX-IV

Analysis of variance for the number of days to first harvest and last harvest

Source	Degrees of freedom	Mean square	
		Days to first harvest	Days to last harvest
Replication	2	1.41	0.24
Date of planting	8	188.80*	1090.16*
Error (a)	16	2.39	0.60
Varying level of Nitrogen	1	8.17	39.19*
Interaction	8	54.75*	2.94*
Error (b)	18	4.24	0.96

*Significant at 5% level

CROP WEATHER RELATIONSHIP IN TOMATO

(*Lycopersicon esculentum* Mill.)

By

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ABSTRACT OF A THESIS

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ABSTRACT

CROP-WEATHER RELATIONSHIP IN TOMATO (*Lycopersicon esculentum* Mill) VARIETY 'SAKTHI'

An experiment was conducted during 1997-98 at the College of Horticulture, Vellanikkara to study to influence of date of sowing and levels of nitrogen on the growth and yield of tomato (*Lycopersicon esculentum* Mill).

The experiment was laid out in split plot design with three replications. The treatment consisted of nine dates of planting starting from June 15th to February 15th in the main plot and two levels of nitrogen (125 kg N ha^{-1} and 75kg N ha^{-1}) in the subplot.

Observations on morphological, phenological and yield attributes were recorded during the course of investigation. The daily values of various weather elements recorded at the Agromet observatory, college of Horticulture, Vellanikkara were collected to work out the crop weather relationship.

February planted crop took less number of days for first flowering, 50 per cent flowering, and had the shortest crop duration. While June planting took maximum number of days for first and 50 per cent flowering. Where as maximum duration of the crop was recorded by planting in October.

December planting was significantly superior to other treatments with regard to yield characters. The maximum number of fruits per plant was obtained for December planting followed by October and November planting.

Application of 125 kg N ha^{-1} significantly improved the yield and yield characters as compared to that in 75 kg N ha^{-1}. Higher dose of nitrogen favoured the

earlier fruit set, maximum duration of the crop, increase in the number of fruits per plant and thus resulted in enhanced fruit yield.

The crop weather relationship studies showed that the morning relative humidity and afternoon relative humidity during the 1st-2nd weeks after planting had a positive effect on the days to first flowering. The minimum temperature (7th-8th week) and morning relative humidity (6th-7th week) were negatively correlated with yield. Days to first flowering showed a negative correlation with maximum temperature, minimum temperature, temperature range and hours of bright sunshine during the 1^{st}-2^{nd} weeks after planting..

The maximum temperature of (31.6°C-32.1°C) and minimum temperature of (24.1°C-24.3°C) found to be optimum for early flowering. Whereas minimum temperature of (22.1°C-23.3°C) and relative humidity during morning hours (70-74%) during 6^{th} and 8^{th} week after planting are optimum for the increase yield.

Under Vellanikkara condition, maximum temperature of 30.6°C-33.7°C, minimum temperature of 22.1°C-24.3°C, bright sunshine hours of 5.2-10.0, morning relative humidity of 70-86 per cent, afternoon relative humidity of 45-59 per cent is required for optimum crop growth.

Based on the experimental data, minimum data set for the validation of tomato model of the IBSNAT has been generated.

Result of the present experiment indicate that at Vellanikkara surrdounding tomato can be successfully raised if seedlings are planted in the middle of December. Weather during October and November are also congenial for getting higher yield. The higher dose of nitrogen (125 kg/ha) gave better yield than the recommended dose of nitrogen.