# GROWTH ANALYSIS STUDIES AND THE RELATIONSHIP OF GROWTH INDICES WITH FRUIT YIELD IN GENOTYPES OF TOMATO (*Lycopersicon esculentum* Mill)

**BY**

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# DECLARATION

I hereby declare that this dissertation embodies the results of my own research work. No part of this thesis has previously been submitted for a degree or any other qualification. Any portion of the work to which the author is indebted to other sources are clearly mentioned and explicit references are given.

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Professor J D Olarewaju Date

Chairman, Supervisory Committee

# CERTIFICATION

This dissertation titled **"GROWTH ANALYSIS STUDIES AND THE RELATIONSHIP OF GROWTH INDICES WITH FRUIT YIELD IN GENOTYPES OF TOMATO (*Lycopersicon esculentum* Mill)"** by Jacob Goke Bodunde, meets the regulations governing the award of the degree of Doctor of Philosophy (Crop Physiology) of Ahmadu Bello University, Zaria, and it is approved for its contribution to scientific knowledge and literary presentation.

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# DEDICATION

To, Tolu, Tomi and Temi, my loving children.

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# ABSTRACT

Tomato *(Lycopersicon esculentum* Mill) is an important fruit vegetable crop all over the world including Nigeria. Its production level has increased in the last 10 years as a result of increased land area under cultivation and improved management practices. Research in the area of physiological determinants of fruit yield in tomato needs to be enhanced as information in this area is hitherto scanty.

Growth analysis studies were conducted for two wet seasons and two dry seasons between 1989 and 1992 to determine the relationship between fruit yield and plant growth indices and to determine genotype responses and differences in growth and dry matter accumulation and distribution. Other areas covered in the study are determination of seasonal influence on dry matter accumulation and distribution. The use of simple and fast leaf rectangular area method in leaf area determination was also examined, and aspects,of the tomato plant growth that could be used as selection indices in crop improvement programmes were examined.

Trials were cited at Samaru (11° $ll^{1}$ N, 07° 38'E) and five genotypes of tomato viz SAMTOM-7 SAMTOM-10, SAMTOM-16, TI-244 and TI-468 were used in all trials. Sampling at weekly intervals, for six weeks starting from three weeks after transplanting was done for the determination of growth indices through leaf area and dry weights.

Results showed that specific growth indices values varied between years and were closely related within season (wet and dry) . Thus environment was viewed to have had a great influence on all growth indices determined. Genotype difference in growth indices per sampling time was not significant. Net assimilation rate and mean crop growth rate significantly differed between genotypes, in each of the two dry seasons. Total plant dry weight was higher in the wet season than in the dry season but this had no direct relationship with fruit yield. The leaf area index (LAI), stem weight ratio, and root weight ratio had significant linear relationship with fruit yield. A high LAI would result in high fruit yield during the dry season but an optimum LAI was not attained. Leaf loss due to fungal attack prevented the establishment of a similar relationship during the wet season.

A high correlation was observed between leaf rectangular area (LRA) and measured leaf area and the use of LRA in leaf area determination is thus considered suitable.

Given the controlling influence of the environment on growth parameters determined in the study, it was suggested that recommendations resulting from growth analysis studies should always define the environment of the study. The need to establish an optimum LAI for high fruit yield in tomato was emphasized because of the observed significant association of the former with fruit yield.

The growth parameters determined indicated that the leaf area index level would determine fruit yield in the tomato crop.

# CHAPTER ONE

## INTRODUCTION

### 1.1 Origin and Distribution of Tomato

The commercial tomato belongs to the species *Lycopersicon esculentum* Mill and has alternative names such as *Solanum lycopersicon* Linn. and *Lycopersicon lycopersicum* (L) Karsten. The genus *Lycopersicon* is a relatively small one within the large family Solanaceae which embraces about 90 genera (Taylor, 1986). Other important species in the genus include *L. pimpinellifolium, L. cheesmanii, L. parviflorum, L. hirsutum, L. chilense,* and *L. peruvianum.*

Hector (1938) described the tomato as a herb with compound leaves, the leaf arrangement being alternate though leaflets are pinnate on each compound leaf. Leaflet shape could be ovate to oblong, with irregularly toothed or lobed margins. The stem which is usually strongly pubescent is angular and could be woody at the base. The flowers are aggregated in small racemose cymes. Each flower is borne on a short pedicel constricted at about the middle point as an abscission layer. It is perfect, pendent, hypogynous and regular.

The fruit is a berry, green when unripe, and golden yellow to red when fully ripe.

The tomato is grown in various parts of the world, including Nigeria, where the occurrence of many local cultivars suggests a possibly long history of its cultivation. Its origin is however traced to the high altitude mountains of the Andes in Peru (Rick, 1956). The crop was first domesticated in Mexico from where it was introduced to Europe by Spaniards, and later to the United States at about the end of the 18th century (Purseglove, 1978). Tomato probably came to Africa through Europe as reported by Villareal (1980).

## 1.2 Importance of Tomato

The tomato is an importantcash and industrial crop and a popular fruit vegetable in Nigeria and elsewhere.

The ripe fresh fruit, apart from its use in soups and stews could be processed into ketchup, paste, puree, powder or juice while the green unripe fruits are useful as pickles and preserves. The seed in the fruit contains up to 24% oil often used as salad oil and in manufacturing oil-based products (Purseglove, 1978). The pulp and other residual waste from the canning industry are used for livestock feed and as manure.

From the nutrition point of view, tomato is said to have the potentials of supplying per hectare, almost as many calories as, and more protein than, rice (Villareal,

1980). Comparing nutrient yield of sixteen different crops on dry matter per day basis, Villareal (1980) reported that tomato ranked 8th highest in vitamin C and protein, 9th in iron and 13th in vitamin A.

## 1.3 Production of Tomato

The major areas of production in Nigeria are found around the Northern Guinea and Sudan savannah ecological zones. Total annual production, crop yield per hectare, and total land area cultivated have had a steady increase in the last two decades (Table 1).

Table 1. Production Trend of Tomato In Nigeria, Africa and the World, 1982 to 1993

| | Area Harvested (1000 ha) | | | | Yield (t/ha) | | | | Fruit Production (1000 MT) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1981 | 1988 | 1990 | 1993 | 1981 | 1988 | 1990 | 1993 | 1981 | 1988 | 1991 | 1993 |
| Nigeria | 38 | 51 | 53 | 55 | 0.69 | 12.26 | 12.26 | 12.36 | 403 | 625* | 650* | 680 |
| Africa | 339 | 439 | 462 | 443 | 14.54 | 18.23 | 18.15 | 20.26 | 4923 | 7811 | 8389 | 8968 |
| World | 2494 | 2829 | 3027 | 2964 | 21.12 | 23.39 | 23.74 | 25.51 | 52,666 | 66,173 | 71,867 | 75,608 |

* Estimates.

Source: FAO Quarterly Bulletin of Statistics: 6 (4) 1993

The average fruit yield of tomato in Nigeria rose from around 10.7t/ha in 1981 to about 12.4t/ha in 1993, a rise brought about by improved crop productivity (FAO, 1993). Compared with both African and World average yields which stand respectively at 20.3t/ha and 25.5t/ha, tomato yield in Nigeria is still very low. The unacceptably low yield results from biotic and abiotic limitations to tomato production under Nigerian conditions. The physiology of fruit yield in tomato has not been as widely reported as those of the cereals and other grain crops where advances have been made in elucidating the physiological basis of grain yield. Khan and Sagar (1967) indeed reported that the type of source - sink association in tomato is in contrast with what obtains in other crops. They explained that tomato has a low efficiency of photosynthate partitioning into the economic organ of the plant.

## 1.4 Growth Analysis Concept

The concept of plant growth analysis was evolved as a result of attempts to explain some interdependent processes in the plant that determine yield, and this was evident in the various works of Blackman (1919) and Watson (1952, 1958). Growth analysis is not an end in itself, rather it forms part of an investigation into particular aspects of plant growth and development which

themselves are a manifestation of many physiological processes.

In general, the purpose of growth analysis is to aid in explaining plant growth from the view point of dry matter production. This is often done through the itemization of total growth into its components which are the rate and duration of growth. The rate of growth component, according to Causton and Venus (1981) is the primary concern of an analyst as the duration of growth is easily determined.

Indices of growth rate that may bear direct or indirect relationship with crop yield include the relative growth rate, the net assimilation rate and the crop growth rate. The leaf area and its derivatives like leaf area ratio, leaf area duration, and leaf area index, are also of significance in plant physiological studies, including yield determination. Kallis and Tooming (1974) reported on the influence of some of these growth functions on the yield of grain crops.

**Objectives Of The Study**

The aims and objectives of this study were:

i) to examine the relationship between some plant growth indices and fruit yield of tomato;

ii) to determine genotype differences in dry matter accumulation and partitioning among organs of the plant;

iii) to determine and explain possible differences in specific growth indices between genotypes;

iv) to examine the suitability or otherwise of the use of a simple leaf area determination method (leaf rectangular area) in growth analysis studies;

v) to suggest for crop improvement purpose what aspect(s) of plant growth in tomato could be improved upon to enhance yield; and

vi) to examine the influence of cropping season on dry matter accumulation.

# CHAPTER TWO

## LITERATURE REVIEW

### 2.1 Tomato Production Trend In Nigeria

Nigeria currently produces about 680 thousand metric tonnes of tomato fruits per year, this being 7.6% of total African production. This production figure is realized from an approximated 55,000 ha land area. Relative to other African countries, this is a low level of productivity as Morocco cultivates an estimated land area of just 29,000 ha but produces about 940000mt (11.3% of African total) while Egypt which is the leading producer in Africa (51.3% of total) occupies that position as a result of high yield. Average yields in Egypt and Morocco are respectively 33t/ha and 30.9t/ha. Both figures above the world average of 25.51t/ha (FAO, 1993).

## 2.2 Physiology of Yield in Tomato

In contrast to what obtains in grain crops, the economic yield component of the tomato (the fruit) has a low dry matter content, and yield is mainly made up of accumulated water in fruits. Thus factors which modify the water status of the plant and the rate of carbon assimilation would determine the relative amounts of sugar, minerals and water in tomato fruits (Anonymous, 1991).

Tomato leaf has a low exporting capacity. Khan and Sagar (1967) in an experiment on translocation in tomato reported that mature leaves of tomato exported only 30% of the carbon fixed by them in 24 hours. The implication of low leaf export is the likelihood of a high leaf dry weight relative to the reproductive structures. In an earlier work by Goodall (1945) it was reported that dry weight increase in an exporting leaf of tomato could be as high as 5 - 10% per day. The high retention of fixed carbon by the tomato leaf could be a major yield limitation as Zelitch (1971) emphasized that the distribution of the products of photosynthesis into tissues that comprise economic yield is important because photosynthesis is said to be responsible for 90 - 95% of total dry matter production in a plant.

A possible compensatory factor with regard to leaf retention of fixed carbon could be found in the work reported by Acock et al. (1978). They observed that the young leaves could start exporting at a very young age, while the rate of photosynthesis in old leaves that are well lit is high. This is contrary to what obtains in other crop plants.

Apart from source - sink competition for assimilates in tomato plants, cases of sink-sink competition exist. Fisher (1977) reported competition between fruit trusses to the effect that if there are many trusses per plant, fruit yield per truss is reduced either because of small sized fruits found per truss or few fruits per truss or both. He also reported reduced carbon assimilation rate as a result of lack of fruit load. This is in agreement with the general phenomenon in plants that the photosynthetic rate of the source is accelerated when the capacity of the sink is large, and retarded if the source capacity exceeds the sink capacity. This, according to Gupta (1992) is because the photosynthetic rate is controlled by the rate of removal of photosynthetic products from the source.

## 2.3 Growth Analysis

### 2.3.1 Growth Rate Analysis:

In terms of plant dry weight and leaf area measurements, growth analysis is founded on the law of compound interest applied to dry weight increase according to Blackman (1919). Growth rate analysis is therefore based on the sequential measurement of growth as dry matter increase. This usually involves a destructive sampling which according to Bleasdale (1978) implies that the different plant samples used at different sampling times should as much as possible represent the population. Bazzaz and Harper (1977) attempted a break-away from the conventional destructive sampling method when they proposed a demographic analysis of the growth of single plants, an idea supported by Hunt (1978).

In growth analysis, plant growth is described by the use of growth indices that often bear relationship with themselves, and with some plant physiological processes. Zelitch (1971) explained that both photosynthesis and respiration play a vital role in the determination of growth rate indices; this suggests that such indices should bear a relationship with yield. The relevance of

photosynthesis in growth analysis is emphasized given the knowledge that mineral status mainly affects the rate of carbon assimilation while photosynthesis is largely responsible for dry weight increase (Zelitch, 1971, Epstein, 1972). In his analysis for ash content of total dry matter in Zea mays, Bidwell (1974) also confirmed the above when he reported 6% minerals ash content.

### 2.3.2 Leaf Area:

The determination of leaf area is prime in growth analysis. Leaf area estimation has been made with various methods which have had varying degree of accuracy (Spencer, 1962, Bleasdale, 1978, Igbokwe et al 1984, Nwachukwu and Ene, 1987). The method of leaf area estimation used in a growth analysis study should be reasonably accurate for the leaf type and if possible should be fairly rapid. Watson and Watson (1953) adopted the use of an indirect method where a known dry weight of leaf sample is used by proportion to determine the area of a given leaf dry weight. The method is fast as only the sample area is measured after which the entire sample is oven-dried.

The direct determination through the use of grids with squares of known areas was used by Freeman and Bolas (1956), while Winter et al (1956) also used the direct

determination method by the use of a planimeter. This would not be suitable for small leaf-lets of a compound leaf as in tomato plant.

In further search of fast leaf area determination methods with acceptable accuracy, Spencer (1962) tried the use of the leaf rectangular area on cassava leaves. This linear measurement he compared with the planimeter and punch methods in simplicity, rapidity and accuracy. He concluded that in spite of the irregular shape of the cassava leaf, linear measurements could be used in determining the leaf area of cassava as he obtained a highly significant positive correlation ($r = 0.941$) when the known leaf area got through a planimeter was plotted against leaf rectangular area. This method was earlier used with a marked degree of accuracy for cotton plant by King and Lawes (1957).

More recently, Nwachukwu and Ene (1987) tried a non-destructive leaf area determination method for ginger plants using a regression equation 'Area = $0.64LW + 1.33$', L and W being length and broadest width of a leaf, respectively. The equation was derived through a regression of leaf area per plant on leaf rectangular area. These authors found this method accurate and rapid.

### 2.3.3 Leaf Area Index:

From leaf area measurements, the area of leaf per unit area of ground can be determined. Watson (1947) called this ratio the leaf area index (LAI). Since the ground area per plant stand is static, it is implied that as the leaf area increases, the LAI value also increases until mutual shading of leaves is attained. Duncan (1969) emphasized the relevance of LAI in yield determination of crops. He explained that a high LAI value favours efficient light interception even at low level of irradiation, such that yield is enhanced through increased photosynthesis. He cautioned that the LAI required for optimum productivity would depend on the leaf angle of the particular crop. Further, on the relevance of LAI in crop yield, Dennett (1975) also reported that when the LAI is known, a reasonable estimate of dry matter production is possible. Biscoe and Gallagher (1977) also reported that at low LAI, dry matter production would be limiting. They suggested that for a crop, the desirable LAI value is one that allows a leaf interception of about 80% of photosynthetically active radiation (PAR). The LAI has in fact been described as the size of the photosynthetic system by Alofe and Amusan (1992).

When the LAI value is plotted against time, the area under the curve represents the area and duration of the leaves and this is termed the leaf area duration (LAD).

### 2.3.4 Net Assimilation Rate

This is the measure of the efficiency of the leaf to produce dry matter and it is also often called unit leaf rate (ULR). This concept has a long history as it was evolved by Gregory (1917) and it is expressed in units of dry weight $m^{-2}$ leaf area $day^{-1}$. Zelitch (1971) opined that the NAR measures the excess of dry matter gained over loss by respiration, meaning that not all changes in photosyntheses are determined NAR.

The calculation of NAR is often based on leaf area but it could also be estimated through other parameters of photosynthetic potential like leaf dry weight (Wareing et al, 1968) and leaf protein or nitrogen content (Williams, 1946). Given the above possibilities, Bleasdale (1978) emphasized that the different methods of NAR estimation often give different values. He therefore suggested that parameters used in estimation should be indicated in the manner of $E_A$, $E_W$, $E_N$ and $E_P$ for estimation using leaf area, leaf dry weight, leaf nitrogen and leaf protein, respectively. However, there seems to be a popular adherence to the use of leaf area

in NAR estimation. Causton and Venus (1981) argued that leaf dry weight is not the best attribute of the leaf in relation to dry matter increases through photosynthesis. They concluded that because of the anatomical and morphological make-up of the leaf, the leaf area remains a better attribute of estimating NAR.

The NAR value is said to be dependent on some other growth indices especially the LAI, and on the source-sink relationship. Adelana and Milbourn (1976) recorded low values of NAR at high LAI in Zea mays and concluded that the observed trend suggests that as LAI increases, NAR decreases. They added that the magnitude of this trend varied between varieties and they fitted a regression equation for each of the two varieties used thus:

$$CV_1: \quad Y = 6.63 - 0.29\ X$$

$$CV_2: \quad Y = 6.42 - 0.26\ X$$

X and Y being LAI and NAR, respectively. The authors added that this relationship would not be valid at LAI value below 2.0 because of incomplete ground cover, in other words, the relationship varies with the amount of PAR. This is in agreement with the earlier work of Watson (1958) who reported that with increasing LAI value from 1-5, NAR value decreases.

In tomato, Fisher (1977) adduced that sink limitation as a result of reduced fruit load would result in low NAR and the corollary is also true. This is the basis of photosynthate reduction following reduced sink size.

The NAR is also to a large extent controlled by the rate of respiration such that a low NAR value may be a result of an increased rate of uncoupled respiration. According to Gupta (1994), such an uncoupled respiration which is usually not geared towards growth exists when the source is in excess of the sink.

The great influence of both photosynthesis and respiration suggests that factors of the environment especially light and temperature indirectly influence the value of NAR value. Causton and Venus (1981) thus indicated that the NAR value could be negative in darkness and could change dramatically positive during light periods under favourable temperature conditions.

In the derivation of the mathematical formula used in estimating NAR, Bleasdale (1978) agreed with Watson (1958) in the use of plant dry weight and leaf area. Thus NAR is given as:

$$NAR = \frac{(W_2 - W_1)\ (\log_e L_2 - \log_e L_1)}{(t_2 - t_1)\ (L_2 - L_1)}$$

Where $W_1$ and $W_2$ are dry weights (gms $day^{-1}$) at times $t_1$ and $t_2$ respectively and $L_1$ and $L_2$ are leaf area ($dm^2$) at times $t_1$ and $t_2$ respectively.

### 2.3.5 Relative Growth Rate

Like NAR, the relative growth rate (RGR) is also a derived rather than a measured quantity. The concept of RGR also has a long history having been evolved by Watson (1952). It is indicative of the relative efficiency of each unit of the plant dry matter in the production of new dry matter. According to Hunt (1978), the practical use of RGR value is that it gives an indication of the combined performance of the various plant parts and it is useful in comparing plant species or varieties treated under uniform conditions. This, according to him is because RGR value accounts for the efficiency of the leaf to photosynthesise (NAR) and the leafiness of the species or variety (the leaf area ratio, LAR).

It was probably in view of the fore-going that Causton and Venus (1981) noted that high value of RGR may

be due to high NAR or high LAR but not both and they explained that RGR value decreases linearly with increasing plant size.

Earlier work by Thomas et al (1973) indicated that the relationship between RGR and the product of NAR x LAR varies even in a single plant depending on the plant's stage of development which determines the number of leaves and cellular respiration.

Working on varieties of onion, Iortsuum and Khan (1989) emphasized that RGR value changes with plant age. Regardless of the variety, they observed that the value was generally high at early growth stage and decreased even to negative values towards maturity.

In the determination of RGR, the plant dry weights at a given time interval are used. Solhaug (1991) used the formula:

$$RGR = \frac{\ln (W_2/W_1)}{t}$$

Where $W_1$ and $W_2$ are initial and final dry weights (mg) respectively and t is the number of weeks between harvests (sampling).

### 2.3.6 Crop Growth Rate

Crop growth rate (CGR) is the parameter that measures the rate of dry matter production per unit area of land per unit time. It was also evolved by Watson (1958) and is expressed as dry weight $m^{-2}$ ground area $day^{-1}$. Watson (1958) further proposed that the value of CGR is a more realistic measure of crop performance and it is a product of NAR and LAI which means that CGR measures both plant photosynthetic efficiency and its leaf area per unit land area. Bleasdale (1978) observed that the implication of the NAR and LAI being constituents of CGR is that if the desirable aim of increasing CGR is to be achieved, either LAI or NAR must be increased. He further explained that since NAR is determined by basic physiological processes of photosynthesis and respiration, its value is difficult to alter. He therefore, suggested that CGR could be increased by increasing LAI to the optimum level through specially the use of N-based fertilizer, this being the fundamental basis of high crop yield consequent upon high CGR value. Bleasdale (1978) thus concluded that increasing crop yield is largely a matter of increasing the interim ceiling LAI, that is, the stage at which the rate of death of the leaves at the base of the canopy due

to low light intensity equals the rate of appearance of young leaves.

The above conclusion is in consonance with the assertion of Adelana and Milbourn (1976) who reported increasing value of CGR as LAI increases in maize (Zea mays). This observation also confirms the report of Wien (1975) that CGR was asymptotically related to LAI in cowpea.

### 2.3.7 Correlation Of Growth Indices

Total dry matter yield is generally correlated with economic yield. According to Watson (1971), this correlation exists, though it is influenced by not only how much assimilate is supplied to the economic plant part but also by how much photosynthate the part is able to accept.

The association between two or more variables could be usefully characterized by the use of appropriate statistical procedures. Gomez and Gomez (1984) reported that correlation and regression analyses allow the examination of association types between variables. Correlation analysis gives indication of the degree of association between variables while regression analysis describes the effect of one or more variables - independent variable(s), on a single variable termed the dependent variable.

# CHAPTER THREE

## MATERIALS AND METHODS

### 3.1 Experimental Site

The series of experiments reported here were conducted at the research field of the Institute for Agricultural Research (IAR), Samaru ($11^0$ $11^1$ N, $7^0$ $38^1$ E). The dry season trials were conducted under irrigation as against the wet season trials whose water supply was met through natural rainfall.

### 3.2 Experimental Materials

Five genotypes of tomato were used for the study viz:

SAMTOM-7: A processing type tomato variety released by the IAR, Samaru. It is determinate in habit and early to medium maturing (8 - 11 weeks after transplanting, i.e WAT). It has a potential yield of up to 56t/ha.

SAMTOM-10: This is an IAR released variety. It was introduced from the IAR & T, Ibadan with the name Ife 1. It is determinate during the dry season but could be somewhat indeterminate and bushy under wet season

conditions. It is of fresh market type, and is early to medium maturing (8 - 11 WAT) and has a potential yield of close to 53t/ha. It as recommended mainly for dry season cultivation in the northern Guinea Savannah.

SAMTOM-16: An introduced line which the IAR and released as a heat-tolerant-variety. It is traced to Israeli origin. It is determinate in habit with a mean height of about 75cm but could be indeterminate in wet season conditions. Fruit is of good processing quality because of its bright red colour and possession of other processing qualities. It has a potential yield of 50 - 55 t/ha.

TI 468: This was introduced line in the IAR germplasm pool from the Ministry of Agriculture of the former USSR. It is indeterminate in habit and fruit is better suited for fresh market. It has a potential yield of about 45 t/ha.

TI 244: It is also an IAR introduction from the Asian Vegetable Research and Development Center (AVRD), Taiwan. It is semi-determinate and medium to late maturing (10 - 11 WAT) relative to the other varieties. Fruits are of good processing type. It has a potential yield of about 55 t/ha.

## 3.3 Nursery

Seeds were sown in nurseries, and recommended standard nursery practices were observed with regard to sowing techniques, seedling nutrition, watering (as applicable) and seedling protection against pests and weeds. Transplanting of seedlings was done at about 4 to 5 weeks after sowing.

## 3.4 Field Layout

### 3.4.1 Experimental Design

The randomized complete block design (RCBD) with a statistical linear model Xij = U + Ti + ej + Eij was used, where

Xij = Value of any observation

U = An unknown constant, the population mean common to all treatment.

Ti = Treatment effects

ej = Block effects

Eij = Error term.

### 3.4.2 Beds and Ridges

The wet season plants were grown on raised beds 1M wide. The dry season plants were grown on 60cm ridges whose furrows served as irrigation channels.

### 3.4.3 Plot Size

Net plot size varied between wet and dry seasons. For the wet season trials, plot size was 4M x 4M ($16M^2$) while it was 8M x 4M ($32M^2$) for the dry season trials.

### 3.4.4 Crop Spacing

The wet season crops were spaced 50cm x 50cm on raised beds. The dry season crops were spaced 45cm apart on 60cm ridges.

## 3.5 Cultural Practices

### 3.5.1 Fertilizer Application

Basal application of NPK (15:15:15) at 300kg/ha was done on the field site prior to transplanting. Top-dressing of the seedlings was done using Calcium Ammonium Nitrate (CAN/Nitrochalk, 26% N) at 3 and 6 weeks after transplanting

(WAT) at the rate of 125kg/ha each application, giving a total of 110 kg N $ha^{-1}$.

### 3.5.2 Irrigation

Water need of the dry season crop was met by weekly surface irrigation. Amount of irrigation water was not quantified but each ridge was soaked at each application.

### 3.5.3 Weeding

Weeds were controlled through manual (hoe) weed removal as the need arose. Crops were free from competition with weeds.

### 3.5.4 Crop Protection

Starting from 3 WAT, the wet season crops were protected against leaf diseases through weekly application of a fungicide (Dithane M45) at the rate of 150g/10 liters water (2.25kg product $ha^{-1}$). Following recommended practices, the crops were mulched with dry grass for enhanced control of leaf diseases and to minimize fruit decay that might result from direct contact of fruit with soil.

### 3.5.5 Harvesting

Fruits that had changed colour from green to red or golden-yellow or at 'breaker' stage were considered ripe and were harvested by hand-picking. Harvested fruits were counted, weighed, with the number and weight recorded as fruit yield. This was then separated into marketable and unmarketable lots.

## 3.6 Data Collection

### 3.6.1 Plant Sampling

Samples of plants for growth analysis studies were taken weekly at five intervals from 3 WAT to 8 WAT. Samples were chosen using pre-determined plant positions (to avoid bias) per each row in a plot. Destructive sampling was done, thus different plants were used in each plot at different sampling times.

In taking the plant samples, loss of plant root was minimized by digging round the plant before uprooting the wet season crop, and for the dry season crop by uprooting immediately after irrigation. Approximately 10% of total initial plant population (5 plants per plot) was used as samples each time.

### 3.6.2 **Leaf Area Determination**

Leaf area was estimated through a combination of the methods of Freeman and Bolas (1956) and Watson and Watson (1953).

Using the direct determination method of Freeman and Bolas (1956), leaflet samples were traced on centimeter graph paper, the number of square centimeters covered being the area of the sample. This leaflet sample of known area was oven dried to constant weight. Whole leaf samples per plant were also oven-dried, and by proportion, using the Watson and Watson (1953) method, the total leaf area was calculated by multiplying the total number of leaflets by a factor derived from the area and dry weight of leaflet sample thus:

| | | |
|---|---|---|
| Area of leaflet sample | = | X $cm^2$ |
| Dry weight of leaflet sample | = | Y g |
| Total leaf dry weight | = | Z g |
| Unit dry wt. (g) LA | = | $\frac{X}{Y}$ $cm^2$ g |
| $\therefore$ Total Leaf Area | = | $\frac{X}{Y}$ .Z($cm^2$) |

### 3.6.3 Leaf Rectangular Area

In order to compare the possible future use of a simpler and less time consuming leaf area determination method in growth studies of tomato, a modified form of the leaf rectangular area (LRA) method of Spencer (1962) was used to determine sample leaf area. Determined LRA values and leaf area values obtained using the method described in 3.6.2 were subjected to simple correlation and linear regression analyses to determine the extent to which LRA can be an alternative method of leaf area determination for tomato. LRA values were not, however, used for the determination of any growth index in this study.

### 3.6.4 Dry Weights

For the determination of total and component dry weights of plant samples, each whole fresh plant sample was severed into its components of roots, stem, leaves and reproductive structures (where applicable) of flowers, and fruits. Each component was enveloped, labelled and oven-dried first at 70 - 80°C for 48 hours and then at 105°C for 1 - 2 hours (Alofe and Amusan, 1982) ensuring constant weight of samples.

Dry weight values of individual components were obtained through an electrical laboratory weighing scale model 'Mettler P 1210'.

Total sample dry weight was obtained by adding the component weights.

### 3.6.5 Determintion of Growth Rates and Growth Ratios

Plant growth indices were determined following Solhaug (1991) as follows:

$$NAR = \frac{(W_2 - W_1) \ln (A_2/A_1)}{(A_2 - A_1)t}$$

$$RGR = \frac{\ln (W_2/W_1)}{t}$$

$$CGR = \frac{W_2 - W_1}{t} \; g \; m^{-2} \; week^{-1}$$

$$LAR = \frac{(A_2 - A_1) \ln (W_2/W_1)}{(W_2 - W_1) \ln (A_2/A_1)}$$

Where, $A_1$ = Initial leaf area

$A_2$ = Final leaf area

$W_1$ = Initial plant dry weight

$W_2$ = Final plant dry weight

$t$ = Number of weeks between two samplings.

The growth ratios were determined for each organ as:

$$\frac{w}{W}$$

Where, w = Dry weight of an organ

W = Total plant dry weight.

### 3.6.6 Fruit Characters

Using a centimeter Veneer type calliper, fruit diameter and length were measured on samples of ten fruits randomly selected per plot from fruits harvested in the third round of picking during the 1989/90 dry season and the 1990 wet season. The third harvest was chosen as it is usually mid-way between early and late pickings and would therefore probably best represent the variety and the season. The mean of calliper readings from top, middle and bottom diameters of each fruit was taken as the true diameter. Fruit length was taken as calliper reading from fruit apex to point of attachment to the receptacle. Mean fruit weight was taken as average of ten fruits weights.

## 3.7 Statistical Analysis

### 3.7.1 Analysis Of Variance

For each season's data, analysis of variance was carried out to determine genotype effect on each

parameter. The form of single season analysis of variance was as follows:

| Source of Variation | DF | MS | F |
|---|---|---|---|
| Replication | r - 1 | rMS | $\frac{rMS}{Error\ MS}$ |
| Genotype | g - 1 | gMs | $\frac{gMS}{Error\ MS}$ |
| Error | (r - 1) (g - 1) | EMS | |
| Total | rg - 1 | | |

A combined analysis of variance was done for all the four year's data to determine year (season) effect on parameters measured following Gomez and Gomez (1984) with the form:

| Source Of Variation | Df | MS | F |
|---|---|---|---|
| Year | y - 1 | yMS | $\frac{yMS}{rMS}$ |
| Reps. within year | y(r-1) | rMS | |
| Genotype | g - 1 | gMS | $\frac{gMS}{y(gMS)}$ |
| Year x Genotype | (y-1)(g-1) | y(gMS) | $\frac{y(gMS)}{EMS}$ |
| Pooled Error | y(r-1)(g-1) | EMS | |
| Total | yrg - 1 | | |

In both the single season and combined analysis of variance, statistical inference were based on variance ratio (F) values according to Snedecor and Cochran (1967).

### 3.7.2 Correlation Analysis

Simple correlation analysis was done to describe the degree of association between growth indices and between each growth index and yield. The coefficients of correlation (r) values were drawn into matrices and statistically significant coefficients were indicated.

Leaf rectangular area (LRA) measurements were also correlated with leaf area determined through the method described in 3.6.2 above; correlation matrices were indicated and statistical inferences were drawn.

### 3.7.3 Regression Analysis

The fruit yield each year was regressed on each growth index in a simple linear regression analysis. This aimed at determining the extent to which each index had linear relationship with fruit yield. The form of regression analysis of variance was:

| Source Of Variation | DF | MS | F |
|---|---|---|---|
| Regression | 1 | $\frac{XY}{1}$ | $\frac{xy}{2}$ |
| | | | $\frac{y^2-b\ xy}{n-2}$ |
| Residual | n-2 | $\frac{y^2-b\ xy}{n-2}$ | |
| Total | n-1 | $\frac{y^2}{n-1}$ | |

The variance ratio (F) test was used to determine the statistical significance of linear regression. Where significant linear relationship was indicated, a regression equation was written.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Dry Matter Accumulation And Distribution

The total dry matter (TDM) per plant increased with plant age, being lowest at first sampling interval and highest at the last sampling interval (Table 2). Mean TDM for each of the four seasons showed that the dry season crop was less efficient in dry matter accumulation than the wet season crop, the difference being statistically significant ($P = 0.05$) at all sampling times before 8 weeks after transplanting (WAT).

Table 2: Total Dry Matter Yield (g Plant$^{-1}$) in Tomato from 4 to 8 weeks After Transplanting (WAT).

| Year | Weeks After Transplating | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| 1989/90 Dry Season | 11.77 | 13.52 | 16.83 | 21.92 | 30.26 |
| 1990 Wet Season | 24.13 | 47.87 | 52.68 | 55.94 | 56.80 |
| 1991 Wet Season | 25.73 | 49.15 | 53.63 | 61.18 | 62.07 |
| 1991/92 Dry Season | 9.85 | 11.49 | 18.47 | 26.68 | 54.43 |
| DMRT (0.05) | 10.74 | 27.93 | 23.14 | 38.00 | NS |

Genotype responses in dry matter accumulation are presented in Figures 1 to 4. For each season and for most genotypes, dry matter yield increases with time. However, cases of declining dry matter production between sampling times were observed with a few genotypes in the wet season crop, especially between sampling periods 6 and 8 WAT. There was no significant difference in TDM accumulation between genotypes.

The dry matter distribution pattern among the various plant morphological components are shown in Tables 3 and 4. The results of the 1989/90 dry season and the 1991 wet season were similar. In both years, at any given sampling time, dry matter in the leaf relative to the total, was higher than 50%. Maximum leaf weight ratio (LWR) value of 60% was recorded in 1989/90 dry season at 6 WAT, and 67% in the 1991 wet season at 4 WAT. Generally, LWR was not less than 42% at any sampling time in all the experiments. Stem dry matter was generally in the range of 20 - 33% of total, ranking next to leaf dry matter at all sampling times. No definite trend of increase or decrease with sampling time was observed with the stem weight ratio (SWR).

Dry matter yield of root relative to total was in the range of 10 - 28%. There was a clear trend in the dry season with the value decreasing with plant age. Such a definite trend was not observed in the wet season crop.

The flower (and/or fruit) dry matter as a proportion of total was generally low during the sampling period. Dry matter Yield of the flower/fruit increased with time in all the experiments.

**Fig.2: Total dry matter (g/plant ) in tomato genotypes 4-8 weeks after transplanting (WAT), 1990 wet season.**

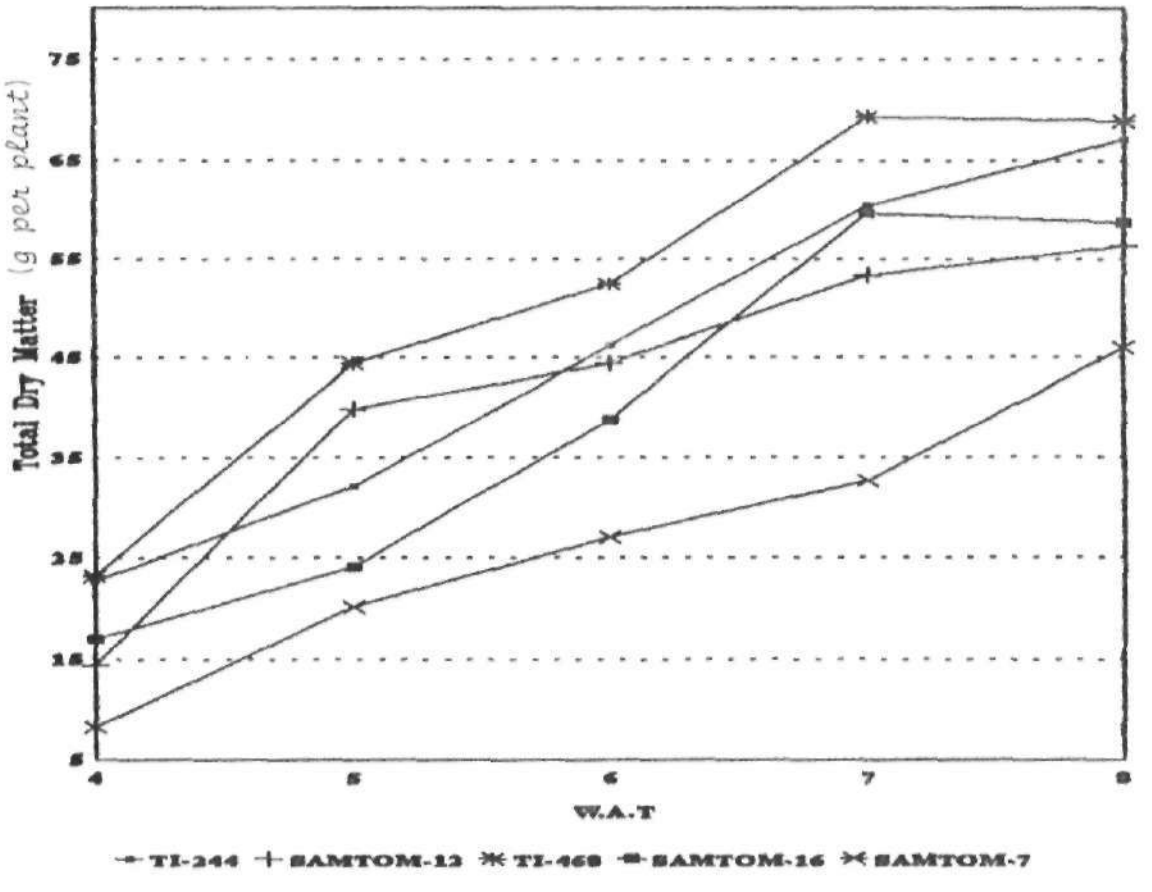


Fig.4: Total dry matter (g/plant ) in tomato genotypes 4-8 weeks after transplanting (WAT), 1991/92 dry season.

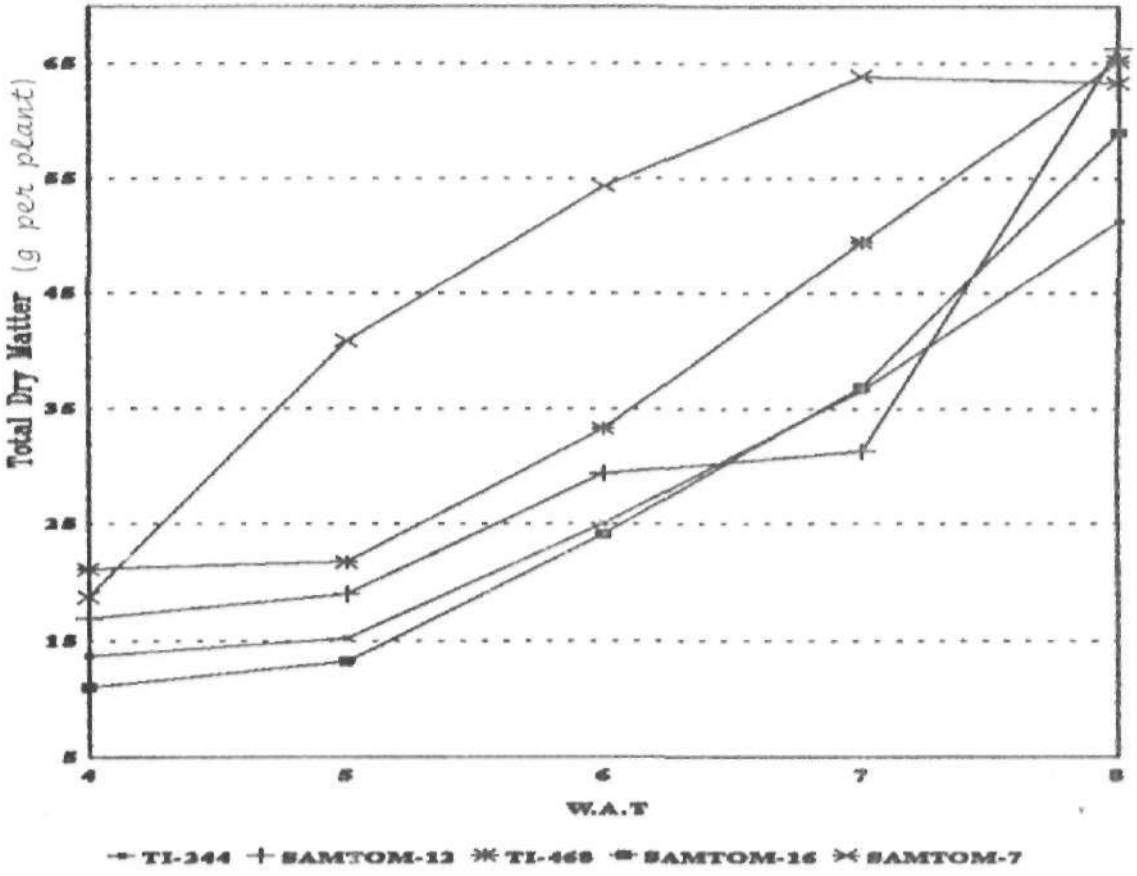


**Table 3: Dry Matter Distribution Ratio Among Morphological Organs of Tomato Plants**

| | Sampling time (WAT)* | | | | |
|---|---|---|---|---|---|
| Plant Organ | 3 - 4 | 4 - 5 | 5 - 6 | 6 - 7 | 7 - 8 |
| | (1989/90 Dry Season) | | | | |
| Leaf | 0.54 | 0.57 | 0.60 | 0.51 | 0.56 |
| Stem | 0.29 | o.31 | 0.26 | 0.28 | 0.22 |
| Root | 0.18 | 0.13 | 0.11 | 0.12 | 0.09 |
| Flower/Fruit | 0.00 | 0.02 | 0.05 | 0.11 | 0.13 |
| | (1990 Wet Season) | | | | |
| Leaf | 0.61 | 0.62 | 0.53 | 0.46 | 0.45 |
| Stem | 0.23 | 0.23 | 0.23 | 0.21 | 0.24 |
| Root | 0.14 | 0.12 | 0.18 | 0.11 | 0.10 |
| Flower/Fruit | 0.01 | 0.04 | 0.08 | 0.22 | 0.23 |

* Weeks after transplanting

Table 4. Dry Matter Distribution Ratio Among Morphological Organs of Tomato Plants

| | Sampling Period (WAT)* | | | | |
|---|---|---|---|---|---|
| | 3 - 4 | 4 - 5 | 5 - 6 | 6 - 7 | 7 - 8 |
| | (1991 Wet Season) | | | | |
| Leaf | 0.67 | 0.56 | 0.65 | 0.57 | 0.54 |
| Stem | 0.22 | 0.29 | 0.24 | 0.28 | 0.24 |
| Root | 0.11 | 0.17 | 0.11 | 0.10 | 0.11 |
| Flower/Fruit | 0.00 | 0.01 | 0.01 | 0.06 | 0.11 |
| | (1991/92 Dry Season) | | | | |
| Leaf | 0.42 | 0.47 | 0.63 | 0.68 | 0.56 |
| Stem | 0.33 | 0,27 | 0.23 | 0.20 | 0.23 |
| Root | 0.26 | 0.23 | 0.13 | 0.11 | 0.10 |
| Flower/Fruit | 0.00 | 0.00 | 0.00 | 0.03 | 0.12 |

* Weeks after transplanting.

## 4.2 Growth Rates

### 4.2.1 Net Assimilation Rate (NAR)

Computed per plant as means of 5 genotypes, weekly values of NAR are shown in Tables 5 to 8. In 1989/90 dry season, the values were low throughout the sampling period (Table 5), while in the 1991/92 dry season, there was a sudden rise at 7 WAT (Table 8). In the 1990 and 1991 wet seasons, NAR values were initially high, followed by a decline, and negative values from 6 WAT (Tables 6 and 7). Thus growth, as measured by NAR differed between the two seasons. Means of the weekly values of NAR (4 - 8 WAT) for different genotypes are shown on Tables 9 and 10. Relatively high NAR values were observed for genotypes SAMTOM-16 and TI-244 during the dry season (Table 9). Genotype difference in mean NAR was significant ($P = 0.05$) in the two dry season experiments.

During the wet season (Table 10), only two genotypes, SAMTOM-7 and SAMTOM-10, did not have a negative mean NAR in at least one of the two wet seasons.

**Table 5: Mean Values of Some Growth Indices in 5 Genotypes of Tomato (1989/90 Dry Season)**

| Growth Index* | (WAT)** | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| NAR (g $cm^{-2}$ $day^{-1}$) | 0.021 | 0.021 | 0.025 | 0.023 | 0.021 |
| RGR (g $g^{-1}$ $WK^{-1}$) | 0.848 | 0.714 | 0.508 | 0.454 | 0.336 |
| CGR (g $m^{-2}$ $day^{-1}$) | 0.712 | 0.898 | 1.992 | 2.401 | 3.312 |

* Mean of 5 Genotypes

** WAT - Weeks after transplanting.

**Table 6: Mean Values of some growth indices in 5 genotypes of Tomato (1990 Wet Season)**

| Growth Index* | (WAT)** | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| NAR (g $cm^{-2}$ $day^{-1}$ | 0.732 | 0.118 | -0.220 | -0.182 | -0.244 |
| RGR (g $g^{-2}$ $WK^{-1}$) | 0.716 | 0.146 | 0.072 | 0.002 | -0.120 |
| CGR (g $m^{-2}$ $day^{-1}$) | 6.55 | 1.37 | -8.47 | -5.19 | -3.330 |

* Mean of 5 Genotypes

** Weeks after transplanting

**Table 7: Mean Values of Some Growth Indices in 5 Genotypes of Tomato (1991 Wet Season)**

| Growth Index*-- | (WAT)** | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| NAR (g $cm^{-2}$ $day^{-2}$) | 0.308 | 0.074 | -0.040 | -0.028 | 0.001 |
| RGR (g $g^{-1}$ $WK^{-1}$) | 0.536 | 0.572 | 3.520 | -0.052 | -0.150 |
| CGR (g $m^{-2}$ $day^{-1}$ | 1.71 | 0.678 | -6.171 | -0.954 | 0.366 |

* Mean of 5 Genotypes

** Weeks after transplanting.

**Table 8: Mean Values of Some Growth Indices in 5 Genotypes of Tomato (1991/92 Dry Season)**

| Growth Index* | (WAT)** | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| NAR (g $cm^{-2}$ $day^{-1}$) | 0.228 | 0.220 | 0.150 | 0.234 | 0.150 |
| RGR (g $g^{-1}$ $WK^{-1}$ | 0.420 | 0.450 | 0,272 | 0.652 | 0.300 |
| CGR (g $m^{-2}$ $day^{-1}$ | 1.764 | 2.830 | 3.430 | 8.540 | 8.550 |

* Mean of 5 Genotypes
** Weeks after transplanting.

### 4.2.2 Relative Growth Rate

In all cases except 1991/92 dry season, the RGR value decreased with sampling time (Tables 5 to 8). In the two wet season experiments, negative values were recorded between 7 and 8 WAT. The mean weekly values for the different genotypes (Table 9 and 10) indicate that SAMTOM-7 in all the years had relatively high RGR. The observed genotype difference was statistically significant during the two wet seasons (Table 10).

### 4.2.3 Crop Growth Rate

The CGR value increased with sampling time in the dry season experiments, the magnitude of the increase being somewhat sharp between 5 and 7 WAT (Tables 5 to 8). The wet season result was contradictory to the fore-going observation. Tables 6 and 7 show that in the wet season, CGR value decreased with time, and negative values were recorded from 5 WAT. Mean of weekly values of CGR on genotype basis, (Tables 9 and 10), shows that higher values of CGR were recorded in the dry season relative to the wet season. Genotypes TI 244 and SAMTOm-16 recorded particularly high CGR in the dry season and a noticeably low value in the wet season, genotype difference being statistically significant in the dry season.

**Table 9: Mean Values of Net Assimilation Rate (NAR), Relative Growth Rate (RGR), and Crop Growth Rate (CGR) In 5 Tomato Genotypes (4 - 8 WAT) During the Dry Season**

| Genotype | 1989/90 Dry Season | | | 1991/1992 Dry Season | | |
|---|---|---|---|---|---|---|
| | NAR ($g\ cm^{-2}\ day^{-1}$) | RGR ($g\ g^{-1}\ WK^{-1}$) | CGR ($g\ m^{-2}\ day^{-1}$) | NAR ($g\ cm^{-2}\ day^{-1}$) | RGR ($g\ g^{-1}\ WK^{-1}$ | CGR ($g\ m^{-1}\ day^{-1}$) |
| SAMTOM-16 | 0.034 | 0.468 | 1.84 | 0.458 | 0.402 | 11.14 |
| TI 244 | 0.036 | 0.722 | 3.98 | 0.148 | 0.422 | 4.58 |
| SAMTOM-10 | 0.032 | 0.592 | 2.89 | 0.102 | 0.420 | 2.28 |
| TI 468 | 0.005 | 0.424 | 0.42 | 0.122 | 0.422 | 3.38 |
| SAMTOM-7 | 0.003 | 0.654 | 0.17 | 0.152 | 0.428 | 3.73 |
| LSD (0.05 | 0.004 | NS | 2.15 | 0.066 | NS | 3.42 |

Table 10: **Mean Values of Net Assimilation Rate (NAR) Relative Growth Rate (RGR) and Crop Growth Rate (CGR) In Five Tomato Genotypes (4 - 8 WAT) During The Wet Season.**

| Genotype | 1990 Wet Season | | | 1991 Wet Season | | |
|---|---|---|---|---|---|---|
| | NAR ($gcm^{-2}$ $day^{-1}$) | RGR ($gg^{-1}$ $WK^{-1}$) | CGR ($gm^{-2}$ $day^{-1}$) | NAR ($gcm^{-2}$ $day^{-1}$) | RGR ($gg^{-1}$ $WK^{-1}$) | CGR ($gm^{-2}$ $day^{-1}$) |
| SAMTOM-16 | -0.151 | 0.046 | -2.21 | 0.234 | 0.463 | 2.11 |
| TI-244 | 0.030 | 0.274 | -4.94 | -0.004 | 0.711 | -0.80 |
| SAMTOM-10 | 0.037 | 0.250 | 3.11 | 0.102 | 0.524 | -2.33 |
| TI-468 | 0.001 | -0.076 | -1.43 | -0.022 | 0.413 | -3.71 |
| SAMTOM-7 | 0.044 | 0.322 | 3.74 | 0.005 | 2.332 | 0.34 |
| LSD (0.05) | NS | 0.61 | 3.42 | 0.104 | 0.766 | 2.15 |

## 4.3 Leaf Area Index

LAI trend appeared season specific (Table 11). In the dry seasons of 1989/90 and 1991/92, LAI (mean of 5 genotypes) increased with time up to the last sampling time (Tables 12 and 13). However, in the wet season, LAI only increased up to 6 WAT or 7 WAT, after which it declined (Tables 14 and 15). This time of decline coincided with when leaf diseases became severe. The 1989/90 (Dry) season LAI value was significantly higher than in any other year at all sampling times.

## 4.4. Leaf Area Ratio (LAR)

Generally from first to last sampling time, no definite trend was observed for LAR (Table 16 - 19). Relatively large values of LAR were recorded in the 1989/90 dry season while low values were recorded in the two wet seasons. The differences between seasons were statistically significant at some of the sampling times (Table 20).

**Table 11: Mean Values of Leaf Area Index (LAI)***

| Year | WAT | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| 1989/90 Dry Season | 1.22 | 2.95 | 5.49 | 6.46 | 11.54 |
| 1990 Wet Season | 0.97 | 1.88 | 2.31 | 1.53 | 1.26 |
| 1991 Wet Season | 0.47 | 1.81 | 3.79 | 4.63 | 3.91 |
| 1991/92 Dry Season | 0.43 | 0.83 | 1.68 | 2.39 | 3.97 |
| LSD (0.05) | 0.48 | 0.97 | 1.92 | 2.51 | 5.02 |

* Mean of 5 genotypes.

Table 12: Leaf Area Index (LAI) Values For The Different Genotypes During the 1989/90 Dry Season

| | WAT | | | | |
|---|---|---|---|---|---|
| Genotype | 4 | 5 | 6 | 7 | 8 |
| SAMTOM-7 | 0.84 | 2.18 | 4.84 | 8.29 | 11.89 |
| SAMTOM-10 | 1.55 | 2.59 | 5.35 | 5.69 | 11.11 |
| SAMTOM-16 | 0.96 | 2.70 | 3.83 | 4.98 | 6.02 |
| TI-244 | 1.44 | 3.68 | 6.29 | 8.28 | 16.94 |
| IT-468 | 1.79 | 3.72 | 7.15 | 5.06 | 11.73 |
| S.E | 0.18 | 0.31 | 0.57 | 0.75 | 1.73 |

Table 13: Leaf Area Index (LAI) Values For The Different Genotypes During the 1991/92 Dry Seson

| | WAT | | | | |
|---|---|---|---|---|---|
| Genotype | 4 | 5 | 6 | 7 | 8 |
| SAMTOM-7 | 0.23 | 0.61 | 1.50 | 2.42 | 3.87 |
| SAMTOM-10 | 0.42 | 0.83 | 1.64 | 2.14 | 3.82 |
| SAMTOM-16 | 0.51 | 0.90 | 1.43 | 2.23 | 3.54 |
| TI-244 | 0.49 | 1.08 | 1.82 | 2.71 | 4.68 |
| TI-468 | 0.50 | 0.72 | 2.01 | 2.52 | 3.89 |
| S. E | 0.05 | 0.08 | 0.11 | 0.10 | 0.19 |

Table 14: Leaf Area Index (LAI) Values For The Different Genotypes During The 1990 Wet Season

| | WAT | | | | |
|---|---|---|---|---|---|
| Genotype | 4 | 5 | 6 | 7 | 8 |
| SAMTOM-7 | 0.72 | 1.92 | 1.76 | 1.94 | 1.23 |
| SAMTOM-10 | 0.42 | 1.52 | 2.06 | 1.15 | 1.25 |
| SAMTOM-16 | 0.94 | 1.27 | 2.42 | 1.62 | 1.13 |
| TI-244 | 1.02 | 2.52 | 2.50 | 1.84 | 1.62 |
| TI-468 | 1.75 | 2.16 | 2.79 | 1.08 | 1.07 |
| S. E | 0.22 | 0.22 | 0.18 | 0.18 | 0.10 |

Table 15: Leaf Area Index (LAI) Values For The Different Genotypes During The 1991 Wet Season.

| | WAT | | | | |
|---|---|---|---|---|---|
| Genotype | 4 | 5 | 6 | 7 | 8 |
| SAMTOM-7 | 0.63 | 1.93 | 3.92 | 6.62 | 7.84 |
| SAMTOM-10 | 0.55 | 1.84 | 3.13 | 4.78 | 2.98 |
| SAMTOM-16 | 0.21 | 1.64 | 2.24 | 3.21 | 1.63 |
| TI-244 | 0.43 | 1.83 | 4.26 | 6.02 | 4.43 |
| TI-468 | 0.52 | 1.81 | 5.41 | 2.50 | 2.69 |
| S.E | 0.07 | 0.05 | 0.53 | 0.79 | 1.08 |

**Table 16: Mean Values of Leaf Area Ratio (LAR)* ($cm^2$ $g^{-1}$)**

| Year | (WAT) | | | | |
|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 |
| 1989/90 Dry Season | 25.03 | 21.48 | 17.01 | 15.26 | 12.52 |
| 1990 Wet Season | 11.00 | 20.10 | 12.09 | 10.50 | 10.29 |
| 1991 Wet Season | 13.23 | 27.80 | 18.40 | 9.00 | 7.90 |
| 1991/92 Dry Season | 23.19 | 23.88 | 14.85 | 14.09 | 10.66 |
| LSD (0.05) | 7.93 | 3.82 | 4.21 | 3.33 | 2.15 |

* Mean of 5 genotypes.

## 4.5 Correlation And Regression

### 4.5.1 Correlation

Matrices of correlation coefficients for 1989/90 dry season, 1990 wet season, 1991 wet season and 1991/92 dry season are respectively shown in tables 17, 18, 19 and 20. In all the years, there was a high, positive and significant (P= 0.05) correlation between NAR and CGR. LAI was significantly correlated with some other growth attributes except during the 1991 wet season.

In the 1989/90 dry season (Table 17), there was positive and significant correlation between LAI and each of fruit yield and flower/fruit weight ratio (FWR). On the other hand, there was a negative and significant correlation between LAI and stem weight ratio (SWR). During the same year, there was a significant and positive correlation between RGR and LAR while correlations between SWR and yield, SWR and FWR were negative and significant.

Other notable highlights of the 1989/90 dry season correlation analysis results include negative but non-significant correlation between LAI and NAR, LAI and RGR, LAI and LWR, LAI and LAR, Yield and RGR. During the 1990 wet season,

positive and significant correlations were observed between NAR and RGR, NAR and CGR, LAI and RWR. Significant negative correlations were observed for LAI Vs FWR, and LWR Vs FWR. The dry weights of the plant morphological components were negatively correlated.

In the wet season of 1991 (Table 18), only two pairs of growth characters; NAR vs CGR, and Yield vs RWR, were significantly positively correlated. Negative but non significant correlations include those between LAI and NAR, and between the dry weights of morphological components.

During the dry season of 1991/92, there was again a significant positive correlation between LAI and FWR. Notable negative correlations were observed between dry weights of morphological components, LAI vs NAR (as in 1989/90 and 1991), and LAI vs RWR.

**Table 17: Simple Correlation Coefficients Between Growth Indices Of Tomato (1989/90 Dry Season).**

| | NAR | RGR | CGR | LAI | LAR | LWR | SWR | RWR | FWR |
|---|---|---|---|---|---|---|---|---|---|
| RGR | 0.261 | | | | | | | | |
| CGR | 0.722** | 0.166 | | | | | | | |
| LAI | -0.058 | -0.270 | 0.527 | | | | | | |
| LAR | -0.251 | 0.582* | -0.442 | -0.505 | | | | | |
| LWR | 0.059 | 0.050 | -0.008 | -0.144 | 0.023 | | | | |
| SWR | -0.154 | 0.244 | -0.417 | -0.655** | 0.416 | -0.069 | | | |
| RWR | 0.140 | 0.401 | -0.057 | -0.207 | 0.292 | -0.533 | 0.036 | | |
| FWR | 0.019 | -0.265 | 0.520 | 0.778** | -0.543 | -0.467 | -0.642* | 0.008 | |
| YIELD | 0.051 | -0.036 | 0.280 | 0.611* | -0.432 | 0.094 | -0.599* | -0.033 | 0.371 |

* Significant at P = 0.05

** Significant at P = 0.01

**Table 18: Simple Correlation Coefficient Between Growth Indices Of Tomato (1990 Wet Season)**

| | NAR | RGR | CGR | LAI | LAR | LWR | SWR | RWR | FWR |
|---|---|---|---|---|---|---|---|---|---|
| RGR | 0.577* | | | | | | | | |
| CGR | 0.894** | 0.506 | | | | | | | |
| LAI | -0.254 | 0.015 | -0.500 | | | | | | |
| LAR | 0.013 | 0.213 | -0.008 | -0.006 | | | | | |
| LWR | 0.331 | 0.333 | 0.188 | 0.228 | 0.274 | | | | |
| SWR | -0.272 | -0.229 | -0.298 | 0.115 | -0.190 | -0.142 | | | |
| RWR | 0.033 | 0.266 | -0.104 | 0.627* | -0.247 | -0.068 | -0.055 | | |
| FWR | -0.290 | 0.367 | -0.069 | -0.591* | -0.006 | -0.791** | -0.189 | -0.371 | |
| YIELD | 0.115 | -0.327 | 0.128 | -0.289 | 0.076 | -0.192 | 0.219 | -0.267 | 0.161 |

* Significant at P = 0.05

** Significant at P = 0.01

Table 19: Simple Correlation Coefficients Between Growth Indices Of Tomato (1991 Wet Season)

| | NAR | RGR | CGR | LAI | LAR | LWR | SWR | RWR | FWR |
|---|---|---|---|---|---|---|---|---|---|
| RGR | -0.282 | | | | | | | | |
| CGR | 0.817** | -0.101 | | | | | | | |
| LAI | -0.497 | 0.343 | -0.429 | | | | | | |
| LAR | -0.035 | 0.481 | 0.025 | 0.332 | | | | | |
| LWR | -0.033 | 0.144 | -0.324 | 0.226 | -0.027 | | | | |
| SWR | 0.090 | -0.085 | 0.294 | -0.213 | -0.131 | -0.305 | | | |
| RWR | 0.160 | 0.101 | 0.095 | -0.286 | 0.180 | -0.557 | -0.117 | | |
| FWR | -0.169 | -0.295 | 0.193 | 0.078 | -0.307 | -0.401 | -0.176 | -0.111 | |
| YIELD | -0.121 | -0.062 | -0.205 | 0.002 | 0.136 | -0.159 | -0.166 | 0.665* | -0.085 |

* Significant at P = 0.05

** Significant at P = 0.01

**Table 20: Simple Correlation Coefficients Between Growth Indices Of Tomato (1991/92 Dry Season)**

| | NAR | RGR | CGR | LAI | LAR | LWR | SWR | RWR | FWR |
|---|---|---|---|---|---|---|---|---|---|
| RGR | 0-175 | | | | | | | | |
| CGR | 0.706* | 0.151 | | | | | | | |
| LAI | -0.178 | -0.197 | 0.444 | | | | | | |
| LAR | -0.541 | -0.190 | -0.363 | 0.190 | | | | | |
| LWR | 0.024 | 0.163 | 0.294 | 0.291 | 0.122 | | | | |
| SWR | -0.077 | -0.039 | -0.342 | -0.402 | 0.205 | -0.691* | | | |
| RWR | 0.064 | 0.099 | -0.468 | -0.692* | -0.158 | -0.665* | 0.454 | | |
| FWR | -0.036 | -0.178 | 0.526 | 0.869** | 0.092 | -0.000 | -0.205 | -0.521 | |
| YIELD | -0.395 | -0.080 | -0.353 | 0.109 | 0265 | -0.317 | 0.499 | -0.021 | 0.088 |

* Significant at P = 0.05

** Significant at P = 0.01

### 4.5.2 Regression Analysis

The regression analysis of variance for 1989/90 dry season showed a highly significant linear relationship between fruit yield and LAI, fruit yield and SWR. The regression equations were respectively:

Yield (t/ha) = 12.5 + 1.17 LAI

($r^2$ = 0.373)

Yield (t/ha) = 45.2 - 93.20 SWR

($r^2$ = 0.359).

The coefficient of determination for linear regression ($r^2$) was in both cases low.

In the 1990 wet season, the regression analysis of variance indicated that there was no linear relationship between fruit yield and any of the growth indices.

In the 1991 wet season, there was a highly significant linear relationship between fruit yield and RWR, with a regression equation.

Yield (t/ha) = 12.1 + 46.7 RWR, ($r^2$ = 0.442).

In the 1991/92 dry season, only SWR showed significant linear relationship with fruit yield. The regression equation was as follows:

Yield (t/ha) = 12.2 + 22.3 SWR ($r^2$ = 0.250).

Regressing fruit yield on all the growth indices put together in each year shows that fruit yield (on one hand) is linearly related to all growth indices put

together (on the other hand). High $r^2$ values of 0.746, 0.599, 0.782 and 0.577 were respectively obtained in 1989/90 dry season, 1990 wet season, 1991 wet season and the 1991/92 dry season.

## 4.6 Fruit Yield

In the 1990 wet season, SAMTOM-10 and TI-10 siginificantly yielded higher than other genotypes. The genotypes were not siginficantly different in all the other years (Table 21).

## 4.7 Leaf Rectangular Area (LRA) And Measured Leaf Area (MLA)

### 4.7.1 Correlation Analysis

Results of the correlation analysis indicating the coefficients of correlation (r) for LRA Vs MLA in the 1989/90 dry season and the 1990 wet season are shown in Tables 22 and 23 respectively. In both years, highly significant positive correlations were obtained for LRA Vs MLA each week from 4 WAT to 8 WAT. Other significant correlations in both years were:

LRA at 4 WAT Vs MLA at 5 WAT

LRA at 6 WAT Vs LRA at 8 WAT

LRA at 6 WAT Vs MLA at 8 WAT

Other significant correlations observed in the 1989/90 dry season are indicated in Table 22.

### 4.7.2 Regression Analysis

Results of the regression analysis of variance in both years indicated that there was a highly significant linear relationship between LRA and MLA at each sampling time. The coefficient of determination for linear regression ($r^2$) was in all cases high. Figures 5 - 9 illustrate the linear relationship, with the $r^2$ values and fit equations for respective sampling times indicated.

**Table 21. Marketable and Unmarketable Fruit yield (t/ha) in 5 genotypes of Tomato**

| Genotype | Yield (t/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1989/90 Dry Season | | 1990 West Season | | 1991 Wet Season | | 1991/92 Dry Season | |
| | M* | U/M** | M | U/M | M | U/M | M | U/M |
| SMATOM-16 | 17.62 | 0.31 | 8.38 | 1.97 | 15.05 | 2.77 | 16.17 | 0.45 |
| TI-244 | 19.71 | 0.14 | 5.30 | 3.84 | 18.52 | 1.47 | 17.48 | 0.17 |
| SAMTOM-12 | 22.85 | 0.68 | 10.68 | 4.98 | 19.63 | 3.01 | 17.35 | 0.95 |
| TI-468 | 19.53 | 0.94 | 10.55 | 6.54 | 20.33 | 4.14 | 18.38 | 1.43 |
| SAMTOM-7 | 21.90 | 0.44 | 5.25 | 2.56 | 15.60 | 1.01 | 17.33 | 0.42 |
| L.S.D. (O.05) | NS | 0.33 | 2.61 | 1.79 | NS | 1.22 | NS | 0.84 |

* Marketable fruits.

** Unmarketable fruits.

Table 22 Correlation Coefficients Between Leaf Rectangular Area (LRA) at 4 WAT to 8 WAT and Measured Leaf Area (MLA) at 4 WAT to 8 WAT in 1989/90 Dry Season

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $LRA_5$ | 0.17481 | | | | | | | | |
| $LRA_6$ | -0.0073 | 0.3026 | | | | | | | |
| $LRA_7$ | 0.2453 | 0.3548 | 0.2711 | | | | | | |
| $LRA_8$ | -0.0185 | 0.1957 | 0.5919 | 0.3608 | | | | | |
| $MLA_4$ | 0.9771** | 0.6744 | -0.0255 | 0.1384 | 0.0311 | | | | |
| $MLA_5$ | 0.7122 | 0.9779** | 0.3163 | 0.3076 | 0.2613 | 0.6551 | | | |
| $MLA_6$ | 0.0429 | 0.3021 | 0.9285** | 0.2805 | 0.5791 | 0.9399 | 0.2918 | | |
| $MLA_7$ | 0.2977 | 0.4314 | 0.2740 | 0.9895** | 0.8446 | 0.1833 | 0.3775 | 0.2848 | 1.0000 |
| $MLA_8$ | -0.0870 | 0.0762 | 0.5147 | 0.4134 | 0.8565** | -0.0545 | 0.0840 | 0.5124 | 0.3813 |
| | $LRA_4$ | $LRA_5$ | $LRA_6$ | $LRA_7$ | $LRA_8$ | $MLA_4$ | $MLA_5$ | $MLA_6$ | $MLA_7$ |

** Significant at P = 0.01

**Table 23: Correlation Coefficients Between Leaf Rectangular Area (LRA) At 4 WAT To 8 WAT And Measured Leaf Area (MLA) At 4 WAT To 8 WAT In 1990 Wet Season**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $LRA_5$ | 0.0018 | | | | | | | | |
| $LRA_6$ | 0.2677 | 0.0581 | | | | | | | |
| $LRA_7$ | -0.0644 | 0.1284 | 0.2042 | | | | | | |
| $LRA_8$ | 0.0384 | -0.0888 | 0.4668 | 0.4547 | | | | | |
| $MLA_4$ | 0.8411** | 0.0612 | 0.0155 | -0.1026 | -0.0522 | | | | |
| $MLA_5$ | 0.4594 | 0.7006* | 0.4130 | 0.0820 | 0.0237 | 0.2239 | | | |
| $MLA_6$ | 0.2332 | -0.0030 | 0.9756** | 0.2023 | 0.5556 | 0.0264 | 0.3184 | | |
| $MLA_7$ | -0.0184 | 0.2488 | -0.0433 | 0.8948** | 0.2147 | -0.0455 | 0.2361 | -0.0736 | |
| $MLA_8$ | -0.1865 | -0.1173 | 0.3441 | 0.2902 | 0.9066** | -0.2029 | -0.0833 | 0.4455 | 0.0716 |
| | $LRA_4$ | $LRA_5$ | $LRA_6$ | $LRA_7$ | $LRA_8$ | $MLA_4$ | $MLA_5$ | $MLA_6$ | $MLA_7$ |

* Significant at P = 0.05

** Significant at P = 0.01

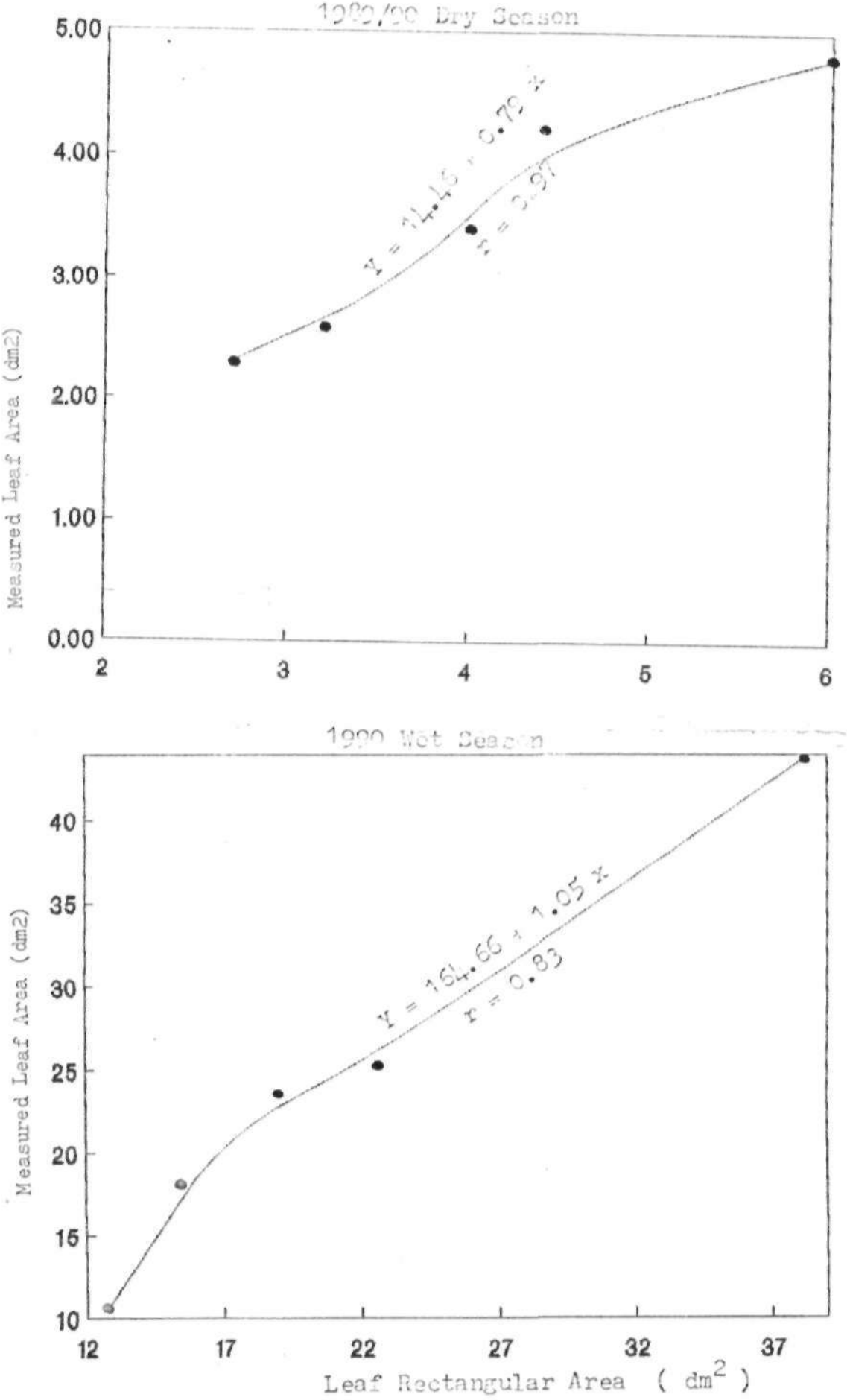



Fig. 5 Relationship Between Leaf Rectangular Area and Measured Leaf Area at 4WAT

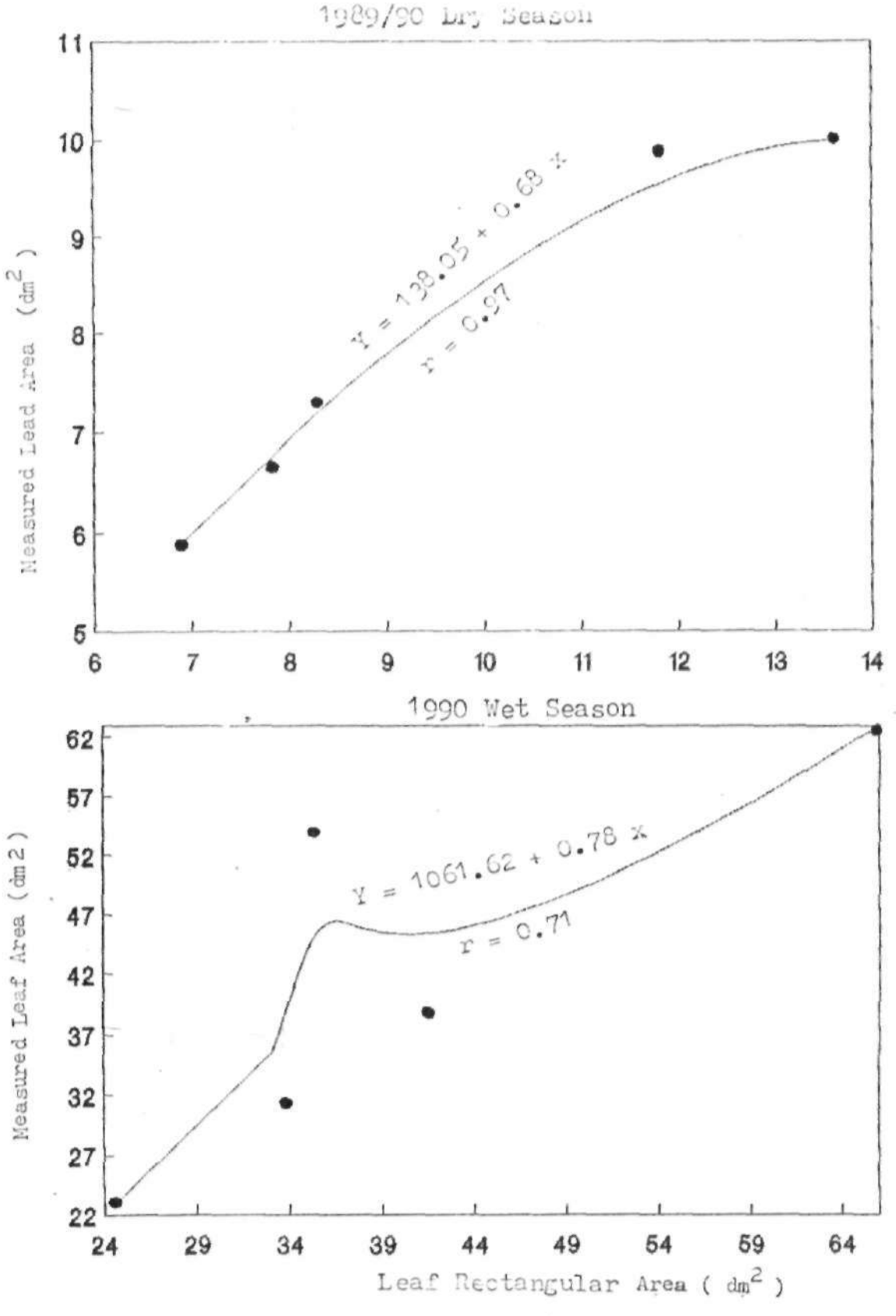



Fig. 6 Relationship Between Leaf Rectangular Area and Measured Leaf Area at SWAT

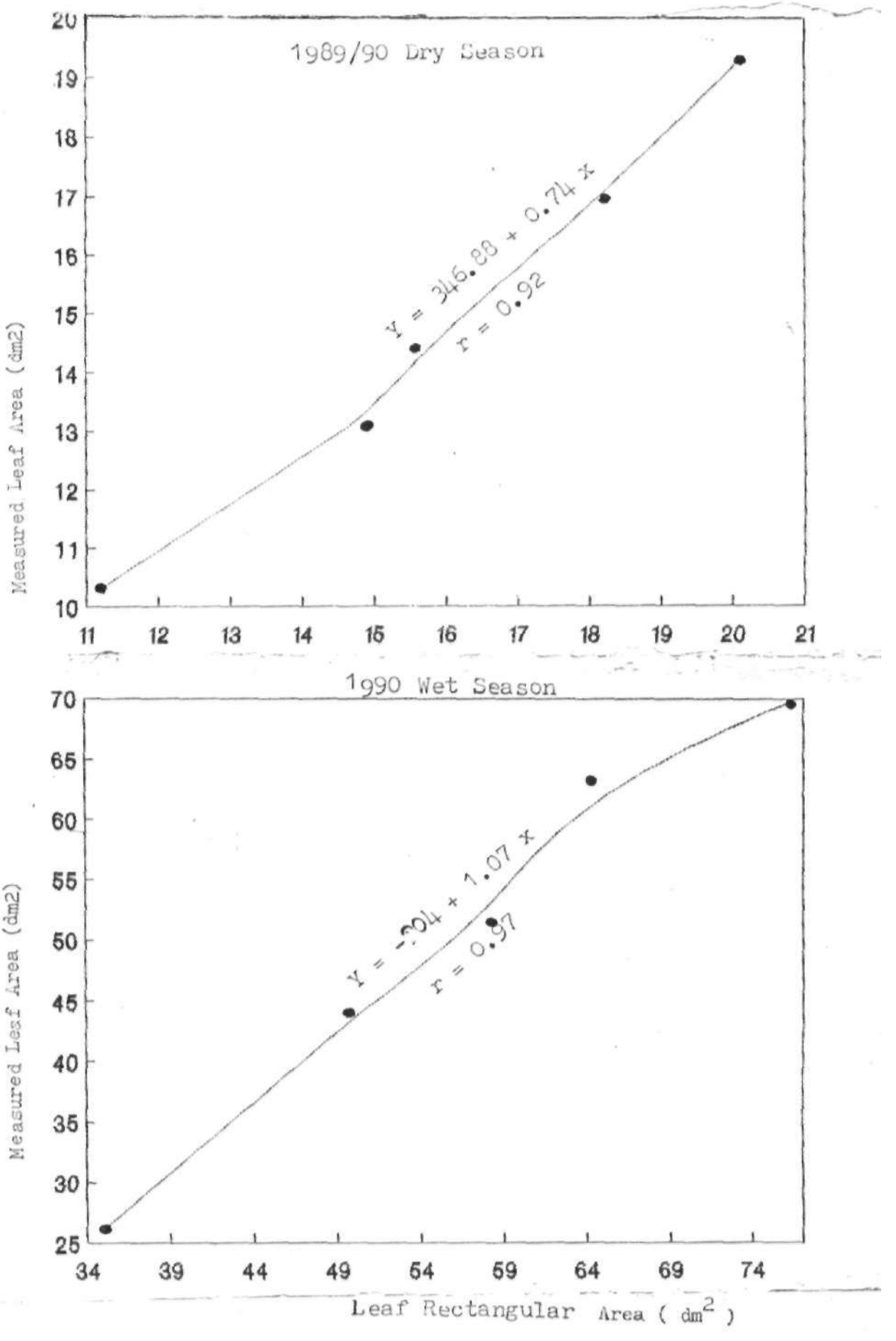



Fig. 7 Relationship Between Leaf Rectangular Area and Measured Leaf Area at 6WAT

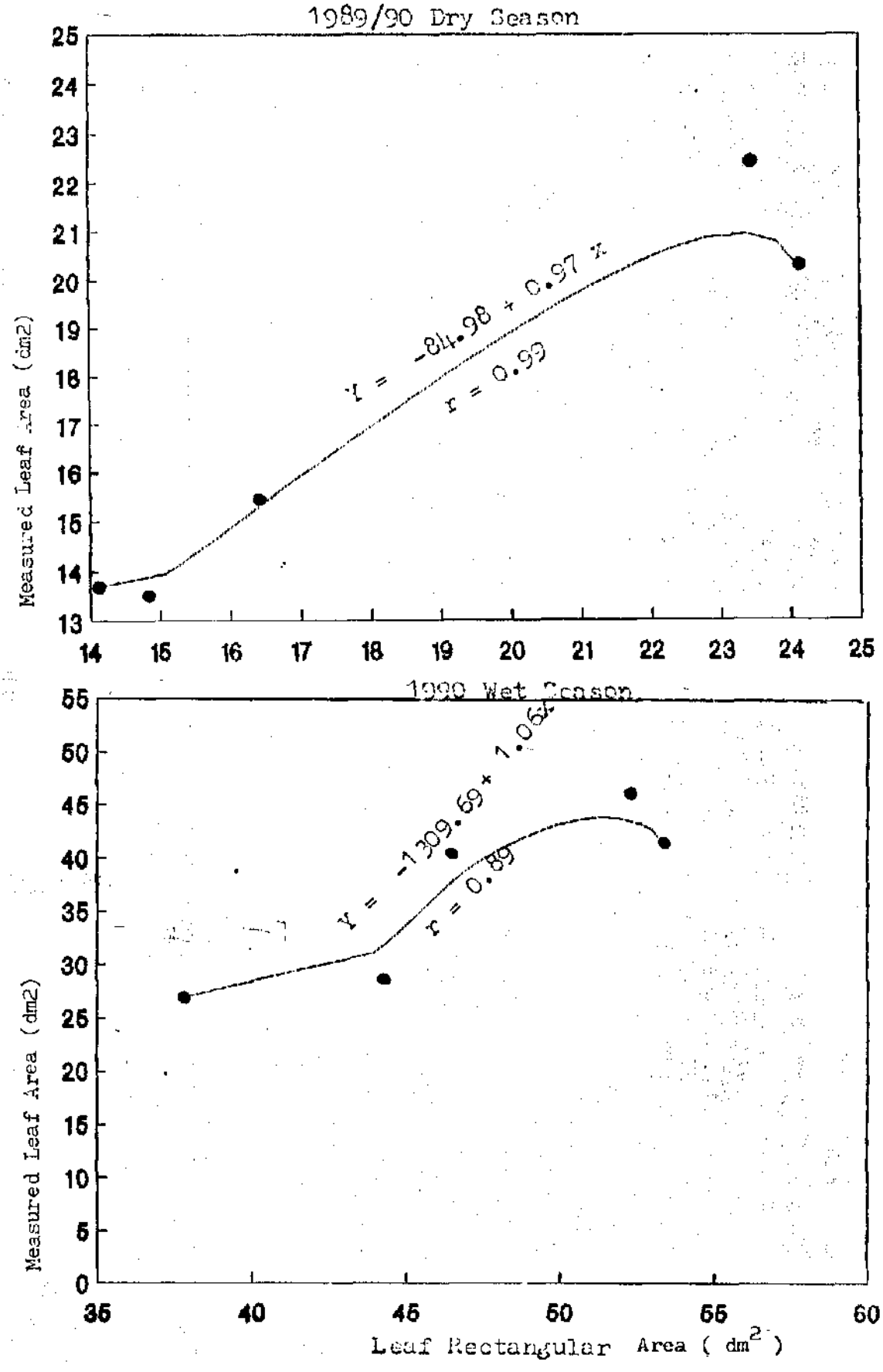
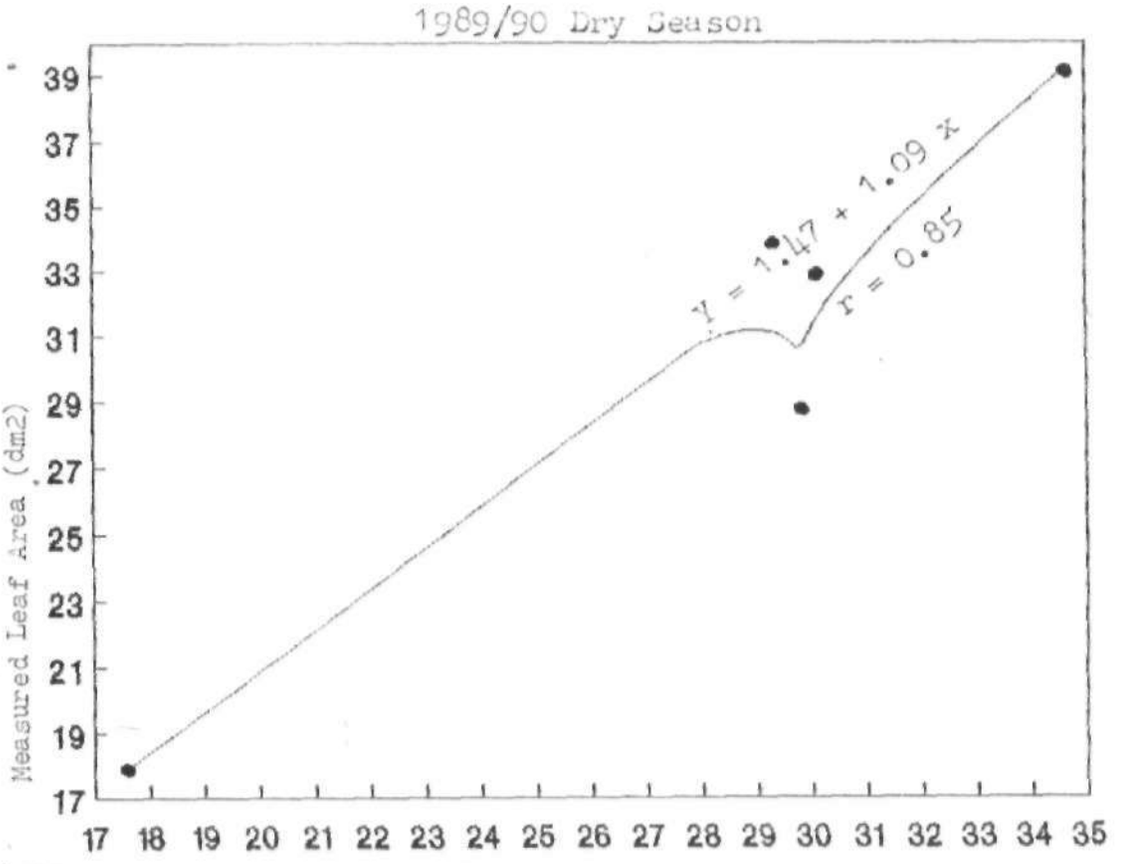



Fig. 8 Relationship Between Leaf Rectangular Area and Measured Leaf Area at 7WAT



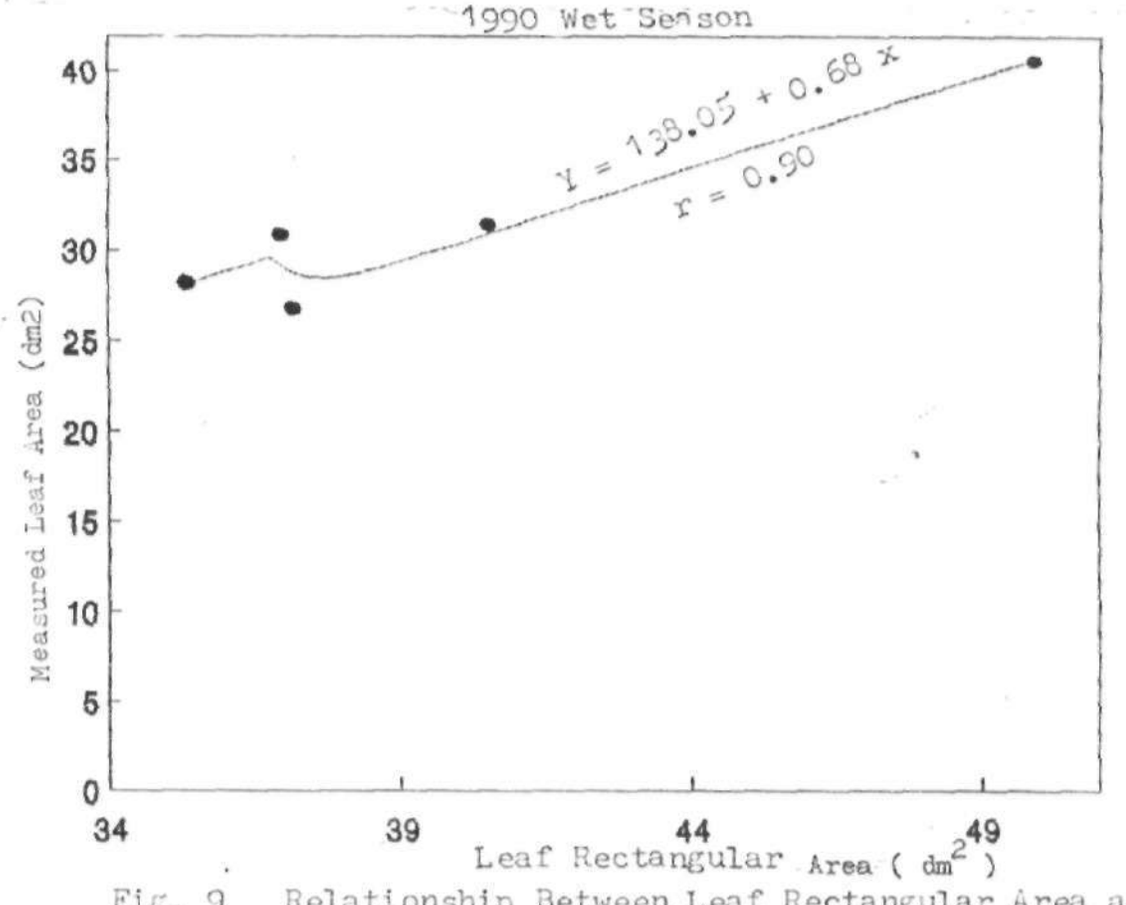




Fig. 9 Relationship Between Leaf Rectangular Area and Measured Leaf Area at 8WAT

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Plant Dry Matter Accumulation

A statistically significant effect of season on plant TDM suggests a great environmental influence on the total growth of the tomato plant. Since soil water status is a major factor varying between the wet and dry seasons, results indicate that adequate moisture during the wet season encouraged high dry matter production and thus high biological yield. Thus high biological yield may not necessarily translate into high economic (fruit) yield as this study reveals that the average fruit yield of the dry season crop was higher than what obtained in the wet season. In explaining why plant dry matter accumulation could significantly vary with season, Snyder and Carlson (1984) opined that soil water and mineral level, temperature and light, are among factors of the environment that would influence dry matter accumulation.

in plants are products of photosynthesis. Snyder and Carlson (1984) emphasized that in crops, source and sink normally interact to influence partitioning of assimilates. A sink - directed partitioning is therefore expected in this study during the fruiting phase of the crop, while the high level of dry matter in the leaves prior to fruiting is understandable.

Negative correlation coefficient (r) values observed in 3 of the 4 seasons for 'LWR Vs Fruit Yield' implies that a high LWR may mean a low fruit yield.

Stem dry matter accounting for approximately a third of total dry matter suggests that between the leaf and stem, more than 80% of TDM is locked up, even when fruiting had commenced. The flower/fruit is thus not much favoured in dry matter distribution in tomato. This type of sink characteristic is perhaps peculiar to the tomato plant as similar observations on sink behaviour and vascular peculiarity in tomato plant were reported by Bonnemain (1965) and Khan and Sagar (1967).

Negative 'r' in all the years in the correlation between FWR and each of LWR, SWR and RWR suggests that dry matter partitioning to the leaf, the stem and the root would be at the expense of flower and/or fruit. However, relating economic yield to dry matter distribution in tomato is difficult because the fruit yield is largely made up of the fruit water content. How the relative amounts of dry matter and water would affect

the fruit weight has not been explained. One can however postulate that the concept of harvest index (HI) as it relates to yield in other crops following the explanation of Sharma and Singh (1982) does not hold for the tomato crop and probably for any similar crop whose economic yield is determined by fresh weight of which water is the major component. The observed significant linear relationship between fruit yield and stem weight ratio in the 1989/90 and 1991/92 dry seasons, therefore, presents contradictory situations as per the foregoing explanation. The 1989/90 fitted equation; Fruit Yield = 45.2 - 93.2 SWR implies that the higher the stem weight ratio, the lower the fruit yield. In fact beyond a SWR value of 48%, a zero fruit yield may be recorded. But the 1991/92 fitted regression equation of, Fruit Yield = 12.2 + 22.3 SWR, implies that the higher the stem weight ratio, the higher the fruit yield. Given the fact that a level of morphological growth and development is required to support acceptable fruit yield, the latter relationship is of reasonable relevance. Recently, Bolarin' et al (1993) reported a similar linear relationship between fruit yield and whole shoot dry weight in tomato.

A similar linear relationship between fruit yield and RWR in the 1990 wet season also suggests yield increase with increasing value of RWR. Inferences based on relationship of any growth trait with root weight are

difficult to make because of the usually unavoidable loss of root parts during sampling as expressed by Watson (1958).

## 5.2 Growth Rates

### 5.2.1 Net Assimilation Rate

The observed differences in NAR trend between the wet and dry seasons was probably due to environmental influence as Adelana and Milbourn (1976) also observed a similar influence of factors of the environment on NAR value in maize crop. Declining values of NAR with plant age in the dry season crop was a result of increasing leafiness of the crop especially at the point where mutual shading of leaves started. Negative NAR of the wet season observed at later stages of plant growth was an indication that mutual shading effect could be very pronounced in the wet season. Under this condition, photosynthetically active leaf area is limited relative to total leaf area. Thus demands of respiring plant parts could outweigh the net gain from photosynthesis as found by Nilwik (1981) who explained that decrease in NAR with increasing plant dry weight in pepper was due to demands of dark respiration. Negative NAR could also be a result of induced leaf senescence due to pathogenesis during the wet season. Since the genotypes are

significantly different in mean NAR in the two dry season trials, morphological difference especially in leaf area formation exist between them.

The two genotypes that did not have negative NAR throughout the wet season of both years (SAMTOM-7 and SAMTOM-10) are probably more suitable for wet season cultivation than the others. The relatively high fruit yield of SAMTOM-10 compared to other genotypes during the wet season supports this view. This is of practical implication as these two genotypes could be recommended for wet season production in preference to others.

Given the result of the correlation analysis, it is doubtful if NAR has a close relationship with yield in tomato. Zelitch (1971) observed that the NAR alone is an inadequate indicator of productivity in crops as it does not account for other factors determining net productivity.

### 5.2.2 Relative Growth Rate

The declining values of relative growth rate (RGR) can be attributed to the increasing level of self shading of the leaves as was the case when Buttery (1969) observed a similar trend in soya-beans. He also observed negative RGR values at the later stage of plant growth as was the case in this study. A negative RGR at a stage of plant growth implies that at that stage, rather than

producing more dry matter, plant materials use existing dry matter to maintain growth. Such is the importance of RGR measure that some authors have described it as a measure of "Specific Growth Rate" (Zelitch, 1971; Causton and Venus, 1981). Decreasing RGR with plant age was similarly observed in lettuce by Hosteijn (1980) and by Nilwik (1981) in pepper. Nilwik explained that the trend was a result of ontogenetic change in growth with plant age. Buttery (1969) similarly recorded negative values of RGR, among other growth indices, under high LAI resulting from high plant population in soya-beans. The tendency of the wet season tomato in determinacy and bushy habit simulates this condition. The usually unavoidable fungal attack of tomato leaf in the wet season also can effectively reduce the leaf area duration even under seemingly high LAI. This is because a fungus infected leaf which is expected to have low photosynthetic activity remains part of the determinants of the plant total leaf area though the duration of its photosynthetic activity is shortened. Though a high RGR indicates relative efficiency of a genotype in dry weight gain over pre-existing dry weight, it does not imply expected high fruit yield. Warren (1972) reported that modern high-yielding varieties of tomato had RGR not higher than their wild progenitors which were very low-yielding. In this study, RGR was indeed negatively correlated with fruit yield in each of the four years,

but since it bears no significant correlation with yield, inferences were not made as regards the direction of fruit yield with a given direction of RGR.

### 5.2.3 Crop Growth Rate

The observed contrasting trend of CGR in the wet and dry season experiments was possibly due to the striking differences between the two seasons in NAR and LAI values. Since CGR is a product of NAR and LAI, (Zelitch, 1971, Bleasdale, 1978, Hunt, 1978), high increases in LAI with plant age as observed in the dry season crop are expected to result in increasing CGR with age. Adelana and Melbourne (1976) also observed highest CGR of 41.5 $gm^{-2}$ $day^{-1}$ at the highest LAI of 12.9 in the maize crop. The decreasing CGR with plant age in the wet season could be a result of very low NAR resulting from low efficiency of the leaves in dry matter production. High CGR has been linked with high economic yield especially in cereals, (Gupta and Olugbemi 1988) and it is attainable through high photosynthetic efficiency and high optimum leaf area index. While high TDM production may be dependent on this relationship in tomato, high fruit yield does not depend on it. This is evident from the non-significant and very low correlation between fruit yield and CGR in all the four years of this study. The high biological yield of the wet season when CGR was low

does not agree with observations on some crops as reported by Zelitch (1971). He indicated that in silage crops of sorghum and maize, sugarcane, spinach and tobacco, average CGR was proportional to estimated total dry weight. However, Mitchell (1976) indicated that a combination of reduced radiant energy reaching each leaf, leaf aging, and as in this case, leaf mal-functioning due to disease infection, would result in low NAR and by inference, low CGR. This situation would exist even under conditions of high total dry matter.

### 5.2.4 Leaf Area Index

The increase in LAI per plant with plant age was a direct effect of increase in leaf area per plant with age. The wide variation in LAI between seasons and between years indicates that crop environment has a great influence on LAI. This was contrary to the view of Hunt (1978) that LAI is largely independent of seasonal changes in the environment.

A highly significant correlation between LAI and FWR in the two dry seasons is interpreted as an indication of a close association between LAI and yield. LAI was in fact significantly and positively correlated with fruit yield in the 1991/92 dry season. Dennett (1975) emphasized the importance of LAI in yield determination in crop plants, a report similar to that of Duncan

(1969). The decline in LAI 6 WAT in the wet season was probably a result of induced senescence of older leaves as a result of fungal leaf spot diseases characteristic of the wet season crop (Erinle 1979). Such a decline may result in failure to attain an optimum LAI necessary for maximum productivity of the crop. The determination of an optimum LAI for tomato crop was not part of this study.

### 5.2.5 Inter-relationship Of NAR, CGR And LAI

The NAR and CGR for any particular season were so closely related that any factor that alters one would alter the other. Highly significant correlation between the two indices each year suggests that plant factors that determine the efficiency of leaf in dry matter production would also determine the overall productivity of the crop in terms of dry matter accumulation. Early work by Watson (1958) indicated that NAR is a major determinant of CGR, the other component being LAI. The relationship between CGR and LAI during the dry season was similar to that described by Adelana and Melbourne (1976) where in the maize crop CGR increased with increasing LAI. Adelana (1977) later explained that the magnitude of CGR is a function of both NAR and LAI. Positive and significant correlation of LAI with FWR and with fruit yield would therefore mean an indirect

relationship between CGR and yield since the value of LAI would dictate CGR value. To influence CGR therefore, either the NAR or the LAI could be altered. However, the manipulation of NAR is not easily accomplished and attention could be on regulating LAI for high productivity. Given the negative correlation between LAI and NAR, it seems that the higher the LAI, the lower the NAR. The same relationship exists between LAI and CGR. Buttery (1969) attributed declining NAR and CGR to a rising LAI in soya-beans. The attainment of a LAI that supports high NAR could thus result in high CGR.

## 5.3. Fruit Yield Prediction Through Regression Analysis

The lack of consistency in how the various growth attributes are related to yield presents a difficulty in the use of regression analysis in explaining yield. The inconsistency between years is probably a result of a strong effect of the environment on growth attributes. However, if details of the environmental factors for each year is known, regression equation(s) for each year would be specific for environments similar to what prevailed in the year. Thus under an environment similar to that of 1989/90 dry season, a high LAI and small SWR would result in high fruit yield. The explanation of the relationship between yield and SWR is further made difficult by the fit equation of 1991/92 dry season. It was at variance

with the 1989/90 dry season equation. The larger the stem weight ratio in 1991/92, the higher the fruit yield. Trying to adopt some of these growth estimates as selection indices for yield in the tomato crop is therefore not feasible. Snyder and Carlson (1984) advocated the use of relatively fast and precise selection procedure in plant screening and emphasized the role of accuracy and repeatability of selection indices. The development of a tomato ideotype would be difficult in a situation where fruit yield indices are not known, the value of breeding crops for desired plant types (ideotypes) was emphasized by Donald (1968).

The great influence of the environment on indices useful in selecting for yield is not peculiar to tomato plant. Thus, after reviewing cases of unreliability in the use of other indices in selecting for yield in various crops, Snyder and Carlson (1984) suggested the need to account for environmental variation in using such indices. How to do this was not specified, but selection criteria based on defined environmental factors are considered relevant. In the tomato plant, factors of the environment relevant in considering such environmental effects include rainfall, temperature, light and relative humidity.

The inter-relationship of the growth indices needs to be understood because they concertedly determine fruit yield. This is evident from the observation that in each of the four years, fruit yield was significantly linearly related to a combination of all growth indices. Regardless of the environment therefore, growth indices are important factors in yield determination, though there could be relative importance of each index in doing so.

## 5.4 Leaf Area And Leaf Rectangular Area Relationship

The significantly close association between estimated leaf area and leaf rectangular area revealed by the correlation analysis result gives the impression that the use of the LRA could be substituted for other methods of leaf area determination in tomato plant. A similarly high correlation between LRA and leaf area through planimeter was obtained by Spencer (1962) for cassava. He concluded that though the compound leaf of cassava is irregular in shape, the use of LRA is suitable as a fast means of determining leaf area. The tomato leaf is similarly compound and irregular in shape. The accuracy of the use of linear measurements in leaf area estimation therefore is not limited to broad leaves with usually regular shapes. However, using the largest width along with the length in tomato leaflets may exaggerate the

area, thus the mean of the top, middle and bottom width was used in this study rather than the largest width used by Spencer (1962) for cassava.

Highly significant linear relationship between LRA and estimated leaf area following the regression analysis of variance strongly indicates the reliability of the use of linear measurements as a rapid means of leaf area determination in the tomato. Very high $r^2$ each sampling time lends credence to this view.

Different fit equations were used for different sampling times because of variations that may exist in leaf morphology and physiology at different stages of tomato plant growth as observed by Khan and Sagar (1967). A single regression equation as used by Nwachukwu and Ene (1984) for leaf area determination at any stage of ginger growth through linear measurements is considered inadequate in this study. Fisher (1970) pointed out that an error in the independent variable (LRA in this case) would normally alter the regression value. This weekly determination of LRA is expected to minimize error and result in a reliable regression value. The tomato compound leaf is made up of irregularly toothed leaflets and the possibility of estimating leaf area through leafelt rectangular area presents a desirable rapid means in studies that require leaf area estimation. The regression of leaf linear dimensions on measured leaf area has variously been used to facilitate leaf area

estimation. Lal and Subbarao (1951) used it for cereals, King and Lawes (1957) used it for cotton, Spencer (1962) used it for cassava and Nwachukwu and Ene (1987) used it for ginger. All these authors observed the reliability and acceptable accuracy of the method for leaf area estimation in the respective crops. Apart from being fast, the LRA can be used as a non-destructive method.

## 5.5 Genotype Difference In Growth Rates

The five genotypes react in a similar manner in any given environment in terms of most of the growth indices. Total dry weight which did not differ significantly between the genotypes is a quantitative attribute of plant size which Opara (1992) observed to have determined fruit yield in *Solanum* (garden egg) varieties. Asiegbu (1991) also observed a similar influence of plant size on yield in tomato. Since no significant fruit yield differences were observed between the genotypes, it is possible that fruit yield did not differ because of similar plant sizes of the genotypes. Earlier reports by Fisher (1969) have indicated that large plant size does not result in poor fruit yield in tomato contrary to the view of some commercial growers. Observations in this study agree with this view.

The genotypes were found to be significantly different in NAR and CGR in the dry season but this does not seem to have reflected on fruit yield. The significant difference in CGR is probably a result of difference in NAR given the relationship between the two indices.

Dry matter distribution among the various plant organs was also similar in the genotypes in any given year. That the fruit was disadvantaged in dry matter distribution was therefore common to all the genotypes.

The indices that had significant linear relationship with fruit yield (LAI, SWR and RWR) were similar among genotypes and this gives a wide application (among varieties) to the use of the derived fit equations predicting yield with those indices. Because of the similarity of these genotypes, the use of genotype means in drawing inferences in this study is also in order. However, where statistical differences exist between genotypes, such inferences based on genotype means would not be appropriate.

## 5.6 Significance Of The Study

Growth analysis studies on crops other than cereals and pulses have not been much reported. Since the improvement of a crop requires a multi-directional approach including the understanding of its growth

attributes, a study of this type on a vegetable crop adds to the pool of available knowledge on the fundamental requirements in improving the crop.

Growth attributes that bear functional relationship with yield in this study can be examined and studied further. If such functional relationships are established beyond doubt, the respective growth trait(s) can form the basis of further improvement work.

Given the observed effect of cropping season on parameters measured in the study, it is revealed that growth studies research on tomato may give contrasting results in wet and dry seasons. Such is the influence of cropping season that the study suggests that inferences based on such a study would only be relevant for the season of study.

The study revealed that good growth of tomato plant is hindered during the wet season as leaf loss due to fungal attack retards growth.

The observation that one of the two genotypes that did not have negative NAR and RGR values during the wet season (SAMTOM-10) had higher economic yield than others suggests that the genotype is probably better adapted for wet season cultivation.

Manual determination of leaf area of plants is laborious and time consuming. It however still remains a handy option in the under-developed world. Thus, the

possible substitution of the fast leaf rectangular area (LRA) method of leaf area estimation for other slow and of equivalent precision manual methods is also considered a significant finding in the study.

# CHAPTER SIX

## SUMMARY AND CONCLUSION

Tomato (*Lycopersicon esculentum* Mill.) is among the wor leading vegetable crops and it is a major vegetable crop of tr and culinary use in Nigeria. Not much has been reported on physiology of fruit yield of this especially in the tropi climate. Studies in the area of growth analysis as it relates fruit yield would be of importance in yield improvement program of the crop.

Growth analysis studies were conducted for four years Samaru using five genotypes of tomato. The objectives of studies include:

(a) The determination of the type of association between s growth indices and fruit yield.

(b) Establishment of genotype difference in dry mat accumulation and distribution.

(c) Examination of the influence of cropping sea (environment) on dry matter accumulation; and

(f) Verification of the reliability of the use of leaf lin measurement (leaf rectangular area) for leaf a estimation for growth studies.

During the study, crops were grown according to recommended nursery and field practices. Plant sampling for growth analysis was done at five weekly intervals starting from 3 WAT. Each sample consisted of about 10% of total initial plant population. Derived growth indices each year, and for the four years combined, were subjected to analysis of variance, and variance ratio (F) test was used to determine statistical significance.

Correlation and simple linear regression analyses were done to establish the degree and type of association between indices and fruit yield each year. Functional relationship between actual leaf area and leaf rectangular area was also determined through regression analysis.

Total dry matter (TDM) per plant varied between season of planting, being higher in the wet than in the dry season. At each sampling time between 4 and 8 weeks after transplanting, relative dry weights of plant morphological parts in most cases was in the order of:

Leaf > Stem > Flower/Fruit > Root.*

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*As observed at each harvest and not cumulative.

The different genotypes were markedly similar in dry matter accumulation both in trend and total per sampling time. The observed seasonality in the magnitude of TDM was viewed as a manifestation of the influence of the environment on total growth. The relatively large proportion of total dry matter traceable to the leaf and stem suggests that a large amount of the product of photosynthesis in the tomato plant is retained in the to leaf and stem during the growth stages covered by this study. This trend could change as the plant progresses in fruit development.

Significant ($P = 0.05$) genotype difference in both NAR and CGR was observed with the dry season crop. Other growth indices did not differ significantly between genotypes. Since both NAR and CGR did not bear functional relationship with fruit yield, a significant difference between genotypes in one or both traits would not explain genotype differences in fruit yield.

Regression analysis of variance indicated a functional linear relationship between LAI and fruit yield. The higher the mean LAI, the higher the fruit yield, thus genotype difference in optimum LAI would result in yield differences. The optimum LAI was not determined in this study. Though SWR had a functional linear relationship with fruit yield, different directions were implied considering the two dry season results, thus another observation of this relationship is a requirement in the definition of the pattern of fruit yield response to SWR.

Generally, negative correlations were observed between LAI and each of NAR, RGR and CGR, thus declining values of each of the indices with plant age was a result of rising LAI.

Comparing the four years, there was obvious inconsistency in the relationship of each growth index with fruit yield. This was considered a general influencing role of the plant environment not only in determining the rate of plant growth but also the relationship between growth attributes and economic yield. It follows therefore that the relationship between a growth index and economic yield could only be described for a defined environment. The use of the correlation coefficient is therefore limited unless a genotype is tested in more than one environment.

Leaf area measurement is vital in growth analysis. The method used should be fast, simple and accurate. In this study, assessment of the reliability of the use of leaf rectangular area (LRA) for leaf area estimation revealed that LRA value was significantly close to actual leaf area value. The coefficient of determination ($r^2$) was high at every sampling time. Thus LRA could be used reliably for leaf area estimation in tomato plant. It has additional merit of its practical use for an intact plant in a non-destructive manner.

The following can be concluded from the study.

Growth analysis studies on tomato may give contrasting results in wet and dry seasons.

Determinate and indeterminate genotypes responded differently in growth traits.

Among the genotypes used in the study, SAMTOM-7 and SAMTOM-10 were more adapted to wet season cultivation relative to others.

No confirmed correlation of fruit yield with any of the growth

indices with yield was established in the study. Observed correlation of growth indices with yield in any other year for confirmation.

The leaf rectangular area method was of acceptable precision in leaf area determination in tomato relative to other manual methods.

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**Appendix Table: Some Fruit Characters in 5 Tomato Genotypes.**

| Genotype | Fruit Diameter (cm) | | Fruit Length (cm) | | Mean Fruit Weight (g) | |
|---|---|---|---|---|---|---|
| | 1989/90 | 1990 | 1989/90 | 1990 | 1989/90 | 1990 |
| SAMTOM-16 | 3.52 | 3.67 | 4.93 | 5.51 | 36.54 | 44.15 |
| TI-244 | 3.63 | 3.66 | 4.90 | 5.07 | 33.98 | 43.64 |
| SAMTOM-10 | 3.95 | 3.96 | 3.54 | 4.29 | 31.05 | 42.71 |
| TI-468 | 3.98 | 3.94 | 3.32 | 4.24 | 36.33 | 48.33 |
| SAMTOM-7 | 3.60 | 3.49 | 4.88 | 5.24 | 34.25 | 40.66 |
| L. S. D. (0.05) | NS | NS | 0.78 | 0.57 | 2.15 | 2.75 |