GROWTH ANALYSIS IN CASTOR GENOTYPES
(*Ricinus communis* L.)

BY

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B.Sc. (Ag.)

THESIS SUBMITTED TO THE
ANDHRA PRADESH AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE
IN THE FACULTY OF AGRICULTURE

DEPARTMENT OF PLANT PHYSIOLOGY
COLLEGE OF AGRICULTURE, RAJENDRANAGAR
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RAJENDRANAGAR, HYDERABAD-500 030.

SEPTEMBER, 1992

CERTIFICATE

Mr. Y. **VENKAT REDDY**, has satisfactorily prosecuted the course of research and that the thesis entitled **"GROWTH ANALYSIS IN CASTOR GENOTYPES (*Ricinus communis* L.)"** submitted is the result of original research work and is sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date: 22-09-92.

Place: Hyderabad.

(Dr. B. GOPAL SINGH)

Chairman & Major Advisor

CERTIFICATE

This is to certify that the thesis entitled "**GROWTH ANALYSIS IN CASTOR GENOTYPES** (Ricinus communis L.)" submitted in partial fulfilment of the requirements for the degree of "**MASTER OF SCIENCE IN AGRICULTURE**" of the Andhra Pradesh Agricultural University, Hyderabad, is a record of bonafide research work carried out by Mr. Y. **VENKAT REDDY** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged by the author of the thesis.

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ACKNOWLEDGEMENTS

With respectful regards and immense pleasure, I wish to express my gratitude to **Dr. B. Gopal Singh**, Associate Professor, Department of Plant Physiology, College of Agriculture, Rajendranagar, Hyderabad, and Chairman of my Advisory Committee, for his invaluable guidance, unstinted encouragement and constructive criticism during the course of this study.

I wish to place on record my sincere thanks to **Dr. T. Madanmohan Reddy** and Dr. I.V. Subba Rao, Members of Advisory Committee who have been a constant source of sage counsel.

I would like to express my profound sense of gratitude to **Dr. B.M.K. Reddy, T. Srinivas** and **S.N. Reddy**, for their co-operation in carrying out my thesis work.

I affectionately acknowledge the help and encouragement received from **V.V.P., M.R, Sokka, Shyam, Subbi, Sammi, Auker, Sagar, Pops, Raghu, Suppy, Ravi, Ramana, Laddu, Angs, Raju, Venu, Hany, M.Vij, P. Shatty, Raj, Ball, S.K., Prabhakar, Chinna & Pedda Narsi, R' Shakar, Gopi, Uma, Venkat** and other friends.

It is not untimely to pay reverence to my parents, brothers, sisters and brothers-in law, whose affection has been the source of inspiration throughout my educational career.

(Y.VENKATA REDDY)

DECLARATION

I, **Y. VENKAT REDDY**, hereby declare that the thessi entitled "**GOROWTH ANALYSIS IN CASTOR GENOTYPES** (**Ricinus communis L.**)" is a result of the original research doen by me. I further declare that the thesis or any part thereof has not been published earlier in any manner.

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Degree to which is Submitted	:	**MASTER OF SCIENCE**
Faculty	:	**AGRICULTURAL SCIENCE**
Department	:	**PLANT PHYSIOLOGY**
Major Advisor	:	**Dr. B. GOPAL SINGH**
University	:	**ANDHRA PRADESH AGRICULTURAL UNIVERSITY**
Year of submission	:	**1992**

ABSTRACT

The growth analysis in castor genotypes was studied during *kharif*, 1990. All the cultivars showed a significant differences for plant height, number of nodes, branches, LAI, CGR, NAR, dry matter production and yield contributing characters. Tall cultivars with short duration showed higher values for number of branches, leaf area, LAI, CGR and dry matter accumulation compared to dwarf cultivars with long duration. The plant height, number of branches, early flowering, CGR, LAI, harvest index and 100-seed weight influence the yield in castor.

INTRODUCTION

CHAPTER I

INTRODUCTION

Castor (Ricinus Communis L.) is the oldest oil seed crop known to man and is cultivated throughout the temperate and tropical regions of the world for its excellent qualities of seed, oil and meal. India is one of the world's principal producers of castor and is grown over an area of about 7 lakh hectares with a production of about 4.69 lakh tonnes (DOR, 1990). The average yield in India is the second highest (601 kg ha^{-1}), after Brazil (631 kg ha^{-1}). Since cultivation of castor in India is largely confined to rainfed situations under very poor agronomic conditions, the possibility of increasing the area under castor is less. Therefore, the higher yield per hectare is the only solution.

Yield is the manifestation of various physiological processes occurring in the plants. These processes are usually modified in the environment and management practices. Hence, a combination of fertilizers and improved varieties, together with higher standards of crop husbandry will be necessary to increase the productivity. Since yield depends on dry matter production and the efficiency of conversion of solar energy to chemical energy contained in plant dry matter, growth analysis represents a promising approach in analysing the complex characters of yield capacity. In view of examining the growth characters in relation to yield the present study entitled "Growth analysis in castor" was taken up with the following objectives.

1. To factorise plant growth by means of growth analysis.

2. To understand partitioning of dry matter production and

3. To study the cultivaral differences for full expression of characters in castor.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Crop productivity usually depends on inherent capacity for photosynthesis and photosynthetic area it develops. The genetic variation in productivity of crop may be related to net assimilation rate (NAR), crop growth rate (CGR), leaf area index (LAI) and partitioning of photosynthates into economic and non-economic sinks. The quantitative importance of these growth parameters in relations to growth behaviour of plant species was elaborated by Watson (1952), Redford (1967), and Buttery and Buzzell (1972). In the last few decades ample information has been generated on choice of growth parameters for comparative assessment of crop performance under field conditions.

Although, Gregory (1917) introduced these parameters for first time, it was Williams (1946) and Watson (1947) used these concepts successfully in physiological and biometric studies. Wallace and Munger (1965) observed differences in NAR among different varieties of dry beans. Weber et al., (1966) found that plant dry weight in soyabean was positively correlated with LAI, but maximum seed yield was obtained at sub-maximal LAI as at maximum LAI a lower proportion of plant dry matter was partitioned into the seed fraction. Variations in dry matter accumulation by different varieties may be related to factors such as leaf area. Net assimilation rate (NAR), leaf area ratio (LAR) and relative growth rate (RGR). (Wallace and Munger 1965).

The influence of leaf area and NAR on total dry matter accumulation indicated that variation in leaf area is more an influential factor for comparison of species and varieties (Balckman and Wilson, 1951; Milthorpe, 1962; Moss, 1960; Nichi Porovich, 1960; Shibles and Macdonald, 1962 and Watson, 1952). According to earlier conclusions, NAR was approximately the same for all species (Heath and Gregory, 1938). But many of the recent studies using both dry matter accumulation and gas exchange procedures indicated that NAR differences do exist both among species and among genetic strains within species. Comparisions among and within species some times shown that differences in LAR are closely associated with variations of RGR (Blackman and Wilson 1951, and Tsunoda, 1959).

Though the technique of growth analysis was used extensively in most of the crops, less information is available in castor. An attemp was, therefore, made to review the available literature on growth analysis in castor.

2.1 PLANT HEIGHT

Plant height in castor is usually determined by the length of internodes. As the length of internodes and node number on primary stem increase, plants tend to grow tall to nearly 3 to 4 m. The internodal distance is hardly one to two cm in the basal nodes and increases gradually to as much as 30 to 40 cm at the top of the main stem in majority of improved cultivars, hybrids and their parents (DOR, 1990). The maximum internodal length rarely exceeds 25 cm while, in genotypes like Sowbhagya and VP-1 which are characterised by condensed internodes the maximal internodal length rarely goes beyond 3 cm at any point on primary stem. Samoilenko, (1977) reported that the range of average plant height in dwarf cultivars and hybrids of castor was 55 to 117 cm compared to 140 cm in tall cultivars.

The internodal distance and consequently the palnt height in castor are greatly influenced by the crop growing situation and season (DOR, 1990). Genotypes which attain 30 to 90 cm height under poor management conditions have been recorded to grow as tall as 200 cm and above in fertile soils and or under high level of management (DOR, 1990). A similar significant increase in plant height over control upto 50 kg N ha^{-1} was also observed for castor genotypes viz., SBH-18 and R-8 (DOR, 1990). The planting time, growing season, plant geometry etc., were also reported to exert substantial influence on plant height in castor (DOR, 1990).

Variation in plant height of sesame with date of sowing was also reported by several workers (Bhattacharya, 1973; Abdel-Rehman et al., 1980; Rao et al., 1985; Ghosh and Bogdi, 1986 and Narayanan and Narayanan, 1987). They reported more plant height in early sown sesame compared to late sown one. This increase in plant height in sesame was continuous till the apperance of flower buds and remains constant during capsule filling stage (Narayanan and Reddy, 1982). In case of groundnut majority of cultivars showed continuous increase in plant height upto 60 to 75 days after emergence (Madhavi, 1988). A gradual increase in plant height as crop ages was also observed in safflower (Saibabu, 1990). The effect of seed size on plant height was also studied in other oil seed crops. Trehan et al., (1977) recorded dwarf plants from small seeds and tall plants from bold seeds in sunflower. Such type of results were also reported in groundnut (Ponnuswamy, 1985) and soybean (Singh et al, 1972).

The relationship between seed size and plant height in groundnut was attributed to the presence of food reserves in the cotyledons and the efficiency with which the seedlings attain photosynthetic activity

(Ponnuswamy, 1985). However, seed size did not exhibit any significant effect on plant height in rape seed (Major, 1977).

A significant and positive association between plant height and seed yield was observed in castor (Laureti, 1981; Muthiah et al, 1982; Turkhede et al, 1982; Laureti, 1988; Sachli, 1986).

2.2 NUMBER OF NODES AND BRANCHES

The number of nodes upto primary raceme on the main stem is an index of crop duration (DOR, 1990). In general higher the node number upto primary raceme later the genotype with its flowering and greater is its tendancy for perenniating habit. By an average, every node contributes about four days for flower initiation in primary raceme. For instance, a variety or genotype possessing mean node number of 12 takes about 45 to 50 days for completion of flower initiation in the primary raceme of varietal population. However, node number varies considerably both within and among genotypes depending on time of planting. In some of the varieties grown in USSR, the stem had 5 to 12 nodes at a 30 to 100 cm height of the stem and the length of the internode was 6 to 10 cm. However, the dwarf varieties showed short internodes measuring a length of 1.5 to 3 cm. (Moshkin, 1956; Zimmerman, 1958; PodkniChenko, 1972; Samoilenko, 1975).

In trpics the number of nodes on the main stem reaches to 18 to 30 while the lateral branches may have 5 or more nodes (Moshkin, 1986). The currently accepted range of variation for node number in different varieties for seed certification is as follows (DOR, 1990).

Variety	Number of nodes
1. Aruna	11.5 - 12.5
2. Bhagya	10.5 - 11.5
3. Sowbhagya	14.5 - 11.5
4. TMU - 5	12.5 - 13.5
5. RC -8	16.5 - 17.5
6. GAVC-I	14.5 - 15.5
7. VP-I	15.5 - 16.5
8. JI - 35	18.5 - 19.5
9. 48-I	16.5 - 17.5

In general all cultivated varieties, hybrids and parental lines of castor are of branching type. Besides genotype, a number of cultural and management factors during the crop growing period also exert profound influence on the expression of branching in castor. Similar variation in branching of Indian mustard based on varied duration was reported by Meharotra _et al._, (1976). They observed more number of primary and secondary branches per plant in late duration types than in the early ones. Irrespective of the cultivar, wider spacing resulted in more number of branches in castor (Reddy et al., 1990). Similarly a decrease in number of branches per plant with the increase in plant populations was recorded in soybean (Weber et al.,1966; Costa et al.,1980; Latifi, 1980; Rajput et al.,1984). Apart from spacing, nutrition also influenced branching. Different levels of nitrogen and sulphur recorded significant effect on number of branches in safflower (Saibabu, 1990). The pattern of branching and ripening in castor revealed that the central spikes in branching types ripen early but yield poorly due to small population. But it is the central spike of poorly branching and single spike castor varieties accounted for almost the entire yeild (Moshkin, 1956).

2.3 INFLORESCENCE

In castor, inflorescence is borne terminally on the main axis and lateral branches and node from which the first originate is a varietal characteristic (Weiss, 1971). The main stem usually terminates in an inflorescence or raceme known as the first or primary spike which is generally the largest one in the plant, while the laterals terminate in secondary, tertiary and quarternary spikes. A distinct variation both interms of yield and oil content of seeds was observed between the various types of inflorescence (Weiss, 1971). In

Poland the highest yield of seeds was obtained from the first racemes while the successive racemes produced lower yields. In USA the 100-seed weight was generally the greatest for primary racemes and lowest for secondary, tertiary and quarternary racemes. The size, shape and compactness of the spike also vary greatly and are determined by genetic constitution (DOR , 1990). However, the genotypic expression is influenced considerably by the environment in which the crop is grown.

From correlation studies it is evident that the number of capsules per primary raceme in castor showed a positive and direct effect on seed yield per plant (Bhatt and Reddy, 1981). In case of Aruna, the primary, secondary and tertiary spikes constitute 78, 13 and 8 per cent of the total seed yeild, respectively (Rao et al.,1981). They also reported that removal of primary and secondary spikes increased the contribution for total yield of 13 to 61 per cent and from 8 to 39 per cent in secondary and tertiary spikes respectively. Quarternary spikes produced after an orderly removal of tertiary, primary and secondary; primary and tertiary and secondary and tertiary spikes contributed 11- 35 per cent to the yield. However, the total yield was not adversely affected by the removal of spikes of any order (Rao et al, 1981).

2.4 DRY MATTER PRODUCTION

Dry matter production largely depends on the size of photosynthetic apparatus and its efficiency. However, a number of cultural and management factors such as spacing, seed size, time of planting, crop season, stage of the crop growth and duration of the crop exert profound influence on dry matter production in castor. Saran and Giri (1986) reported that dry matter production per leaf or plant in the late sown crop was more in castor. The influence of spacing or plant population on growth of determinate soybean indicated that the fresh weight and total dry weight to be maximum at a spacing of 7.6 cm or less (Webber *et al*.,1966; Herbert and Literfiled, 1984; Ramseur *et al*.,1985). However, the dry matter production per plant was decreased for corresponding increase in plant population (Enyi, 1973).

Variation in dry matter production with seed size was studied by Singh *et al*.,1972 in soybean. They observed higher dry matter production in plants raised from larger seeds compared to the plants grown from smaller seeds. Dry matter production in early sown sunflower, groundnut and sesame was more compared to late sown crop (Sangoil and Silva, 1985; Bell, 1986). Nearly a month delay in sowing recorded 58 to 67 per cent more dry matter accumulation in leaf and whole plant respectively. However, Jankins and Leitch (1986) reported that the pattern of dry matter accumulation in winter oil seed rape was affected to a large extent by sowing date but no significant effect was recorded on total dry matter production at final harvest.

The effect of crop season on dry matter production elucidated that its proportion in the reproductive parts of sesame would be high during summer compared to winter season (Narayan and Narayanan, 1987).

The changes in dry matter production in the ontogeny of mustard (Chaturvedi et al.,1985) and soybean (Anderson and Vasilas, 1985) indicated that it was more during pod formation stage, which further depends on the duration of pod formation stage. In sesame the rate of phytomass production will be slow upto flowering (16 per cent of total dry matter) compared to 80 per cent at reproductive phase (Reddy and Narayanan, 1987). Safflower also accumulates dry matter slowly upto 30 DAS and increases significantly thereafter upto 90 DAS (Saibabu, 1990).

2.5 DRY MATTER PARTITIONING

Crop yield depends on the ability of the crop to assimilate dry matter and on that of economic sink to accept the dry matter produced. Shibles and Weber (1966) and Uprety, et al (1980) indicated that grain yield was not only influenced by total dry matter production but also the manner in which the photosynthates are distributed within the plant. William et al.,(1975) observed a decline in leaf weight at maximum vegetative growth stage while the stem weight remains constant. In their studies Williams et al.,(1975) further indicated that peak kernel growth had to occur for higher yield in groundnut. Duncan et al., (1978) opined that a large part of the yield difference among the peanut cultivars with nearly the same crop growth rates was associated with differences in partitioning of daily photosynthates and that in a high yielding cultivar more of the daily assimilate production was apportitioned to the developing fruits. Hence the most influential physiological factor in yield determination would be partitioning of photosynthates during pod filling.

2.6 GROWTH ATTRIBUTES

Growth analysis in crop plants was first studied by British Scientists (Blackman 1919; Briggs, Kidd & West 1920; Williams 1946; Watson 1952; Combe 1960; and Blackman 1968). In recent times it has become an important technique of considerable value in ecophysiological studies. Though the term growth can be defined as irreversible change in size, mathematically it can be described by estimating the dry matter production in plants. The dry weights in ecology are usually referred as primary values. These values are basically important in analysing crop growth through the standard method of growth analysis.

2.6.1 Leaf Area Index (LAI)

Leaf area index is a suitable index for active growth, particularly, at vegetative phase. Watson (1947) attributed increased leaf area for increase in phytomass and concluded that variation in leaf area is a supporting factor in determining the differences in phytomass accumulation. Shibles and Webber (1965) reported an increase in phytomass production with an increase in LAI in soybean. However, the rate of phytomass production declines at higher levels of leaf area index.

Marked variation among varieties of Indian mustard with respect of LAI were observed by Meharotra et al.,(1976). They recorded the lowest LAI in short duration varities, while Prasad and Eshanullah (1990) observed an increase in LAI with the increase in frequency of irrigation at later stages of crop growth in mustard and rape seed.

In case of sunflower the leaf area was maximum at flowering and minimum at harvesting stage and almost intermediate at early stages of crop growth. However, EC 68415 recorded more LAI than EC 68414 at all stages of crop growth.

2.6.2 Relative Growth Rate (RGR)

Relative growth rate as a physiogical parameter of growth analysis was first suggested by Gregory (1917) and West et al., (1920). Subsequently Williams (1946) and Wallace and Mungar (1965) contributed a great deal in finding its trend and significance in relation to other parameters. Koller et al., (1970) reported that an increase in RGR was the result of greater demand for assimilates in rapidly growing soybean crop. In case of sunflower varieties (EC 68414 and EC 68415) the values for RGR were more during early growth stages and decreased gradually to a minimum at harvesting stage (Vidyasagar, 1979).

2.6.3. Crop Growth Rate (CGR)

The magnitude of variation for CGR has been studied by several workers in soybean. Enyi (1973) reported lower values of CGR for the genotypes with long reproductive phase when compared to the genotypes with short reproductive phase.

2.6.4 Net Assimilation Rate (NAR)

Considerable differences, among the varieties of Indian mustard were reported for NAR (Meharotra et al.,1976). It was generally low at pre-flowering stage than at active flowering stage. It further exhibited a considerable decline at pod maturation or late flowering stage in the early and late varieties respectively.

2.7 YIELD

Yield in castor is a highly variable factor and varies with the genotype, the cultural and management practices adopted and also the parameters like plant height, number of branches and nodes, length of spike, capsule per spike and other important growth attributes. Rao and Singh (1988) reported that cultivar Aruna is significantly superior over Sowbhagya with reference to seed yield. This was attributed to the maximum contribution of tertiaries to the extent of 45% of the total yield. Moreover, the spike flowers and matures before the rainy season due to the short stature of Aruna. In case of Sowbhagya the contribution of primaries would be 50 per cent to the total yield, while the tertiaries mature under stress conditions due to its late duration. The mere number of capsules per plant and 100 seed weight in Bhagya excelled the other varieties in recording higher seed yield (Kale et al.,1986).

Higher seed yield in castor can be achieved with increased levels of irrigation, fertilization and at plant density of 3,7000 to 5,5555 plants per hectare

(Rao and Venkateswarlu (1988). But in delayed sowing plant density did affect seed yield (Laureti, 1983). However, the decrease in seed yields in late sown crop was attributed to the reduction in plant height, panicle length and proportion of filled capsules (Turkhede et al., 1982).

From path coefficient analysis it is obvious that seed yield was directly influenced by number of capsules per primary raceme and number of seeds per plant (Sachli, 1986). Moreover the plant height, number of nodes upto the main inflorescence, number of days to flowering, length of first raceme, length of female portion of the inflorescence 100 seed weight and oil content had a positive association with seed yield in castor (Laureti, 1981 and Muthiah et al., 1982).

2.8 HARVEST INDEX

The term "biological yield" was proposed by Nichiporovich to represent the total dry matter accumulation of a plant system. Similarly "economic yield" and "agricultural yield" have been used interchangeably to refer to the volume or weight of those plant organs that comprise the product of economic or agricultural value. The proportion of biological yield represented by economic yield has been called the "coefficient of effectiveness", the migration coefficient, and the "harvest index". In groundnut Natarajaratnam (1979) expressed that HI was highly correlated with yield and high harvest index indicated a favourable partitioning of dry matter to pods.

Singh et al.,(1978) observed significant differences among the genotypes of groundnut with respective biological yield, number of pods per plant, harvest index, 100-kernal weight and shelling out turn. Hiremath et al., (1984) observed varietal difference in groundnut and concluded that photosynthetic rate influenced pod yield through total dry matter and harvest index. Similarly colasante and Costa (1981) studied variability in harvest index of 20 soybean cultivars from diff,ernt maturity groups. They observed high harvest index for early cultivars compared to the late maturing cultivars. Velu and Krishna (1985) observed wide variations in harvest index among the varieties of groundnut.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present study was conducted at college farm, Rajendranagar, Hyderabad during Kharif, 1990. Seeds of the cultivars viz., Aruna, 48-1, PCS-3, Sowbhagya, VP-1 and were obtained from the Regional Agricultural Research Station (RARS) Palem, APAU, Hyderabad.

The field trial was conducted following Randamised Block Design (RBD) with five treatments replicated four times.

The size of the plot was 4m x 4m and the spacing adopted was 90cm x 50cm as per the recommendations of RARS, Palem, APAU. All the recommended package of practices were adopted. Necessary prophylactic measures were taken up by applying the crop with dithane M-45 and bavestin to control seedling blight.

GROWTH CHARACTERS

For the purpose of non-destructive analysis five plants at a stretch in each plot were selected in the middle of the plot and were labelled. These plants were used for recording data on plant height, stem girth, number of leaves, number of nodes and branches, length of the spike, nodes at which spike formed and yield components. For destructive analysis viz., estimation of dry matter accumulation and measurement of leaf area, five plants in each plot were sampled at different growth stages. All the above observations were made at 30, 60, 90 days after sowing and at maturity.

3.1 PLANT HEIGHT

Height of the plant was recorded from ground level to the top of growing point and expressed in cm.

3.2 STEM GIRTH

The stem girth was measured with the help of a vernier calipers and represented in cm.

3.3 STEM HOLLOWNESS

The stem hollowness (mm) was calculated from a known length of stem piece with mercury. The amount of mercury occupied in the hollow portion of stem was collected separately and its weight was recorded. From this data the volume of the stem was calculted by using the following formula.

$$\underline{\text{Volume}}\ (V) = \frac{\text{Weight of mercury}}{\text{density of mercury (13.6)}}$$

From this volume the hollowness was calculated as follows.

$$r = \sqrt{\frac{V}{\Pi h}}$$

Diameter (mm) = r x 2

3.4 NUMBER OF LEAVES, BRANCHES AND NODES (PER PLANT)

At all the observations the number of primary, secondary and tertiary branches, the number of leaves and the number of nodes on each branch were counted and recorded.

3.5 NODES AT WHICH THE SPIKES DEVELOPED

The nodes at which the primary, secondary and lateral spikes developed was recorded.

3.6 LENGTH OF THE SPIKES

The length of the primary, secondary and lateral spikes was measured and recorded in cm.

3.7 WEIGHT OF THE SPIKES

The weight of different spikes was recorded at different growth stages and expressed in grams.

3.8 100-SEED WEIGHT

For this purpose first an unknown size of the seed sample was weighed and the number of seeds in the above sample was counted. Based on this data the 100 seed weight was calculated and recorded in grams.

3.9 SEED YIELD

The net yield per plant and m^{-2} area basis was calculted and expressed in grams.

3.10 HARVEST INDEX (%)

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.11 LEAF AREA

The leaf area at different gorwth stages was estimated with the help of a leaf area meter and expressed in cm^2 (LI-3100, Lincoln, Nebraska, USA).

3.12 DRY MATTER PRODUCTION

For this purpose the plants sampled at all observations were separated into leaf and stem and then kept in hot air oven at a temperature of 75^{o} C till constant weight was attained and the weights were recorded in grams.

3.13 DAYS TO 50 PER CENT FLOWERING

Days required from sowing to 50 per cent flowering were recorded when 50 per cent of the total plants in the individual plots reached flowering stage.

3.14 GROWTH ANALYSIS

All the growth parameters were analysed in applying formulae as described by Watson (1952). Radford (1967) and Sestak *et al*. (1971).

3.14.1 Leaf Area Index

$$LAI = \frac{\text{Leaf area}}{\text{Unit land area}}$$

3.14.2 Leaf Area Ratio ($cm^2\ g^{-1}$)

$$LAR = \frac{\text{Leaf area per plant}}{\text{Total plant dry weight}}$$

3.14.3 Specific Leaf Area ($cm^2\ g^{-1}$)

$$SLA = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.14.4 Specific Leaf Weight ($g\ cm^{-2}$)

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.14.5 Leaf Weight Ratio

$$LWR = \frac{\text{Leaf wight}}{\text{Plant weight}}$$

3.14.6 Relative Growth Rate (g g^{-1} day^{-1})

$$RGR = \frac{\log_e W_1 - \log_e W_2}{(t_2 - t_1)}$$

where W_1 and W_2 are the natural logorithemic values of dry weight at time t_1 and t_2, respectively.

3.14.7 Crop Growth Rate (g m^{-2} day^{-1})

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

where W_1 and W_2 are the dry weights at time t_1 and t_2 respectively and P is the land area.

3.14.8 Net Assimilation Rate (g dm^{-2}day^{-1})

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

where W_1 and W_2 are plant dry weights and L_1, L_2 are leaf area values at times t_1 and t_2 respectively.

3.15 OIL PER CENT

The percentage of oil in the seed was estimated for all the treatments with the help of nuclear magnetic reronance (NMR) equipment.

3.16 STATISTICAL ANALYSIS

The results were analysed as per the standard statistical procedure outlined by Panse and Sukhatme (1967).

3.17 METEOROLOGICAL DATA

Meteorological data pertaining to rainfall, relative humidity, sunshine, wind velocity etc. recorded during the period of experiment was given in the Appendix.

RESULTS

Table 1: Plant height in five castor cultivars at diffrent growth stages

Cultivars	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Maturity
Aruna	20.50	106.25	177.52	226.45
48-1	20.10	104.35	175.25	224.51
Pcs-3	19.95	103.75	172.56	223.25
Sowbhagya	17.52	75.45	120.25	135.45
VP-1	16.95	71.25	115.35	120.26
CD (5%)	1.18	0.89	1.47	1.89

CHAPTER IV

RESULTS

The results pertaining to the growth analysis of five castor cultivars are presented in this chapter.

4.1 PLANT HEIGHT

Generally plant height in castor exhibited an increasing trend at all growth stages (Table 1). The magnitude of increase in plant height was more (79 per cent) between 30 and 60 days after sowing compared to other observations in all the five cultivars. Among the cultivars, Aruna recorded significantly higher values (226.5 cm) followed by 48-1 (224.5 cm) and PCS-3 (223.3 cm). The plant height was minimum in cv. VP-1 (120.3 cm).

4.2 STEM GIRTH

The cultivars had also a continous increase in stem girth till they attain harvestable maturity. The cultivaral idfference for stem girth was significant at all observations except at harvest (Table 2). Among the cultivars, Sowbhagya and PCS-3 recorded significantly higher values for stem girth compared to other cultivars. Among the cultvars, Aruna recorded consistently the minimum values in comparison with other cultivars.

Table 2 : Stem grith and stem hollowness of five castor cultivars at diffrent growth stages

Cultivars	Stem grith (cm)				Stem hollowness (mm)			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Aruna	1.67	2.55	2.87	4.41	0.80	3.66	5.65	5.40
48-1	1.92	3.25	4.12	4.56	1.66	3.47	7.25	4.75
Pcs-3	1.70	3.89	4.59	5.01	0.75	4.22	6.19	5.57
Sowbhagya	1.69	3.32	5.01	5.29	1.10	5.25	7.16	5.35
VP-1	1.83	2.77	4.27	4.57	0.69	3.50	5.50	5.12
CD (5%)	0.70	0.66	0.73	NS	0.36	0.94	1.24	NS

4.3 STEM HOLLOWNESS

Similar to plant height and stem girth, stem hollowness increased upto 90 DAS and thereafter showed a declining trend in all the cultivars (Table 2). The initial significant difference observed at 30, 60 and 90 DAS was levelled off at maturity. However, the maximum value of 7.25 mm shown by cv. 48-1, was decreased to minimum value of 4.95 mm at harvest. On an averaage stem hollowness was low in Aruna compared to other cultivars.

4.4 DAYS TO 50 PER CENT FLOWERING

The data indicated that the cultivars differed significantly for the days taken to flowering (Table 3). Flowering was early in PCS-3 (36 days) compared to Sowbhagya which took more number of days to 50 per cent flowering (53 days) compared to 48-1 (50 days), VP-1 (47 days) and Aruna (40 days) respectively.

4.5 NUMBER OF NODES

At all growth stages the number of nodes increased continuously in all the cultivars (Table 4). A comparision of the cultivars indicated that Sowbhagya and VP-1 recorded significantly higher values compared to others. The lowest number of nodes was observed in cv, Aruna. The per cent increase in nodal number in Sowbhagya was around 28 over Aruna.

Table 3: Days to 50% flowering in five castor cultivars

Cultivars	Days to 50% flowering
Aruna	40
48-1	50
Pcs-3	36
Sowbhagya	53
VP-1	47
CD (5%)	2.12

Table 4 : Number of nodes in five castor cultivars at diffrent growth stages

Cultivars	Number of nodes			
	30 DAS	60 DAS	90 DAS	Maturity
Aruna	4.10	9.50	10.75	12.25
48-1	4.00	11.60	14.75	16.50
Pcs-3	3.75	9.75	11.12	13.50
Sowbhagya	3.90	10.25	12.00	14.62
VP-1	3.60	10.50	14.25	15.50
CD (5%)	0.48	1.68	2.03	2.80

4.6 NUMBER OF BRANCHES

The data revealed that the number of branches differed significantly among the cultivars. (Table 5). Aruna recorded maximum number of primary (3.6) and tertiary (6.8), while VP-1 recorded the minimum number of primary (2.3), secondary, (2.5) and tertiary (3.1) branches. However, the number of secondary and tertiary branches were maximum in PCS-3 (3.6) and 48-1 (3.4) respectively.

4.7 NUMBER OF LEAVES

In all the cultivars the number of leaves followed the similar trend on observed in plant height, stem girth and number of nodes (Table 6). The cultvars differed significantly for number of leaves at all stages except at 30 DAS. However, there was a remarkable increase in the number of leaves between 90 DAS and maturity. The per cent of increase was nearly 35 in Sowbhagya followed by PCS-3 and Aruna.

4.8 LEAF AREA

All the cultivars exhibted an increase in leaf area upto 90 DAS followed by a decrease at maturity (Table 7). In all the cultivars the per cent of increase in leaf area was maximum (68 per cent) between 60 and 90 DAS. At all observations the trend of

Table 5 : Number of primary, secondary and teritiary branches in five castor cultivars at maturity

Cultivars	Number of branches		
	Primary	Secondary	Tertiary
Aruna	3.6	3.5	6.8
48-1	3.2	3.4	6.5
Pcs-3	3.4	3.6	6.3
Sowbhagya	2.5	2.8	3.2
VP-1	2.3	2.5	3.1
CD (5%)	0.52	0.82	0.69

Table 6: Number of leaves in five castor cultivars at diffrent growth stages

Cultivars	Number of leaves			
	30 DAS	60 DAS	90 DAS	Maturity
Aruna	6.35	10.50	34.77	41.60
48-1	6.33	11.00	25.62	35.75
Pcs-3	6.55	9.25	22.12	43.87
Sowbhagya	6.20	10.25	26.50	46.75
VP-1	6.40	9.50	17.37	25.50
C D (5%)	NS	1.50	2.16	1.86

Table 7 : Leaf area and leaf area index in five castor cultivars at diffrent growth stages

Cultivars	Leaf area (cm^2)				Leaf area index			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Aruna	192.96	1151.25	3878.10	2811.74	0.042	0.250	0.85	0.620
48-1	245.50	1432.97	4540.16	3229.73	0.054	0.310	1.00	0.710
Pcs-3	220.17	1697.75	5473.37	2823.95	0.050	0.370	1.201	0.620
Sowbhagya	175.60	1508.40	4747.10	2255.20	0.038	0.330	1.004	0.490
VP-1	190.71	966.07	2343.37	2121.82	0.042	0.220	0.51	0.460
CD (5%)	NS	660.70	2365.86	NS	0.004	0.047	0.108	0.029

increase in leaf area was inconsistent among the cultivars. But cv.48-1 recorded maximum leaf area (246 cm^2) at 30 DAS and retained more area (3230 cm^2) at maturity compared to other cultivars. The values for leaf area were the lowest in cv.VP-1.

4.9 LEAF AREA INDEX

A close look at the data indicated that LAI differed significantly at all observations in all the cultivars (Table 7). The LAI followed a similar trend to that of leaf area. It was again cv.48-1 that recorded higher values for LAI (0.71) and the minimum was in VP-1 (0.46).

4.10 DRY MATTER PRODUCTION

4.10.1 Leaves

The data indicated that dry matter production in leaves increased significantly upto 90 DAS and at maturity it showed a declining trend (Table 8). The per cent of increase in dry matter was more between 30 and 59 DAS rather than at 60 - 89 DAS. All the cultivars showed a decrease of 50 - 60 per cent in dry matter production of leaves at maturity. The cultivars Sowbhagya, 48-1 and Aruna recorded significantly higher values compared to others.

Table 8 : Dry matter production of five castor cultivars at diffrent growth stages (g)

Cultivars	Dry matter production											
	Leaves/plant				Stem/plant				Total/m^2			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Aruna	1.78	16.95	27.85	11.30	0.72	20.75	41.65	105.25	5.50	86.77	227.74	374.26
48-1	1.89	17.23	28.45	12.34	0.75	19.74	39.89	102.25	5.80	84.08	209.97	354.83
Pcs-3	1.65	16.12	27.24	11.12	0.76	19.85	40.35	104.01	5.31	81.40	209.20	359.58
Sowbhagya	1.90	17.82	28.78	12.78	0.85	21.45	42.62	106.25	6.05	388.63	195.45	346.23
VP-1	0.89	12.52	18.56	8.92	0.68	17.75	35.25	85.65	3.45	70.22	168.10	292.31
CD (5%)	0.104	0.47	1.60	1.20	0.11	1.43	1.85	4.71	0.345	4.15	3.63	3.44

4.10.2 Stem

Unlike leaves, the dry matter production in stems of all the genotypes had a significant and continous increase upto maturity in all the cultivars (Table 8). The per cent of increase in all the cultivars was more (60 to 70 per cent) between 90 DAS and maturity. Similar to leaves, the dry matter production in stem was more in cv, Sowbhagya and Aruna compared to others.

4.10.3 Total Dry Matter Production

A close look at the data further indicated that total dry matter production in all the cultivars showed a significant and continous increase upto maturity (Table 8). The per cent of increase in all the cultvars was more (60 - 70 per cent) from 90 DAS which corresponds mainly tothe capsule formation stage. The cultivars Aruna, PCS-3 and 48-1 recorded signficantly higher values compared to others. The proportion of photosynthates partitioned was more (60 - 67 per cent) into stem followed by spikes (24 - 30 per cent) and leaves (6 - 7 per cent) respectively (Fig. 1).

4.11 LEAF AREA RATIO (LAR)

From the data it is obvious that there were two peaks in the values for LAR in all the cultivars (Table 9).

The first and second peaks were at 30 and 90 DAS

Fig. 1 : Partitioning of dry matter in different component parts of castor cultivars at maturity

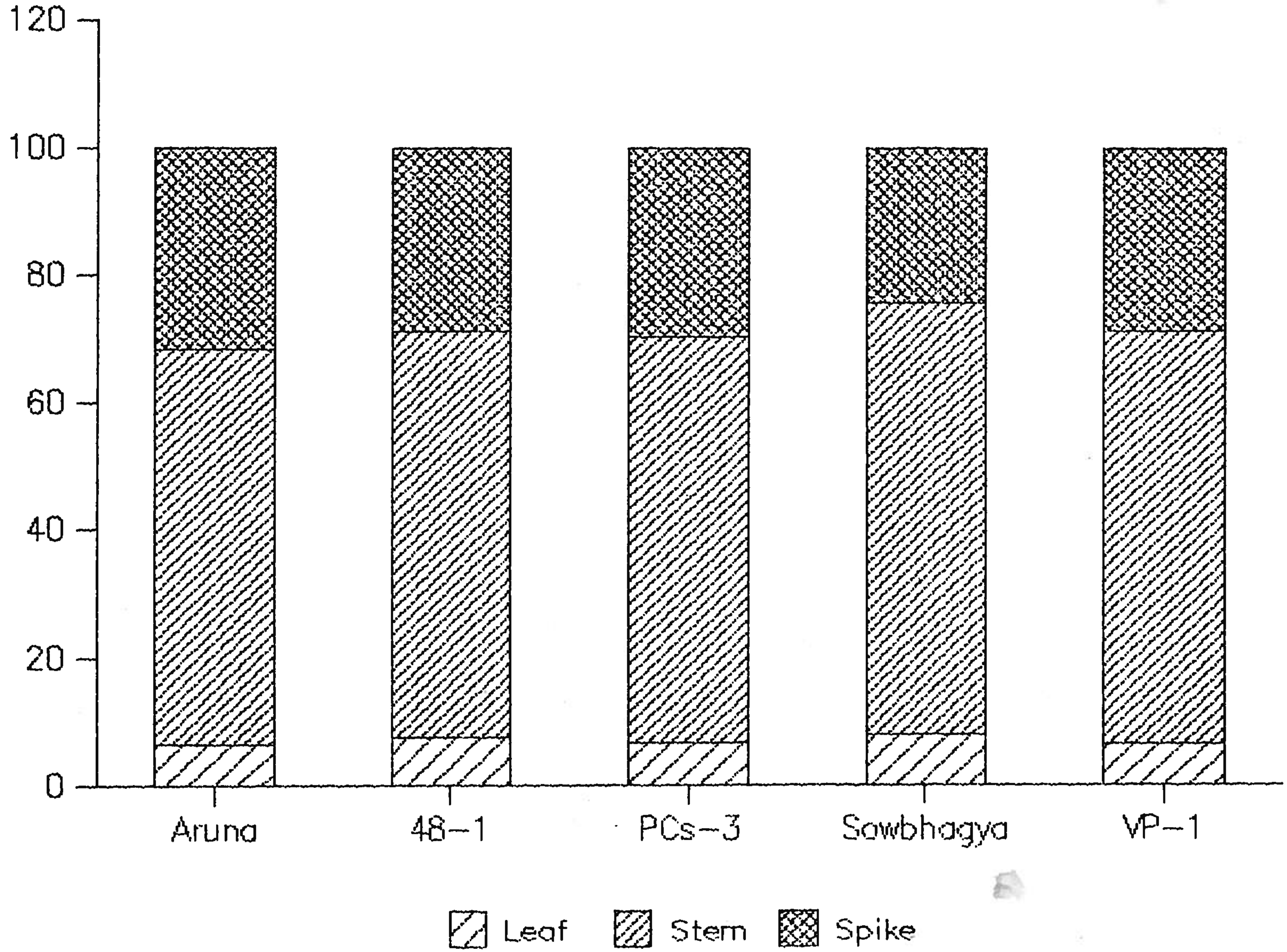

Table 9 : Leaf area ratio and leaf weight ratio in five castor cultivars at diffrent growth stages

Cultivars	Leaf area ratio (cm^2 g^{-1})				Leaf weight ratio			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Aruna	77.18	29.18	37.46	13.75	1.56	0.94	0.59	0.14
48-1	92.99	37.49	47.57	20.02	1.56	0.99	0.65	0.17
Pcs-3	83.33	45.88	57.55	17.28	1.49	0.95	0.63	0.15
Sowbhagya	63.85	37.43	53.43	17.86	1.52	0.96	0.72	0.18
VP-1	121.12	30.26	30.66	15.96	1.23	0.85	0.53	0.15
CD (5%)	44.42	2.40	2.93	1.86	0.64	0.04	0.01	0.004

respectively. However, the cultivars differed significantly at all observations. Among the cultivars 48-1 maintained higher values for LAR and it was minimum in VP-1. During the second spell of increase the cvs, Sowbhagya and PCS-3 also recorded higher values.

4.12 LEAF WEIGHT RATIO

Generally the cultivars showed a significant decrease as crop advanced age (Table 9). In all the cultivars there was remarkable decrease in the values for LWR at maturity. However, cvs, Sowbhagya and 48-1 recorded maximum value at 30 and 60 DAS, while it was minimum in VP-1.

4.13 SPECIFIC LEAF AREA

From the data it is obvious that SLA increased significantly at all observations except at 60 DAS (Table 10). Almost all the cultivars showed a similar trend in recording values for SLA. However, cv, 48-1 recorded the highest values followed by PCS-3 and VP-1.

4.14 SPECIFIC LEAF WEIGHT

In general, the specific leaf weight increased gradually upto 60 DAS followed by gradual decline (Table 10). All the cultivars differed significantly at all growth stages for the values of SLW. The cultivars also did not show a constant trend at different observa-

Table 10 : Specific leaf area ratio and specfic leaf weight ratio in five castor cultivars at different growth stages

Cultivars	Specific leaf area (cm^2 g^{-1})				Specific leaf weight(mg cm^{-2})			
	30 DAS	60 DAS	90 DAS	Maturity	30 DAS	60 DAS	90 DAS	Maturity
Aruna	108.40	67.99	139.24	199.50	9.22	14.72	7.18	5.01
48-1	129.89	83.16	159.58	261.72	7.69	12.02	6.26	3.86
Pcs-3	138.84	105.31	200.93	253.95	7.19	9.47	4.97	4.33
Sowbhagya	92.41	84.64	163.64	220.00	10.82	11.81	6.09	4.54
VP-1	214.29	77.16	126.25	237.87	4.66	12.95	7.92	4.20
CD (5%)	3.81	3.74	4.22	4.30	0.27	1.06	0.28	0.48

tions. It was Sowbhagya, Aruna and VP-1 recorded maximum values at 30, 60 and 90 DAS respectively, whereas VP-1, 48-1, PCS-3 recorded low values at 30 DAS, 60 DAS and maturity respectively.

4.15 CROP GROWTH RATE (CGR)

A close look at the data indicated that values for CGR showed a steady increase upto harvest (Table 11). The cultivars also exhibited a signficant difference at all growth stages. The CGR was maximum in Sowbhagya, PCS-3 andAruna whereas VP-1 recorded minimum values for CGR.

4.16 RELATIVE GROWTH RATE (RGR)

The cultivars did not exhibit any significant difference for the RGR estimated at the different growth stages. However, in all the cultivars RGR, however, had a decreasing trend as crop advanced age (Table 12).

4.17 NET ASSIMILATION RATE (NAR)

It is quite interesting to note that NAR also followed a similar trend to that of RGR, but it was signficant among the cultivars compared to non-significant values in the latter one (Table 18). Though the cultivars showed simlar trends, the values were maximum in Aruna (0.74 to 2.29) compared to the lowest (0.59 to 1.57) in PCS-3.

Table 11 : Crop growth rate in five castor cultivars at diffrent growth stages

Cultivars	Crop growth rate (g m^{-2} day^{-1})		
	30-59 DAS	60-89 DAS	90-Maturity
Aruna	2.70	4.68	4.88
48-1	2.60	4.20	4.81
Pcs-3	2.53	4.25	4.99
Sowbhagya	2.75	3.52	5.02
VP-1	2.22	3.26	4.07
CD (5%)	0.11	0.12	0.35

Table 12 : Relative growth rate and net assimilation rate of five Castor cultivars at different growth stages

Cultivars	Relative growth rate ($g\ g^{-1}\ day^{-1}$)			Net assimilation rate ($g\ dm^{-2}\ day^{-1}$)		
	30-59 DAS	60-89 DAS	90-Maturity	30-59 DAS	60-89 DAS	90-Maturity
Aruna	0.090	0.030	0.016	2.29	0.94	0.74
48-1	0.089	0.030	0.017	1.76	0.70	0.56
Pcs-3	0.087	0.030	0.018	1.57	0.60	0.59
Sowbhagya	0.089	0.026	0.019	2.00	0.56	0.52
VP-1	0.100	0.030	0.018	2.11	0.95	0.82
CD (5%)	NS	NS	NS	0.16	0.04	0.03

Table 13 : Nodes at which spikes form in five castor cultivars

Cultivars	Nodes at which spikes form		
	Primary	Secondary	Lateral
Aruna	12.25	4.00	3.75
48-1	16.50	4.75	4.00
Pcs-3	13.50	5.12	4.37
Sowbhagya	14.62	5.25	3.97
VP-1	15.50	5.25	6.30
CD (5%)	2.80	0.74	1.23

4.17 NODES AT WHICH SPIKES FORM

The nodes from which the spikes developed differed signficantly in all the cultivars (Table 13). The primary, secondary and tertiary spikes of all the cultivars were positioned on the top nodes of primary, secondary and tertiary branches respectively. This ranking has slightly changed for position of lateral spikes. It was in VP-1 the lateral spike positioned on 6.30 node of secondary spike. In Aruna, all the spikes were positioned on lower nodes compared to other cultivars.

4.19 LENGTH OF SPIKES

There was a significant difference in the length of primary, secondary and lateral spikes at different growth stages (Table 14). Among the cultivars, VP-1 recorded maximum length for primary spike (36.87) while, Sowbhagya had the lowest value (22.9). The cultivaral difference for the length of secondary spike showed variations. It was maximum in Aruna and the minimum was in PCS-3. Though Aruna recorded maximum length of lateral spikes at 90 DAS, (9.50) it was the highest value in VP-1 at maturity (15.50). The minimum length of lateral spike was observed in PCS-3 (8.87).

Table 14 : Length of primary, Secondary and lateral spikes in five castor cultivars at diffrent growth stages

Cultivars	Length of primary spike (cm)			Length of secondary spike (cm)		Length of lateral spike (cm)	
	60 DAS	90 DAS	Maturity	90 DAS	Maturity	90 DAS	Maturity
Aruna	8.87	26.25	27.57	25.25	25.50	9.50	14.25
48-1	4.65	25.87	27.12	18.37	18.25	3.80	12.45
Pcs-3	13.50	31.87	33.79	14.75	15.50	6.12	8.87
Sowbhagya	4.00	20.87	22.29	16.62	16.95	5.40	12.00
VP-1	9.60	35.62	36.87	22.00	22.62	8.87	15.50
CD (5%)	3.24	6.84	4.34	8.35	8.70	5.37	1.30

Table 15: **Weight of primary, scondary and lateral spikes in five castor cultivars at diffrent growth stages**

Cultivars	Weight of primary spike (g)			Weight of lateral spikes (Secondary and lateral) (g)	
	60 DAS	90 DAS	Maturity	90 DAS	Maturity
Aruna	1.74	22.62	25.45	11.40	28.12
48-1	1.25	18.75	20.25	8.35	26.25
Pcs-3	1.03	21.25	24.90	6.25	23.37
Sowbhagya	1.02	12.35	18.33	4.92	20.02
VP-1	1.16	18.50	20.05	4.10	18.25
CD (5%)	0.16	1.25	1.32	0.85	1.40

4.20 WEIGHT OF SPIKES

The data revealed a significant increase in the weight of spikes as crop advanced in age (Table 15). The weight of primary spike was maximum between 60 and 90 DAS (17.5 g) compared to growth stages between 90 DAS and maturity (3g). For both the spikes the weight was maximum in Aruna (28.12 g) compared to other cultivars. The weight of the primary, and secondary spikes including total ones was minimum in Sowbhagya (38.35 g) and VP-1 (38.3 g) respectively.

4.21 SEED YIELD

All castor cultivars were harvested in two pickings. The first picking contributed the yield from primary, secondary and lateral spikes, whereas the second picking contributed spikes other than primary ones. The cultivars differed signficantly for seed yield recorded from primary spike, and secondary and lateral spikes in first picking (Table 16). In Aruna, PCS-3 and 48-1 the primary spike contributed maximum (23 per cent) to the seed yield per plant compared to other cultivars (20 per cent). The contributions of secondary and lateral spikes to the total yield was also maximum in Aruna (79 per cent).

Table 16: Seed yield, harvest index and 100-seed weight of five castor cultivars

Cultivars	Seed yield/ plant/primary spike (g)	Seed yield/plant/ secondary and lateral spikes (g)		Total yield (g)		Harvest index (%)	100 seed weight (g)
	1st picking	1st picking	Second picking	Per plant	Per m^2		
Aruna	12.8	18.9	20.9	51.2	1154.1	23.6	16.5
48-1	10.1	16.6	19.6	46.4	1020.7	22.4	27.6
Pcs-3	10.5	15.9	18.1	44.5	97.9	21.4	23.4
Sowbhagya	5.2	6.5	13.4	25.2	55.4	13.8	14.9
VP-1	9.4	8.5	6.9	24.7	544.3	15.7	14.3
CD (5%)	1.06	1.2	2.04	2.9	1.7	1.1	0.8

Second Picking

The yield relation in second picking was mainly from secondary and lateral spikes. Their contribution to the total yield was maximum in Sowbhagya (53 per cent) followed by Aruna (41 per cent).

The contribution of secondary and lateral spikes to the total yield was minimum (27 per cent) in VP-1 in the second picking compared to other cultivars. On the whole Aruna excelled the other cultivars in recording higher yield followed by 48-1 and PCS-3 (Table 16).

4.22 YIELD COMPONENTS

4.22.1 100-Seed Weight

The data indicated that 100 seed weight also differed significantly among the cultivars (Table 16). 100-seed weight was maximum in 48-1 (27.6 g) while it was minimum in VP-1 (14.3 g).

4.22.2 Harvest Index

Similar to 100-seed weight and yield, the values for harvest index also differed significantly (Table 16). A comparison of the cultivars show that harvest index was maximum in Aruna (23.6) followed by 48-1 (22.4) and PCS-3 (21.4 g). The lowest value recorded was in Sowbhagya (13.8 g).

Table 17: Per cent of oil in different cultivars of castor

Cultivars	Oil content (%)
Aruna	51
48-1	48
Pcs-3	48
Sowbhagya	47
VP-1	47
CD (5%)	1.87

4.23 OIL PER CENT

The cultivars showed a significant difference in oil content (Table 17). It was maximum in Aruna (51%) followed by 48-1 (48%) PCS-3 (48%), Sowbhagya (47%) and VP-1 (47%).

DISCUSSION

CHAPTER V

DISCUSSION

The productivity of a crop usally depends on its inherent capacity for photosynthesis and photosynthetic area it develops. The genotypic variation in productivity of a crop may be related to the parameters viz., net assimilation rate (NAR), crop growth rate (CGR), leaf area index (LAI) and partitioning of total photosynthates into economic and non-economic sinks. These tools of growth analysis were less used in understanding the physiological basis of yield in non-leguminous oil seeds. An attempt was therefore made to exploit the physiological and morphological changes determining the yield in castor.

From the results it is evident that plant height in castor is a varietal character. The cultivars viz., Aruna, 48-1 and PCS-3 can be grouped as tall ones, whereas Sowbhagya and VP-1 as dwarf ones (Table 1). The decrease in plant height may be attributed to the condensed internodes in Sowbhagya and VP-1 where the maximum length of internodes rarely goes beyond 3 cm. at any point on the primary stem (DOR, 1990). In some of the reports, though plant height was measured to 55 to 117 cm in dwarf cultivars and 140 cm in tall cultivars (Samoilenko, 1977), there was further exploitation in plant height of Aruna and 48-1 recording more than 220 cm while Sowbhagya and VP-1 to the value of 120 cm under Rajendranagar conditions. This further explains that castor can respond to the change in fertility status of the soil. The influence of crop growing situation and season on plant height in castor was also reported by DOR (1990).

The cultivars with more plant height were tended to record less values for stem girth. It is apparent from the data (Table 1 & 2) that Aruna and Sowbhagya with a plant height of 226 cm and 135 cm recorded the stem girth of 4.4 cm and 5.3 cm respectively. Thus the values for other cultivars also indicated a negative association between plant height and stem girth.

Stem hollowness is one of the conspicuous characters the castor genotypes possess. Though the cultivars showed variation for hollowness in the early stages, it was levelled off at the time of maturity. But it is quite interesting to observe from the data (Table 2) that greater the plant height, lesser was the hollowness and is apparent from the values of 4.95 cm in cv.48-1 which had nearly a plant height of 225 cm. The cultivars Aruna and PCS-3 also showed a similar response. From this, it is obvious that an increase in plant height is associated with the decrease in stem girth and hollowness in castor cultivars.

The number of nodes upto primary raceme on the main stem varied greatly in different cultivars. Aruna, PCS-3 and 48-1 recorded lesser number of nodes while Sowbhagya and VP-1 had higher values for number of nodes on the main stem (Table 4). Similar variation in node number was also reported in castor genotypes (DOR, 1990). The less number of nodes in Aruna and PCS-3 and more number of nodes in Sowbhagya and VP-1 was attributed to short and long duration of castor cultivars respectively (DOR, 1990). Further, it was also reported that on an average every node contributed about 4 days for flower initiation in primary raceme of castor. A close look at the data also indicated that Aruna, a short duration cultivar exhibited profuse branching, whereas it was shy branching in long duration cultivar like VP-1. Though branching was related to duration, it was the number of tertiary branches contributed more to total number of branches. The data indicated that Aruna, 48-1 and PCS-3 recorded more number of tertiaries (Table 5). Such profuse branching in late duration varities compared to early types was reported in Indian Mustard (Meharotra _et al_., 1976).

In all the cultivars, the number of leaves, leaf area and LAI followed a similar trend. The taller ones like Aruna, 48-1 and PCS-3 recorded higher values for the above parameters compared to shorter cultivars viz., Sowbhagya and VP-1. The higher values for LAI in 48-1, Aruna and PCS-3 might be due to more branching as discussed earlier in this chapter. Moreover, the maximum values for LAI at 90 DAS correspond to the full bloom stage.

The data also indicated that there was a general increase in dry matter production with the increase in LAI. It was almost true in case of Aruna and PCS-3 compared to VP-1. But this increase did not continue beyond the values of 0.62 and is apparent in cv. 48-1 where the LAI of 0.71 recorded a total dry matter production of 350 gm^{-2} compared to 374 gm^{2} in Aruna with a LAI of 0.62. This clearly envisages that the optimum LAI for higher dry matter production in castor would be 0.6 for a population of 22000 ha^{-1}. Moreover, the photosynthetic efficiency in terms of net assimilation rate was also more at LAI of 0.6. An optimum LAI for higher dry matter production was also reported by Shibles and Webber (1966).

In all the cultivars, the pattern of dry matter accumulated in component parts indicated that the proportion of dry matter contributed to the total plant dry weight was more in stem compared to leaf (Fig 1). However, the total dry matter accumulated in tall cultivars (Aruna, 48-1 and PCS-3) with short duration was more compared to dwarf cultivars with long duration (Sowbhagya and VP-1). The data also revealed that the tall cultivars with greater 100-seed weight (27.6 g) recorded more values for dry matter accumulation than that of dwarf one with low test weight (14.3 g). Similar variation in dry matter production with the changes in seed size was also reported in soybean (Singh et al., 1972) and castor (Rao, 1991). The increase in dry matter production during capusle formation stage was also observed in other crops like mustard (Chaturvedi et al., 1985) and soybean (Anderson and Vasilas, 1985).

The trends observed for leaf weight ratio in Aruna indicated that dry matter was being partitioned preferentially into leaf in the early stages (30 DAS) and thereafter, it was more in non-leaf tissue resulting in descreasing leaf area ratio as the growth progressed. Almost an opposite trend could be observed in case of Sowbhagya. The similarity between LAR and LWR, except for a slight increase in LAR at 90 DAS, indicated that LAR was being affected primarily by LWR. The lesser changes observed in LAR compared to LWR further elucidated that changes in SLA were of too small to have much effect on trends in LAR compared to the magnitude of changes in LWR being affected by SLW. Such relationship of LAR with SLA and LWR with SLW was reported in soybean too (Koller et al., 1970).

The amount of dry matter produced per unit of dry matter (RGR) is the product of NAR and LAR. The relative growth rate in all castor cultivars decreased as season progressed, but it was non-significant at all observations. From this it is obvious that neither NAR nor LAR could contribute for achieving significant difference in the values for RGR, though they (LAR & NAR) showed significant differences. Thus, the rate of photosynthates produced for a given photosyntehtic area might be same otherwise there would have been changes in RGR for the cultivars studied. Moreover, the potosynthetic surfaces in castor other than leaves are less prominent. Such conclusion can, however, be made if these cultivars are once again studied under ideal management.

The dry matter produced during a particular interval (CGR) is the product of NAR and LAI. It represents the sum of CGR's of individual components. Unlike RGR and NAR, the CGR showed a continous increase in all the cultivars (Table 11). Generally it had higher values in tall growing cultivars viz., PCS-3, Aruna and 48-1 compared to short stature cultivars viz., Sowbhagya and VP-1.1 Since the CGR associated changes are related to NAR and LAI, the increased CGR in all the cultivars was therefore due to more contributary effect of LAI rather than NAR. Though the trends followed in

CGR and LAI were similar upto 90 DAS, the decrease in LAI thereafter, indicated that during final observation i.e., 90 DAS to maturity, the surface area of senescing leaves was not considered in calculation of LAI. Morever, to calculate growth parameters precisely, it is imperative to add the weight of fallen leaves to the values of total above ground dry matter.

From the data, on some of the above growth parameters discussed, it is further clear that the demand for current photosynthates by potential sinks, preferably the racemes, was less and thereby the NAR values (photosyntehtic activity) were tended to decrease in all the castor cultivars. Hence, the production potential in castor can be realized more by increasing the utilization of photosynthates by reproductive units rather than non-economic parts like stem. The increase in seed yield by increased demand for photosynthates during rapid seed development was reported by Koller _et al_., (1970) in soybean.

The main stem in castor usually terminates in primary spike while the laterals terminate in secondary, tertiary and quarternary spikes (Weiss, 1971). In all the cultivars the lateral spikes contributed more to the total yield (60-78 per cent) than to primary spikes (20-26 per cent). The distinct variation in terms of yield for the various types of spikes was also observed by Rao and Singh (1988). They reported that the seed yield of Aruna is significantly superior over Sowbhagya and was attributed to the maximum contribution of tertiaries to the extent of 45 per cent to the total yield. The low yield of Sowbhagya was related to the maturity of tertiaries under s tress conditions. Further, the genetic determinants viz., the size, shape and compactness of spikes in castor vary greatly and can contribute to the total yield (DOR,1990).

The data also revealed that seed yield was more in cultivars viz., Aruna, 48-1 and PCS-3 which were taller with more number of branches and took nearly 8 to 17 days less for 50 per cent flowering compared to cvs. Sowbhagya and VP-1 (Table 3). A positive association of seed yield with plant height and early flowering was also reported in castor (Lauret, 1981 and Muthaih et al., 1982).

The increase in yield of Aruna, 48-1 and PCS-3 can also be attributed to higher values for harvest index, 100-seed weight and oil per cent. Thus exploitation of growth and yield attributes viz., plant height, number of lateral branches, crop growth rate, LAI, Harvest index and 100-seed weight as yield determinants of castor can offer greater promise to the breeders.

SUMMARY

CHAPTER VI

SUMMARY

The present investigation "Growth Analysis in Castor" was aimed at studying the cultivaral differences for full expression of physiological characters in five cultivars of castor viz., Aruna, 48-1, PCS-3, Sowbhagya and VP-1. The field experiment was conducted on red sandy loamy soil at College of Agriculture, Rajendranagar, Hyderabad, during kharif, 1990.

All the cultivars showed a significant difference for plant height, number of nodes, branches, LAI, CGR, NAR, dry matter production and yield contributing characters.

The increase in plant height is associated with decrease in stem girth and hollowness in castor cultivars.

The short duration cultivars viz., Aruna, 48-1, and PCS-3 exhibited profuse branching whereas it was shy branching in long duration cultivars like Sowbhagya and VP-1. The tertiary branches contributed more to total number of branches.

The taller ones like Aruna, 48-1 and PCS-3 recorded higher values for leaf area and LAI compared to dwarf cultivars viz., Sowbhagya and VP-1. The higher

values for leaf area and LAI in tall cultivars attributed to profuse branching. The dry matter production and net assimilatin rate was more at optimum LAI 0.6.

The proportin of dry matter contributed to the total plant dry weight was more in stem compared to leaf. The 100-seed weight and total dry matter accumulated in tall cultivars with short duration was more compared to dwarf cultivars with long duration.

As growth progressed, the decline in leaf area ratio was attributed to more partitioning of dry matter into non-leaf tissue. The lesser changes in LAR compared to LWR further elucidated that changes in SLA were of too small to have much effect on trends in LAR compared to the magnitude of changes in LWR being affected by SLW.

The RGR showed declining trend as season progressed, but it was non-significant at all observations. Neither NAR nor LAR could contribute for achieving significant difference in the values for RGR.

Unlike RGR and NAR, the CGR showed a continuous increase in all the cultivars, it is attributed to be more contributary effect of LAI rather than NAR. The higher CGR values were recorded in taller cultivars compared to dwarf ones.

The decrease in LAI with a corresponding increase in CGR was attributed to the non-inclusion of surface area of senescing leaves in the calculation of LAI at later stages of growth 90 DAS.

The decrease of NAR values in all the castor cultivars attributed to the less demand for current photosynthates in potential sinks.

In all the cultivars the lateral spikes contributed more to the total yield (60-78%) than that of primary spike (20-26%).

The higher values for plant height, number of branches, CGR, LAI, harvest index, 100-seed weight and early flowering in cvs Aruna, 48-1, PCS-3 would have contributed for higher yield.

LITERATURE CITED

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Abdel Rahman K A, Hassaballa E A, Elmorshidu M A and Khalifa M A 1980 Physiological response of sesame to sowing dates, nitrogen fertilizer, hill spacings, Research Bulletin , Faculty of Agriculture 1235:13.

Alba E, Greco I and Altini R 1981 Identification by means of path coefficeint of secondary characters which affect other agronomically important characters. Annals della Facolta di Agraria Universita dibari 1981-82.

Anderson L R and Vasilas B L 1985 Effects of planting date on two soybean cultivars, seasonal dry matter accoumulation and seed yeild. Crop science 25(6):979-1004.

Bell M 1986 Effect of sowing date on the growth and develpment of irrigated peanuts (Arachis hypogaea L.) cultivar early bunch in a monsoonal tropical environment. Australian Journal of Agricultural Research. 37(4) 361-373.

Bhattacharya B 1973 Studies on the effects of manurial treatment and sowing dates on growth and yield of sesamum varieties under lateritic upland conditions. Indian Agriculturist 17(1): 17-25.

Bhatt D and Reddy T P 1981 Correlations and path analysis in castor (Ricinus communis.L). Canadian Journal of Genetics and Cytology 23(3): 525-531.

Blackman V H 1919 The compound interest Law and plant growth. Annals of Botany 33:353-360.

Blackman G E and Wilson G L 1951 Physiological and ecological studies in the analysis of plant environment. VII. An analysis of the different effects of light intensity on the net assimilation rates leaf area ratio and relative growth rate of different species. Annals of Botany N.S. 15: 373-408.

Blackman G E 1968 The application of the concepts of growth analysis to the assessment of productivity in Eckardt, UNESCO pp : 243-259.

Briggs G E, Kidd G and West C 1920 Annals of Applied Biology. 7:202

Buttery B R 1969 Effects of plant population and fertilizer on the growth and yield of soybeans. Canadian Journal of Plant science 49 : 659-673.

Buttery B R 1970 Effects of variation in leaf area index on growth of maize and soybeans. Crop science 10(1): 9 - 13.

Buttery B R and Buzzell 1972 Some differences in soybean cultivars observed by growth analysis. Canadian Journal of Plant Science. 52: 13-20.

Chaturvedi G S, Singh B B, Rajendra Prasad, Padmakar and Yadav D N 1985 Physico-morphological determinants of yield in Indian Mustard (Brassica Juncea L.). Abstracts of National Seminar on plant physiology. Imphol.8

Colasante L O and Costa J A 1981 Harvest index and Biological yield for comparison of the efficiency of soybean cultivars. Pesquisa Agropecinia Brasileria 16(2): 225-230.

Combe D E 1961 An analysis of the growth of Trema guineensis. Journal of Ecology. 48:219-231.

Costa J A Oplinger E S and Pendleton J W 1980 Response of soybean cultivars to planting patterns. Agronomy Journal 72(1):153-156.

Donald C N 1968 The breeding of crop ideotypes Enphytica. 17: 385-403.

DOR 1990 Seed production in castor. Technology Bulletin Directorate of Oil Seeds Research, Hyderabad - 500 030.

Duncan W G, Mccloud D E, Mcgrew R L and Boote K J 1978. Physiological aspects of peanut yield in procurement. Crop science 18: 1015-1020.

Enyi G C 1973 Effect of plant population on growth and yeild of soybean. Journal of Agricultural Science 18(1):131-138.

Ganga Saran and Gajendra Giri 1987 Effect of seedings time and nitrogen on summer castor. Indian Journal of Agronomy 32(2):155-157.

Ghosh D C and Bagdi P R 1986 Yield variations in sesamum sown at monthly intervals in subhumid lateritic acid tract of West Bengal. Madras Agricultural Journal 73(1)23-29.

Harisingh, Yadav A K, Yadav T P and Chhabra M L 1982 Genetic variability and heritability for morpho-physiological attributes in groundnut. Indian Journal of Agricultural Science 52(7) : 432-434.

Heath O V S and Gregory F G 1938. The constancy of the mean net assimilation rate and its ecological importance. Annals of Botany N.S.2 : 811-818.

Herberet S J and Litcerfield G V 1984 Growth response of short season soybean to variations in row spacings and density. Field crops Research 9(3/4) : 163-171.

Hiremath S M, Janardhan K V Habib A F and Panchal Y C 1984 Varietal differences in leaf photosynthetic rate and its relationship with certain leaf characters. Journal of Nuclear Agriculture & Biology, 13(4) 103-105.

Jayaveer Rao S 1991 Effect of seed size on germination, vigour, growth and yield in castor (*Ricinus communis* L.). M Sc (Ag) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Jen kins P D and Leitch M H 1986 Effects of sowing date on the growth and yield of winter oil-seed rape (Brassica napus L.). Journal of Agricultural Sciences United Kingdom 107(2) : 405-420.

Kale U V, Dgoble M V, Sheike V B and Khatig E A 1986 Varietal performance of castor at Parbhani under rainfed conditions. Journal of Maharastra Agricultural University 11(3) : 376-377.

Koller H R, Nyquistand W E and Chorush I S 1970 Growth analysis of the soybean community. Crop Science 10:407-412.

Latifi N 1980 Yield and Morphological response of soybeans to time of irrigation and sowing rate. Dissertation Abstracts International B. 40(11) : 5098.

Laureti D 1981 (Comparative trial of Ricinus cultivars) provedi confornto fra cultivar di ricino. Sements Elette 27(3) 23-28.

Laureti D 1983 (Castor special - Anticipating sowing for improved yields) special ricino Anticipare le semine per migliorare le rese. Informatore Agrario 39 (23) : 26236 - 26238.

Laureti D 1988 Genotype - environment interaction and stability of castor (Ricinus communis L.) Cultivars Special Ricino Interzione genotype - ambientee stabilita di varieta di ricino (Ricinus communis L.). Agricultura Ricerca 10 (89) 39-42.

Madhavi K 1988 Studies on some Morphological and physiological characters with specific reference to their inter-relationship and heterosis in Arachis hypogaea L. Ph.D Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Major D J 1977 Influence of seed size on yield and yield components of rape. Agronomy Journal 69 :541-543.

Mehrotra O N Saxena H K and Moosa Mohammed 1976 Physiological analysis of varietal differences in seed yield of Indian Mustard (Brassica Juncea L.). Indian Journal of Plant PHysiology 21 (1 &2) : 139-146.

Mehrotra N, Choudhary B D and Malik D S 1982 Studies on the stability of productive plant populations for increased castor bean (Ricinus communis L.) yield in rainfed conditions. Haryana Agricultural University, Journal of Research 12(1) 119-121.

Milthorpe F L 1960 The relative importance of the different physiological processes in the determination of yield. Dent. Akad. der Landwirtwiss. Tagungsber. 48: 11-19.

Moshkin V A 1956 Kachertvo Urozhaya Semyan Kleshcheviny V Suyazis Usloviyami Sozrevaniya (Quality of castor seeds with regards to ripening conditons. Avtoreb. Kand. diss. Krasnodar. In Castor (ed. Moshkin V A 1986) A Merind Publishing Company Private Limited, New Delhi Castor pp. 28-29.

Moss D N 1960 Photosynthesis The corn plant as a converter. Proceeding Fifteenth Annual Hybrid Corn Industry Research Conference Publication No. 15 : 54-60.

Mulkey J R, Drawe H J and Elledge R E 1987 Planting date effects on plant growth and development in sesamae Agronomy Journal 79 (7/8): 701-703.

Muthiah A, Monivannan M, Natarajan C, Palanisamy G A and Jeyaraj (182) Correlation and Path analysis in Ricinus communis L. Madras Agricultural Journal 69(9) 561-563.

Narayan V and Narayanan A 1987 Yield variations caused in cultivar, seasons and population density of Sesamum indicum L. Journal of Oil Seeds Research 4:19-27.

Narayanan A and Balakrishna Reddy K 1982 Growth development and yield of sesamae (Sesamum indicuss L.) cultivars. Field Crops Research 5 : 217-224.

Natarajratnam N 1979 Dry matter production and harvest index trends in groundnut (*Arachis hypogaea* L.) Madras Agricultural Journal 66 : 218-221.

Nichiporovich A A 1960 Photosynthesis and the theory of obtaining high crop yields. Fifteenth Timirjazev Lecture USSR Academy Science Translation and Review in JN Black and D J Watson Field crop abstract 169-175.

Patil R G, Radder G D, Patil V C and Ramachandrappa A K 1986. Dry matter production and distribution in bunch groundnut varieties as influenced by the time of sowing and foliar application of nitrogen and iron. Madras Agricultural Journal 71 (3) : 177-181.

Podkuichenko G V 1972 Tr. Popriki botanik, genetike, selektsi, Vol. 46, issue 3. Lenin grad. In castor (ed. Moshkin V A 1986) Amerind publishing Company Private Limited, New Delhi castor pp.28-29.

Ponnuswamy A S 1985 seed size in relation to leaf area and crop growth in groundnut (*Arachis hypogaea* L.) Cv pol I and TMVZ. Madras Agricultural Journal 72:352-354.

Prasad V K and Eshanullah MD 1990 Effect of irrigation and nitrogen on soil and plant nitrogen, leaf water potential, growth and yield of Mustard. Annals of Agricultural Research 11 (1) : 47-55.

Radford P J 1967 Growth analysis formulae their use and abuse. Crop Science 7 (3) : 171-175.

Rajput M S, Tunio S, Rajput M A and Rajput F K 1984 Effect of row and plant spacing on yield and yield components in soybean. Pakistan Journal Agricultural Reasearch 5 (2) : 83-7.

Ramseur E L, Wallace S V and Quisenberry V L 1985 Growth of braxton soybeans as influenced by irrigation and intra row spacing. Agronomy Journal 77(1) : 163-168.

Rao CH, Hamilton R I and Rao UMB 1981 Note on effect of nipping spikes of different sequential orders on the yield of 'Aruna castor'. Indian Journal of Agricultural Science 51 (7) : 531-532.

Rao A R, Kondap S M, Bhoji Reddy and Miza W A 1985 Phenological behaviour and yield of sesamum cultivars under different dates of sowing and row spacings. Journal of Oil Seeds Research 2: 129-133.

Rao C M, and Venkateshwarlu M S 1988 Effect of irrigation, nitrogen and plant density on yield attributes and yield of castor varieties. Journal of Research, Andhra Pradesh Agricultural University, Hyderabad 16 (1) : 37-39.

Rao J S 1991 Effect of seed size on germination, vigour, growth and yield in castor (Ricinus communis L). M.Sc (Ag) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Reddy K B and Naryanan A 1987 Dry matter production and nutrient uptake in sesame (Sesamum indicum L.) genotypes. In Abstracts of National Seminar on plant physiology and Biochemistry of Oil seed plants. Tirupati 5.

Reddy R N, Hanumantha Rao and Raghavulu P 1990 studies on growth and yield of different soybean varieties at varying spacing. The Andhra Agricultural Journal 37 (3) : 218-322.

Sachli I K 1986 (Wright path coefficient method for establishing characters for selection in castor bean) In Voprosy Prikladroi Fiziologi genetiki maslichnykh kul'tur. 20-24.

Saibabu M S 1991 Studies on the effect of Nitrogen and sulphur on nutrient uptake, yield and oil content of safflower (carthamus tinctorius L.). M.Sc (Ag) Thesis, Andhra Pradesh Agricultural University, Hyderabad.

Samoilenko T I 1977 Byul VIR, issue 69. In. Castor (ed. Moshkin VA 1986) Amerind publishing Company Private Limited, New Delhi Castor pp. 28-29.

Samoilenko, T I 1977 (A study of dwarf samples of the castor collection). Byulleten Vsesoyuznogo ordena Leninai ordena Druzhby Narodov Nauchnoissledovatel's Kogo Instituta Restenievedestva imeni N I vavilova No.69, 76-78.

Sangoil L and Silva P A 1985 Date of sowing of sunflower II Effects on leaf area index, disease incidence, biological yield and harvest index. Lavoure Arrozeira 38 (362) : 6-13.

Saran G and Giri G, 1987 Effect of seedings time and nitrogen on summer castor. Indian Journal of Agronomy 32 (2) : 155-157.

Sestak Z, Catsby J and Jarvis P G 1971 Promotion of leaf Expansion by kinetin and benzylamino Pyrin Plant Phisiology 31 : 321-322.

Shibles R M and Mc Donald H A 1962 Photosynthetic area and rate in relation to seedling vigor of birds food trefoil. Crop Science 2 (4) : 299-302.

Shibles R M and Weber C R 1966 Introduction of solar radiation interception by various soybean planting patterns. Crop Science 5: 575-577.

Singh J N, Tripathi S K and Nego P S 1972 Note on the effect of seed size on germination, growth and yield of soybean. Indian Journal of Agricultural Science 42: 83-86.

Singh S B, Singh H G and Singh and Singh R R 1981 Path coefficient analysis in castor. Madras Agrcultural Journal 68 (10) : 688-689.

Tsunoda A A 1959 Developmental analysis of yielding ability in varieties of field crops. Leaf area per plant and leaf area ratio. Japanese Journal of Breeding 9 (2) : 161-168.

Trehan K B, Hireachand and Mehta S K 1977 Effect of different seed sizes on the yield and some qualitative characters of sunflower (Helianthus annus L). Madras Agricultural Journal 64 : 174-176.

Turkhede B B, Saran G and De R 1982 Response of castor variation to dates of seedling under dryland conditions by North-West India. Indian Journal of Agricultural Research 16 (4) : 209-214.

Uprety D C, Tomar O P S and Sirohi G S 1979 A note on the yield determining factors in cow pea (Vigna unguiculata L.) varieties. Indian Journal of plant physiololgy XXII 2 : 156-159.

Velu G and Gopalakrishnan S 1985 Habitual and varietal variation in yeild, harvest index and quality characteristics of groundnut. Madras Agricultural Journal 72(9) : 518-521.

Vidyasagar C 1979 Effect of Nitrogen, Phosphorus and potassium combinations along with different types of Boron Application on growth, nutrition, yield and oil content of sunflower (Helianthus annus L.) M Sc (Ag) Thesis, Andhra Pradesh Agricultural Unviersity, Hyderabad.

Walllace D M and Munger H M 1965 Studies of the physiological basis for yield differences I growth analysis of six dry bean varieties. Crop science 5 : 343-348.

Watson D J 1947 Comparative Physiological studies on the growth of field crops Variation in NAR and leaf area between species and varieties and within and between years. Annals of Botany N S 2 : 41-76.

Watson D J 1952 The physiological basis of variation. Advance Agronomy 4 : 101-145.

Watson 1958 The dependance of NAR on LAI. Annals of Botany 22 :37-54.

Weber C R Shibles R M and Byth D E 1966 Effect of plant population and row spacing on soybean development and production. Agronomy Journal 58 (1) : 99-102.

Weiss E A 1971 1971 General characteristics of the plants In castor sesame and Safflower (ed. Weiss E A 1971) Leonard Hill London pp 60-64.

West C 1920 A quantitative analysis of plant growth parts I and II Analysis of Applied Biology 7 : 103-123 and 202-223.

Williams R F 1946 The physiology of plant growth with special reference to the concept of net assimilation rate. Annals of Botany N S 10 : 41-72.

Williams J H, Wilson H and Bate G C 1975 The growth of groundnuts (<u>Arachis hypogaea</u> L.) cultivars in Rhodesia Rhodesia Journal of Agricultural Research 13:131-144.

Zimmerman L H 1958 Advance in Agrnomy vol 6 No. 5. <u>In</u> castor (ed. Moshkin V A 1986) Amerind Publishing Company private Limited, New Delhi Castor pp 28-29.

APPENDIX

APPENDEX

WEATHER DATA

Standard week	Temperature °C		Relative humidity		Sunshine hrs/day	Rainfall (mm)	Rainy days	Evaporation (mm/day)	Wind velocity (kMPH)
	Maximum	Minimum	7.14am	2.14pm					
26	31.40	22.90	80.00	36.00	8.2	6.00	1	6.00	15.30
27	31.10	23.10	82.00	41.00	5.9	7.20	2	5.40	13.30
28	30.50	22.20	85.00	42.00	5.9	43.80	4	5.00	16.20
29	29.10	21.90	88.00	48.00	2.3	38.10	4	4.30	14.40
30	29.90	21.80	82.00	37.00	8.7	27.20	2	5.50	15.30
31	31.90	23.00	77.00	29.00	8.5	0.00	0	6.60	9.90
32	31.20	22.70	87.00	36.00	7.1	51.60	2	5.00	6.70
33	26.60	21.70	90.00	53.00	1.7	128.20	4	4.40	17.50
34	28.00	21.70	86.00	41.00	4.7	18.40	2	4.10	17.20
35	28.50	22.00	85.00	61.00	4.8	18.30	3	3.70	12.10
36	29.60	22.50	82.00	40.00	4.0	15.20	1	3.70	10.70
37	30.60	22.50	80.00	34.00	7.2	12.40	1	4.10	4.80
38	31.40	22.60	76.00	33.00	8.3	9.00	1	3.80	3.90
39	30.70	22.30	48.00	32.00	6.5	29.90	2	4.30	4.90
40	28.40	21.00	82.00	39.00	6.4	62.60	3	3.80	7.20
41	29.90	21.80	84.00	35.00	5.7	58.40	1	4.70	2.80
42	30.10	16.10	69.00	26.00	10.1	0.00	0	5.30	2.90
43	28.40	20.20	82.00	38.00	5.7	23.60	2	3.30	4.00
44	29.50	19.50	58.00	27.00	10.1	0.00	0	3.70	3.70
45	30.00	17.70	74.00	26.00	8.7	17.00	1	3.90	2.00
46	28.90	18.30	82.00	28.00	7.6	4.40	1	3.70	3.60
47	27.90	19.20	87.00	51.00	5.1	15.20	3	1.80	2.70