A COMPARATIVE STUDY OF CERTAIN CULTIVARS OF *MANIHOT ESCULENTA* CRANTZ WITH SPECIAL REFERENCE TO CERTAIN MORPHOLOGICAL CHARACTERISTICS, PHOTOSYNTHESIS AND WATER RELATIONS.

by

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It is hereby declared that this is my own work, both in conception and execution and that the opinions expressed or conclusions reached are not to be regarded as reflecting the views of the above-mentioned persons.

A M ZOBOLO

JANUARY 1992

DEDICATION

To my late father

Enock

for his love   and

faith in education.

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SUMMARY

Cassava (*Manihot esculenta* Crantz) is cultivated for its tuberous roots. In this study four cultivars MSAF 2, CMC 40, M 170 and M 5 were compared for their yield and morphological and physiological characteristics.

The cultivars were planted in the field and in pots. Photosynthesis and transpiration were measured using a portable Infra - red CO_2 analyser. The leaf chamber had an area of 1120 mm². Measurements were made between 9:30 and 15:30. The leaf area was determined using a ΔT area meter. The leaf water potential was measured with a pressure bomb. The chlorophyll *a* was extracted with 90 % acetone and determined spectrophotometrically. The drying of the plant material was done at 105 °C in an oven.

The photosynthetic rate decreased from top to bottom within the plant's canopy. The maximum photosynthetic rate obtained ranged from 8,4 to 10,97 μmol CO_2 m^{-2} s^{-1}. CMC 40 had the lowest leaf photosynthetic rate. The winter retention of LAI and photosynthesis were the lowest in CMC 40.

The photosynthetic rate was high in the morning and declined in the afternoon. In MSAF 2 the photosynthetic rate decreased when the leaf water potential was

below $-0,5$ MPa. In CMC 40, M 170 and M 5 the photosynthetic rate decreased when the leaf water potential was below $-0,6$ MPa. A decrease in the photosynthetic rate with a decreasing leaf water potential was followed by a decrease in the relative transpiration rate in MSAF 2. CMC 40 had the lowest transpiration rate. The chlorophyll *a* content was lowest in CMC 40. The maximum chlorophyll *a* content ranged from 0,96 to 1,19 µg mm^{-2} in field plants and from 0,32 to 0,40 µg mm^{-2} in potted plants. The chlorophyll *a* content was high during the first growth season and declined in post winter regrowth in all the cultivars.

Plant height, leaf numbers, LAI and the partitioning of dry matter followed a seasonal pattern in all the cultivars. The total dry mass increased as LAI increased up to 1,31 in potted plants and up to LAI 2,42 – 6,14 in field plants. In the first year of growth in field plants, the tuber dry mass increased with LAI up to levels of 2,29 – 3,61, then declined. In the potted plants, the tuber dry mass increased with LAI up to 1,2 and continued to increase in spite of the decline in LAI, which was still close to 0,8. At 707 DAP, MSAF 2 had the highest root dry mass while CMC 40 had the lowest. The maximum tuber dry mass obtained was 110-353 g m^{-2} in potted plants and 2505-3577 g m^{-2} in field plants. The number of tubers per plant was highest in M 170 (7,5-

9,4) and lowest in CMC 40 (3,2 - 4,25). MSAF 2 was intermediate (6,25 - 6,6).

CMC 40 and M 5 had a higher stem dry mass than M 170 and MSAF 2. Except for a few exceptions, a significantly higher LAI resulted in a significantly higher root yield only if it coincided with a significantly higher HI. The maximum HI ranged from 0,7 - 0,8 in field plants and from 0,39 - 0,82 in potted plants.

OPSOMMING

Cassava (*Manihot esculenta* Crantz) word ter wille van hulle wortelknolle gekweek. Die opbrengs en morfologiese en fisiologiese kenmerke van vier cultivars, MSAF 2, CMC 40, M 170 en M 5 is bestudeer en vergelyk.

Hierdie cultivars is in die veld en in potte geplant. Fotosintese en transpirasie is deur middel van 'n Infrarooi CO_2-analiseerder gemeet. Die oppervlak van die blaarkamer was 1120 mm^2. Metings is tussen 9:30 en 15:30 geneem. Die blaaroppervlak is bepaal met behulp van 'n ΔT oppervlakmeter. Blaarwaterpotensiaal is deur middel van 'n drukbom bepaal. Chlorofil *a* is deur middel van 90 % asetoon onttrek en spektrofotometries bepaal. Die plantmateriaal is teen 105 °C in 'n oond gedroog.

Die tempo van fotosintese het van bo na onder in die plant se blaardak afgeneem. Die snelste fotosintese-tempo wat bepaal is, strek tussen 8,4 en 10,97 μmol CO_2 m^{-2} s^{-1}. CMC 40 het die stadigste fotosintese-tempo. MSAF 2 het die hoogste blaaroppervlakindeks maar M 170 het 'n hoër gemiddelde opbrengs as MSAF 2 gehad. Die retensie van blaaroppervlak-indeks gedurende die winter, sowel as die fotosintese-tempo was die laagste in CMC 40.

Soggens is die tempo van fotosintese vinnig en dit neem af in die middag. Wanneer die blaarwaterpotensiaal van MSAF 2 laer as -0,5 MPa is, daal die tempo van fotosintese. Die tempo van fotosintese in CMC 40, M 170 en M 5 neem af wanneer die blaarwaterpotensiaal benede -0,6 MPa daal. 'n Afname in die blaarwaterpotensiaal en die gepaardgaande daling in die tempo van fotosintese, is gevolg deur 'n daling in die relatiewe transpirasie-tempo in MSAF 2. CMC 40 se transpirasie-tempo was die stadigste en het ook die laagste chlorofil a-inhoud gehad. Die maksimum chlorofil a-inhoud strek tussen 0,96 en 1,19 μg mm^{-2} in veldplante en tussen 0,32 en 0,40 μg mm^{-2} in potplante. Al die cultivars het 'n hoë chlorofil a-inhoud gedurende die eerste groeiseisoen getoon, met 'n afname tydens hergroei na die winter.

In al die eksperimente en vir al die cultivars het planthoogte, aantal blare, blaaroppervlak-indeks en droemateriaalveropreiding 'n seisoenale patroon gevolg. Die totale droë massa neem toe wanneer die blaaroppervlak-indeks toeneem tot 1,31 in potplante en tot 2,42 - 6,14 in veldplante. Gedurende die eerste jaar se groei, het die droë massa veldplante se knolle toegeneem tot blaaroppervlak-indeks-vlakke van 2,29 - 3,61, en het daarna afgeneem. Die droë massa van potplantknolle het 'n daarna afgeneem. Die droë massa van potplantknolle het 'n styging getoon met hoër blaaroppervlak-indeks-vlakke van

tot 1,2 en daarna het die droë massa, ten spyte van 'n afname in die blaaroppervlak-indeks tot naby 0,8, steeds gestyg. Na 707 dae van groei, het MSAF 2 se wortels die hoogste droë massa gehad en CMC 40 die laagste. Die maksimum droë massa verkry van potplantknolle is 110 – 353 g m^{-2} en van veldplantknolle, 2505 – 3577 g m^{-2}. Die meeste knolle per plant is by M 170 gevind (7,5 – 9,4) en die minste by CMC 40 (3,2 – 4,25). MSAF 2 lê tussen hierdie twee (6,25 – 6,6).

Die droë massa van CMC 40- en M 5-stingels is hoër as die van M 170 en MSAF 2. Afgesien van enkele uitsonderings het 'n betekenisvolle hoër blaaroppervlak-indeks slegs tot 'n betekenisvolle hoër wortel opbrengs gelei indien dit met 'n betekenisvolle hoër oesindeks saamgeval het. Die hoogste oesindeks strek tussen 0,73 en 0,81 by veldplante en tussen 0,39 en 0,82 by potplante.

CHAPTER ONE

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perrenial crop of outstanding potential production and a rich source of energy and chemicals (San Jose, 1983). Over 90 % of the worlds cassava production is used for human consumption. In Nigeria it is commonly eaten as Gari (Hahn, Terry, Leuschner & Akobundu, 1979). The tuberous roots are the economically important parts in cassava. In South African rural area and in Mocambique, cassava has become very important to people with low income. Such people inhabit dry areas and have poor agricultural practices. Cassava is at an advantage compared to other crops in that it can extract large amounts of nutrients from poor soils, can tolerate drought, acid soils and can withstand locust attack. It is therefore a valuable famine reserve (Jennings, 1970 ; Kawano, Daza, Amaya, Rios & Goncalves, 1978). The tendency of cassava to increase the distribution of dry mass to the roots also occurs under water stress. During such a water stress, cassava follows a conservative pattern of water use, closing its stomates and reducing the formation of new leaves (Cock, 1982).

Cassava has a low nutrient value. According to Oke (1975), the chemical composition of roots varies with cultivars, plant age and growing conditions. He reported the following analysis (Table 1.1).

Table 1.1. Chemical composition of cassava roots.

Moisture   : 62 %

Carbohydrates   : 35 %

Protein   : 01 %

Fat   : 0,3%

Mineral matter rich in Ca (13-33 mg 100 g^{-1})   : 01 %

The root proteins are deficient in S – containing amino acids (Jennings, 1970). It is essential to eliminate toxic HCN before consuming the roots of cassava. This can be achieved by removing the rind (periderm + phloem) and xylem fibres at the core where high concentrations of HCN are found (Wood, 1965). In urban areas, cassava is used as animal feed (Jennings, 1970) and as raw material for industrial starch and ethanol production.

The establishment of the Centro International de Agriculture Tropical (CIAT) near Cali (Colombia), the International Institute of Tropical Agriculture (IITA) at Ibadan (Nigeria) and the Anglo – American Cassava Research Station at Mtunzini (Northern Natal – South Africa) led to extensive research on the morphology and physiology of cassava. There are many clones of cassava. In the clone MSAF 2, M stands for *Manihot esculenta*; SAF stands for its native country (South Africa), and 2 stands for the accession number in the country's collection. The yield and quantity of HCN varies in the different clones. Daphne (1980) compared the yield of MSAF 2 with four other clones and found it to be the best producer.

Table 1.2. Average cassava root yields for 1977 – 1978 season

clone	Root yield (t ha^{-1} a^{-1}) all sites	ten best sites
MSAF 2	19,0	26,1
MMOC 1	13,3	17,7
MSAF 1	12,9	16,0
MMOC 2	10,9	12,7
MMOC 3	12,3	15,7
Average	13,7	17,6

MOC = Mocambique

Williams and Ghazali conducted an experiment in 1969 using cassava plants having narrow-lobed and broad-lobed leaves. They found that the leaves of narrow-lobed plants were vertically orientated at midday whereas those of broad-lobed plants were orientated horizontally. The cultivar with narrow-lobed and vertically orientated leaves outyielded the one with broad-lobes and horizontal orientation. In South Africa, however, the highest yield was obtained in the cultivar MSAF 2 which had broad-lobed leaves with a horizontal orientation (Table 1.2). It is against this background that a decision was taken to compare the yield, morphological and physiological characteristics of MSAF 2 with other cultivars. In the choice of cultivars I included two with broad-lobed leaves (MSAF 2 and CMC 40) and two with narrow-lobed leaves (M 170 and M 5).

CHAPTER TWO

2. LITERATURE REVIEW ON MORPHOLOGICAL AND PHYSIOLOGICAL
CHARACTERISTICS OF CASSAVA.

2.1. MORPHOLOGICAL DETERMINANTS OF YIELD

Cassava can outyield all other food crops in terms
cal ha^{-1} (Vries, Ferweda & Flach, 1967). The plant
characteristics which affect yield are as follows :

2.1.1. The winter retention of leaves

Provided water is not limiting, the cultivars which
retain their leaves in winter have the best root
weight between 10 - 15 months (Jennings, 1970).

2.1.2. The ratio of tops to roots.

Cassava tops use the carbohydrates available to
achieve their growth potential and the roots accept what
is left over (Cock, Franklin, Sandoval & Juri, 1979). The
balance between top growth and root growth is determined
by top growth potential, which is largely determined
by branching pattern (Tan & Cock, 1979). The ratio of
tops to roots must be 1:1 for better yield

(Jennings, 1970).

2.1.3. The size of leaves.

Leaves of the highest yielding variety possessed attenuated lobes, which tended to have a more vertical midday orientation, whereas the lowest yielding variety possessed large broad-lobed leaves with more horizontal orientation. Vertically-orientated leaves allow more light to penetrate the canopy (Williams & Ghazali, 1969).

2.1.4. The number and size of the tubers.

The best yield is obtained when the root number is from 9 to 10 (Cock *et al*, 1979). *Root sink activity in the* Cubana variety seems to be limited by genotype and total root dry matter lost by respiration (San Jose & Mayobre, 1982).

2.1.5. The leaf area index

High crop growth rates are associated with a high LAI. Authors differ with regards to the maximum LAI, eg 3,5 - 4 (Cock *et al*, 1979); 7 - 12 (Keating, Evenson & Fukai, 1982b).

2.1.6. The root secondary thickening.

Root tuber initiation is always preceded by a small amount of normal secondary thickening, but secondary thickening does not always lead to tuber initiation (Lowe, Mahon & Hunt, 1982). The bulk of starch grains are stored in the xylem parenchyma which is formed through secondary growth (Hunt, Wholey & Cock, 1977; Indira & Kurian, 1977).

2.2. *PHYSIOLOGICAL DETERMINANTS OF YIELD*

2.2.1. Daylength

Daylengths greater than a critical threshold of between 12 and 13 hours promote flowering and forking in cassava (Keating, Evenson & Fukai, 1982a). Yields of cassava storage roots are reduced by long days (Anonymous, 1985a; Jennings, 1970 and Lowe, Mahon & Hunt, 1976).

2.2.2. Photosynthesis.

The photosynthetic capability of a plant community depends on both the amount and the efficiency of its photosynthetic surface area (Aslam, Lowe & Hunt, 1977). San Jose (1983) made the following observations on cassava photosynthesis :

- The maximum photosynthetic rate is from 0,55 to 1,10 mg CO_2 m^{-2}s^{-1}

- Except for the 2112 UCV cultivar (Perreira, 1977), photosynthesis is not saturated with radiant energy even at the maximum diurnal irradiance.

- The optimum temperature for photosynthesis is from 25 to 30 °C.

- Photosynthesis is greater than dark respiration.

- CO_2 compensation concentration is high (50-68 cm^{3}m^{-3}).

- There is a high ratio of water efflux to CO_2 uptake (109 -138).

- The leaf diffusive resistance is high.

Palta (1983) observed a decline in leaf photosynthesis and in leaf diffusive conductivity under short periods of water deficit. Decreases in the photosynthetic rate associated with decreases in the leaf water potential are caused by increases in the stomatal resistance and mesophyll resistance to gaseous diffusion (Beadle, Stevenson & Thurtell, 1973). The stomatal conductance is inversely related to the leaf air humidity difference.

According to El-Sharkawy, Cock & Held (1984), the maximum photosynthetic rates of unwatered plants at high humidity are lower (16 µmol CO_2 m^{-2}s^{-1}) than well watered plants (24 µmol CO_2 m^{-2}s^{-1}). Since these rates were obtained with high humidity, the lower rates in

unwatered plants were attributed to partly closed stomata in response to decreased bulk leaf water potential, but could also be due to changes in mesophyll resistance. There is a decline in stomatal conductivity towards midday and in the afternoon in response to high light intensity under field conditions. At low solar radiation, heliotropic response enables leaves to be placed in the direction of the sun and increase photosynthesis. The photosynthetic activity varies among the cultivars, thus Hunt *et al*, (1977) observed a higher net assimilation rate *for* one high yielding cultivar than *for* two lower yielding types. There is evidence for some degree of night opening of the stomata in tapioca which could supplement the day-time uptake of CO_2 (Williams, 1971). While environmental factors have strong direct influence on photosynhtesis, the demand by sinks *for* assimilate can also determine photosynthetic supply (Williams, 1972; Gifford & Evans, 1981).

2.2.3 Transpiration.

Some cultivars have *low* stomatal resistances and high transpiration rates eg 200 g m^{-2} h^{-1} (Hunt *et al*, 1977). The transpiration rate increases as vapour pressure deficit increases from 1 to 2,5 kPa and declines with further increase in vapour pressure deficit. The

stomatal closure at large vapour pressure deficit reduces transpiration and results in a stable bulk of leaf water potential.

The relative transpiration rate decreases with decreasing water potential (Ike, 1982; Beadle et al, 1973). The stomata of cassava are strikingly sensitive to humidity as illustrated by their rapid closure in the dry air. The stomatal closure occurs due to water stress in the guard cells and the epidermis (Sheriff, 1977). The drooping of leaves at midday is more pronounced in the plants grown in pots with limited soil water, such drooping is gradual and acropetal. It results in the decrease in irradiance levels and conservation of water.

CHAPTER THREE

3. MATERIALS AND GENERAL METHODS

3.1. Location

Experiments were conducted at the University of Zululand namely in the garden for field work and the Botany department for laboratory work. Experiments were carried out from October 1987 to May 1990. Some observations were made at the Anglo - American Cassava Research Station, Mtunzini. Meteorological data for the period September 1987 to June 1989 are presented in Table 3.1. The chemical properties of the topsoil (0 - 200 mm) of the experimental field is presented in Table 3.2. The graphs for meteorological data are shown from Fig 3.1 to Fig 3.9.

3.2. The Cultivars

All the cultivars used in these experiments were taken from the Anglo - American Cassava Research Station at Mtunzini. The cultivars present at Mtunzini Research Station were MSAF 2 (an indigenous type to South Africa), three imported types viz. CMC 40 (M Col 1468), M 170 and M 5. There were several hybrids prepared through cross breeding. The hybrids were P1-16, P1-19, P1-111, P1-124,

TABLE 3.1. Meteorological data at the University of Zululand for the period September 1987 to June 1989.

Year	Temperature			Preci-pitation	Class A pan Evaporation	Rela-tive Humi-dity%	Global radia-tion
	mean	max	min				
	°C	°C	°C	m	mm		kJ m^{-2}s^{-1}
1987							
Sep	20,1	24,6	15,6	0,60	120,0	85,28	1,7
Oct	20,5	25,6	15,4	0,10	137,6	81,41	2,1
Nov	22,9	27,7	18,1	0,13	162,1	88,25	1,8
Dec	26,2	32,0	20,4	0,13	187,9	86.28	2,2
1988							
Jan	26,2	32,2	20,2	0,05	192,5	82,13	2,4
Feb	25,9	30,7	21,1	0,29	177,8	84,43	2,4
Mar	25,5	29,8	21,2	0,21	149,8	89,76	1,9
Apr	24,0	29,3	18,6	0,02	114,9	78,20	1,7
May	21,0	28,1	13,9	0,04	73,4	88,20	1,4
Jun	18,3	24,0	12,5	0,08	46,5	84,50	1,2
Jul	18,7	26,5	10,9	0,03	81,3	85,30	1,4
Aug	19,7	25,9	13,5	0,04	101,3	84,80	1,5
Sep	21,5	27,8	15,2	0,08	121,3	83,90	1,5
Oct	22,3	28,8	15,8	0,18	167,1	85,70	1,8
Nov	22,4	28,0	16,8	0,22	178,9	85,00	2,4
Dec	22,9	27,8	17,9	0,40	175,6	84,10	2,4
1989							
Jan	24,1	28,1	20,2	0,14	157,6	–	2,6
Feb	24,0	27,8	20,3	0,32	123,7	–	2,1
Mar	25,5	30,1	20,8	0,06	109,9	–	2,3
Apr	22,2	27,3	17,1	0,08	102,1	–	1,7
May	20,6	25,6	15,6	1,07	69,7	–	1,3
Jun	16,8	21,8	11,7	0,07	30,8	–	1,2

TABLE 3.2 Chemical properties of the top - soil
(0 - 200 mm) in the Experimental field.

Nutrient	mg 100g^{-1}
P	0,26
K	9,40
Ca	21,90
Mg	7,41
Na	0
Zn	0,13
pH (KCL)	4,3
CEC*	31,4

*me 100g^{-1}, extracted with 1 N NH$_4$-acetate at pH 7
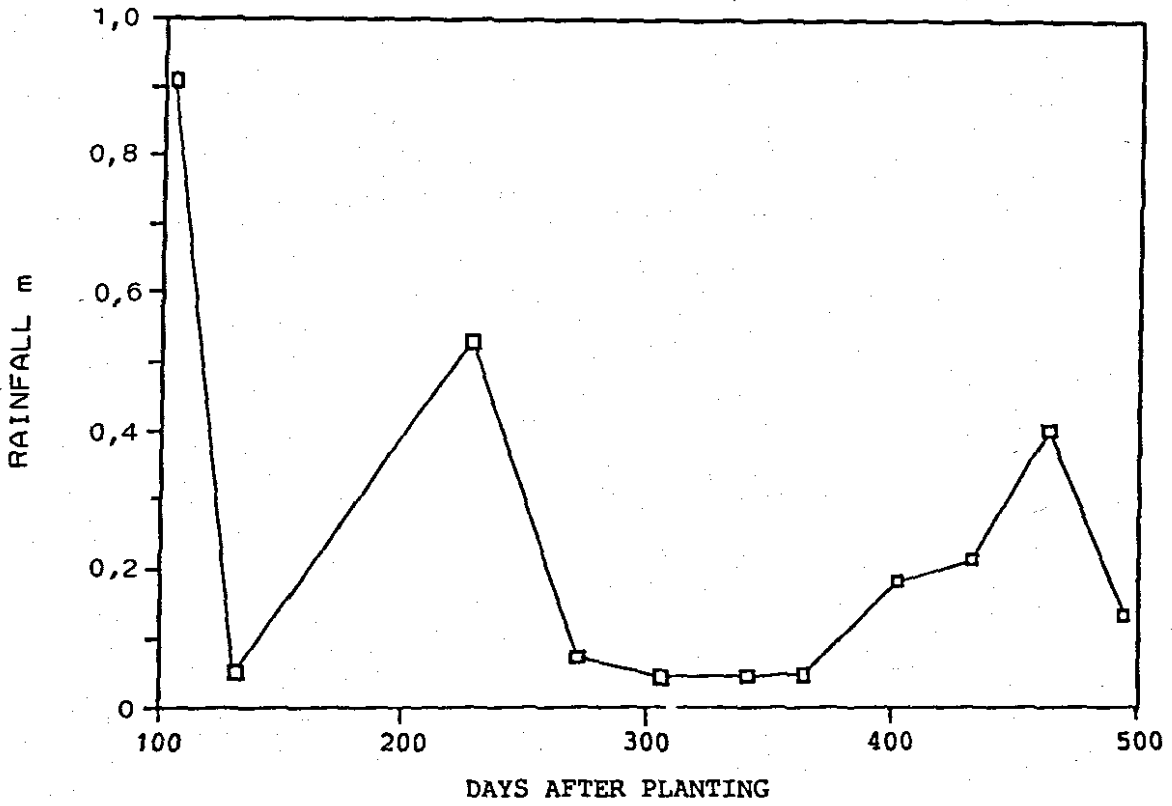
Figure 3.1 Rainfall at the University of Zululand for Experiment 1.
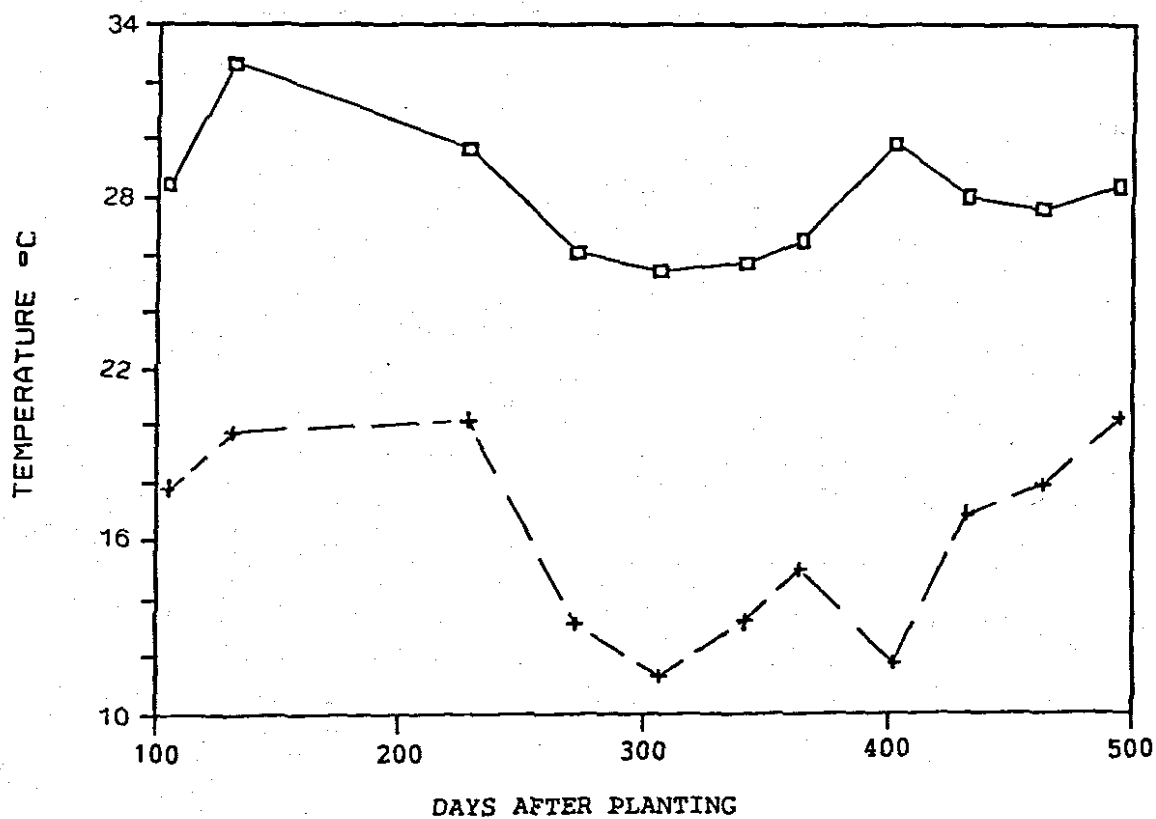
Figure 3.2 Maximum (□) and minimum (+) temperatures at the University of Zululand for Experiment 1.
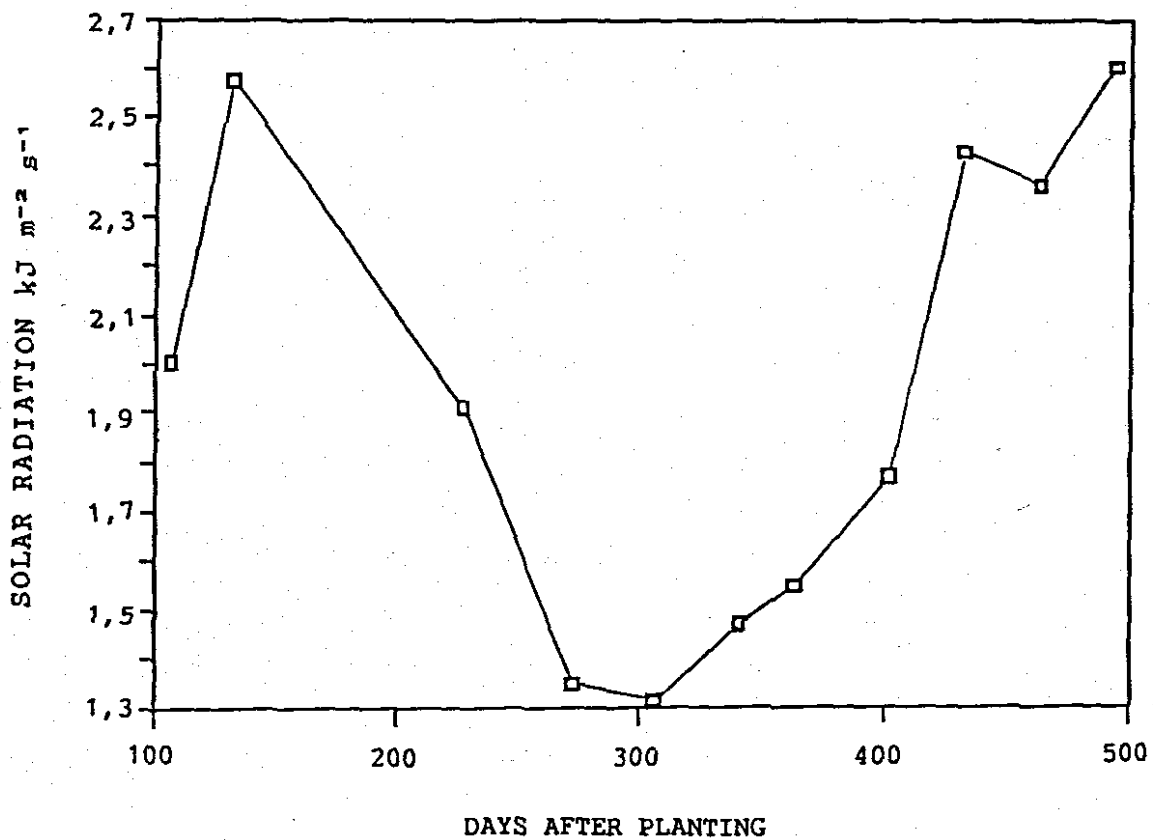
Figure 3.3 Solar radiation at the University of Zululand for Experiment 1.
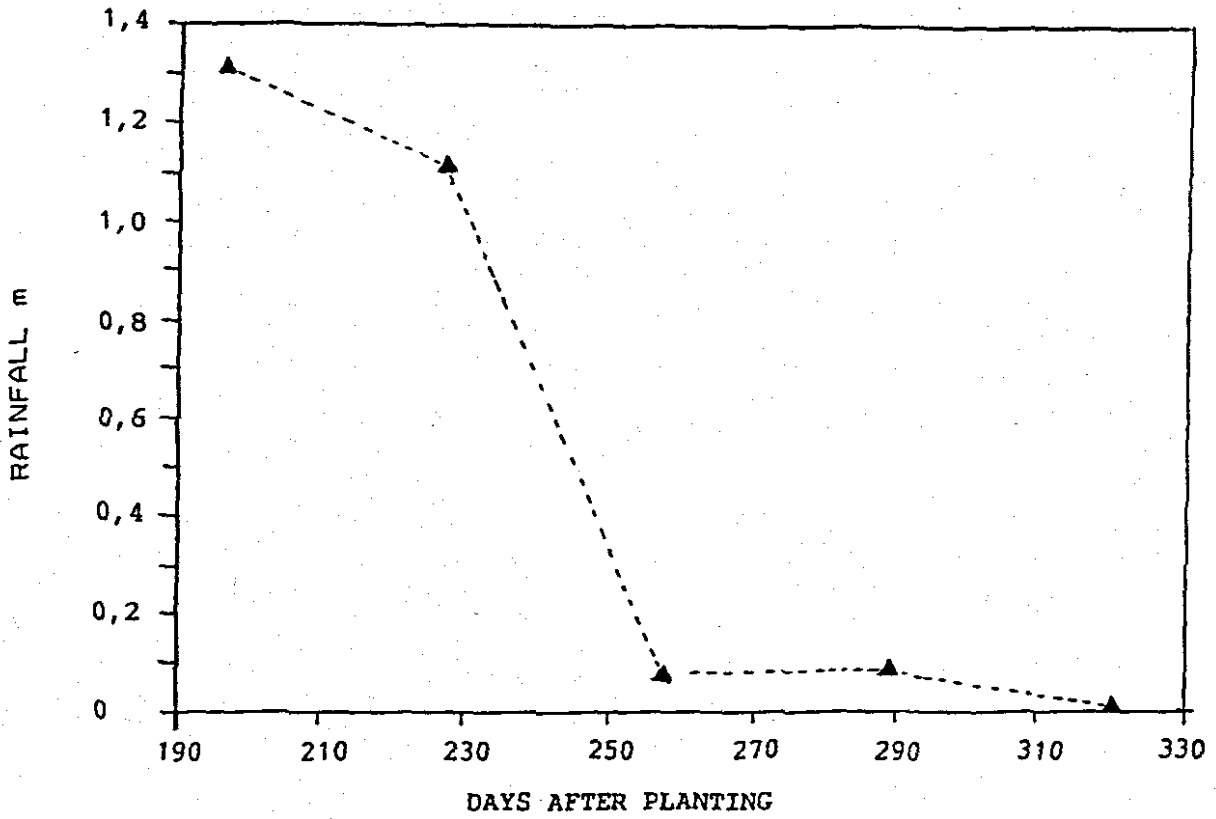
Figure 3.4 Rainfall at the University of Zululand for Experiment 2A.
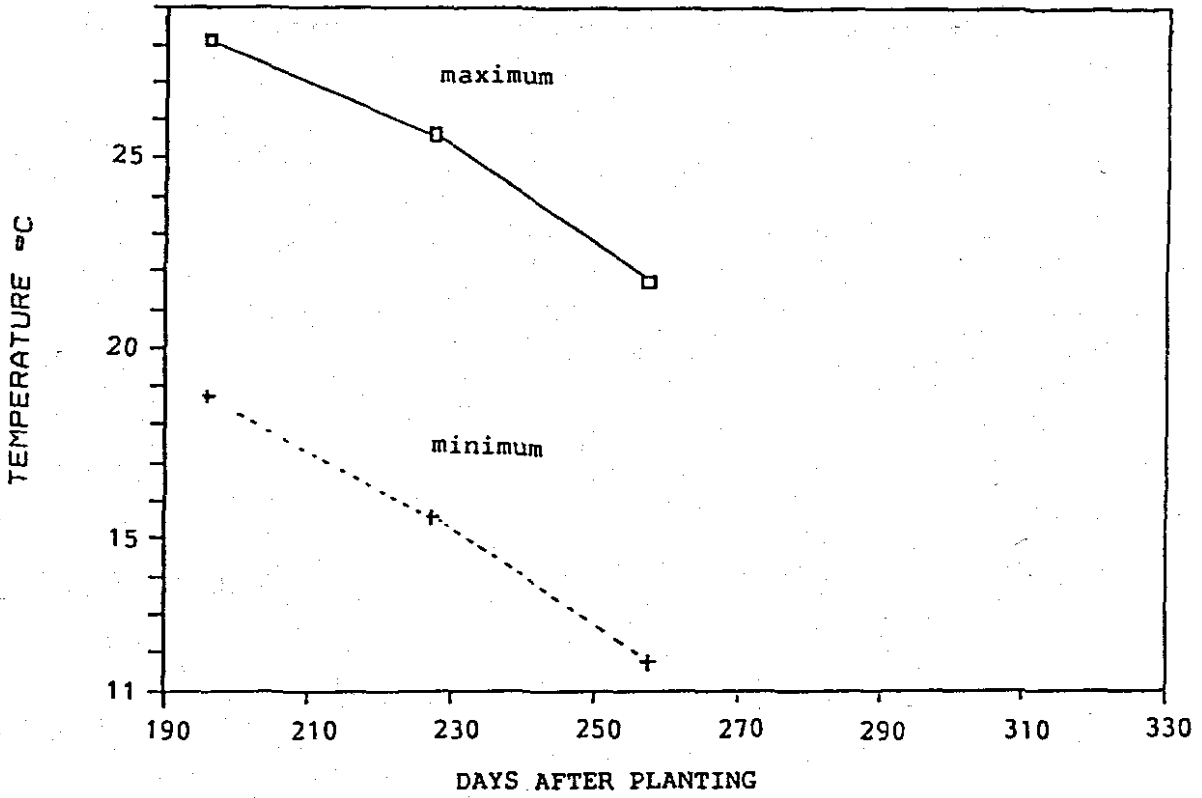
Figure 3.5 Maximum (□) and minimum (+) temperatures at the University
of Zululand for Experiment 2A. In this and other graphs,
data for 288 and 319 DAP is not available because the
instrument became faulty.
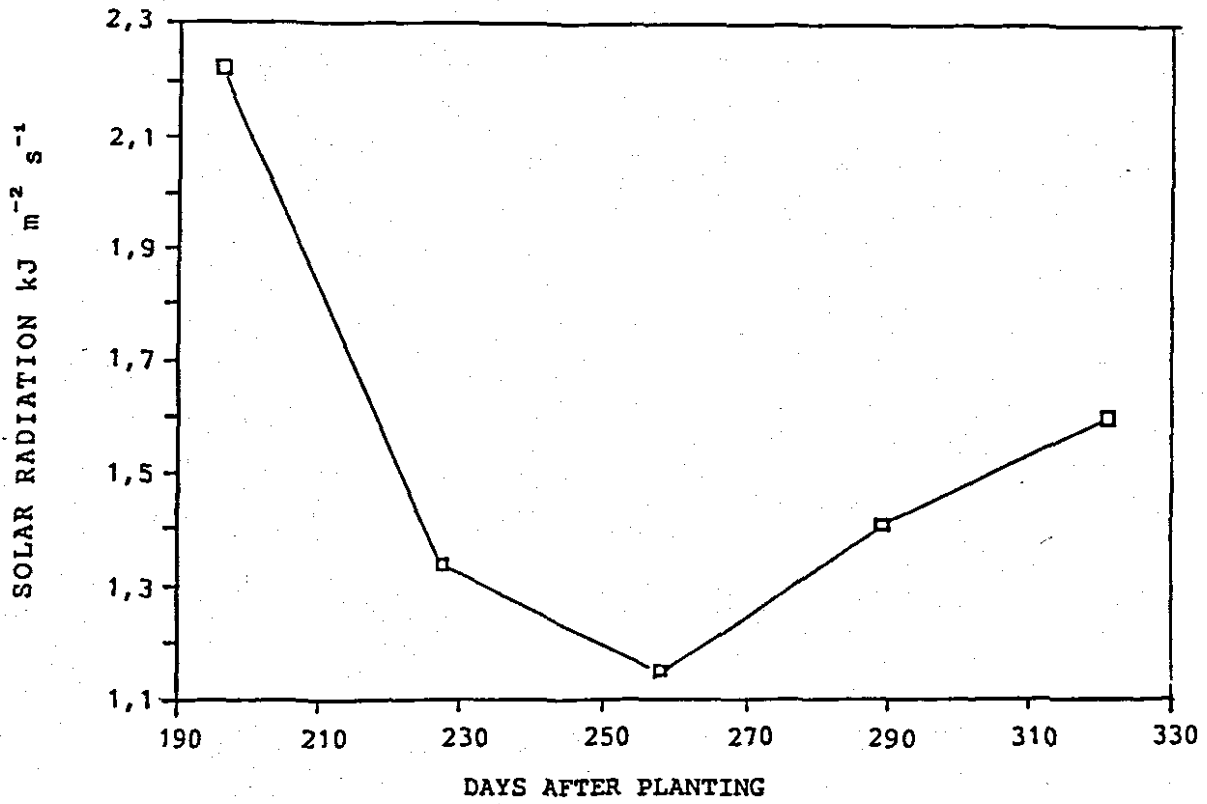
Figure 3.6 Solar radiation at the University of Zululand for Experiment 2A.
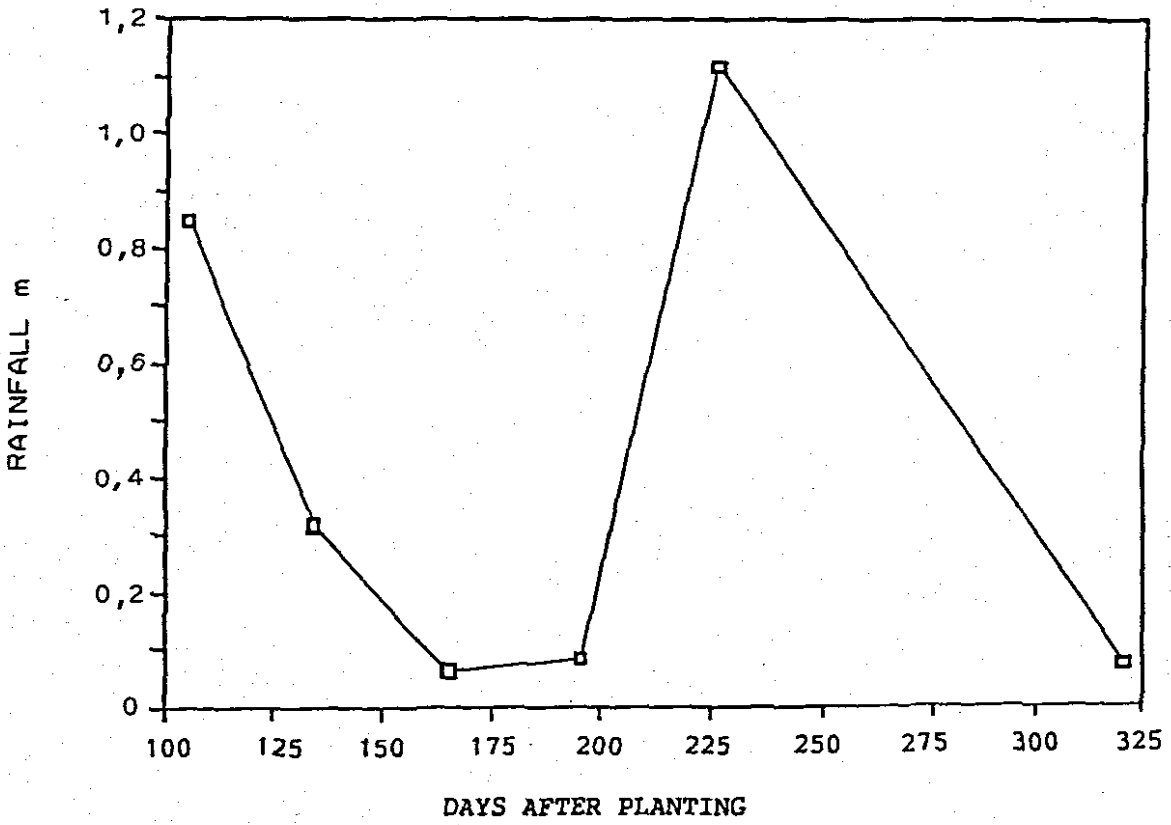
Figure 3.7 Rainfall at the University of Zululand for Experiment 2B.
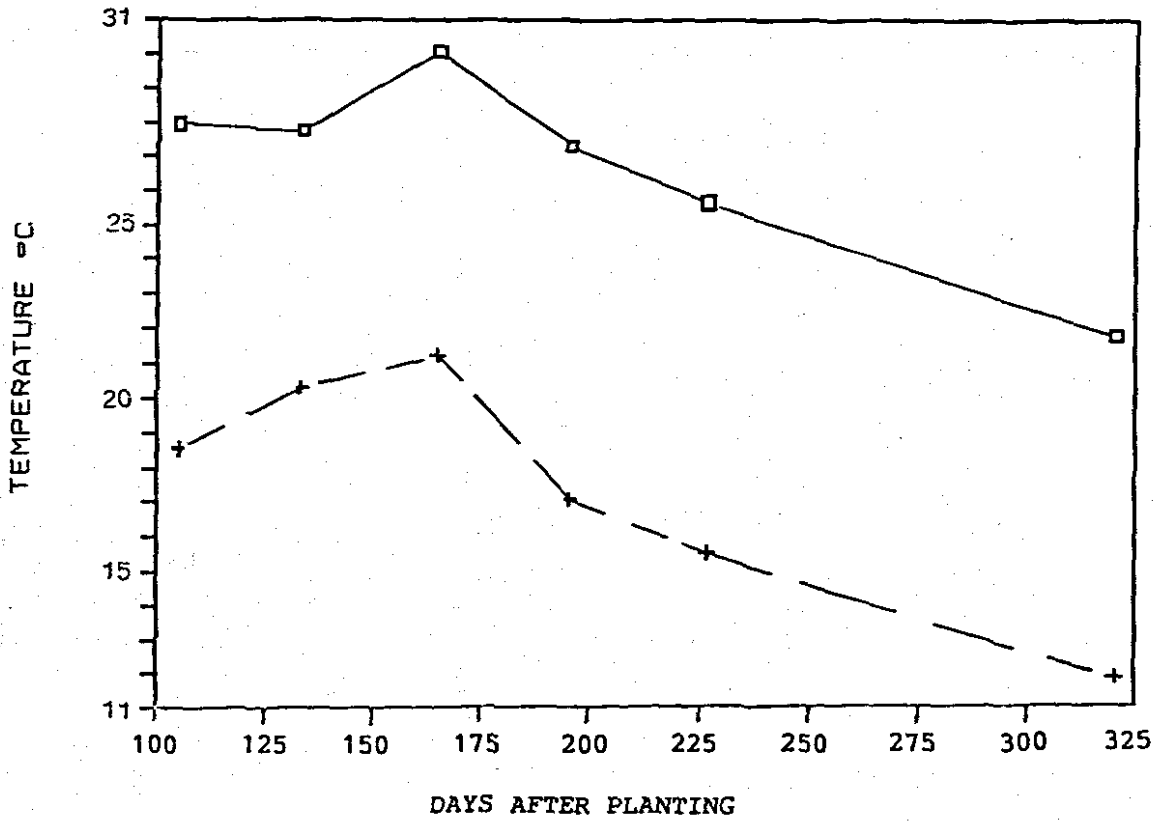
Figure 3.8 Maximum (□) and minimum (+) temperatures at the University
of Zululand for Experiment 2B.
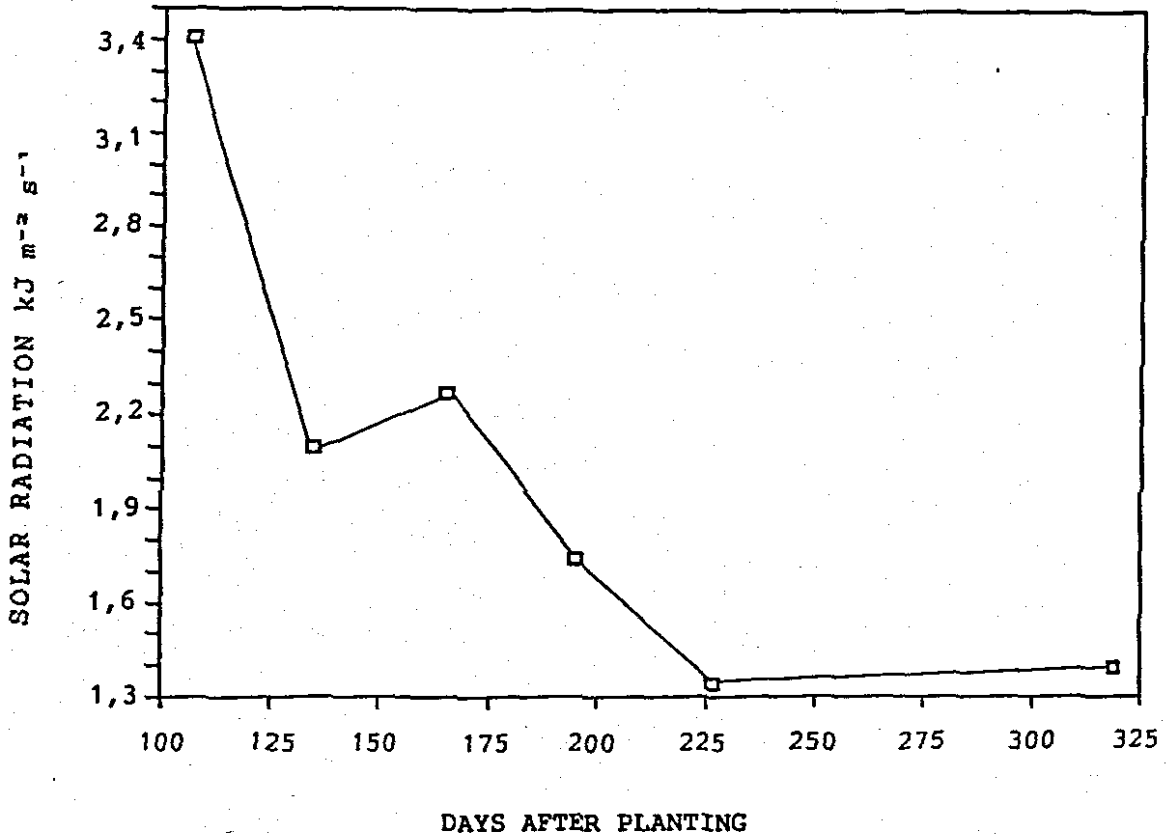
Figure 3.9 Solar radiation at the University of Zululand for

Experiment 2B.
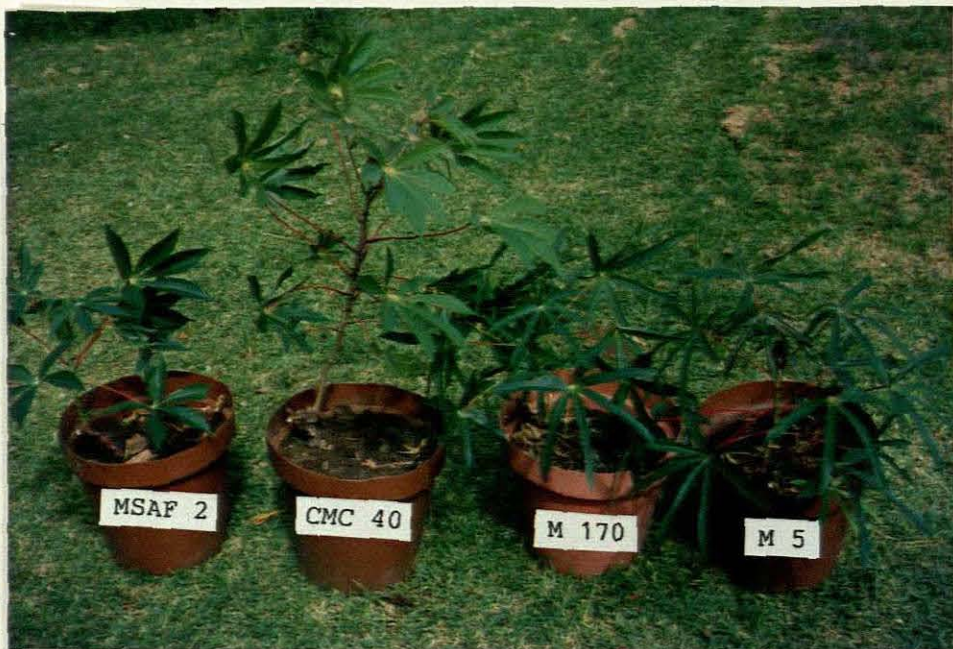
Figure 3.10   The cultivars of cassava (*Manihot esculenta* Crantz).

P2-14, P3-8, P4-10, P15-17 and P20-24. The cultivars MSAF 2, CMC 40, M 170 and M 5 were chosen for their high yielding ability in Northern Natal (T.B.Vorster, personal communication). The Anglo-American Research team could not release any of the hybrids for my use because they were still determining their yielding ability. The photographs of the cultivars used are presented in Fig 3.10. 170 and 5 are accession numbers used by the Anglo - American Research team at Mtunzini.

The cultivar MSAF 2 is short with lanceolate broad-lobed leaves. The central lobe is approximately 139 mm long; its breadth is approximately 40 mm; leaf apex is acaminate; the leafy shoot is green with red stripes above the point of origin of the petioles; the petioles are red with green areas towards the top and bottom. The length of petioles of fully expanded leaves range from 46 to 153 mm.

The cultivar CMC 40 is tall, with lanceolate broad-lobed leaves. The central lobe is approximately 131 mm long; its breadth is approximately 47 mm; leaf apex is acaminate; leafy shoot is red towards the bottom with green stripes towards the top; the petioles of fully expanded leaves are red and their length range from 63 to 213 mm.

The cultivar M 170 is short, with oblong narrow-lobed leaves. The central lobe is approximately 143 mm long; its

N ↑

CHC 40	M 170	M 5	M 170	MSAF 2	CHC 40	M 170	CHC 40	M 5	M 170	CHC 40	MSAF 2
M 5	MSAF 2	CHC 40	M 5	M 170	M 5	CHC 40	MSAF 2	M 170	MSAF 2	M 170	CHC 40
MSAF 2	M 5	MSAF 2	CHC 40	M 5	M 170	M 5	CHC 40	MSAF 2	CHC 40	M 5	M 170
M 170	MSAF 2	M 170	MSAF 2	CHC 40	M 5	M 170	MSAF 2	CHC 40	M 5	MSAF 2	M 5
M 5	M 170	CHC 40	MSAF 2	M 170	MSAF 2	M 5	MSAF 2	CHC 40	M 170	MSAF 2	M 5
CHC 40	MSAF 2	M 5	M 170	CHC 40	M 5	CHC 40	M 170	MSAF 2	M 170	CHC 40	M 170

Figure 3.11 The schematic representation of the distribution of experimental plots for various cultivars of cassava. The area of the field was 60m x 30m.

case care was taken to ensure that roots were not wounded (as they would rot). For potted plants, the pots used were 18 l filled with the same soil present in the experimental garden, thus the same fertiliser was used at 20 g per plant. After sprouting, the weaker shoots were eliminated and only one was left per plant. Any additional shoots were eradicated whenever they were observed. Dry cuttings were replaced with plants of the same age that had been planted in black plastic bags. All the experiments varied from 12 to 24 months. The plots were randomly distributed (Fig 3.11) in the field with an area of 60m x 30m. Each plot was 5m x 5m. There were 36 plants per plot. The test plants harvested were in the centre of each plot and surrounded by two border rows of the same cultivar (Fig 3.12).

3.4. Measurement of the growth process

3.4.1. Branching pattern, number of active apices and plant height

Plant height was measured from the point of origin of the new shoot from old planting piece to the general height of the canopy. The number of active apices per branching pattern were determined at each harvest.
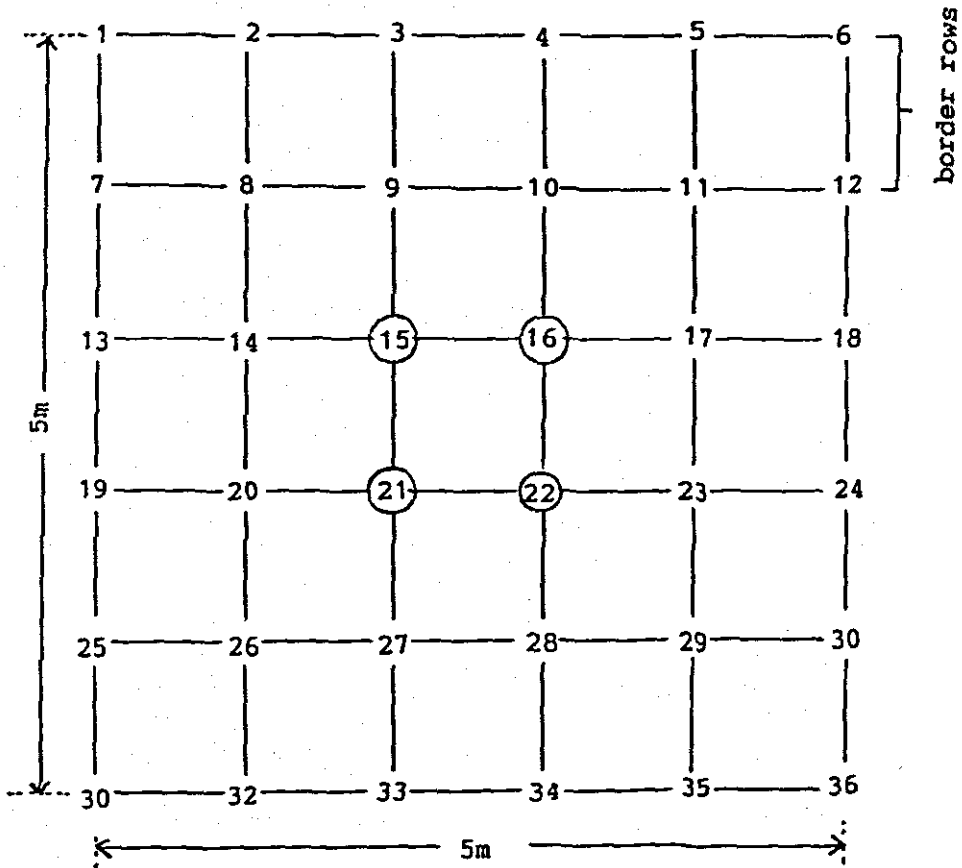
Figure 3.12 The schematic representation of the distribution of plants per plot. The numbers 1 to 36 represent test plants whose spacing was 1m x 1m. The encircled plants are the ones which were harvested.

3.4.2. Fallen leaves and total leaf numbers

The number of fallen leaves was determined by counting the number of bare nodes of the shoot. The total number of leaves was equal to the bare nodes plus the present leaves. Fallen leaves were not added to the total dry weight.

3.4.3. Fresh and dry weight

For field conditions, the sample size varied from 4 to 8 whereas in potted plants it was always maintained at 5 plants per harvest. These plants were separated into original planting piece, stems, petioles, leaves, storage and non - storage roots. A root greater than 10 mm in diameter was regarded as a storage one. The samples were weighed and oven dried at 105 °C to a constant dry weight for a minimum of 72 hours. The number of storage roots was determined in some harvests.

3.4.4. The leaf area

At harvests with low leaf numbers, all the leaves were used in three plants per cultivar to determine area using a ΔT area meter. When the leaf numbers were high (eg 150 DAP), a sub - sample of 50 leaves was taken and the area measured, after which the leaves were dried

and weighed. Using the weight of the sub-sample and the total leaf dry weight per plant, the total leaf area was calculated. Both the upper and lower surfaces of the leaf were used in the calculation of leaf area. The petioles were excluded from leaf area determination. The leaf area was divided by 1m² ground surface to obtain LAI (Coombs, Hall, Long & Scurlock; 1985).

3.4.5. Flowering and fruiting habit

In those cultivars that flower, the time of flowering and the dry weight of fruits was determined at each harvest.

3.4.6. Chlorophyll *a* content

For chlorophyll *a* analysis, the samples were taken from the inner border row (Fig 3.9) of each sample plot and not from the harvested specimens. The first fully expanded leaf adjacent to the apical bud, whose central lobe was greater than or equal to 10mm in width, was regarded as the first one. The chlorophyll *a* content was determined in the fifth, seventh and twelfth leaf. At each harvest, a cork borer (diameter 5,7 mm) was used to make cylindrical discs from which the chlorophyll *a* content was determined. Leaf discs were made in the central lobe towards the middle on either side of the midrib where possible. Extraction was done in 90 % acetone and determined

spectrophotometrically at 663 nm and 750 nm. Calculation was done according to the method described by Vollenweider (1971).

3.4.7. Statistical analysis

Statistical tables by Rohlf and Sokal (1981) were used in the calculation of minimum significant differences.

3.4.8. Non-standard abbreviations

D   = leaf area duration
DAP   = days after planting
DM   = dry matter
HI   = harvest index
LAI   = leaf area index
PAR   = photosynthetic active radiation

CHAPTER FOUR

4. DISTRIBUTION OF DRY MATTER AND YIELD IN CASSAVA

4.1. INTRODUCTION

Various researchers have determined the characteristics of high yielding cassava varieties. It is generally conceded that harvest index of high yielding cassava is high (Williams and Ghazali, 1969; Cock, 1976). A high yield is associated with a balance between the leaf and root production, and leaf area index must not decline excessively in the later growth stages (Cock, 1976). Positive correlations between the yield and LAI indicate that photosynthesis is limiting to dry matter production in cassava (Hunt et al, 1977). High yields are not necessarily due to the production of large total biomass (Williams and Ghazali, 1969; Cock, 1976). A high number of tubers per plant resulted in a high HI (Connor, Cock & Parra, 1981). The Anglo - American research team at Mtunzini (Personal communication) and Daphne (1980) have observed a high yield in MSAF 2.

I am not aware of any publications which compare the the distribution of dry matter in MSAF 2 with the imported cultivars CMC 40, M 170 and M 5. The purpose of the

research reported in this chapter is to compare the distribution of dry matter at various harvests in MSAF 2, CMC 40, M 170 and M 5.

4.2. MATERIALS AND METHODS.

The research reported in this chapter is composed of two experiments on the basis of planting times. The general experimental procedure and meteorological data are reported in chapter 3.

Experiment 1 : Planting was done on 26/09/87 in experimental plots on campus of the University of Zululand.

Harvest	Date	Number of DAP
H1	09/01/88	106
H2	05/02/88	133
H3	10/05/88	228
H4	24/06/88	273
H5	28/07/88	307
H6	01/09/88	342
H7	24/09/88	365
H8	01/11/88	403
H9	01/12/88	433
H10	01/01/89	464
H11	01/02/89	495

Harvest	Date	Number of DAP
H12	31/07/89	707

The number of plants harvested was as follows:

H1   : 7 plants per cultivar

H2 to H11: 4 plants per cultivar

H12   : 8 plants per cultivar

Experiment 2A : Planting was done on 17/10/88 in experimental plots on campus of the University of Zululand.

Harvest	Date	Number of DAP
H1	30/04/89	196
H2	31/05/89	227
H3	30/06/89	257
H4	31/07/89	288
H5	31/08/89	319

The number of plants harvested was as follows:

H1 to H4 : 4 plants per cultivar

H5   : 6 plants per cultivar

Experinent 2B : Planting was done on 17/10/88 in polyethylene pots.

Harvest	Date	Number of DAP
H1	31/01/89	107
H2	28/02/89	135
H3	31/03/89	166
H4	30/04/89	196
H5	31/05/89	227
H6	31/08/89	319

The number of plants harvested was as follows:

H1 to H5 : 5 plants per cultivar

H6   : 6 plants per cultivar

In all the experiments named above, the number of storage roots and the dry mass of roots, stems, petioles, leaf blades, fruit and seed was determined.

4.3. RESULTS

4.3.1. COMPARISON OF TOTAL DRY MATTER PRODUCTION IN CASSAVA CULTIVARS.

4.3.1.1. Total dry mass for experiment 1.

The results of this experiment are shown in Fig 4.1. The graphs depict that growth was very slow during the first two harvest viz 106 and 133 DAP. MSAF 2 and M 170 reached the peak of total dry mass at the same time (307

Figure 4.1 Total dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (▲) at different times after planting for Experiment 1. In this and other graphs, vertical lines indicate minimum significant differences (p = 0,05 and p = 0,01).

DAP) and thereafter underwent winter decline. CMC 40 and M 5 reached their peaks at 342 DAP. The decline in total dry mass at the commencement of the winter regrowth was due to the mobilization of reserves in the root and stem, exclusion of fallen leaves and dry shoot tips. These were excluded because they mixed with those from border rows and could not be identified with precision. At 106, 307, 403, 433, 464 and 495 DAP, the cultivars did not differ significantly in their total dry mass. At 133 DAP, CMC 40 had a significantly higher (p=0,05) total dry mass than M 170 whereas MSAF 2, CMC 40 and M 5 did not differ significantly. At 228 DAP, for p=0,05, the total dry mass in M 5 was significantly higher than in MSAF 2. M 170 was significantly higher than CMC 40. For p=0,01, MSAF 2 was significantly lower than M 170. At 273 DAP MSAF 2 had a significantly lower (p=0,05) total dry mass than both CMC 40 and M 170. At 342 DAP, M 170 had a significantly lower (p=0,05) total dry mass than CMC 40. MSAF 2, M 5 and CMC 40 did not differ significantly. At 365 DAP M 170 had a significantly lower (p=0,05) total dry mass than M 5. MSAF 2 had a significantly higher (p=0,01) total dry mass than M 170.

Figure 4.2 Total dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (▲) at different times after planting for Experiment 2A.

4.3.1.2. Total dry mass for experiment 2A.

The results of this experiment are shown in Fig 4.2. At 227, 257, and 288 and 319 DAP, the cultivars did not differ significantly in their total dry mass. At 196 DAP, CMC 40 had a significantly higher ($p=0,05$) total dry mass than both MSAF 2 and M 170. M 5 was significantly lower ($p=0,01$) than CMC 40.

4.3.1.3. Total dry mass for experiment 2B

There was a gradual increase in total dry mass from 107 to 166 DAP (Fig 4.3). At 107 and 196 DAP, the cultivars did not differ significantly in their total dry mass. At 135 DAP, M 170 was significantly lower ($p=0,05$) than M 5. At 166 DAP, MSAF 2 was significantly higher ($p=0,05$) than M 5. Furthermore, MSAF 2 was significantly higher ($p=0,01$) than CMC 40. At 227 DAP, both CMC 40 and M 5 had a significantly lower ($p=0,01$) total dry mass than MSAF 2. At 319 DAP, MSAF 2 had a significantly higher ($p=0,05$) total dry mass than M 5 while CMC 40 was significantly lower ($p=0,05$) than M 5. Both MSAF 2 and M 170 were significantly higher ($p=0,01$) than CMC 40.

Figure 4.3 Total dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊)
and M 5 (∆) at different times after planting for
Experiment 2B.

Figure 4.4 Root dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (▲) at different times after planting for Experiment 1.

4.3.2. THE PRODUCTION OF ROOT DRY MASS AND ROOT NUMBERS

4.3.2.1. The production of root dry mass in experiment 1.

The storage roots appeared within the first 106 DAP (Fig 4.4). Two kinds of adventitious roots were observed viz those arising from submersed nodes (nodal roots) and those at the lower end of the cutting (basal roots). At 106, 307 and 464 DAP, the cultivars did not differ sinificantly in their root dry mass. At 133 DAP, CMC 40 had a significantly higher (p=0,05) root dry mass than both MSAF 2 and M 5. At 228 DAP, M 170 had a significantly higher (p=0,01) root dry mass than both MSAF 2 and CMC 40. At 273 DAP, M 170 was significantly higher (p=0,05) than M 5 whereas MSAF 2, M 5 and CMC 40 did not differ significantly. Furthermore, M 170 was significantly higher (p=0,01) than MSAF 2. At 342 DAP, CMC 40 was significantly higher (p=0,05) than M 170. At 365 DAP, no significant difference was observed among the cultivars for p=0,05. MSAF 2 was significantly higher (p=0,01) than M 170. At 403 DAP, M 170 had a significantly higher (p=0,05) root dry mass than both MSAF 2 and M 5. At 433 DAP, CMC 40, M 170 and M 5 were significantly higher (p=0,01) than MSAF 2. At 495 DAP, M 170 was significantly higher (p=0,01) than M 5. At 707 DAP, CMC 40 and M 5 were significantly lower (p=0,05) than MSAF 2.

Figure 4.5 Root dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇)
and M 5 (▲) at different times after planting for
Experiment 2A.

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4.3.2.2. The root dry mass and root numbers for experiment 2A.

The results of this experiment are shown in Fig 4.5. At 227, 257, and 288 DAP, the differences in root dry mass among the cultivars were not statistically significant. At 196 DAP, for p=0,01, CMC 40, MSAF 2 and M 170 were significantly higher than M 5. At 319 DAP, for p=0,05, M 5 was significantly higher than M 170. MSAF 2 was significantly higher (p=0,01) than M 170.

There were variations in the number of tuberous roots in the cultivars studied (Table 4.1). At 257 DAP MSAF 2 had a significantly higher (p=0,05) number of tubers than CMC 40. For p=0,01, the number of tubers in M 170 was significantly higher than in CMC 40.

Table 4.1. Root numbers at 257 DAP for experiment 2A (mean values from four plants).

Cultivar	Tuberous root number
MSAF 2	6,25
CMC 40	4,25
M 170	7,50
M 5	6,75

Figure 4.6 Root dry mass for MSAF 2 (□), CMC (+), M 170 (◊)
and M 5 (Δ) at different times after planting for
Experiment 2B.

4.3.2.3. The production of root dry mass and root numbers
for experiment 2B.

The results of this experiment are shown in Fig 4.6. At
107 DAP MSAF 2 and M 170 were significantly higher
($p=0,05$) than M 5 and CMC 40. At 135 DAP, MSAF 2 had a
significantly higher ($p=0,05$) root dry mass than both
M 170 and M 5. CMC 40 was significantly lower
($p=0,05$) than M 5. For $p=0,01$, MSAF 2 was significantly
higher than CMC 40. At 166 DAP, M 170 had a significantly
higher ($p=0,05$) root dry mass than CMC 40. MSAF 2 was
significantly higher ($p=0,01$) than CMC 40, M 170 and M 5.
At 196 DAP MSAF 2 was significantly higher ($p=0,05$) than
CMC 40 whereas M 5 was significantly lower ($p=0,01$) than
MSAF 2. At 227 DAP, MSAF 2 and M 170 were significantly
higher ($p\approx0,01$) than CMC 40. M 5 was significantly lower
($p=0,01$) than MSAF 2. At 319 DAP, MSAF 2 and M 170
had a significantly higher ($p=0,01$) root dry mass
than both CMC 40 and M 5. The root dry mass of
CMC 40 was significantly lower ($p=0,01$) than in M 5.

The variations in tuberous root numbers are presented in
Table 4.2. At 319 DAP M 170 had a significantly higher
($p=0,01$) number of tubers than both CMC 40 and M 5.
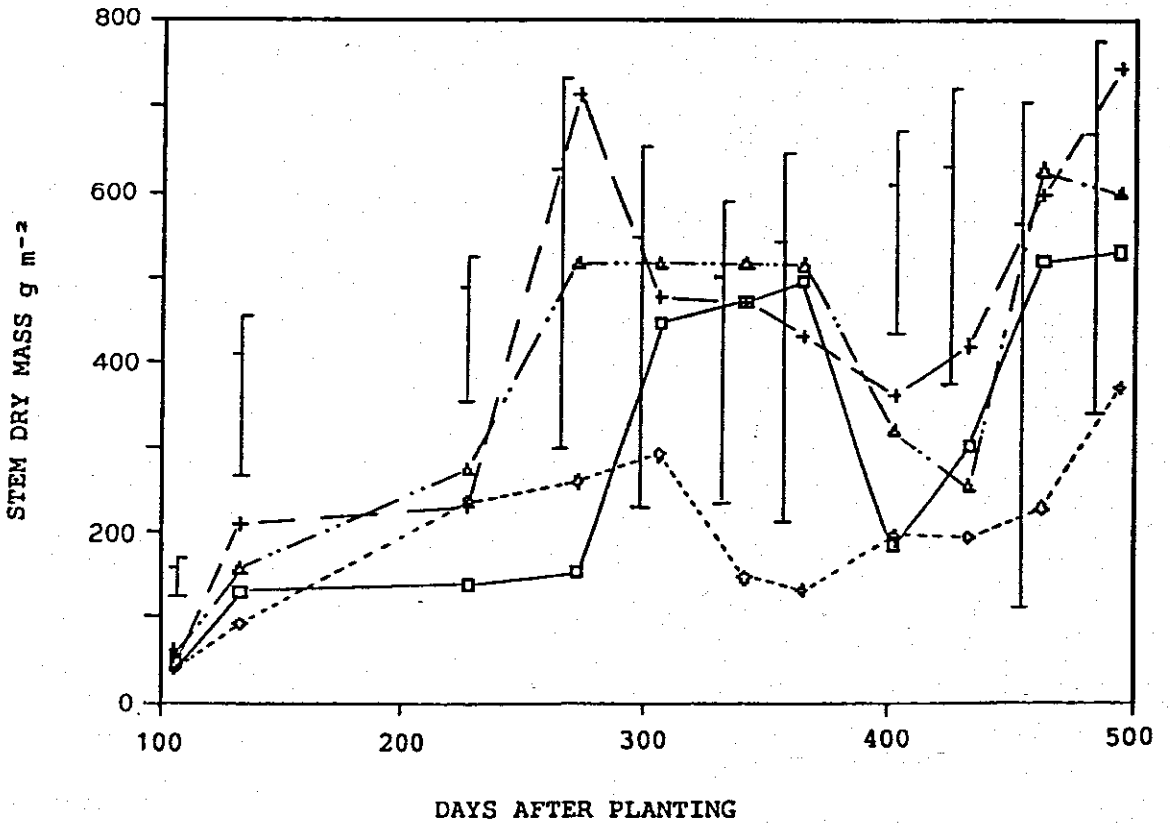
Figure 4.7 Stem dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (△) at different times after planting for Experiment 1.

Table 4.2. Root numbers at 319 DAP for experiment 2B (mean
values from five plants).

Cultivar	Tuberous root number
MSAF 2	6,4
CMC 40	3,2
M 170	7,4
M 5	3,2

4.3.3. THE PRODUCTION OF STEM DRY MASS

4.3.3.1. The stem dry mass for experiment 1

The results of this experiment are shown in Fig 4.7. In
the first year of growth, CMC 40 and M 5 showed a gradual
increase in stem dry mass from 106 to 273 DAP where they
reached their peaks. The short cultivars viz MSAF 2 and
MSAF 2 reached their peaks in the first year of growth at
307 and 365 DAP respectively. For CMC 40, the winter
decline after maximum growth in the first year was
observed at 307 DAP. The winter decline in MSAF 2 and M 5
was observed at 403 DAP. M 170 had its winter decline at
342 DAP. At 106, 133, 307, 403, 433 and 464 DAP, the
differences in stem dry mass among the cultivars were
not statistically significant. At 228 DAP, M 5 had a
significantly higher (p=0,05) stem dry mass than
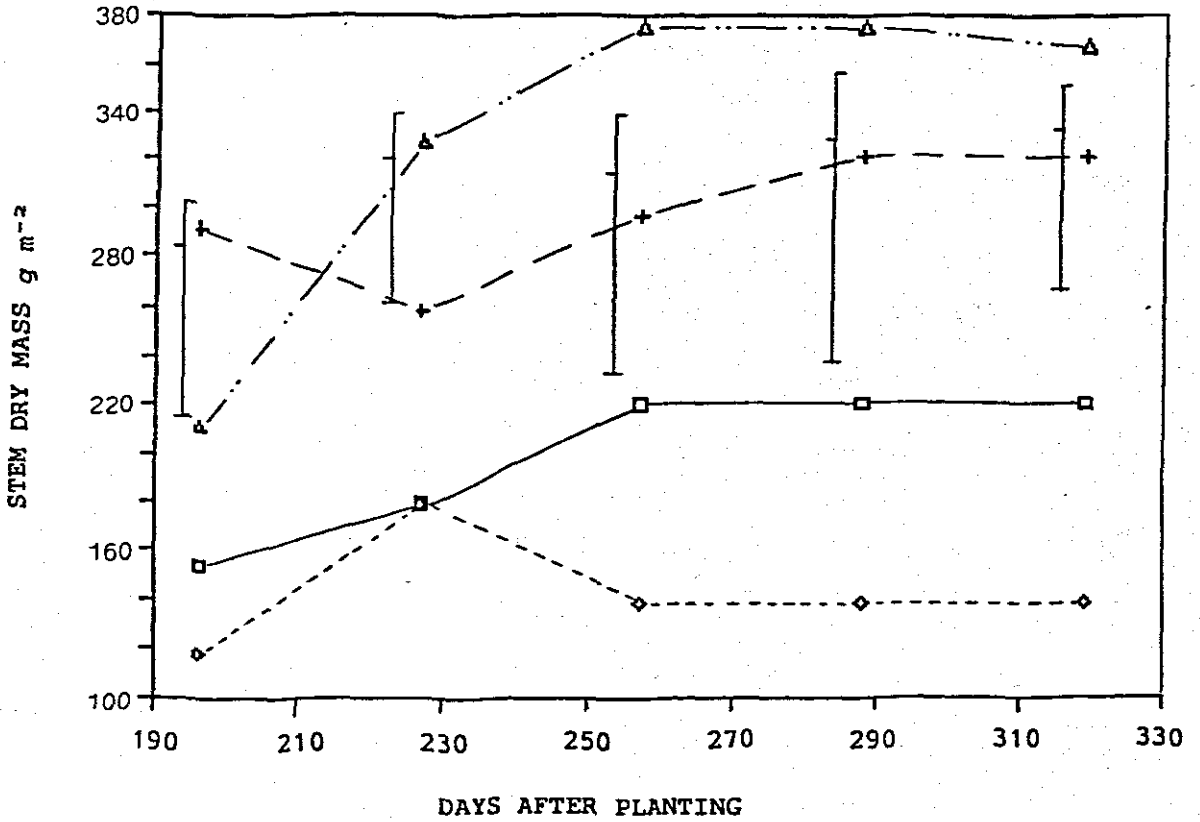
Figure 4.8   Stem   dry   mass   for   MSAF 2 (□), CMC 40 (+), M 170 (◊)

and   M 5 (△)   at   different   times   after   planting   for

Experiment 2A.

MSAF 2. At 273 DAP, M 5 was still significantly higher (p=0,05) than MSAF 2. The stem dry mass of CMC 40 was significantly higher (p=0,01) than in both MSAF 2 and M 170. At 342 DAP, MSAF 2, CMC 40 and M 5 were significantly higher (p=0,05) than M 170. At 365 DAP, both MSAF 2 and M 5 had a significantly higher (p=0,05) stem dry mass than M 170. At 495 DAP, CMC 40 had a significantly higher (p=0,05) stem dry mass than M 170.

4.3.3.2. The stem dry mass for experiment 2A.

The results of this experiment are shown in Fig 4.8. At 196 DAP, CMC 40 had a significantly higher (p=0,01) stem dry mass than both MSAF 2 and M 170. At 227 DAP, M 5 had a significantly higher (p=0,01) stem dry mass than both MSAF 2 and M 170. At 257 DAP, CMC 40 was significantly higher (p=0,01) than M 170. M 5 was significantly higher (p=0,01) than both MSAF 2 and M 170. At 288 DAP, M 5 was still significantly higher (p=0,05) than MSAF 2. For p=0,01, M 5 and CMC 40 were significantly higher than M 170. At 319 DAP, CMC 40 was significantly higher (p=0,05) than MSAF 2. M 5 was significantly higher (p=0,01) than both MSAF 2 and M 170. CMC 40 was significantly higher (p=0,01) than M 170.
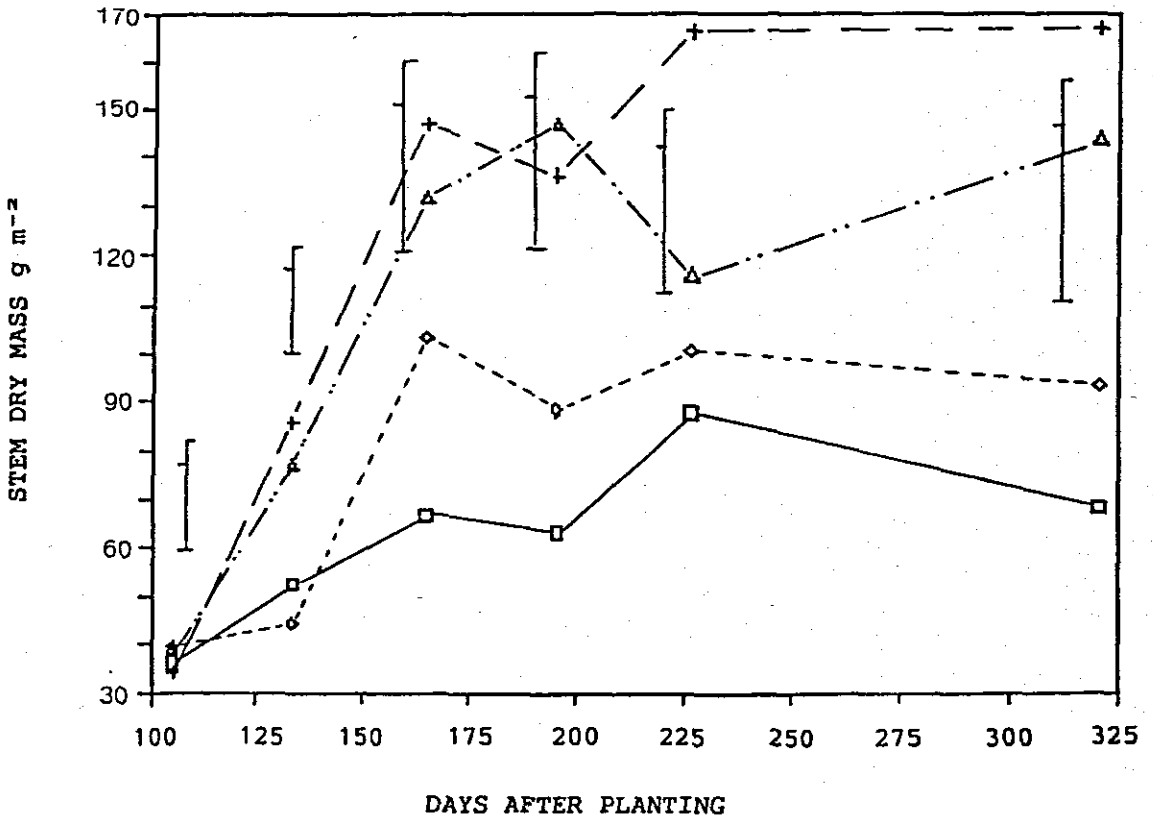
Figure 4.9 Stem dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊)

and M 5 (▲) at different times after planting for

Experiment 2B.

4.3.3.3. The stem dry mass for experiment 2B.

The results of this experiment are shown in Fig 4.9. The dry mass of stems in all the cultivars showed an increase from 107 to 166 DAP. At 107 DAP, the cultivars did not differ significantly in their stem dry mass. At 135 DAP, M 5 had a significantly higher ($p=0,05$) stem dry mass than MSAF 2. CMC 40 was significantly higher ($p=0,01$) than both MSAF 2 and M 170. M 5 was significantly higher ($p=0,01$) than CMC 40. At 166 DAP, CMC 40 was significantly higher ($p=0,05$) than M 170. CMC 40 and M 5 had a significantly higher ($p=0,01$) stem dry mass than MSAF 2.   At 196 DAP, CMC 40 had a *significantly higher* ($p=0,05$) stem dry mass than M 170. Both CMC 40 and M 5 were significantly higher ($p=0,01$) than MSAF 2. M 5 was significantly higher ($p=0,01$) than M 170. At 227 DAP, CMC 40 was significantly higher ($p=0,01$) MSAF 2, M 170 *and* M 5.   At 319 DAP, M 5   was significantly higher ($p=0,05$) than M 170. CMC 40 was significantly higher ($p=0,01$) than both MSAF 2 and M 170. M 5 was also significantly higher ($p=0,01$) than MSAF 2.

-53-
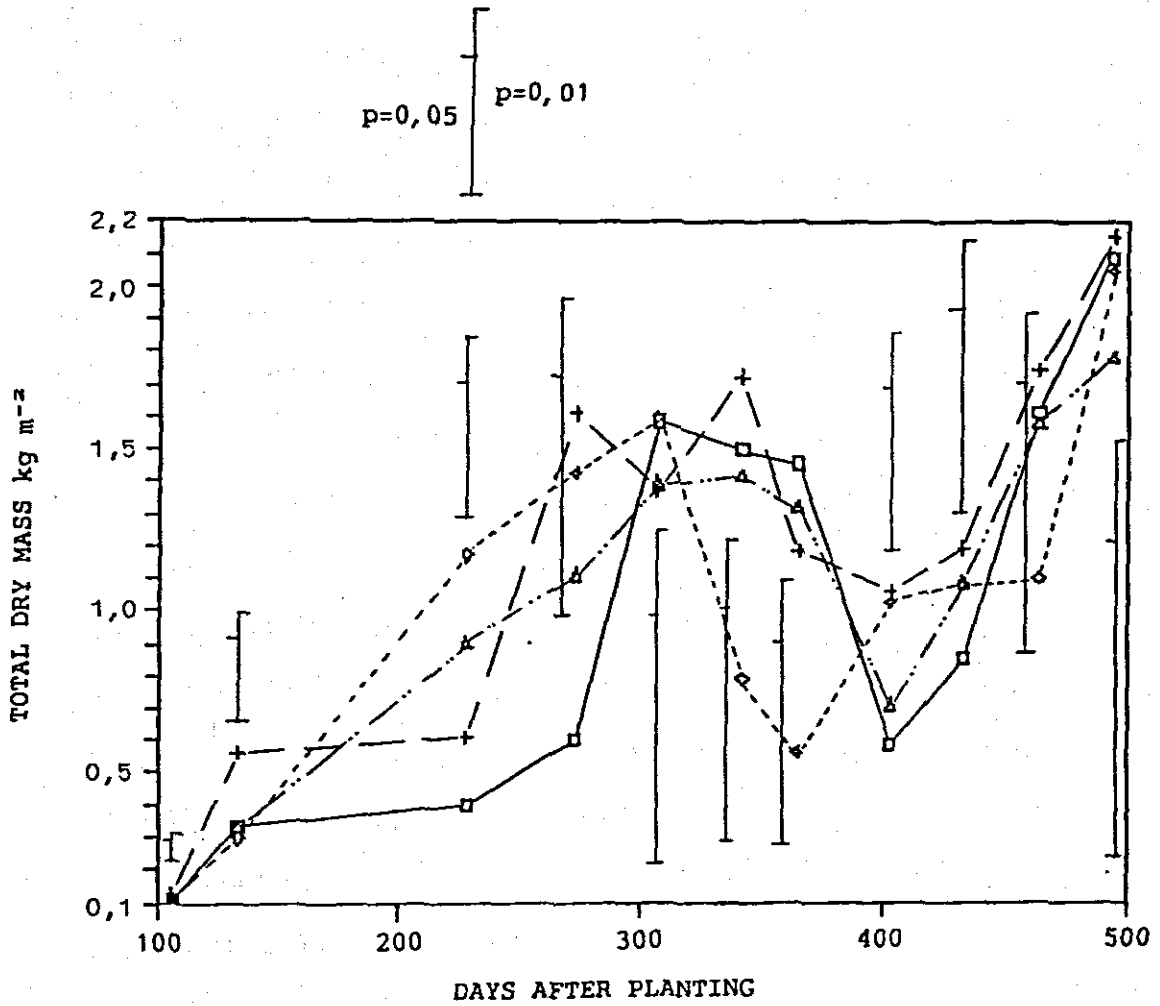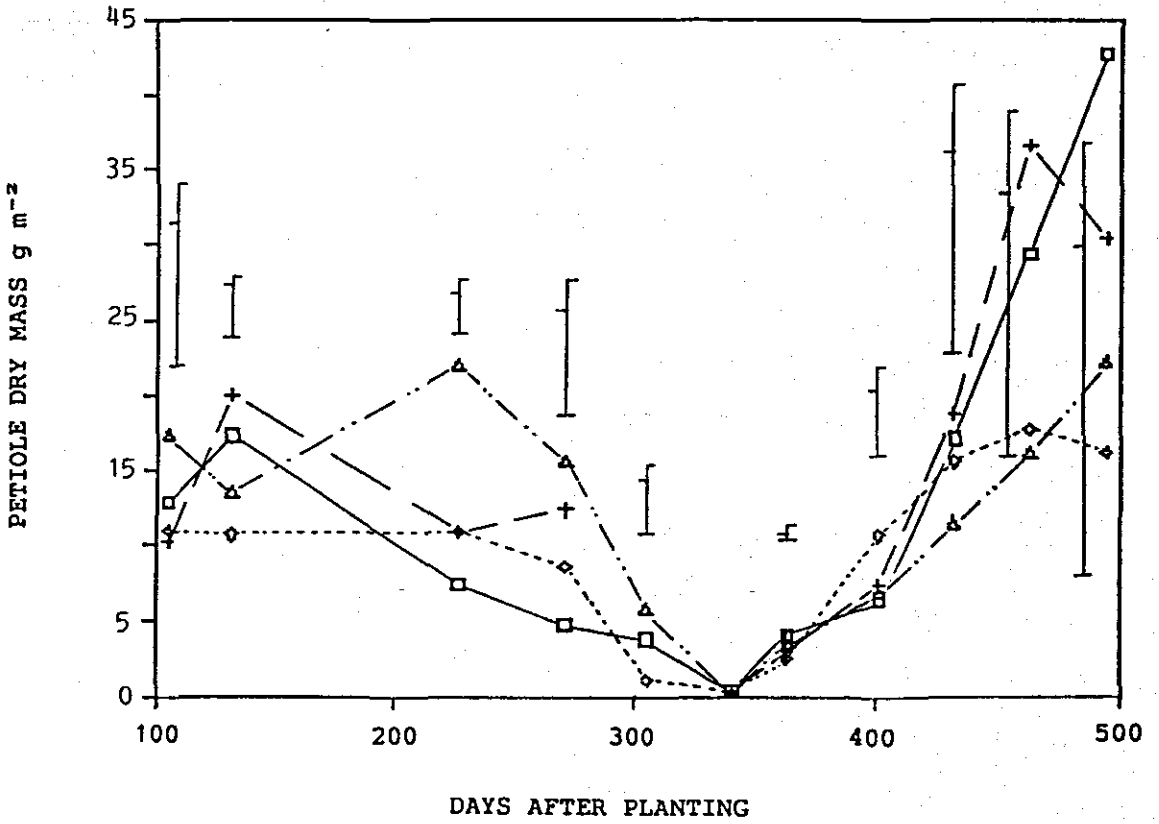

Figure 4.10 Petiole dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (▵) at different times after planting for Experiment 1.

4.3.4. THE PRODUCTION OF PETIOLE DRY MASS.

4.3.4.1. The petiole dry mass for experiment 1.

The production of petiole dry mass exhibited a seasonal
pattern (Fig 4.10). In all the cultivars the lowest value
was observed at 342 DAP when leaf fall was at its
maximum. At 133 DAP, MSAF 2 had a significantly higher
(p=0,05) petiole dry mass than M 5. For p=0,01, CMC 40
had a significantly higher petiole dry mass than
both M 170 and M 5. MSAF 2 was significantly higher
than M 170. At 228 DAP, MSAF 2 was significantly lower
(p=0,05) than both CMC 40 and M 170. M 5 was
significantly higher (p=0,01) than MSAF 2, CMC 40 and M
170. At 273 DAP, for p=0,05 CMC 40 was significantly
higher than MSAF 2, M 5 was significantly higher than
M 170. For p=0,01, M 5 was significantly higher than
MSAF 2. At 307 DAP, M 5 was significantly higher (p=0,01)
than M 170. At 342 DAP, MSAF 2 was significantly higher
(p=0,01) than CMC 40. At 365 DAP, M 5 was significantly
higher (p=0,05) than CMC 40. For p=0,01, MSAF 2 was
significantly higher than both CMC 40 and M 170, M 5 was
significantly higher than M 170. At 106, 403 and 433
DAP the cultivars did not differ significantly
in their petiole dry mass. At 464 DAP, CMC 40 was
significantly higher (p=0,05) than both M 170 and M 5. At
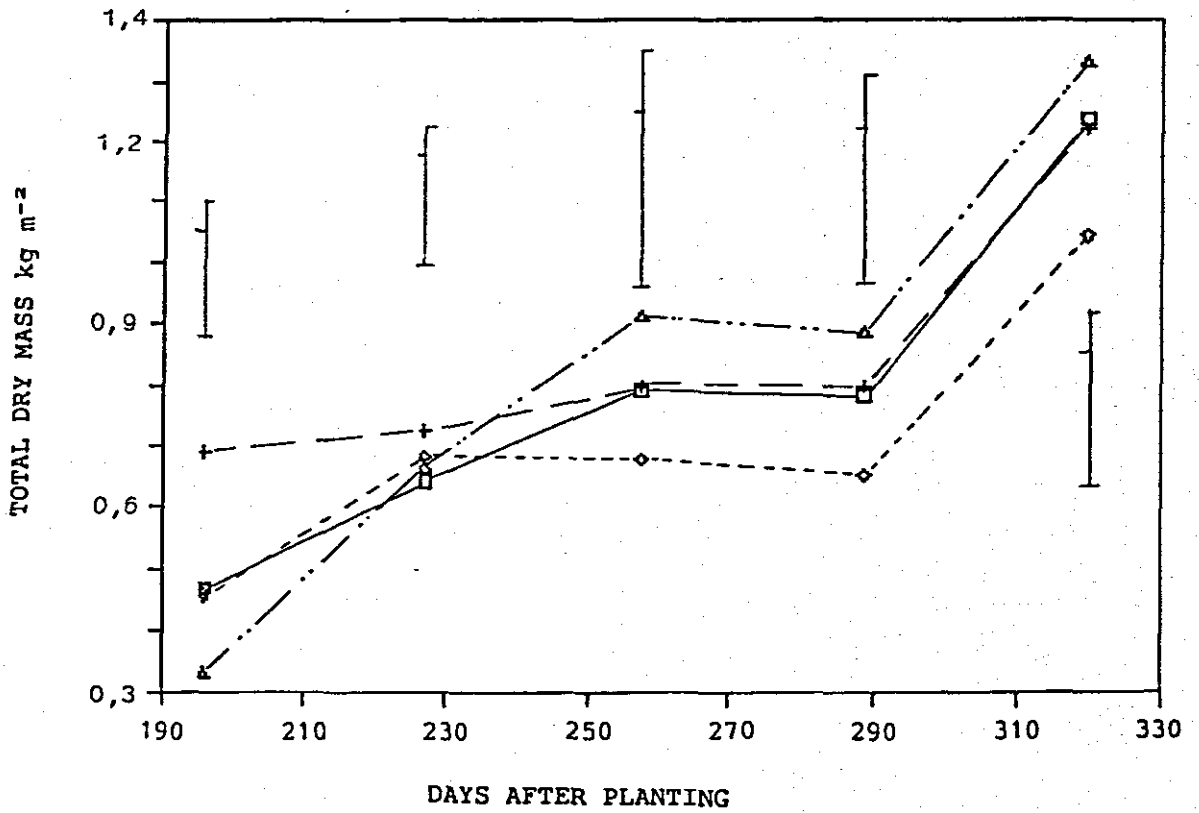495 DAP, MSAF 2 was significantly higher (p=0,05) than
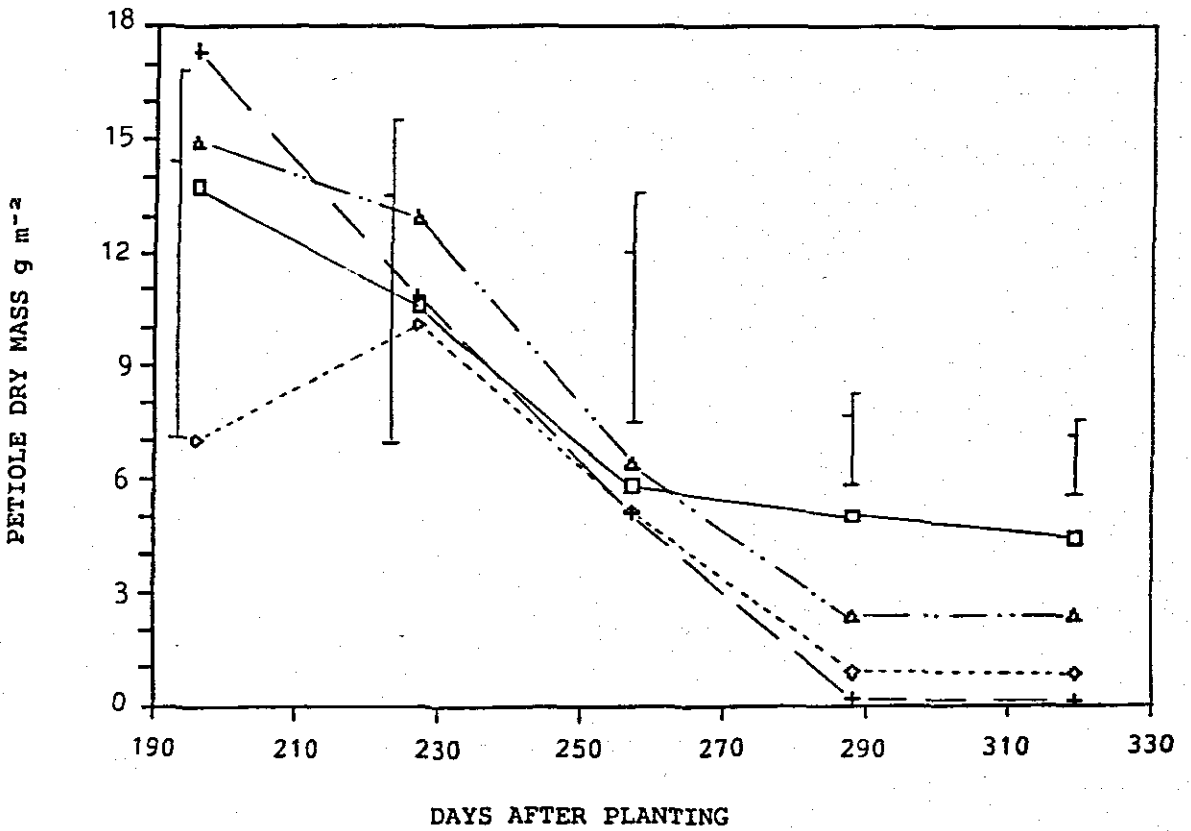
Figure 4.11 Petiole dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (△) at different times after planting for Experiment 2A.

M 170.

4.3.4.2. The petiole dry mass for experiment 2A.

During the first harvest, CMC 40, M 5 and MSAF 2 were already at their peaks of petiole dry mass production (Fig 4.11). M 170 had its peak at 227 DAP. From 227 to 288 DAP, all the cultivars underwent a decline. At 196 DAP, M 5 had a significantly higher (p=0,05) petiole dry mass than M 170. CMC 40 had a significantly higher (p=0,01) petiole dry mass than M 170. At 227 and 257 DAP, the cultivars did not differ significantly in their petiole dry mass. At 288 DAP, M 5 had a significantly higher (p=0,05) petiole dry mass than CMC 40. For p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. At 319 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 5 was significantly higher than CMC 40.

4.3.4.3. The petiole dry mass for experiment 2B.

The results of this experiment are shown in Fig 4.12. In all the cultivars there was an increase in petiole dry mass from 107 to 135 DAP. CMC 40 and M 5 reached their maximum petiole production at 135 DAP. MSAF 2 and M 170 reached their peaks at 166 DAP. From 166 to 319 DAP all the cultivars underwent a decline in petiole
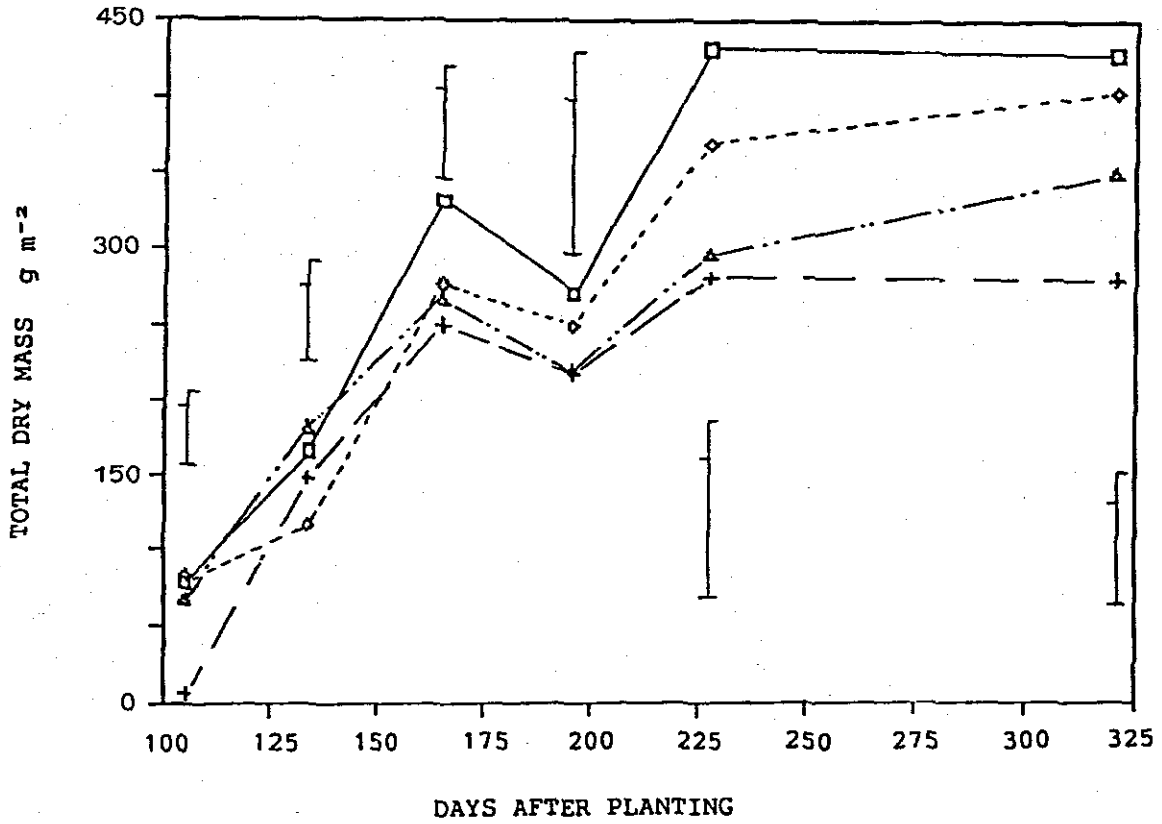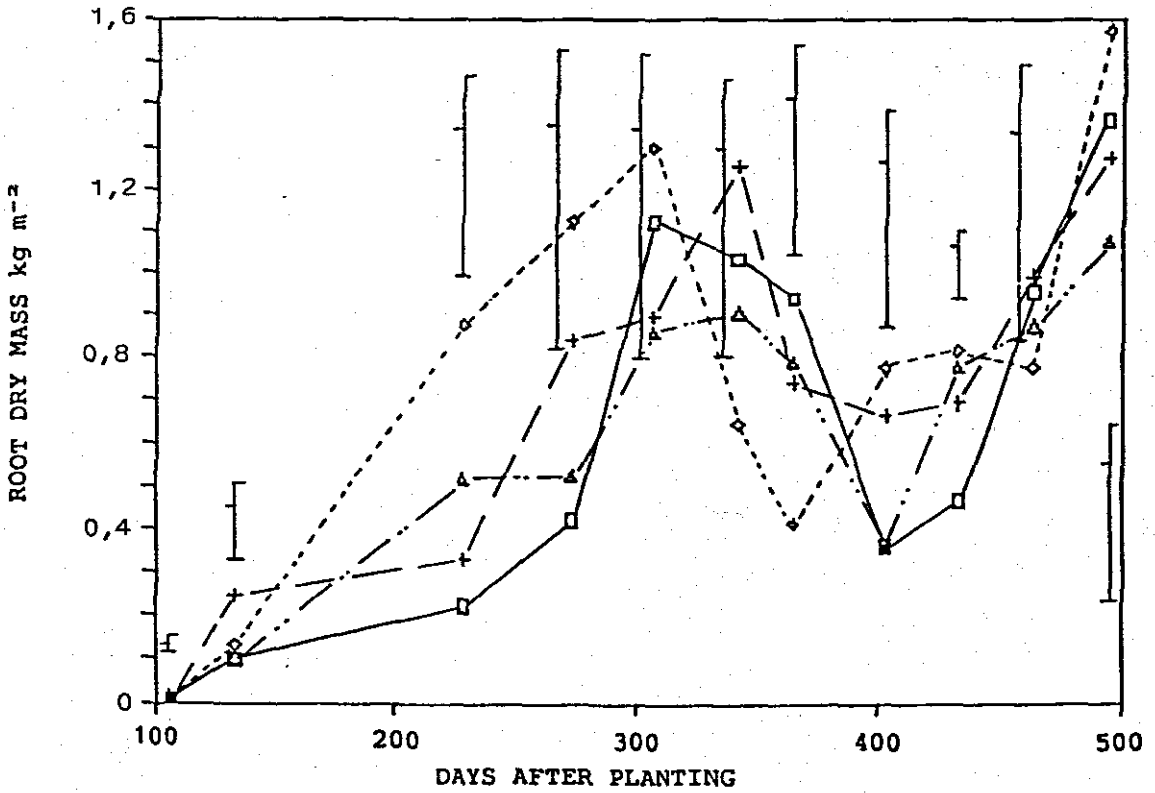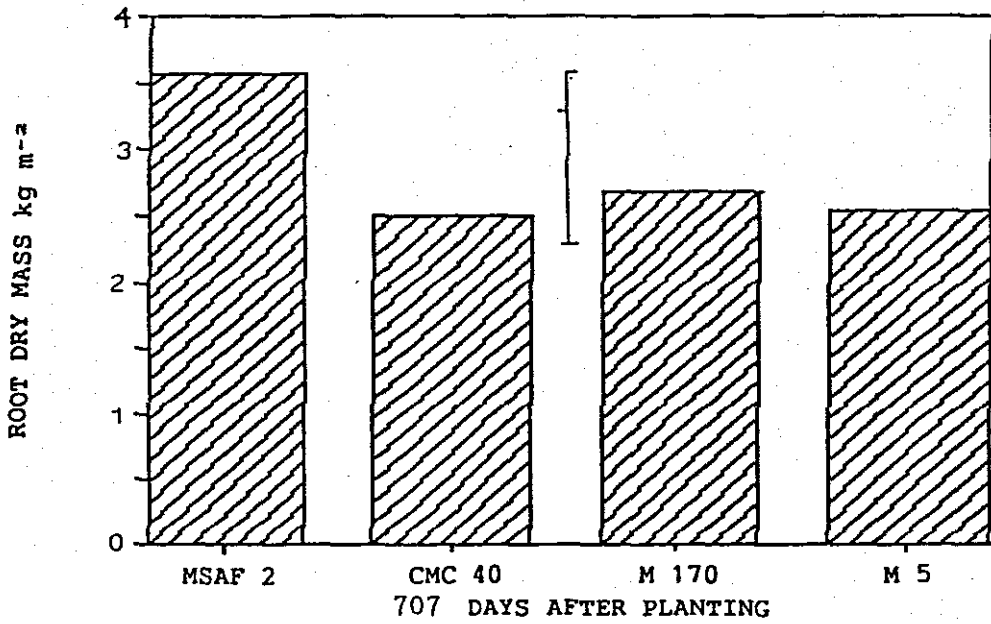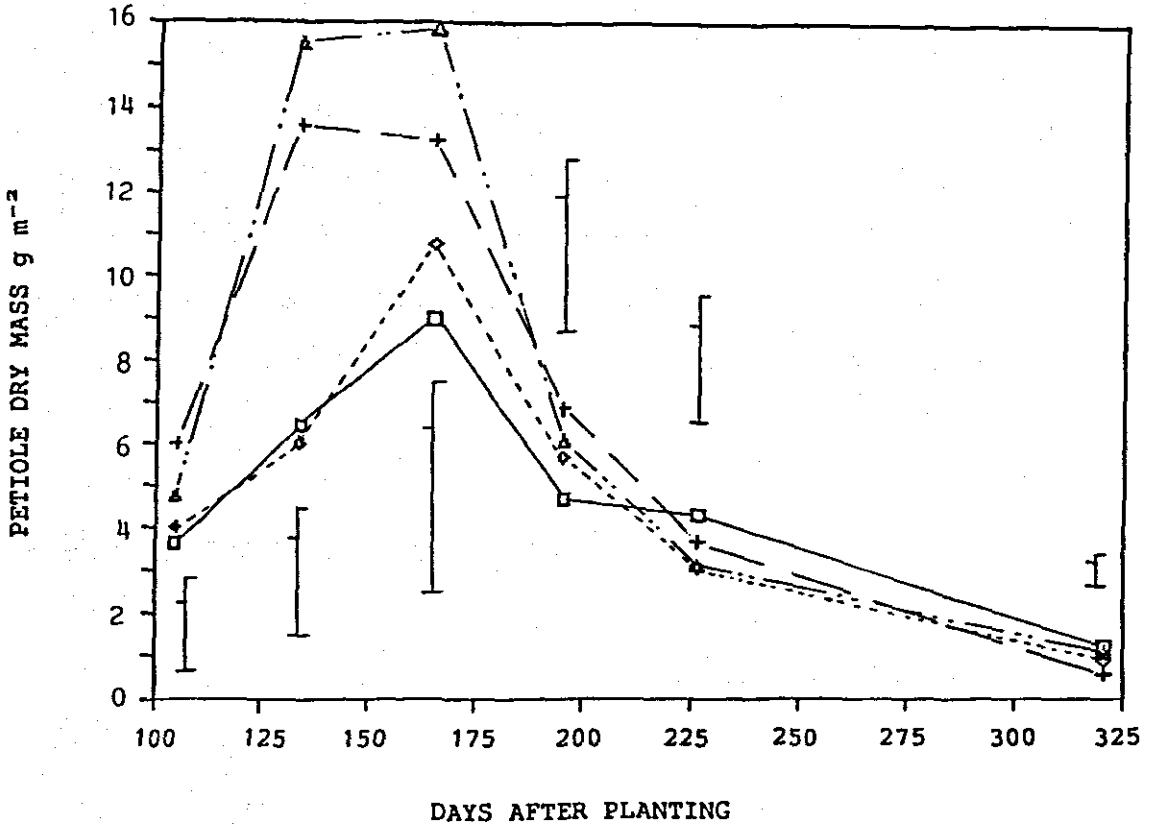
Figure 4.12 Petiole dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (△) at different times after planting for Experiment 2B.

production. At 107 DAP, CMC 40 was significantly higher (p=0,05) than M 170. For p=0,01, CMC 40 was significantly higher than MSAF 2. At 135 DAP, CMC 40 and M 5 were significantly higher (p=0,01) than both MSAF 2 and M 170. At 166 DAP CMC 40 had a significantly higher (p=0,05) petiole dry mass than MSAF 2. For p=0,01, M 5 had a significantly higher petiole dry mass than both MSAF 2 and M 170. At 196 and 227 DAP the cultivars did not differ significantly in their petiole dry mass. At 319 DAP, MSAF 2 had a significantly higher (p=0,05) petiole dry mass than CMC 40.

4.3.5. THE PRODUCTION OF LEAF DRY MASS.

4.3.5.1. The leaf dry mass for experiment 1

The results of this experiment are shown in Fig 4.13. There was an increase in leaf dry mass in all the cultivars from 106 to 133 DAP. M 170 and MSAF 2 had a decline in leaf dry mass from 133 to 342 DAP due to winter conditions. M 5 had an increase from 133 to 228 DAP, thereafter a decline to 342 DAP. CMC 40 had a second peak at 273 DAP after which it declined to 342 DAP. During post winter regrowth, there was an increase in leaf dry mass in all the cultivars from 365 to 464 DAP. At 106, 433, 464 and 495 DAP the cultivars did not differ significantly in their leaf dry mass. At 133 DAP, MSAF 2
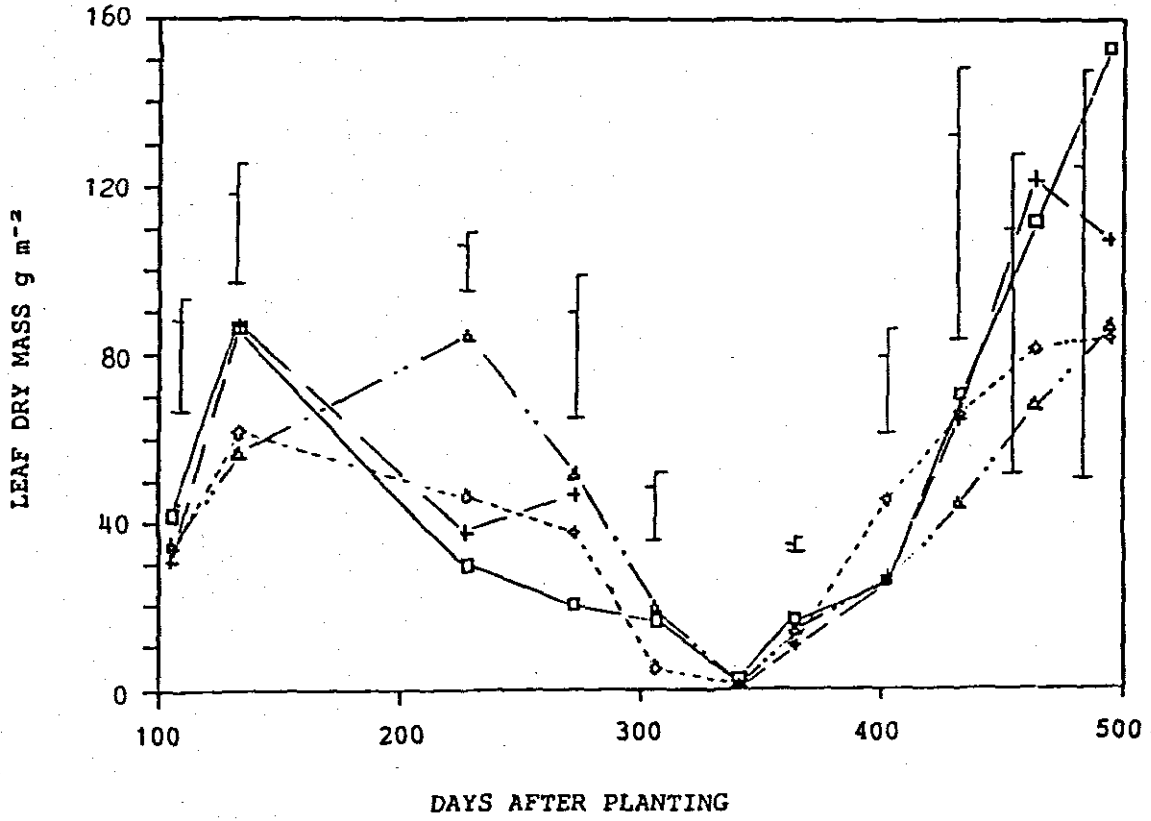
Figure 4.13 Leaf dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (△) at different times after planting for Experiment 1.
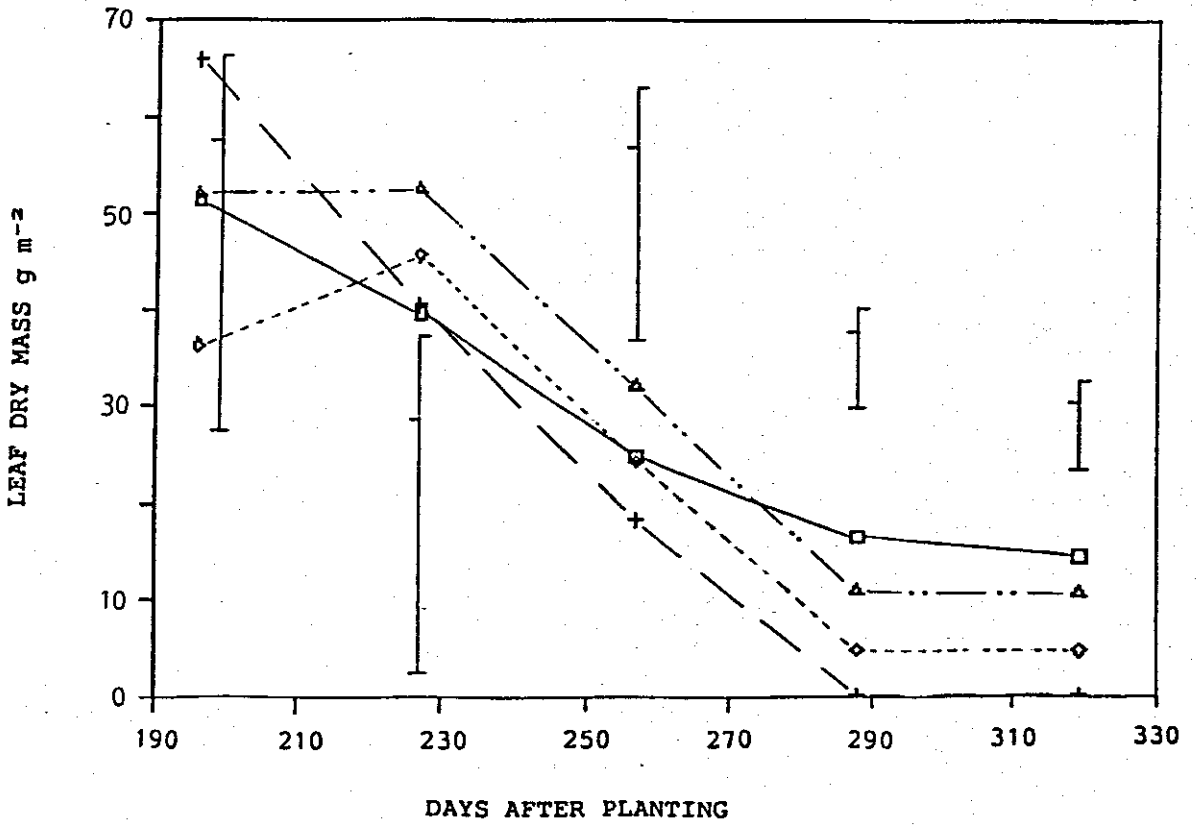
Figure 4.14 Leaf dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (△) at different times after planting for Experiment 2A.

and CMC 40 had the highest leaf dry mass and were significantly higher (p=0,05) than M 170. M 5 was significantly lower (p=0,01) than both MSAF 2 and CMC 40. At 228 DAP, M 5 was significantly higher (p=0,01) than MSAF 2, CMC 40 and M 170. Furthermore, M 170 was significantly higher (p=0,01) than MSAF 2. At 273 DAP, M 5 and CMC 40 were significantly higher (p=0,05) than MSAF 2. At 307 DAP, CMC 40 lost all the leaves and thus became the lowest producer. M 5 was significantly higher (p=0,05) than M 170. At 342 DAP, MSAF 2 was significantly higher (p=0,05) than M 5. For p=0,01, MSAF 2 was significantly higher than CMC 40. At 365 DAP, MSAF 2 outyielded all other cultivars and was significantly higher (p=0,05) than M 5. For p=0,01, both MSAF 2 and M 5 were significantly higher than CMC 40 and M 170. At 403 DAP, M 170 was significantly higher (p=0,05) than MSAF 2, CMC 40 and M 5.

4.3.5.2. The leaf dry mass for experiment 2A.

The results of this experiment are shown in Fig 4.14. At 196, 227 and 257 DAP, the differences among the cultivars were not statistically significant. At 288 and 319 DAP, M 5 was significantly higher (p=0,01) than CMC 40. MSAF 2 was significantly higher (p=0,01) than both CMC 40 and M 170.
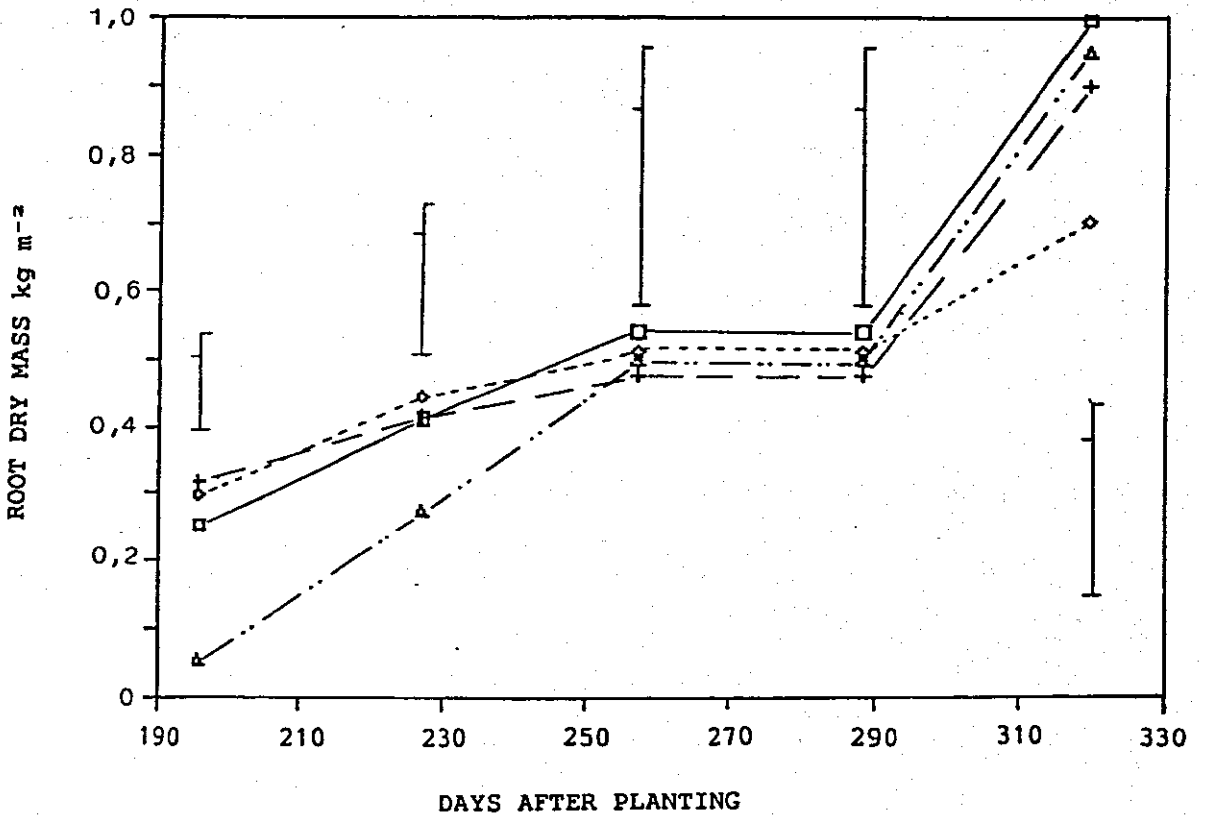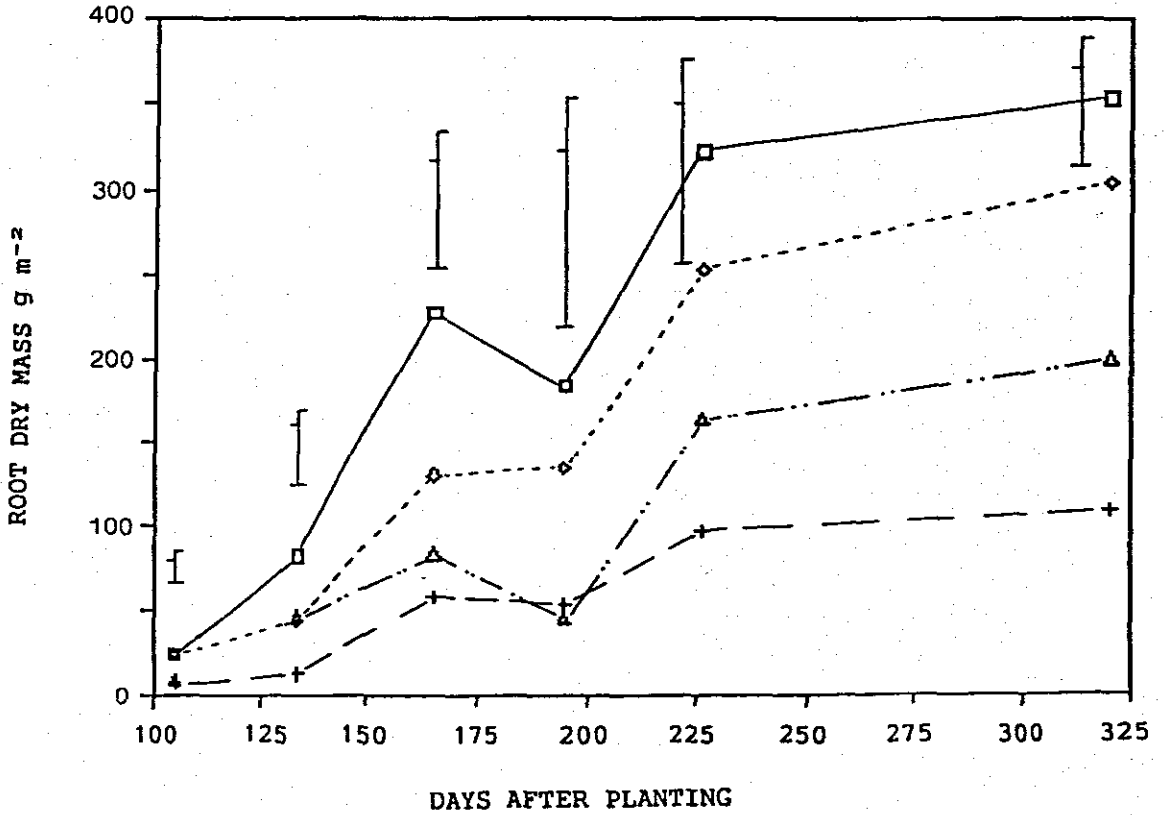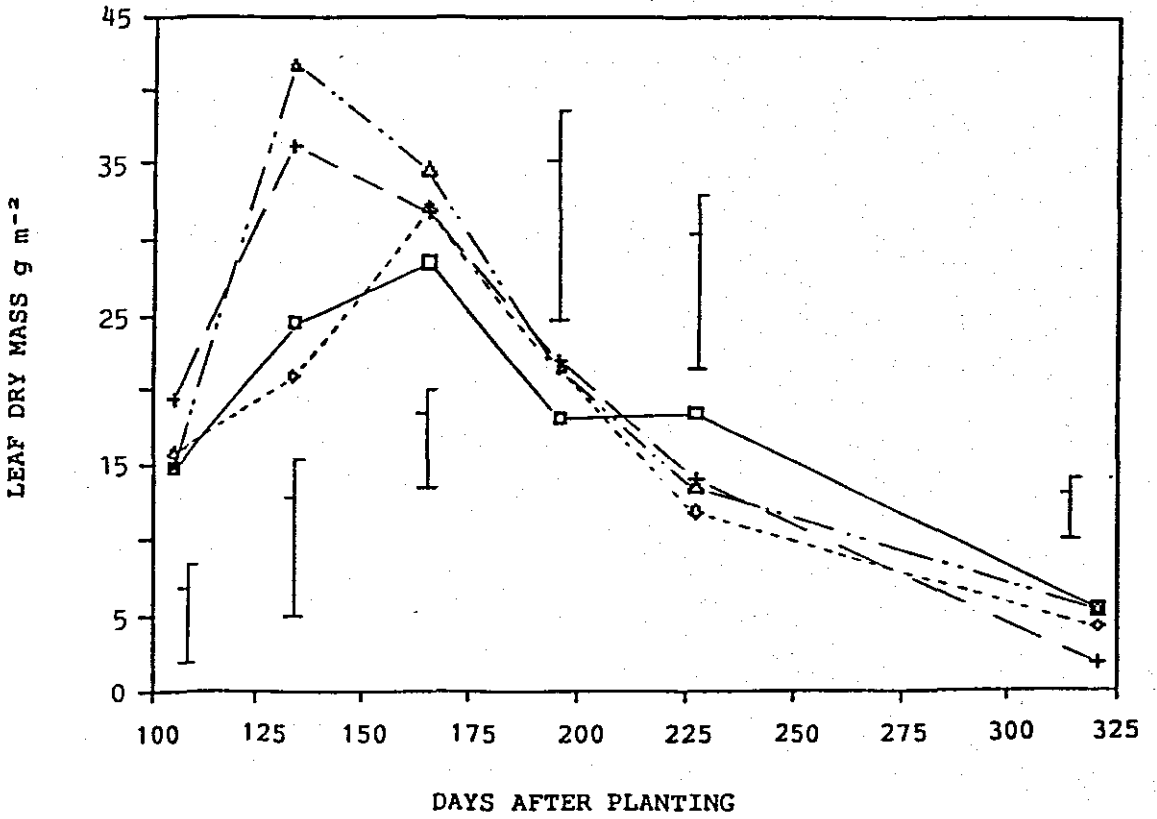
Figure 4.15 Leaf dry mass for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (Δ) at different times after planting for Experiment 2B.

4.3.5.3. The leaf dry mass for experiment 2B.

The results of this experiment are shown in Fig 4.15. There was an increase in leaf dry mass from 107 to 135 DAP. At 135 DAP, CMC 40 and M 5 reached their maximum values with M 5 the highest. At 166 DAP, MSAF 2 and M 170 reached their peaks, with M 170 higher than MSAF 2. At 107, 196 and 227 DAP the differences in leaf dry mass among the cultivars were not statistically significant. At 135 DAP, CMC 40 and M 5 were significantly higher (p=0,01) than both MSAF 2 and M 170. At 166 DAP, M 5 was significantly higher (p=0,05) than MSAF 2. At 319 DAP, CMC 40 had a significantly lower (p=0,05) leaf dry mass than both MSAF 2 and M 5.

4.3.6. HARVEST INDEX.

4.3.6.1. The harvest index for experiment 1.

Harvest Index = storage organ dry mass
               total dry mass

The results of this experiment are shown in Fig 4.16. At 106 DAP the cultivars did not differ significantly in their harvest indices (HI). At 133 DAP, CMC 40 and M 170 had a significantly higher (p=0,05) HI than M 5.
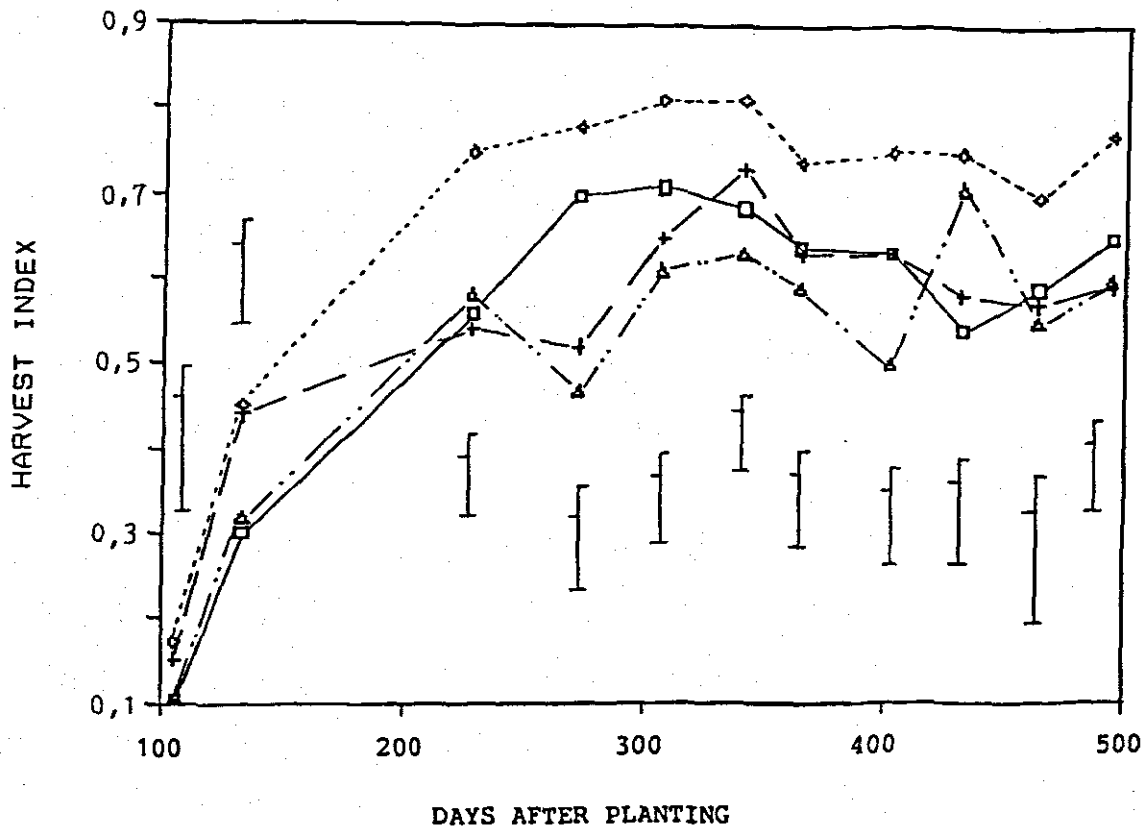
Figure 4.16 Harvest index for MSAF 2 (□), CMC 40 (+), M 170 (◇)
and M 5 (△) at different times after planting for
Experiment 1.

For p=0,01, CMC 40 and M 170 were significantly higher than MSAF 2. At 228 DAP, M 170 had a significantly higher (p=0,01) HI than MSAF 2, CMC 40 and M 5. At 273 DAP, MSAF 2 and M 170 had a significantly higher (p=0,01) HI than M 5 and CMC 40. At 307 DAP, M 170 was significantly higher (p=0,05) than MSAF 2. For p=0,01, M 170 was significantly higher than both CMC 40 and M 5. At 342 DAP, HI in M 170 was significantly higher (p=0,05) than in CMC 40 and MSAF 2. For p=0,01, M 170 had a significantly higher HI than M 5. At 365 DAP, the HI in M 170 was significantly higher than in CMC 40 and M 5 at p=0,05 and p=0,01 respectively. At 403 DAP, M 170 had a significantly higher (p=0,05) HI than both MSAF 2 and CMC 40. M 5 had a significantly lower (p=0,05) HI than both MSAF 2 and CMC 40. M 170 had a significantly higher (p=0,01) HI than M 5. At 433 DAP, M 5 was significantly higher (p=0,05) than CMC 40. M 170 was significantly higher (p=0,01) than both CMC 40 and MSAF 2. M 5 was also significantly higher (p=0,01) than MSAF 2. At 464 DAP, M 170 was significantly higher (p=0,05) than M 5. At 495 DAP, M 170 had a significantly higher (p=0,01) HI than MSAF 2, CMC 40 and M 5.
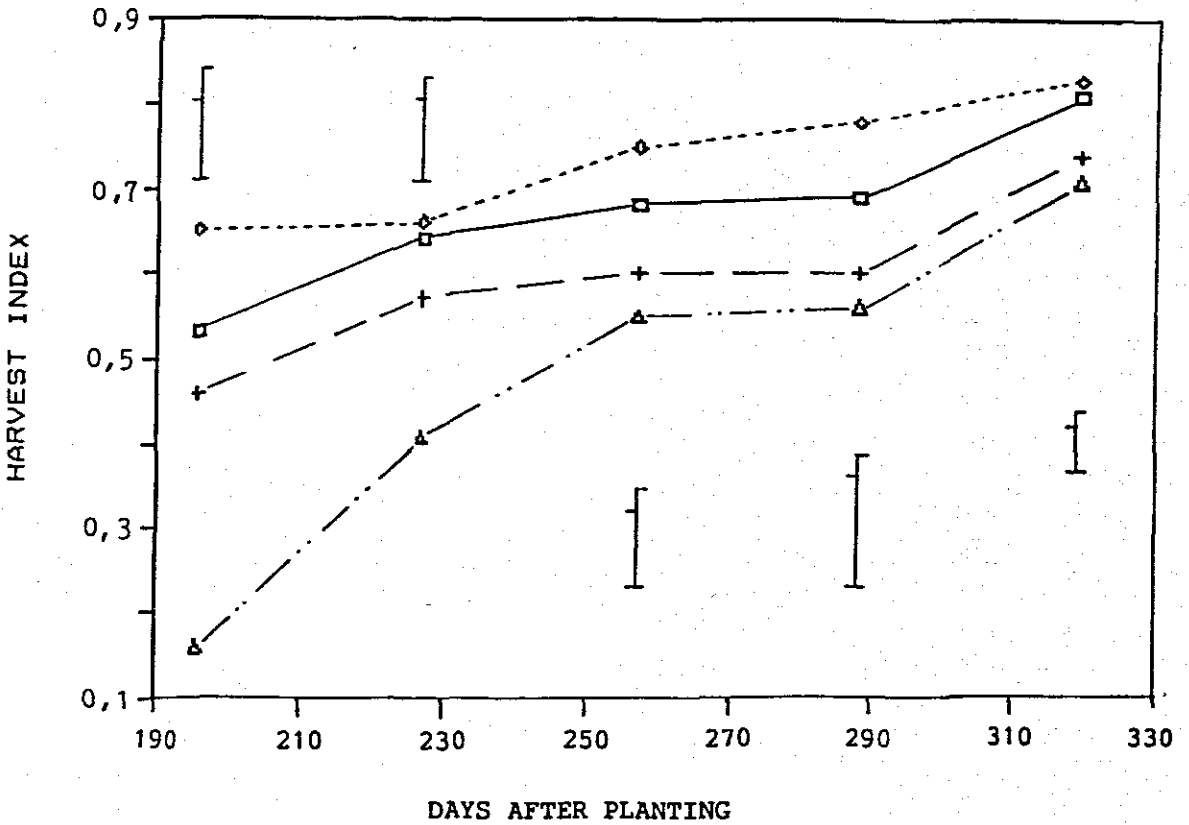
Figure 4.17 Harvest index for MSAF 2 (□), CMC 40 (+), M 170 (◇) and M 5 (△) at different times after planting for Experiment 2A.

4.3.6.2. Harvest index for experiment 2A.

In this experiment HI increased from 196 to 319 DAP in all
the cultivars (Fig 4.17). At 196 DAP, M 170 had a
significantly higher (p=0,05) HI than MSAF 2. For
p=0,01, the HI in MSAF 2, CMC 40 and M 170 was
significantly higher than in M 5. HI in M 170 was
significantly higher than in CMC 40. At 227 DAP, HI in M 5
was significantly lower (p=0,01) than in MSAF 2, CMC 40
and M 170. At 257 DAP, MSAF 2 and M 170 were
significantly higher (p=0,01) than M 5. M 170 had a
significantly higher (p=0,01) HI than CMC 40. At 288 DAP,
M 170 had a significantly higher (p=0,05) HI than CMC
40. For p=0,01, the HI in M 170 was significantly higher
than in M 5. At 319 DAP, HI in M 170 was
significantly higher (p=0,01) than in CMC 40. MSAF 2
and M 170 had a significantly higher (p=0,01) HI than M 5.

4.3.6.3. Harvest index for experiment 2B.

The results of this experiment are shown in Fig 4.18. At
107 DAP, MSAF 2 and M 170 had a significantly higher
(p=0,01) HI than M 5 and CMC 40. At 135 DAP, M 5 had a
significantly higher (p=0,05) HI than CMC 40. For p=0,01,
MSAF 2 and M 170 were significantly higher than CMC 40. HI
in MSAF 2 was significantly higher than in M 5. At 166
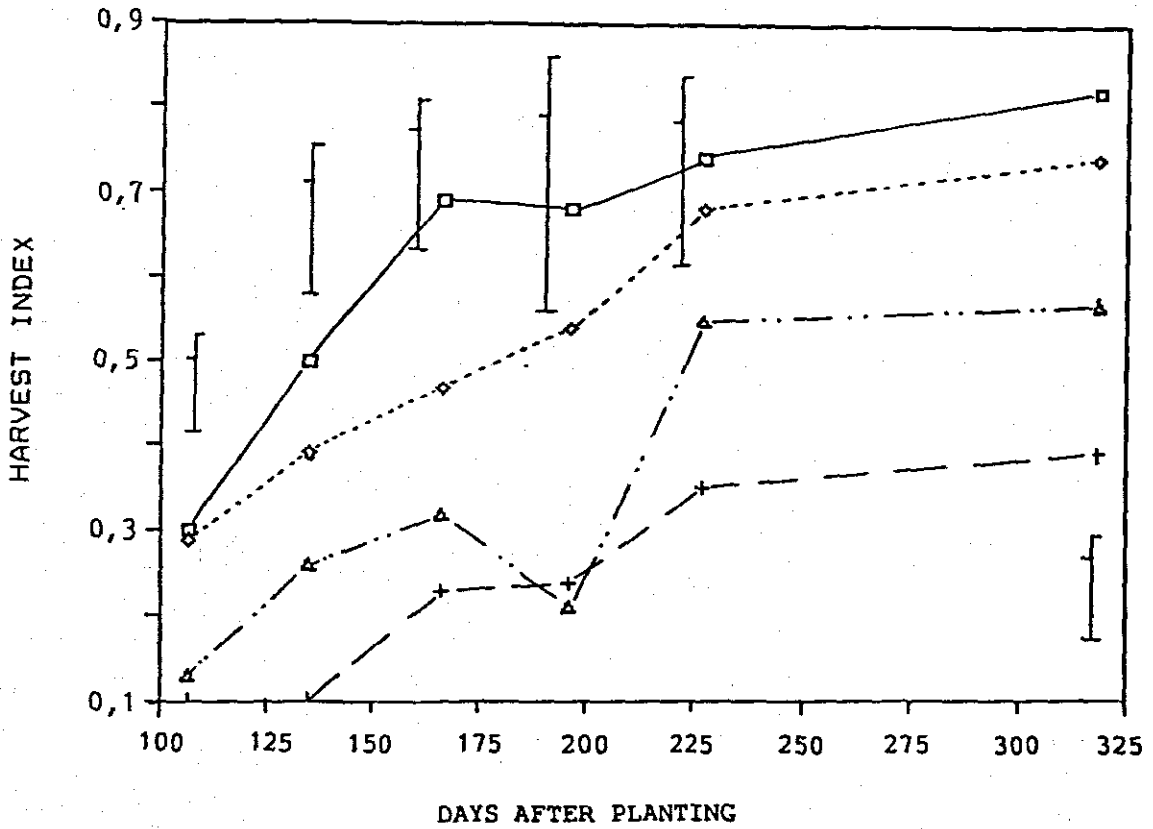
Figure 4.18 Harvest index for MSAF 2 (□), CMC 40 (+), M 170 (◊) and M 5 (△) at different times after planting for Experiment 2B.

Fig. 19 Temperature, rainfall, solar radiation and the distribution of dry mass in MSAF 2 at different times after planting for Experiment 1. In this and other graphs, vertical lines have been omitted because the value of n was not constant in all the treatments.

DAP, HI in MSAF 2 was significantly higher (p=0,01) than in CMC 40, M 170 and M 5. M 170 had a significantly higher (p=0,01) HI than CMC 40. At 196 DAP, HI in M 170 was significantly higher (p=0,05) than in M 5. HI in MSAF 2 was significantly higher (p=0,01) than both CMC 40 and M 5. At 227 DAP, HI in M 5 was significantly higher (p=0,05) than in CMC 40. For p=0,01, MSAF 2 and M 170 were significantly higher than CMC 40. At 319 DAP, HI in MSAF 2 and M 170 were significantly higher (p=0,01) than in CMC 40 and M 5. Furthermore, M 5 had a significantly higher (p=0,01) HI than CMC 40.

4.3.7. PARTITIONING OF DRY MATTER IN CASSAVA CULTIVARS.

4.3.7.1. Dry matter partitioning and yield in MSAF 2

4.3.7.1.1. Experiment 1

The results of this experiment are shown in Fig 4.19. The total dry mass for the first harvest was significantly lower (p=0,01) than that of the fifth, sixth, seventh, nineth, tenth and eleventh harvest. The total dry mass for the first harvest was significantly lower (p=0,05) than that of the fourth harvest. The second, third, fourth, and eighth harvests were significantly lower (p=0,01) than the fifth, seventh, tenth and eleventh harvests. The fifth and tenth harvests had a

significantly higher (p=0,01) total dry mass than the sixth, and nineth harvests. The sixth harvest was significantly higher (p=0,05) than the nineth harvest. For p=0,05, the seventh harvest had a significantly higher total dry mass than the nineth harvest. For p=0,01, the nineth harvest had a significantly lower total dry mass than the tenth and eleventh harvests. The root dry mass for the first harvest was significantly lower (p=0,05) than that of the fourth harvest. For p=0,01, the first harvest had a significantly lower root dry mass than the fifth, sixth, seventh, nineth, tenth eleventh and twelfth harvests. The second harvest was significantly lower (p=0,01) than the fifth, sixth, seventh, tenth, eleventh and twelfth harvest. The third harvest had a significantly lower (p=0,01) root dry mass than the fifth, sixth, seventh, tenth, eleventh and twelfth harvest. The fourth harvest was significantly lower (p=0,05) than the fifth, sixth, seventh, tenth, eleventh and twelfth harvest. The fifth and sixth harvests were significantly higher (p=0,01) than the eighth and nineth harvest and lower than the twelfth harvest. For p=0,05, the seventh harvest was significantly higher than the nineth harvest. The seventh harvest had a significantly higher (p=0,01) root dry mass than the eighth harvest and lower than the twelfth harvest. The eighth harvest was significantly lower

(p=0,01) than the tenth, eleventh and twelfth harvest. For p=0,05, the nineth harvest was significantly lower than the tenth harvest. The nineth harvest had a significantly lower (p=0,01) root dry mass than the eleventh and twelfth harvest. The tenth harvest had a significantly lower (p=0,01) root dry mass than the twelfth harvest. The eleventh harvest was significantly lower (p=0,01) than the twelfth harvest.

The stem dry mass for the first harvest was significantly lower (p=0,01) than in the fifth, sixth, seventh, tenth and eleventh harvest. For p=0,05, the second harvest had a significantly lower stem dry mass than the seventh harvest. For p=0,01, the second harvest was significantly lower than the tenth and eleventh harvest. The third harvest had a significantly lower (p=0,05) stem dry mass than the seventh harvest. For p=0,01, the third harvest was significantly lower than the tenth and eleventh harvests. The fourth harvest was significantly lower (p=0,05) than the seventh, tenth and eleventh harvests.

The leaf dry mass for the first harvest was significantly lower (p=0,05) than in the second harvest. The leaf dry mass for the first harvest was significantly lower (p=0,01) than in the tenth and eleventh harvest. For p=0,01, the second harvest was significantly higher than

the third, fourth, fifth, sixth, seventh, eighth and lower than the eleventh harvest. The third harvest had a significantly lower (p=0,01) leaf dry mass than the tenth and eleventh harvest. For p=0,05, the fourth harvest was significantly lower than the nineth harvest. For p=0,01, the fourth harvest was significantly lower than the tenth and eleventh harvest. The fifth harvest had a significantly lower (p=0,05) leaf dry mass than the nineth harvest. For p=0,01, the fifth harvest was significantly lower than the tenth and eleventh harvest. The sixth harvest was significantly lower (p=0,01) than the nineth, tenth and eleventh harvest. The seventh harvest was significantly lower (p=0,05) than the nineth harvest. For p=0,01, the seventh harvest was significantly lower than the tenth and eleventh harvests. The eighth harvest was significantly lower (p=0,01) than the tenth and eleventh harvests. For p=0,05, the nineth harvest had a significantly higher leaf dry mass than the seventh harvest. For p=0,01, the nineth harvest was significantly lower than the eleventh harvest.

4.3.7.1.2. Experiment 2A

The results of this experiment are shown in Fig 4.20. The total dry mass for the first harvest was significantly lower (p=0,01) than in the third, fourth and fifth harvests. For p=0,01, the fifth harvest had a

Figure 4.20   Temperature, rainfall, solar   radiation   and   the

distribution of dry mass   in   MSAF 2   at   different

times   after planting for Experiment 2A.

significantly higher total dry mass than the second, third and fourth harvests.

The root dry mass for the first harvest was significantly lower (p=0,01) than in the third, fourth and fifth harvest. For p=0,01, the fifth harvest was significantly higher than the second, third and fourth harvest.

The stem dry mass for the first harvest was significantly lower (p=0,01) than in the third, fourth and fifth harvest. For p=0,05, the second harvest was significantly lower than the third fourth and fifth harvests.

The leaf dry mass for the first harvest was significantly higher (p=0,01) than in the third, fourth and fifth harvest. For p=0,05, the second harvest was significantly higher than the fourth harvest. For p=0,01, the second harvest was significantly higher than the fifth harvest.

4.3.7.1.3. Experiment 2B

The results of this experiment are shown in Fig 4.21. The total dry mass for the first harvest was significantly lower (p=0,01) than in the second, third, fourth, fifth and sixth harvests. The second harvest was significantly lower (p=0,01) than the third, fourth, fifth and sixth harvests. The third and fourth harvests were significantly

Figure 4.21   Temperature, solar radiation and   the   distribution
              of   dry mass   in   MSAF 2   at   different times after
              planting   for Experiment 2B.

lower (p=0,01) than the fifth and sixth harvests.

The root dry mass for the first and second harvests was significantly lower (p=0,01) than in the third, fourth, fifth and sixth harvests. The third and fourth harvests were significantly lower (p=0,01) than the fifth and sixth harvests.

The stem dry mass for the first harvest was significantly lower (p=0,05) than in the third and sixth harvests. For p=0,01, the first harvest was significantly lower than the fifth harvest. The second harvest was significantly lower (p=0,05) than the fifth harvest.

The leaf dry mass for the first harvest was significantly lower (p=0,01) than in the second and third harvests and was significantly higher than in the sixth harvest. The second harvest was significantly higher (p=0,01) than the sixth harvest. The third harvest was significantly higher (p=0,01) than the fourth, fifth and sixth harvests. For p=0,01, the fourth and fifth harvests were significantly higher than the sixth harvest.

Figure 4.22 Temperature, rainfall, solar radiation and the distribution dry mass in CMC 40 at different times after planting for Experiment 1.

4.3.7.2. Dry matter partitioning and yield in CMC 40

4.3.7.2.1. Experiment 1

The results of this experiment are shown in Fig 4.22. The first harvest had a significantly lower ($p=0,05$) total dry mass than the eighth harvest. For $p=0,01$, the first harvest was significantly lower than the fourth, fifth, sixth, seventh, nineth, tenth and eleventh harvests. The second harvest was significantly lower ($p=0,05$) than the fourth, sixth and tenth harvest. For $p=0,01$, the second harvest was significantly lower than the eleventh harvest. The total dry mass for the third harvest was significantly lower ($p=0,05$) than the sixth and tenth harvests. For $p=0,01$, the third harvest was significantly lower than the eleventh harvest. For $p=0,05$, the eighth harvest had a significantly lower total dry mass than the eleventh harvest.

The root dry mass for the first harvest was significantly lower ($p=0,01$) than in the fourth, fifth, sixth, seventh, eighth, nineth, tenth, eleventh and twelfth harvests. For $p=0,05$, the second harvest was significantly lower than the fourth and fifth harvest. The second harvest was significantly lower ($p=0,01$) than the sixth, tenth, eleventh and twelfth harvest. The third harvest was significantly lower ($p=0,05$) than the tenth harvest. For

p=0,01, the third harvest was significantly lower than the sixth, eleventh and twelfth harvests. The root dry mass for the fourth harvest was significantly lower (p=0,01) than in the twelfth harvest. The fifth harvest was significantly lower (p=0,01) than the twelfth harvest. The sixth harvest was significantly higher (p=0,05) than the eighth harvest. For p=0,01, the sixth harvest had a significantly lower root dry mass than the twelfth harvest. The seventh harvest was significantly lower (p=0,01) than the twelfth harvest. For p=0,05, the eighth harvest was significantly lower than the eleventh harvest. The eighth harvest had a significantly lower (p=0,01) root dry mass than the twelfth harvest. For p=0,05, the nineth harvest was significantly lower than the eleventh harvest. For p=0,01, the nineth, tenth and eleventh harvests were significantly lower than the twelfth harvest.

The first harvest had a significantly lower (p=0,05) stem dry mass than the fifth and sixth harvests. For p=0,01, the first harvest was significantly lower than the fourth, tenth and eleventh harvests. For p=0,05, the second and third harvests had a significantly lower stem dry mass than the fourth and eleventh harvests.

The leaf dry mass for the first harvest was significantly lower (p=0,01) than in the second, tenth and eleventh
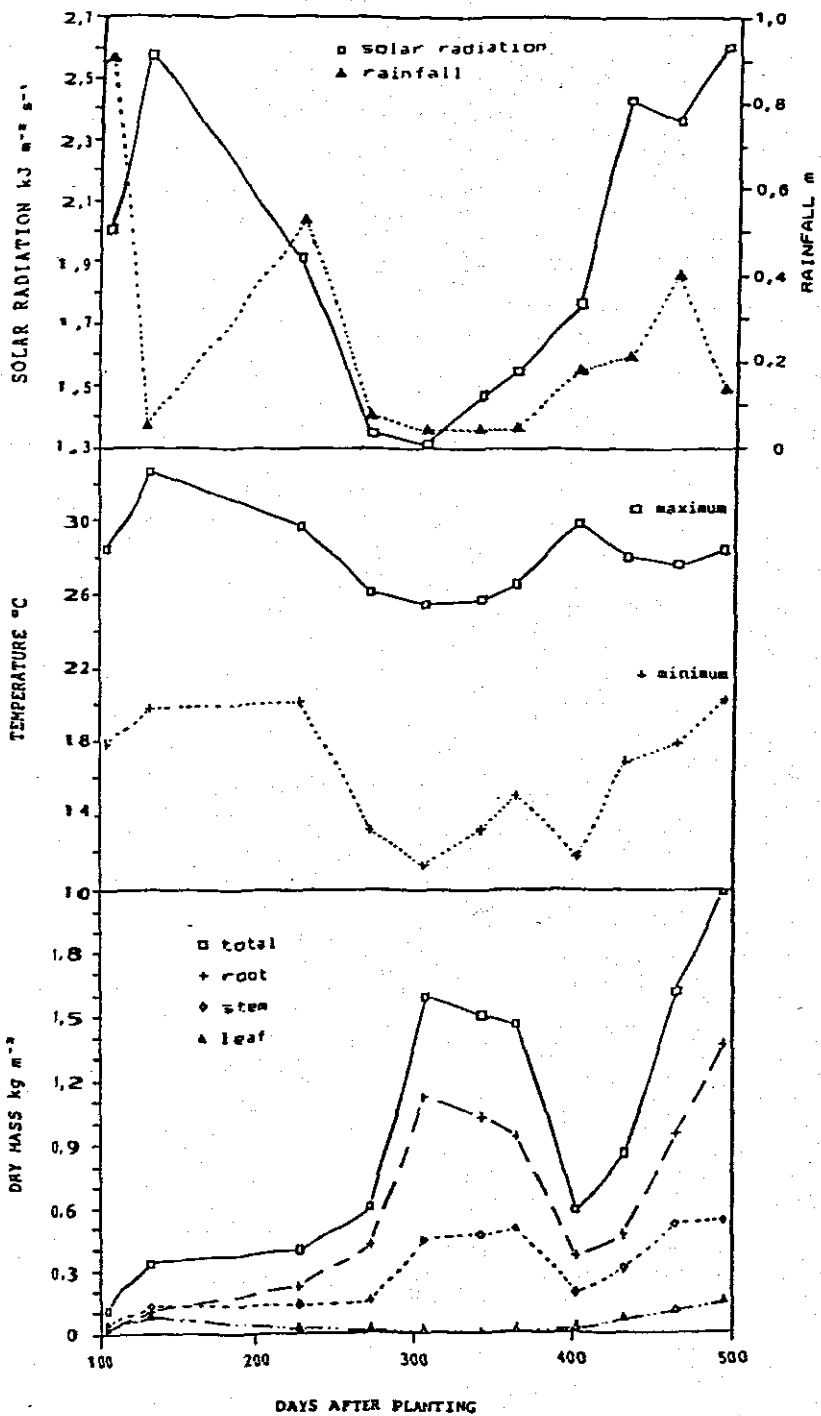
Figure 4.23 Temperature, rainfall, solar radiation and the
distribution of dry mass in CMC 40 at different
times after planting for Experiment 2A.

harvests. The second harvest was significantly higher (p=0,05) than the third harvest. For p=0,01. the second harvest had a significantly higher leaf dry mass than the fifth, sixth and seventh harvests. The third harvest was significantly lower (p=0,01) than the tenth and eleventh harvests. The fourth harvest was significantly lower (p=0,01) than the tenth and eleventh harvests. The sixth harvest had a significantly lower (p=0,01) leaf dry mass than the nineth, tenth and eleventh harvests. For p=0,05, the seventh harvest was significantly lower than the nineth harvest. For p=0,01, the seventh and eighth harvests had a significantly lower leaf dry mass than the tenth and eleventh harvests. The nineth harvest was significantly lower (p=0,01) than the tenth harvest.

4.3.7.2.2. Experiment 2A

The results of this experiment are shown in Fig 4.23. The fifth harvest had a significantly higher (p=0,05) total dry mass than the third and fourth harvests. For p=0,01, the fifth harvest was significantly higher than the first and second harvests.

The root dry mass for the fifth harvest was significantly higher (p=0,01) than in the first, second, third and fourth harvests.
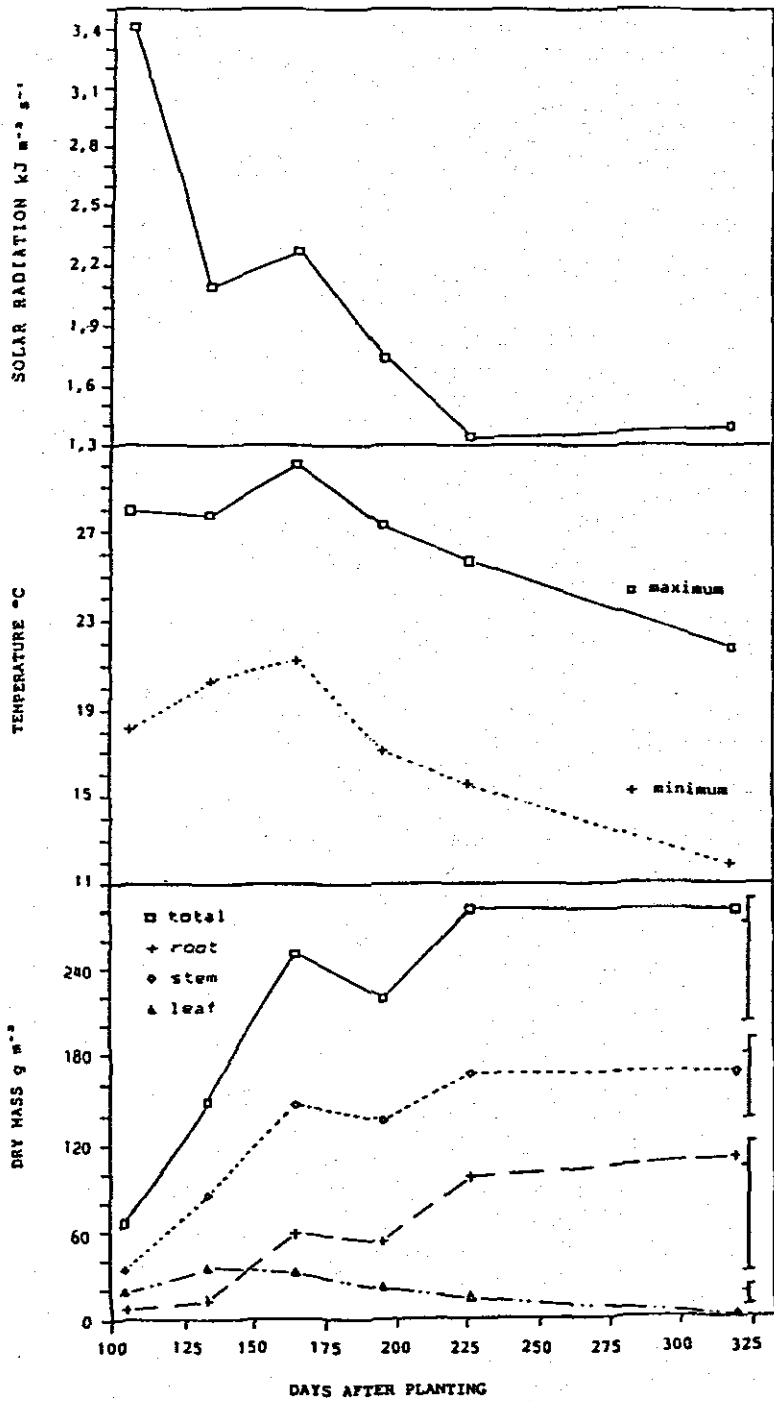
Figure 4.24   Temperature, solar radiation and the distribution
              dry mass in CMC 40   at different times after
              planting   for Experiment 2B.

The stem dry mass for all harvests did not differ significantly.

The first harvest had a significantly higher (p=0,05) leaf dry mass than the second harvest. For p=0,01, the first harvest was significantly higher than the third, fourth and fifth harvests. The second harvest had a significantly higher (p=0,01) leaf dry mass than the fourth and fifth harvests.

4.3.7.2.3. Experiment 2B

The results of this experiment are shown in Fig 4.24. The total dry mass for the first harvest was significantly lower (p=0,05) than in the second harvest. For p=0,01, the first harvest was significantly lower than the third, fourth, fifth and sixth harvests. For p=0,05, the second harvest was significantly lower than the fourth harvest. The second harvest was significantly lower (p=0,01) than the third, fifth and sixth harvests.

The root dry mass for the first harvest was significantly lower (p=0,01) than the fifth and sixth harvest. For p=0,05, the second harvest was significantly lower than the fifth harvest. For p=0,01, the second harvest was significantly lower than the sixth harvest.

The stem dry mass for the first harvest was significantly lower (p=0,05) than the second harvest. For p=0,01, the first harvest was significantly lower than the third, fourth, fifth and sixth harvests. The second harvest was significantly lower (p=0,05) than the fourth harvest. For p=0,01, the second harvest was significantly lower than the third, fifth and sixth harvests.

The leaf dry mass for the first harvest was significantly lower (p=0,01) than in the second and third harvests. For p=0,01, the first harvest was significantly higher than the sixth harvest. The second harvest was significantly higher (p=0,01) than the fourth, fifth and sixth harvest. The third harvest was significantly higher (p=0,05) than the fourth harvest. For p=0,01, the third harvest was significantly higher than the fifth and sixth harvests. The fourth and fifth harvests were significantly higher (p=0,01) than the sixth harvest.

4.3.7.3. Dry matter partitioning and yield in M 170

4.3.7.3.1. Experiment 1

The results of this experiment are shown in Fig 4.25. The total dry mass for the first harvest was significantly lower (p=0,05) than in the sixth harvest. For p=0,01, the first harvest had a significantly
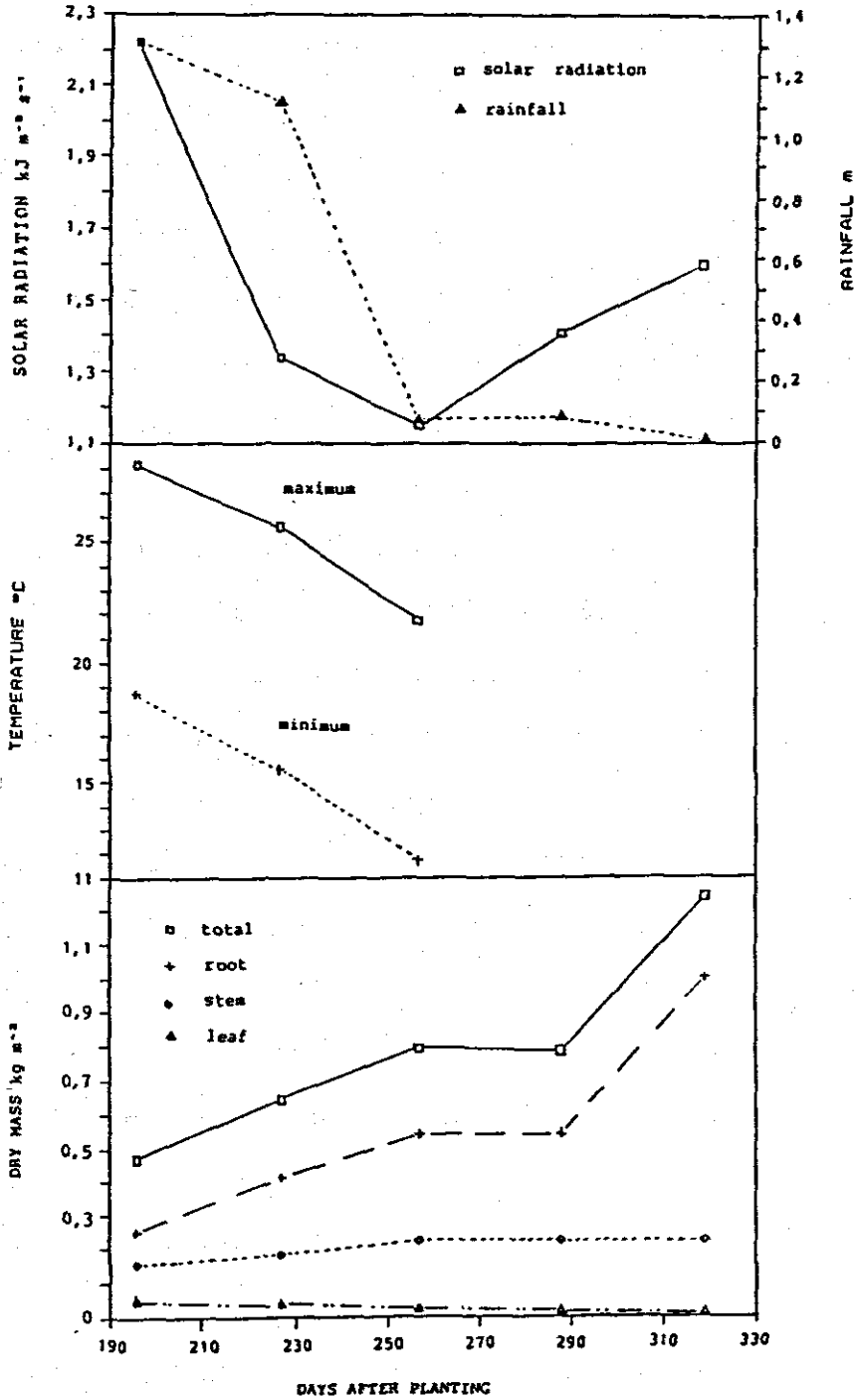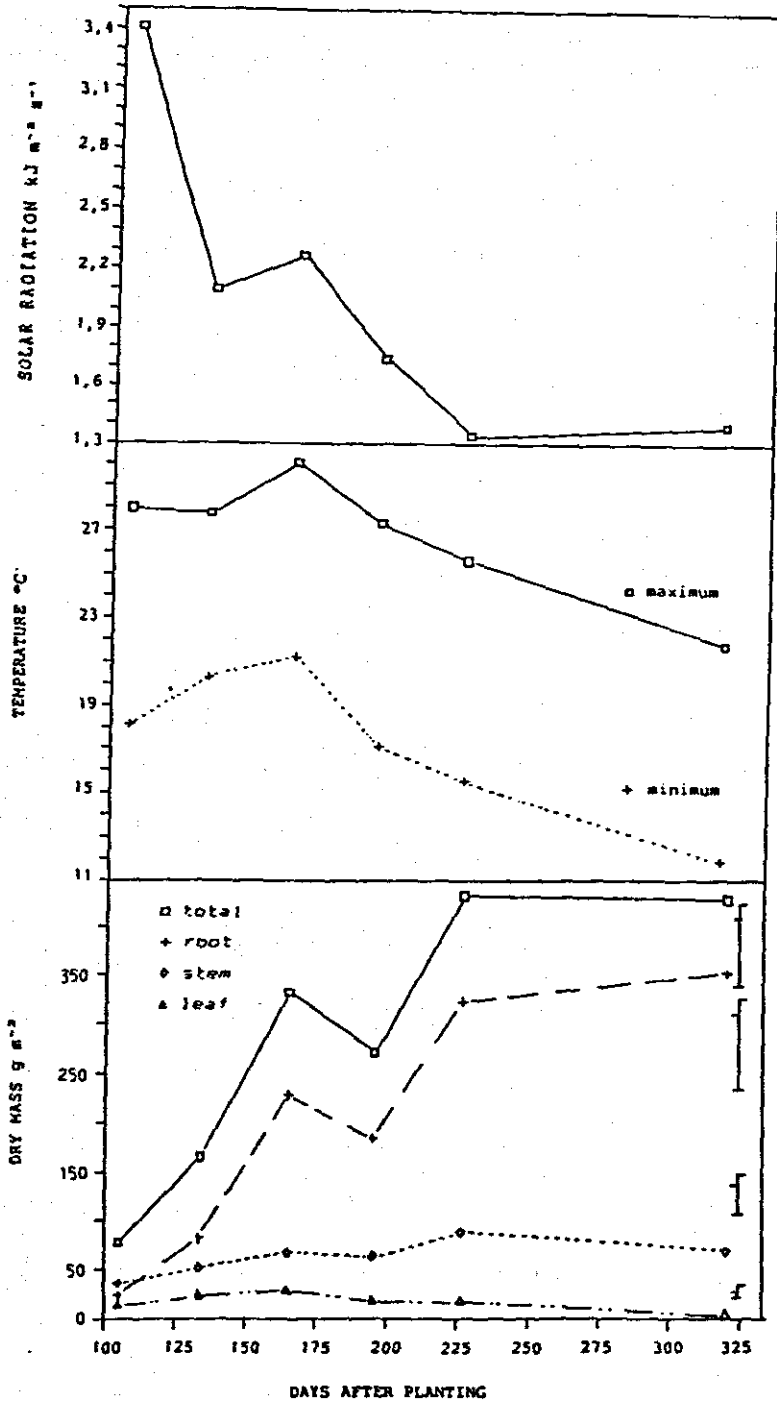
Figure 4.25 Temperature, rainfall, solar radiation and the distribution of dry mass in M 170 at different times after planting for Experiment 1.

lower total dry mass than the third, fourth, fifth, eighth, nineth, tenth and eleventh harvests. The second harvest was significantly lower ($p=0,05$) than the third, nineth and tenth harvests. For $p=0,01$, the second harvest was significantly lower ($p=0,01$) than the fourth, fifth and eleventh harvests. The third harvest was significantly lower ($p=0,05$) than the eleventh harvest. The fourth harvest had a significantly higher ($p=0,05$) total dry mass than the seventh harvest. For $p=0,05$, the fifth harvest was significantly higher than the sixth harvest. The fifth harvest was significantly higher ($p=0,01$) than the seventh harvest. For $p=0,01$, the sixth, seventh, eighth, nineth and tenth harvests were significantly lower than the eleventh harvest.

The root dry mass for the first harvest was significantly lower ($p=0,05$) than in the sixth harvest. For $p=0,01$, the first harvest was significantly lower than the third, fourth, fifth, eighth, nineth, eleventh and twelfth harvests. The second harvest was significantly lower ($p=0,05$) than the third and nineth harvests. For $p=0,01$, the second harvest was significantly lower than the fourth, fifth, eleventh and twelfth harvests. The third harvest had a significantly lower ($p=0,05$) root dry mass than the eleventh harvest. The third harvest had a significantly lower ($p=0,01$) root dry mass than the twelfth harvest. The fourth harvest was significantly

higher (p=0,05) than the seventh harvest. For p=0,01, the fourth harvest was significantly lower than the twelfth harvest. The fifth harvest was significantly higher (p=0,05) than the sixth harvest. For p=0,01, the fifth harvest was significantly higher than the seventh and lower than the twelfth harvest. The sixth, seventh, eighth, nineth and tenth harvests were significantly lower (p=0,01) than the eleventh and twelfth harvests. The eleventh harvest had a significantly lower root dry mass than the twelfth harvest.

The stem dry mass for the first harvest was significantly lower (p=0,01) than in the third, fourth, fifth, eighth, nineth, tenth and eleventh harvest. The second harvest was significantly lower (p=0,05) than the tenth harvest. For p=0,01, the second harvest was significantly lower than the third, fourth, fifth and eleventh harvest. The third harvest was significantly lower (p=0,05) than the eleventh harvest. For p=0,05, the fourth harvest was significantly higher than the seventh harvest. The fifth harvest was significantly higher (p=0,01) than the sixth and seventh harvests. For p=0,01, the sixth, seventh, eighth and nineth harvests were significantly lower than the eleventh harvest. The tenth harvest had a significantly lower (p=0,05) stem dry mass than the eleventh harvest.

The leaf dry mass for the first harvest was significantly

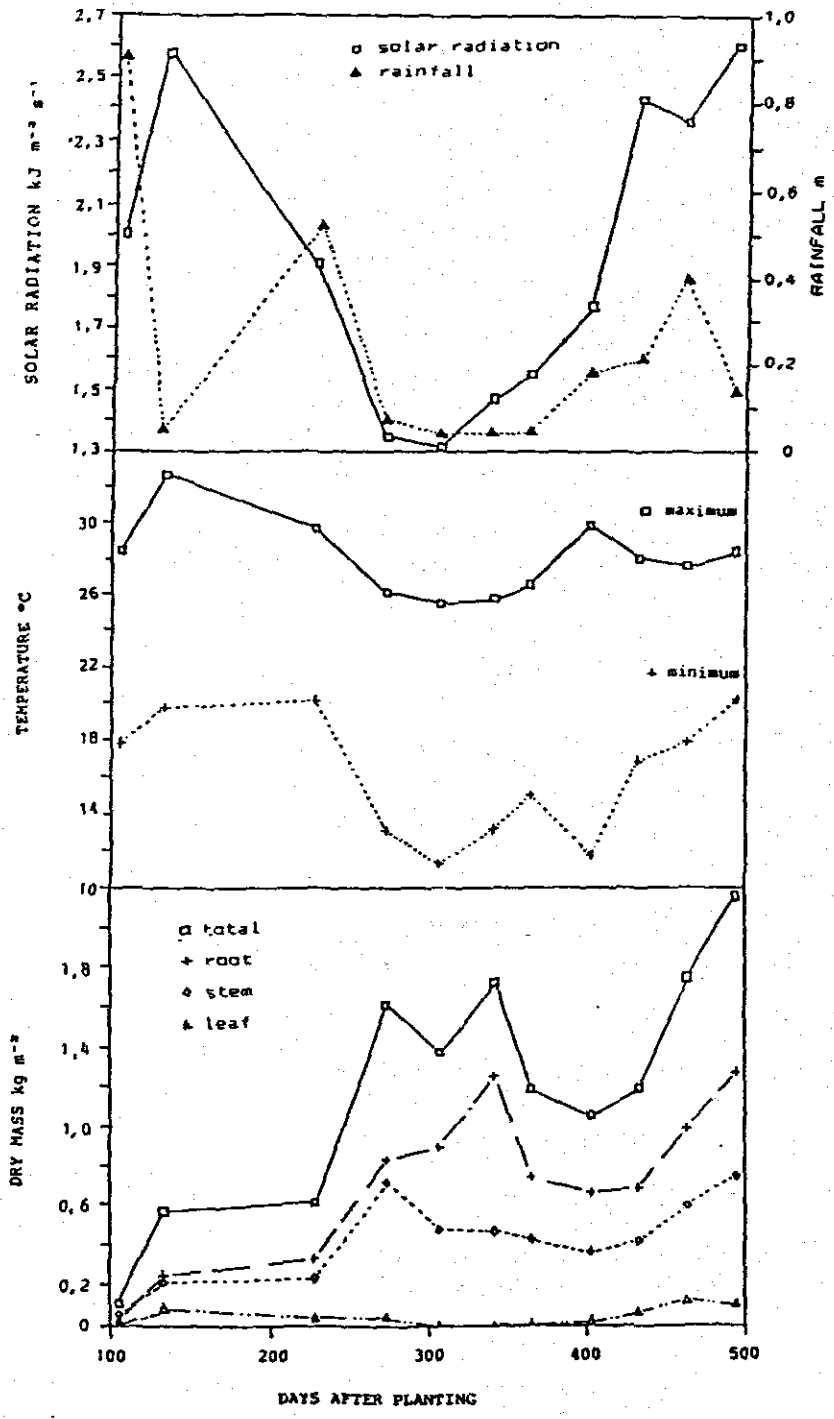Figure 4.26 Temperature, rainfall, solar radiation and the
distribution dry mass in   M 170 at different
times after planting for Experiment 2A.

lower (p=0,01) than in the tenth and eleventh harvests. For p=0,01, the second harvest was significantly higher than the fifth, sixth and seventh harvests. The third harvest was significantly higher (p=0,05) than the fifth and sixth harvests. For p=0,05, the fourth harvest was significantly lower than the tenth and eleventh harvests. For p=0,05, the fifth and sixth harvests were significantly lower than the eighth harvest. For p=0,01, the fifth, sixth and seventh harvests had a significantly lower leaf dry mass than the nineth, tenth and eleventh harvests.

4.3.7.3.2. Experiment 2A

The results of this experiment are shown in Fig 4.26. The total dry mass for the fifth harvest was significantly higher (p=0,01) than in the first harvest.

The root dry mass for the first harvest was significantly lower (p=0,05) than in the third and fourth harvests. For p=0,05, the fifth harvest was significantly higher than the third and fourth harvests. The fifth harvest was significantly higher (p=0,01) than the first and second harvests.

The stem dry mass did not differ significantly at all harvests.
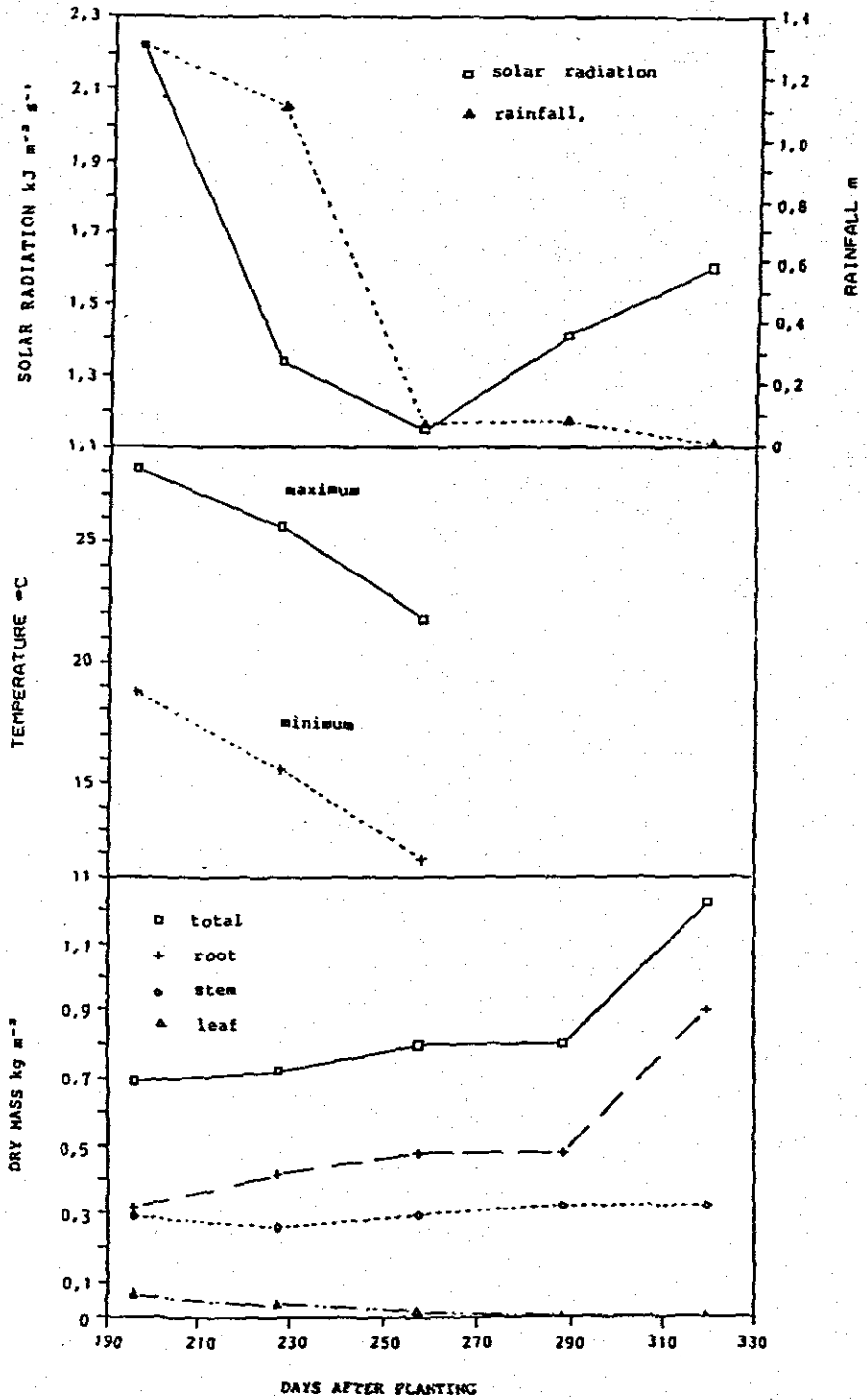
Figure 4.27 Temperature, solar radiation and the distribution

dry mass in M 170 at different times after

planting for Experiment 2B.

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The leaf dry mass for the first harvest was significantly higher (p=0,01) than the fourth and fifth harvests. The second harvest was significantly higher (p=0,05) than the third harvest. For p=0,01, the second harvest was significantly higher than the fourth and fifth harvest. The third harvest had a significantly higher (p=0,05) leaf dry mass than the fifth harvest.

4.3.7.3.3. Experiment 2B

The results of this experiment are shown in Fig 4.27. The total dry mass for the first and second harvests were significantly lower (p=0,01) than the third, fourth, fifth and sixth harvests. For p=0,01, the third harvest was significantly lower than the sixth harvest. The fourth harvest was significantly lower (p=0,05) than the fifth harvest. For p=0,01, the fourth harvest was significantly lower than the sixth harvest.

The root dry mass for the first harvest was significantly lower (p=0,05) than the third and fourth harvests. The first harvest had a significantly lower (p=0,01) root dry mass than the fifth and sixth harvest. For p=0,01, the second, third and fourth harvests were significantly lower than the fifth and sixth harvests.

The stem dry mass for the first and second harvests was significantly lower (p=0,01) than in the third, fourth, fifth and sixth harvests.

The leaf dry mass for the first harvest was significantly higher (p=0,05) than in the sixth harvest. For p=0,01, the first harvest was significantly lower than the third harvest. The second harvest had a significantly lower (p=0,05) leaf dry mass than the third harvest. The second harvest was significantly higher (p=0,01) than the sixth harvest. For p=0,05, the third harvest was significantly higher than the fourth harvest. The third harvest was significantly higher (p=0,01) than the fifth and sixth harvests. The fourth harvest was significantly higher (p=0,01) than the sixth harvest.

4.3.7.4. Dry matter partitioning and yield in M 5

4.3.7.4.1. Experiment 1

The results of this experiment are shown in Fig 4.28. The total dry mass for the first harvest was significantly lower (p=0,01) than in the third, fourth, fifth, sixth, seventh, nineth, tenth and eleventh harvest. The second harvest had a significantly lower (p=0,05) total dry mass than the fourth, sixth and nineth harvest. For p=0,01, the second harvest was significantly lower than the fifth,
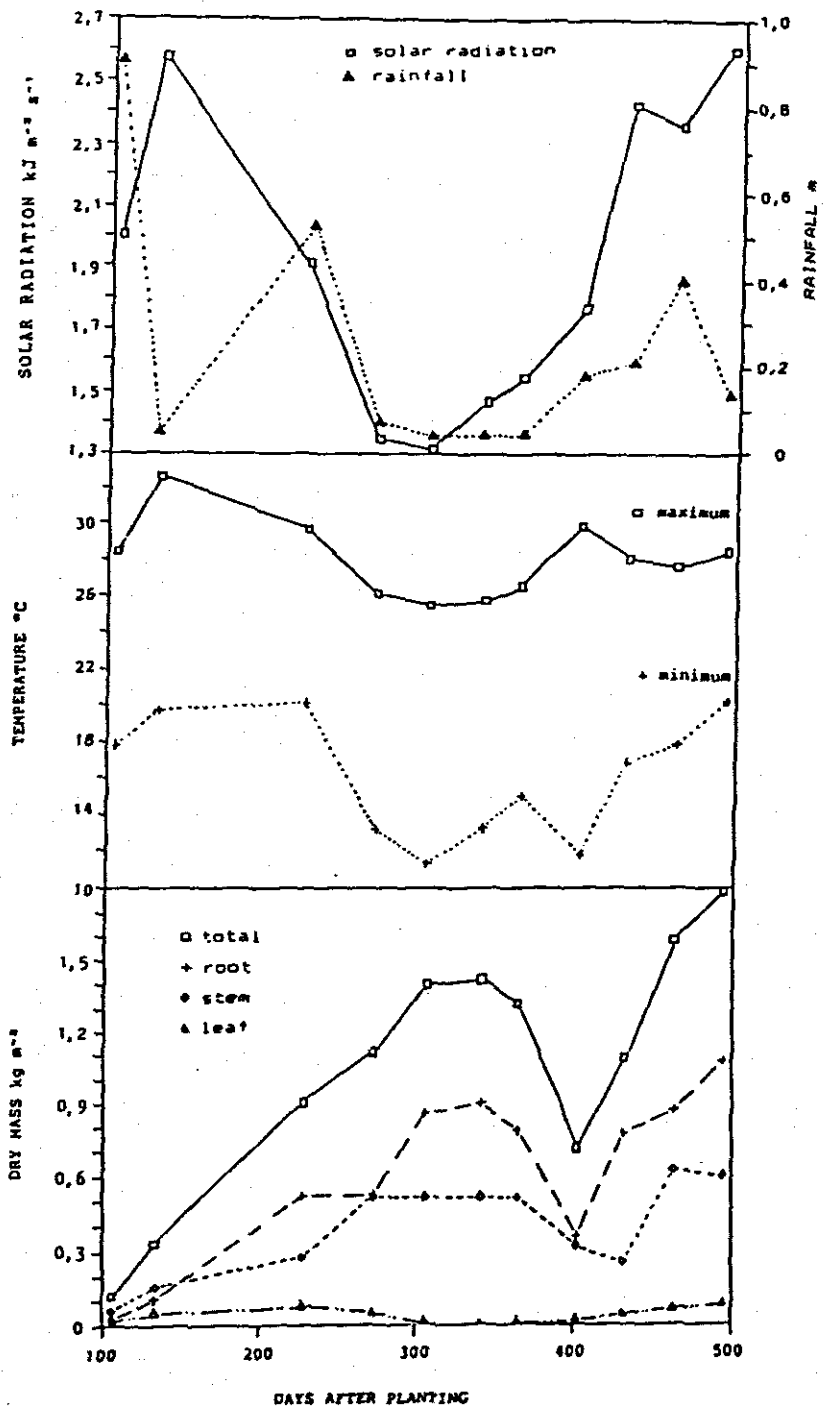
Figure 4.28 Temperature, rainfall, solar radiation and the
distribution of dry mass in M 5 at different
times after planting for Experiment 1.

seventh, tenth and eleventh harvest. The third harvest was significantly lower (p=0,01) than the eleventh harvest. For p=0,01, the eighth harvest was significantly lower than the tenth and eleventh harvest. The nineth harvest had a significantly lower (p=0,05) total dry mass than the eleventh harvest.

The first harvest had a significantly lower (p=0,05) root dry mass than the nineth harvest. For p=0,01, the first harvest had a significantly lower root dry mass than the fifth, sixth, seventh, tenth, eleventh and twelfth harvest. The second harvest had a significantly lower (p=0,05) root dry mass than the fifth, sixth and tenth harvest. For p=0,01, the second harvest was significantly lower than the eleventh and twelfth harvest. For p=0,01, the third, fourth, sixth, seventh, eighth, nineth, tenth and eleventh harvests were significantly lower than the twelfth harvest.

The stem dry mass for the first harvest was significantly lower (p=0,05) than in the eighth harvest. For p=0,01, the first harvest was significantly lower than the fourth, fifth, sixth, seventh, tenth and eleventh harvest. The second harvest was significantly lower (p=0,01) than the fourth, fifth, sixth, seventh, tenth and eleventh harvest. The third harvest was significantly lower (p=0,01) than the tenth and eleventh harvest. For p=0,05, the fourth

harvest was significantly higher than the nineth harvest. The eighth harvest had a significantly lower (p=0,05) stem dry mass than the eleventh harvest. For p=0,01, the eighth harvest was significantly lower than the tenth harvest. The nineth harvest was significantly lower (p=0,01) than the tenth and eleventh harvest.

The leaf dry mass for the first harvest was significantly higher (p=0,05) than in the sixth and lower than in the tenth harvest. For p =0,01, the first harvest was significantly lower than the third and eleventh harvest. For p=0,05, the second harvest was significantly higher than the fifth harvest. The second harvest was significantly higher (p=0,01) than the sixth and seventh harvest. The third harvest was significantly higher (p=0,01) than the fifth, sixth, seventh, eighth and nineth harvest. For p=0,05, the fourth harvest was significantly higher than the seventh and lower than the eleventh harvest. The fourth harvest was significantly higher (p=0,01) than the sixth harvest. For p=0,01, the fifth, sixth, seventh and eighth harvests had a significantly lower leaf dry mass than the tenth and eleventh harvests. The sixth harvest was significantly lower than the nineth harvest. The nineth harvest was significantly lower than the eleventh harvest.
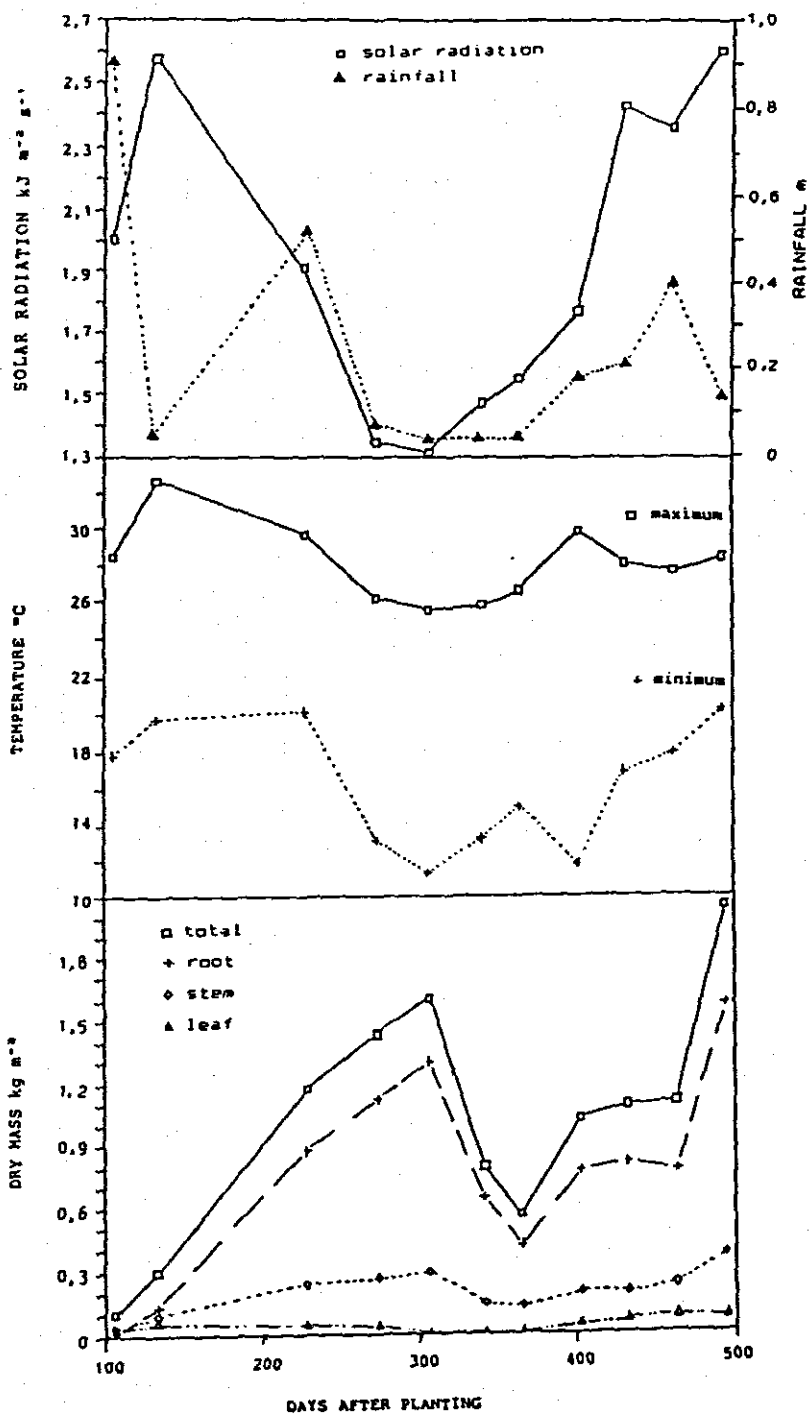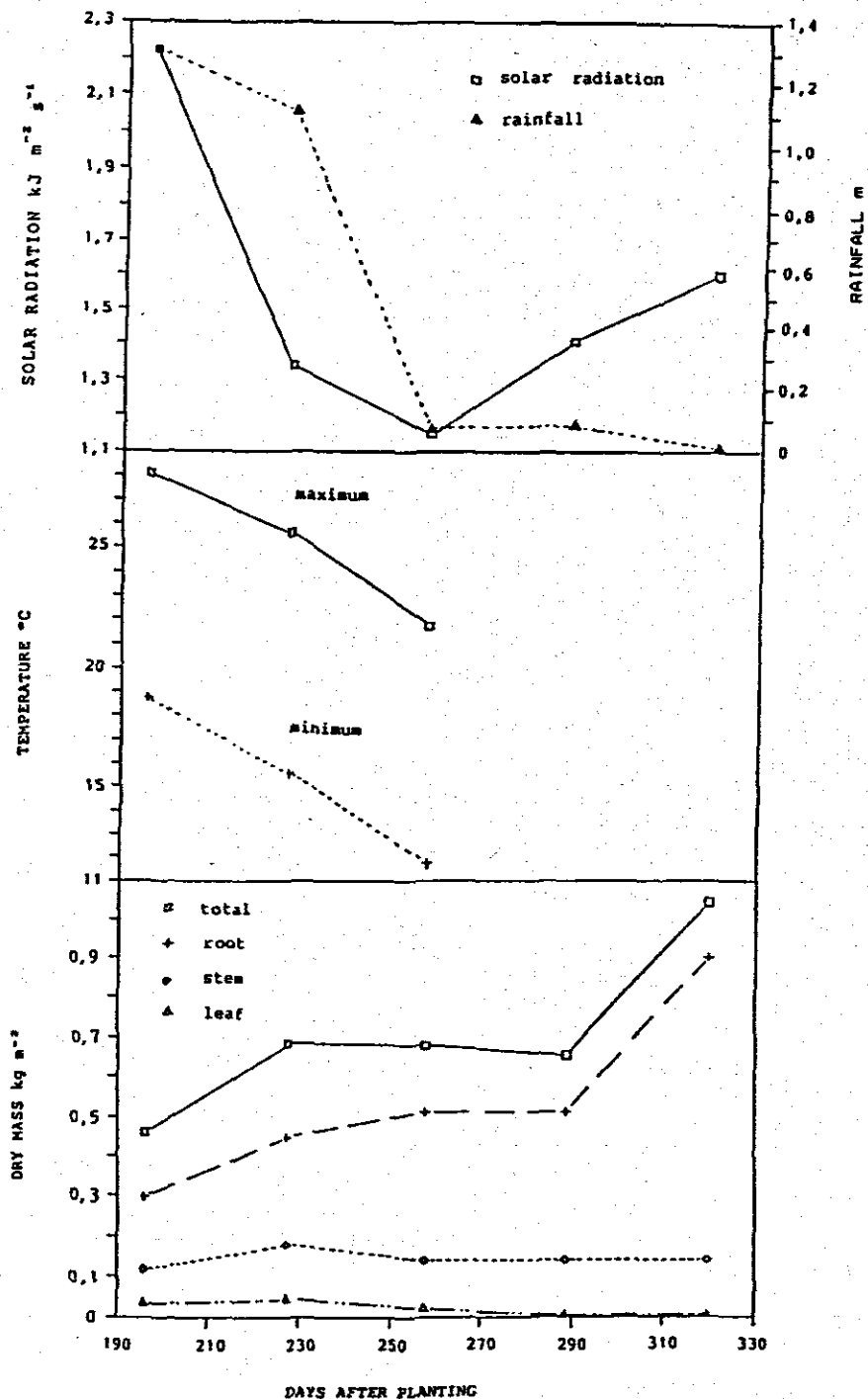
-97-
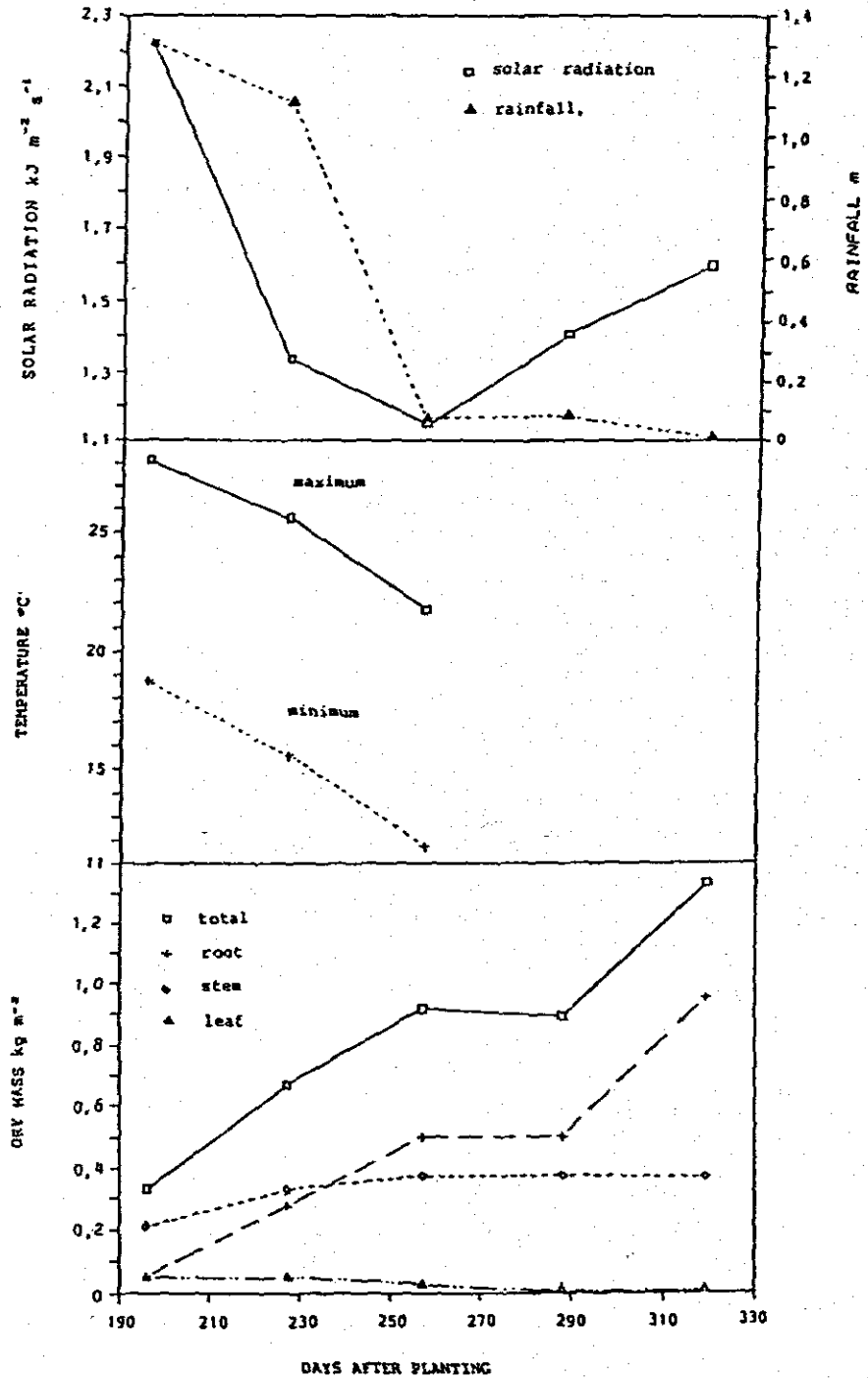
Figure 4.29 Temperature, rainfall, solar radiation and the distribution dry mass in M 5 at different times after planting for Experiment 2A.

4.3.7.4.2. Experiment 2A

The results of this experiment are shown in Fig 4.29. The total dry mass for the first harvest was significantly lower ($p=0,05$) than in the third and fourth harvest. For $p=0,01$, the first harvest was significantly lower than the fifth harvest. The second harvest was significantly lower ($p=0,01$) than the fifth harvest. For $p=0,05$, the fourth harvest was significantly lower than the fifth harvest.

The root dry mass for the first harvest was significantly lower ($p=0,01$) than the third, fourth and fifth harvest. The fifth harvest had a significantly higher ($p=0,01$) root dry mass than the second, third and fourth harvest. The stem dry mass did not differ significantly at all harvests.

The leaf dry mass for the first harvest was significantly higher ($p=0,05$) than in the third harvest. For $p=0,01$, the first harvest was significantly higher than the fourth and fifth harvest. The second harvest was significantly higher ($p=0,05$) than the third harvest. For $p=0,01$, the second harvest was significantly higher than the fourth and fifth harvest. The third harvest had a significantly higher ($p=0,05$) leaf dry mass than the fourth harvest. For $p=0,01$, the third harvest was significantly higher than the fifth harvest.
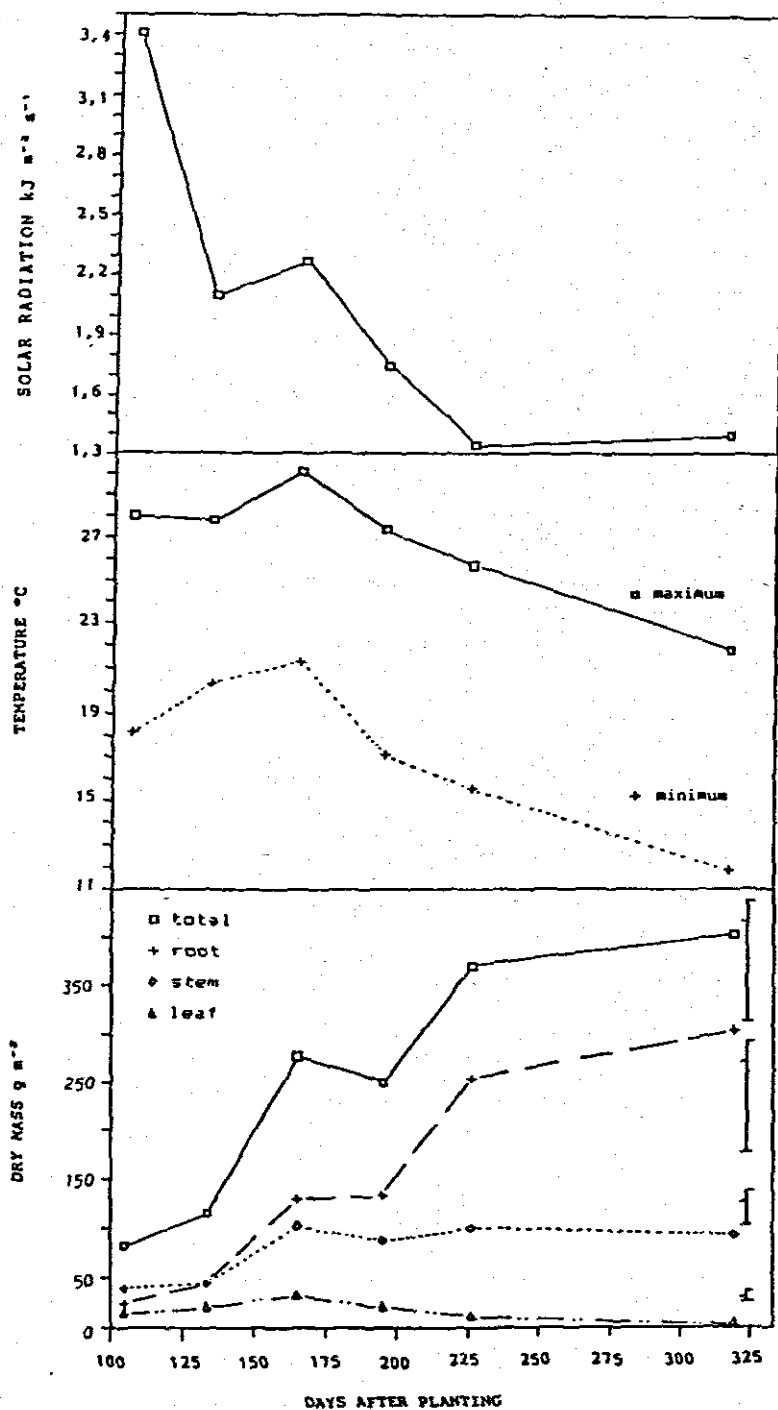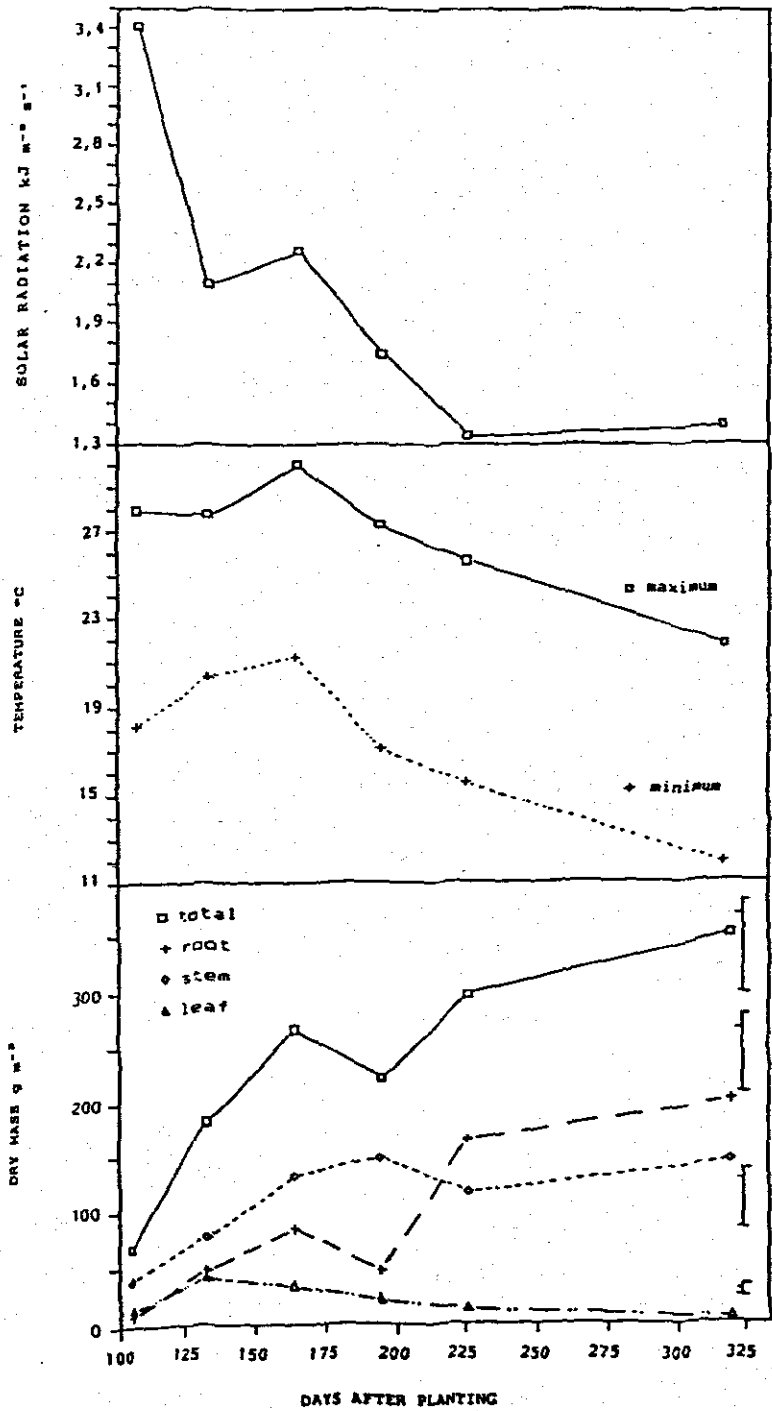
Fig. 4.30 Temperature, solar radiation and the distribution of dry mass in M 5 at different times after planting for Experiment 2B.

4.3.7.4.3. Experiment 2B

The results of this experiment are shown in Fig 4.30. The total dry mass for the first harvest was significantly lower ($p=0,01$) than the second, third, fourth, fifth and sixth harvest. The second harvest was significantly lower ($p=0,01$) than the third, fifth and sixth harvest. The third harvest was significantly lower ($p=0,01$) than the sixth harvest. For $p=0,05$, the fourth harvest was significantly lower than the fifth harvest. The fourth harvest had a significantly lower ($p=0,01$) total dry mass than the sixth harvest.

The root dry mass for the first harvest was significantly lower ($p=0,01$) than the third, fifth and sixth harvest. For $p=0,01$, the second, third and fourth harvests were significantly lower than the fifth and sixth harvests.

The stem dry mass for the first harvest was significantly lower ($p=0,01$) than the third, fourth, fifth and sixth harvest. The second harvest had a significantly lower stem dry mass than the third, fourth and sixth harvest.

The leaf dry mass for the first harvest was significantly lower ($p=0,01$) than in the second, third and fourth harvest. For $p=0,01$, the first harvest was significantly higher than the sixth harvest. The second harvest was

significantly higher (p=0,01) than the third, fourth, fifth and sixth harvest. The third harvest was significantly higher (p=0,01) than the fourth, fifth and sixth harvest. The fourth harvest was significantly higher (p=0,01) than the fifth and sixth harvest. The fifth harvest was significantly higher (p=0,01) than the sixth harvest.

4.3.8. THE PRODUCTION OF FRUIT AND SEED DRY MASS.

The results are shown in Tables 4.3 and 4.4. In both Tables, no seed and fruit dry mass was produced in MSAF 2. In experiment 2A CMC 40 had a significantly higher (p=0,01) dry mass than both M 170 and M 5. In experiment 2B (April harvest), CMC 40 had a significantly higher (p=0,05) dry mass than M 5. In experiment 2B (May harvest) the cultivars did not differ significantly in their fruit and seed dry mass.

TABLE 4.3. Fruit and seed dry mass for the cultivars
MSAF 2, CMC 40, M 170 and M 5 for
Experiment 2A (May Harvest).

Cultivar	g plant⁻¹
MSAF 2	*
CMC 40	10,44
M 170	2,49
M 5	0,5

TABLE 4.4. Fruit and seed dry mass for the cultivars
MSAF 2, CMC 40, M 170 and M 5 for
Experiment 2B.

Cultivars	April g plant⁻¹	May g plant⁻¹
MSAF 2	*	*
CMC 40	2,36	3,86
M 170	0,43	1,22
M 5	0,32	0,67

* = Flowering did not occur, thus seeds and fruits were
not formed

4.4. DISCUSSION AND CONCLUSIONS

The total dry mass revealed that CMC 40 established more rapidly than M 170 in both field experiments (1 and 2A). This was however not the case in experiment 2B. The differences in dry mass observed in experiment 1 were probably due to differences in peaking and declining times. The results of the three experiments are not consistent. There wasn't much difference in the average monthly temperature, rainfall and solar radiation for the three experiments (Table 3.1). It is not likely that the climatic conditions played a role in the inconsistency of the three experiments. The rapid increase in total dry matter from 107 to 166 DAP (Fig 4.3) was consistent with the findings of Howeler & Cadavid (1983) who found a slow accumulation of dry mass during the first 2 months and a rapid increase in dry mass during the next 4 months. In field plants (experiment 1 and 2A) the total DM was higher than in potted plants (experiment 2B). Pot plant conditions restricted growth but to a lesser extent in MSAF 2 than in CMC 40 at 319 DAP (Fig 4.3).

The main period of root tuber growth started at 3 - 4 months after planting and was consistent with the findings of Enyi (1973), Wholey and Cock (1974), Boerboom (1978) and Keating et al, (1982a). CMC 40 had the lowest root DM (Fig 4.6). According to San Jose and Berrade (1983),

excess humidity is an indirect yield depressant by causing root rot. In the present study, the tubers wounded during weeding became rotten in the presence of excess rainfall.

The maximum tuber DM obtained in the present study at 319 DAP ranged from 110 to 353 g m^{-2} in potted plants and from 857 to 1299 g m^{-2} at 307 DAP in field plants. Therefore field plants (experiment 1 and 2A) had a higher yield than potted plants (experiment 2B). Cock et al (1979) obtained a maximum yield of 2200 g m^{-2} a^{-1}. Therefore, the yield obtained in the present study after one year was low compared to the one reported in the literature. In the present study, the highest yield was obtained at 707 DAP and it ranged from 2505 to 3577 g m^{-2} with the lowest in CMC 40 and the highest MSAF 2 (Fig 4.4).

According to Ramanujam (1980), the number of tubers per plant was 10 in non - branched and 9 in branched types. Keating et al, (1982a) obtained 10 to 14 tubers per plant (10 000 plants per hectare). If the number of tubers was smaller than 10, the limited sink either limited the total dry matter production or the stem accepted more carbohydrates (Cock et al, 1979). In the present study the number of tubers per plant was less than 10, therefore the cultivars used had a limited sink capacity. In both experiment 2A and 2B, the number of tubers per plant was

lower in CMC 40 than in both M 170 and MSAF 2. Therefore the low yield in CMC 40 could have been due to a limited sink capacity.

The stem and leaf growth had influence over root growth with the roots receiving excess carbohydrates after the requirements of the top had been fulfilled (Cock et al, 1979). In the present study, CMC 40 and M 5 had a higher stem DM than M 170 and MSAF 2 (Fig 4.8 and 4.9). Therefore, in CMC 40 and M 5 the stem had a higher demand for carbohydrates and less were passed to the roots for storage. The limited stem growth (Fig 4.9) was probably responsible for a higher yield (Fig 4.6) in MSAF 2. The maximum stem DM ranged from 68,53 to 167,03 g m^{-2} at 319 DAP in potted plants and from 371,56 to 747,29 g m^{-2} at 495 DAP in field plants.

In potted plants the maximum petiole DM ranged from 8,96 to 15,87 g m^{-2} where the lowest value was in MSAF 2 and the highest in M 5 (Fig 4.12). In field plants, the maximum petiole DM ranged from 16,19 to 42,76 g m^{-2} where the lowest was in M 170 and the highest in MSAF 2 (Fig 4.10).

In experiment 1, at 307 DAP M 5 had a higher leaf DM than M 170 (Fig 4.13). Even in experiment 2A M 5 had a higher leaf dry mass than M 170 at 319 DAP although they did not

differ in experiment 2B (Fig 4.14 & 4.15). The maximum leaf DM ranged from 83,9 to 153,3 g m^{-2} in field plants and from 28,54 to 41,74 g m^{-2} in potted plants.

In all the experiments, the production of leaf dry mass followed a seasonal pattern (Fig 4.19 to Fig 4.30).

According to Boerboom (1978), the partitioning of DM between storage roots and shoots is constant over the whole life of cassava. In the present study, Boerboom's relationship did not hold because there are seasonal variations. The decline in the root and stem DM during post winter regrowth (Fig 4.19 and Fig 4.22) at 403 DAP was probably due to the mobilization of reserves. Such observations were consistent with the findings of Keating *et al*, (1982c).

If the harvest index is high, yield is also high (Cock, 1976). The present study was consistent with Cocks' findings because in the first year of growth, M 170 had the highest yield (Fig 4.4) and the highest HI (Fig 4.16). The maximum HI ranged from 0,7 to 0,8 in field plants (experiment 1 and 2A) and from 0,39 to 0,82 in potted plants (experiment 2B). In both experiment 1 and 2A, M 170 had a higher HI than M 5 at 319 DAP. In this instance, the cultivars did not differ significantly in their root yield.

CHAPTER FIVE

5. CANOPY CHARACTERISTICS IN CASSAVA CULTIVARS

5.1. INTRODUCTION

The rate of photosynthesis plus development of leaf area are important in determining storage root yield of cassava. Results of this study reported in Chapter 6 support this hypothesis. The LAI is determined by the number of active apices, the rate of leaf formation per apex, leaf size and leaf life. The number of active apices is determined by branching habit (Irikura, Cock & Kawano, 1979). Cassava has an indeterminate habit with sympodial branching (Connor & Cock, 1981). Enyi (1973) showed that reducing the number of stems per plant increased yield slightly at closer spacing, suggesting that types without branches might have an advantage.

I am not aware of any publications which explain the yield of MSAF 2 in relation to canopy characteristics. The purpose of research reported in this chapter is to explain the variation in yield in terms of canopy characteristics in MSAF 2, CMC 40, M 170 and M 5.

5.2. MATERIALS AND METHODS

Research reported in this chapter is composed of twoexperiments on the basis of planting times. The general experimental procedure and meteorological data are reported in chapter 3.

Experiment 1: Planting was done on 26/09/87 in experimental plots on campus of the University of Zululand.

Harvest	Date	Number of DAP
H1	09/01/88	106
H2	05/02/88	133
H3	10/05/88	228
H4	24/06/88	273
H5	28/07/88	307
H6	01/09/88	342
H7	24/09/88	365
H8	01/11/88	403
H9	01/12/88	433
H10	01/01/89	464
H11	01/02/89	495

The number of plants harvested per cultivar varied from 3 to 7 at each harvest.

Experiment 2A: Planting was done on 17/10/88 in experimental plots on campus of the University of Zululand.

Harvest	Date	Number of DAP
H1	30/04/88	196
H2	31/05/89	227
H3	30/06/89	257
H4	31/07/89	288
H5	31/08/89	319

The number of plants harvested was as follows:

H1 to H5: 4 plants per cultivar

Experiment 2B: Planting was done on 17/10/88 in polyethylene pots.

Harvest	Date	Number of DAP
H1	31/01/89	107
H2	28/02/89	135
H3	31/03/89	166
H4	30/04/89	196
H5	31/05/89	227
H6	31/08/89	319

The number of plants harvested was as follows:

H1 to H6: 5 plants per cultivar

Figure 5.1 Temperature, rainfall, solar radiation and plant
height for cassava cultivars at different times
after planting for Experiment 1.

In all the experiments, plant height, profuse branching, leaf numbers and the number of active apices were determined.

5.3. RESULTS

5.3.1. PLANT HEIGHT

5.3.1.1. Plant height for experiment 1.

During the first year of growth, there was an increase in plant height in all the cultivars from 106 to 273 DAP (Fig 5.1). From 106 to 403 DAP, MSAF 2 was the shortest cultivar. At 106 DAP CMC 40 was significantly taller ($p=0,05$) than M 170 and M 5. For $p=0,01$, CMC 40 was significantly taller than MSAF 2. At 133 DAP, for $p=0,01$ MSAF 2 was significantly shorter than CMC 40, M 170 and M 5. CMC 40 and M 5 were significantly taller than M 170. At 228 DAP, for $p=0,01$ MSAF 2 was significantly shorter than CMC 40, M 170 and M 5. CMC 40 was significantly taller than all the other cultivars. M 5 was significantly taller than M 170. At 273, 307, and 342 DAP, for $p=0,01$ MSAF 2 was significantly shorter than CMC 40, M 170 and M 5. CMC 40 and M 5 were significantly taller than M 170. At 365, 403, 433, 464 and 495 DAP, CMC 40 and M 5 were significantly taller ($p=0,01$) than both MSAF 2 and M 170.

Figure 5.2 Temperature, rainfall, solar radiation and plant height for cassava cultivars at different times after planting for Experiment 2A.

5.3.1.2. Plant height for experiment 2A

In all the cultivars, there was an increase in plant height from 196 to 227 DAP (Fig 5.2). From 227 to 319 DAP, CMC 40 and M 5 were the tallest and MSAF 2 the shortest cultivar. From 196 to 319 DAP, CMC 40 and M 5 were significantly taller (p=0,01) than both MSAF 2 and M 170.

5.3.1.3. Plant height for experiment 2B

In this experiment plant height increased from 107 to 166 DAP in all the cultivars (Fig 5.3). At all harvests, the tallest cultivar was CMC 40 and the shortest was MSAF 2. At 107 DAP, for p=0,01 MSAF 2 was significantly shorter than CMC 40, M 170 and M 5. CMC 40 was significantly taller than all the other cultivars. At 135 DAP CMC 40 was significantly taller (p=0,01) than MSAF 2, M 170 and M 5. MSAF 2 and M 170 were significantly shorter (p=0,01) than M 5. At 166 DAP, for p=0,01, MSAF 2 was significantly shorter than CMC 40, M 170 and M 5. CMC 40 was significantly taller than M 170 and M 5. M 5 was significantly taller than M 170. At 196 DAP, for p=0,05, M 170 was significantly taller than MSAF 2 and shorter than M 5. For p=0,01, CMC 40 was significantly taller than MSAF 2, M 170 and M 5. From 227 to 319 DAP,

Figure 5.3   Temperature, solar radiation and plant height for

cassava cultivars at different times after planting
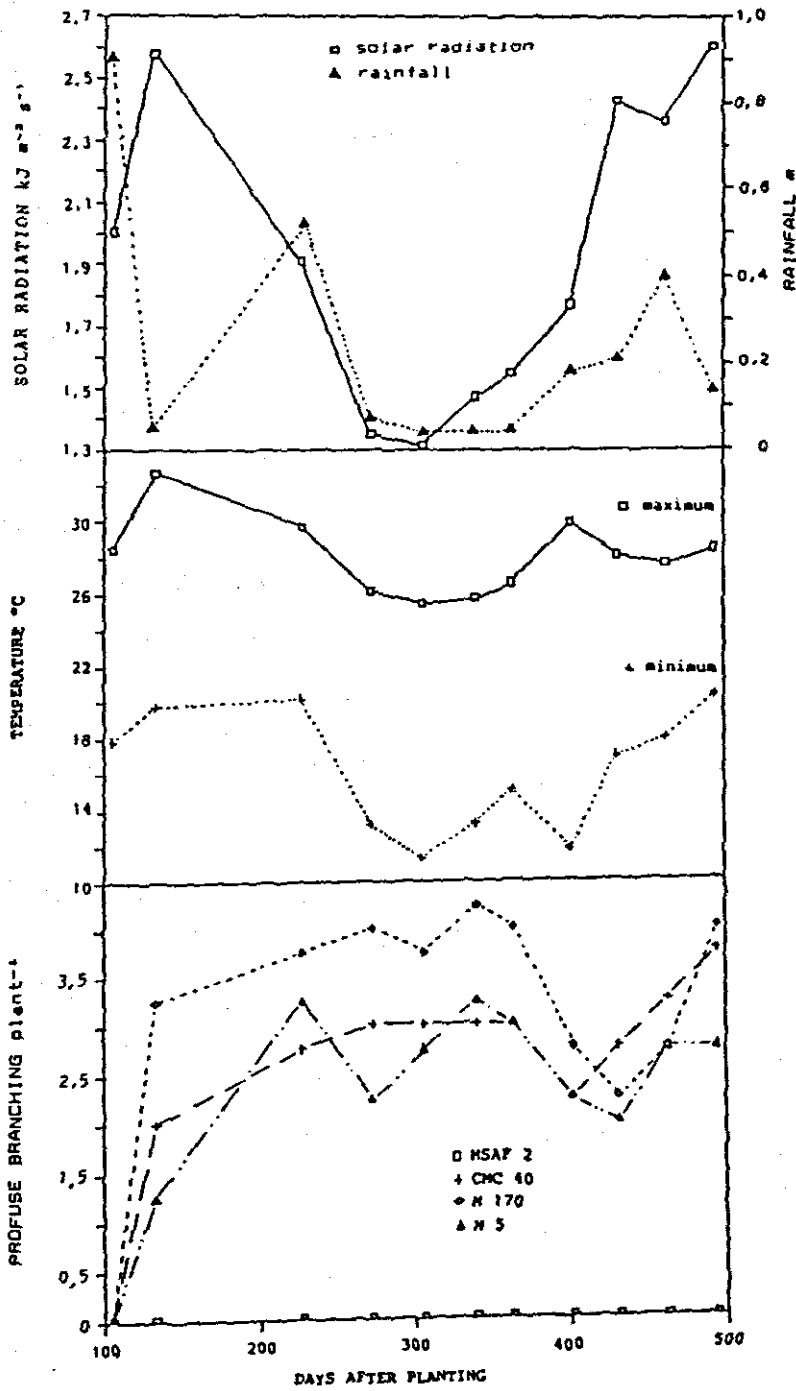
for Experiment 2B.

Figure 5.4   Temperature,   rainfall, solar   radiation and profuse
branching   for   cassava cultivars at different times
after planting for Experiment 1.

for p=0,01 CMC 40 was significantly taller than MSAF 2, M 170 and M 5. MSAF 2 was significantly shorter than all the other cultivars. M 170 was significantly shorter than M 5.

5.3.2. TWO OR THREE - POINT BRANCHING PATTERN.

5.3.2.1. Branching pattern for experiment 1

Results of this experiment are shown in Fig 5.4. MSAF 2 did not produce profuse branches. The differences in branching pattern between the cultivars were not statistically significant.

5.3.2.2. Branching pattern in experiment 2A

The results of this experiment are shown in Fig 5.5 and in Table 5.1. The number of nodes per branch from planting to first branch level in M 5 was significantly higher (p=0,01) than in CMC 40. From first to second branch level, M 170 had a significantly lower (p=0,01) number of nodes than both CMC 40 and M 5. From second to third branch level, CMC 40 had the highest number of nodes per branch. CMC 40 was significantly higher (p=0,01) than both M 170 and M 5. The number of nodes in M 170 was significantly higher (p=0,01) than in M 5.

Figure 5.5 Temperature, *rainfall, solar* radiation and profuse

branching for cassava cultivars at *different times*

after planting for Experiment 2A.

Table 5.1. The number of nodes and active apices at each branch level in the cultivars MSAF 2, CMC 40, M 170 and M 5 for Experiment 2A.

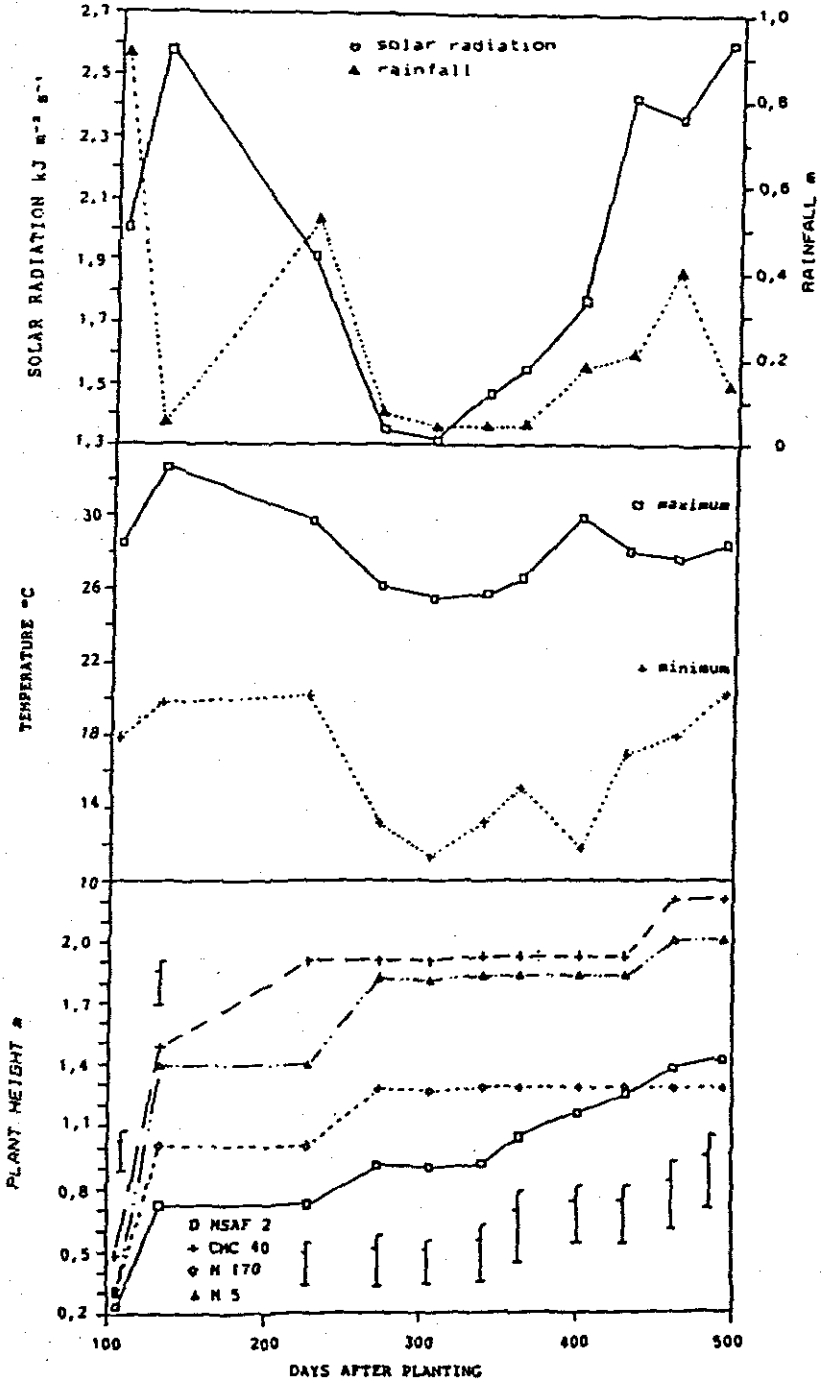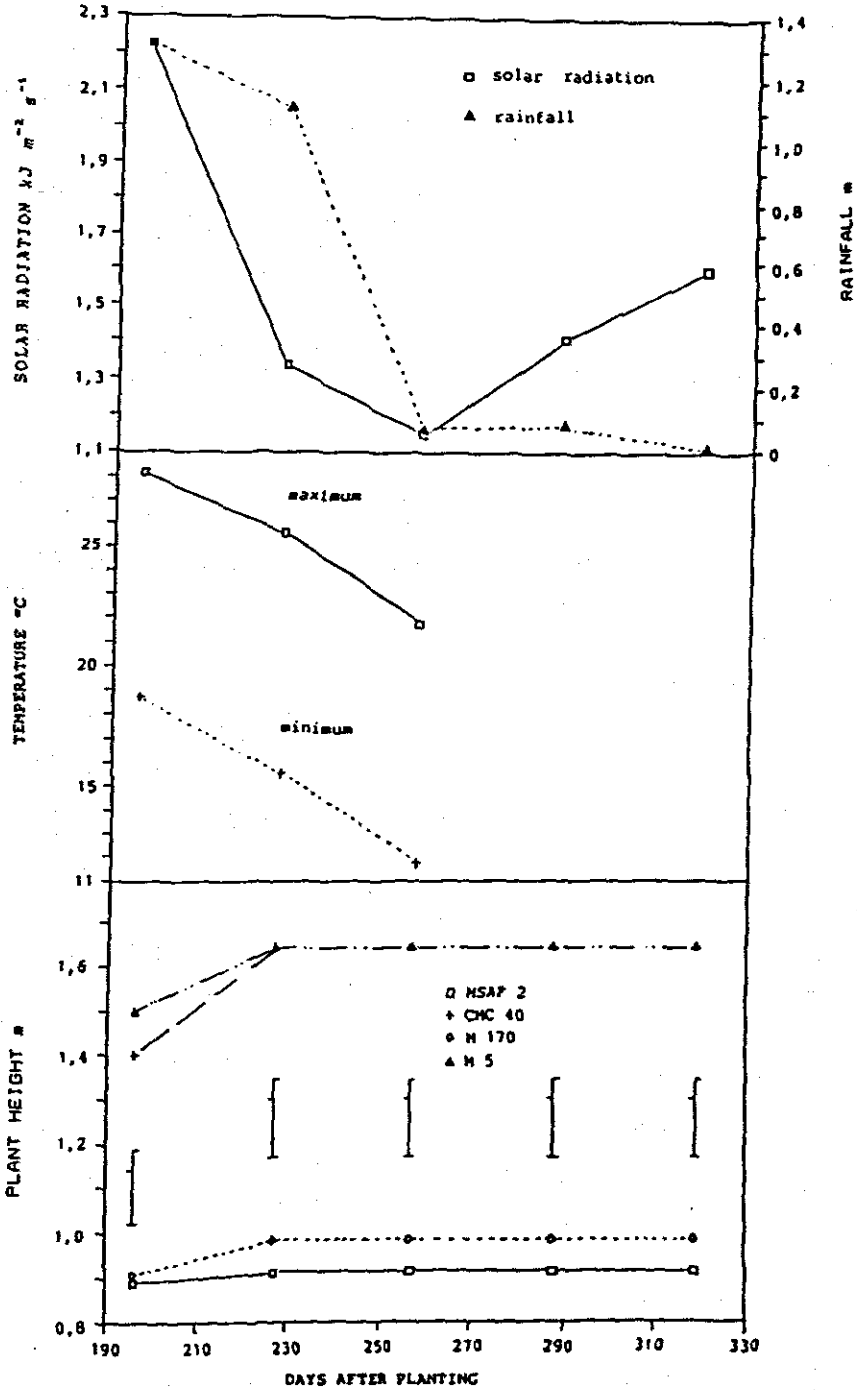|		CULTIVARS		
Number of nodes per branch from:	MSAF 2	CMC 40	M 170	M 5
Planting to first branch level	*	32,0	34,2	65,8
First to second branch level	*	25,8	18,0	26,9
Second to third branch level	*	19,9	15,1	11,3
Number of days from:				
Planting to first branch level	*	107	107	107
First to second branch level	*	28	28	89
Second to third branch level	*	61	61	61
Number of active apices at:				
First branch level	*	2,8	2,8	2,8
Second branch level	*	7,6	6,4	7,6

* = Data not available due to the absence of profuse branching
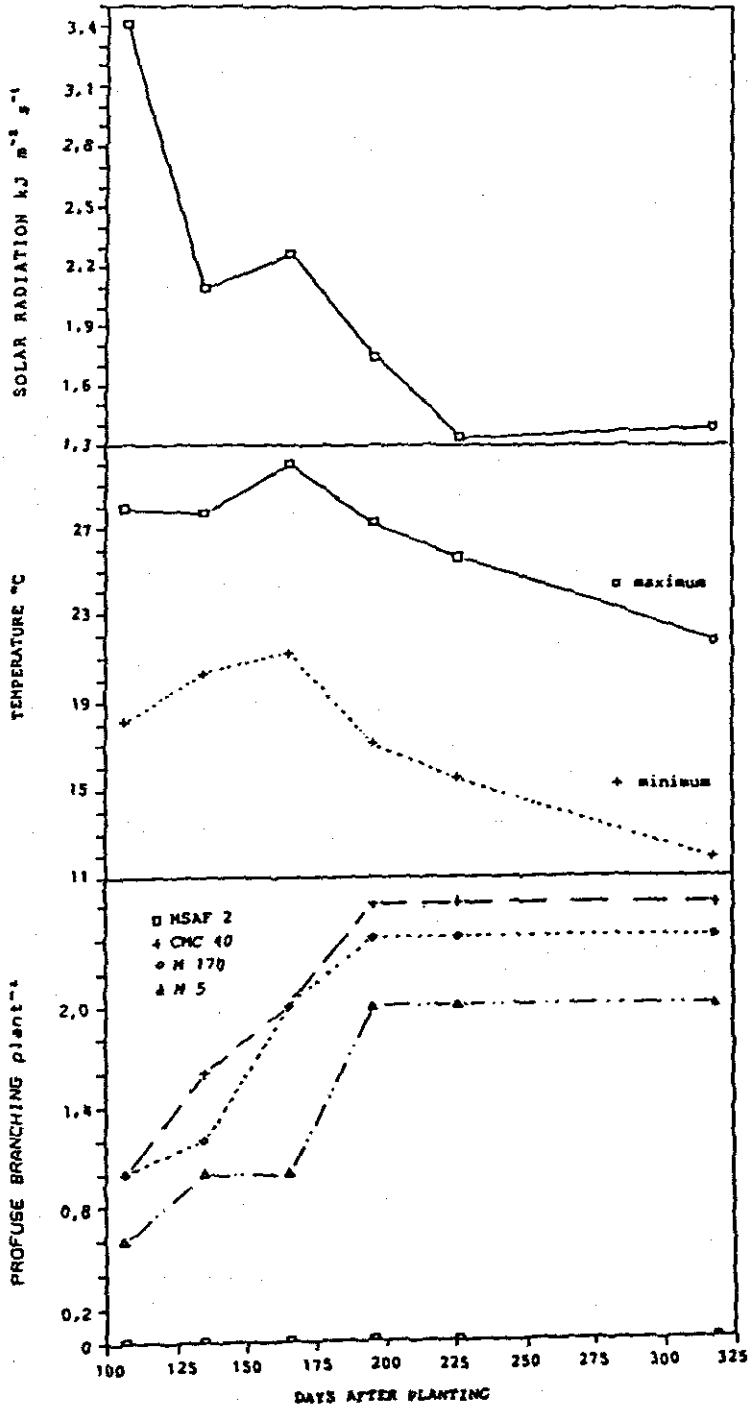
Figure 5.6 Temperature, solar radiation and profuse branching for cassava cultivars at different times after planting for Experiment 2B.

The number of days from planting to first branch level wasthe same in CMC 40, M 170 and M 5. The number of days from first to second branch level was high in M 5 and low in both CMC 40 and M 170. The number of days from second to third branch level was the same in CMC 40, M 170 and M 5.

The number of active apices per branch level was the same in all the cultivars. The number of active apices at second branch level was slightly higher in CMC 40 than in M 170 and M 5. However, the differences were not statistically significant.

5.3.2.3. Branching pattern for experiment 2B

The results of this experiment are shown in Fig 5.6 and in Table 5.2. In this experiment MSAF 2 did not produce profuse branches.

Differences in branching pattern between the cultivars were not statistically significant.

The number of nodes from planting to first branch level in the cultivar M 5 was significantly higher ($p=0,01$) than in both CMC 40 and M 170. From first to second branch level, M 5 still had a significantly higher ($p=0,05$) number of nodes than M 170. From second to third branch

Table 5.2. The number of nodes and active apices at each
branch level in the cultivars MSAF 2, CMC 40,
M 170 and M 5 for Experiment 2B.

CULTIVARS

Number of nodes per branch from:	MSAF 2	CMC 40	M 170	M 5
Planting to first branch level	*	25,8	23,2	37,8
First to second branch level	*	15,1	14,2	18,9
Second to third branch level	*	12,4	13,2	8,2
Number of days from:				
Planting to first branch level	*	107	107	107
First to second branch level	*	28	28	89
Second to third branch level	*	61	61	*
Number of active apices at:				
First branch level	*	3,0	2,2	2,8
Second branch level	*	6,0	5,2	5,0

* = Data not available due to the absence of profuse
branching

level, M 5 had a significantly lower (p=0,01) number of nodes per branch than both CMC 40 and M 170.

The number of days from planting to first branch level was the same in CMC 40, M 170 and M 5. From first to second branch level, M 5 had a significantly higher (p=0,01) number of days than both CMC 40 and M 170. M 5 did not have the third level of branching pattern. CMC 40 and M 170 had the same number of days from second to third branch level.

The number of active apices at first and second branch level did not differ significantly in all the cultivars. However, CMC 40 had a slightly higher number of active apices than both M 170 and M 5.

5.3.3. CUMULATIVE LEAF NUMBERS.

5.3.3.1. Cumulative leaf numbers for experiment 2A

The results of this experiment are shown in Fig 5.7. At 196 DAP the total number of leaves in CMC 40 and M 170 was significantly higher (p=0,01) than in MSAF 2. At 227 DAP M 170 had a significantly higher (p=0,05) number of leaves than CMC 40. For p=0,01, M 170 and M 5 had a significantly higher number of leaves than MSAF 2. At 257, 288 and 319 DAP M 170 had a significantly higher
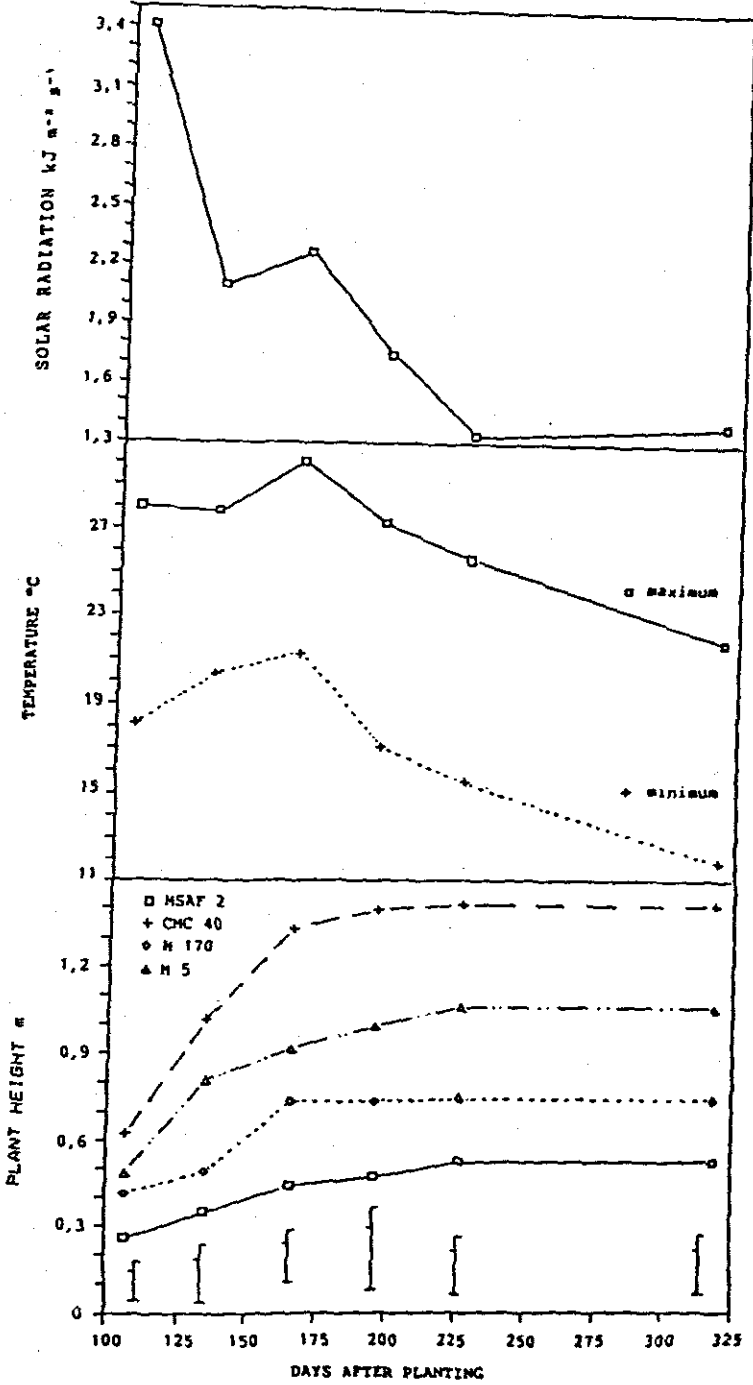
Figure 5.7 Temperature, solar radiation and cumulative leaf numbers for cassava cultivars at different times after planting for Experiment 2A.

Figure 5.8 Temperature, solar radiation and cumulative leaf numbers for cassava cultivars at different times after planting for Experiment 2B.

(p=0,05) number of leaves than MSAF 2. For p=0,01, the total number of leaves in M 5 was significantly higher than in MSAF 2.

5.3.3.2. Cumulative leaf numbers for experiment 2B.

The results of this experiment are shown in Fig 5.8. At 107 DAP the total number of leaves in M 170 was significantly higher (p=0,05) than in MSAF 2. At 135 DAP M 5 had a significantly higher (p=0,05) number of leaves than MSAF 2. The leaf number in CMC 40 was significantly higher (p=0,05) than in M 170. For p=0,01, CMC 40 had a significantly higher number of leaves than MSAF 2. At 166 DAP, for p=0,01, the total number of leaves in MSAF 2 was significantly lower than in CMC 40 and M 170. CMC 40 had a significantly higher number of leaves than M 5. At 196 DAP the number of leaves in MSAF 2 was significantly lower (p=0,01) than in CMC 40, M 170 and M 5. From 227 to 319 DAP the total number of leaves in CMC 40 and M 170 was significantly higher (p=0,01) than in MSAF 2.

5.3.4. THE NUMBER OF LEAVES PRESENT AT EACH HARVEST.

5.3.4.1. The number of leaves present in experiment 2A

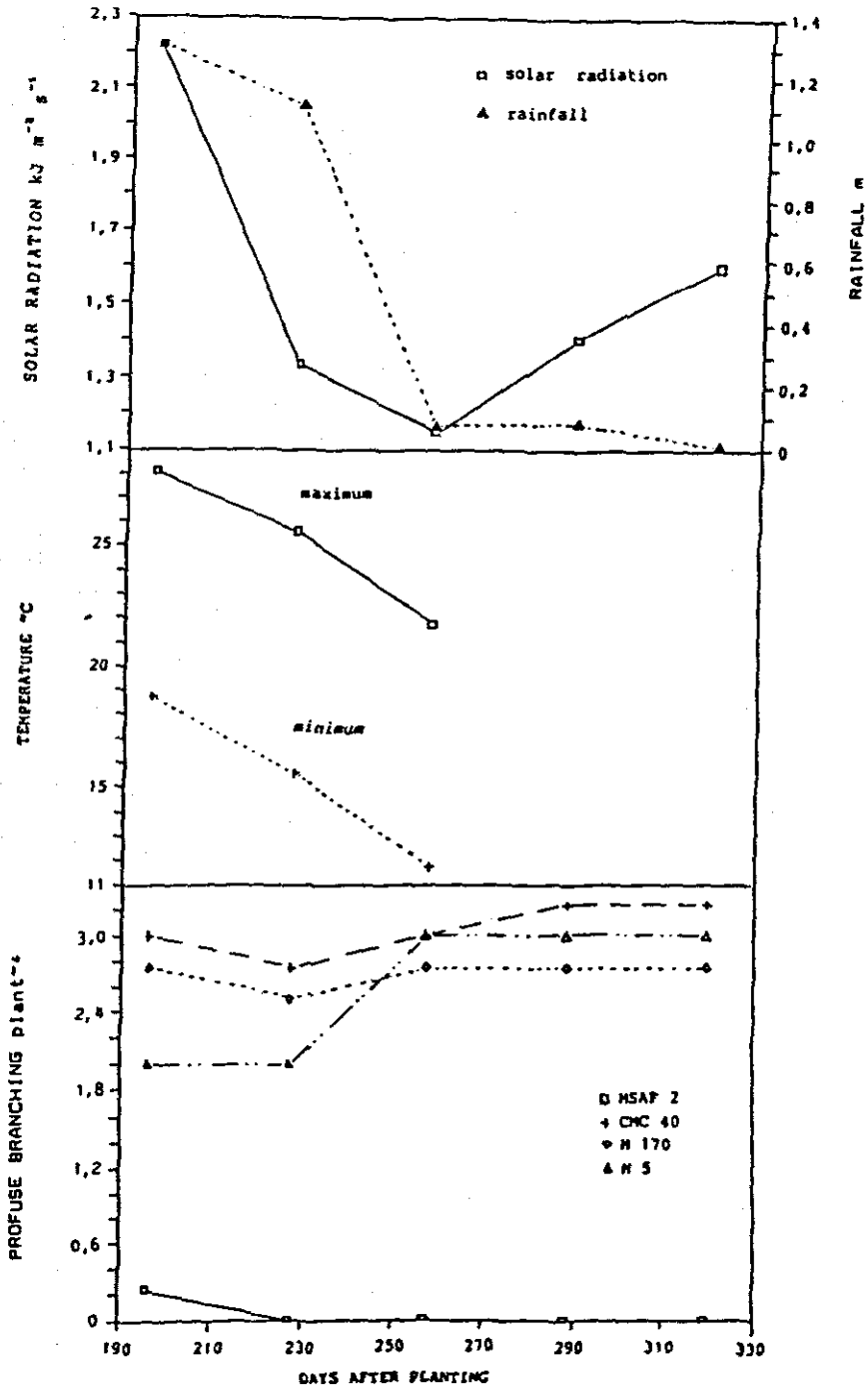The results of this experiment are shown in Fig 5.9. In

Figure 5.9 Temperature, rainfall, solar radiation and present

leaf numbers for cassava cultivars at different

times after planting for Experiment 2A.

both CMC 40 and MSAF 2 there was a decline in leaf numbers from 196 to 319 DAP. In the narrow - leaved plants (M 170 and M 5) there was an increase in the number of leaves from 196 to 227 DAP, and thereafter a decline to 288 DAP. At 196 DAP M 170 had a significantly higher (p=0,05) number of leaves than MSAF 2. CMC 40 had a significantly higher (p=0,01) number of leaves than MSAF 2. At 227 DAP, for p=0,05 M 5 retained a significantly higher number of leaves than MSAF 2. M 170 also retained a significantly higher (p=0,01) number of leaves than MSAF 2. At 257 DAP the number of leave in M 170 was significantly higher (p=0,05) than in MSAF 2. M 5 retained a significantly higher (p=0,01) number of leaves than MSAF 2. From 288 to 319 DAP CMC 40 retained a significantly lower (p=0,05) number of leaves than both MSAF 2 and M 170.

5.3.4.2. The number of leaves present in experiment 2B

The results of this experiment are shown in Fig 5.10. At 107 DAP for p=0,01, MSAF 2 retained a significantly lower number of leaves than both CMC 40 and M 170. At 135 DAP CMC 40 and M 5 retained a significantly higher (p=0,01) number of leaves than MSAF 2. At 166 DAP the number of leaves in CMC 40 and M 170 was significantly higher (p=0,01) than in MSAF 2 and M 5. At 196 DAP MSAF 2 had a significantly lower (p=0,01)
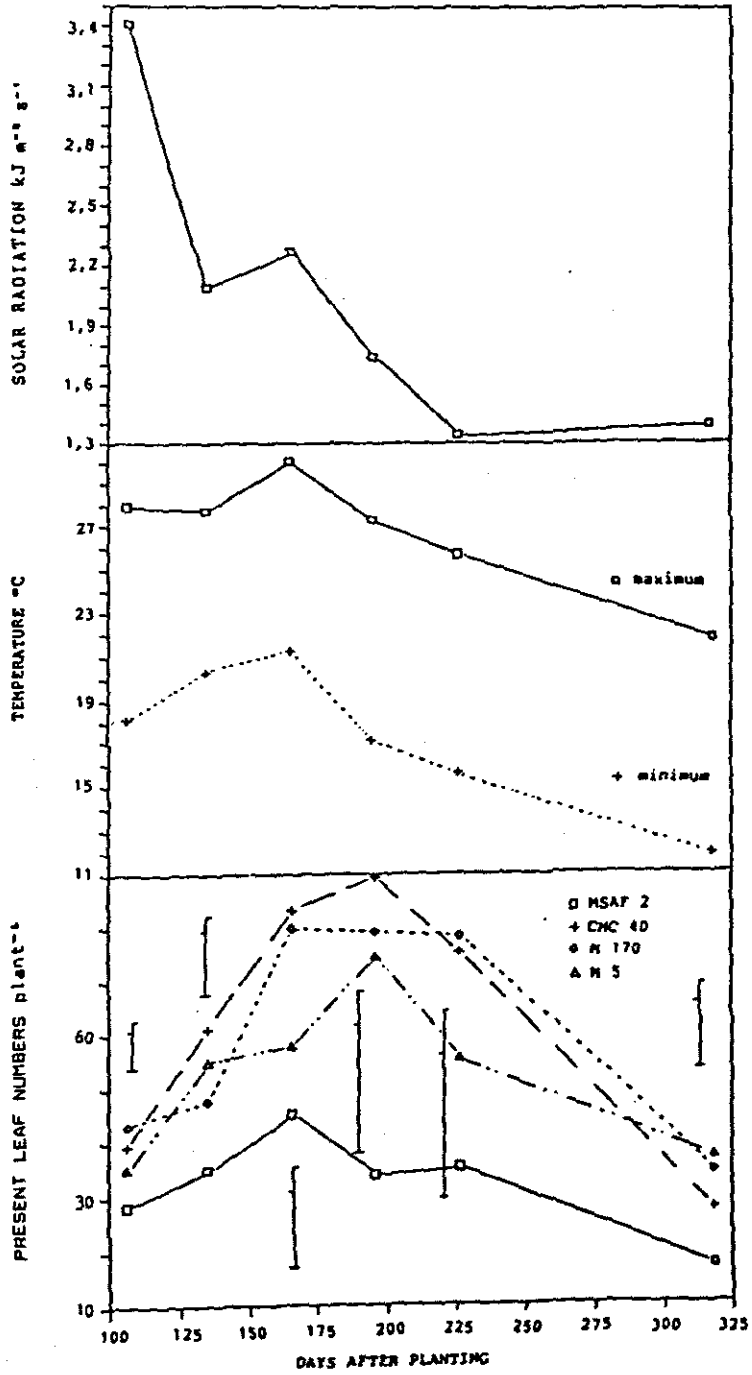
Figure 5.10 Temperature, solar radiation and present leaf numbers for cassava cultivars at different times after planting for Experiment 2B.

Figure 5.11 Temperature, rainfall, solar radiation and fallen
leaf numbers for several cassava cultivars at
different times after planting for Experiment 2A.

number of leaves than CMC 40, M 170 and M 5. At 227 DAP MSAF 2 retained a significantly lower (p=0,05) leaf number than CMC 40. For p=0,01 M 170 had a significantly higher number of leaves than MSAF 2. At 319 DAP M 170 had a significantly higher (p=0,05) number of leaves than MSAF 2. M 5 also retained a significantly higher (p=0,01) number of leaves than MSAF 2.

5.3.5. LEAF FALL

5.3.5.1. Leaf fall in experiment 2A

There was a seasonal increase in leaf fall in all the cultivars from 196 to 288 DAP (Fig 5.11). At 196 DAP leaf fall in CMC 40 and M 170 was significantly higher (p=0,01) than in MSAF 2. At 227 DAP leaf fall in M 5 was significantly higher (p=0,05) than in CMC 40. Forp=0,01 M 170 and M 5 had a significantly higher leaf fall than MSAF 2. Leaf fall in CMC 40 was significantly lower than in M 170. At 257 DAP M 5 had a significantly higher (p=0,05) leaf fall than MSAF 2. From 288 to 319 DAP M 170 had a significantly higher (p=0,05) leaf fall than MSAF 2. Leaf fall in M 5 was also significantly higher (p=0,01) than in MSAF 2.
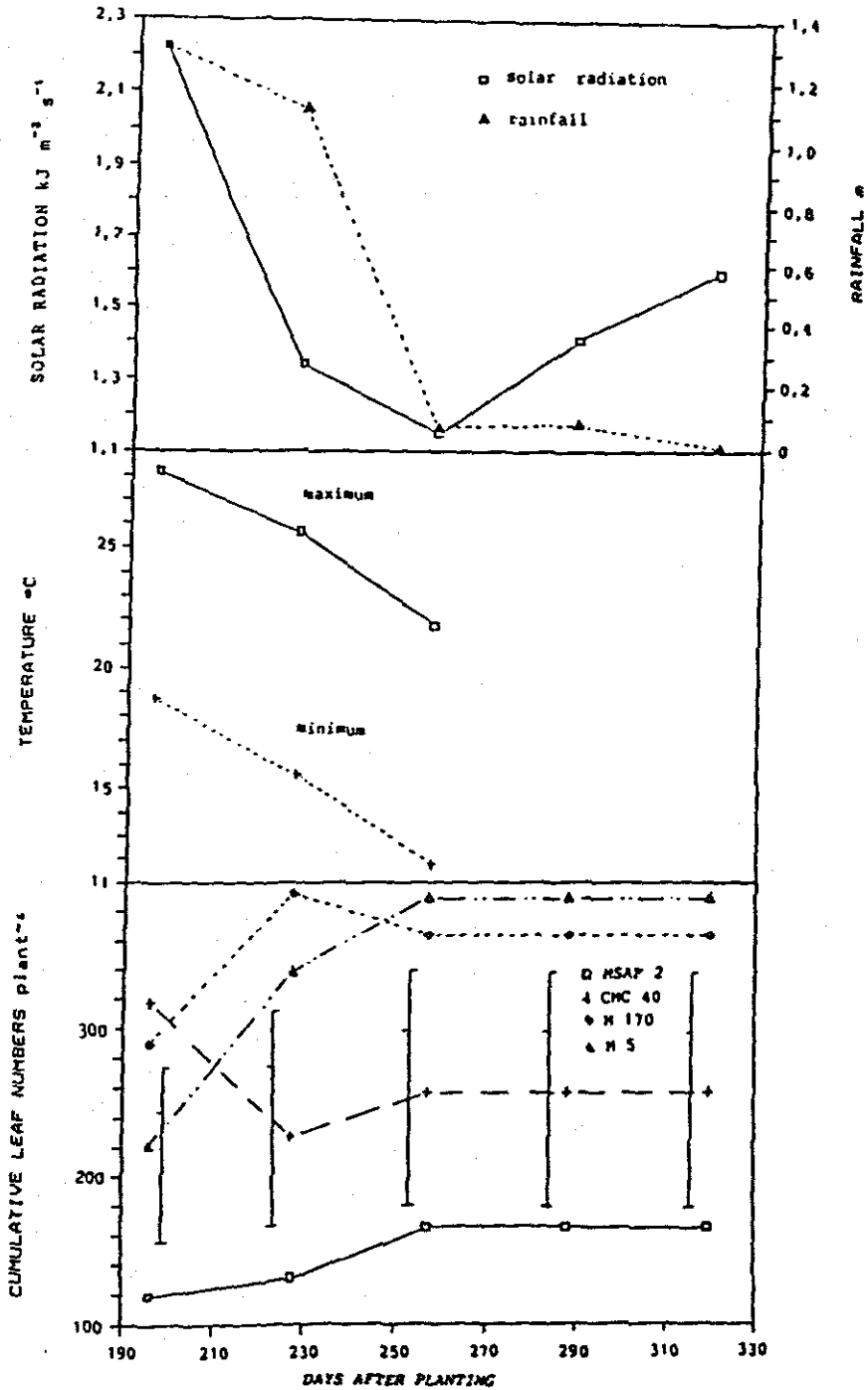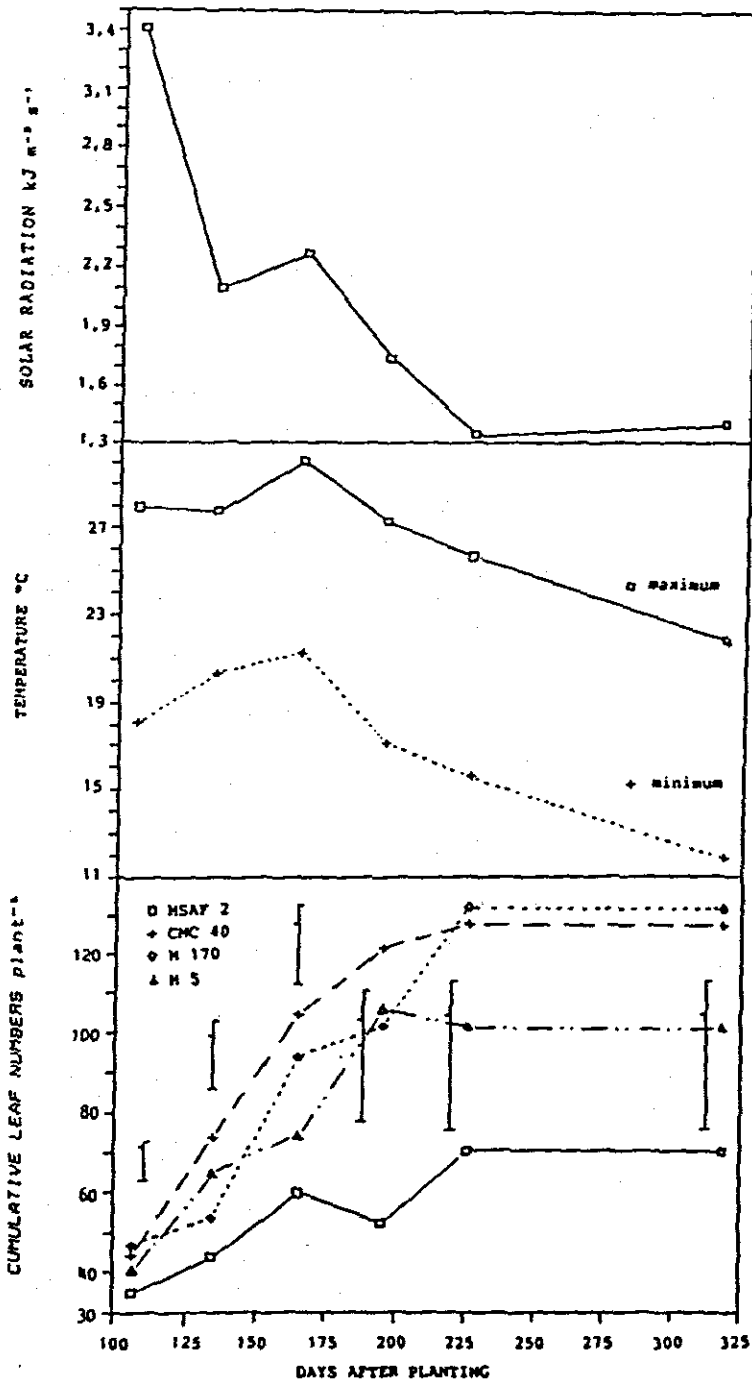
Figure 5.12 Temperature, solar radiation and fallen leaf numbers for cassava cultivars at different times after planting for Experiment 2B.

5.3.5.2. Leaf fall in experiment 2B

The results of this experiment are shown in Fig 5.12. At 107 and 227 DAP the cultivars did not differ significantly in their leaf fall. At 135 DAP leaf fall in CMC 40 was significantly higher (p=0,01) than in M 170. At 166 DAP leaf fall in CMC 40 was significantly higher (p=0,05) than in MSAF 2. For p=0,01 CMC 40 had a significantly higher leaf fall than M 170. At 196 DAP CMC 40 had a significantly higher (p=0,05) leaf fall than M 170. For p=0,01 leaf fall in CMC 40 and M 5 was significantly higher than in MSAF 2. At 319 DAP leaf fall in CMC 40 and M 170 was significantly higher (p=0,05) than in MSAF 2.

5.3.6. LEAF AREA INDEX.

5.3.6.1. Leaf area index for experiment 1

The results of this experiment are shown in Fig 5.13. In the first year of growth, there was an increase in leaf area index (LAI) from 106 to 133 DAP in all the cultivars. From 133 to 342 DAP, CMC 40, M 170 and MSAF 2 underwent a gradual decline in LAI due to seasonal leaf fall. During post winter regrowth, all the cultivars had an increase in LAI from 365 to 464 DAP. In MSAF 2 and M 5 LAI increased from 464 to 495
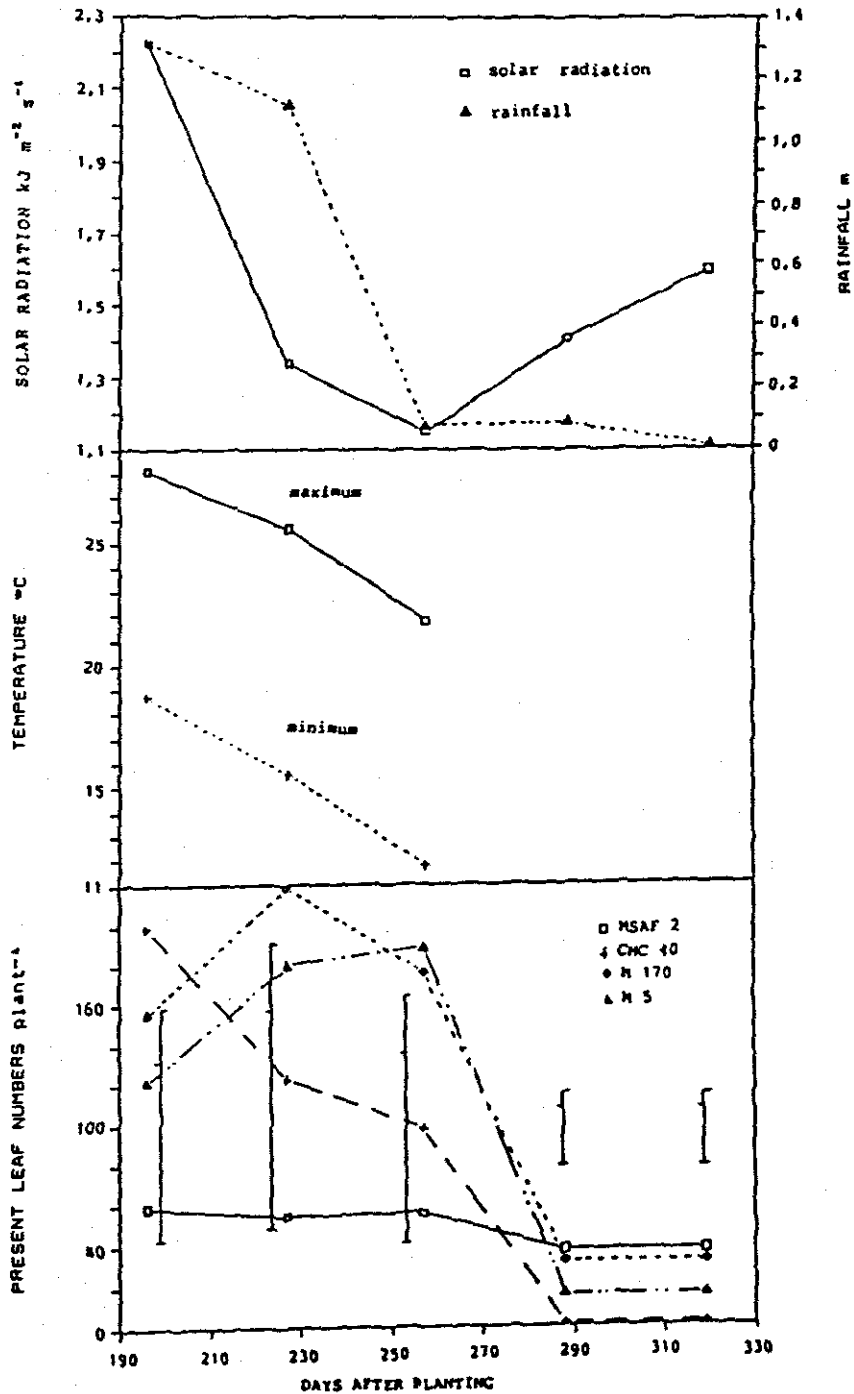
Figure 5.13 Temperature, rainfall, solar radiation and LAI for cassava cultivars at different times after planting for Experiment 1.

DAP, while in M 170 and CMC 40 there was a decline.

At 106 DAP, LAI in MSAF 2 was significantly higher (p=0,01) than in CMC 40, M 170 and M 5. At 133 DAP, MSAF 2 and CMC 40 had a significantly higher (p=0,01) LAI than M 170 and M 5. At 228 DAP, M 5 was significantly higher (p=0,01) than MSAF 2, CMC 40 and M 170. At 273 DAP, for p=0,05, CMC 40 was significantly higher than M 170. M 170 was significantly higher than MSAF 2. For p=0,01, CMC 40 and M 5 were significantly higher than MSAF 2. M 5 was significantly higher than M 170. At 307 DAP, MSAF 2 and M 5 were significantly higher (p=0,01) than M 170. At 342 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 5 and M 170 were significantly higher than CMC 40. At 365 DAP, for p=0,05, MSAF 2 was significantly higher than CMC 40. M 5 was significantly higher than M 170. For p=0,01, MSAF 2 was significantly higher than M 170. At 403 DAP, M 170 was significantly higher (p=0,01) than MSAF 2, CMC 40 and M 5. At 433 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 and M 170 were significantly higher than M 5. At 464 DAP, MSAF 2 and CMC 40 were significantly higher (p=0,01) than M 170 and M 5. At 495 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 was significantly higher than M 170 and M 5. M 5 was significantly higher than M 170.
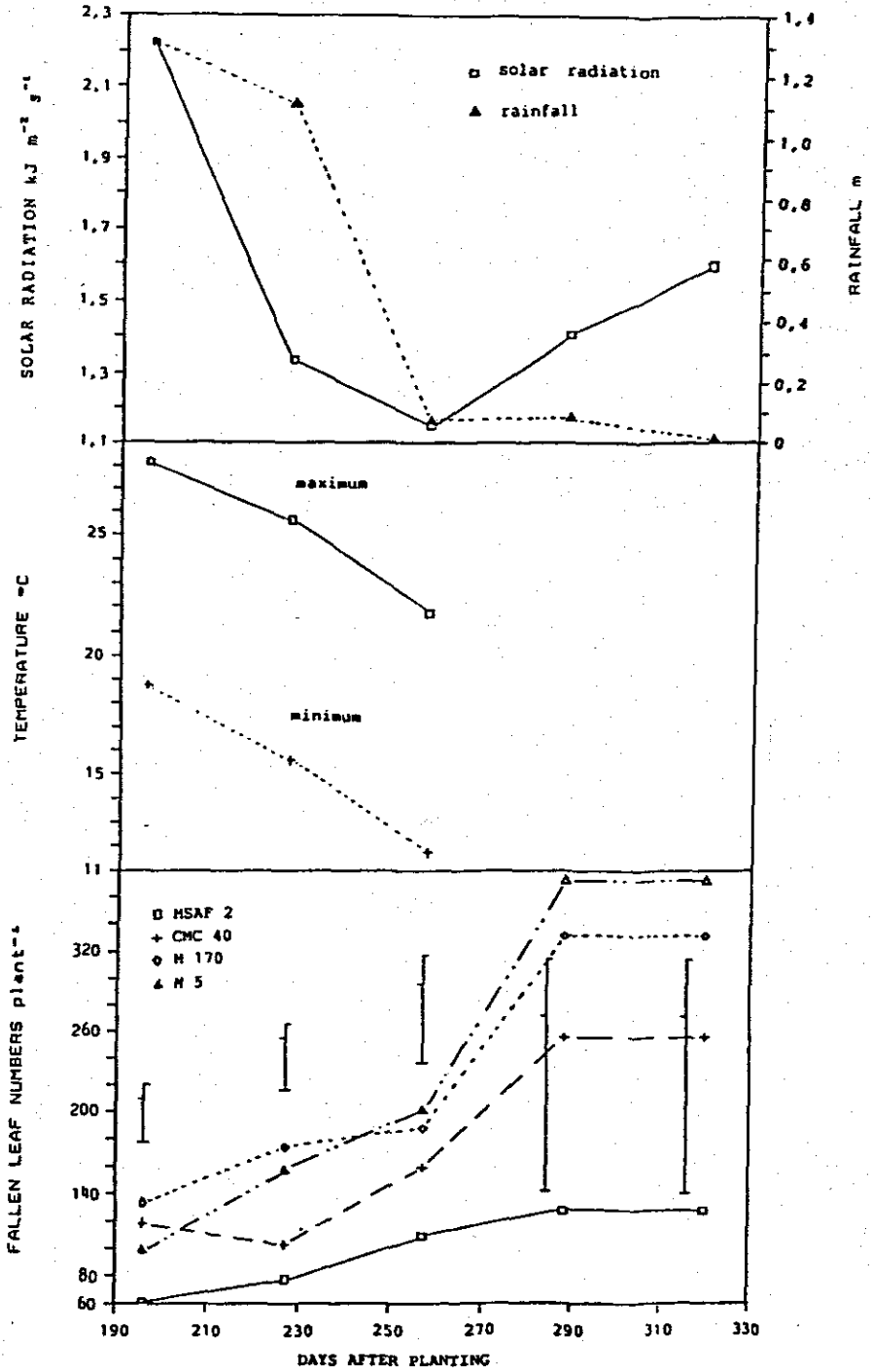
Figure 5.13   Temperature, rainfall, solar radiation and LAI   for

cassava cultivars at different times after planting

for Experiment 1.

DAP, while in M 170 and CMC 40 there was a decline.

At 106 DAP, LAI in MSAF 2 was significantly higher (p=0,01) than in CMC 40, M 170 and M 5. At 133 DAP, MSAF 2 and CMC 40 had a significantly higher (p=0,01) LAI than M 170 and M 5. At 228 DAP, M 5 was significantly higher (p=0,01) than MSAF 2, CMC 40 and M 170. At 273 DAP, for p=0,05, CMC 40 was significantly higher than M 170. M 170 was significantly higher than MSAF 2. For p=0,01, CMC 40 and M 5 were significantly higher than MSAF 2. M 5 was significantly higher than M 170. At 307 DAP, MSAF 2 and M 5 were significantly higher (p=0,01) than M 170. At 342 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 5 and M 170 were significantly higher than CMC 40. At 365 DAP, for p=0,05, MSAF 2 was significantly higher than CMC 40. M 5 was significantly higher than M 170. For p=0,01, MSAF 2 was significantly higher than M 170. At 403 DAP, M 170 was significantly higher (p=0,01) than MSAF 2, CMC 40 and M 5. At 433 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 and M 170 were significantly higher than M 5. At 464 DAP, MSAF 2 and CMC 40 were significantly higher (p=0,01) than M 170 and M 5. At 495 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 was significantly higher than M 170 and M 5. M 5 was significantly higher than M 170.

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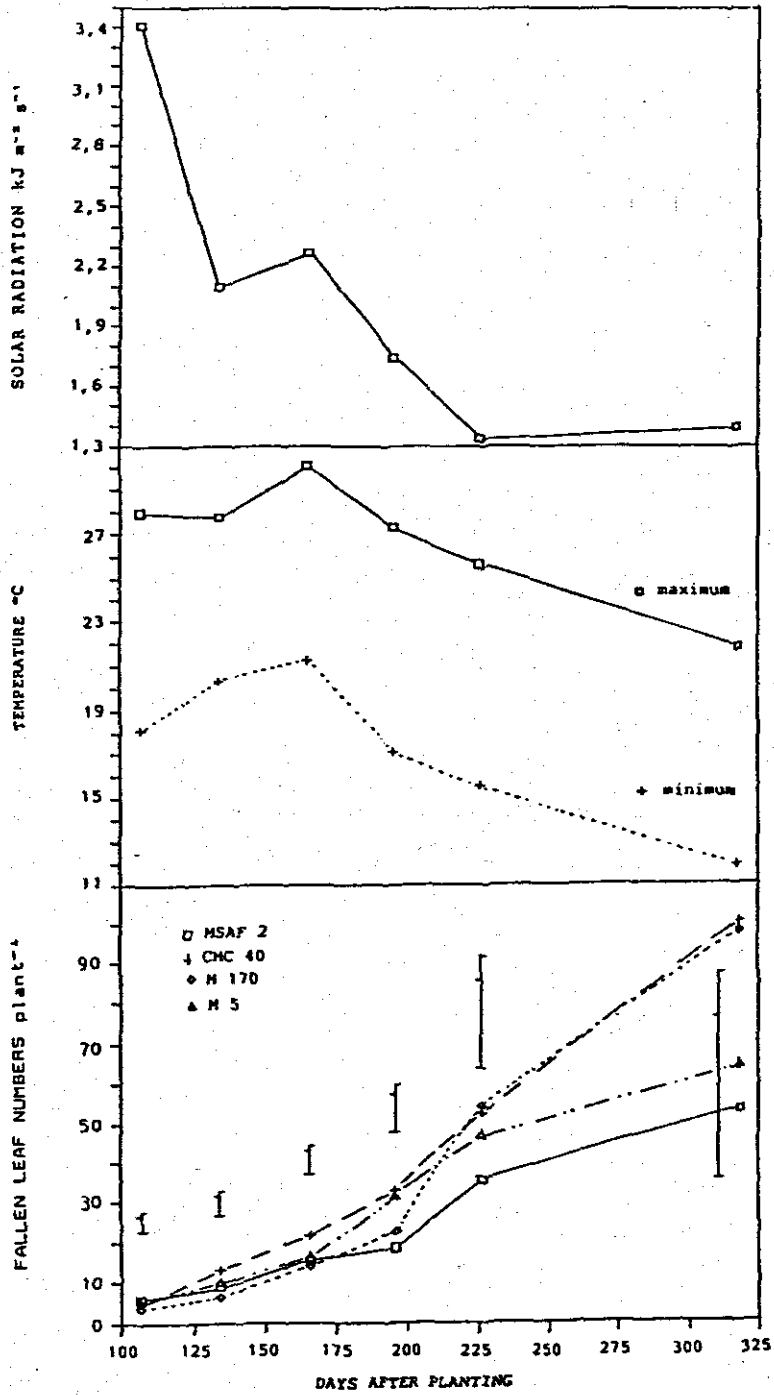Figure 5.14   Temperature, rainfall, solar radiation and LAI   for

cassava cultivars at different times after planting

for Experiment 2A.

5.3.6.2. Leaf area index for experiment 2A

The results of this experiment are shown in Fig 5.14. M 170 and M 5 had an increase in LAI from 196 to 227 DAP. From 227 to 288 DAP, all the cultivars had a decline in LAI.

At 196 DAP, for p=0,01, CMC 40 had a significantly higher LAI than MSAF 2, M 170 and M 5. MSAF 2 was significantly higher than M 170 and M 5. M 5 was significantly higher than M 170. At 227 DAP, M 5 was significantly higher (p=0,01) than CMC 40. At 257 DAP, for p=0,05, M 170 was significantly higher than CMC 40. For p=0,01, MSAF 2 and M 5 were significantly higher than CMC 40. M 5 was significantly higher than M 170. At 288 and 319 DAP, for p=0,05, M 5 was significantly lower than MSAF 2 and significantly higher than CMC 40. For p=0,01, MSAF 2 was significantly higher than CMC 40 and M 170.

5.3.6.3. Leaf area index for experiment 2B

The results of this experiment are shown in Fig 5.15. From 107 to 135 DAP, there was an increase in LAI in all the cultivars. M 5 and CMC 40 reached their maximum LAI at 135 DAP while MSAF 2 and M 170 reached their maximum LAI at 166 DAP. There was a general decline in LAI from 196 to 319 DAP in all the cultivars.
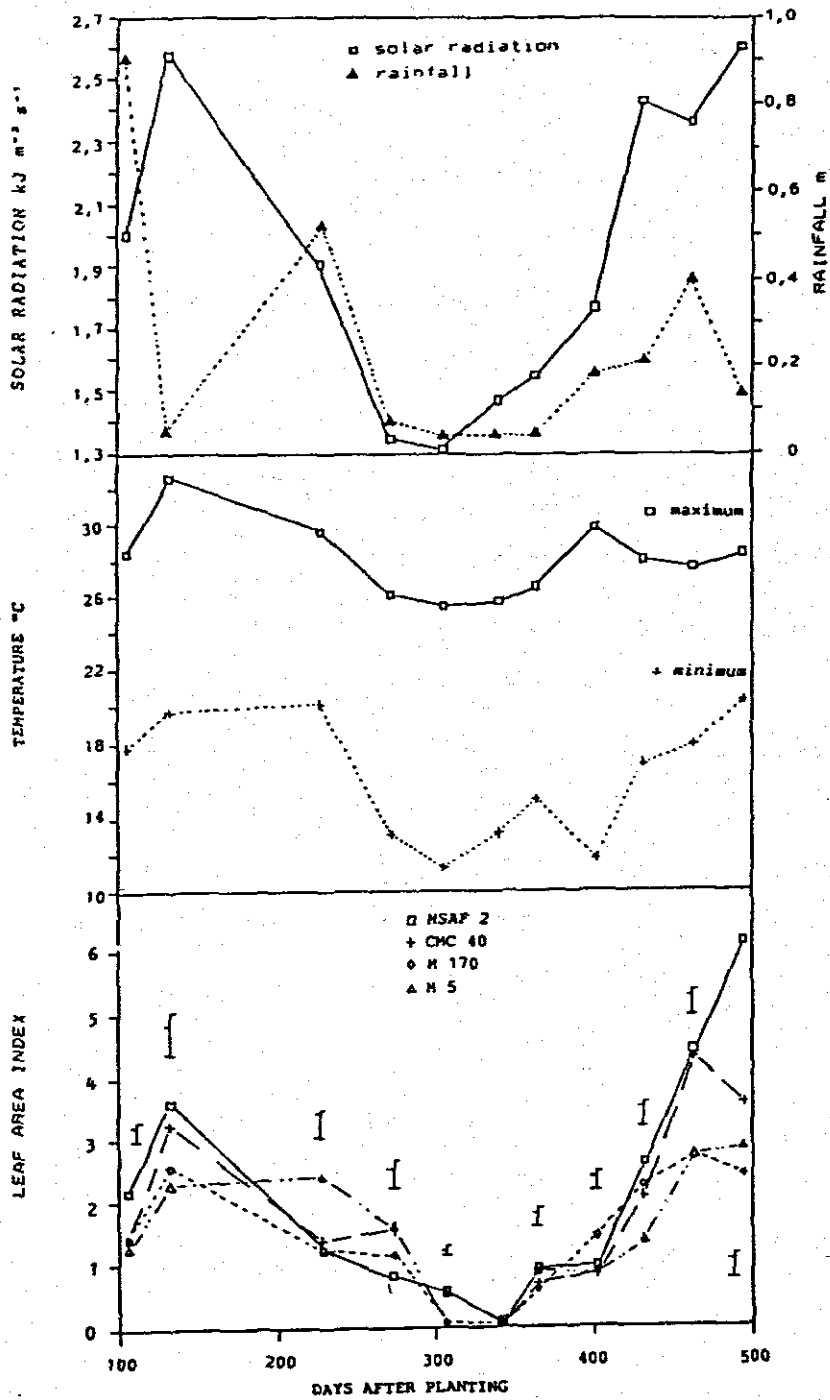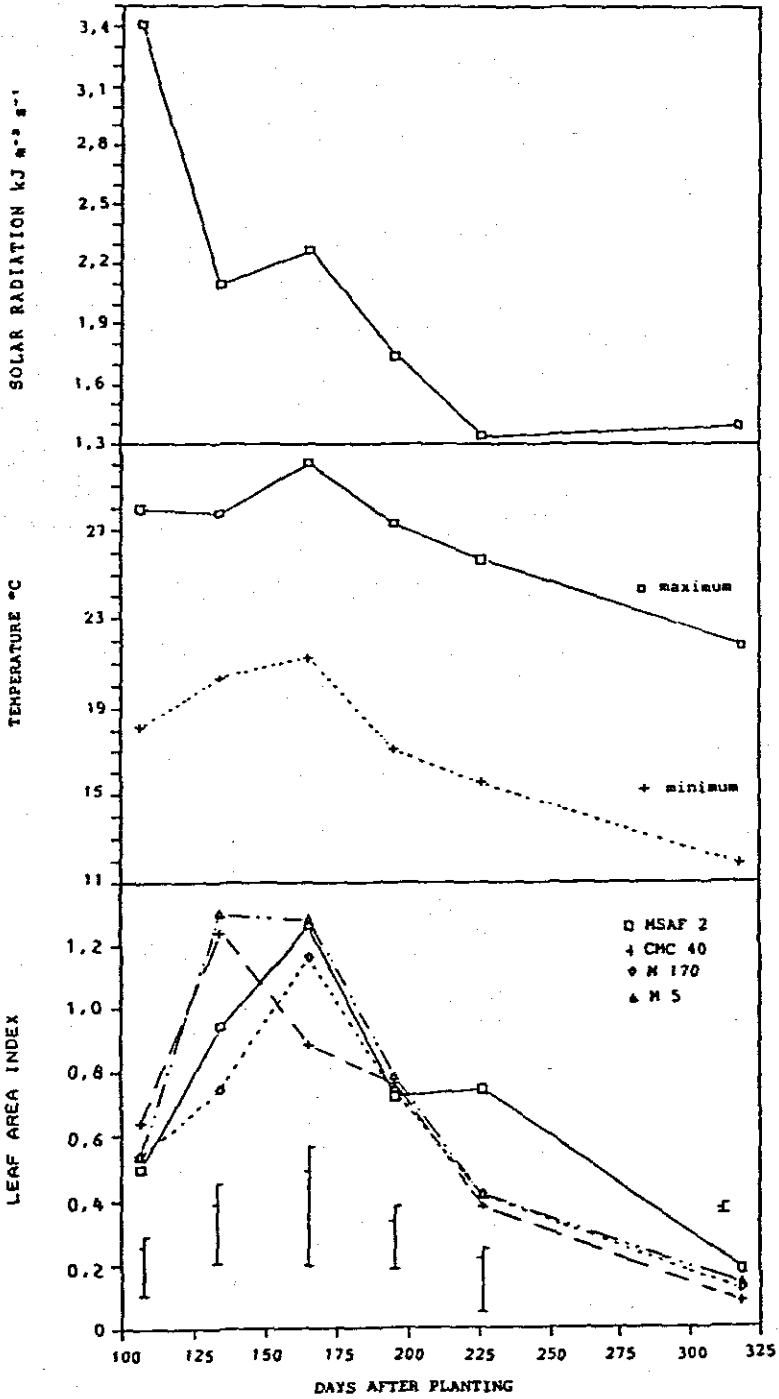
Figure 5.15 Temperature, solar radiation and LAI for cassava cultivars at different times after planting for Experiment 2B.

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At 107 and 196 DAP, the cultivars did not differ significantly in their LAI. At 135 DAP, for p=0,05, MSAF 2 was significantly higher than M 170. For p=0,01, CMC 40 and M 5 were significantly higher than MSAF 2 and M 170. At 166 DAP, MSAF 2 and M 5 were significantly higher (p=0,01) than CMC 40. At 227 DAP, MSAF 2 was significantly higher (p=0,01) than CMC 40, M 170 and M 5. At 319 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 5 was significantly higher than CMC 40 and M 170. M 170 was significantly higher than CMC 40.
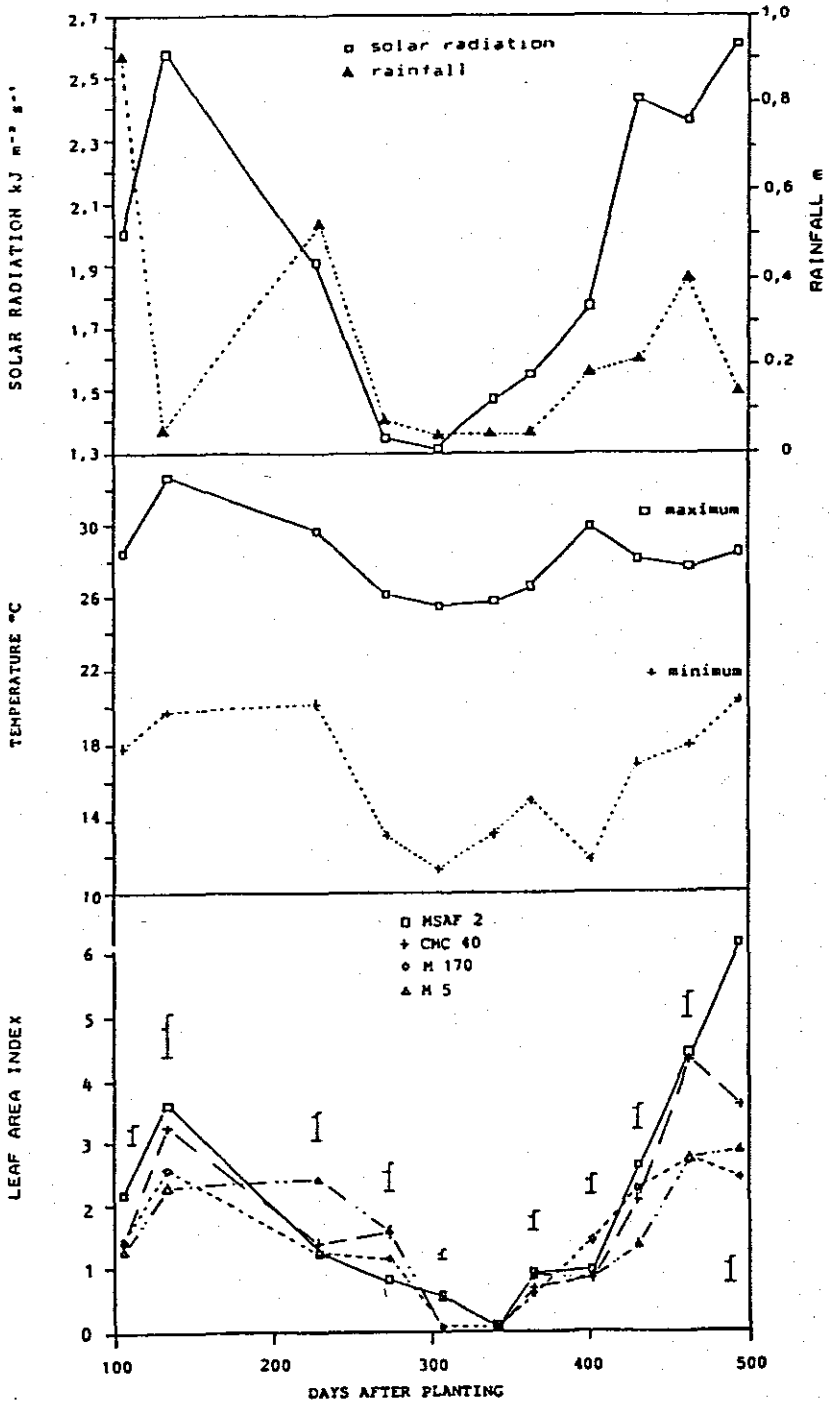
5.3.7 Leaf area duration

$$D = \frac{(L_1 + L_2).(t_2 - t_1)}{2}$$

where L= leaf area index

t= time

Leaf area duration is a measure of the persistance of the assimilatory surface (Coombs et al, 1985). In experiment 2A, M 5 had a higher leaf area duration than M 170 yet their yields did not differ significantly (Fig 5.17 and Fig 4.5). In experiment 1 at 495 DAP, the leaf area duration in M 170 was slightly lower than that of MSAF 2, CMC 40 and M 5 (Fig 5.16), yet its yield was
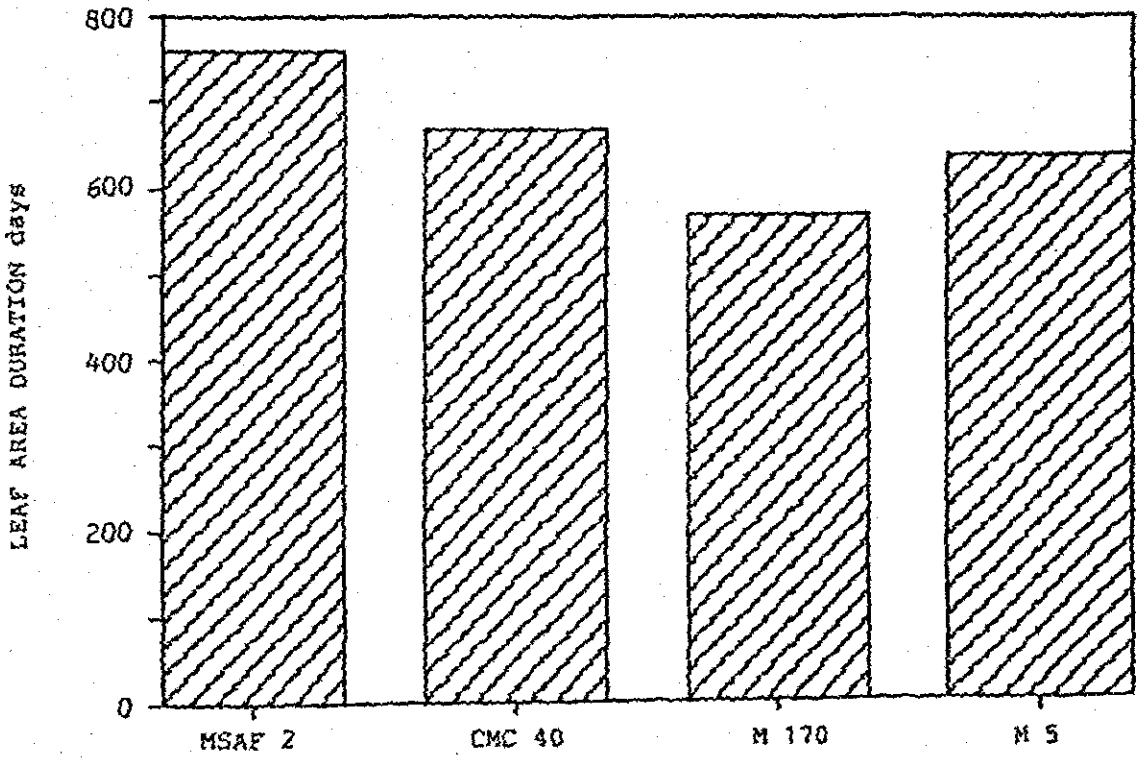
Figure 5.16 Leaf area duration for cassava cultivars at 495 DAP for

Experiment 1.
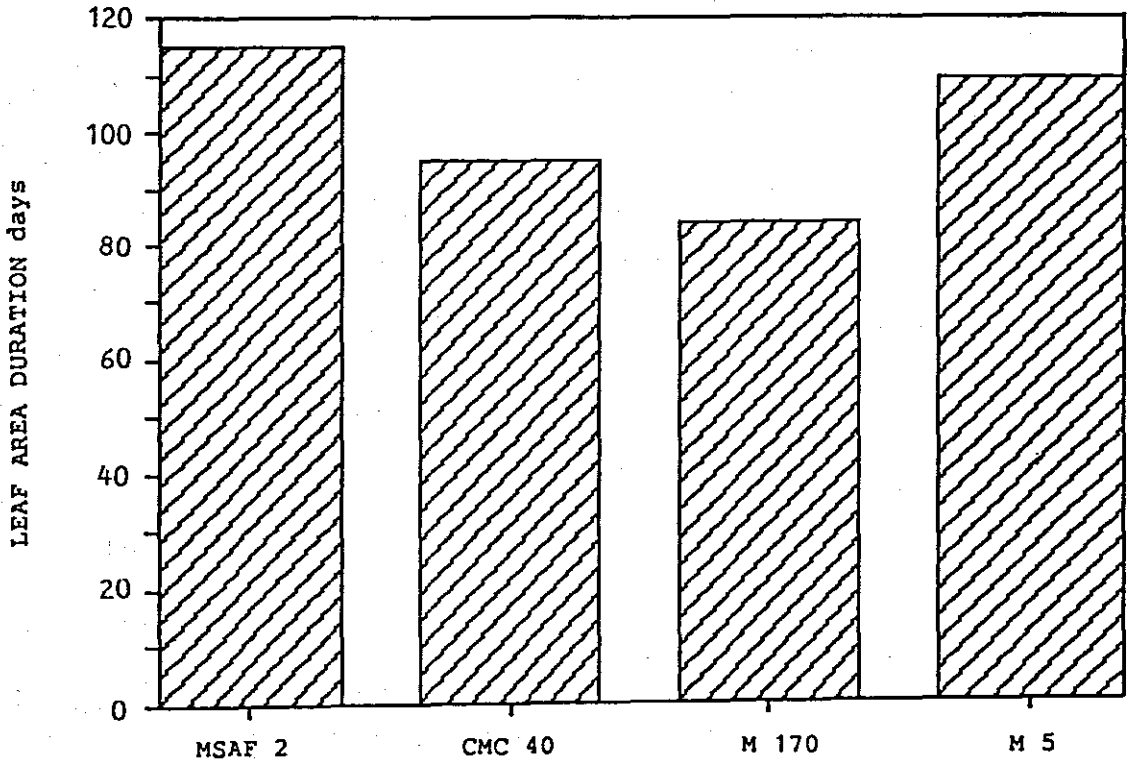
Figure 5.17   Leaf area duration for cassava cultivars   at 319 DAP   for
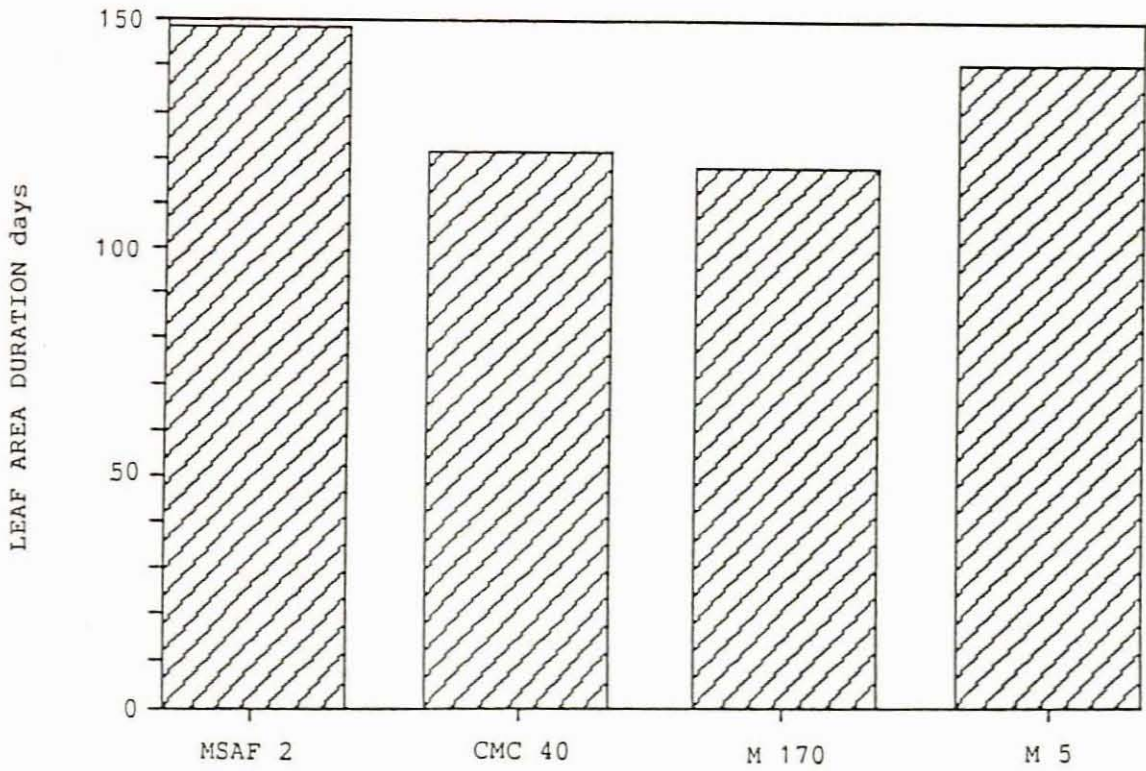
Experiment 2A.

Figure 5.18 Leaf area duration for cassava cultivars at 319 DAP for Experiment 2B.

significantly higher than that of M 5 (Fig 4.4). In experiment 2B, MSAF 2 had a higher leaf area duration than M 170, yet their yields did not differ significantly (Fig 4.6 and Fig 5.18). In the same experiment 2B, M 5 had a higher leaf area duration than M 170, yet its yield was significantly lower than in M 170. Therefore, a high leaf area duration did not always result in a high yield in the experiments which were performed.

5.4. DISCUSSION AND CONCLUSIONS

Non - branching plants grow significantly taller than branched plants (Ramanujam, 1980). In the present study, Ramanujam's statement was not applicable. MSAF 2 lacked profuse branching and was the shortest cultivar while CMC 40 had three - point branches and was the tallest cultivar (Fig 5.3 and Fig 5.6). The maximum plant height at 433 DAP ranged from 1,25 to 1,9 m in the field plants (Fig 5.1). In the potted plants at 319 DAP, the maximum plant height ranged from 0,52 to 1,41 m (Fig 5.3).

Branching has important implications in terms of canopy development and dry matter partitioning (Keating *et al*, 1982a). Profuse branching habit is undesirable as the growth of the aerial part increased more in proportion to the growth of tubers, resulting in lower HI (Ramanujam,

1980). In the present study, Ramanujam's statement was applicable to CMC 40 and M 5. Both cultivars had more stem DM than M 170. On the otherhand, profuse branching in M 170 resulted in the increase in LAI as it was narrow-lobed. In experiment 2A at 319 DAP, the broad-lobed MSAF 2 lacked profuse branching while the narrow-lobed M 170 possessed it, and the yield in MSAF 2 was significantly higher than in M 170 (Fig 4.5; Fig 5.5). In experiment 1 and 2B at 319 DAP, MSAF 2 lacked profuse branching while M 170 possessed it, yet the two cultivars did not differ significantly in their root yields (Fig 4.4; 4.6; 5.4 and 5.6). Therefore, in the present study Ramanujam's statement was not applicable in the cultivar M 170.

The cumulative leaf number per plant at all harvests was lowest in the non - branching MSAF 2 than in the branched CMC 40, M 170 and M 5. In experiment 2A at 319 DAP, both M 170 and M 5 had a higher cumulative leaf number than MSAF 2 (Fig 5.7) whereas in experiment 2B at 319 DAP, M 170 and CMC 40 had a significantly higher cumulative leaf number than MSAF 2 (Fig 5.8). As profuse branching increased, the newly formed leaves had a smaller area. Increased leaf life is associated with a high yield (Irikura et al, 1979). In experiment 2A at 319 DAP, CMC 40 had the lower winter retention of leaves than MSAF 2 (Fig 5.9) although their yields did not differ

significantly (Fig 4.5). In experiment 2B at 319 DAP, M 170 had a higher winter retention of leaves than MSAF 2 although their yields did not differ significantly (Fig 4.6 and 5.10). Therefore, in the present study, increased leaf life was not associated with a high yield.

The leaf fall is caused by severe water stress (Ike and Thurtell, 1981) and by a 95 % shading combined with a translocated factor, probably auxin (Rosas, Cock & Sandoval, 1976). In the present study, the cultivars with profuse branching (CMC 40, M 170 and M 5) had the higher rate of leaf fall than MSAF 2.

The flowering in cassava is associated with profuse branching. Because profuse branching was lacking in MSAF 2, no seed and fruit formation occurred in 1988 and 1989 experiments (Fig 5.4 and Fig 5.6).

Keating et al, (1982c) obtained a LAI as high as 14 per year. In the present study, the highest LAI obtained was 3,6 per year in MSAF 2. Over the same period of time, Cock (1976) and Enyi (1973) obtained a maximum LAI of 8. Therefore, the cultivars cultivated in South Africa gave a much lower LAI. The cultivars with a high LAI were better yielders than those with a low LAI (Sinha and Nair, 1971; Enyi, 1973). In order to improve yield, plants should maintain a LAI from 3 to 3,5 for a long period

(Anonymous, 1976). In the present study, MSAF 2 had the highest LAI at 495 DAP (Fig 5.13), yet it did not outyield M 170 (Fig 4.4).

The total dry matter and LAI were higher in plants grown in the field (experiment 1 and 2A) than in potted plants (experiment 2B). Thus pots suppressed the production of total dry mass. At 495 DAP, MSAF 2 had the highest LAI (Fig 5.13). According to Keating et al (1982c), the total DM is predicted to increase up to LAI 6-11 depending on the temperature. In the present study, the total DM increased up to LAI 1,3 in potted plants (Fig 4.3; Fig 5.15) and to LAI 2,4 - 6,1 in field plants (Fig 4.1; 4.2; 5.13 and 5.14).

A high leaf area duration is associated with a high yield (Sinha and Nair, 1971). In experiment 2A, leaf area duration and yield were higher in MSAF 2 than in M 170 (Fig 4.5 and Fig 5.17). In experiment 1 at 495 DAP, M 170 outyielded M 5 although its leaf area duration was slightly lower than that in M 5 (Fig 4.4 and Fig 5.16). In experiment 2B, M 5 with a higher leaf area duration than M 170, had a significantly lower yield than M 170 (Fig 4.6 and Fig 5.18). Thus a high leaf area duration did not always result in a high yield.

In all the experiments, plant height, profuse branching, cumulative leaf numbers, present leaf numbers, leaf fall and leaf area index followed a seasonal pattern.

CHAPTER SIX

6. PHOTOSYNTHESIS, WATER RELATIONS AND CHLOROPHYLL A
CONTENT

6.1. INTRODUCTION

The organic matter in the plant body is derived from photosynthesis and the accumulation of organic matter in the vegetation requires photosynthetic energy. Total net photosynthesis per unit soil surface (m^2) is a function of light energy absorbed per unit leaf area, the response of net photosynthesis to light, total leaf area (m^2) and the number of days of assimilation. Net photosynthesis is a function of light intensity, CO_2 concentration in the atmosphere within the vegetation, temperature, water supply, nutrition and physiological state of the plant (Lawlor, 1987). It is difficult to draw generalisations on cassava photosynthesis because data is available on a few cultivars only (San Jose, 1983).

To my knowledge, no research has been done on photosynthesis and water relations of MSAF 2. The purpose of research reported in this chapter is to compare MSAF 2,

CMC 40, M 170 and M 5 with reference to photosynthesis, water potential, transpiration and chlorophyll *a* content.

6.2 MATERIALS AND METHODS

6.2.1. Plant material and growth conditions

The cuttings used were two years old, 190 mm long, 225 mm diameter and of uniform mass in all the cultivars except M 170 whose shoots were much smaller. The planting dates were as follows:

Experiment 1 : Planting was done on 26/09/87 in experimental plots on campus of the University of Zululand.

Experiment 2A : Planting was done on 17/10/88 in experimental plots on campus of the University of Zululand.

Experiment 2B : Planting was done on 17/10/88 in 18 l polyethylene pots (bottom diameter 255 mm, top diameter 365 mm, height 335 mm) filled with stones (30 mm thick) at the bottom and a mixture of sand and topsoil from the experimental field (1:1 v/v).

Experiment 3 and 3A: Planting was done on 07/08/89 in 18 l polyethylene pots (bottom diameter 255 mm, top diameter 365 mm, height 335 mm) filled with stones (30 mm thick) at the bottom and a mixture of sand and topsoil from the experimental field (1 : 1 v/v). In experiment 3, measurements of photosynthesis, transpiration and leaf water potential were made on the same day at various time intervals in all the cultivars, whereas in experiment 3A measurements were made on one cultivar per day.

After two weeks when the cuttings were established, they were thinned to one plant per pot and all shoots but the longest were removed from the cuttings. The plants were watered with one litre of tap water twice daily. After four weeks, 20g of fertiliser 2:3:4 (30) Zn was added per pot. The plants were sprayed regularly against insects using merkaptothion. Plants in the experimental field were not watered. Potted plants were grown in the open at natural daylength. Data on photosynthesis and other parameters were recorded on the following sunny days:

Exp. 1   : 01/04/88 to 18/04/88   (203 DAP)
Exp. 2A & 2B: 01/03/89 to 23/05/89   (135 DAP)
Exp. 3   & 3A: 08/03/90 to 03/05/90   (213 DAP)

Meteorological data for the growing period have been

presented in Table 3.1. For the measurements, the experimental plants were always kept outdoors under natural environmental conditions at the University of Zululand.

6.2.2. Gas exchange measurements

Rates of CO_2 and H_2O exchange by attached leaf parts were measured using a battery portable infra-red carbon dioxide analyser (model LCA series from the Analytical development Co. Ltd, Hoddesdon, England) fitted with a Data Logger type DL2. The flow rate in the air supply unit was 300 ml per min. The air supply unit was supplied with a 4 meter air sampling probe which took air well above head height to avoid local CO_2 disturbance. A sharp pointed iron or steel rod screwed into the adaptor enabled the probe to stand upright in soft ground. Air entering air supply unit was dried by passing through a pair of absorbing columns connected in series. The chemical used was silica gel.

The Parkinson Leaf chamber had a volume of $1,2 \times 10^{-5}$ m^3. Chamber air was stirred by an inbuilt impeller ensuring concentration gradients are minimised and the leaf boundary layer resistance was small. The window area was 1120 mm^2. Adjacent to the chamber window was a sensor for monitoring photosynthetic active radiation. Additionally,

there were sensors for humidity and temperature within the chamber. The leaf chamber was positioned so that during measurement the lamina portion being measured was in the same location within the canopy as during growth, but perpendicular to the direction of irradiation.

The readings were taken rapidly (within 30 seconds). Photosynthetic measurements were made between 9:30 and 15:30. During measurements, the Data Logger collected and calculated data from the leaf chamber analyser. It uses an RCA 1802 microprocessor and has 8 kilobytes of memory which can store 240 sets of leaf chamber analyser results. The stored results were transmitted via the RS 232 interface to Hewlett Packard 86B computer where the results were re – computed using our own equations and stored on diskette. According to Anonymous (1985b), photosynthesis and transpiration are calculated as follows:

Calculate the mass flow of air per unit leaf area through the cuvette

$$W = (V/1000) \times (1/22.4) \times (273/(273+t_a)) \times (P/1.013) \times (10000/a)$$
$$= ((V \times P)/((273+t_a)a)) \times 120.311 \ mol \ m^{-2} \ s^{-1}$$

where V is the volume flow in ml s^{-1}

    P is the atmospheric pressure in bars

    a is the projected leaf area in the cuvette

    t_a is the air temperature

Assuming that dry air enters the cuvette, transpiration rate from the leaf (E) can be calculated as follows:

$$E = (e_o/(P - e_o)) \times W \text{ mol } m^{-2} \text{ } s^{-1}$$

where e_o is the water vapour pressure in the air emerging from the cuvette

$$e_o = e_s \times h_c/100$$

where e_s is the saturated vapour pressure at cuvette temperature

h_c is the relative humidity in the cuvette (%)

Assimilation rate (A) mol m^{-2} s^{-1} = $(C_i - C_c') \times W$

where c_i is the CO_2 concentration (VPM) in the dry air entering the leaf cuvette

C_c' is the diluting effect of water picked up in the leaf cuvette

$$C_c' = P \cdot C_c/(P - e_o)$$

where Cc is the corrected concentration

6.2.3. Leaf water potential

Directly after each gas – exchange measurement was completed the petiole was cut from the plant and its leaf water potential was measured by the pressure chamber (Scholander, Hammel, Bradstreet & Hemmingsen 1965). During the sample preparation bark and phloem were removed to avoid latex interference (Ike, Thurtell & Stevenson, 1978).

6.3. RESULTS

6.3.1. PHOTOSYNTHESIS AND WATER RELATIONS

6.3.1.1. Variation in PAR, transpiration and photo-synthesis from top to bottom within the canopy in MSAF 2, CMC 40, M 170 and M 5 for experiment 1.

Results of this experiment are shown in Fig 6.1 – Fig 6.3. The highest amount of PAR was observed in the top leaves and the lowest PAR in the bottom leaves. In all the cultivars, there was a decline in photosynthetic rate from top to bottom within the plant's canopy.

In the top leaves, photosynthesis in M 170 was significantly higher (p=0,05) than in M 5. For p=0,01,
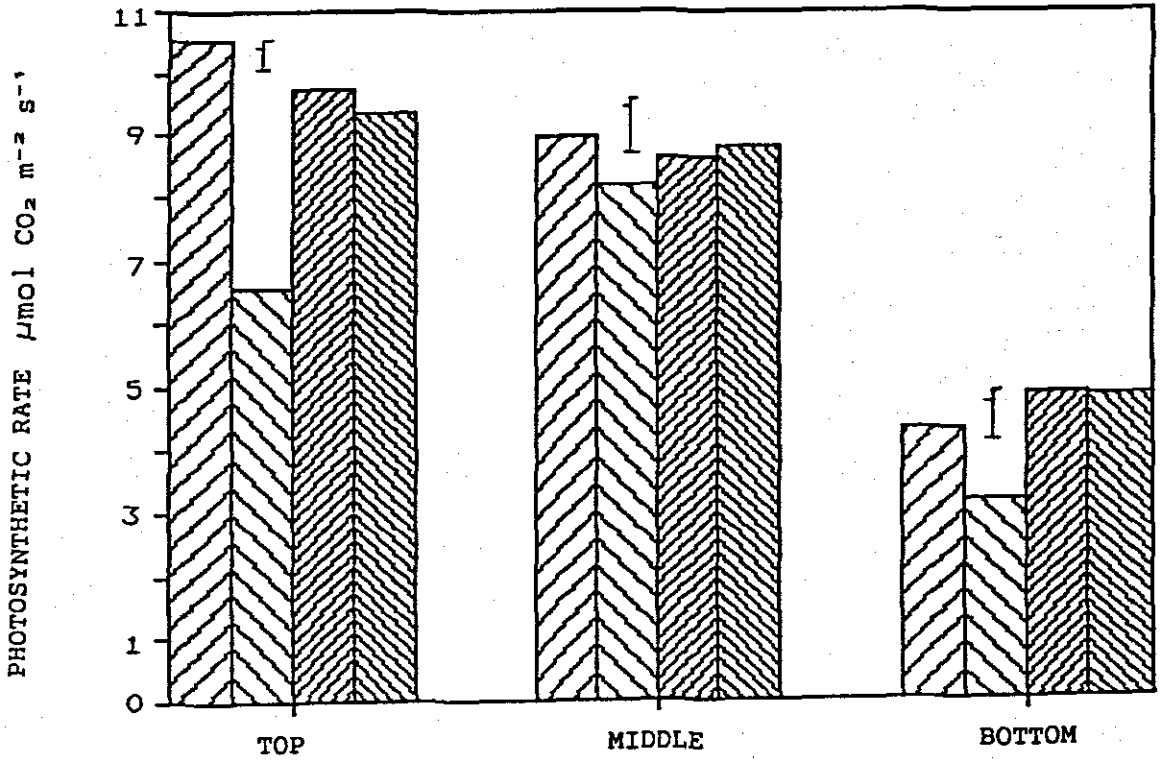
Figure 6.1 Variation in photosynthetic rate from top to bottom within the canopy in cassava cultivars MSAF 2, ▨ ; CMC 40, ▨ ; M 170, ▨ ; and M 5, ▨ .
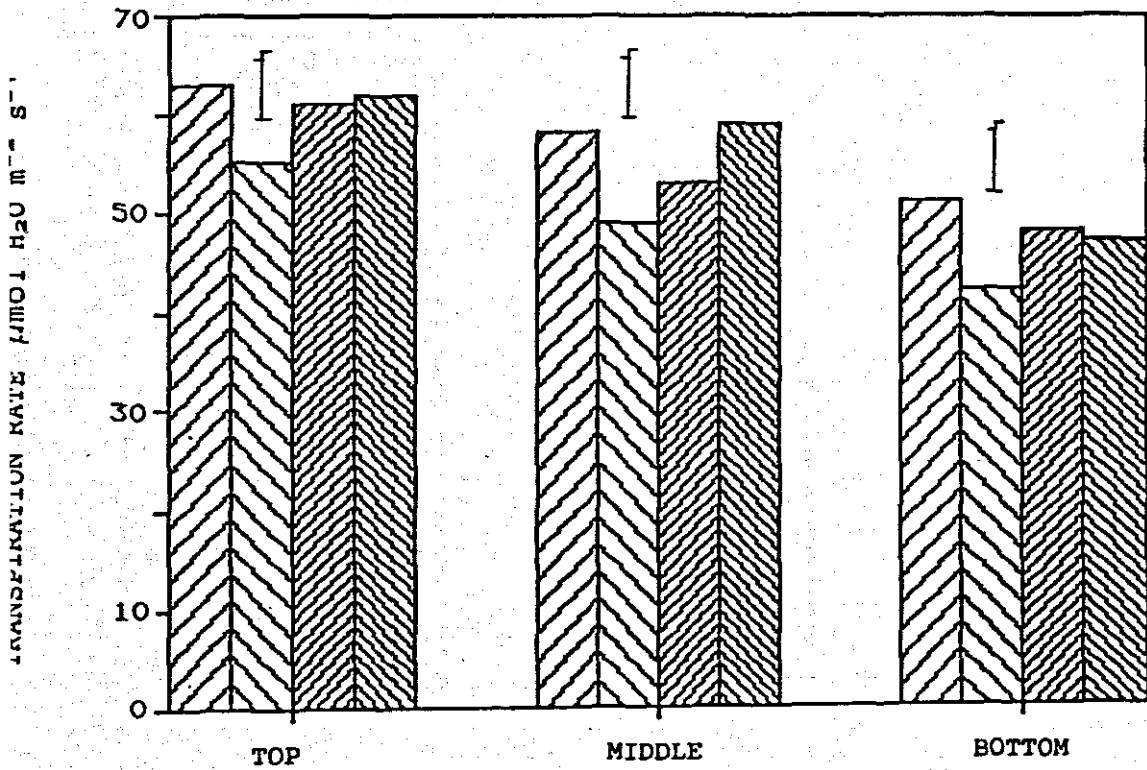
Figure 6.2 Variation in transpiration rate (T) from top to bottom

within the canopy in cassava cultivars MSAF 2, ▨ ;

CMC 40, ◩ ; M 170, ▨ ; and M 5, ▨ . (T × 100).
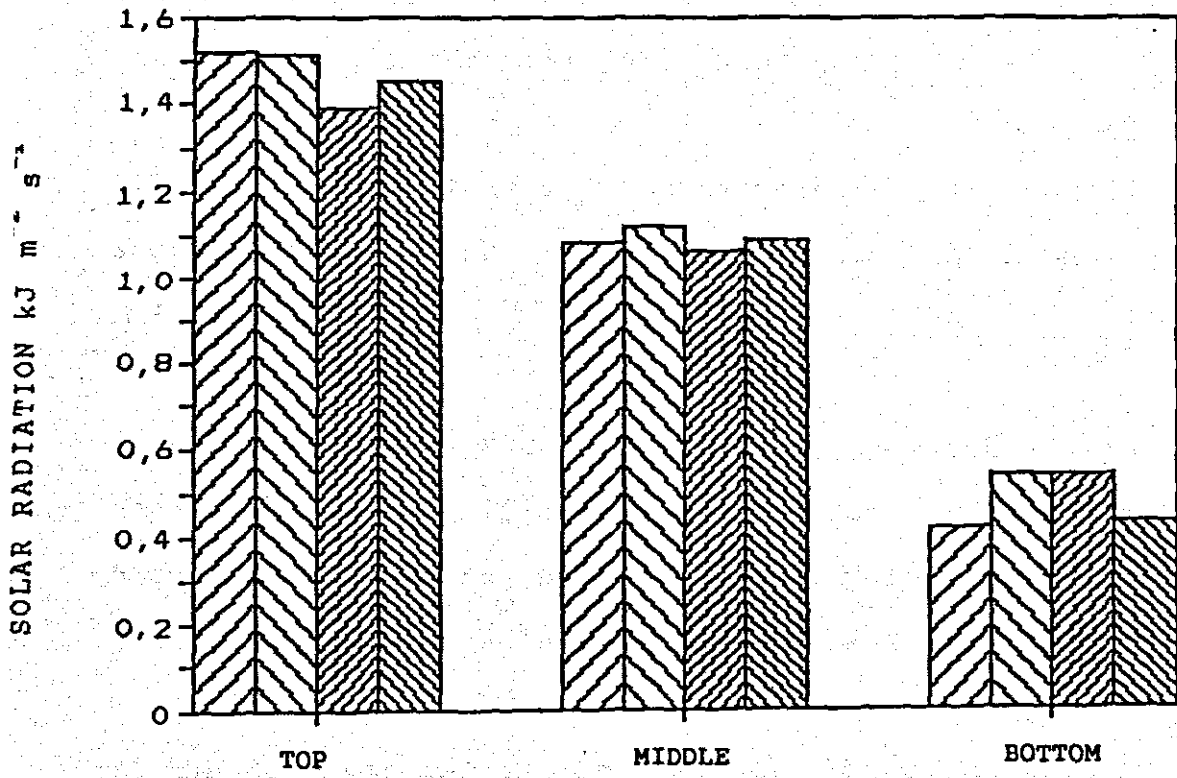
Figure 6.3 Variation in PAR from top to bottom within the canopy in cassava cultivars MSAF 2, ▨ ; CMC 40, �«ll ; M 170, ▨ ; and M 5, ▧ .

MSAF 2 had a significantly higher photosynthesis than CMC 40, M 170 and M 5. M 170 and M 5 were significantly higher than CMC 40.

In the middle leaves, photosynthesis in MSAF 2 was significantly higher ($p=0,01$) than in CMC 40.

In the bottom leaves, photosynthesis in CMC 40 was significantly lower ($p=0,01$) than in MSAF 2, M 170 and M 5.

In the cultivar MSAF 2, for $p=0,01$, photosynthesis in the top leaves was significantly higher than in the middle and bottom leaves. Photosynthesis in the middle leaves was significantly higher than in the bottom leaves.

In the cultivar CMC 40, for $p=0,01$, photosynthesis in the top leaves was significantly lower than in the middle leaves and significantly higher than in the bottom leaves. Photosynthesis in the middle leaves was significantly higher than in the bottom leaves.

In the cultivar M 170, for $p=0,01$, photosynthesis in the top leaves was significantly higher than in the middle and bottom leaves. Photosynthesis in the middle leaves was significantly higher than in the bottom leaves.

In the cultivar M 5, for p=0,05, the top leaves had a significantly higher photosynthesis than the middle leaves. For p=0,01, the top and middle leaves had a significantly higher photosynthesis than the bottom leaves.

In the top leaves, M 170 and M 5 had a significantly higher (p=0,05) transpiration than CMC 40. MSAF 2 had a significantly higher (p=0,01) transpiration than CMC 40.

In the middle leaves, M 5 had a significantly higher (p=0,05) transpiration than M 170. MSAF 2 and M 5 were significantly higher (p=0,01) than CMC 40.

In the bottom leaves, M 170 had a significantly higher (p=0,05) transpiration than CMC 40. MSAF 2 was significantly higher (p=0,01) than CMC 40.

In all the cultivars, the rate of transpiration decreased slightly from top to bottom within the plant's canopy.

In the cultivar MSAF 2, transpiration in the middle leaves was significantly higher (p=0,05) than in the bottom leaves. Transpiration in the top leaves was significantly higher (p=0,01) than in the bottom leaves.

In the cultivar CMC 40, for p=0,05, transpiration in the middle leaves was significantly lower than in the top leaves and significantly higher than in the bottom leaves. Transpiration in the top leaves was significantly higher (p=0,01) than in the bottom leaves.

In the cultivar M 170, for p=0,01, transpiration in the top leaves was significantly higher than in the middle and bottom leaves.

In the cultivar M 5, transpiration in the top and middle leaves was significantly higher (p=0,01) than in the bottom leaves.

6.3.1.2. Changes in photosynthesis and transpiration in MSAF 2, CMC 40, M 170 and M 5 from morning to afternoon for experiment 1 (1988).

The results of this experiment are shown in Fig 6.4 & 6.5. In all the cultivars there was a decline in photosynthetic rate from morning to afternoon. From 9:00-11:55, M 5 had a significantly higher (p=0,05) photosynthetic rate than CMC 40. M 170 had a significantly higher (p=0,01) photosynthetic rate than CMC 40.

From 12:00-13:55, the differences in photosynthetic rate between MSAF 2, M 170 and M 5 were not statistically
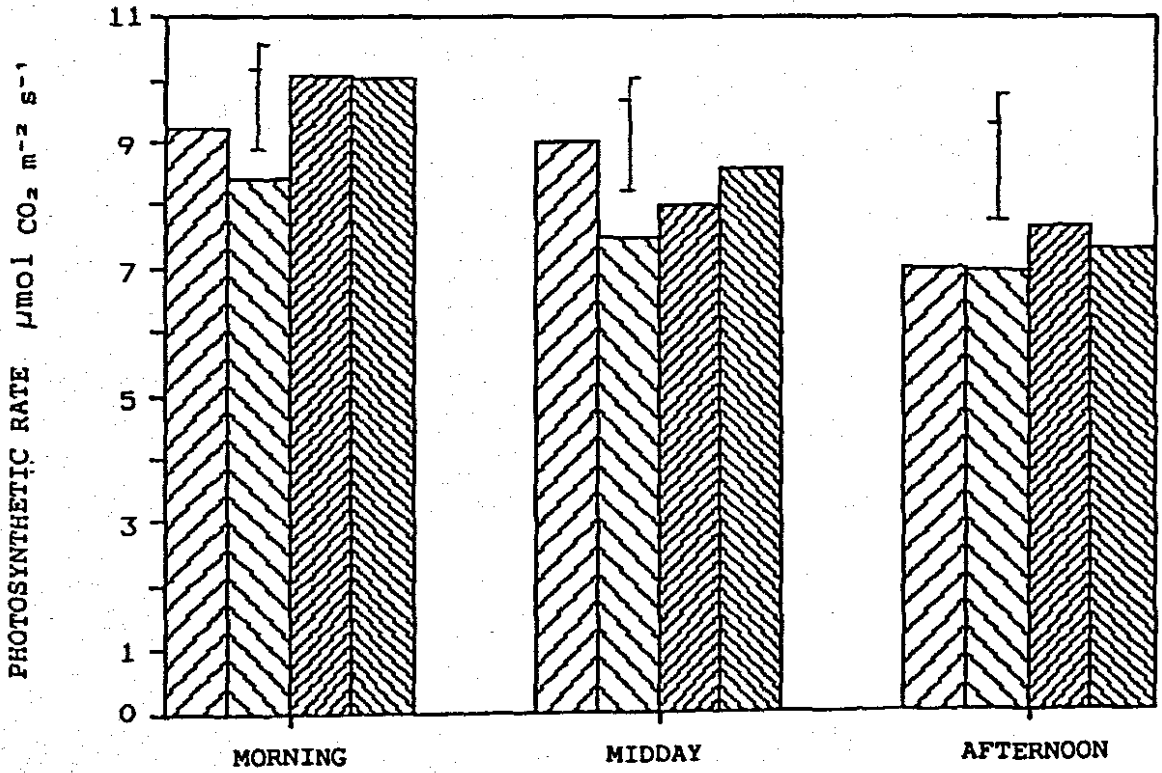
Figure 6.4 Changes in photosynthetic rate from morning to afternoon

in cassava cultivars MSAF 2, ▨ ; CMC 40, ◩; M 170,

▨ ; and M 5, ▨ in 1988.

Figure 6.5 Changes in transpiration rate (T) from morning to afternoon in cassava cultivars MSAF 2, ▨ ; CMC 40, ◩ ; M 170, ▧ ; and M 5, ▧ in 1988. (T × 100)

(p=0,01) significant. MSAF 2 had a significantly higher (p=0,05) photosynthetic rate than CMC 40.

In the afternoon (14:00-15:30), the differences in photosynthetic rate between the cultivars were not statistically significant.

In all the cultivars, there was a decline in the rate of transpiration from 9:00 to 15:30.

In the morning, MSAF 2, M 170 and M 5 did not differ significantly in their rates of transpiration. MSAF 2 had a significantly higher (p=0,05) rate of transpiration than CMC 40.

From 12:00 to 13:55, MSAF 2 had a significantly higher (p=0,05) rate of transpiration than CMC 40. M 5 also had a significantly higher (p=0,01) rate of transpiration than CMC 40.

In the afternoon (14:00-15:30), the differences in the rates of transpiration between the cultivars were not statistically significant.
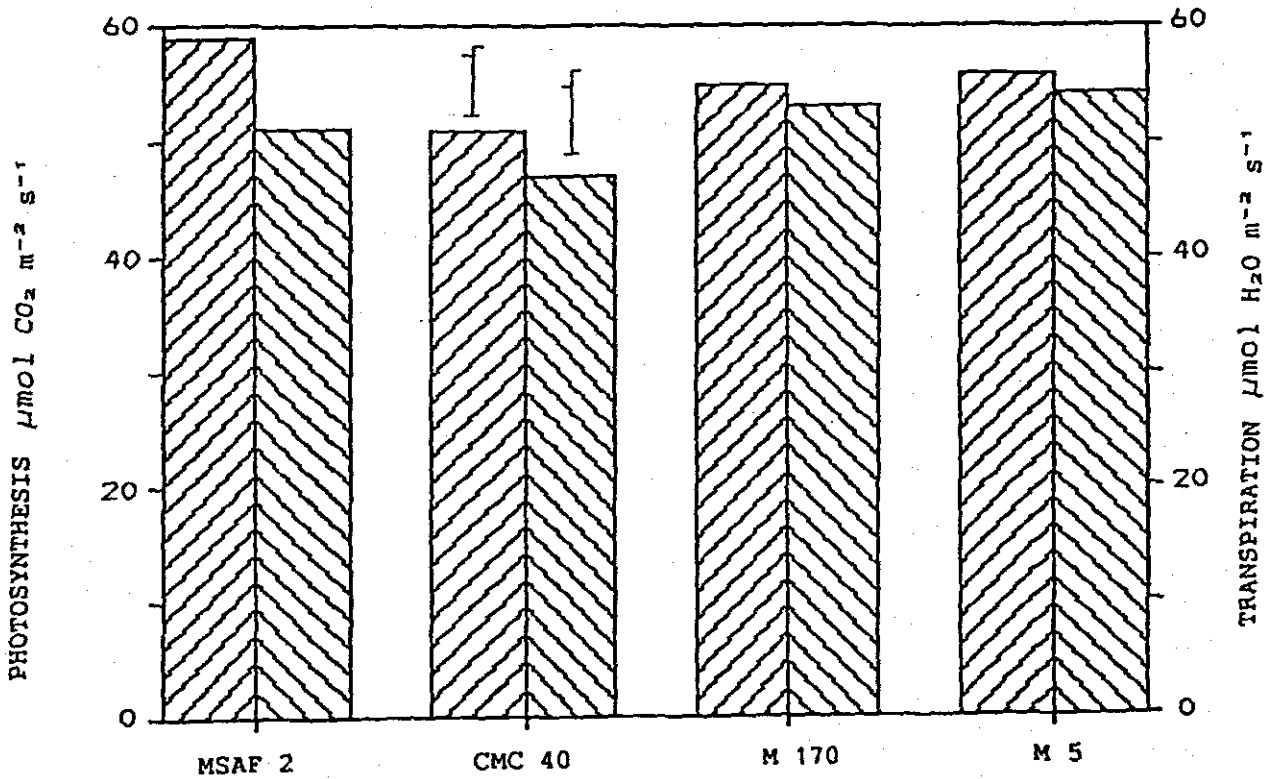
Figure 6.6 Average rates of transpiration (T) ▨ ; and photosynthesis (P) ▧ ; for cassava cultivars in 1988. ($P \div 6$; $T \times 100$).

6.3.1.3. Average transpiration and photosynthesis for the cultivars MSAF 2, CMC 40, M 170 and M 5 for experiment 1 (1988).

The results of this experiment are shown in Fig 6.6. For p=0,05, MSAF 2 and M 170 had a significantly higher photosynthetic rate than CMC 40. The photosynthetic rate in M 5 was significantly higher (p=0,01) than in CMC 40.

CMC 40 had a significantly lower (p=0,05) rate of transpiration than M 5. The rate of transpiration in MSAF 2 was significantly higher (p=0,01) than in CMC 40.

6.3.1.4. Changes in photosynthesis and transpiration in the cultivars MSAF 2, CMC 40, M 170 and M 5 from morning to afternoon for experiment 2A (1989).

Results of this experiment are shown in Fig 6.7 - Fig 6.8. In the morning (9:00 -11:55), photosynthesis in M 170 was slightly higher than in MSAF 2, CMC 40 and M 5. The lowest photosynthetic rate was observed in CMC 40. The differences in photosynthetic rates between the cultivars were not statistically significant.

At midday (12:00 -13:55), there was a decline in photosynthetic rate in the cultivars CMC 40, M 170 and M 5 while MSAF 2 had an increase. MSAF 2 had a
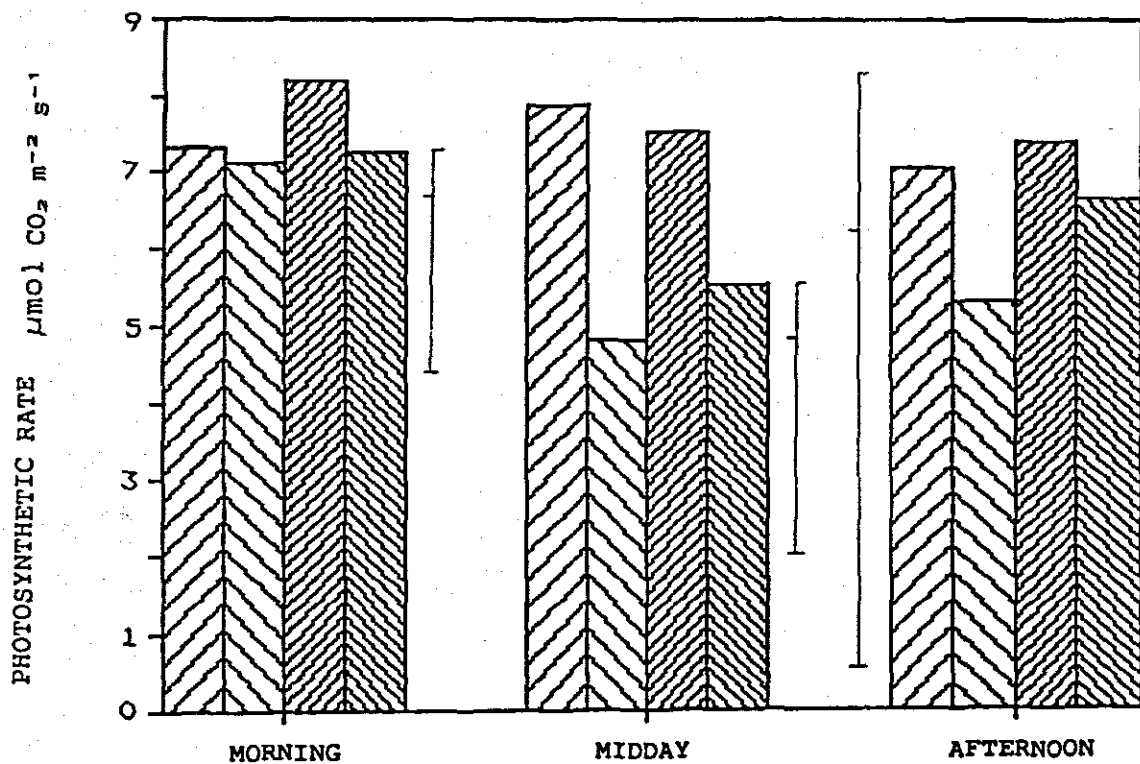
Figure 6.7 Changes in photosynthetic rate from morning to afternoon in cassava cultivars MSAF 2, ▨; CMC 40, ◩; M 170, ▨ ; and M 5, ▨ in 1989.
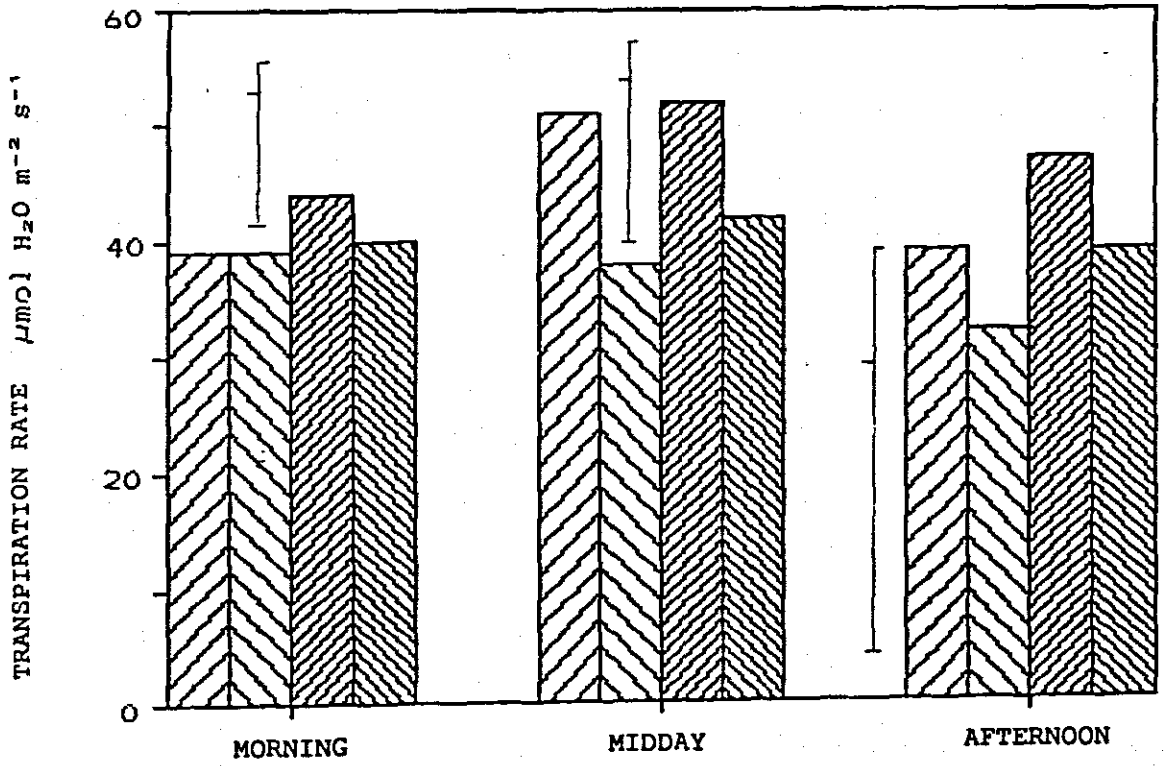
Figure 6.8 Changes in transpiration rate (T) from morning to afternoon in cassava cultivars MSAF 2, ▨ ; CMC 40, ◪ ; M 170, ▨ ; and M 5, ▨ in 1989. (T × 100).

significantly higher (p=0,05) photosynthetic rate than CMC 40.

From 14:00 to 15:30, there was a decline in photosynthetic rate in MSAF 2 and M 170 while CMC 40 and M 5 had an increase. The differences in photosynthetic rate between the cultivars were not statistically significant.
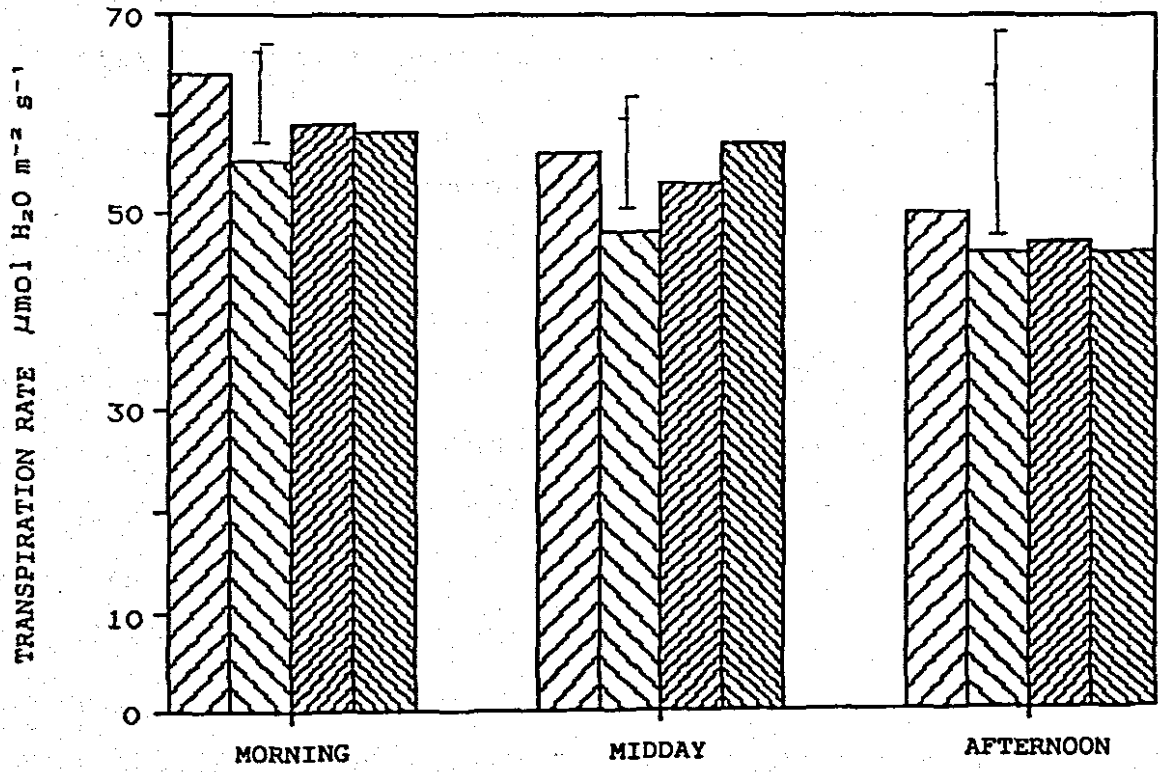
In the morning, the differences in transpiration between the cultivars were not statistically significant.

At midday, the rate of transpiration increased in MSAF 2, M 170 and M 5. In CMC 40 there was a decrease in the rate of transpiration. Transpiration rate in M 170 was significantly higher (p=0,05) than in CMC 40.

From 14:00 to 15:30, there was a decline in the rate of transpiration in all the cultivars. The differences in transpiration rate between the cultivars were not statistically significant.

6.3.1.5. Average transpiration and photosynthesis for the cultivars MSAF 2, CMC 40, M 170 and M 5 for experiment 2B (1989).

The results of this experiment are shown in Fig 6.9. The differences in photosynthetic rate between the cultivars
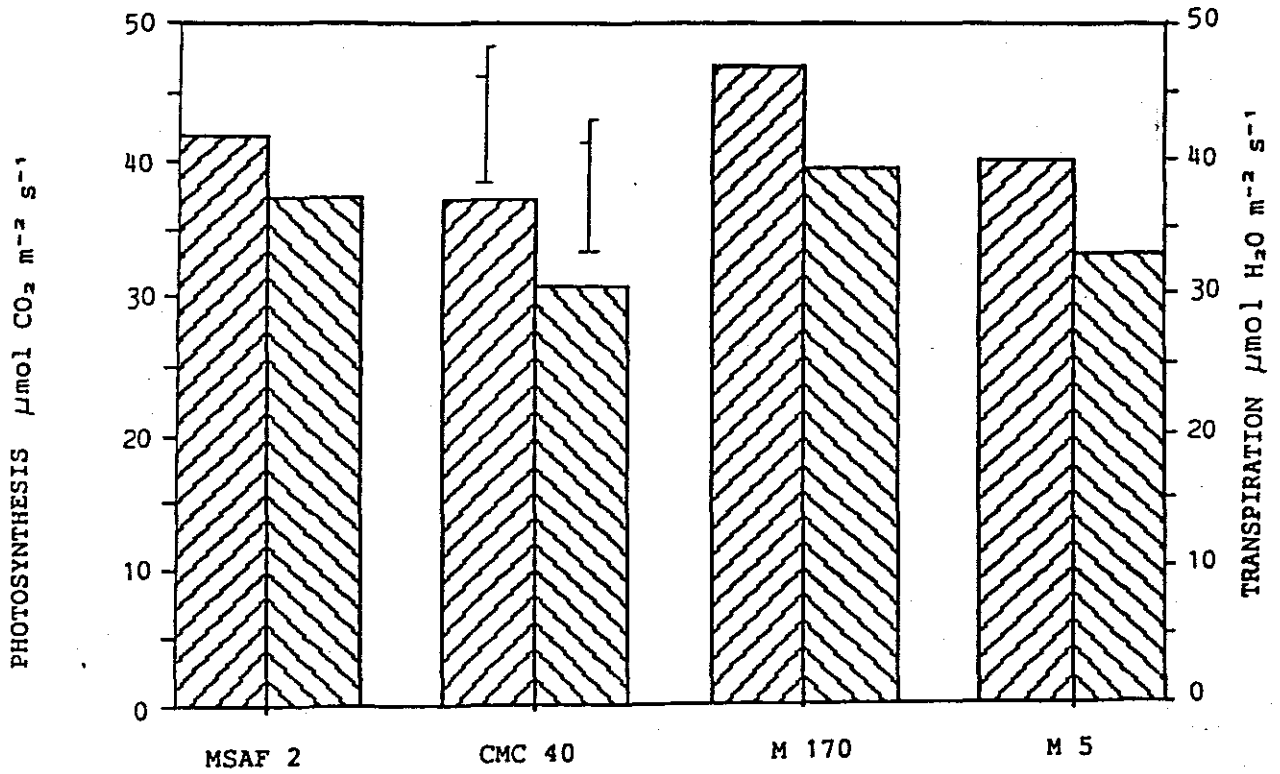
Figure 6.9 Average rates of transpiration (T) ▨ ; and photosynthesis (P) ◩ ; for cassava cultivars in 1989. (P ÷ 5; T × 100).
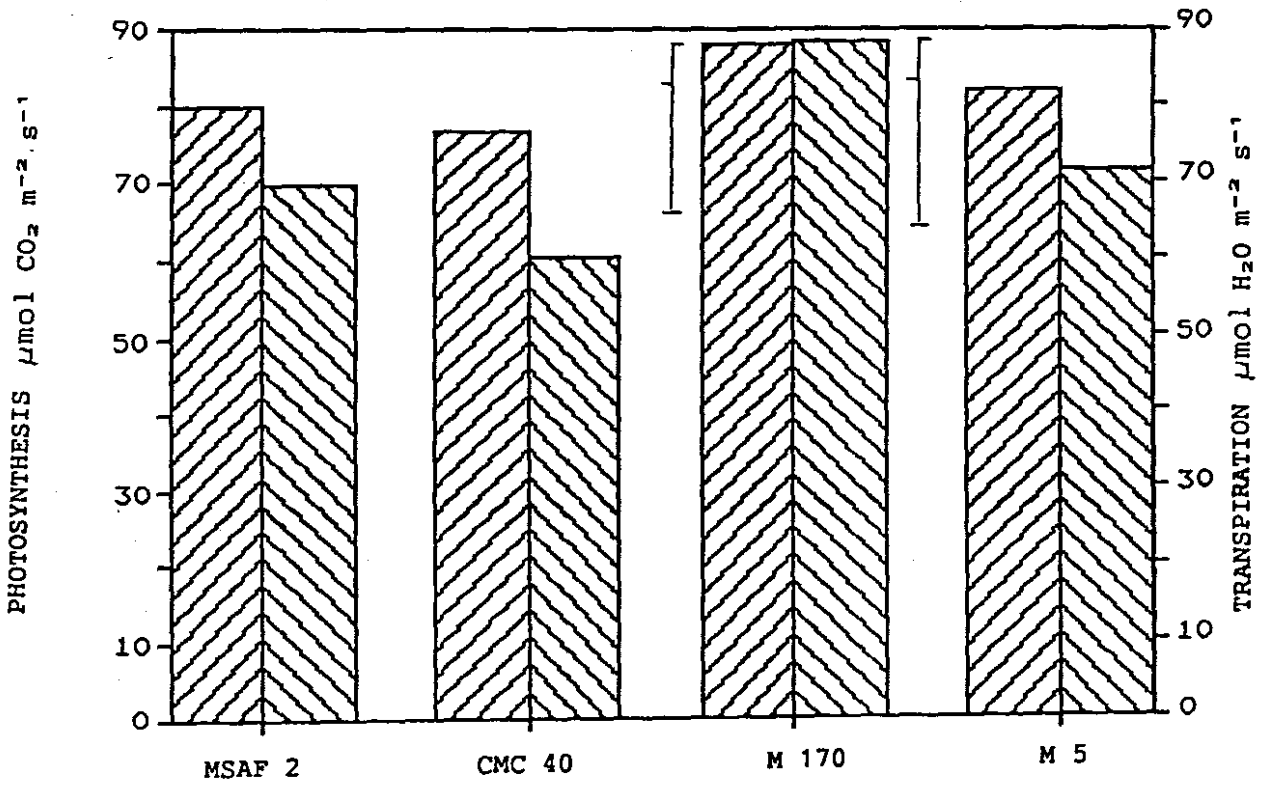
Figure 6.10 Average rates of transpiration (T) ⟨⟨⟨ ; and photosynthesis (P) ⟨⟨⟨ ; for cassava cultivars in 1990. (P ÷ 10; T × 100).

cultivars MSAF 2, M 170 and M 5 were not statistically significant. M 170 had a significantly higher (p=0,05) photosynthetic rate than CMC 40.

The rate of transpiration in M 170 was significantly higher (p=0,05) than in CMC 40.

6.3.1.6. Average transpiration and photosynthesis for the cultivars MSAF 2, CMC 40, M 170 and M 5 for experiment 3 (1990).

The results of this experiment are shown in Fig 6.10. MSAF 2, M 170 and M 5 did not differ significantly in their photosynthetic rates. M 170 had a significantly higher (p=0,05) photosynthetic rate than CMC 40.

The cultivars did not differ significantly in their rates of transpiration.

6.3.1.7. Comparison of photosynthesis, leaf water potential and transpiration in MSAF 2, CMC 40, M 170 and M 5 for experiment 3 (1990).

Results of this experiment commence from Fig 6.11 to Fig 6.16. In the the morning, all the cultivars had maximum photosynthetic rate at 10:40. At 12:30, MSAF 2 and M 170 had second peaks of photosynthesis.
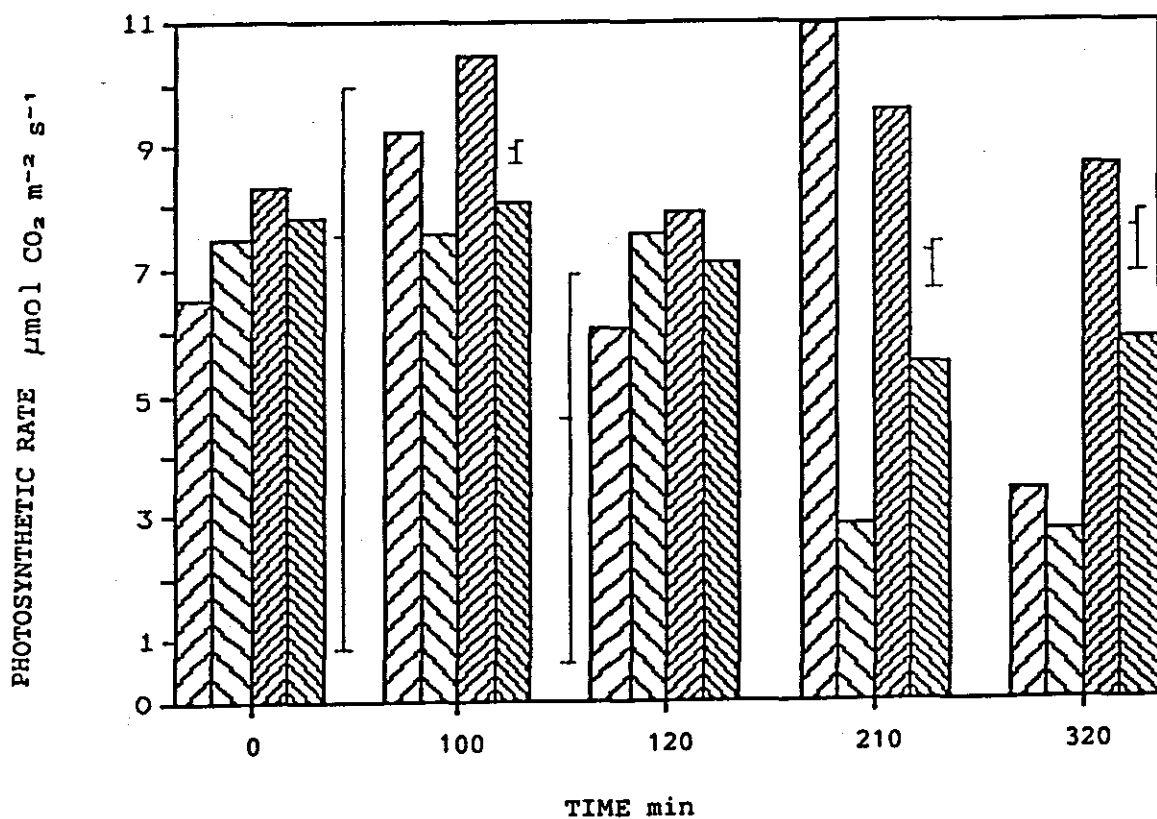
Figure 6.11 Comparison of photosynthetic rates in cassava cultivars MSAF 2, ▨ ; CMC 40, ◨ ; M 170, ▨ ; and M 5, ▨ from morning to afternoon in 1990.

(X-axis, 0 min = 9:00).
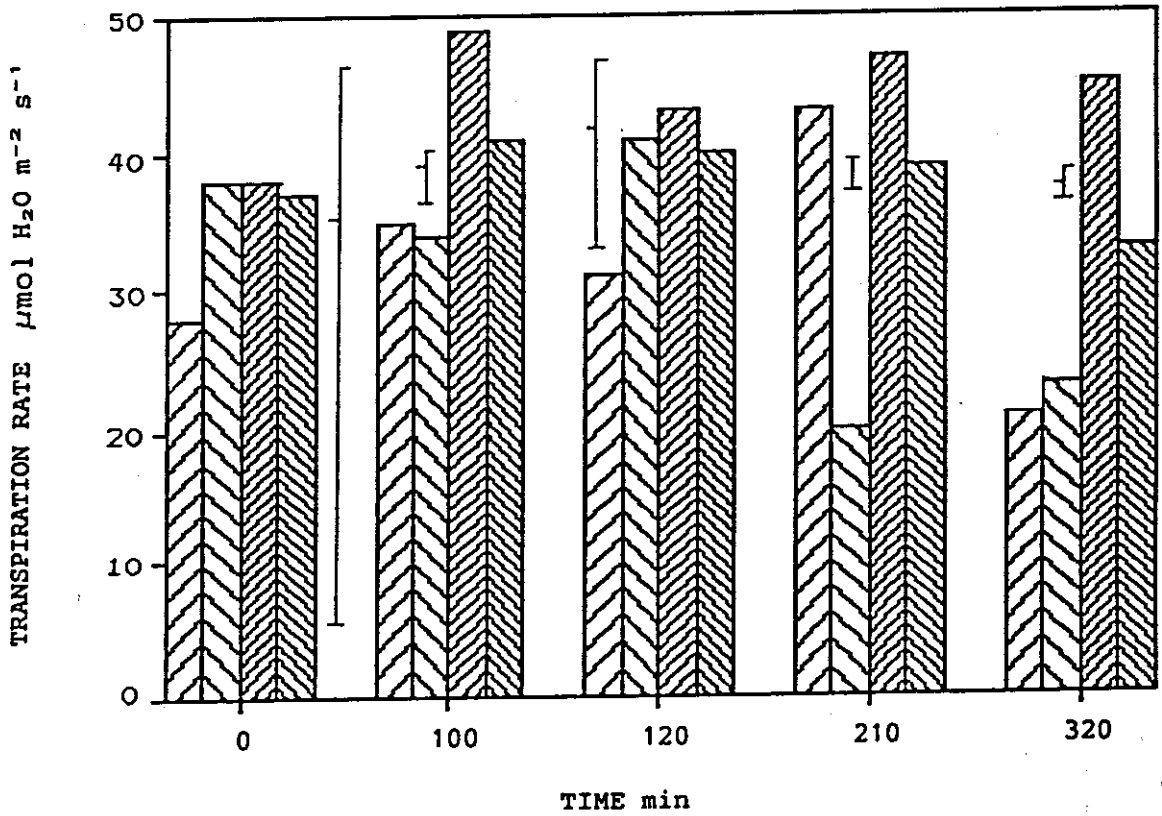
Figure 6.12   Comparison   of   transpiration   rates   (T)   in   cassava cultivars   MSAF 2, ▨ ;   CMC 40, ◩ ;   M 170, ▨ ; and   M 5, ▧   from   morning   to   afternoon in 1990. (T × 100. X-axis, 0 min = 9:00).

Apparently stomates closed at 11:00 and re - opened after midday. Photosynthetic rate decreased with decreasing leaf water potential and transpiration. In MSAF 2, photosynthesis decreased when the leaf water potential decreased below -0,53 MPa. In CMC 40, photosynthesis decreased at leaf water potential below -0,55 MPa. In M 170 and M 5, photosynthesis decreased at leaf potential below -0,58 MPa.

At 9:00 the cultivars did not differ significantly in their rates of photosynthesis and transpiration.

At 10:00, the photosynthetic rate in M 170 was significantly higher (p=0,01) than in CMC 40, MSAF 2 and M 5. MSAF 2 had a significantly higher (p=0,01) photosynthetic rate than CMC 40 and M 5. CMC 40 had a significantly lower (p=0,01) photosynthetic rate than M 5. For p=0,01, M 170 had a significantly higher rate of transpiration than MSAF 2, CMC 40 and M 5. M 5 was significantly higher than MSAF 2 and CMC 40.

At 11:00, the cultivars did not differ significantly in their photosynthetic rate. MSAF 2 had a significantly lower (p=0,05) rate of transpiration than CMC 40, M 170 and M 5.

At 12:00, the photosynthetic rate in MSAF 2 was

Figure 6.13 Changes in photosynthetic (P), ▱ ; and transpiration
(T), ◹ ; rates versus leaf water potential (ψ_L) ▨ ;
in the cultivar MSAF 2 for Experiment 3. (T $\times$ 400;
ψ_L $\div$ 10). X-axis, 0 min = 9:00).
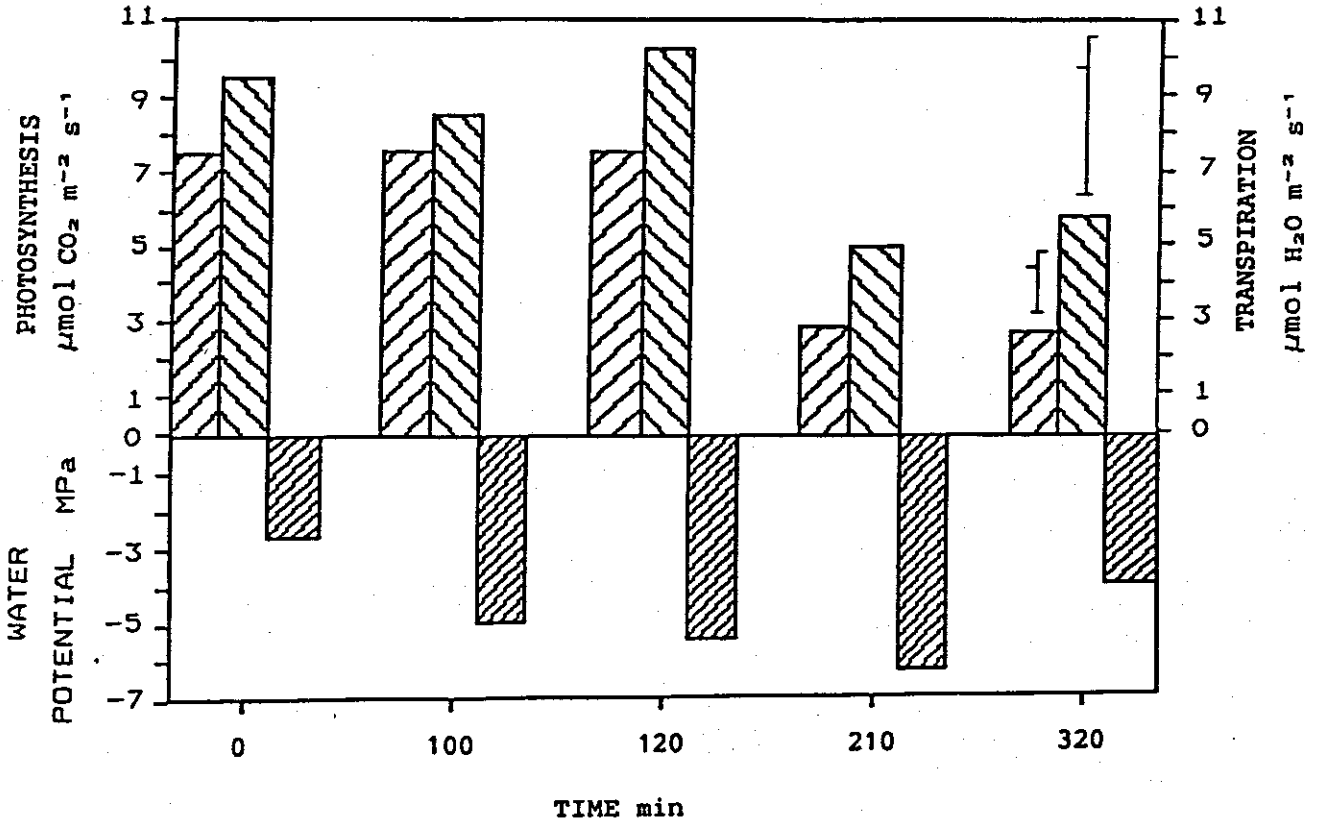
Figure 6.14 Changes in photosynthetic (P), ▨ ; and transpiration (T), ◹ ; rates versus leaf water potential (ψ_L) ▨ ; in the cultivar CMC 40 for Experiment 3. ($T \times 400$; $\psi_L \div 10$; X-axis, 0 min = 9:00).
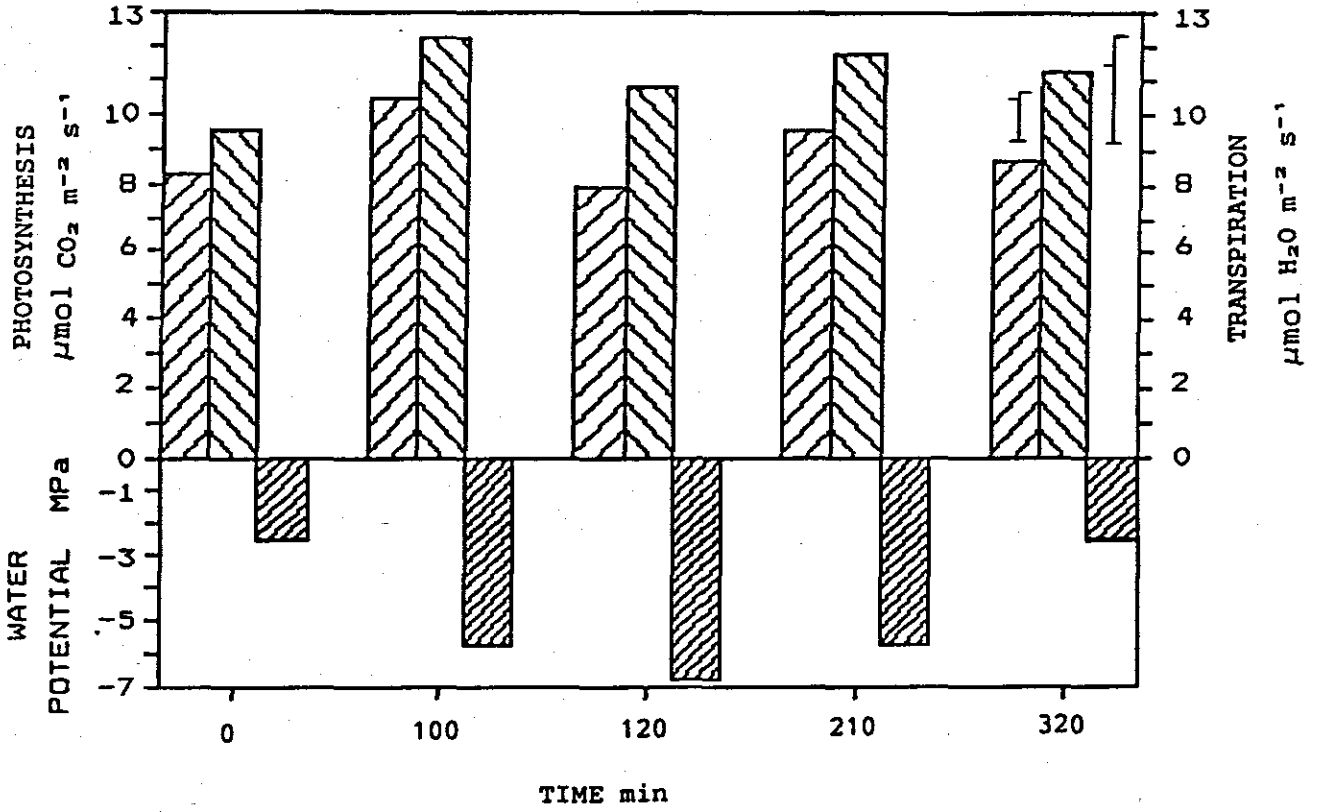
Figure 6.15 Changes in photosynthetic (P), ▱ ; and transpiration
(T), ◁ ; rates versus leaf water potential (ψ_l) ▨
in the cultivar M 170 for Experiment 3. (T × 400;
$\psi_L \div 10$; X-axis, 0 min = 9:00).
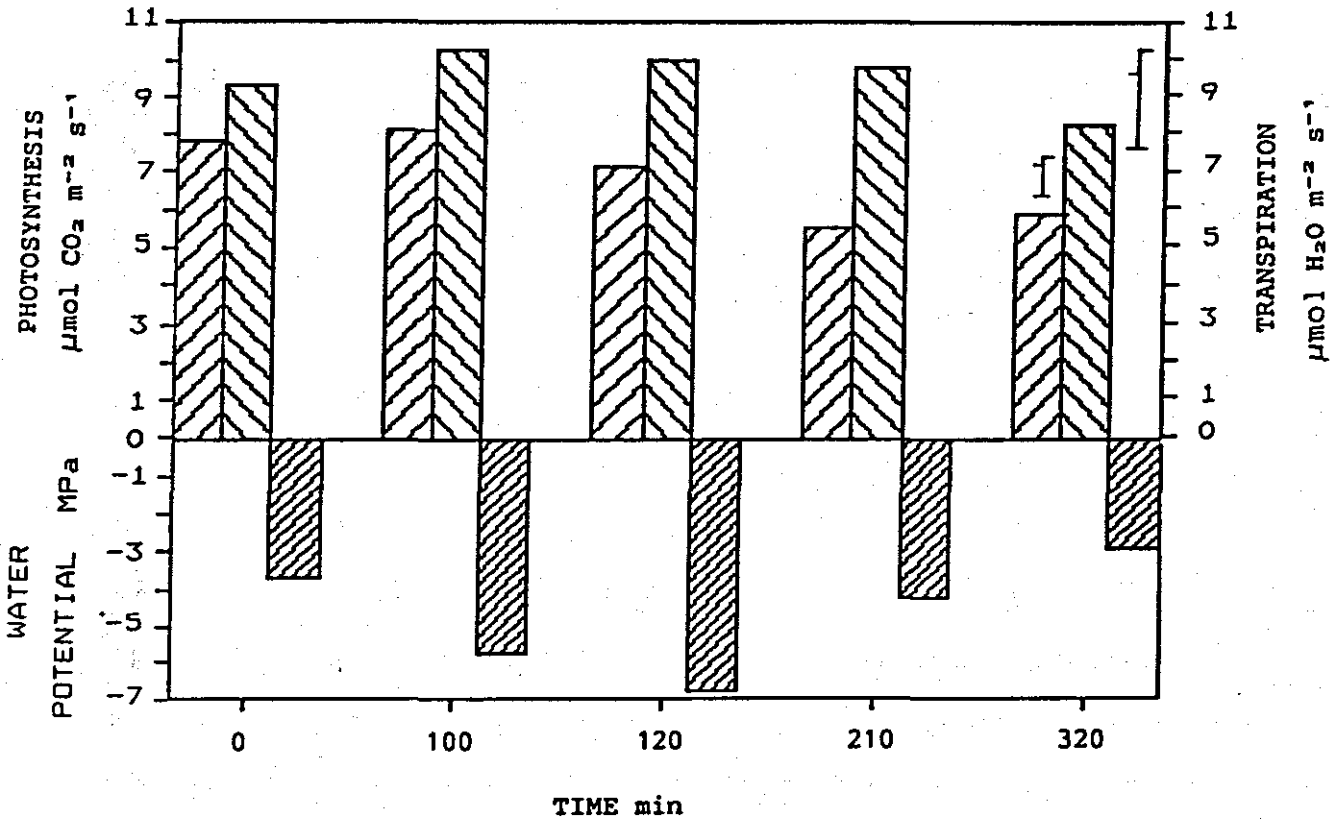
Figure 6.16 Changes in photosynthetic (P), ⊿⊿; and transpiration (T), ◁◁; rates versus leaf water potential (ψ$_L$) ⊿⊿ in the cultivar M 5 for Experiment 3. (T × 400; ψ$_L$ ÷ 10; X-axis, 0 min = 9:00).

significantly higher (p=0,01) than in CMC 40, M 170 and M 5. M 170 had a significantly higher (p=0,01) photosynthetic rate than both CMC 40 and M 5. Photosynthetic rate in M 5 was significantly higher (p=0,01) than in CMC 40. The rate of transpiration in M 170 was significantly higher (p=0,01) than in MSAF 2, CMC 40 and M 5. Transpiration in MSAF 2 was significantly higher (p=0,01) than in CMC 40 and M 5. CMC 40 had a significantly lower (p=0,01) transpiration rate than M 5.

At 14:20, MSAF 2 had a significantly higher (p=0,05) photosynthetic rate than CMC 40. M 170 had a significantly higher (p=0,01) photosynthetic rate than MSAF 2, CMC 40 and M 5. CMC 40 and MSAF 2 had a significantly lower (p=0,01) photosynthetic rate than M 5. Transpiration in M 170 was significantly higher (p=0,01) than in MSAF 2, CMC 40 and M 5. MSAF 2 and CMC 40 had a significantly lower (p=0,01) rate of transpiration than M 5. Transpiration rate in CMC 40 was significantly higher (p=0,01) than in MSAF 2.

6.3.1.8. Photosynthesis versus leaf water potential and transpiration in the cultivar MSAF 2 for experiment 3A (1990).

The results of this experiment are shown in Fig 6.17. From 10:30 to 11:30, there was an increase in photosynthetic

significantly higher (p=0,01) than in CMC 40, M 170 and M 5. M 170 had a significantly higher (p=0,01) photosynthetic rate than both CMC 40 and M 5. Photosynthetic rate in M 5 was significantly higher (p=0,01) than in CMC 40. The rate of transpiration in M 170 was significantly higher (p=0,01) than in MSAF 2, CMC 40 and M 5. Transpiration in MSAF 2 was significantly higher (p=0,01) than in CMC 40 and M 5. CMC 40 had a significantly lower (p=0,01) transpiration rate than M 5.

At 14:20, MSAF 2 had a significantly higher (p=0,05) photosynthetic rate than CMC 40. M 170 had a significantly higher (p=0,01) photosynthetic rate than MSAF 2, CMC 40 and M 5. CMC 40 and MSAF 2 had a significantly lower (p=0,01) photosynthetic rate than M 5. Transpiration in M 170 was significantly higher (p=0,01) than in MSAF 2, CMC 40 and M 5. MSAF 2 and CMC 40 had a significantly lower (p=0,01) rate of transpiration than M 5. Transpiration rate in CMC 40 was significantly higher (p=0,01) than in MSAF 2.

6.3.1.8. Photosynthesis versus leaf water potential and transpiration in the cultivar MSAF 2 for experiment 3A (1990).

The results of this experiment are shown in Fig 6.17. From 10:30 to 11:30, there was an increase in photosynthetic

Figure 6.17 Changes in photosynthetic (P), ⊿⊿ ; and transpiration (T), ◱◲ ; rates versus leaf water potential (ψ) ⊿⊿⊿ ; in the cultivar MSAF 2 for Experiment 3A. (T × 400; $\psi_L \div 10$; X-axis, 0 min = 10:30).

and transpiration rates and a decrease in leaf water potential. From 12:30, photosynthesis and transpiration decreased when the leaf water potential was below -0,50 MPa. At p=0,05, the rate of photosynthesis at 12:30 and at 14:00 was significantly lower than at 11:30.

For p=0,01, the rate of photosynthesis at 11:30 was significantly higher than at 15:00. The rates of transpiration at 11:30 and 12:30 were significantly higher than at 10:30, 14:00 and 15:00. The rate of transpiration at 14:00 was significantly higher (p=0,05) than at 10:30 and 15:00.

6.3.1.9. Photosynthesis versus leaf water potential and transpiration in the cultivar CMC 40 for experiment 3A (1990).

Results of this experiment are shown in Fig 6.18. The decline in photosynthetic and transpiration rates occurred when the leaf water potential dropped below -0,64 MPa. Differences in photosynthetic rates at different time intervals were not statistically significant. Transpiration rate at 11:00 was significantly higher (p=0,01) than at 15:00.
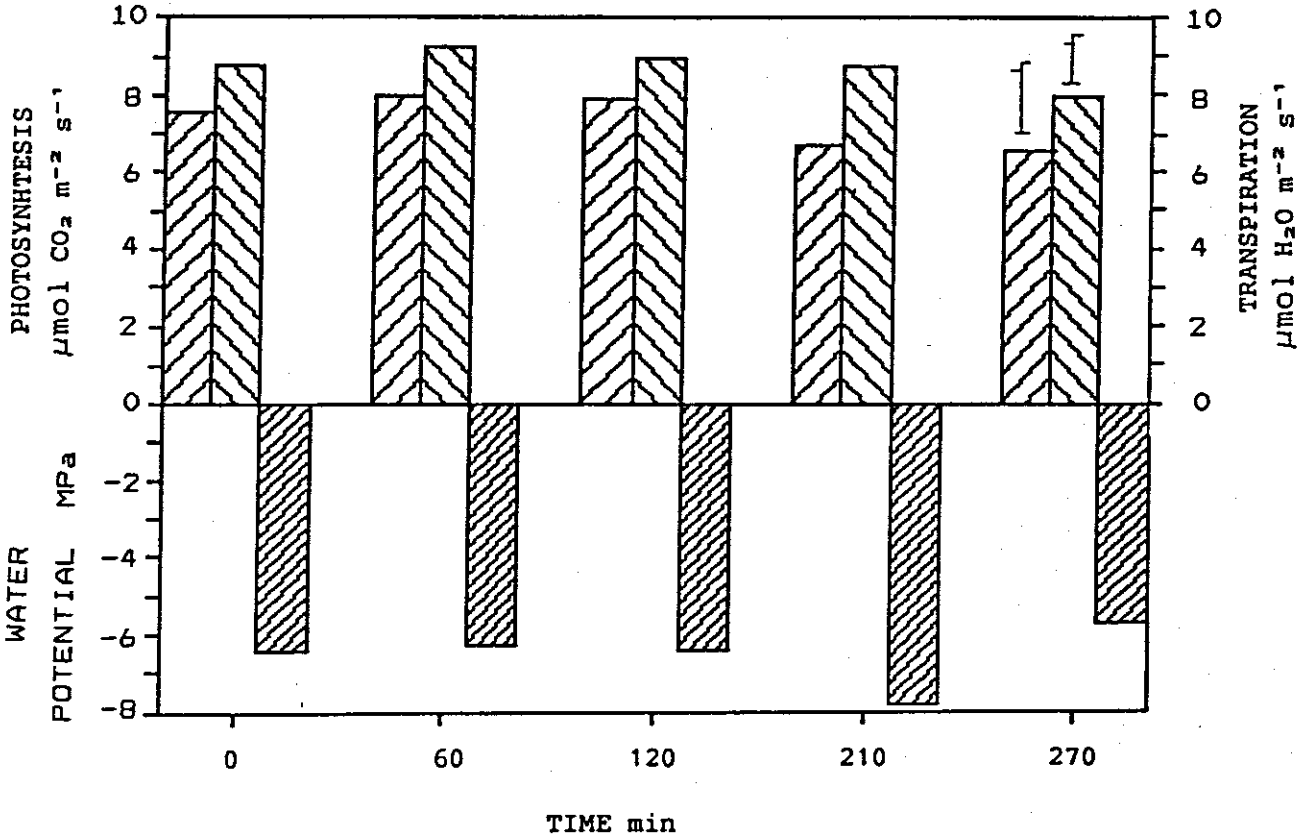
Figure 6.18   Changes   in   photosynthetic (P),   ⧄ ; and transpiration

(T),   ⧅ ;   rates versus leaf water potential (ψ)   ⧄ ;

in   the   cultivar   CMC 40   for Experiment 3A. (T × 400;
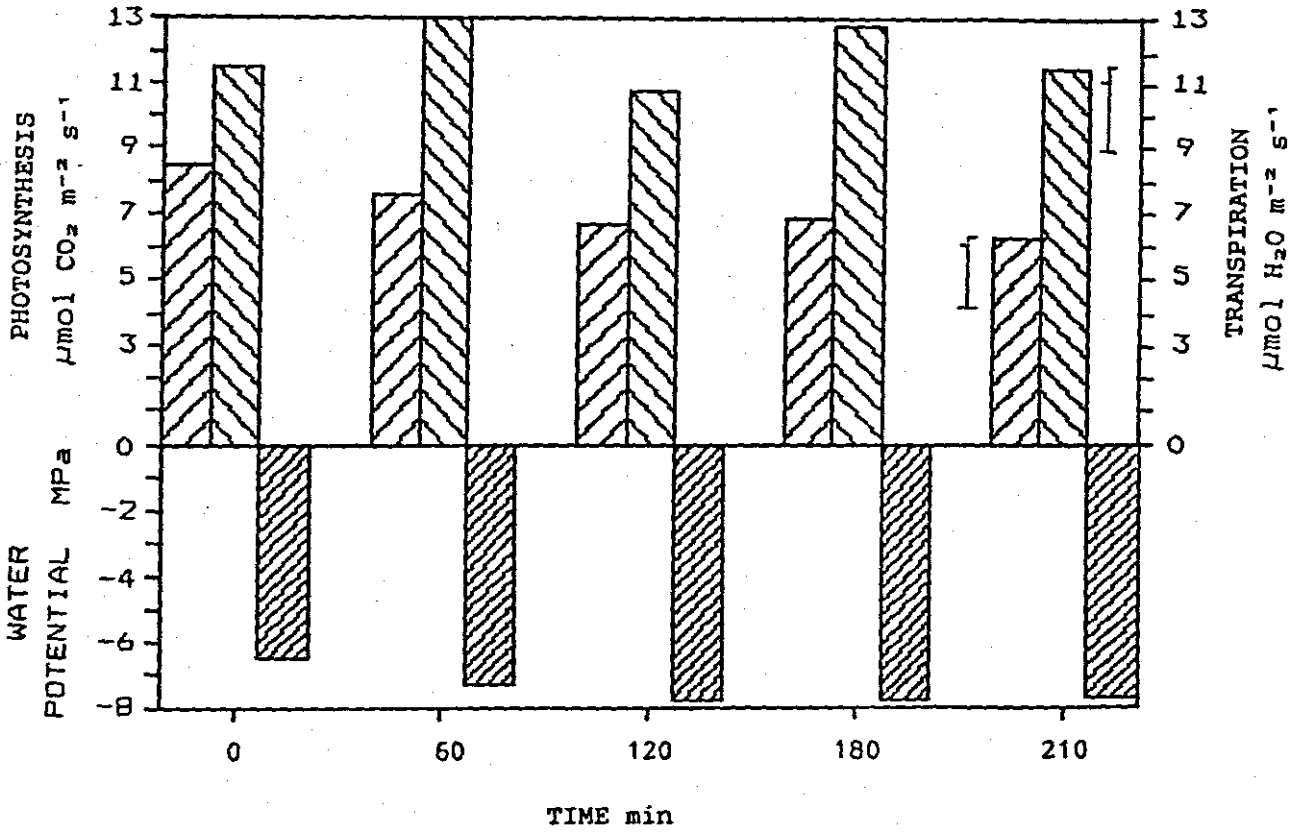
$\psi_L \div 10$; X-axis, 0 min = 10:30).

Figure 6.19   Changes in photosynthetic (P), ⧄ ; and transpiration

(T), ⧅ ;   rates versus leaf water potential (ψ) ⧄ ;

in   the   cultivar   M 170   for   Experiment 3A. (T × 400;

ψ_L   ÷ 10; X-axis, 0 min = 11:30).

6.3.1.10. Photosynthesis versus leaf water potential and transpiration in the cultivar M 170 for experiment 3A (1990).

Results of this experiment are shown in Fig 6.19. In this experiment, the water potential below which photosynthetic rate declined was -0,65 MPa. There was a general decrease in photosynthetic rate from 11:30 to 15:00. Transpiration rate was the highest at 12:00 and 14:30.

For p=0,05, the photosynthetic rate at 13:30 was significantly lower than at 11:00. The rate of transpiration at 12:00 was significantly higher than at 13:00. For p=0,01, the photosynthetic rate at 11:00 was significantly higher than at 15:00. Transpiration rates at different time intervals did not differ significantly.

6.3.1.11. Photosynthesis versus leaf water potential and transpiration in M 5 for experiment 3A (1990).

Results of this experiment are shown in Fig 6.20. Photosynthetic and transpiration rates increased from 9:00 to 11:00. The decrease in photosynthetic rate at 12:30 was soon followed by an increase which occurred at 14:00. It is likely that stomates closed at 12:30 and re-opened at 14:00. The leaf water potential below which photosynthetic
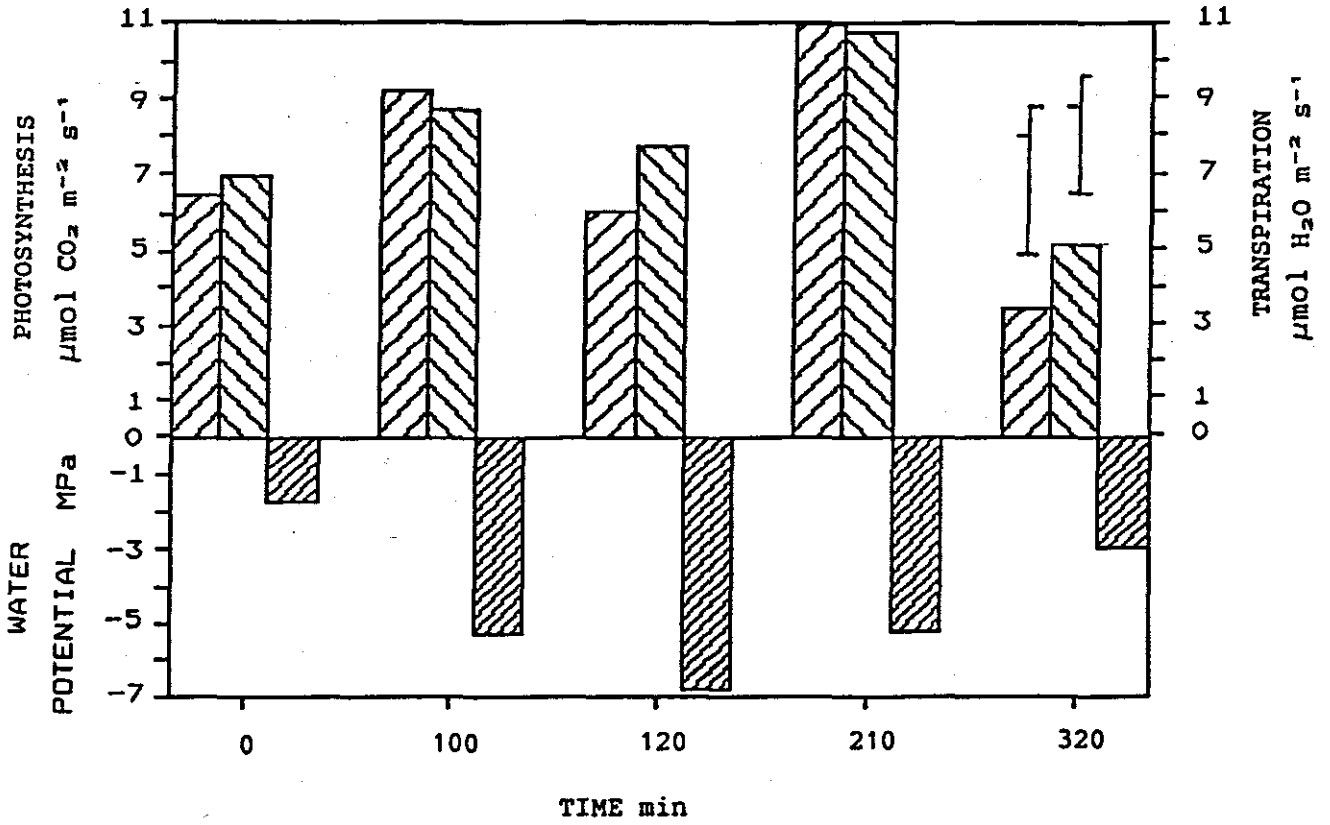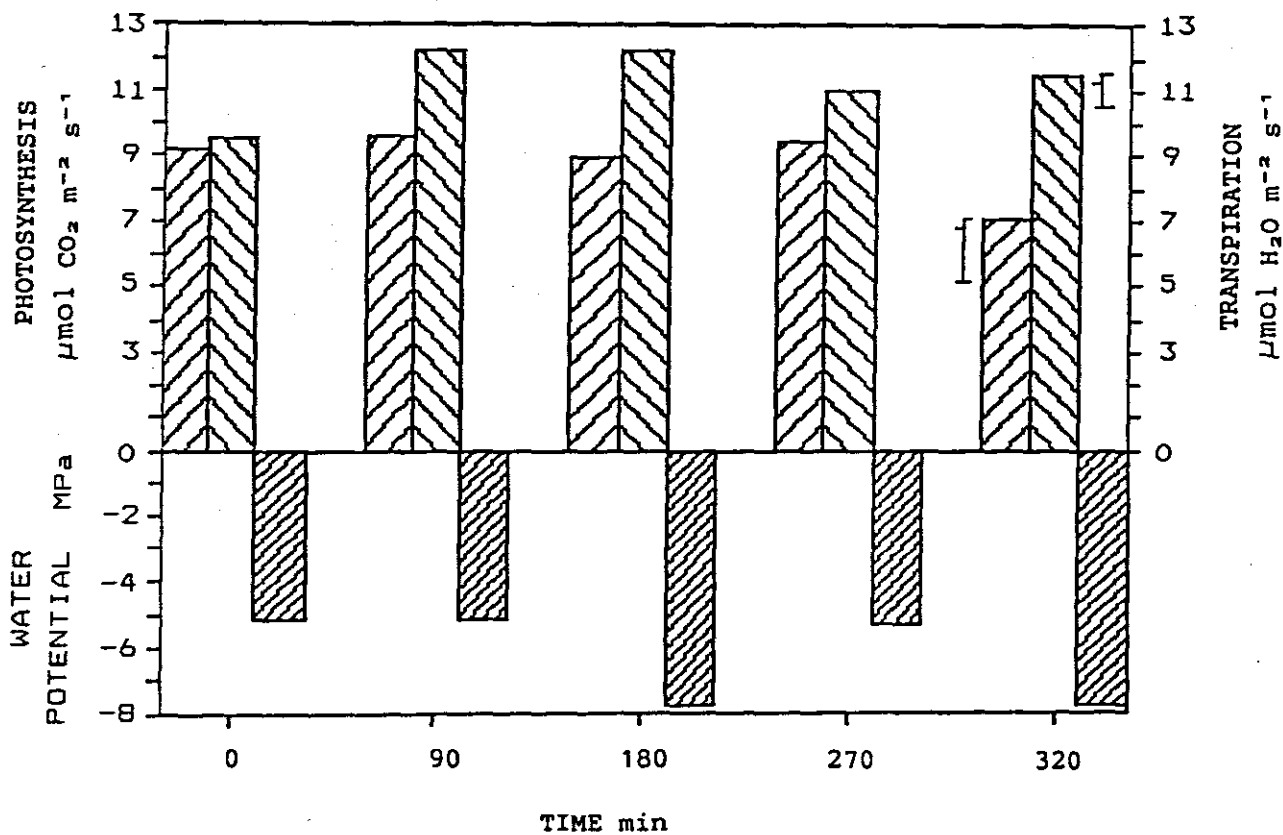
Figure 6.20 Changes in photosynthetic (P), ▨ ; and transpiration (T), ▨ ; rates versus leaf water potential (ψ$_L$) ▨ ; in the cultivar   M 5   for   Experiment 3A. (T $\times$ 400; ψ$_L$ $\div$ 10; X-axis, 0 min = 9:00).

rate dropped was -0,52 MPa.

For p=0,05, the photosynthetic rate at 12:00 was significantly higher than at 15:00. For p=0,01, photosynthetic rate at 15:00 was significantly lower than the rate at 9:00, 11:00 and 14:00. Transpiration rate at 11:00 was significantly higher (p=0,05) than at 14:00.

The rate of transpiration at 9:00 was significantly lower (p=0,01) than the rate from 11:00 to 15:00. The rate of transpiration at 12:00 was significantly higher (p=0,01) than the rate at 14:00. For p=0,05, transpiration rate at 11:00 was higher than at 14:00.

6.3.2. CHLOROPHYLL *A* CONTENT IN CASSAVA.

6.3.2.1. Comparison of chlorophyll *a* content in cassava cultivars.

6.3.2.1.1. Experiment 1

The results of this experiment are shown in Fig 6.21. In all the cultivars, there was a decline in chlorophyll *a* content from 228 to 273 DAP associated with unfavourable winter conditions. At 106 DAP M 170 had a significantly higher (p=0,05) chlorophyll *a* content than MSAF 2. M 5 had a significantly lower
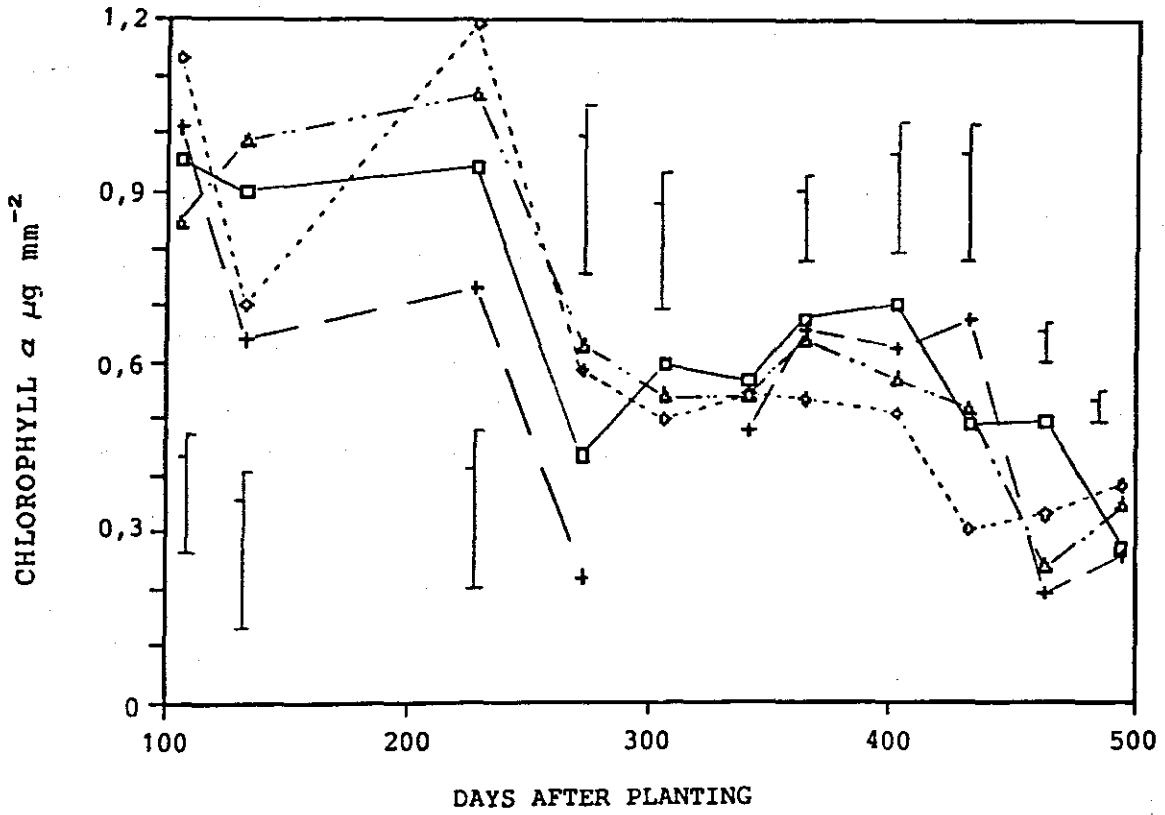
Figure 6.21 Chlorophyll *a* content for MSAF 2 (□), CMC 40 (+),
M 170 (◦) and M 5 (△) at different times after
planting for Experiment 1.

(p=0,01) chlorophyll *a* content than M 170.

At 133 DAP the chlorophyll *a* content of MSAF 2 was significantly higher (p=0,05) than that of CMC 40. M 5 had a significantly higher chlorophyll *a* content than both CMC 40 and M 170. At 228 DAP, for p=0,05, M 170 had a higher chlorophyll *a* content than MSAF 2. For p=0,01, both M 170 and M 5 had a significantly higher chlorophyll *a* content than CMC 40.

At 273 DAP both M 170 and M 5 had a significantly higher (p=0,01) chlorophyll *a* content than CMC 40. At 307 and 342 DAP, the cultivars did not differ significantly in their chlorophyll *a* content. At 307 DAP, CMC 40 was excluded from statistical analysis because it had no leaves. At 365 DAP MSAF 2 and CMC 40 had a significantly higher (p=0,05) chlorophyll *a* content than M 170. At 403 DAP, for p=0,05, MSAF 2 had a significantly higher chlorophyll *a* content than M 170. At 433 DAP M 5 had a significantly higher (p=0,05) chlorophyll *a* content than M 170. CMC 40 also had a significantly higher (p=0,01) chlorophyll *a* content than M 170. At 464 DAP the chlorophyll *a* content in MSAF 2 was significantly higher (p=0,01) than in CMC 40, M 170 and M 5. M 170 had a significantly higher (p=0,01) chlorophyll *a* content than both CMC 40 and M 5. At 495 DAP M 170 and M 5 had a significantly higher
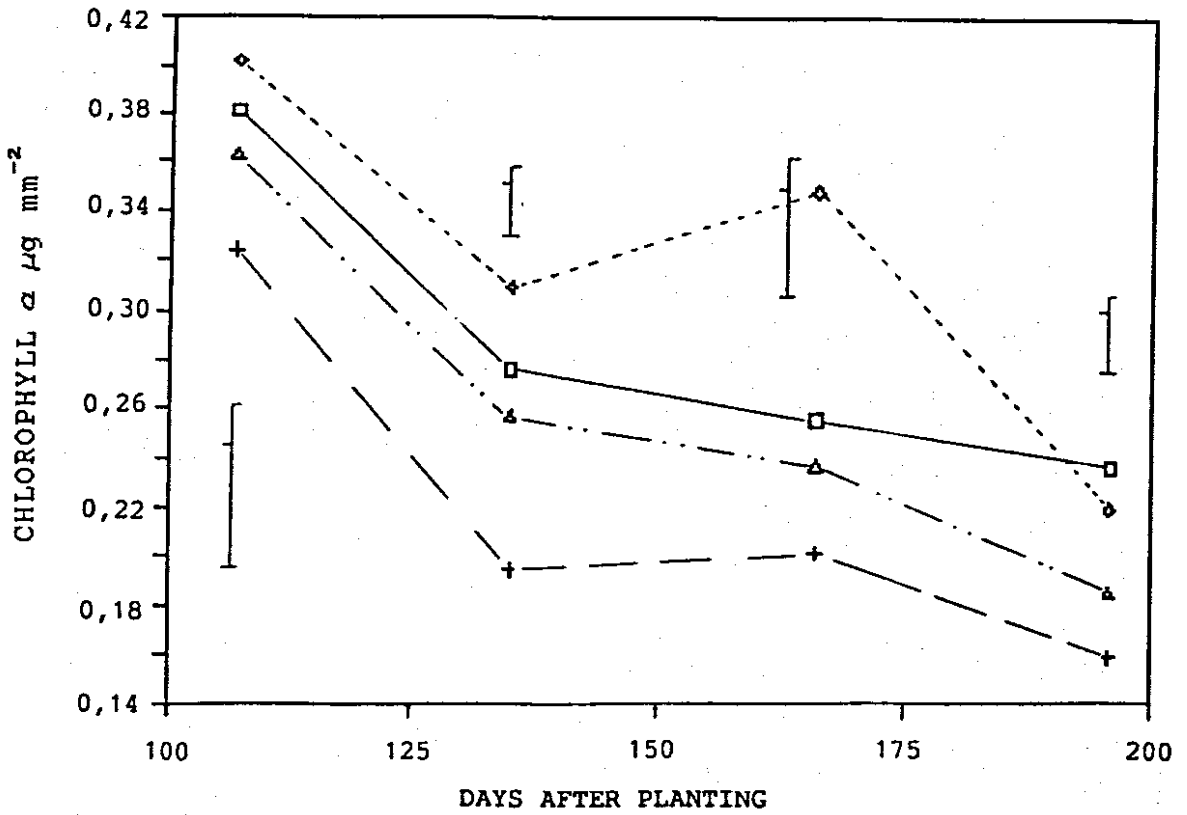
Figure 6.22 Chlorophyll *a* content for MSAF 2 (□), CMC 40 (+),

M 170 (◊) and M 5 (▲) at different times after

planting for Experiment 2B.

(p=0,01) chlorophyll *a* content than both MSAF 2 and CMC 40.

6.3.2.1.2. Experiment 2B

The results of this experiment are shown in Fig 6.22. In all the cultivars there was a decline in chlorophyll *a* content from 107 to 135 DAP. At 166 DAP, M 170 and CMC 40 had an increase in chlorophyll *a* content. From 166 to 196 DAP, there was a second decline in chlorophyll *a* content in all the cultivars.

At 107 DAP, the cultivars did not differ significantly in their chlorophyll *a* content. At 135 DAP MSAF 2, M 170 and M 5 had a significantly higher (p=0,01) chlorophyll *a* content than CMC 40. For p=0,01, M 170 had a significantly higher chlorophyll *a* content than M 5. At 166 DAP, for p=0,05, M 170 had a significantly higher chlorophyll *a* content than MSAF 2. The chlorophyll *a* content in CMC 40 and in M 5 was significantly lower (p=0,01) than in M 170. At 196 DAP MSAF 2 had a significantly higher (p=0,05) chlorophyll *a* content than M 5. Both M 170 and MSAF 2 had a significantly higher (p=0,01) chlorophyll *a* content than CMC 40.

Figure 6.23 Temperature, rainfall, solar radiation and chlorophyll *a* content of the leaves of MSAF 2 at different times after planting for Experiment 1.

6.3.2.2. Variation in chlorophyll *a* content in the 5th, 7th and 12th leaves in the cultivar MSAF 2.

6.3.2.2.1. Experiment 1

Results of this experiment are shown in Fig 6.23. At 106 DAP, for p=0,01, the 7th leaf had a significantly higher chlorophyll *a* content than the 5th and 12th leaves. The chlorophyll *a* content in the 5th leaf was significantly higher than in the 12th leaf. At 133 DAP, the 5th leaf had a significantly lower (p=0,05) chlorophyll *a* content than the 12th leaf. At 228, 273 and 464 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant. At 307 and 342 DAP, the 7th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 12th leaf. At 365 DAP, for p=0,05, the 5th leaf had significantly lower chlorophyll *a* content than the 7th leaf. For p=0,01, the 12th leaf had a significantly higher chlorophyll *a* content than the 5th and 7th leaves. At 403 DAP, for p=0,05, the chlorophyll *a* content in the 7th leaf was significantly lower than in the 12th leaf. For p=0,01, the 12th leaf had a significantly higher chlorophyll *a* content than the 5th leaf. At 433 DAP, the chlorophyll *a* content in the 7th leaf was significantly higher (p=0,05) than in the 5th and lower than in the 12th leaf. The 12th leaf was
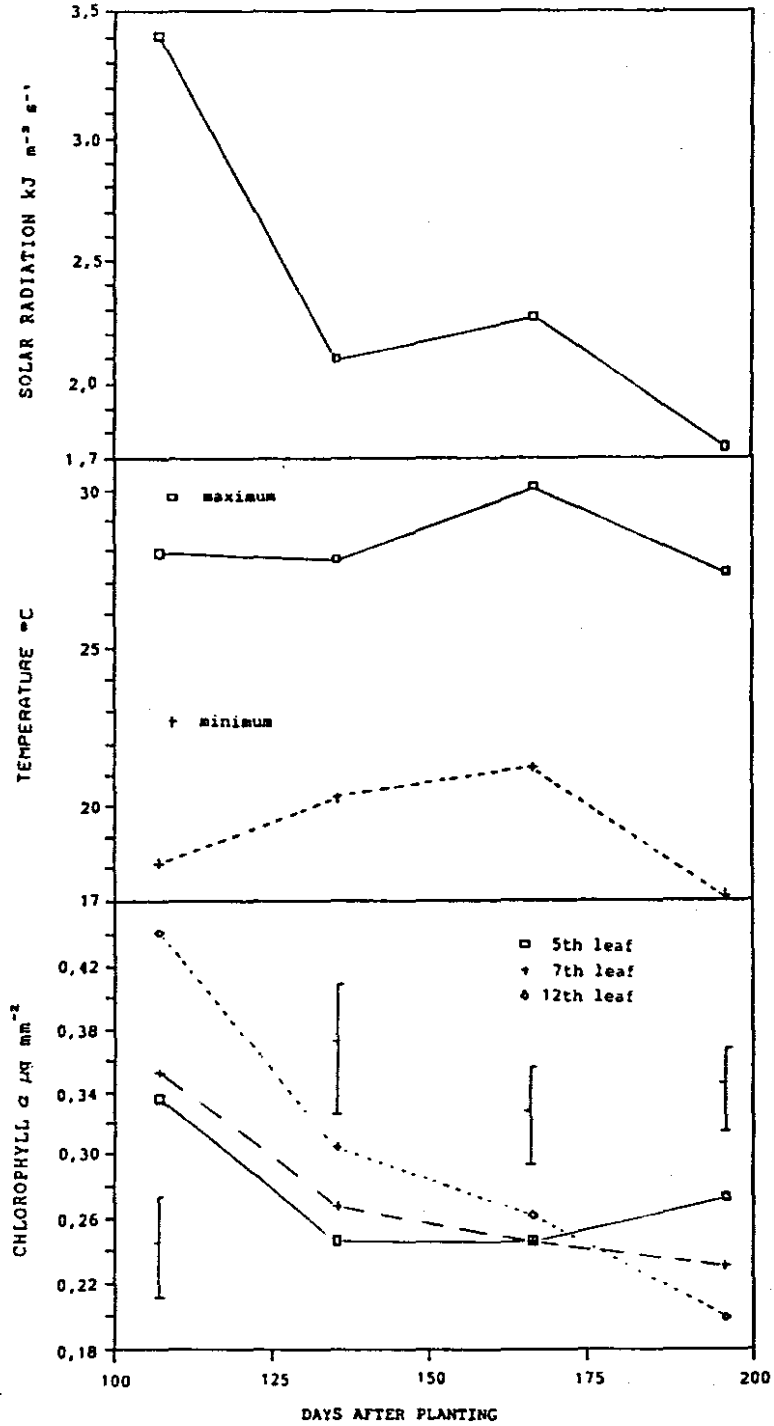
Figure 6.24   Temperature, solar   radiation   and   chlorophyll *a*

content of the leaves of MSAF 2 at different times

after planting for Experiment 2B.

significantly higher (p=0,01) than the 5th leaf. At 495 DAP, the 5th leaf had a significantly lower (p=0,05) chlorophyll *a* content than the 7th and 12th leaves.

6.3.2.2.2. Experiment 2B

Results of this experiment are shown in Fig 6.24. At 107 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 7th leaf. For p=0,01, the 12th leaf had a significantly higher chlorophyll a content than the 5th leaf. At 135 and 166 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant. At 196 DAP, the 5th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 12th leaf.

6.3.2.3. Variation in the chlorophyll *a* content in the 5th, 7th and 12th leaves in the cultivar CMC 40.

6.3.2.3.1. Experiment 1

Results of this experiment are shown in Fig 6.25. At 106 and 133 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 5th leaf. At 228 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 7th leaf. For p=0,01, the 12th leaf had a significantly higher
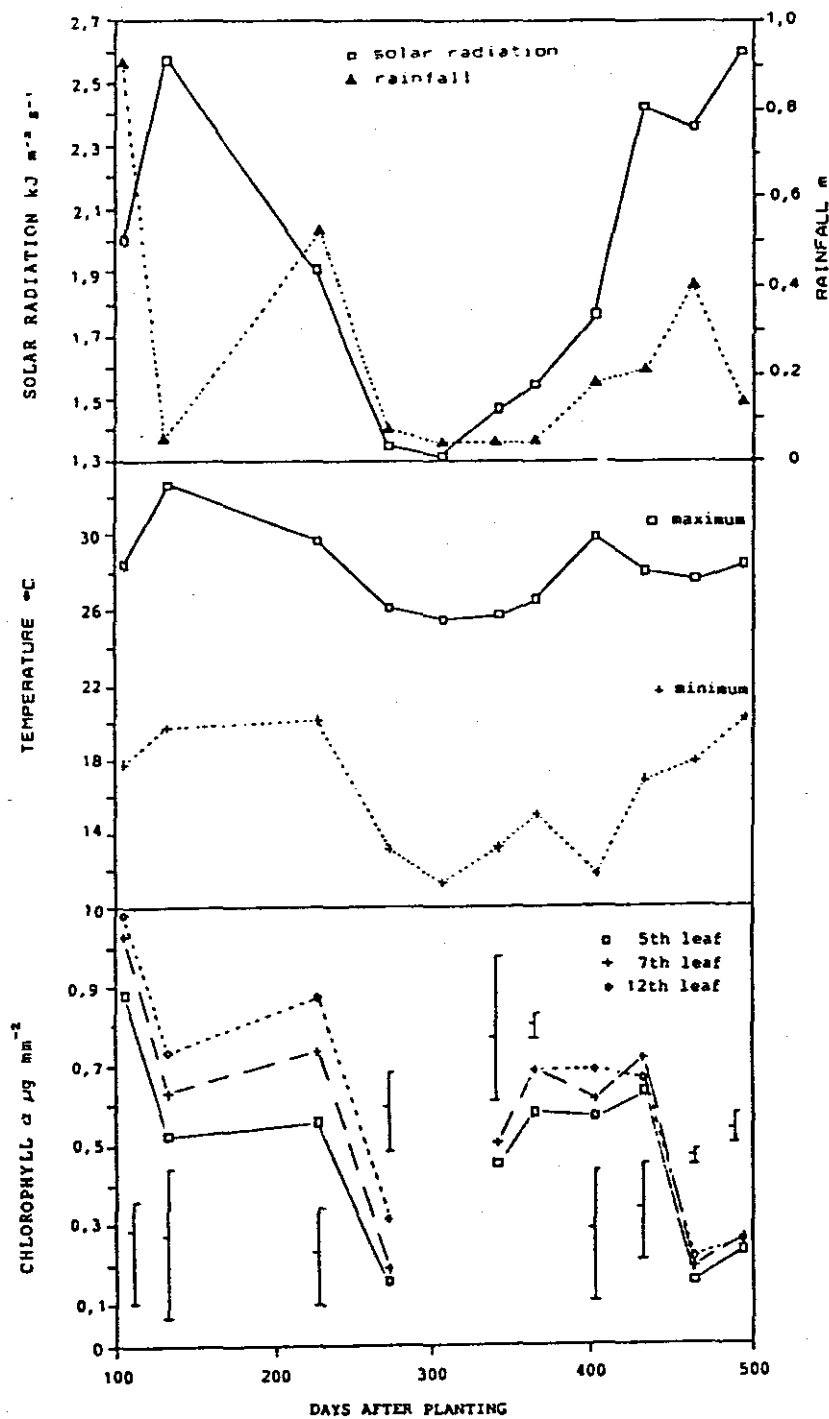
Figure 6.25 Temperature, rainfall, solar radiation and chlorophyll *a* content of the leaves of CMC 40 at different times after planting for Experiment 1.
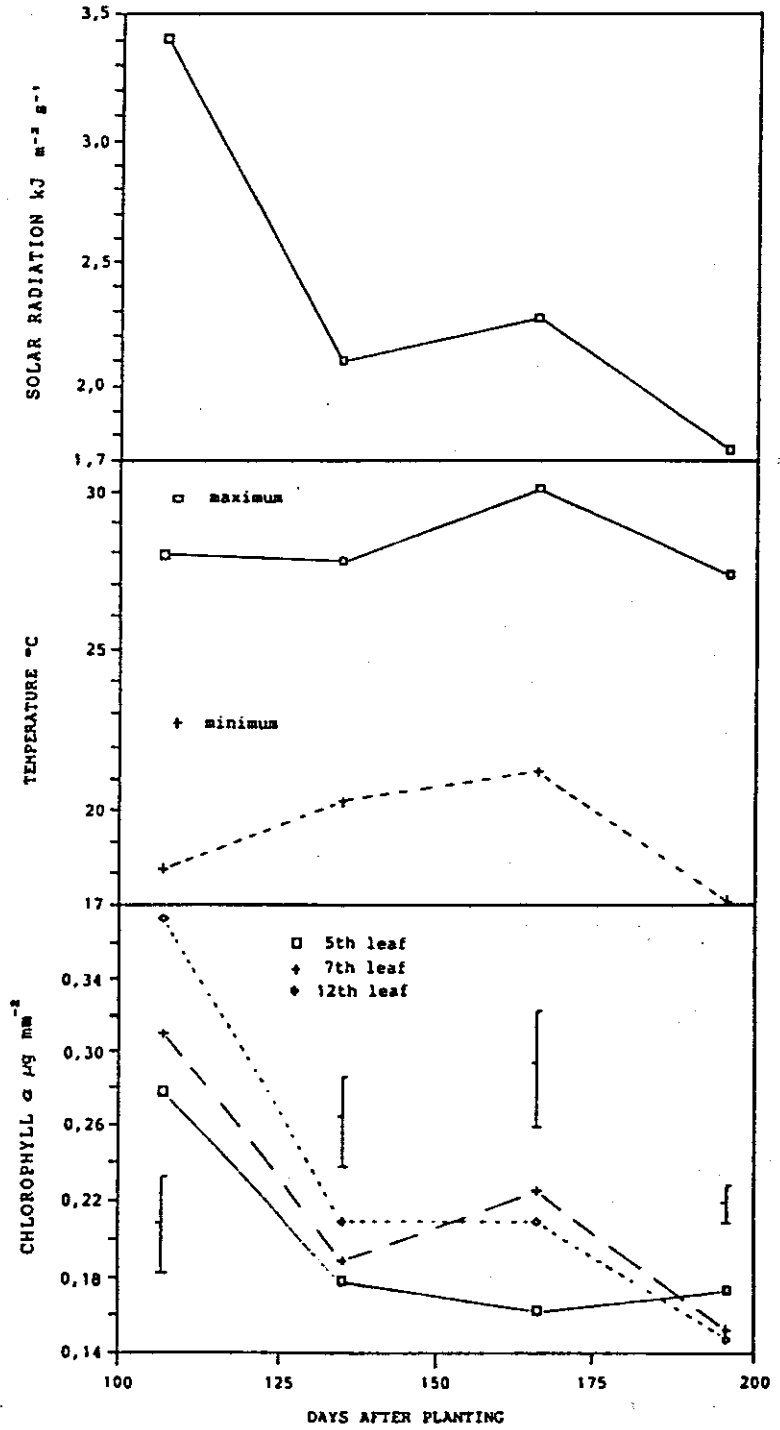
Figure 6.26 Temperature, solar radiation and chlorophyll *a* content of the leaves of CMC 40 at different times after planting for Experiment 2B.

chlorophyll *a* content than the 5th leaf. At 273 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 5th and 7th leaf.

At 342, 403, 433 and 495 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant. At 365 DAP, the 5th had a significantly lower (p=0,01) chlorophyll a content than the 7th and 12th leaves. At 464 DAP, for p=0,05, the 7th leaf had a significantly higher chlorophyll *a* content than the 5th leaf.

The chlorophyll *a* content of the 12th leaf was significantly higher than that of the 7th leaf. For p=0,01, the 12th leaf had a significantly higher chlorophyll *a* content than the 5th leaf.

6.3.2.3.2. Experiment 2B

Results of this experiment are shown in Fig 6.26. At 107 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 7th leaf. The 5th leaf had a significantly lower (p=0,01) chlorophyll *a* content than the 12th leaf. At 135 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant. At 166 DAP, the 7th leaf ha a significantly higher (p=0,05) chlorophyll *a* content than
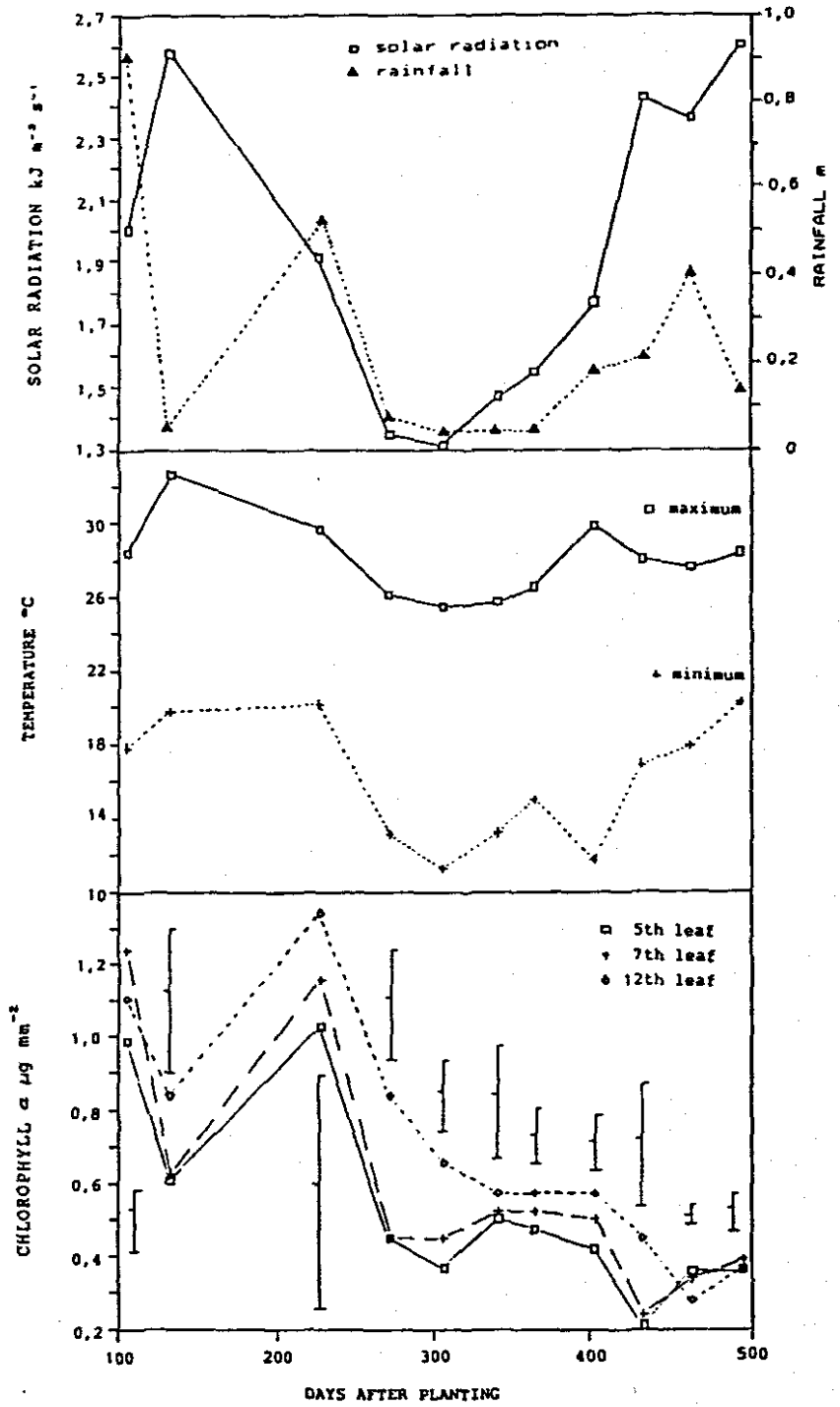
Figure 6.27 Temperature, rainfall, solar radiation and
chlorophyll *a* content of the leaves of M 170 at
different times after planting for Experiment 1.

the 5th leaf. At 196 DAP, the 5th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 7th and 12th leaves.

6.3.2.4. Variation in the chlorophyll *a* content in the 5th, 7th and 12th leaves in the cultivar M 170.

6.3.2.4.1. Experiment 1

Results of this experiment are shown in Fig 6.27. At 106 DAP, the 5th leaf had a significantly lower (p=0,05) chlorophyll *a* content than the 12th leaf. The 7th leaf had a significantly higher (p=0,01) chlorophyll a content than the 5th leaf. At 133, 228, 342 and 495 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant. At 273 DAP, the 12th leaf had a significantly higher (p=0,01) chlorophyll a content than the 5th and 7th leaves. At 307 DAP, for p=0,05, the 12th leaf had a significantly higher chlorophyll *a* content than the 7th leaf. The chlorophyll *a* content of the 2th leaf was significantly higher (p=0,01) than that of the 5th leaf. At 365, 403 and 433 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 5th leaf. At 464 DAP, the 7th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 12th leaf. For p=0,01, the 5th leaf had a significantly higher chlorophyll a
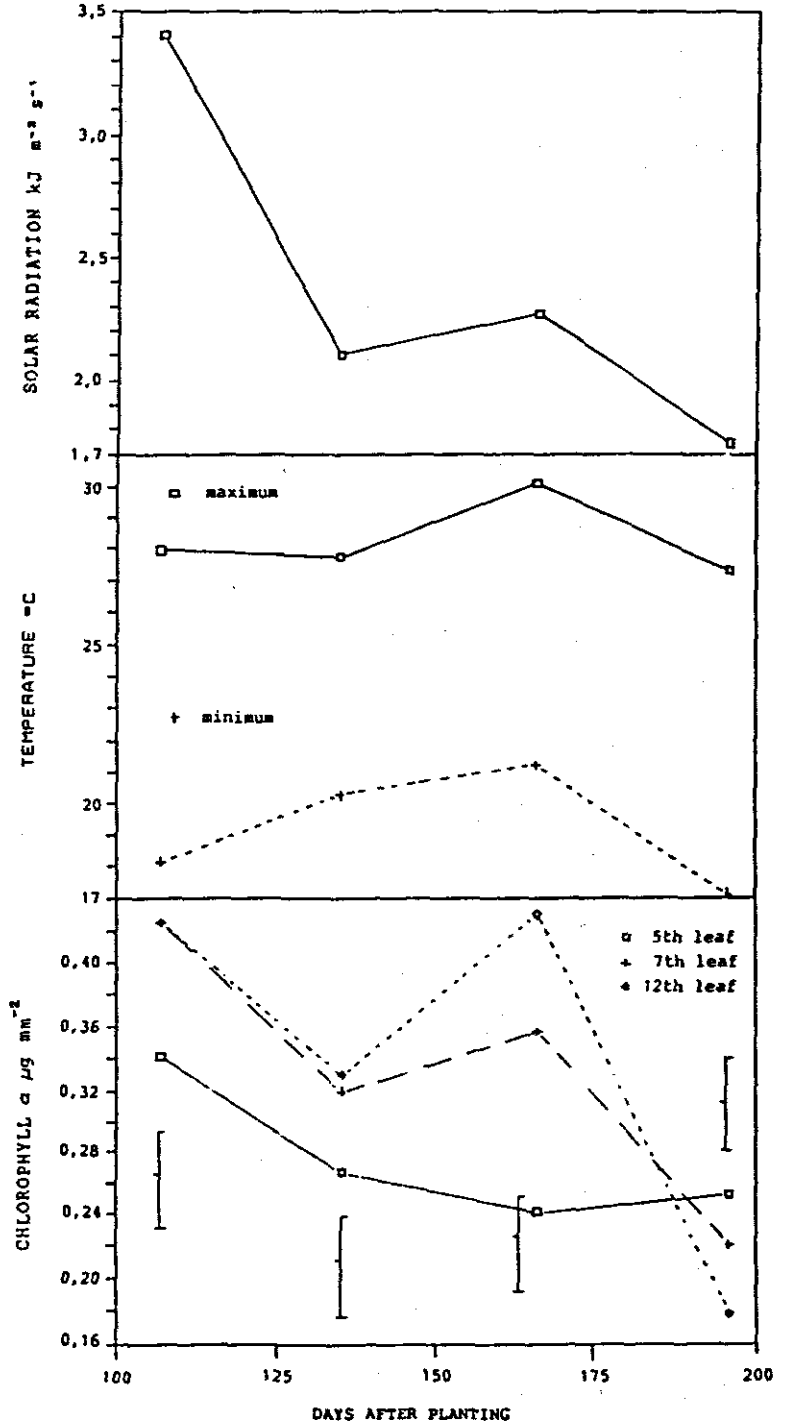
Figure 6.28 Temperature, solar radiation and chlorophyll *a* content of the leaves of M 170 at different times after planting for Experiment 2B.

content than the 12th leaf.

6.3.2.4.2. Experiment 2B

Results of this experiment are shown in Fig 6.28. At 107 DAP, the chlorophyll a content of the 5th leaf was significantly lower ($p=0,01$) than that of the 7th and 12th leaves. At 135 DAP, the differences in chlorophyll a content among the leaves were not statistically significant. At 166 DAP, the 12th leaf had a significantly higher ($p=0,05$) chlorophyll a content than the 7th leaf. For $p=0,01$, the 7th and 12th leaves had a significantly higher chlorophyll a content than the 5th leaf. At 196 DAP, the 5th leaf had a significantly higher ($p=0,05$) chlorophyll a content than the 12th leaf.

6.3.2.5. Variation in the chlorophyll a content in the 5th, 7th and 12th leaves in the cultivar M 5.

6.3.2.5.1. Experiment 1

Results of this experiment are shown in Fig 6.29. At 106 DAP, the 7th and 12th leaves had a significantly higher ($p=0,01$) chlorophyll a content than the 5th leaf. At 133, 228, 365 and 433 DAP, the differences in chlorophyll a content among the leaves were not statistically
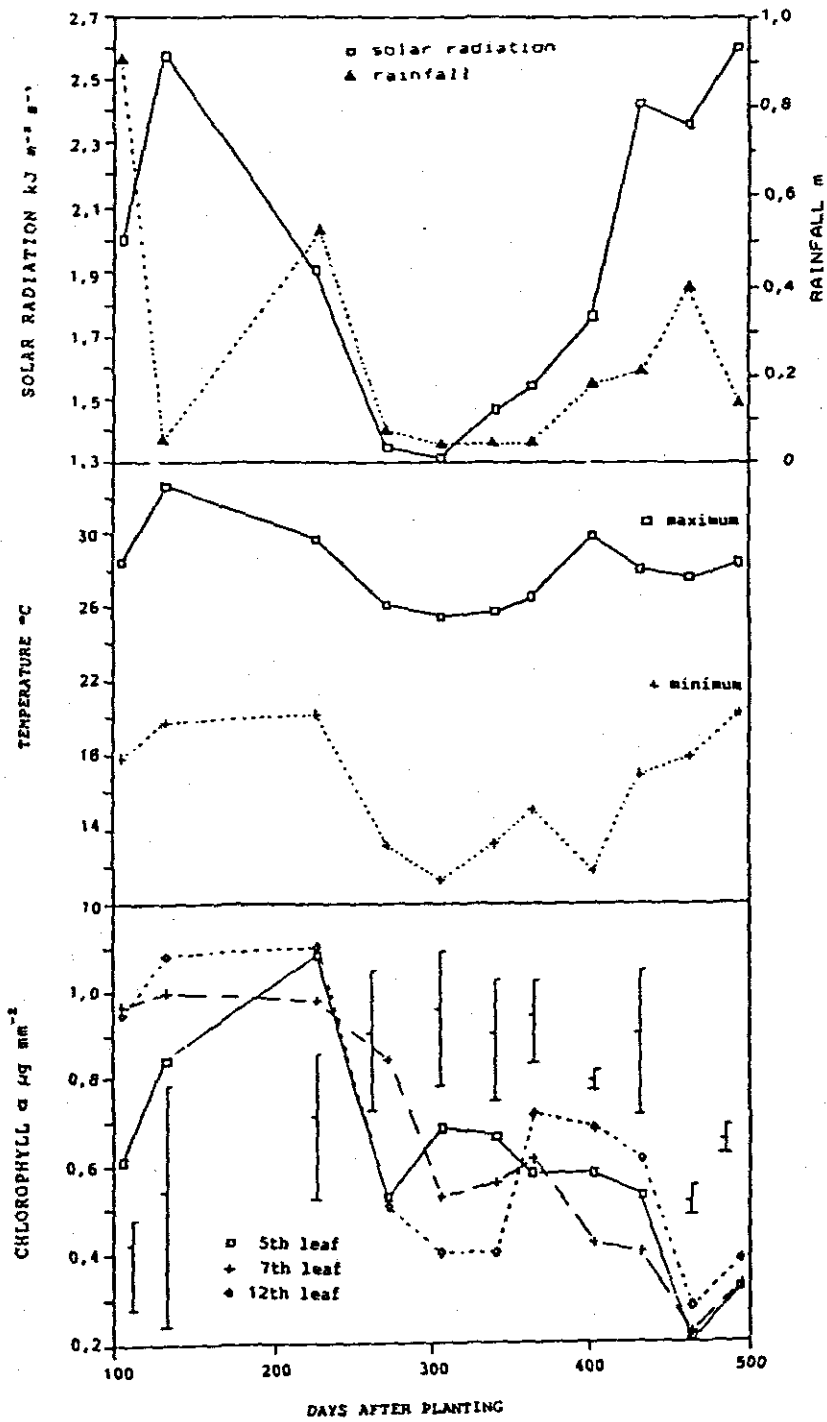
Figure 6.29 Temperature, rainfall, solar radiation and chlorophyll *a* content of the leaves of M 5 at different times after planting for Experiment 1.

significant. At 273 DAP, the 5th and 12th leaves had a significantly lower (p=0,05) chlorophyll *a* content than the 7th leaf. At 307 and 342 DAP, the 5th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 12th leaf. At 403 DAP, for p=0,01, the 12th leaf had a significantly higher chlorophyll *a* content than the 5th and 7th leaves. The 5th leaf had a significantly higher chlorophyll *a* content than the 7th leaf. At 464 and 495 DAP, the 12th leaf had a significantly higher (p=0,05) chlorophyll *a* content than the 5th and 7th leaves.

6.3.2.5.2. Experiment 2B

Results of this experiment are shown in Fig 6.30. At 107 DAP, the 12th leaf had a significantly higher (p=0,01) chlorophyll *a* content than the 5th and 7th leaves. At 135, 166 and 196 DAP, the differences in chlorophyll *a* content among the leaves were not statistically significant.

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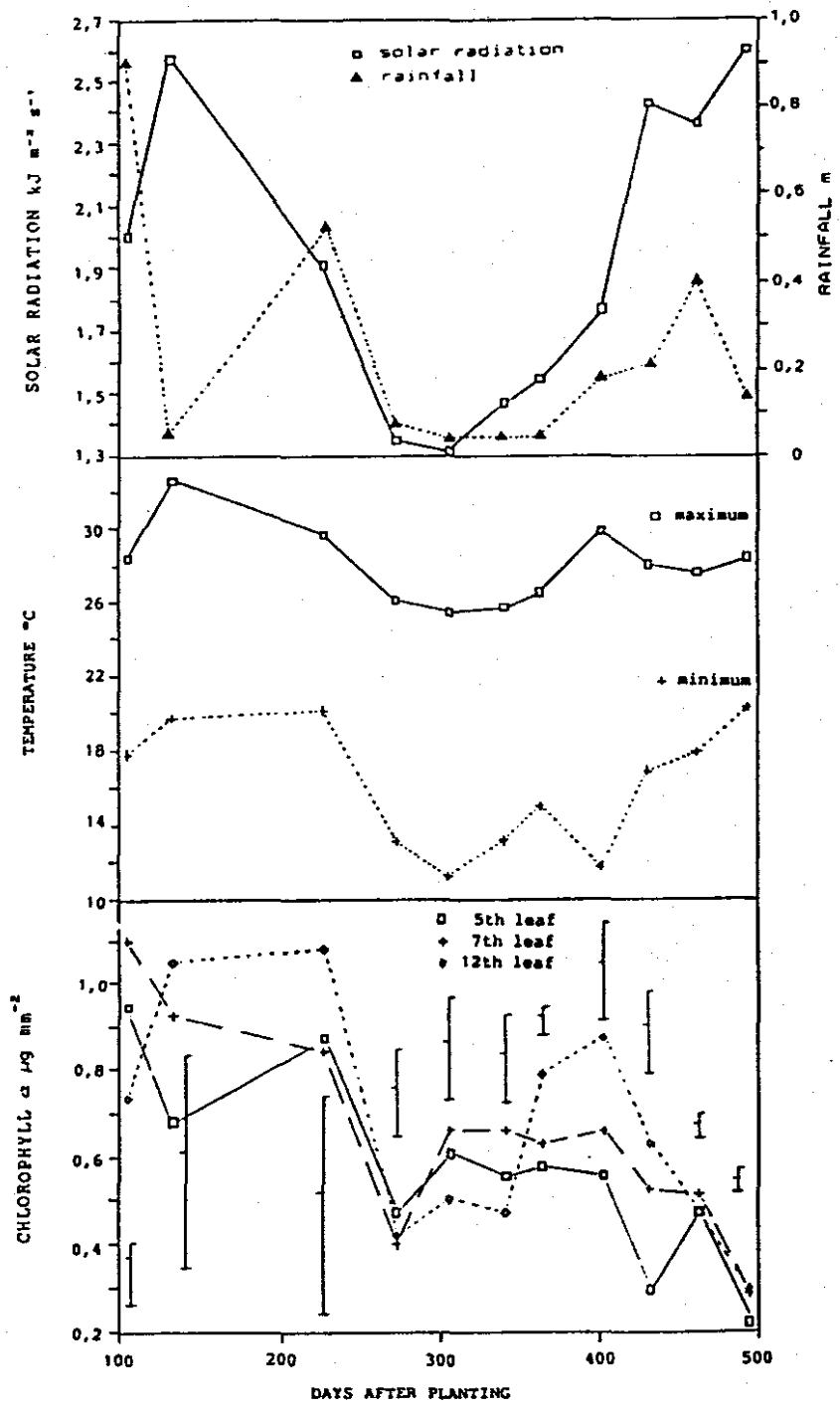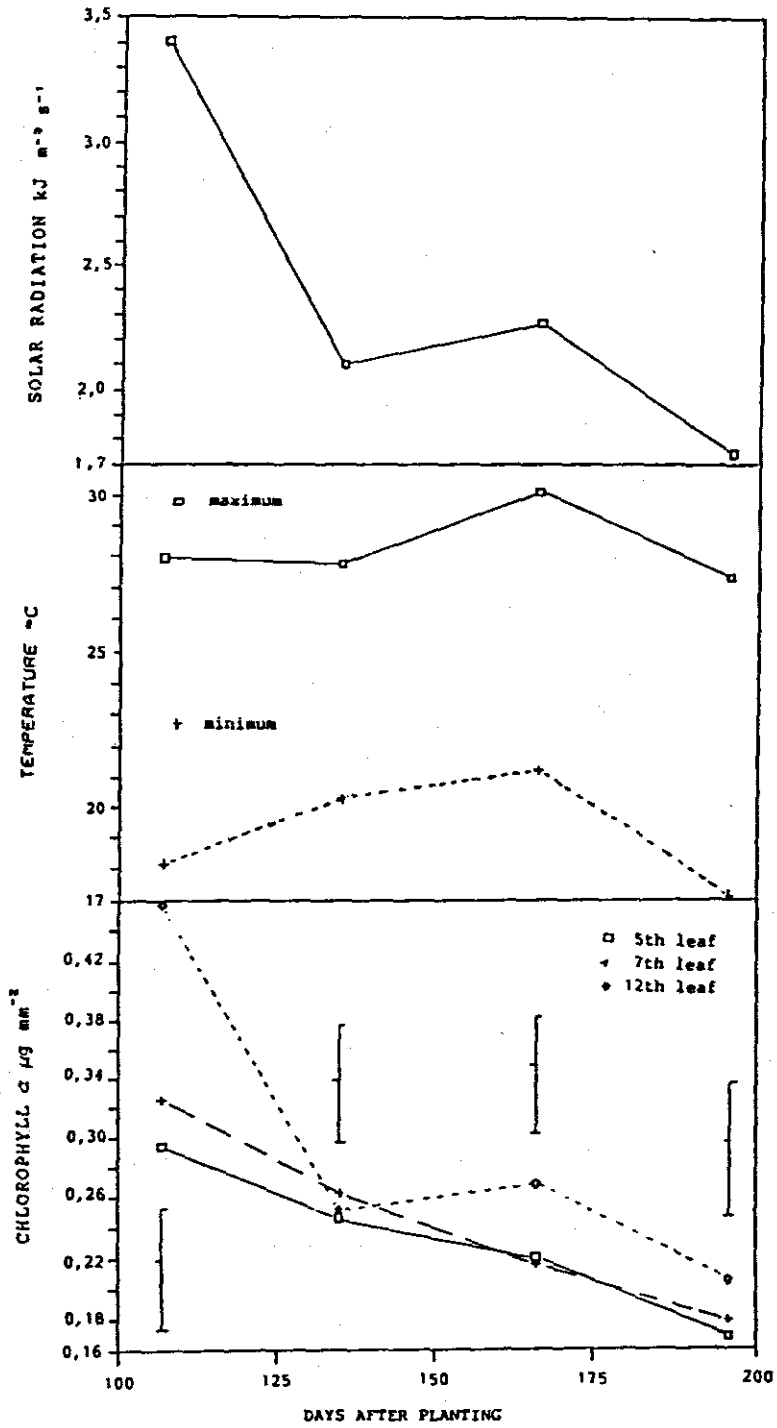
Figure 6.30   Temperature, solar radiation and   chlorophyll *a*

content of the leaves of M 5 at different times

after planting for Experiment 2B.
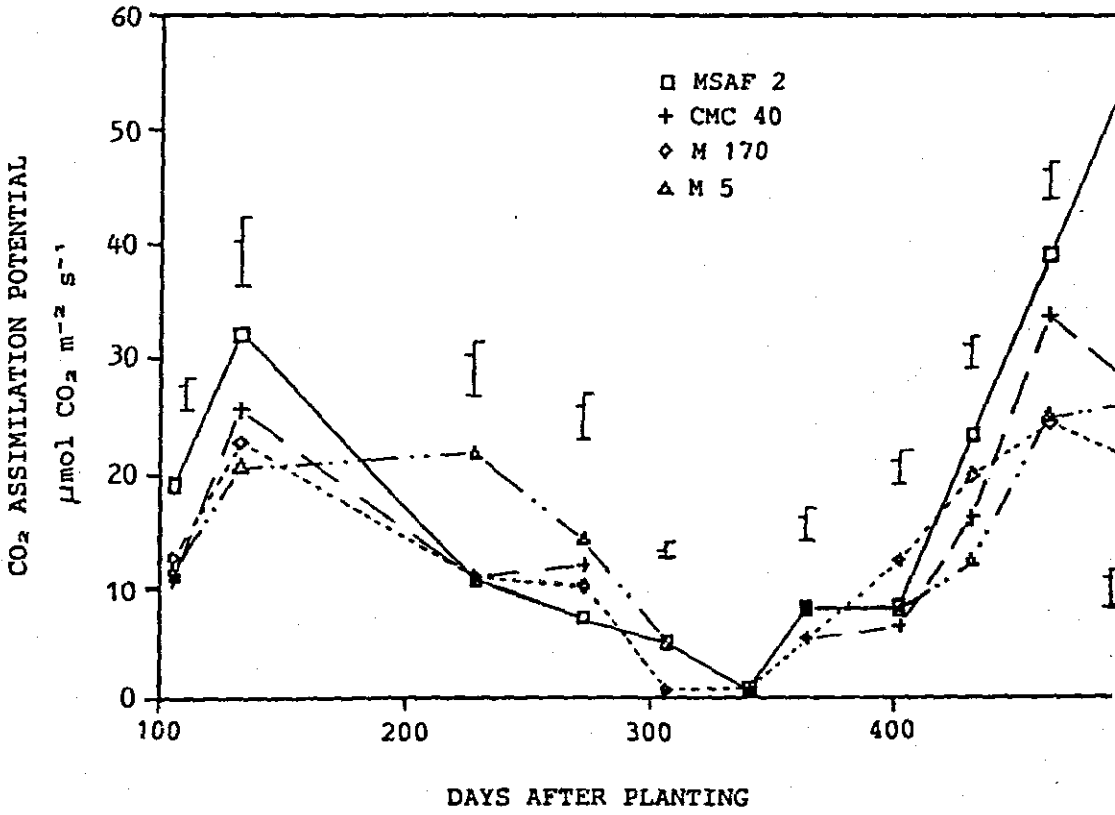
Figure 6.31 The CO_2 assimilation potential for cassava cultivars at different times after planting for Experiment 1.

6.3.3. CO₂ ASSIMILATION POTENTIAL

6.3.3.1. CO₂ assimilation potential for experiment 1 (1988)

The CO_2 assimilation potential is the product of LAI and the photosynthetic rate. The photosynthetic values which were used are 8,85 for MSAF 2; 7,82 for CMC 40; 8,86 for M 170 and 9,06 for M 5 all expressed in μmol CO_2 m^{-2} s^{-1}. In the present study, there was an increase in the CO_2 assimilation potential from 106 to 133 DAP in all the cultivars. From 133 to 342 DAP, CMC 40, MSAF 2 and M 170 had a decline in the CO_2 assimilation potential. In M 5, the CO_2 assimilation potential increased from 133 to 228 DAP, thereafter declined to 342 DAP. From 342 to 464 DAP, there was an increase in the CO_2 assimilation potential in all the cultivars (Fig 6.31).

At 106, the CO_2 assimilation potential in M 170 was significantly higher (p=0,05) than in CMC 40. For p=0,01, MSAF 2 had significantly higher CO_2 assimilation potential than CMC 40, M 170 and M 5. At 133 DAP, CMC 40 was significantly higher (p=0,05) than M 5. MSAF 2 was significantly higher (p=0,01) than CMC 40, M 170 and M 5. At 228 DAP, M 5 was significantly higher (p=0,01) than CMC 40, M 170 and MSAF 2. At 273 DAP, M 170 was significantly higher (p=0,05) than MSAF 2. For p=0,01,

M 5 was significantly higher than MSAF 2 and M 170. CMC 40 was significantly higher than MSAF 2. At 307 DAP, MSAF 2 and M 5 were significantly higher (p=0,01) than M 170. At 342 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 170 and M 5 were significantly higher than CMC 40. At 365 DAP, for p=0,01, MSAF 2 and M 5 were significantly higher than CMC 40 and M 170. At 403 DAP, for p=0,05, MSAF 2 was significantly higher than CMC 40. For p=0,01, M 170 was significantly higher than MSAF 2, CMC 40 and M 5. At 433 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 170 was significantly higher than CMC 40 and M 5. CMC 40 was significantly higher than M 5. At 464 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 was significantly higher than M 170 and M 5. At 495 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. CMC 40 and M 5 were significantly higher than M 170.

6.3.3.2. CO_2 assimilation potential for experiment 2A (1989).

The photosynthetic values which were used to calculate the CO_2 assimilation potential were 7,46 for MSAF 2; 6,11 for CMC 40; 7,86 for M 170 and 6,6 for M 5 all expressed in μmol CO_2 m^{-2} s^{-1}. M 170 and M 5 had an increase in the CO_2 assimilation potential from 196 to 227 DAP,
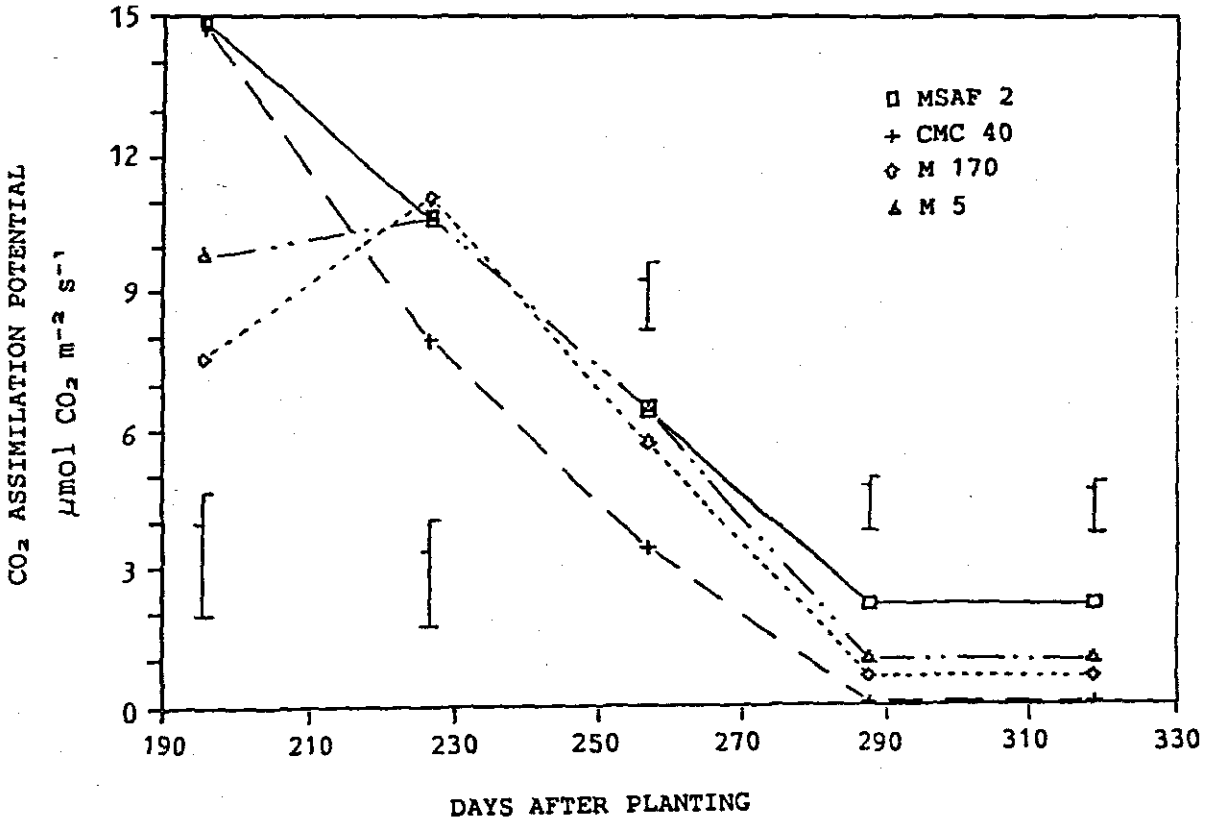
Figure 6.32 The CO_2 assimilation potential for cassava cultivars at different times after planting for Experiment 2A.

whereas in CMC 40 and MSAF 2 there was a decline (Fig 6.32).

At 196 DAP, the CO_2 assimilation potential in M 5 was significantly higher (p=0,05) than in M 170. For p=0,01, MSAF 2 and CMC 40 were significantly higher than M 170 and M 5. At 227 and 257 DAP, MSAF 2, M 170 and M 5 were significantly higher (p=0,01) than CMC 40. At 288 and 319 DAP, for p=0,05, M 5 was significantly lower than MSAF 2 and significantly higher than CMC 40. For p=0,01, MSAF 2 was significantly higher than CMC 40 and M 170.

6.3.3.3. CO_2 assimilation potential for experiment 2B (1989).

The photosynthetic values which were used to calculate the CO_2 assimilation potential were 7,0 for MSAF 2; 6,03 for CMC 40; 8,84 for M 170 and 7,17 for M 5 all expressed in μmol CO_2 m^{-2} s^{-1}. In all the cultivars, the CO_2 assimilation potential increased from 107 to 135 DAP (Fig 6.33). In all the cultivars, there was a decline in the CO_2 assimilation potential from 166 to 319 DAP.

At 107 DAP, the differences in the CO_2 assimilation potential between the cultivars were not statistically significant. At 135 DAP, M 5 and CMC 40 were significantly
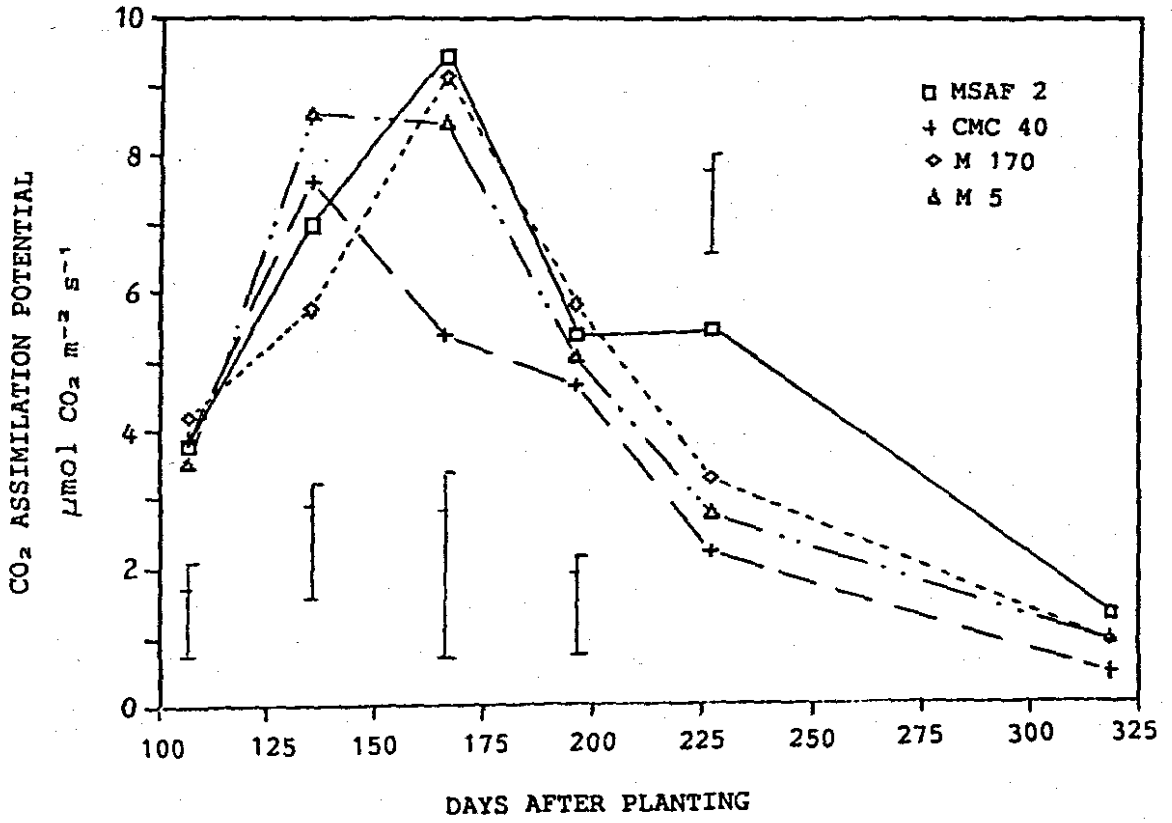
Figure 6.33 The CO_2 assimilation potential for cassava cultivars at different times after planting for Experiment 2B.

higher (p=0,01) than M 170. M 5 was significantly higher (p=0,01) than MSAF 2. At 166 DAP, MSAF 2, M 170 and M 5 were significantly higher (p=0,01) than CMC 40. At 196 DAP, M 170 was significantly higher (p=0,05) than CMC 40. At 227 DAP, MSAF 2 was significantly higher (p=0,01) than CMC 40, M 170 and M 5. At 319 DAP, for p=0,01, MSAF 2 was significantly higher than CMC 40, M 170 and M 5. M 170 and M 5 were significantly higher than CMC 40.

6.3.4. Efficiency of water use by cassava cultivars

The number of μmoles of H_2O required to assimilate one μmole of CO_2 was calculated by using the average transpiration rates and average photosynthetic rates for the whole study. This information is contained in Fig 6.34. According to Fig 6.34, M 170 was the most efficient in use of water and CMC 40 was the least efficient inspite of its lower transpiration rate.

6.4. DISCUSSION AND CONCLUSIONS

In the cultivars MSAF 2, M 170 and M 5, there was a decrease in photosynthetic rate from top to bottom within the plant's canopy (Fig 6.1). Such observations were consistent with those of San Jose (1983) where maximum photosynthesis in the upper canopy leaves was 0,772 mg CO_2
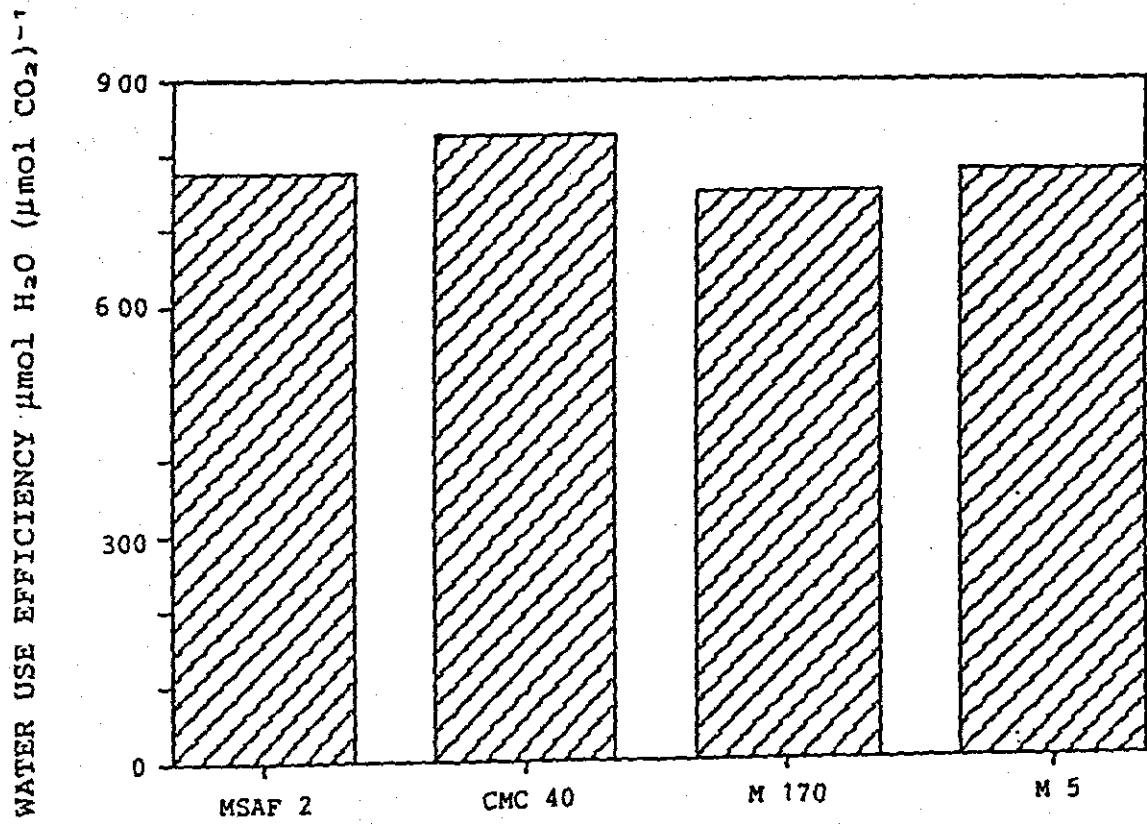
Fig 6.34   Efficiency of water use by cassava cultivars for
the whole study period (1988 – 1990).

m^{-2} s^{-1} (17,55 μmol CO_2 m^{-2} s^{-1}) and the lower canopy had 0,556 mg CO_2 m^{-2} s^{-1} (12,64 μmol CO_2 m^{-2} s^{-1}). The decline in PAR and photosynthesis followed the same pattern different from transpiration which showed very little decline (Fig 6.1 to Fig 6.3). If transpiration is used as a measure of stomatal conductance, it should be clear that the decline in photosynthesis is the result of the decline in PAR and not stomatal conductance (Fig 6.1 and Fig 6.3). The lower rate of photosynthesis in the top leaves of CMC 40 (Fig 6.1) is also not as a result of a lower stomatal conductance and must therefore be the result of another factor probably chlorophyll a content (Fig 6.25 and 6.26). The maximum photosynthetic rates obtained in the present study ranged from 8,4 to 10,97 μmol CO_2 m^{-2} s^{-1}. The present study gave a lower value than the ones obtained by other researchers eg Mahon, Lowe & Hunt, (1977) reported a maximum photosynthetic rate of 27,7 to 29 mg CO_2 dm^{-2} h^{-1} (17,45 to 18,27 μmol CO_2 m^{-2} s^{-1}).

Aslam et al (1977) obtained a maximum photosynthetic rate of 17,5 mg CO_2 dm^{-2} h^{-1} (11,03 μmol CO_2 m^{-2} s^{-1}). El-Sharkawy & Cock, (1984) obtained maximum photosynthetic rates of 16 μmol CO_2 m^{-2} s^{-1} for unwatered plants at high humidity and 24 μmol CO_2 m^{-2} s^{-1} for watered plants. El-Sharkawy, Cock & Held, (1984) obtained a maximum photosynthetic rate of 26 μmol CO_2 m^{-2} s^{-1}. Therefore the maximum photosynthetic rates obtained in the present

study were low compared to the ones reported in the literature.

High productivity requires not only maintenance of large leaf area but also high levels of photosynthetic activity in the leaf tissues (Mahon, Lowe & Hunt, 1976). Partitioning of assimilates for high yield must balance the production of new photosynthetic tissues required for rapid photosynthesis against high harvest index for root yield. The CO_2 assimilation potential and LAI were high in MSAF 2 at 106, 133, 433 and 495 DAP (Fig 5.13 and 6.31).

The photosynthetic rate was high in the morning and declined in the afternoon (Fig 6.4). The afternoon decrease in gaseous exchange was related to a water stress. As photosynthesis and transpiration rates increased, there was a decline in the leaf water potential. When the leaf water potential reached a certain low (critical) value, stomates closed and photosynthesis declined. These observations were consistent with the reports by Ike *et al* (1978) and by Palta (1983). Taiz & Zeiger (1991) as well as El-Sharkawy, Cock & Held, (1984) state that stomata of casava were unusually responsive to decreasing water availability, and stomatal conductance and transpiration decreased so much that leaf water potential and

transpiration remained nearly constant during drought. In the present study, the leaf water potential declined from the morning to the afternoon, thus the observations of Taiz and Zeiger (1991) and that of El-Sharkawy, Cock & Held, (1984) could not be demonstrated. According to Ghuman and Lal (1983), the leaf water potential decreased with time after sunrise, decreased to a minimum around 15:00 and then increased towards sunset. In this study, an increase in water potential towards sunset was observed although not reported in this dissertation.

A decrease in net photosynthetic rate associated with a decrease in leaf water potential is caused by an increase in stomatal and mesophyll resistances to gaseous diffusion (Boyer, 1970; Beadle et al, 1973). Due to closure of stomates, leaf water potential increased and stomates reopened. In MSAF 2 photosynthetic rate decreased when the leaf water potential was below -0,5 MPa (Fig 6.13 and Fig 6.17). In CMC 40, M 170 and M 5, photosynthetic rate decreased when the leaf water potential was below -0,6 MPa (Fig 6.14; 6.15; 6.16; 6.18; 6.19; 6.20). For several species, closure of stomata under water stress has been observed to occur over a narrow range of leaf water potential, the absolute values of which vary with th species (Ehlig and Gardner, 1964; Beadle et al, 1973). In corn, photosynthetic and transpiration rates decreased when the leaf water potential was -0,8 MPa (Dube,

Stevenson & Thurtell, 1974; Beadle *et al*, 1973). Well watered cassava plants had a leaf water potential of -0,61 MPa at a maximum photosynthetic rate of 29,9 mg CO_2 dm^{-2} h^{-1} (18,84 μmol CO_2 m^{-2} s^{-1}). As water was withheld, leaf water potential and photosynthesis declined (Palta, 1982). Ike (1982) observed a decline in transpiration and photosynthesis of cassava plants when the leaf water potential was below -0,3 MPa. It is difficult to draw generalisations on photosynthesis versus leaf water potential for cassava plants because very few studies have thus far been done.

A decrease in the relative net photosynthesis with decreasing leaf water potential closely followed decrease in relative transpiration (Fig 6.13; Ike, 1982). According to Mahon, Lowe, Hunt & Thiagarajah (1977) the decreased CO_2 uptake in the afternoon was paralleled by a decreased transpiration rate, suggesting stomatal closure as the cause of the decline. In the present study M 5 and M 170 maintained high transpiration rates inspite of the decline in photosynthesis and leaf water potential (Fig 6.16; 6.19). In such plants it is likely that cuticular transpiration occurred (Sheriff, 1977). The average maximum transpiration obtained in the present study ranged from 7700 to 8800 μmol H_2O m^{-2} s^{-1} (Fig 6.10). San Jose (1983) and El-Sharkawy & Cock, (1984) reported maximum transpiration of 60,75 mg H_2O m^{-2} s^{-1} (3374,99 μmol H_2O

m^{-2} s^{-1}) and 4,27 mmol H_2O m^{-2} s^{-1} (4270 μmol H_2O m^{-2} s^{-1}) respectively. Therefore, the present study gave higher transpiration rates than the ones reported in the literature. Wilting of leaves at midday on very hot days was observed in all the cultivars. Such wilting was gradual and acropetal. According to El-Sharkawy & Cock, (1984), partial stomatal closure at large vapour pressure deficit gave greater water use efficiency in cassava. Under field conditions Williams (1971) also observed rapid decrease in stomatal conductivity after midday in three cassava cultivars.

In experiment 1, the chlorophyll a content was higher in the first than in the second growth season in all the cultivars. During the second growth season from 433 to 495 DAP, there was a decline in the chlorophyll a content in three cultivars. This could have been caused by a lack of some nutrients because the fertiliser was applied during the first growth season when planting was done. As the chlorophyll a content declined from 433 to 495 DAP (Fig 6.21), the LAI increased in M 5 and MSAF 2 (Fig 5.13). In experiment 2B, a similar pattern of decline in chlorophyll a content with increasing LAI was observed in all the cultivars (Fig 5.15; 6.22). In experiment 2B, the decline in chlorophyll a content could not have been caused by a lack of nutrients because the fertiliser was applied on a regular basis. Field conditions (experiment

1) gave a higher chlorophyll *a* content than pot conditions (experiment 2B).

In experiment 1 during the first year of growth (133 to 273 DAP) CMC 40 had a significantly lower chlorophyll *a* content than M 5 (Fig 6.21). In experiment 2B, CMC 40 had a significantly lower chlorophyll *a* content than M 170 (Fig 6.22). Since the photosynthetic rate at high light intensity is correlated with total chlorophyll *a* content, this explains why CMC 40 had a slightly lower photosynthetic rate than M 170 and M 5 (Fig 6.6; 6.9; 6.10). According to Aslam *et al* (1977), the photochemical apparatus is not affected in ageing leaves of cassava until late in senescence when the chlorophyll *a* content decreases. MSAF 2, M 170 and M 5 performed photosynthetically fairly equal, but due to its higher LAI, MSAF 2 could have been more efficient.

Table 7.1. A summary of the occasions on which one cultivar outyielded
another in root dry mass and other relevant morphological
characteristics.

Exp	DAP	Cultivars	Positive factors				Negative factors			
1	495	M 170 > M 5	HI						LAI	
	707	MSAF 2 > CMC 40								
	707	MSAF 2 > M 5								
2A	319	MSAF 2 > M 170		PDM	LDM	LAI				
2B	319	MSAF 2 > M 5	HI			LAI	SDM	PH		PLN
	319	MSAF 2 > CMC 40	HI	PDM	LDM	LAI	SDM	PH		
	319	M 170 > CMC 40	HI			LAI	SDM	PH		
	319	M 170 > M 5	HI				SDM		LAI	
	319	M 5 > CMC 40	HI		LDM	LAI		PH		

LDM = leaf dry mass

PDM = petiole dry mass

PH = plant height

PLN = present leaf numbers

SDM = stem dry mass

CHAPTER SEVEN

7. GENERAL DISCUSSION AND CONCLUSIONS

Two field trials and one pot plant trial were conducted at the University of Zululand. Various morphological and physiological characteristics were studied and related to root yield. These were stem dry mass, petiole dry mass, leaf dry mass, harvest index, plant height, profuse branching, cumulative leaf numbers, leaf fall, present leaf numbers, leaf area index, chlorophyll a content, leaf area duration, tuberous root numbers, photosynthetic rate, transpiration rate, leaf water potential, CO_2 assimilation potential and the efficiency of water use.

A summary of the instances where one cultivar had a significantly higher root dry mass than another cultivar at the end of an experiment or at the end-of-season's harvest is presented in Table 7.1. Also contained in Table 7.1 are those instances where the same cultivar differed significantly for other characteristics.

According to Table 7.1, there are nine occasions on which one cultivar significantly outyielded another: MSAF 2 in five instances, M 170 in three instances and M 5 in one instance. MSAF 2 was never outyielded whilst CMC 40 never

outyielded another cultivar. Based on root yield, the cultivars can therefore be ranked as follows: MSAF 2 (broad-lobed), M 170 (narrow-lobed), M 5 (narrow-lobed) and CMC 40 (broad-lobed). At 707 DAP in experiment 1, MSAF 2 had a significantly higher yield than both CMC 40 and M 5. Unfortunately, other morphological characteristics could not be recorded because the plants had already died back due to drought.

According to Table 7.1, the cultivar which had a significantly higher yield than the other also had a significantly higher HI except experiment 2A where MSAF 2 had a significantly higher yield than M 170, yet the HI for the two cultivars did not differ significantly. Cock (1976) also observed that the cultivars with a high HI had a high yield.

In experiment 1 at 495 DAP and in experiment 2B at 319 DAP, M 170 had a significantly higher yield than M 5. In both instances there were no significant differences in LAI but they differed in HI. Except for the above named instances, the cultivars with a higher yield constantly had a higher LAI (Table 7.1). The cultivars Msitu Zanzibar and M Col 113 had a maximum LAI of 8 and yields of 2304 and 2100 g m^{-2} a^{-1} respectively (Enyi, 1973; Cock, 1976). In the present study, MSAF 2 had a maximum LAI of 3,6 and a yield of 1119,99 g m^{-2} a^{-1}.

In experiment 2B at 319 DAP, the cultivar M 170 had a significantly higher yield than M 5 although the cultivars did not differ significantly in height. In all other instances, a cultivar with a higher yield was significantly shorter than the other cultivar. M 5 had a significantly higher yield than CMC 40 although the cultivars did not differ significantly in stem dry mass. In all other instances, a cultivar with a higher yield had a significantly lower stem dry mass (Table 7.1).

MSAF 2 had a significantly higher yield than CMC 40 (Table 7.1). The number of tubers which correspond with these harvest dates was not determined for experiment 2A. In experiment 2B, the number of tubers in MSAF 2 was significantly higher than in CMC 40 (Table 4.2). In experiment 2A at 257 DAP, MSAF 2 had a significantly higher number of tubers than CMC 40 (Table 4.1). Therefore, the high yield in MSAF 2 as compared with CMC 40 could partly be due to a high number of tubers. A number of tubers smaller than 10 per plant limited the sink capacity and resulted in a low yield (Cock et al, 1979; Keating et al, 1982a). In the present study, the highest number of tubers obtained was 9,4 in M 170. Therefore, the present study gave a lower number of tubers than the ones reported in the literature.

Profuse branching was desirable in the narrow-lobed plant (M 170) with a low shoot dry mass. It resulted in an increase in LAI (Chapter 5). Profuse branching did not occur in MSAF 2. During post - winter regrowth, several buds formed new shoots below the dry apical bud in MSAF 2. Consequently, MSAF 2 had the highest LAI which is probably the reason for its improved higher yield at 707 DAP (Chapters 4 & 5).

Flowering is associated with profuse branching in cassava. In 1990, potted plants used for measurement of photosynthetic rate received excess rainfall and the weather was generally cloudy even in the absence of rainfall. Such conditions could have played a role in the three - point branching which was observed in MSAF 2. More research is needed on the effect of light on flowering and on the effect of profuse branching on the yield in MSAF 2.

The average leaf photosynthetic rates (1988 - 1990) in the cultivars studied are presented in Table 7.2). The photosynthetic rate in CMC 40 was generally lower than in M 170.

Table 7.2. Average photosynthetic values for cassava cultivars for the whole study period (1988 – 1990).

Cultivar	Photosynthesis μmol CO_2 m^{-2} s^{-1}
MSAF 2	7,77
CMC 40	6,65
M 170	8,52
M 5	7,61

A number of researchers have measured the photosynthetic rate of CMC 40. The maximum photosynthetic rates for different cassava cultivars reported in the literature are presented in Table 7.3.

Table 7.3. The maximum photosynthetic rates for cassava cultivars reported in the literature.

Cultivar	Original value $mg\ CO_2\ dm^{-2}\ h^{-1}$	Converted value $\mu mol\ CO_2\ m^{-2}\ s^{-1}$	Reference
CMC 40	16,00	10,08	Aslam *et al* (1977)
CMC 40	20,12	12,68	Mahon, Lowe & Hunt (1977)
M Col 22	29,00	18,27	Mahon, Lowe & Hunt (1977)

M Col 22 ⎤
M Col 1467 ⎟
M Col 1686 ⎬   -   26,00   El-Sharkawy, Cock & Held
M Col 1689 ⎟   (1984)
M Col 2059 ⎟
M Col 2063 ⎦

M Col 22 ⎤
M Mex 59 ⎟
M Col 638 ⎬   30,00   18,90   Palta (1982)
M Ven 218 ⎦

Table 7.4. The maximum photosynthetic rates recorded
during the present study (1988 - 1990).

Cultivar	photosynthesis $\mu mol\ CO_2\ m^{-2}\ s^{-1}$
MSAF 2	10,97
CMC 40	8,40
M 170	10,48
M 5	10,05

The maximum photosynthetic rates recorded for the various
cultivars in the present study are presented in Table 7.4.
The maximum photosynthetic rates obtained in the present
study were low compared to the ones reported in the
literature. The photosynthetic rate for CMC 40 recorded in
the present study was slightly lower than the ones
reported in the literature.

A comparison of photosynthesis and chlorophyll *a* content
for the present study is presented in Tables 7.5 & 7.6.
In both Tables, CMC 40 had the lowest chlorophyll a
content and the lowest photosynthesis. These findings are
consistent with the ones reported by Aslam *et al* (1977)
presented in Table 7.7 where he compared five cultivars
and found CMC 40 to be the lowest. The chlorophyll *a*

content reported by Aslam *et al* (1977) could not be compared with the present study because they were expressed in different ways.

Table 7.5. Photosynthesis versus chlorophyll *a* content for cassava cultivars at 228 DAP for experiment 1.

Cultivar	Photosynthesis μmol CO_2 m^{-2} s^{-1}	Chlorophyll *a* μg mm^{-2}
MSAF 2	8,77	0,92
CMC 40	6,96	0,72
M 170	8,94	1,17
M 5	8,78	1,05

Table 7.6. Photosynthesis versus chlorophyll *a* content for cassava cultivars at 135 DAP for experiment 2B.

Cultivar	Photosynthesis μmol CO_2 m^{-2} s^{-1}	Chlorophyll *a* μg mm^{-2}
MSAF 2	7,43	0,27
CMC 40	4,49	0,19
M 170	8,44	0,30
M 5	5,36	0,25

Table 7.7. Photosynthesis versus chlorophyll *a* content for
cassava cultivars reported by Aslam *et al*
(1977).

Cultivar	Photosynthesis $mg\ CO_2\ dm^{-2}\ h^{-1}$	Chlorophyll a $mg\ (g\ fresh\ weight)^{-1}$
M Pan 70	20	3,70
M Mex 17	20	4,15
M Ven 47	20	3,55
M Col 946	20	3,55
CMC 40	16	2,70

Table 7.8. Average transpiration rate for cassava
cultivars for the whole study period (1988 –
1990).

Cultivar	Transpiration $\mu mol\ H_2O\ m^{-2}\ s^{-1}$
MSAF 2	6033
CMC 40	5500
M 170	6400
M 5	5930

According to to Table 7.8, CMC 40 had the lowest transpiration rate. The number of μmoles of H_2O required to assimilate one μmol CO_2 was the highest in CMC 40 and the lowest in M 170. Therefore, M 170 was the most efficient in use of water and CMC 40 the least efficient inspite of its lower transpiration rate (Fig 6.34). San Jose (1983) reported a transpiration rate 80 mg H_2O m^{-2} s^{-1} (4444,44 μmol H_2O m^{-2} s^{-1}) whereas El-Sharkawy & Cock (1984) obtained 4,2 mmol H_2O m^{-2} s^{-1} (4270 μmol H_2O m^{-2} s^{-1}). Thus in the present study higher transpiration rates were recorded than the ones reported in the literature.

Table 7.9. Cassava cultivars ranked according to root dry mass, photosynthetic rate, average chlorophyll *a* [results of two experiments], efficiency of water use and stomatal conductance (using transpiration rate as a measure).

1	2	3	4	5
MSAF 2	MSAF 2	M 170	M 170	M 170
M 170	M 170	M 5	MSAF 2	MSAF 2
M5	M 5	MSAF 2	M 5	M 5
CMC 40	CMC 40	CMC 40	CMC 40	CMC 40

1 = root dry mass

2 = photosynthetic rate

3 = chlorophyll *a*

4 = effifiency of water use

5 = stomatal conductance

In summary, the morphological characteristics which best explain the differences in root dry mass are HI, LAI and to a lesser extent stem dry mass and plant height.

In an attempt to determine the relative importance of LAI and HI, a study was made of the instances where a

Table 7.10. Instances where the LAI and/or HI of one cultivar significantly exceeded that of another but did not coincide with a significantly improved root yield.

Exp	DAP	LAI Cultivar	HI Cultivar
1	307	MSAF 2 > M 170	
	307	M 5 > M 170	
	495	MSAF 2 > CMC 40	
	495	MSAF 2 > M 170	
	495	CMC 40 > M 170	
	495	CMC 40 > M 5	
2A	319	MSAF 2 > M5	
	319	MSAF 2 > CMC 40	
	319	M 5 > CMC 40	
2B	319	MSAF 2 > M 170	
1	307		M 170 > MSAF 2
	307		M 170 > CMC 40
	307		M 170 > M 5
	495		M 170 > MSAF 2
	495		M 170 > CMC 40
2A	319		M 170 > CMC 40
	319		M 170 > M 5

significantly better LAI and HI did not result in a significantly improved root yield (Table 7.10). From the Table 7.10 it is clear that there were 10 instances inwhich the LAI of one cultivar significantly exceeded that of another without this resulting in a significantly improved root yield. The important thing to note however is that none of the 10 instances coincided with a significantly improved HI. From the information contained in Tables 7.1 and 7.10, it should be clear that for the 4 cassava cultivars used in this study, unless a better LAI coincides with a better HI and vice versa it seldom leads to an improved root yield.

In an attempt to assess the role of the physiological characteristics on root yield, Table 7.9 was constructed. The lower photosynthetic rate, lower average chlorophyll *a* content, lower water use efficiency and lower stomatal conductance are consistent with the lower root yields observed in CMC 40 (Table 7.1 and 7.9).

A comparison of the yield for various cassava cultivars reported in the literature is presented in Table 7.11. The maximum yield obtained in the present study was low compared to the ones reported in the literature. Meteorological and other data corresponding with the yield reported in the literature was not available. It is therefore not possible to explain the lower yield recorded

Table 7.11. Storage root yield for various cassava cultivars reported
in the literature.

Cultivars	Storage root DM yield g m^{-2}	Age months	Location	Reference
M Col 22	2100	12	Colombia	Cock (1976)
Jurai	2000	9	Malaysia	Williams (1974)
M Mex 11	2000	11	Colombia	Cock, Wholey & Gutierrez (1977)
M Col 22	2200	11	Colombia	Cock, Wholey & Gutierrez (1977)
Msitu Zanzibar Aipin Valenca Amani 4026/16	1009 - 2323	12	Sierra Leone	Enyi (1973)
MSAF 2 CMC 40	850 - 1300	10	kwadlangezwa	Present study (Exp 1)
M 170 M 5	702 - 999	10	Kwadlangezwa	Present study (Exp 2A)

during this study. The production of cassava by the Anglo-American research team for commercial purposes closed down because the yield in their field trials did not meet their expectations. Therefore, the low yield obtained in the present study was consistent with the observations made by the Anglo-American research team at Mtunzini (Personal communication).

Factors that could have contributed to the lower yield recorded in this study as compared to yields reported in the literature are as follows: lower LAI, lower photosynthetic rates, higher transpiration rates and a smaller number of tubers.

Little is known about the performance of these cultivars in other regions to indicate whether the edaphic and /or climatic conditions in Zululand are unsuitable or whether the cultivars used are inferior.

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