

EFFECTS OF THE ENVIRONMENT ON THE PERFORMANCE OF  
TOMATO (LYCOPERSICON ESCULENTUM MILL)  
IN THE NORTHERN GUINEA SAVANAH OF NIGERIA

BY

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A thesis submitted to the Postgraduate School,  
Ahmadu Bello University in partial fulfillment for the  
award of the Degree of Master of Science in Crop  
Physiology in the Department of Plant Science

February, 1987

DECLARATION

I hereby declare that this thesis is a documentation of my research findings. It has not been presented before in any application for a higher degree.

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Name and Signature of Candidate.

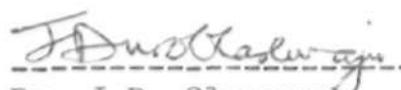
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CERTIFICATION

This thesis entitled "Effects of the environment on the performance of tomato (Lycopersicon esculentum Mill) in the northern guinea savanah of Nigeria" by Jacob Goke Bodunde meets the regulations governing the award of the Degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

  
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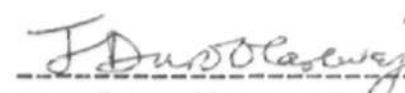
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DEDICATION

To late Chief Thomas Bodunde, a loving father.  
He would appreciate this work more than anyone else  
if he had lived to see it.

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ABSTRACT

Two sets of experiments were conducted with the broad objective of assessing the effects of some cultural practices on the reduction of temperature around tomato plants grown during hot periods in the Northern Guinea Savannah ecological zone of Nigeria. Each experiment was conducted at two locations in 1985 (Samaru, 11°11'N, 7°38'E, and Kadawa 11°39'N, 8°2'E) and one location (Kadawa) in 1986.

In the first experiment, three types of spatial arrangements were compared to ascertain what beneficial effects arrangement conferred on heat-stressed tomato plants. The results showed that plants arranged on both sides of the furrow or in a sunken bed had better growth, development, and yield than those on only one side of the furrow. Number of days from sowing to flowering and maturity were, however, not influenced by treatments.

In the second trial, the effect of a shade crop of maize on the micro-environment around tomato plants was studied. Shading depressed growth and development of tomato plants. Although a higher proportion of flowers set fruits under shade, fewer flowers were formed in the shade treatments than in the sole tomato treatment.

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CHAPTER 1

INTRODUCTION

The tomato plant (Lycopersicon esculentum Mill) is a member of the solanaceae family of flowering plants. The family embraces about 75 genera and over 2,000 species of plants which include peppers (Capsicum spp), tobacco (Nicotiana tabacum L), Irish potato (Solanum tuberosum L), and the garden egg (Solanum spp.). The tomato plant is native to the Peru-Ecuador area of South America but it is now cultivated in varying scales all over the world. The crop tolerates a range of climate though it has been classified as a warm season crop (Richard, 1967).

Tomato fruits can be eaten raw or cooked and can be processed into juice, ketchup, puree, paste and powder. The tomato is therefore an important industrial crop. Green fruits can also be used as preserves and pickles. In 1973, tomato assumed the position of one of the most important fruits in terms of world tonnage produced (about 33 million metric tons), being exceeded only by oranges, grapes and bananas. Europe and North America accounted for as much as 68% of the total hectareage and 77% of total world production (Anonymous, 1972).

In Nigeria, tomato is mainly cultivated in the Northern Guinea Savannah ecological zone between latitudes 10°N and 12°30' N. The average yield in these areas has been put at 25 metric tons/ha although given adequate management, yield of up to 37 metric tons/ha can be obtained (Anonymous, 1976). Tomato production trend in Nigeria shows a progressive increase in land area under its cultivation and total fruit production. Between 1961-65, average annual production in Nigeria was 186,000 metric tons which rose to about 225,000 tons between 1973-77 (Villareal, 1980). By 1980, production was as high as 400,000 metric tons (Anonymous, 1980). This increase in annual production was a result of increasing land area under cultivation and increase in yield per hectare (table 1).

Table 1. Tomato Production Trend in Nigeria

| Year    | Land Area Cultivated (ha) | Yield (kg/ha) | Production (Thousand Metric tons) |
|---------|---------------------------|---------------|-----------------------------------|
| 1967-71 | 22,000                    | 9,985         | 220                               |
| 1978    | 33,000                    | 10,152        | 335                               |
| 1979    | 35,000                    | 10,286        | 360                               |
| 1980    | 38,000                    | 10,526        | 400                               |

Source - F.A.O. Production Year Book Vol. 34 (1980).

The relatively low level of tomato production in Nigeria over the years is due to both managerial and environmental factors. Quinn (1971) observed that tomatoes transplanted during the months of January - April in the Northern Guinea Savannah had uneconomical yields due mainly to high temperature. If temperature could be modified close to optimum (26/16°C day/night) during this same period, tomato production could be made profitable because of the low incidences of leaf spot diseases and fruit rotting.

There is very little information available on the use of crop spatial arrangements and crop shelter to reduce the deleterious effects of high temperatures on crops. Blackman and Wilson (1951) reported that shading tomato plants to about 50% full day light reduced growth only slightly. Marshall (1967) pointed out that shelter shade modifies environmental temperature, and yields of some crops could be greater when sheltered.

This study explores the suitability of some spatial arrangements and use of crop shelter in modifying the micro-environment of tomatoes grown during hot seasons.

## CHAPTER 2

### REVIEW OF LITERATURE

#### 2.1. Plant-Environment Interaction:

The environment of the plant comprises soil around its root zone and the above ground surrounding of the shoot. According to Bannister, (1976), the interaction between plants and the environment is complex, the physical environment determines the plant that grows and the plants influence the physical environment.

Certain environmental factors can limit growth or actively regulate it by selective or specific action affecting growth processes like seed germination, bud dormancy and growth, flowering and fruit set. Chu et al (1974) pointed out that the interaction between the effects of temperature extremes and tissue water potential, on growth and metabolism of plants is complex. It is, however, clear that supra-optimal temperatures result in rapid transpiration and lowering of tissue water potential of plant.

Some plants have the ability to survive extremes of temperature without suffering permanent injury. Such plants are said to be temperature resistant. The temperature resistance of a plant results from the ability of the protoplasm to tolerate cold or heat (tolerance) and the effectiveness of the mechanism aimed at delaying and preventing temperature damage or injury (avoidance).

These two mechanisms make up the temperature resistance of a plant and it is summarised as, Resistance = Avoidance + Tolerance (Larcher, 1973).

## 2.2. Temperature and Growth:

The tomato plant tolerates a range of (environmental) temperatures though it requires a fairly precise optimum for its maximum growth. Went (1957) recorded the fastest growth rate in tomato seedlings at a day temperature of 26°C and night temperature of 20°C. With day/night temperatures of 23°C/17°C, growth rate was slow but plants were more sturdy.

Hussey (1964) worked on tomato plants under a controlled environment and observed that dry matter accumulation was maximum at 26°C. Opinions differ as to which of shoot and root temperature influences growth more. It was reported by Went (1944) that growth rate of tomato is influenced mainly by shoot temperature and that root temperature is only important when other root environmental factors are sub-optimal. A similar observation was made by Shishido and Hori (1980). They worked with day/night air (shoot) temperatures of 24°C/17°C, 17°C/12°C and reported that growth rate of the tomato plant was slower at the low shoot temperature (17°C/12°C) irrespective of three root temperatures. This suggests a greater role of shoot temperature in growth rate.

Some other workers concentrated their efforts mainly on determining optimum root temperature for optimum growth. Lingle and Davis (1959) observed maximum growth rate of young tomato plants at soil temperature between 26.7 - 29.4°C, and Boxall (1962) reported that young tomato plants had their maximum growth rate at soil temperature of 25°C.

Specific effects of shoot and root temperatures were reported by Phatak et al. (1966). They explained that shoot temperature determines the position of the first inflorescence (as to number of nodes before flowering) because shoot temperature of 10-13°C reduced the number of nodes before first inflorescence as compared to 16-21°C. Conversely, with root temperature of 10-13°C, the number of flowers per inflorescence was greater than at 16-21°C.

Similarly, the different effects of day and night temperatures have been explained. Went (1957) reported that 80-90% of plant growth takes place at night. Night temperature influences the number of leaves the tomato plant produces before first inflorescence (a function of earliness) and the number of flowers per inflorescence (a function of crop size or yield) (Huxley, 1962). He explained that night temperature lower than optimum reduces the number of leaves before first inflorescence (enhances earliness) and induces high number of flowers per inflorescence (High crop size). The corollary can

therefore be true that high night temperature delays maturity (First harvest) and reduces yield.

### 2.3. Temperature and Stem Growth:

Went (1957) reported that the rate of stem elongation in tomato plant is night temperature dependent, and Abdel-Rahman et al. (1957) observed slow growth rate of tomato plant stem under low night temperature. A decrease in night temperature from 25.3°C to 9.2°C with constant day temperature resulted in 63% reduction in shoot weight. The rate of stem elongation is often used to express the growth intensity of plants, and stem growth has been found to be dependent on environmental temperature. Ting (1982) stated that linear measurements of stem growth are ordinarily good indications of growth of the entire plant since growth is always co-ordinated.

### 2.4. Temperature and Leaf Growth:

Leaves, as the major source of photosynthates in the plant are indices of photosynthetic potential and they can affect the plant's net assimilation rate. Lang (1952) explained that leaf count can be used as an index of the amount of vegetative growth before flowering.

In the tomato plant, the number of leaves produced, especially before first flowering, is influenced by the prevailing temperature. Roodenbourg (1947) recorded low number of leaves before flowering in tomatoes grown under lower (unspecified) day and night temperatures.

Calvert (1957) made a similar observation at 26°C/15°C (High/Low) and explained that the means of the day and night temperature is the determining factor. He noted inter-varietal differences in number of leaves before first inflorescence. Phatak et al (1966) also observed fewer number of leaves before first flowering in tomatoes grown under low temperatures of 10-13°C.

#### 2.5. Temperature and Flowering:

The process of flower formation in the tomato has been variously reported as being influenced by the prevailing environmental temperature (Went 1944, Learner and Wittwer 1953, Wittwer 1963). The flowering process can be induced, delayed or modified by both day and night temperatures. The modification can take a number of forms ranging from varying the number of days from sowing to anthesis, number of flowers per inflorescence, to induction of flower abortion. Each of these forms of heat effects had been observed by various workers. Huxley (1962) indicated that night temperature affects especially the number of flowers per inflorescence of tomato plants. Whereas high night temperature (above 18°C) results in increased number of flower per inflorescence, low night temperature (14-18°C) reduces the number. But Phatak (1967) emphasised that the flower number per inflorescence is solely influenced by the root temperature because a low range of root temperature (10-13°C) resulted in more number of flowers per inflorescence when compared with a range of 15-20°C.

Lewis (1953) subjected tomato seedlings to three temperature regimes of 14°C, 25°C, and 30°C immediately after cotyledon expansion and observed that the lowest temperature, (14°C), gave the highest number of flowers per inflorescence. In the opinion of Calvert (1957) the number of flowers per inflorescence is greatly affected by the prevailing temperature between the 9th and 15th day after cotyledon expansion.

#### 2.6. Floral Development:

Studies have shown that temperature, among other environmental factors, influences the morphology and development of floral parts in tomato. This is the most likely explanation for yield differences between seasons. Iwahori and Takahashi (1964) subjected tomato plants to daily 3 hour period of 40°C and observed that the flowering process was most sensitive to this temperature 5-9 days before anthesis, and up to 2 days after anthesis. This is the period of active meiosis in the anther. It was suggested that this temperature must have affected only the stamen because plants grown under the same temperature but hand-pollinated with normal pollen set fruits normally.

In agreement with the foregoing authors, Fugishita (1970) reported that the period of temperature sensitivity is between 10-18 days before anthesis, a period which includes meiotic and premeiotic phases of anther development. However, the pistillate flower could also be

affected by extremes of temperature. Smith (1932) observed abortion of embryo sac in tomato plants grown at 36.7°C in the field. This was due to lack of fertilisation caused by slow growth of the pollen tube and heat sensitivity of the ovule. He also observed ovule degeneration at that temperature which he explained was largely due to failure of fertilisation.

Much as it is established that high temperature affects both pollen germination and ovule development, opinions vary as regards optimal temperature for pollen germination and pollen tube growth. For example, Calvert (1964) put it about 27.5°C, Torfs (1967) and Dempsey (1970) put it at 25°C while Abdalla and Verkerk (1968) reported 27°C. The variation between estimates of the different authors might be due to differential heat tolerance ability of the different cultivars used, among other things.

#### 2.7. Floral Morphology:

High temperature effects on floral morphology in tomatoes have been variously reported (Howlet 1934, 1939, Johnson and Hull 1953). Morphological disorders have an adverse effect on both pollination and fertilization. According to Howlet (1939), the length of the tomato flower pistil in relation to the stamen is influenced by high temperature. The pistil is normally supposed to be positioned under the staminal cone, but under certain conditions, the pistil can malform such that the stigma

is placed well above the anther. This phenomenon is termed "Pistil Extrusion" and it renders self-pollination difficult, tomato is mainly self-pollinated with only about 14-25.7% outcrossing (Rick 1958).

#### 2.8. Floral Abscission:

A large degree of observed poor fruit set in tomatoes under high temperature can be due to flower abscission. Floral abscission can occur at any stage of development from flower bud formation to post-anthesis (Shelby, 1975). Flower abscission has been differentiated from flower abortion (Olaewaju, 1980). Flowers that stopped growing and fail to reach anthesis are said to be "aborted", while flowers that drop after anthesis are said to be "abscised". The phenomenon of flower abscission had been variously referred to as "blossom drop" (Radspinner, 1922), "June drop" (Went and Carter, 1948), "Flower drop" (Saito and Ito, 1967) and "Post-anthesis shedding" (Olaewaju, 1980).

Floral abscission is not necessarily a case of infertility because Leopold and Scott (1952) were able to obtain normal fruit development in naturally abscised flowers which they hand-pollinated, and they concluded that abscised flowers are potentially fertile. Physiological explanations have been given for general abscission phenomenon because it is influenced by other organs of plants. It is usually preceded by the creation of an abscission layer at the base of the

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organ involved. For example, in leaves, abscission layer is created across the petioles where the leaves later sever. According to Salisbury and Ross (1969), abscisic Acid, (ABA), is secreted when plants are exposed to injury, disease and environmental stresses.

#### 2.9. Temperature and Fruit Set:

Varieties with ability to set fruits under temperature stress are essential for tomato production in the tropics. Night temperature is said to be more critical than day temperature for tomato fruit set and fruits will only set under a limited range of night temperature of 15-20°C (Went, 1944, 1949). It was also observed in sweet pepper (Olareswaju, 1980) that high night temperature results in low fruit set as a result of increased post-anthesis flower shedding. Experience at the Asian Vegetable Research and Development Centre (AVRDC), Taiwan, shows that under natural conditions, both day and night temperatures could affect fruit setting process (Villareal, 1980). Out of the 4,600 tomato accessions screened at the AVRDC, only 39 were found to have heavy fruit set under high (unspecified) day and night temperatures. Villareal (1980) pointed out that the physiological basis of tolerance of the cultivars varies, while some have high ovule and/or pollen viability, others possess high pollen production ability and resistance to extrusion.

Ten cultivars were grown under high night temperature by Schaible (1962) and only two set fruits at night temperatures between 22.8-26.7°C. The other cultivars could only set fruits when night temperature was between 13.9-16.7°C. A similar report was made by Huxley (1962) who observed that no fruit would set in most tomato cultivars when night temperature was higher than 22°C. Shelby (1975) worked on 3 cultivars of tomato and concluded that significant differences occur in their ability to set fruit naturally under high temperature.

Amans *et al.* (1986) reported significant differences in yields of tomato cultivars transplanted in February in the guinea savannah zone of Nigeria. They observed superior performance in a line characterised by large fruit size and prolific habit.

Reasons for varietal differences in ability to thrive and set fruits under high temperature are not yet clear. Some authors give physiological reasons, others explained it with purely genetic reasons. Johnson and Hull (1953) reported that varietal differences in fruit set ability under heat stress were due to either difference in the ability to activate auxin or difference in the ability to resist auxin destruction by heat. Giving genetic reasons, Powers *et al.* (1950) opined that the high fruit set ability of the tomato cultivar

"Porter" was determined by 4 major gene pairs, and that one pair, of the four, had an effect as great as the other three put together. But Salvioli (1963) had a contrasting opinion as he observed that the ability of fruit set under heat stress was determined by a simple recessive gene.

More recently, a yet different genetic reason was adduced by Shelby (1975) who explained that fruit set ability under heat is controlled by one dominant gene with minor modifiers, and that the observed differences between varieties are due to genetic reasons unrelated to pollination and fertilization.

The complex nature of heat tolerance ability, however, suggests a polygenic inheritance. This has been suspected by some of the early workers on this topic (Went, 1957, Schaible, 1962).

Certain varietal characteristics have also been linked with heat tolerance ability in tomatoes and the relationship is either by genetic linkage or pleiotropy. For example, Mullison and Mullison (1948) indicated that determinate cultivars are superior to indeterminate under heat.

CHAPTER 3

RESEARCH PROCEDURES

3.1. Experiments and objectives

Two sets of experiments were conducted at two locations (Samaru, 11°11'N, 7°38'E, and Kadawa, 11°39' N, 8°2'E) in the 1984/85 dry season, and at one location (Kadawa) in the 1985/86 dry season. Experiment I was to examine the effect of microclimate created by three types of spatial arrangements on the performances of two cultivars of tomato, (Ife 1 and Harvester) grown during hot periods. Experiment II was aimed at assessing the possible cooling effect of maize, (Zea mays cv. Western yellow), as a shade crop, on the growth and yield of tomato cultivar Roma VF grown in a hot environment.

3.2. Experiment 1

3.2.1. Experimental procedure

Seeds of tomato cvs. Ife 1 and Harvester were sown at Samaru on 17 January 1985 and at Kadawa on 15 January 1985 in the first year, and on 20 January 1986 at Kadawa in the second year. Following recommended nursery management practices, seedlings were transplanted 4 weeks after sowing in all cases.

3.2.2. Description of cultivars

The two tomato cultivars used have been described by Quinn (1980). They are both determinate in habit. Ife 1 is early maturing while Harvester is medium-to-late maturing.

### 3.2.3. Experimental Design

The design was a 3 x 2 split plot factorial, with spatial arrangements as the main treatments and cultivars as the sub-treatments.

There were 3 spatial arrangements coded thus:-

- A1 - Planting along single sides of water lines of ridges.
- A2 - Planting on both sides of water lines of ridges
- A3 - Planting on sunken beds.

The two tomato cultivars were coded as:-

- C1 - Ite 1
- C2 - Harvester.

There were 3 replications and sub-plot size was 6 x 2m with spacing at 50 cm between plants in a row and 60 cm between ridges. Crops were irrigated once a week throughout their field life.

### 3.2.4. Fertilizer Application

There was a basal application of a compound fertilizer (N.P.K. 15-15-15) in all cases during land preparation at the rate of 300 kg/ha. Growing plants were top-dressed with Calcium Ammonium Nitrate (C.A.N. 26% N) at the rate of 250 kg/ha applied in two split doses at 3 and 6 weeks after transplanting.

### 3.2.5. Data Collection

Data were collected on a total of 13 parameters. Data collected on the field were based on 10 plants

randomly selected in the 2 mid-rows of each plot. The various parameters are:-

- (i) Plant Height - Taken as the length of the shoot apex of main axis of a plant to the ground level, measured with a meter rule. Measurement was made weekly from 4 weeks after transplanting till first harvest (8 weeks after transplanting).
- (ii) Number of Leaves - Weekly counts of the number of leaves per plant were made for 5 weeks starting from 4 weeks after transplanting.
- (iii) Leaf Area - Leaf areas of selected plants per plot were measured at 7 weeks after transplanting (peak of vegetative growth) using a planimeter in 1985. In the 1986 experiment, it was not measured because of limitations faced in the absence of a planimeter.
- (iv) Number of Branches - The number of primary branches per plant was recorded at first harvest (maturity).
- (v) Number of Leaves before flowering - Taken as the number of leaves per plant on the day visible evidence of flowering was noticed.
- (vi) Number of flowers - Number of flowers was recorded weekly from first flowering to maturity.
- (vii) Number of fruits - The total number of mature fruits (marketable and unmarketable) set per plant was recorded.
- (viii) Percentage flowers resulting in fruit set - The proportion of the total flowers that resulted in fruits taken as a percentage. This was calculated as follows:

$$\frac{\text{Fruit per plant}}{\text{Flowers per plant}} \times \frac{100}{1}$$

- (ix) Fruit Diameter - The mean of Veneer calliper readings of top, middle and bottom diameters of 5 randomly selected fruits per plot, taken in centimeters.
- (x) Fruit Length - Mean length of 5 randomly selected fruits per plot.
- (xi) Days to 50% flowering - Number of days from sowing to the day 50% of plants in a plot showed anthesis.
- (xii) Days to Maturity - Number of days from sowing to the day of first harvest, that is, when fruits show visible signs of ripeness.
- (xiii) Total fruit yield - Cumulative fresh weight of harvested marketable fruits expressed in kg/plant.

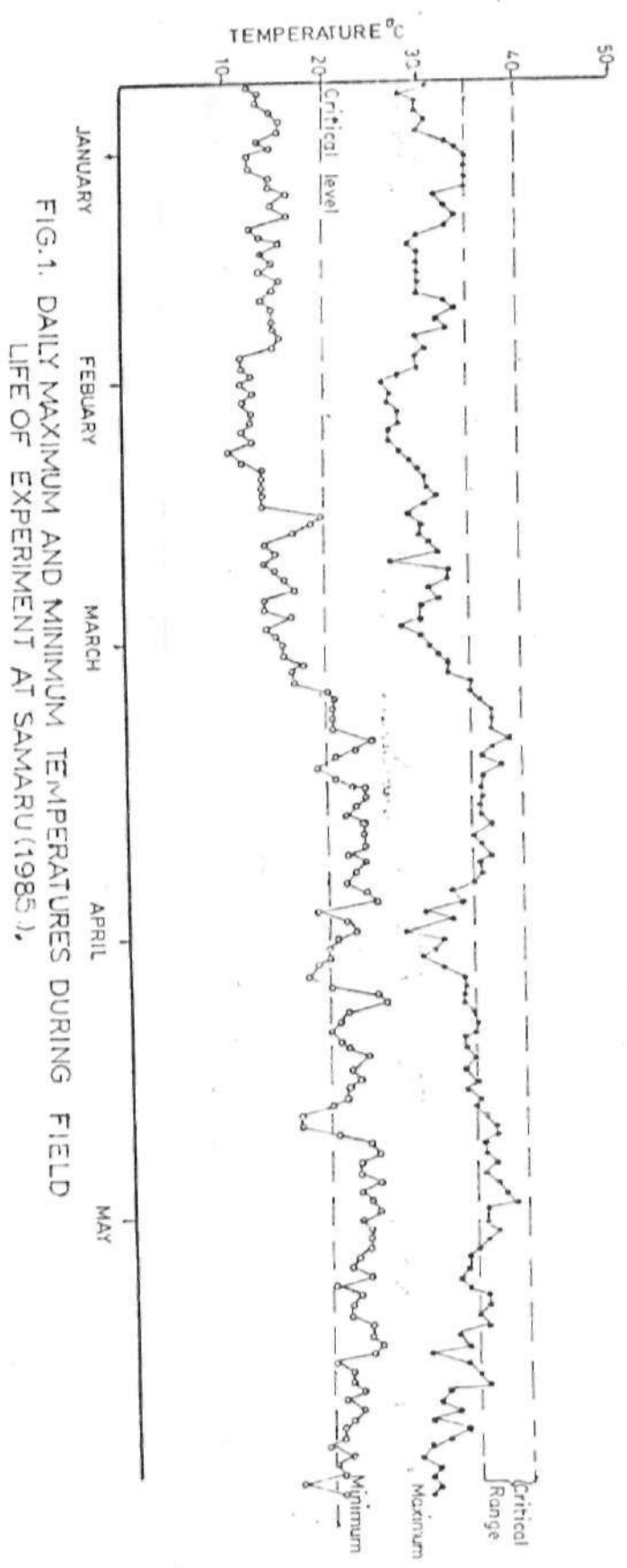
#### 3.2.6. Temperature Data

Daily records of maximum and minimum air temperatures were taken for the periods of the experiments (Figures 3.3). Data were taken at meteorological stations about 1 km and 0.3 km away from experimental sites at Samaru and Kadawa respectively.

#### 3.2.7. Statistical Analysis

Split plot analysis of variance was done on the parameters taken to draw inferences. The form of analysis of variance for each parameter was based on the following sketch:-

Samaru 1985



KADAWA 1985

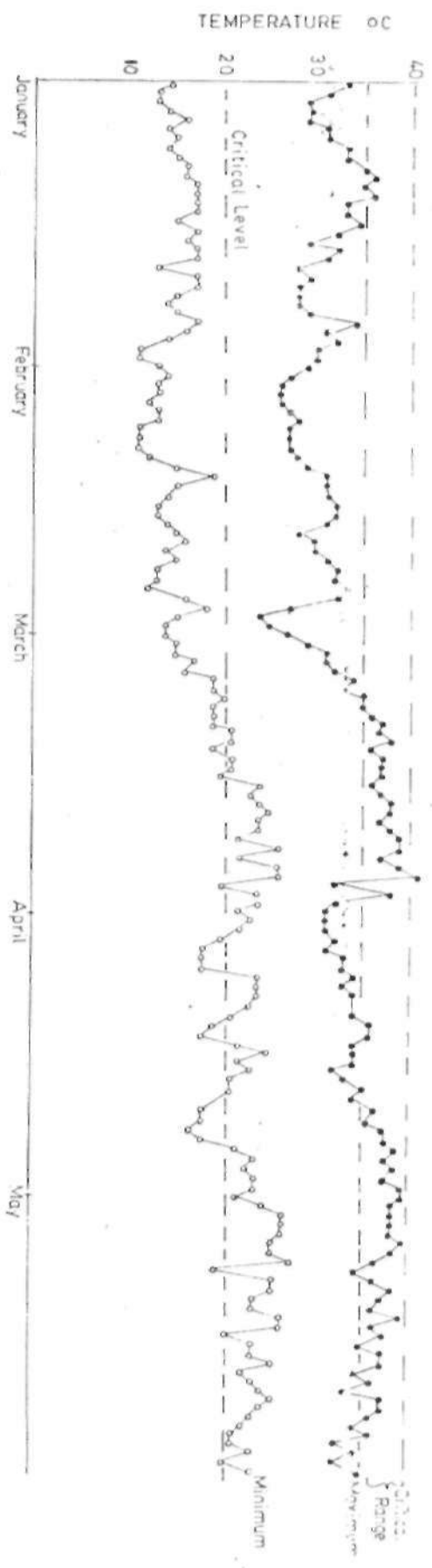


FIG. 2: DAILY MAXIMUM & MINIMUM TEMPERATURES DURING  
FIELD LIFE OF EXPERIMENT AT KADAWA (1985)

KADAWA 1986

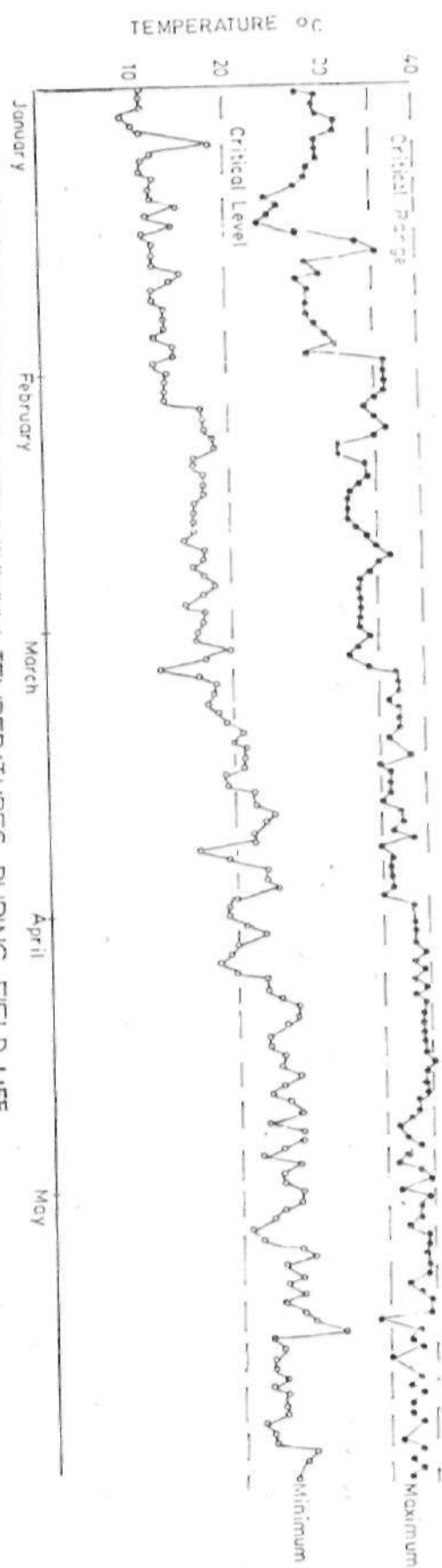


FIG. 3 : DAILY MAXIMUM AND MINIMUM TEMPERATURES DURING FIELD LIFE OF EXPERIMENT AT KADAWA(1986).

| Sources of variation | d.f.          |
|----------------------|---------------|
| Total                | $rab - 1$     |
| Replication          | $r - 1$       |
| Factor "A"           | $a - 1$       |
| Error 'a'            | $(a-1)(r-1)$  |
| Factor 'B'           | $b-1$         |
| AB Interaction       | $(a-1)(b-1)$  |
| Error 'b'            | $a(b-1)(r-1)$ |

### 3.3. Experiment II

3.3.1. Nursery - Seeds of tomato cultivar Roma Vf were sown at Samaru and Kadawa on 17 January 1985 and 15 January 1985 respectively and on 20 January 1986 at Kadawa. Adequate nursery care was given until seedlings were transplanted.

3.3.2. Transplanting - Seedlings were transplanted 4 weeks after sowing at Kadawa and 5 weeks after sowing at Samaru. Maize, (Zea mays) Cv. Western Yellow, was planted 4 weeks before transplanting at each location.

3.3.3. Experimental Design - In both locations, the design was a Randomised Complete Block (RCB) with 4 replicates. There were 5 treatments, viz:-

- A - 2 rows of maize with a row of tomato in-between
- B - 1 row of maize between 2 rows of tomato
- C - 2 rows of maize with 2 rows of tomato in-between

- D - Maize-tomato mixture on same rows
- E - Sole tomato but planted on both sides of ridge to give a full canopy cover.

Figure 4 illustrates the relative tomato-maize mixtures.

3.3.4. Plot size - Because of the variation in land space required by the different treatments, plot sizes varied. Sizes ranged from 6 x 2 m to 6 x 4 m. All data were therefore collected on per plant basis.

3.3.5. Spacing - Spacing for maize in all cases was 75 cm intra ridges. Inter-ridge spacing was 60 cm.

Tomato spacing was 50 cm intra-ridge except in treatment D where each tomato plant was between two maize stands.

3.3.6. Fertilizer Application - The land used was base dressed with N.P.K. (15-15-15) at the rate of 300 kg/ha. The maize plants received a further dose of N.P.K. (15-15-15) at tasselling stage at the rate of 150 kg/ha. The tomato plants were top-dressed with Calcium Ammonium Nitrate (C.A.N., 26% N) at the rate of 250 kg/ha in two split doses of 125 kg/ha each at 3 and 6 weeks after transplanting.

3.3.7. Data Collection - This was done as in Experiment

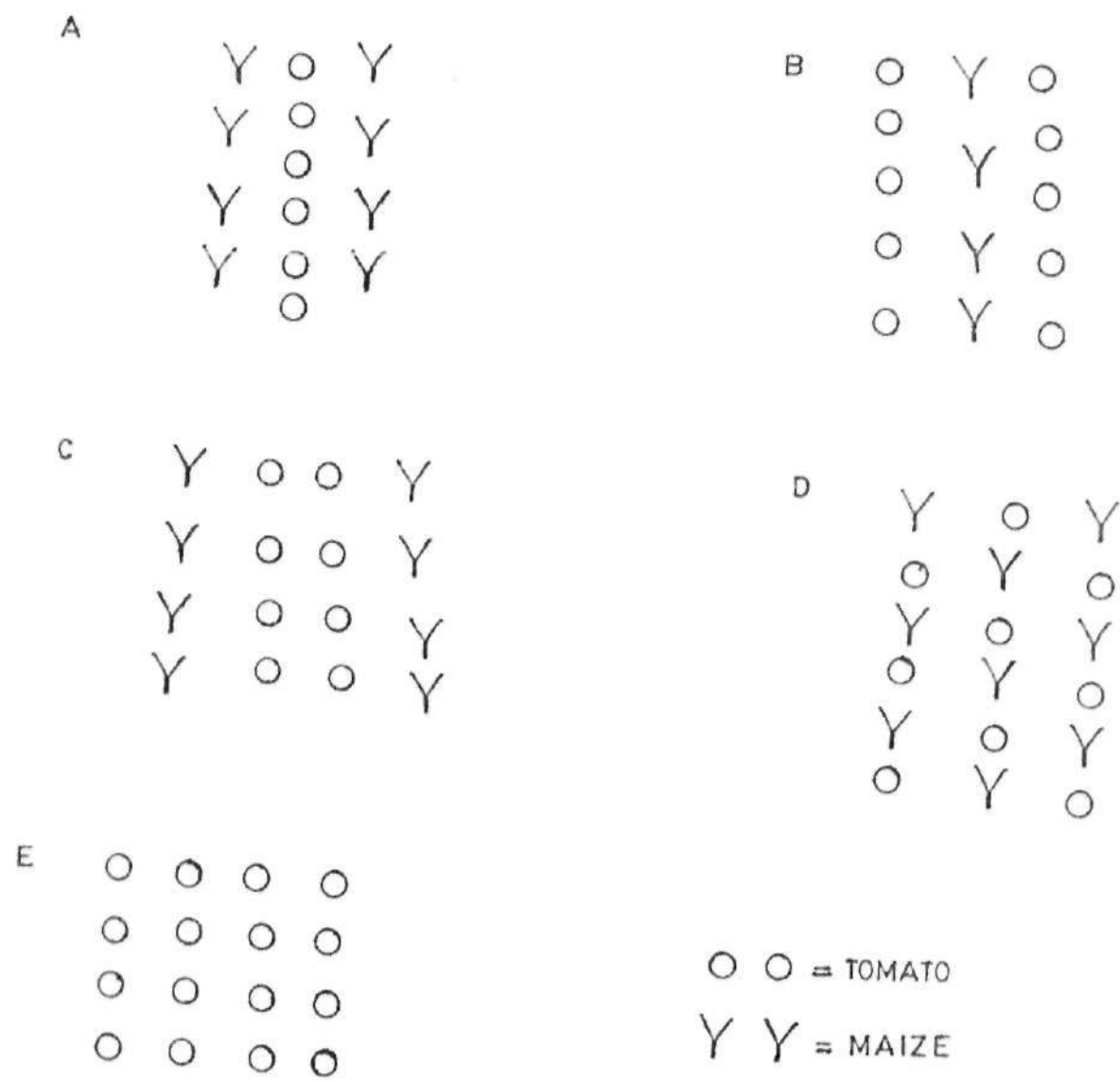


FIG. 4: REGIMES OF MAIZE SHADE

3.3.8. Statistical Analysis - Analysis of variance (ANOVA) was done for the same parameters as in Experiment I.

## CHAPTER 4

### RESULTS

#### 4.1. Experiment I

##### 4.1.1 Leaf formation, Leaf Area and Leaves at Flowering

The records of the number of leaves per plant in all the experiments are shown in appendix tables 1 and 2. The rate of leaf formation was initially slow, increasing sharply between 5-8 weeks after transplanting. There was no significant difference in the number of leaves per plant under the different arrangements throughout the period of measurement. Leaf area per plant 7 weeks after transplanting did not differ significantly for each cultivar under different arrangements in the 1985 experiments as shown in tables 2 - 5.

The number of leaves per plant at the onset of flowering was within a narrow range in all the experiments. This is indicated for each cultivar and each experiment in tables 2 - 7. At Samaru in 1985, it was 6 - 7 leaves while it was 8 - 10 and 6 - 9 at Kadawa in 1985 and 1986 respectively.

4.1.2. Flower formation: The total number of flowers set per plant under the different arrangements was not statistically different in all the experiments (Tables 2 - 7). Weekly monitoring of flower formation for 5 weeks showed that there was a progressive increase in the cumulative number of flowers produced up to 8 weeks

Table 2: Effects of 3 Spatial Arrangements on Growth, Yield and Yield Related Parameters on Tomato cv Life 1 grown during hot seasons in Senegal (1985)

| Character                                    | A1    | A2    | A3    | S.E.D. | L.S.D.<br>(P=0.05) |
|----------------------------------------------|-------|-------|-------|--------|--------------------|
| Yield (kg/plant)                             | 0.29  | 0.39  | 0.57  | 0.18   | n.s.               |
| Number of Fruits/plant                       | 14    | 26    | 36    | 4.50   | 12.51              |
| Highest number of Flowers/plant              | 54    | 67    | 66    | 10.31  | n.s.               |
| % Flowers Resulting in Fruit set             | 25.93 | 38.81 | 54.55 | 3.03   | 7.42               |
| Fruit Diameter (cm)                          | 3.30  | 4.38  | 3.89  | 0.14   | n.s.               |
| Fruit Length (cm)                            | 3.82  | 3.96  | 3.86  | 0.14   | 0.39               |
| Plant Height (cm) at first Harvest           | 44.30 | 44.90 | 40.43 | 3.59   | n.s.               |
| Branches/Plant at first Harvest              | 10    | 9     | 9     | 0.92   | n.s.               |
| No. of Leaves at Flowering                   | 7     | 7     | 6     | 0.51   | n.s.               |
| Leaf Area per plant 7 WAT (cm <sup>2</sup> ) | 1196  | 875   | 1768  | 492.85 | n.s.               |
| Days to 50% Flowering (AS)                   | 45    | 50    | 47    | 4.31   | n.s.               |
| Days to Maturity (AS)                        | 109   | 105   | 102   | 2.86   | n.s.               |

A1 - Planting in single water lines. A2 - Planting in double water lines.

A3 - Planting in sunken beds W.A.T. - Weeks after Transplanting

A.S. - After sowing. n.s. Not significant.

Table 3: Effects of 3 Spatial Arrangements on Growth, Yield and Yield-Related Parameters on Tomato cv. Harvester grown during hot seasons in Samaru (1985)

| Character                                    | A1                                   | A2    | A3    | S.E.D. | L.S.D.<br>(P=0.05) |
|----------------------------------------------|--------------------------------------|-------|-------|--------|--------------------|
| Yield (kg/plant)                             | 0.18                                 | 0.59  | 0.33  | 0.18   | n.s.               |
| Number of Fruits/plant                       | 12                                   | 27    | 28    | 4.50   | 12.51              |
| Highest Number of Flowers/Plant              | 50                                   | 65    | 71    | 10     | n.s.               |
| % Highest Flowers Resulting in Fruit Set     | 24.00                                | 41.54 | 39.44 | 3.03   | 7.42               |
| Fruit Diameter (cm)                          | 2.28                                 | 2.57  | 2.50  | 0.14   | n.s.               |
| Fruit Length (cm)                            | 4.80                                 | 5.06  | 6.28  | 0.14   | 0.39               |
| Plant Height (cm) at First Harvest           | 39.53                                | 38.53 | 35.20 | 3.59   | n.s.               |
| Branches/Plant at First Harvest              | 10                                   | 10    | 10    | 0.92   | n.s.               |
| Number of Leaves at Flowering                | 7                                    | 6     | 6     | 0.51   | n.s.               |
| Leaf Area per Plant 7 WAT (cm <sup>2</sup> ) | 658                                  | 1248  | 1099  | 492.85 | n.s.               |
| Days to 50% Flowering(AS)                    | 54                                   | 50    | 50    | 4.31   | n.s.               |
| Days to Maturity (AS)                        | 107                                  | 105   | 107   | 2.86   | n.s.               |
| A1 - Planting in single water lines.         | A2 - Planting in double water lines. |       |       |        |                    |
| A3 - Planting in sunken beds                 | W.A.T.- Weeks after transplanting    |       |       |        |                    |
| A.S.- After sowing                           | n.s. - Not significant.              |       |       |        |                    |

Table 4: Effects of 3 Spatial arrangements on Growth, Yield and Yield-Related Parameters on Tomato cv. Life 1 grown during hot season in Kadawa (1985)

| Character                                    | A1    | A2    | A3    | S.E.D. | L.S.D.<br>(P=0.05) |
|----------------------------------------------|-------|-------|-------|--------|--------------------|
| Yield (kg/Plant)                             | 0.31  | 0.34  | 0.48  | 0.20   | n.s.               |
| Number of Fruits/plant                       | 17    | 19    | 33    | 1.60   | 4.44               |
| Highest Number of Flowers/Plant              | 62    | 63    | 64    | 6.68   | n.s.               |
| % Flowers Resulting in Fruit Set             | 27.42 | 30.16 | 51.56 | 0.75   | 2.07               |
| Fruit Diameter (cm)                          | 3.90  | 4.43  | 4.10  | 0.08   | 0.23               |
| Fruit Length (cm)                            | 3.89  | 4.10  | 3.75  | 0.24   | n.s.               |
| Plant Height (cm) at First Harvest           | 66.83 | 68.30 | 66.80 | 3.14   | n.s.               |
| Branches/Plant at First Harvest              | 8     | 10    | 11    | 1.59   | n.s.               |
| Number of Leaves at Flowering                | 9     | 8     | 8     | 1.10   | n.s.               |
| Leaf Area Per Plant 7 WAT (cm <sup>2</sup> ) | 1258  | 1371  | 1360  | 114.26 | n.s.               |
| Days to 50% Flowering (AS)                   | 44    | 43    | 43    | 1.80   | n.s.               |
| Days to Maturity (AS)                        | 105   | 101   | 104   | 4.86   | n.s.               |

A1 - Planting in single water lines. A2 - Planting in double water lines.

A3 - Planting in sunken beds W.A.T. - weeks after transplanting.

A.S. - After sowing n.s. - Not significant.

Table 5: Effects of 3 Spatial arrangements on Growth, Yield and Yield Related Parameters on Tomato cv Harvester grown during hot season in Kadapa (1985)

| Character                                    | A1    | A2    | A3    | S.E.D. | L.S.D.<br>(P=0.05) |
|----------------------------------------------|-------|-------|-------|--------|--------------------|
| Yield (kg/plant)                             | 0.17  | 0.39  | 0.30  | 0.20   | n.s.               |
| Number of Fruits/plant                       | 18    | 30    | 27    | 1.60   | 4.44               |
| Highest Number of Flowers/Plant              | 70    | 70    | 70    | 6.68   | n.s.               |
| % Flowers Resulting in Fruit Set             | 25.71 | 42.86 | 38.57 | 0.75   | 2.07               |
| Fruit Diameter (cm)                          | 2.63  | 2.80  | 2.83  | 0.08   | n.s.               |
| Fruit Length (cm)                            | 5.80  | 6.20  | 6.34  | 0.24   | n.s.               |
| Plant Height (cm) at First Harvest           | 67.23 | 66.53 | 66.33 | 3.14   | n.s.               |
| Branches/Plant at First Harvest              | 9     | 10    | 11    | 1.59   | n.s.               |
| Number of Leaves at Flowering                | 10    | 9     | 8     | 1.10   | n.s.               |
| Leaf Area per Plant 7 WAT (cm <sup>2</sup> ) | 1508  | 1385  | 1872  | 114.26 | n.s.               |
| Days to 50% Flowering(A.S)                   | 46    | 46    | 49    | 1.80   | n.s.               |
| Days to Maturity (A.S)                       | 113   | 104   | 104   | 4.86   | n.s.               |

A1 - Planting in single water lines.

A2 - Planting in double water lines.

A3 - Planting in sunken beds

W.A.T.- Weeks after transplanting.

A.S.- After sowing

n.s.- Not significant.

Table 6: Effects of 3 Spatial Arrangements on Growth, Yield and Yield Related Parameters on Tomato cv Life 1 grown during hot seasons in Katsina (1986)

| Character                             | A1                                   | A2    | A3    | S.E.D. | L.S.D.<br>( $\bar{r}=0.05$ ) |
|---------------------------------------|--------------------------------------|-------|-------|--------|------------------------------|
| Yield (kg/plant)                      | 0.33                                 | 0.38  | 0.38  | 0.03   | n.s.                         |
| Number of Fruits/plant                | 9.88                                 | 16.13 | 18.58 | 1.40   | n.s.                         |
| Highest Number of<br>Flowers/plant    | 71.27                                | 72.10 | 68.57 | 12.43  | n.s.                         |
| % Flowers Resulting in<br>Fruit Set   | 13.72                                | 23.02 | 21.85 | 6.16   | n.s.                         |
| Fruit Diameter (cm)                   | 3.60                                 | 3.54  | 3.44  | 0.18   | n.s.                         |
| Fruit Length (cm)                     | 4.63                                 | 3.77  | 3.72  | 0.37   | n.s.                         |
| Plant Height (cm) at<br>First harvest | 47.27                                | 52.67 | 47.40 | 2.27   | n.s.                         |
| Branches/plant at first<br>harvest    | 9.00                                 | 6.53  | 9.33  | 0.48   | n.s.                         |
| Number of Leaves at<br>Flowering      | 7.83                                 | 7.33  | 6.93  | 0.16   | n.s.                         |
| Days to 50% Flowering (AS)            | 53.00                                | 47.67 | 53.33 | 2.87   | n.s.                         |
| Days to Maturity (AS)                 | 100.00                               | 95.67 | 95.67 | 1.59   | n.s.                         |
| A1 - Planting in single water lines   | A2 - Planting in double water lines. |       |       |        |                              |
| A3 - Planting in sunken beds          | W.A.T. - Weeks after transplanting   |       |       |        |                              |
| A.S. - After sowing                   | n.s. - Not significant.              |       |       |        |                              |

Table 7: Effects of Spatial Arrangements on Growth, Yield Related Parameters on Tomato cv Harvester grown during hot seasons in Kaduna (1986)

| Character                          | A1     | A2     | A3    | S.E.D. | L.S.D.<br>(P=0.05) |
|------------------------------------|--------|--------|-------|--------|--------------------|
| Yield (kg/plant)                   | 0.21   | 0.31   | 0.32  | 0.03   | n.s.               |
| Number of Fruits/plant             | 11.60  | 16.16  | 16.74 | 1.40   | n.s.               |
| Highest Number of Flowers/plant    | 62.43  | 65.73  | 61.60 | 12.43  | n.s.               |
| % Flowers Resulting in Fruit Set   | 18.42  | 26.61  | 29.90 | 6.16   | n.s.               |
| Fruit Diameter (cm)                | 2.35   | 2.25   | 2.34  | 0.18   | n.s.               |
| Fruit Length (cm)                  | 5.16   | 4.91   | 5.13  | 0.39   | n.s.               |
| Plant Height (cm) at First Harvest | 38.93  | 39.67  | 41.10 | 2.27   | n.s.               |
| Branches/plant at First Harvest    | 8.47   | 6.93   | 7.47  | 0.48   | n.s.               |
| Number of Leaves at Flowering      | 6.80   | 7.00   | 7.27  | 0.16   | n.s.               |
| Days to 50% Flowering (n.s)        | 53.33  | 52.00  | 53.33 | 2.87   | n.s.               |
| Days to Maturity (n.s)             | 101.00 | 101.00 | 98.33 | 1.59   | n.s.               |

A1 - Planting in Single Water lines      A2 - Planting in Double Water lines

A3 - Planting in Sunken beds      W.A.T.- Weeks after Transplanting

A.S.- After sowing      n.s.- Not significant.

after transplanting as shown in Appendix tables 3 and 4. This observation was true for all the experiments.

#### 4.1.3. Plant Height and Branches per Plant

At maturity, the height of plants under the different arrangements were not significantly different in any of the experiments. The values fell within a narrow range in each experiment (tables 2 - 7).

Plant height monitored 4 - 8 weeks after transplanting as an index of growth showed that there was no statistical difference in the height of plants under the different arrangements at any point in time. As shown in appendix tables 5 and 6, slight differences only occurred during the first few weeks after transplanting and tended to level up at around 7 - 8 weeks after transplanting.

The number of primary branches produced per plant at maturity was not significantly altered by arrangement in all the experiments (tables 2 - 7). For each cultivar at same location and same year, there was a very narrow range of the number of primary branches per plant.

#### 4.1.4. Percentage Flowers Resulting in Fruit set

There was a highly significant effect of arrangement on the proportion of the highest number of flowers set that actually resulted in fruit set in both locations

in 1985 (tables 2 - 5). Low percentages were generally obtained under the single water line arrangement.

There was also a significant arrangement x cultivar interaction at both locations as shown in figure 5. With Ife 1, the number of flowers which developed into fruits was highest under the sunken bed arrangement, followed by the double water lines. In Harvester, a different trend was observed as the highest percentage was obtained in double water line, followed by sunken bed.

The percentages of flowers resulting in fruit set in 1986 were generally lower than the 1985 figures and arrangements showed no significant effects. However, as shown in tables 6 and 7, a similar trend with the 1985 result was observed for each cultivar.

4.1.5. Fruit per Plant: Interaction between arrangement and cultivar was significant on number of fruits set per plant in Samaru in 1985 as shown in figure 6, both cultivars had least number of fruits in the single water line arrangement. Harvester set more fruits than Ife 1 in double water line but both cultivars set highest number of fruits in the sunken bed arrangement. Such an interaction was not observed in any of the Kadawa experiments.

PERCENTAGE FLOWERS RESULTING IN FRUIT SET

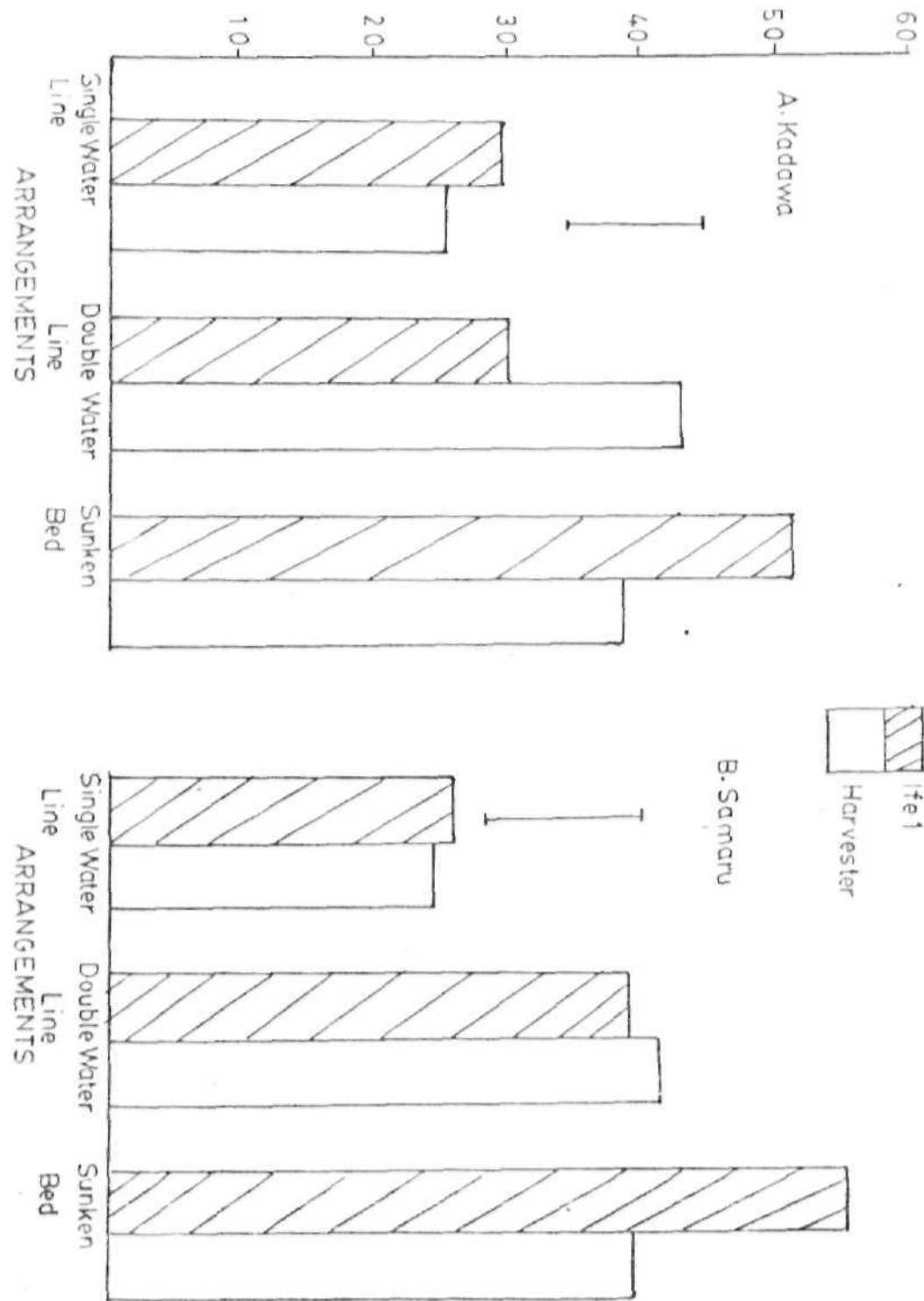


FIG 5: EFFECTS OF ARRANGEMENT X CULTIVAR INTERACTION ON THE PERCENTAGE FLOWER RESULTING IN FRUIT SET UNDER HEAT-STRESS.  
 I = LSD Arrangement x Cultivar ( $P = 0.05$ )

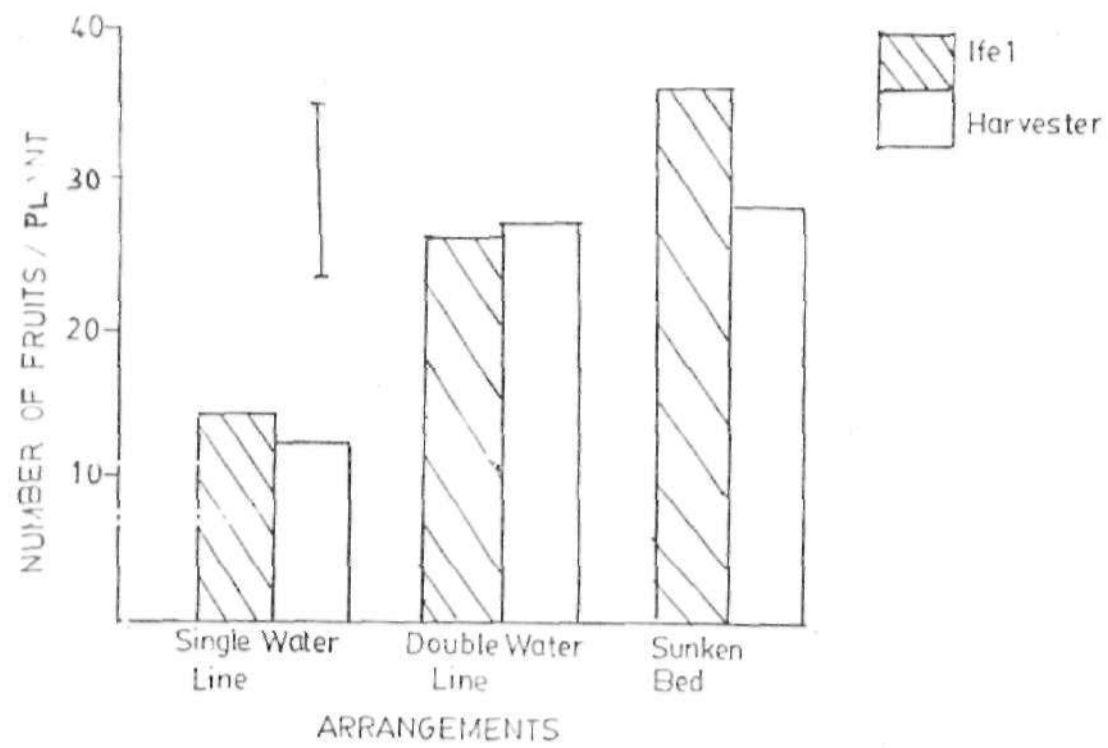


FIG. 6: EFFECT OF ARRANGEMENT X CULTIVAR INTERACTION ON NUMBER OF FRUITS PER PLANT IN TWO TOMATO CULTIVARS UNDER HEAT-STRESS.

$\left| \right|$  = LSD Arrangement x Cultivar  
 (P=0.05)

Arrangement as a factor had significant effects on the total number of fruits set per plant in both locations in 1985. Higher number of fruits were set per plant under the sunken bed arrangement except at Kadawa where Harvester set more fruits in the double water line arrangement (table 5).

No significant effect of arrangement was observed in 1986, but for both cultivars, more fruits were set in the double water line and sunken bed arrangements than in the single water line arrangement (Tables 6 and 7).

4.1.6. Fruit Diameter and Length: The effect of arrangements on fruit diameter was significant only for cv Ife 1 in the 1985 experiments in both locations. Fruits of both cultivars were, however, relatively larger under the double water line and sunken bed arrangements than in the single water line arrangement. In both locations and with both cultivars, the order was, double water line > sunken bed > single water line.

Ife 1 fruit is normally larger than Harvester and this was reflected in the observations. In the 1985 experiments, arrangement had significant effects on fruit length in Samaru in both cultivars (Tables 2 and 3). Though no significant effect was observed at Kadawa, a similar trend to Samaru was obtained. The trend for each cultivar was as follows:-

Ife 1 : Sunken bed } Double water line } Single  
water line.

Harvester : Double water line } Sunken bed } Single  
water line

Arrangements had no significant effect on fruit length in the 1986 experiment (tables 6 and 7). Harvester fruits are normally longer than Ife 1 fruits and this was reflected in the observations.

#### 4.1.7. Days to 50% Flowering and Days to Maturity

Arrangements did not significantly affect the number of days from sowing to 50% flowering. Plants at Samaru generally attained 50% flowering within a time range of 45 - 50 days (tables 2 and 3) while at Kadawa it was 44 - 49 and 47 - 53 days in 1985 and 1986 respectively (tables 4 - 7).

There was no significant effect of arrangements on the number of days from sowing to maturity in all the experiments. In the 1985 experiments, days to maturity ranged from 102 - 109 and 101 - 113 in Samaru and Kadawa respectively with the single water line arrangement generally in the upper limit of each range (tables 2 - 5). The observed range for 1986 was 95 - 101 days after sowing as shown in tables 6 and 7.

4.1.8. Yield (Kg/plant) - In both locations of the experiment in 1985, there was a significant interaction between arrangements and cultivars on yield as shown in

Figure 7. There were marked differences in the responses of the cultivars to the arrangements; cv. Harvester produced the highest yield under the double-water-line arrangement, and cv Ife 1 under the sunken bed arrangement. Both cultivars had significantly lower yield in the single water line arrangement. There was no significant interaction between arrangement and cultivar on yield in the 1986 Kadawa experiment although it was observed that Ife 1 was superior to Harvester under all arrangements (Tables 6 and 7). The yields of Ife 1 under the sunken bed and double water line arrangements in 1986 were at par and higher than in the single water line arrangement. The difference was however not significant. Harvester, in contradiction to the 1985 observation, had highest yield in the sunken bed arrangements.

Considering arrangements as a factor, yields obtained under the single water line arrangement were generally lower than were obtained under the sunken bed and double water line arrangements in all the experiments, the differences were however not statistically significant (tables 2 - 5).

#### 4.2. Experiment II

##### 4.2.1. Leaf formation and Leaf area per Plant

Leaf formation recorded weekly for 5 weeks in both locations in 1985 and at Kadawa in 1986 are represented by figures 8 and 9 respectively. At Kadawa, significant differences were observed in the number of leaves per plant in all the 5 weeks in 1985 and from 5th to 8th

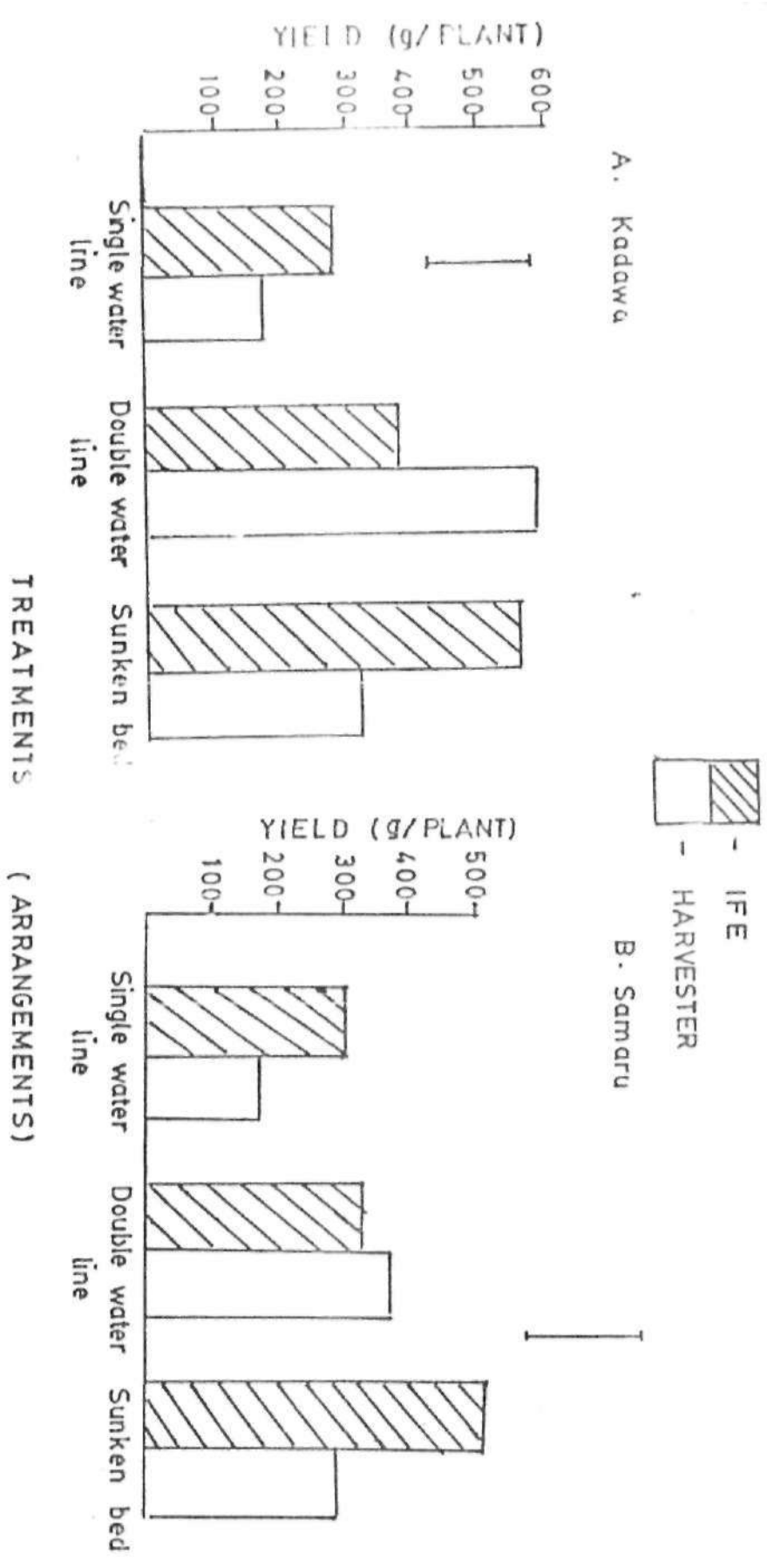
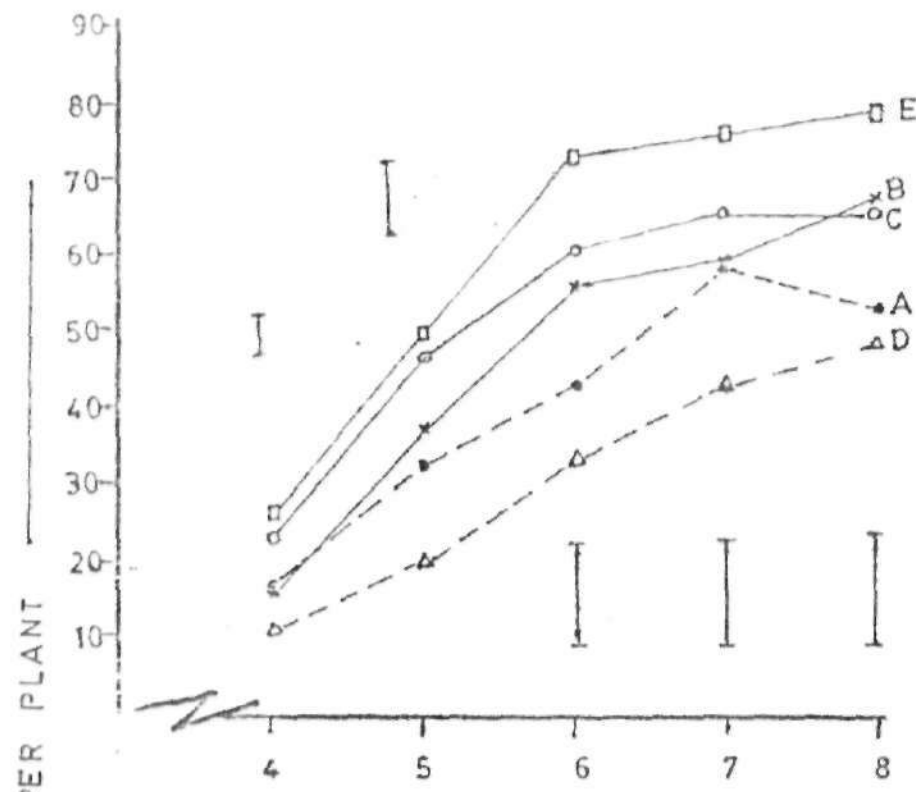


FIG. 7: EFFECT OF ARRANGEMENT X CULTIVAR INTERACTION ON YIELD OF TWO TOMATO CULTIVARS UNDER HEAT STRESS.  $\bar{I}$  = LSD Arrangement x Cultivar ( $P \leq 0.05$ )

Kadawa



Samaru

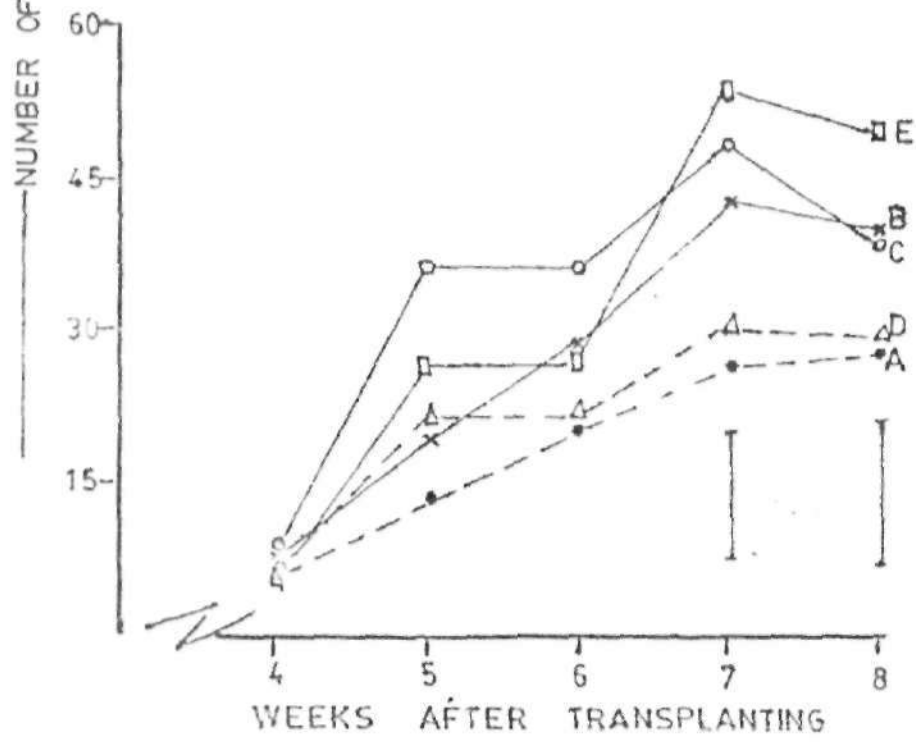


FIG.8: EFFECT OF VARIOUS REGIMES OF MAIZE SHELTER SHADE ON LEAF FORMATION IN HEAT-STRESSED TOMATO (1985).  $\bar{I} \pm \text{LSD (P=0.05)}$

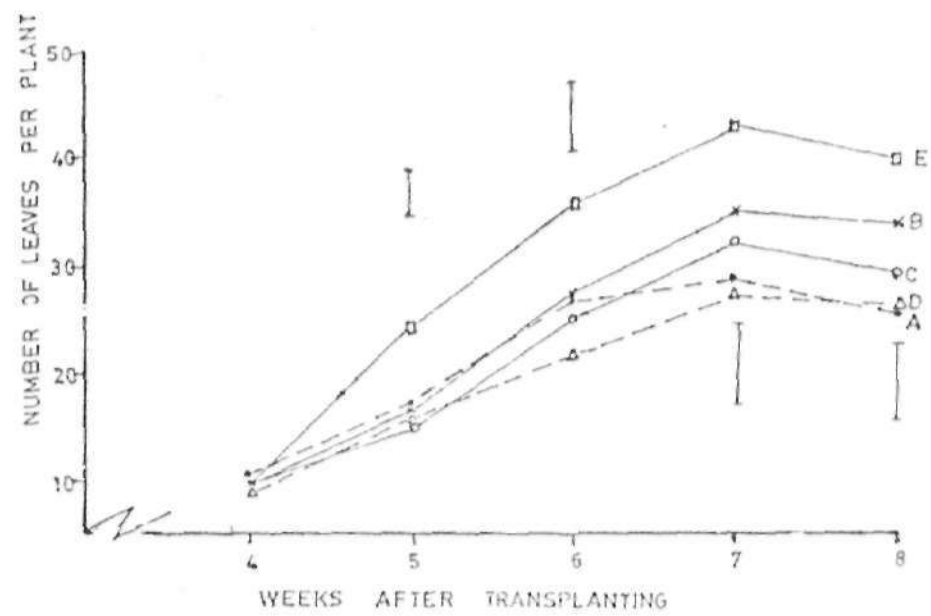


FIG.9: EFFECT OF VARIOUS REGIMES OF MAIZE SHELTER SHADE ON LEAF FORMATION IN HEAT-STRESSED TOMATO (1986)  
 ┘ = LSD (P=0.05)

weeks after transplanting in 1986. At 7 weeks after transplanting, there was a significant treatment effect on leaf area in both locations in 1985 as shown in tables 8 and 9.

At Samaru, leaf area data 7 weeks after transplanting showed that  $E > B > A = C = D$  while the data at Kadawa indicated that  $E > C = B > A > D$ . Leaf area was not taken in Kadawa in 1986 to allow for a comparison due to lack of appropriate instrument.

4.2.2. Flower formation: More flowers were produced at Kadawa than at Samaru in 1985 (tables 10 and 11). At Samaru, more flowers were formed under treatment B and E than in the other 3 treatments which did not differ in the number of flowers formed. At Kadawa, E set significantly more flowers than the other treatments while treatment D had the lowest.

In the 1986 experiment, highest number of flowers was formed in treatment B; it was, however, not statistically higher than those in treatments E, C and A (table 12).

Weekly count of flowers produced from 5 - 9 weeks after transplanting showed the same trend among treatments at the same location in 1985. At Kadawa, significant differences in cumulative number of flowers were observed 7 - 9 weeks after transplanting. More

Table 8: Effect of Maize shade on some vegetative growth Parameters of Tomato (cv Roma VF) During the hot season at Samaru (1985)

| Treatments   | Plant Height<br>at Maturity<br>(cm) | Primary<br>Branches<br>at Maturity | Number of<br>Leaves at<br>First<br>Flowering | Leaf Area<br>Per Plant<br>7 W.A.T.<br>(cm <sup>2</sup> ) |
|--------------|-------------------------------------|------------------------------------|----------------------------------------------|----------------------------------------------------------|
| A            | 35.7 bc                             | 4.9 bc                             | 7.6                                          | 467.3 c                                                  |
| B            | 45.6 ab                             | 8.9 ab                             | 7.87                                         | 703.8 b                                                  |
| C            | 45.3 abc                            | 6.9 bc                             | 8.2                                          | 465.1 bc                                                 |
| D            | 36.8 bc                             | 4.9 bc                             | 6.7                                          | 352.4 c                                                  |
| E            | 50.0 a                              | 9.2 a                              | 8.9                                          | 1028.7 a                                                 |
| S.E.D.       | 4.4                                 | 1.0                                | 0.9                                          | 108.1                                                    |
| L.S.D.(0.05) | 9.6                                 | 2.1                                | n.s.                                         | 235.5                                                    |

Means followed by the same letter in the same column are not significantly different at 5% level of probability.

W.A.T. - Weeks after Transplanting

A - one row of tomato between 2 rows of Maize

B - One row of maize between 2 rows of tomato

C - 2 rows of tomato between 2 rows of maize

D - Maize-tomato mixture on same rows

E - Sole tomato.

Table 9: Effect of Maize Shade on some Vegetative Growth Parameters of Tomato (cv Roma VF) During the Hot Season at Kadawa (1985).

| TREATMENTS | PLANT HEIGHT<br>AT MATURITY<br>(CM) | PRIMARY<br>BRANCHES<br>AT<br>MATURITY | NUMBER OF<br>LEAVES AT<br>FIRST<br>FLOWERING | LEAF AREA<br>PER PLANT<br>7 W.A.T.<br>(CM <sup>2</sup> ) |
|------------|-------------------------------------|---------------------------------------|----------------------------------------------|----------------------------------------------------------|
| A          | 62.4                                | 7.0 ab                                | 8.4                                          | 1236.3 c                                                 |
| B          | 65.2                                | 8.1 ab                                | 8.8                                          | 1305.5 b                                                 |
| C          | 66.7                                | 6.9b                                  | 9.0                                          | 1349.9 b                                                 |
| D          | 59.4                                | 6.8 b                                 | 7.9                                          | 243.4 d                                                  |
| E          | 73.7                                | 9.3 a                                 | 10.1                                         | 1538.5 a                                                 |
| S.E.D.     | 4.8                                 | 1.0                                   | 1.2                                          | 26.3                                                     |
| LSD (0.05) | n.s.                                | 2.3                                   | n.s.                                         | 57.3                                                     |

Means followed by the same letter in the same column are not significantly different and 5% level of probability.

Table 10: Effect of Maize Shade on Earliness and Yield Parameters of Tomato (cv Roma VF) During the Hot season at Savar (1985)

| TREATMENTS | HIGHEST NUMBER OF FLOWERS PER PLANT | DAY TO 50% FLOWERING (A.S.) | DAYS TO Maturity (A.S.) | NUMBER OF FRUITS PER PLANT | % FLOWERS RESULTING IN FRUIT SET | FRUIT DIAMETER (CM) | FRUIT LENGTH (CM) | YIELD/PLANT (KG) |
|------------|-------------------------------------|-----------------------------|-------------------------|----------------------------|----------------------------------|---------------------|-------------------|------------------|
| A          | 34.2 b                              | 46.8                        | 110.3                   | 15.3 c                     | 44.7 b                           | 2.6 a               | 5.3ab             | 0.18 c           |
| B          | 45.3a                               | 46.0                        | 112.0                   | 17.2abc                    | 37.8c                            | 2.2b                | 5.2b              | 0.27b            |
| C          | 35.6b                               | 46.3                        | 106.8                   | 17.7ab                     | 49.7a                            | 2.5a                | 5.2b              | 0.32b            |
| D          | 32.6b                               | 47.0                        | 108.5                   | 16.0bc                     | 45.0 a                           | 2.5a                | 4.7c              | 0.17c            |
| E          | 49.7a                               | 45.0                        | 105.0                   | 18.5a                      | 37.1c                            | 2.4ab               | 5.6a              | 0.58a            |
| S.E.D.     | 3.1                                 | 1.4                         | 3.1                     | 1.1                        | 1.9                              | 0.1                 | 0.1               | 0.03             |
| LSD (0.05) | 6.8                                 | n.s.                        | n.s.                    | 2.3                        | 4.2                              | 0.2                 | 0.3               | 0.07             |

Means followed by the same letter in the same column are not significantly different at 5% level of probability.

- T.S - after sowing
- A - One row of tomato between 2 rows of Maize.
  - B - One row of maize between 2 rows of tomato.
  - C - 2 rows of tomato between 2 rows of maize.
  - D - Maize-tomato mixture.
  - E - Sole tomato.

Table 11: Effect of Maize Shade on Earliness and Yield Parameters of Tomato  
(cv Roma VF) During the Hot Season at Kaduna (1985)

| TREATMENTS | HIGHEST<br>NUMBER OF<br>FLOWERS | DAYS TO<br>50%<br>FLOWERING | DAYS TO<br>MATUREITY<br>(A.S.) | NUMBER<br>OF FRUIT<br>PER PLANT | % FLOWERS<br>RESULTING<br>IN FRUIT<br>SET | FRUIT<br>DIAMETER<br>(CM) | FRUIT<br>LENGTH<br>(CM) | YIELD/<br>PLANT<br>(KG) |
|------------|---------------------------------|-----------------------------|--------------------------------|---------------------------------|-------------------------------------------|---------------------------|-------------------------|-------------------------|
| A          | 56.1 bc                         | 45.5 ab                     | 90.0                           | 13.4 b                          | 32.8 c                                    | 2.7                       | 5.2 bc                  | 0.27 c                  |
| B          | 55.1 bc                         | 45.3 b                      | 90.0                           | 13.4 b                          | 35.1 b                                    | 2.5                       | 5.2 bc                  | 0.31 b                  |
| C          | 61.0 b                          | 44.5 b                      | 90.0                           | 21.0 a                          | 38.9 a                                    | 2.6                       | 5.3 bc                  | 0.30 b                  |
| D          | 44.6 c                          | 48.0 a                      | 93.5                           | 13.7 c                          | 30.7 c                                    | 2.7                       | 4.5 c                   | 0.13 d                  |
| E          | 91.2 a                          | 43.8 b                      | 90.0                           | 24.0 a                          | 27.3 d                                    | 2.6                       | 6.1 a                   | 0.51 a                  |
| S.E.D      | 6.7                             | 1.2                         | 3.3                            | 1.8                             | 1.0                                       | 0.1                       | 0.3                     | 0.01                    |
| LSD (0.05) | 14.5                            | 2.7                         | n.s.                           | 3.9                             | 2.1                                       | n.s.                      | 0.5                     | 0.02                    |

Means followed by the same letter in the same column are not significantly different at 5% level of probability.

- A.S. - After sowing
- A - One row of tomato between 2 rows of maize.
  - B - One row of maize between 2 rows of tomato.
  - C - 2 rows of tomato between 2 rows of maize.
  - D - Maize-tomato mixture.
  - E - Sole tomato.

Table 12: Effect of Maize shade on Earliness and Yield Parameters of Tomato (cv Roma VF) During the Hot season at Kadawa (1986)

| TREATMENTS | HIGHEST<br>NUMBER OF<br>FLOWERS SET<br>PER PLANT | DAYS TO<br>50%<br>Flowering<br>(D.S.) | DAYS TO<br>MATURITY<br>(D.S.) | NUMBER OF<br>FRUITS SET<br>PER<br>PLANT | % FLOWERS<br>RESULTING<br>IN FRUIT<br>SET | FRUIT<br>DIAMETER<br>(CM) | FRUIT<br>LENGTH<br>(CM) | YIELD/<br>PLANT<br>(KG) |
|------------|--------------------------------------------------|---------------------------------------|-------------------------------|-----------------------------------------|-------------------------------------------|---------------------------|-------------------------|-------------------------|
| A          | 51.2 bc                                          | 66.0 a                                | 101.0                         | 26.5 a                                  | 67.4 a                                    | 2.1 ab                    | 4.7 a                   | 0.40                    |
| B          | 79.3                                             | 64.3 ab                               | 99.3                          | 28.1 a                                  | 58.6 a                                    | 2.3 a                     | 3.4 b                   | 0.41                    |
| C          | 54.6 b                                           | 62.5 b                                | 99.3                          | 26.3 a                                  | 52.2 a                                    | 1.7 a                     | 4.7 a                   | 0.43                    |
| D          | 33.3 c                                           | 59.0 c                                | 99.2                          | 11.3 b                                  | 14.1 b                                    | 1.9 bc                    | 4.1 ab                  | 0.21                    |
| E          | 65.1 ab                                          | 59.0 c                                | 101.0                         | 23.4 a                                  | 39.3 ab                                   | 1.9 bc                    | 4.9 a                   | 0.43                    |
| S.E.D.     | 9.2                                              | 1.6                                   | 2.9                           | 4.6                                     | 13.4                                      | 0.1                       | 0.3                     | 0.076                   |
| LSD (0.05) | 20.1                                             | 3.4                                   | n.s.                          | 10.1                                    | 29.3                                      | 0.3                       | 0.7                     | n.s.                    |

Means followed by the same letter in the same column are not significantly different at 5% level of probability.

- D.S. - After sowing.  
 A - One row of tomato between 2 rows of maize.  
 B - One row of maize between 2 rows of tomato.  
 C - 2 rows of tomato between 2 rows of maize.  
 D - Maize-tomato mixture.  
 E - Sole tomato.

flowers were formed by E than by any other treatments. Treatment B compared favourably with E throughout the 5 weeks at Samaru and the 2 treatments had significantly more flowers than the other treatments at 8 and 9 weeks after transplanting (Figure 10).

The 1986 weekly count of flowers at Kadawa also showed that differences in flower formation between treatments became significant only at 8 weeks after transplanting (Figure 11).

#### 4.2.3. Plant Height and Primary Branches:

Height at maturity was significantly affected by treatments at both locations in 1985. The shortest plants were recorded under treatments A and D in Samaru and D in Kadawa and mean plant height was higher at Kadawa for all treatments (tables 8 and 9). However in the 1986 experiment at Kadawa, plant height at maturity did not differ between treatments as shown on table 13.

Weekly recording of plant height showed that at Kadawa (1985), significant differences only existed between plants under various treatments at 5 and 6 weeks after transplanting. In Samaru, however, plant height was significantly different throughout the 5 weeks (Figure 12). Treatment differences in height throughout the 5 week period were not significant in 1986 at Kadawa (Figure 13).

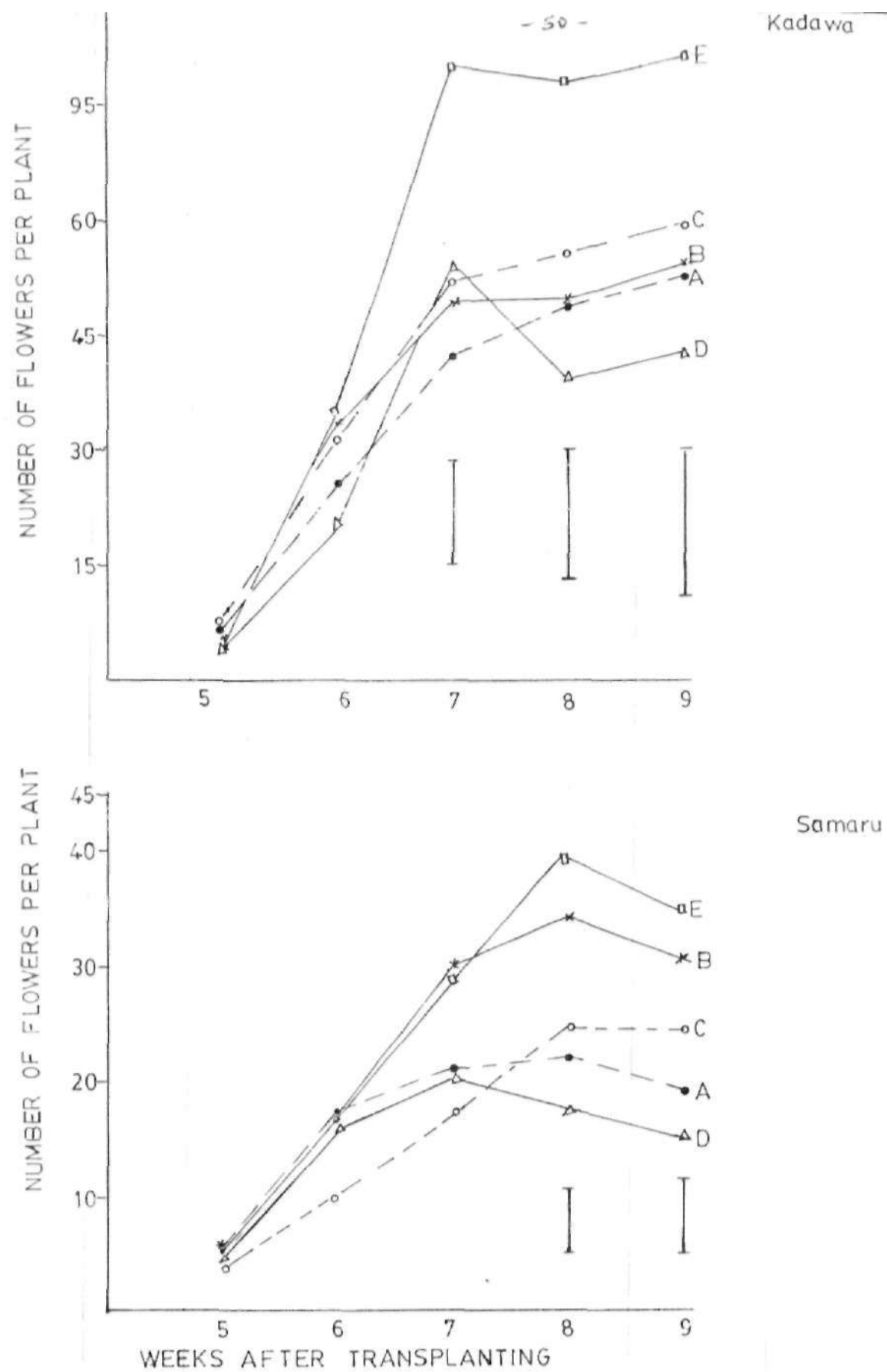


FIG.10: EFFECT OF VARIOUS REGIMES OF MAIZE SHELTER SHADE ON FLOWER FORMATION IN HEAT-STRESSED TOMATO (KADAWA 1986)

— LSD (P=0.05)

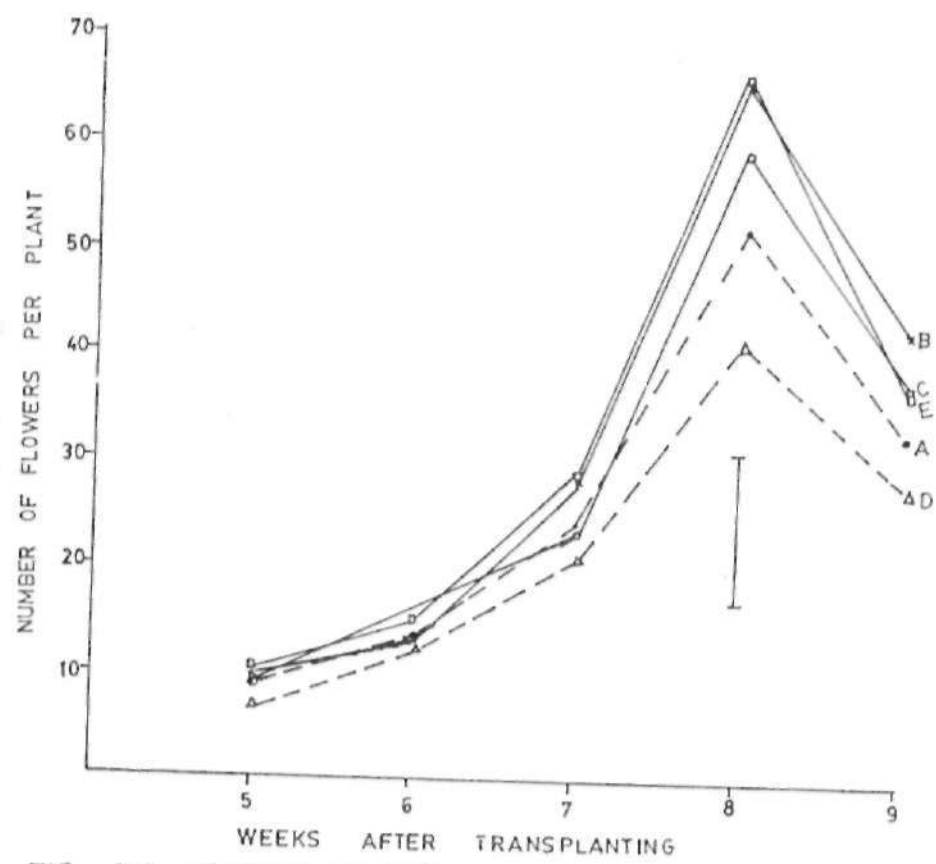


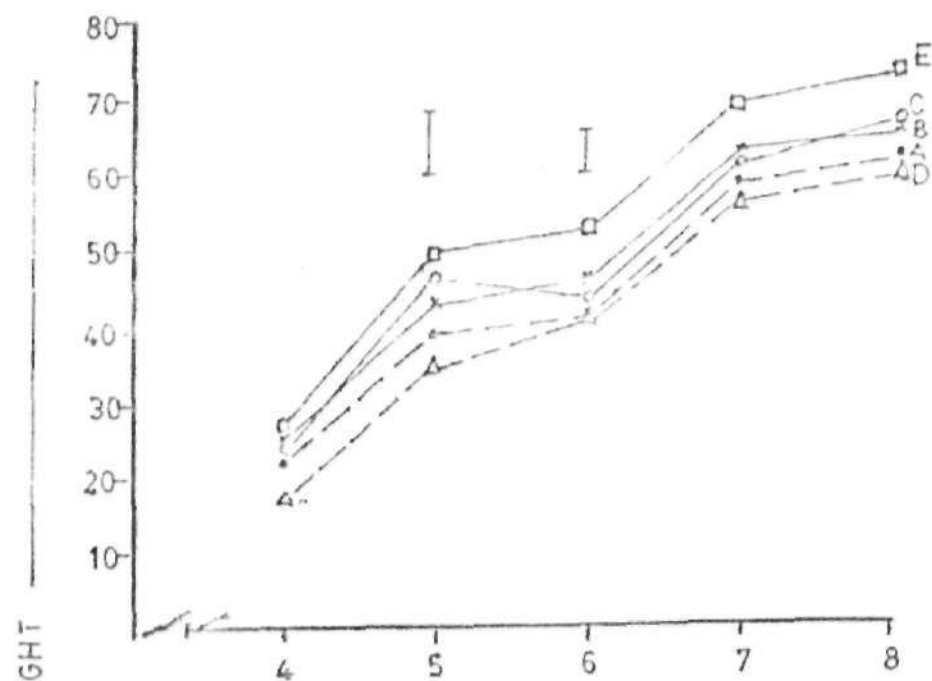
FIG. 11: EFFECT OF VARIOUS REGIMES OF MAIZE SHADE ON FLOWER FORMATION IN HEAT-STRESSED TOMATO (KADAWA, 1986)

= LSD ( $P=0.05$ )

Table 13: Effect of Maize Shade on some Vegetative Growth Parameters of Tomato (cv Roma VF) During the Hot season at Kadawa (1986 ).

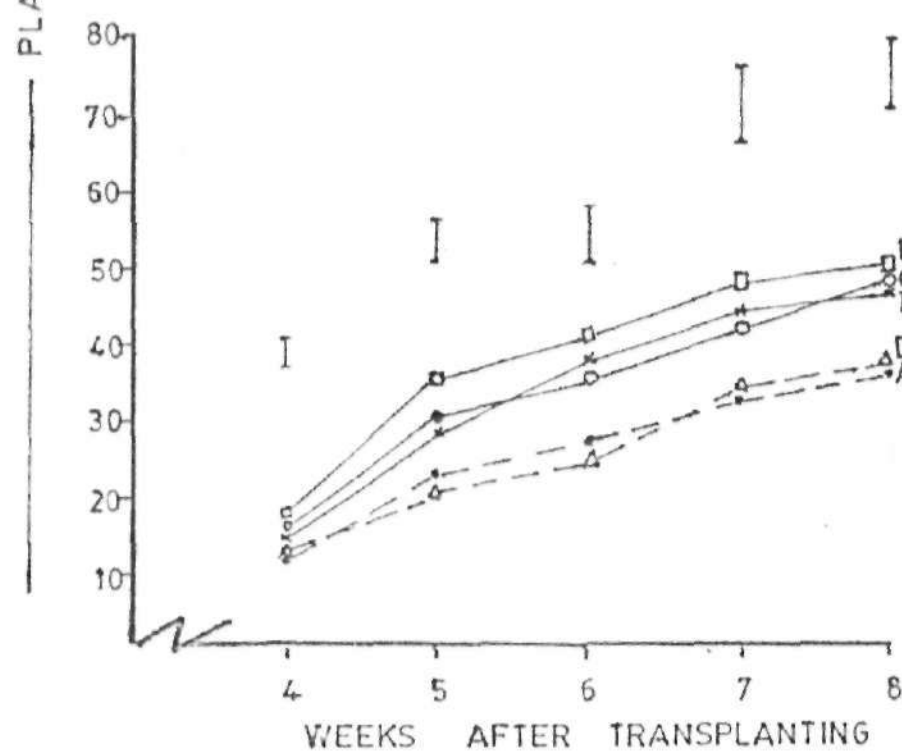
| TREATMENTS | PLANT HEIGHT<br>AT MATURITY<br>(CM) | PRIMARY<br>BRANCHES<br>AT<br>MATURITY | NUMBER OF<br>LEAVES AT<br>FIRST FLOWERING |
|------------|-------------------------------------|---------------------------------------|-------------------------------------------|
| A          | 37.2                                | 5.7                                   | 9.6                                       |
| B          | 36.8                                | 4.6                                   | 9.8                                       |
| C          | 33.0                                | 5.2                                   | 8.1                                       |
| D          | 33.0                                | 4.9                                   | 9.7                                       |
| E          | 36.4                                | 7.6                                   | 9.1                                       |
| S.E.D.     | 3.7                                 | 0.9                                   | 2.1                                       |
| LSD(0.05)  | n.s.                                | n.s.                                  | n.s.                                      |

- A - One row of tomato between 2 rows of Maize  
B - One row of Maize between 2 rows of tomato  
C - 2 rows of tomato between 2 rows of maize  
D - Maize-Tomato mixture on same rows  
E - Sole tomato.



PLANT HEIGHT

Samaru



WEEKS AFTER TRANSPLANTING

FIG. 12: EFFECT OF VARIOUS REGIMES OF MAIZE SHELTER SHADE ON PLANT HEIGHT OF HEAT-STRESSED TOMATO, (1985).

I = LSD(0.05)

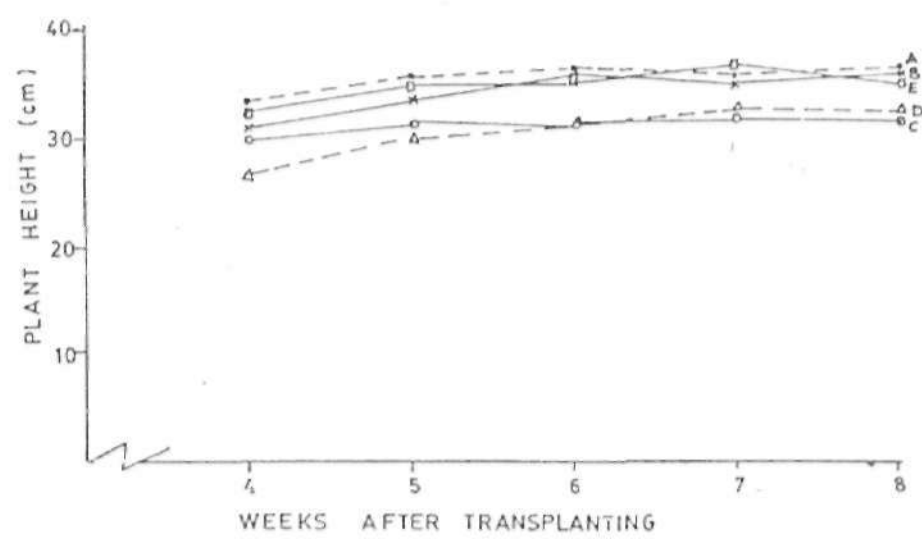


FIG. 13: EFFECT OF VARIOUS REGIMES OF MAIZE SHELTER SHADE ON PLANT HEIGHT IN HEAT-STRESSED TOMATO (KADAWA 1986)

At maturity, there was a significant effect of treatments on the number of primary branches per plant at both locations in 1985. No such difference was, however, observed in 1986. The formation of primary branches per plant was highest under treatments E and B at both locations in 1985 with treatment D producing the least number of primary branches (Tables 8 and 9). The 1986 result showed that treatment E also had the highest number of primary branches per plant which was, however, not statistically different from the values under other treatments as shown in Table 13.

#### 4.2.4. Percentage Flowers Resulting in Fruit Set

There were highly significant effects of treatments on the percentage flowers that resulted in fruits at both locations in 1985, and higher percentages were observed in Samaru in all treatments, (Tables 10 and 11).

Treatment C had the highest percentage in both locations, and was significantly higher than E in both locations. The intermediate regimes of shade (A and B) had higher percentages than E. The heaviest shade regime, (D) also had higher fruit set percentage than E.

There was also a significant treatment effect on the observed percentages of flowers resulting in fruit set at Kadawa in 1986 with the highest percentage

207500

recorded in treatment A (Table 12). This was not statistically higher than values of treatments B, C, and E. The lowest percentage was observed under treatment D, a value that was not significantly lower than that of E (Sole tomato).

4.2.5. Fruits Set Per Plant : The total number of fruits set per plant was relatively low under all treatments and was shown to be significantly affected by treatment in all the experiments.

In the 1985 experiment, greater number of fruits were set per plant at Kadawa than at Samaru (Tables 10 and 11). Treatment E, (Sole tomato), was similar to B and C at Samaru and C in Kadawa as far as fruit set was concerned. Fruits per plant was least in treatment D at Kadawa and in A and D at Samaru. In 1986, fruit set was similar in treatments A, B, C and E, and significantly higher than in D as shown on Table 12.

4.2.6. Fruit Diameter and Length : There was a significant treatment effect on fruit diameter at Samaru in 1985 and at Kadawa in 1986. Fruit diameter at Samaru, in 1985, was similar in treatments A, C, D and E and were higher than in B, while at Kadawa, (1986), B had the highest diameter and C the least, (Tables 10-12).

The effect of treatment on fruit length was highly significant in all the experiments. Results in both years showed that the longest fruits were obtained under treatment E, the sole tomato. All regimes of shade resulted in fruit length reduction. This trend was observed in all the experiments (Tables 10 - 12).

4.2.7. Days to 50% Flowering and Days to Maturity:

The number of days from sowing to 50% flowering in 1985 at Samaru was 45-47. In the same year at Kadawa, it was 44-48 days, with plants under treatment D taking longer time than other treatments to attain 50% flowering. These are shown in Tables 10 and 11..

Longer days to flowering were observed in the 1986 Kadawa experiment than in 1985; 50% flowering stage was only reached between 59 and 66 days after sowing. Contrary to the 1985 observation, plants under treatment D attained 50% flowering earlier than others except E. This is shown on Table 12

The number of days from sowing to maturity was not significantly different between treatments in all the experiments as shown on tables 10, 11 and 12. The highest number of days to maturity was observed in Samaru in 1985 where all plants matured between 105 - 112 days; at Kadawa in the same year, it was between 90 - 93 days. The 1986 range at Kadawa was 99 - 101 days after sowing.

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4.2.8. Yield: In both locations in 1985, yield was significantly highest in the sole tomato treatment (Treatment E) as shown in tables 10 and 11. Treatments B and C (both mild shade treatments), did not differ in yield while treatment D, (highest regime of shade) had the lowest yield. The 1986 yield at Kadawa did not differ significantly between treatments (Table 12) but treatment D had the lowest yield.

## CHAPTER 5

### DISCUSSION

#### 5.1. Experiment I

##### 5.1.1. Effect of Arrangement on Leaves at First Flowering, Leaf Formation, and Leaf Area Under Heat Stress

The non-significant difference in the number of leaves at first flowering under the 3 arrangements was due to the fact that the expected canopy that would modify the micro-environment was not yet formed at the onset of flowering. The high temperature effect was therefore the same on all the arrangements at this stage. Because the number of leaves for each variety was not significantly different at any stage of the plant growth, it could be inferred that whatever temperature modification any of the three arrangements imposed on the plants was not enough to alter the potential leaf formation rate of the plants under heat stress.

Using leaf production as an index of the plant vegetative growth (Lang, 1952), the plants grew at equal rate under heat stress regardless of arrangements. That leaf area 7 weeks after transplanting was also not significant means that the rate of leaf area development was the same under all arrangements. A possible explanation for this is that the leaves were unprotected and equally exposed to heat hazard in all the arrangements.

5.1.2. Effect of Arrangements on Plant Height and Primary Branches at Maturity under Heat Stress:

It cannot be inferred from this study that whatever alteration the arrangements made on the plant's immediate environment affected the ultimate height and the branching capacity of the plants differently. The linear measurement of plant height as a growth index over a period of time as recommended by Ting (1982) showed that growth rate of the plant under heat stress was not altered by any of the three arrangements, meaning that the magnitude of the modifying effect of any of the arrangements on the environment was not enough to have any significant effect on the rate of stem elongation and the ultimate plant height at maturity.

5.1.3. Effect of Plant Arrangement on Fruit Set

The count of the number of fruits set per plant in addition to fruit weight was made because

- (a) fruit set is probably the parameter most affected by heat stress,
- (b) not all fruits that were set actually result in the ultimate marketable yield because fruits can drop before they mature or get rotten before they are harvested,
- (c) fruits of different varieties differ in average weight, and since yield was recorded in weight, the numerical value of the fruits set in varieties under similar treatments was a good basis for comparison.

The low number of fruits set per plant in both cultivars at both locations and both years (at Kadawa) is probably a direct result of the effect of heat stress on the process of fruit development.

While the number of flowers formed per plant did not differ between arrangements, there was a significant difference in number of fruits per plant in both locations and both varieties in 1985. It can therefore be speculated that differences that existed between the arrangements must have affected the processes leading to fruit formation rather than flower formation itself. This is in agreement with the findings of Iwahori and Takahashi (1964) that low fruit set under heat stress was not a result of non-formation of flowers but a result of poor process of floral development preparatory to fruit formation.

The wide gap between number of fruits and number of flowers per plant suggests a high degree of flower abortion in all arrangements but more so in the single water line arrangement. It could also be due to mere flower abscission rather than abortion because in most cases, anthesis was reached before flowers dropped. Both phenomena which were clearly differentiated by Olarewaju (1980) could be responsible for the low percentages of fruit set especially in the single water line arrangement. The flower abscission phenomenon is

most probable in this case because of the role of heat stress in influencing the secretion of abscissic acid.

The critical month for the flowering process in this experiment was March. It was the month most of the flowers were formed. Average temperatures at both locations were very high in this month ( $35.1^{\circ}\text{C}$  and  $35.2^{\circ}\text{C}$  at Samaru and Kadawa respectively in 1985 and  $35.9^{\circ}\text{C}$  at Kadawa in 1986). These were close to Smith's (1932)  $36.7^{\circ}\text{C}$  which resulted in abortion of embryo sac and ovule degeneration in tomato flower, and they were also within the  $32.8 - 37.8^{\circ}\text{C}$  range of Johnson and Hull (1953) which induced floral malformation that hindered normal pollination. The temperatures which prevailed during the life of these experiments are also higher than the variously estimated optimum for tomato growth by several authors (Calvert 1964, Torfs 1967, Verkerk 1968 and Dempsey 1970). The daily minimum temperature which is the nearest to night temperature was higher than  $20^{\circ}\text{C}$  in most of the days in the months of March and April (figures 1-3).

The significant interaction between arrangement and cultivar in percentage flowers resulting in fruit set in both locations in 1985 indicated that while cv Ife 1 would set highest number of fruits under heat stress when planted on sunken beds, cv. Harvester would do better on double water lines arrangement. The reason for this interaction observed in both locations in 1985 can not be easily explained.

5.1.4. Effect of Arrangements on Fruit Diameter and Length under Heat Stress

It is difficult to explain the observed significant difference in fruit diameter of cv Life 1 under the various arrangements in 1985 in terms of heat stress. Fruit diameter was observed to be greater under the sunken bed and double water line arrangements than in the single water line arrangement. It could be that the metabolic processes of respiration and photosynthesis were more adversely affected in the single water line arrangement. The effect could be in form of a more rapid rate of degradation of assimilate than rate of accumulation in the developing fruit. This could have affected the fruit size resulting in smaller fruits where the heat stress effect was more severe.

The non-significant difference in fruit diameter observed at Kadawa in 1986 was due to the poor establishment of plants in all arrangements that year, a situation which altered the expected canopy form under each arrangement.

The same factors that affected the fruit diameter under each arrangement were likely to have affected the fruit length, hence longer fruits were got from the sunken bed and double water line arrangements than in the single water line in 1985. The contradictory observation in 1986 could also be due to the poor establishment of transplanted seedlings.

5.1.5. Effect of Arrangement on Days to 50% Flowering and Days to Maturity under Heat Stress

These two parameters are indices of earliness in the crop. That none of them was significantly affected by arrangements means that earliness of the crop as affected by heat stress could not be altered. The fact that in all the experiments, plants reached 50% flowering 45-52 days after sowing means that the month of February was the critical month (for this experiment) for the parameter because seeds were sown in mid-January, and by inference it is also the critical month for days to maturity because plants of the same variety which flowered at the same time would normally mature at the same time.

Maximum temperature in February at both locations was not very high, it is likely therefore that there was no adverse effect of temperature on these parameters because the observation for days to 50% flowering agreed with the earlier report by Nuamah (1976) who screened 7 tomato cultivars in Ghana and observed a range of 43-68 days from sowing to anthesis. He also recorded 71-110 days to maturity which compares favourably with the range of 97-107 days observed in this study.

5.1.6. Effect of Arrangement on Yield under Heat Stress

The comparatively low yields obtained under the three arrangements in all the experiments can be attributed to the prevailing high temperatures during the period of the experiment. A similar observation was made by Quinn (1971)

when he reported uneconomical yields in tomatoes grown between January and April as a result of high temperature.

The observed difference in the performance of the two varieties agrees with report by Shelby (1975) who also observed differences in fruit set abilities of three tomato cultivars grown under high temperature. The higher yields (though non-significant) that were recorded under the double water line and sunken bed arrangements can be attributed to an assumed lower micro-environment temperature imposed on the plants by these arrangements. This micro-environment, in the context of its use here comprises the space between the top of the plant canopy and the first 5-10 cm soil depth where most of the roots are concentrated. The close canopy formed under these arrangements had the ability to reduce water loss in the soil more than in the single water line arrangement; this water loss reduction ability is a condition similar to frequent irrigation which according to Owonubi and Yayock (1981) can lower sub-soil temperature relative to the surface temperature. This might be one of the mechanisms with which the crop can combat heat stress because soil/root temperature greater than optimum had been found to adversely affect the tomato plant, (Lingle and Davis 1959, Boxall 1962 and Phatak et al. 1966).

Another reason for the higher yields under the double water line and sunken bed arrangements could have been that the air temperature immediately above the soil surface was cooler (because of the canopy cover) than under the single water line arrangement where the canopy coverage was not entire. This presented a condition similar to bare soil; the air temperature was therefore unmodified, and because the air temperature was high, the soil temperature was similarly high because air and soil temperature are positively correlated. This is in line with the finding of Owonubi and Yayock (1981).

The low yield in the single water line arrangement should not be mistaken for a water stress effect because the weekly irrigation given in all arrangements was adequate for the tomatoes.

Much as the effect of heat stress in yield reduction in this study is not undermined, mention should be made of the high incidence of leaf curl virus disease, despite insecticidal sprays against the white fly vector. This would have reduced the photosynthetic efficiency of the leaves and therefore their rate of dry matter accumulation.

The significant interaction between arrangement and cultivar on yield in both locations in 1985 indicated that the best arrangement for highest yield under heat stress varied with cultivars. This might be partly due to the growth habit of different cultivars as well as different levels of susceptibility of the cultivars to heat stress.

## 5.2. Experiment II

5.2.1. Plant Vegetative Growth: There was no significant difference between treatments in the number of leaves per plant at first flowering because the maize shelter was yet to produce enough shade that could give a difference at that stage of tomato growth. The significant difference that existed between treatments in the number of leaves per plant generally from 7 weeks after transplanting is expected. This is the peak of vegetative growth in both the tomato and maize plants. That the unshaded treatment was more vegetative at this stage of growth in all the experiments supports the view of Marshall (1967) that shade cast by shelter can depress growth in some crop species. This also explains why at 7 weeks after transplanting, leaf area was greatest in the no-shade treatment in 1985 when leaf areameasurement was taken. This larger leaf area in the unshaded treatment means a good canopy which, in addition to good interception of incoming radiation, has a good soil coverage which is effective in reducing both soil surface and root zone temperatures.

Plant height was the vegetative parameter most affected by shade especially in the 1985 experiment at both locations. The response of the number of primary branches to the treatments was in line with those of other growth indices because growth is a concerted process in all the plant parts. The importance of the number of primary branches was discussed in experiment I.

#### 5.2.2. Flower Formation and Percentage Flowers resulting in Fruit Set

The high rate of flower formation in the sole tomato (no-shade) treatment compared to the shade treatment in both locations in 1985 points to the possibility that even under heat stress, the flowering potential of the tomato plant is reduced if shaded. However, in 1986, the no-shade treatment was only significantly better than only the heaviest shade treatment.

The significantly higher percentage flowers that resulted in fruit set indicated that shade provided a good condition for fruit set under heat stress. This had no positive relationship with observed yields because fewer flowers were formed under shade treatments. The modifying effect of shade here might be in terms of providing optimum relative humidity condition for pollen germination and pollen tube growth.

#### 5.2.3. Fruit Diameter and Length

The inconsistency observed in fruit diameter in the various experiments means that the parameter was not influenced by any of the shade regimes. The significant treatment effect on fruit length at both locations in 1985 and the wide (though insignificant) difference in fruit length between sheltered and unsheltered treatments suggest that shelter shade had influenced fruit length. The length of the fruit in this case determined the fruit

size as the diameter did not significantly differ between treatments. The unsheltered treatment had longer fruit, and therefore better fruit size, because of more efficient photosynthetic process due to better exposure of the leaves to incoming solar radiation.

5.2.4. Yield: The facts that the no-shelter treatment had significantly higher yields at both locations in 1985, and the heaviest shade treatment the lowest yields in all the experiments, indicate that the tomato crop is possibly not tolerant to shade even under heat stress. A threshold regime of shade that would reduce temperatures around the plant and enhance yield was not also established in this study. This is because all the intermediate regimes of shade between the two extremes, (the no shade treatment and tomato-maize mixture treatment) did not yield better than, and in some cases yielded significantly lower than, the no shade treatment.

The cultivar used in this study, Roma VF, which is a determinate cultivar, cannot be used to make any general remark regarding the response of the species Lycopersicon esculentum to shade treatments. According to Stoeckeler (1963), varieties within species may differ in their physiological response to shade provided by crop shelter. Marshall (1967) also reported that crop yield could be higher where there is a shelter effect but added that such an observation would depend on species, climate and soil.

It is easy to conclude from this study that even under high temperature regime, the greater the intensity of shade on the tomato crop, the lower the yield. The tomato leaf probably needs a high degree of light interception for optimum photosynthesis, a condition that was made less possible under the shade treatments.

It was not that there was no cooling of any kind in the plant environment in the no-shade treatment because the planting arrangement of the tomato was such that gave a good cover on the soil surface, a condition that could reduce temperature in the crop root zone according to Precht et al (1973). The beneficial effect of reduced root temperature on heat-stressed tomatoes was observed by Quinn (1971) when he recommended mulching as a means of combating high soil temperature.

## CHAPTER 6

### SUMMARY AND CONCLUSION

Studies were carried out to assess the effects of spatial arrangements and shelter shade on the performances of non-heat-tolerant tomato cultivars grown during the hot period of February - May at Samaru and Kadawa in 1985 and at Kadawa in 1986.

Two sets of experiments were conducted. In Experiment I, the effect of 3 different spatial arrangements on growth, development and yield of two tomato cultivars (Ife and Harvester) was assessed. The 3 spatial arrangements were:

- (a) planting on single sides of water lines of ridges,
- (b) planting on double sides of water lines of ridges,
- (c) planting on sunken bed.

In Experiment II, four different maize shade regimes and a no-shade treatment were assessed using tomato cv. Roma VF.

Results showed that the sunken bed and double water line arrangements were better than single water line for growth, development and yield. This observation was a result of higher leaf area index (LAI) in the sunken bed and double water lines than in the single water line arrangement. High LAI means a good soil coverage which can reduce the impact of heat on the surface and sub-surface soil temperature, (Appendix table 7).

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In Experiment II, the use of shelter shade was not an effective means of combating heat stress in tomato. Shelter shade of any regime suppressed growth and development of the tomato plant, as shaded plants formed fewer number of leaves, branches, and flowers. Though shelter shade favoured fruit setting, this could not compensate for its role in flower number reduction.

From this study it is concluded that heat stress on a tomato plant cannot be combated by the provision of an overhead shade. It is better combated through planting arrangements that can cool the tomato plant environment without necessarily affecting its light interception. This implies that the root environment of heat-stressed tomato plant is easier to control than the shoot environment.

Because of the high labour input needed in constructing sunken beds, the double water line planting is recommended for tomato cultivation under high temperature regimes. Plants performance did not differ significantly under the two arrangements (sunken bed and double water line) and both were better than the single water line planting.

Further studies in this direction should attempt to:

1. Quantify the proportion of yield reduction due to leaf curl virus disease in periods of heat stress and that due to heat per se. This becomes necessary in view of the high incidence of the disease on tomato around the months of March and April.

2. Explore the use of auxin spray on heat stressed tomato as auxin inactivation had been adduced as a physiological reason for poor performance under heat stress.
3. Screen varieties for heat tolerance because a pronounced varietal difference in response to treatment was observed in Experiment I.

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Appendix table 1: Effects of 3 types of spatial arrangements on cumulative number of leaves per plant at Samaru and Kadawa (1985)

| PLANT<br>TREAT*             | CULTIVAR  | WEEKS AFTER TRANSPLANTING |        |        |        |        |        |        |        |
|-----------------------------|-----------|---------------------------|--------|--------|--------|--------|--------|--------|--------|
|                             |           | 4                         | 5      | 6      | 7      | 8      |        |        |        |
|                             |           | Samaru                    | Kadawa | Samaru | Kadawa | Samaru | Kadawa | Samaru | Kadawa |
| A1                          | Ife 1     | 18.61                     | 10.40  | 42.80  | 37.60  | 59.70  | 62.30  | 67.87  | 75.77  |
|                             | Harvester | 15.55                     | 9.86   | 44.97  | 33.37  | 66.60  | 50.07  | 64.00  | 53.73  |
| A2                          | Ife 1     | 14.90                     | 14.00  | 44.97  | 48.67  | 62.23  | 58.53  | 65.58  | 72.40  |
|                             | Harvester | 12.80                     | 15.73  | 35.43  | 47.13  | 50.90  | 64.63  | 48.53  | 75.93  |
| A3                          | Ife 1     | 14.50                     | 13.93  | 37.27  | 47.57  | 62.70  | 67.90  | 60.47  | 80.80  |
|                             | Harvester | 10.60                     | 14.53  | 38.90  | 51.23  | 73.40  | 66.83  | 67.73  | 73.83  |
| Mean                        |           | 14.49                     | 13.08  | 40.68  | 44.26  | 62.59  | 61.71  | 62.36  | 73.08  |
| S.E.D.                      |           | 5.91                      | 5.14   | 9.75   | 6.37   | 13.54  | 10.58  | 5.90   | 8.89   |
| L.S.D. (0.05) (Arrangement) |           | n.s.                      | n.s.   | n.s.   | n.s.   | n.s.   | n.s.   | n.s.   | n.s.   |

W1 - Planting along single sides of water lines of ridges.

W2 - Planting along double sides of water lines of ridges.

W3 - Planting on sunken beds.

n.s. - Not significant.

Appendix table 2: Effects of 3 types of spatial arrangements on cumulative number of leaves per plant at Kadawa (1986)

| ARRANGEMENT* | CULTIVAR  | WEEKS AFTER TRANSPLANTING |       |       |       |       |
|--------------|-----------|---------------------------|-------|-------|-------|-------|
|              |           | 4                         | 5     | 6     | 7     | 8     |
| A1           | Ife 1     | 37.60                     | 62.33 | 75.97 | 75.23 | 74.28 |
|              | Harvester | 33.37                     | 44.07 | 53.73 | 55.43 | 55.02 |
| A2           | Ife 1     | 48.67                     | 58.53 | 72.40 | 74.10 | 75.60 |
|              | Harvester | 47.57                     | 64.63 | 69.93 | 77.80 | 77.90 |
| A3           | Ife 1     | 47.57                     | 67.90 | 80.80 | 82.80 | 82.05 |
|              | Harvester | 51.23                     | 66.83 | 79.83 | 80.80 | 80.02 |

A1 - Planting on single sides of water lines of ridges.

A2 - Planting in double sides of water lines of ridges.

A3 - Planting in sunken beds.

Appendix table 3: Effects of 3 types of spatial arrangements on number of flowers per plant at Samaru & Kadawa (1985)

| ARRANGEMENTS                | CULTIVAR  | WEEKS AFTER TRANSPLANTING |       |               |       |               |       |               |
|-----------------------------|-----------|---------------------------|-------|---------------|-------|---------------|-------|---------------|
|                             |           | 5                         |       | 6             |       | 7             |       | 8             |
|                             |           | Samaru Kadawa             |       | Samaru Kadawa |       | Samaru Kadawa |       | Samaru Kadawa |
| A1                          | Ife 1     | 0.72                      | 12.42 | 6.53          | 33.57 | 24.80         | 53.17 | 53.93         |
|                             | Harvester | 0.73                      | 12.77 | 8.03          | 35.23 | 31.03         | 55.67 | 47.20         |
| A2                          | Ife 1     | 2.87                      | 12.83 | 9.17          | 33.00 | 37.37         | 43.83 | 67.43         |
|                             | Harvester | 4.80                      | 12.33 | 15.77         | 34.83 | 43.13         | 55.53 | 64.30         |
| A3                          | Ife 1     | 2.07                      | 17.17 | 9.17          | 35.53 | 33.10         | 51.37 | 62.83         |
|                             | Harvester | 3.90                      | 12.00 | 13.87         | 37.47 | 42.27         | 53.57 | 70.93         |
| Mean                        |           | 2.52                      | 13.25 | 10.52         | 34.94 | 35.28         | 52.38 | 61.10         |
| S.E.D.                      |           | 2.81                      | 2.15  | 5.34          | 4.85  | 5.29          | 8.19  | 6.33          |
| L.S.D. (0.05) (Arrangement) |           | n.s.                      | n.s.  | n.s.          | n.s.  | n.s.          | n.s.  | n.s.          |

\*A1 - Planting along single sides of water line

A2 - Planting along double sides of water line

A3 - Planting on sunken beds

n.s. - Not significant

Appendix table 4: Effects of 3 types of spatial arrangements on cumulative number of flowers per plant at Kadawa (1986)

| ARRANGEMENT*            | CULTIVAR  | WEEKS AFTER TRANSPLANTING |       |       |       |       |
|-------------------------|-----------|---------------------------|-------|-------|-------|-------|
|                         |           | 5                         | 6     | 7     | 8     | 9     |
| A1                      | Ife 1     | 6.53                      | 24.80 | 53.93 | 54.33 | 43.07 |
|                         | Harvester | 8.03                      | 31.03 | 47.20 | 46.03 | 37.03 |
| A2                      | Ife 1     | 9.77                      | 37.37 | 67.43 | 67.70 | 54.40 |
|                         | Harvester | 15.77                     | 43.13 | 64.30 | 65.13 | 51.80 |
| A3                      | Ife 1     | 9.17                      | 33.10 | 62.83 | 66.17 | 54.70 |
|                         | Harvester | 13.87                     | 42.27 | 70.93 | 62.60 | 49.10 |
| Mean                    |           | 10.52                     | 35.21 | 61.10 | 60.33 | 48.35 |
| S.E.D.                  |           | 2.15                      | 5.84  | 8.19  | 6.26  | 5.43  |
| LSD (0.05)(Arrangement) |           | n.s.                      | n.s.  | n.s.  | n.s.  | n.s.  |

\*A1 - Planting in single sides of water lines of ridges.  
A2 - Planting in double sides of water lines of ridges.  
A3 - Planting in sunken beds.

## Jenkinson &amp; Kadawa (1985)

[illegible]

\*4.1 - Planting along single sides of water lines

A2 - Planting along double sides of water lines

### A3 - Flattening on sunken beds

Appendix table 6: Effects of 3 types of spatial arrangements on Plant height (cm) at Kadawa (1986)

| ARRANGEMENT*              | CULTIVAR  | WEEKS AFTER TRANSPLANTING |       |       |       |       |
|---------------------------|-----------|---------------------------|-------|-------|-------|-------|
|                           |           | 4                         | 5     | 6     | 7     | 8     |
| A1                        | Ife 1     | 43.26                     | 47.30 | 66.37 | 66.70 | 66.83 |
|                           | Harvester | 39.27                     | 44.03 | 66.40 | 66.93 | 67.23 |
| A2                        | Ife 1     | 40.27                     | 39.63 | 68.53 | 68.13 | 68.30 |
|                           | Harvester | 46.93                     | 52.93 | 66.23 | 66.37 | 66.53 |
| A3                        | Ife 1     | 43.90                     | 50.03 | 65.73 | 66.33 | 66.80 |
|                           | Harvester | 43.57                     | 52.77 | 68.17 | 68.30 | 68.33 |
| Mean                      |           | 42.89                     | 47.80 | 66.91 | 67.13 | 67.34 |
| S.E.D.                    |           | 4.32                      | 4.45  | 3.54  | 3.36  | 3.40  |
| L.S.D.(0.05)(Arrangement) |           | n.s.                      | n.s.  | n.s.  | n.s.  | n.s.  |

\*A1 - Planting in single sides of water lines of ridges.

A2 - Planting in double sides of water lines of ridges.

A3 - Planting in sunken beds.

Appendix table 7: Leaf Area Index (LAI) Estimate for  
the 3 spatial arrangements (1985)  
7 U.A.T.

|           | A1     |        | A2     |        | A3     |        |
|-----------|--------|--------|--------|--------|--------|--------|
|           | Samaru | Kadawa | Samaru | Kadawa | Samaru | Kadawa |
| Ife 1     | 0.40   | 0.42   | 0.30   | 0.46   | 0.59   | 0.45   |
| Harvester | 0.22   | 0.50   | 0.42   | 0.46   | 0.37   | 0.62   |
| Mean      | 0.39   |        | 0.41   |        | 0.51   |        |