EFFECT OF PHOTOPERIOD ON GROWTH AND PARTITIONING OF PHOTOSYNTHATES IN GROUNDNUT (*Arachis hypogaea* L.)

By
MANOHAR BHUKTA B. Sc. (Ag)

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ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY
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CERTIFICATE

Mr. Manohar Bhukta has satisfactorily prosecuted the course of research and that the thesis entitled **"EFFECT OF PHOTOPERIOD ON GROWTH AND PARTITIONING OF PHOTOSYNTHATES IN GROUNDNUT (*Arachis hypogaea* 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 there of has not been previously submitted by him for a degree of any university.

Date: 27/1/99

(Dr. C.L Narasimha Rao)
Chairman
Associate Professor
Department of Plant Physiology
College of Agriculture
Hyderabad - 30

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF PHOTOPERIOD ON GROWTH AND PARTITIONING OF PHOTOSYNTHATES IN GROUNDNUT (*Arachis hypogaea* L.)"** submitted in partial fulfilment of the requirements for the degree of 'Master of science in Agriculture'of Acharya N. G. Ranga Agricultural university, Hyderabad is a record of bonafide research work carried out by Mr.Manohar Bhukta 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 assistance and help received during the course of investigations has been duly acknowledged by the author of the thesis.

(Dr. C.L.Narasimha Rao)
Chairman of the Advisory committee

Thesis approved by the student's advisory committee

Chairman : **(Dr. C.L.Narasimha Rao)** ----------
Associate Professor
Department of Plant Physiology
College of Agriculture
Rajendranagar, Hyderabad - 500030

Co - Chairman : **(Dr. R. C. Nageswara Rao)** ----------
Senior Scientist
Genetic Resources Enhancement program
ICRISAT Asia center
Patancheru, Hyderabad A. P. - 502324

Member : **(Dr. P.S.Sarma)** ----------
Professor and Head
Department of Plant Physiology
College of Agriculture
Rajendranagar, Hyderabad - 500030

Member : **(Mr. N.Vivekananda)** ----------
Associate Professor
Department of Genetics and Plant Breeding
College of Agriculture
Rajendranagar, Hyderabad - 500030

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"MANOHAR BAKTA"

DECLARATION

I, **Mr MANOHAR BHUKTA,** hereby declare that the thesis entitled **"EFFECT OF PHOTOPERIOD ON GROWTH AND PARTITIONING OF PHOTOSYNTHATES IN GROUNDNUT (*Arachis hypogaea* L.)"** is the result of the original research work done by me. I further declare that the thesis of part thereof has not been published earlier in any manner.

Date 27/1/99

Place: Hyderabad

(MANOHAR BHUKTA)

Author	:	**MANOHAR BHUKTA**
Title of the thesis	:	**Effect of photoperiod on growth and partitioning of photosynthates in groundnut (*Arachis hypogaea* L.).**
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Major Advisor	:	**Dr. C.L. Narasimha Rao**
University	:	**ACHARYA N G RANGA AGRICULTURAL UNIVERSITY**
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ABSTRACT

Effect of photoperiod on growth and partitioning of photosynthates was examined in nine selected groundnut genotypes by subjecting them to short day (SD, 8 hr), natural day length (ND) and long day (LD, 16 hr) photoperiods. Short day treatments were imposed by manually operated rain (sun) out shelters covered with a black cloth, which were moved and taken off from the experimental plots at specified times. Long day treatment was imposed by using incandescent electrical bulbs (100W) controlled by a timer.

Photoperiods failed to influence thermal time to 50% emergence, flowering initiation and 50% flowering. But, it did

influence rate of flowering and days to accumulation of 25 flowers, which were hastened by SD. However, ND and LD prolonged the flowering and total flower number was 70 and it was 42 in SD conditions. LD also prolonged days to flower cessation.

The influence of Photoperiods on reproductive structures was very prominent. SD promoted reproductive structures, i.e. juvenile pod number, immature pod number and mature pod number. SD also favoured higher partitioning of photosynthates to pods (0.714) compared to ND (0.675), LD (0.521). All genotypes were sensitive to photoperiod, although the magnitude of sensitivity varied among genotypes. Based on partitioning NC Ac 17090 and ICGMS 42 classified as most sensitive, while ICGV 88438, ICGV 86564 and TAG 24 as moderately sensitive and ICGV 86015, ICGV 87128, TMV2 and ICGV 86031 as relatively less sensitive types.

Photoperiod also altered the total to sub-terranean peg ratio (STPGR), total pod to mature pod ratio (MTPGR), total peg to pod ratio (PPR) and stem to leaf weight ratio (ST: LF). These were lower under LD than in SD treatments. The results suggested that the above ratios can be used as potential indicator of genotypic sensitivity to photoperiod in groundnut in a given photoperiod environments.

Translocation studies using ^{14}C revealed that, LD treatment resulted in reduction in the translocation of current assimilates to pods (18%) compared to SD (42%). However, under LD, translocation towards stem and leaf was greater (31 and 33%) than that under SD (22 and 18%). In case of NC Ac 17090 and ICGMS 42, translocation to pods was almost zero under LD indicating degree of sensitivity of these genotypes to photoperiods. In TMV2 and ICGV 87128 the translocation to pods was maintained more or less the same.

In four selected genotypes influence of photoperiod on protein metabolism was studied using gel-electrophoresis. ICGMS 42, NC Ac 17090, TMV 2 and ICGV 86564 varied in their protein metabolism

under SD and LD conditions. In ICGMS 42, NC Ac 17090 and ICGV 864564(sensitive genotypes) under SD conditions, new bands with 45.7 and 41 kDa were observed, while it was absent in TMV2 (insensitive). There were also quantitative changes in protein due to influence of photoperiod, SD treatment resulted in high intensity bands at 69 to 72 kDa, while LD showed high intensity bands of 20 to 25 kDa in all four genotypes.

The results indicate that,

1. There is significant effect of photoperiod on groundnut, although the degree of sensitivity varied with genotypes.
2. Crop phenological events upto flowering and pod set were less affected due to photoperiod compared to post-reproductive growth processes.
3. The effect of photoperiod was significant on partitioning of photosynthates to reproductive structures with long day favouring translocation of current photosynthates to vegetative structures (leaves and stems) while short day promoted translocation of photosynthates to pod.
4. Photoperiod seen to regulate the translocation of current assimilates from leaves to either vegetative or reproductive growth.
5. SD treatment seems to have hastened the maturity by making growing pegs (pods) as competing sinks for photosynthates.
6. Photoperiod sensitivity can be assessed by leaf to stem ratio, peg to pod ratio and partitioning of assimilates to pods.
7. The present investigation also revealed photoperiod sensitivity could be assessed through molecular means (SDS-PAGE).

LIST OF ABREVIATIONS

Abbreviations	
Apegn	Aerial peg number (m^{-2}).
CGR	Crop growth rate ($g\ m^{-2}\ d^{-1}$).
Impdn	Immature pod number (m^{-2}).
Jvpdn	Juvenile pod number (m^{-2}).
LAI	Leaf area index.
Mpdn	Mature pod number (m^{-2}).
MSTL	Main stem length (cm).
MTPdR	Mature pod ratio (m^{-2}).
PGAR	Peg addition rates ($pegs\ m^{-2}\ d^{-1}$).
PGR	Pod growth rate ($g\ m^{-2}\ d^{-1}$).
PPR	Total peg to pod ratio.
SLA	Specific leaf area ($cm^2\ gm^{-1}$).
SGR	Seed growth rate ($g\ m^{-2}\ d^{-1}$).
Spegn	Sub-terranean peg number (m^{-2}).
SPGR	Sub-terranean peg to pod ratio.
VGR	Vegetative growth rate ($g\ m^{-2}\ d^{-1}$).

Chapter I

Introduction

Peanut or groundnut is a member of the genus *Arachis* of tribe *Aeschynomenae* and subtribe *Stylosanthinae* of family leguminosae . The only species in the genus of significant economic importance is *Arachis hypogaea* L., with all parts of the plants having dietary significance to humans and live stock . Among crop plants in the world standing between mankind and starvation peanuts rank thirteenth in importance. Due to its adaptability to wide range of soil and climatic conditions, groundnut has spread from it's origin South America to most of the countries within the boundaries of 40^0N to 40^0S latitudes.

Groundnut is an important commercial and food crop in semiarid tropics(SAT) which produces 67% of the total world's production . Groundnut kernels are rich in proteins(25%) and these are widely used for edible oil and in confectionery purposes, i.e. as roasted peanuts, peanut candies, peanut butter. The vegetative portion of the crop is also of value as animal feed. It is rich in proteins, Vit-$B_1$and Vit-B_2 and niacin (Burn and Huffman , 1975).

On global basis, the crop is cultivated in 21m ha area, with 28.18 m tons production. India is the world second largest producer, with an area of 8.2 m ha and 8.2 m tons of production (U.S.D.A, Dec-97), accounting for 55% of total oil seed production in the country. In India, the average productivity is about 900 kg/ha, which is 1/3 of crops potential yields recorded elsewhere (Survey of Indian agriculture, 1997). In spite of extensive research accomplishment, groundnut continues to be an unpredictable legume, showing inconsistency in pod and oil yield over seasons, years, and locations. Optimum

conditions for growth and development of peanut are rarely met. An understanding of the conditions necessary for optimum provides a way to assess why expectations may not have met.

The greatest emphasis over the past decade has been increasing the understanding of the role of environmental and genetic factors in modifying phenology and growth. To some extent these advances have occurred because of the decreasing level of research resources for empirical experimentation over larger number of sites. Another factor contributing to these changes has been the increase in complexity of the problems that would require inter-disciplinary effort to resolve. But, it is clear that there have been major advances over the past decade in both knowledge of crop physiology and in the application of this knowledge to resolving crop improvement and production problems. Successful groundnut production lies in cultivar selection. According to Sprague(1969) " The assessment of the potential contribution to biological efficiency can be studied more readily when extreme types are involved." In this regard photoperiod plays a key role in cultivar selection and it's adaptability.

Earlier works at International Crops Research Institute for Semi-Arid Tropics (ICRISAT), On the effect of photoperiod on groundnut has limited to two photoperiod regimes, i.e. normal day length and extended day length(Flohr, 1989, Witzenberger, 1985). The present study was the first attempt to study the effects of wider range of photoperiod regimes, short day (8 hr), normal day(10-12 hr) and long day(16 hr) under field conditions.

Photoperiods vary along latitudes and seasons. India lies within a Latitudinal range of 8^0-36^0 N. The major groundnut cultivating states in India fall in the range of 8^0-28^0 N. From meteorological data it is evident that the duration of day length varies from 10 to 14 hr between the two important seasons (rainy and post-rainy season). Hence, the studies on the effects of photoperiod on crop productivity will help in understanding adaptation of the crop and in developing selection tool for wider adaptation (with photoperiod insensitivity) or specific adaptation (photoperiod sensitivity) however, most of the experiments in this regard were carried out under controlled environmental conditions. There is limited information on photoperiod effects under field conditions. Though, there was some attempts on understanding the physiological changes under varied photoperiod regimes, these were confined to non-leguminous crops and plants. Thus the present study was carried out with following objectives

1. To investigate the effect of photoperiod on phenology of the crop.
2. To investigate effect of photoperiod on translocation of photosynthate to different organs of the plants.
3. To investigate genotypic responses to photoperiodic sensitivity
4. To investigate the physiological and molecular basis of photoperiod sensitivity among genotypes.

Chapter II

REVIEW OF LITERATURE

Groundnut in general considered as day neutral plant. According to reports of Smith (1954), Fontainer (1957) and Wynne *et al.* (1973) Evans and King (1975), Bunting *et al.* (1985) showed that groundnut is insensitive to photoperiod.

Despite extensive research accomplishment, groundnut continues to be unpredictable legume showing inconsistency in pod yield over seasons, years and locations. According to Branch and Hiberland (1989) Groundnut genotype selected for high yield at one location may have unpredictable performance, when moved to locations with differing environmental regimes due to genotype x environment interactions.

So, there is a change in both qualitative and quantitative aspects due to photoperiod. We will go through the works of various scientists, on qualitative and quantitative parameters of groundnut and the effect of photoperiods on them

2.1 Effect of photoperiod on ground flowering:

Goldin and Har-tzook (1966) reported that flowering in groundnut is greatly influenced by season. The flowering distribution was bell-shaped, with a peak in the third month of the growing season. A rapid increase in flower output was noticed up to the 30th day in POL-1, following which there was a slow advancement till the 44 th day. A steep fall in flower production was noticed up to the 51st day. the decrease in blooming was slow from the 52 day until its cessation on the 100th day (Muralidharan, 1978).

Sengupta *et al.* (1977) worked with 8- groundnut genotypes namely, TMV-1, TMV-2, TMV-10, J-111, POL-1, C-148, M-145 and M-13 and exposed them to 6,8,10,14

and 24 hrs of photoperiods from 10 th day of germination and found that increase in day length from 6 to 10 hr hastened flowering (5 to 7 days) in TM-1, TMV-2, J-11 and M-13, but beyond 10 hr delayed flowering. POL-1 and C-148 were less insensitive. Not only flowering but also flowering periodicity had some dramatic changes when exposed to short day conditions. It also increased rates of growth for selection in segregating population (Emery *et al.*, 1981). Upadhyaya and Nigam (1994) Worked on early maturity of groundnut (Arachis *hypogaea* L.) with three genotypes, Chico and Gangapuri (early maturing) and M 13 (Late maturing) and their studies laid importance on the fact that first flower and days to accumulation of Twenty-five flowers are responsible for early maturity. But, Photoperiods did not influence thermal time to flowering or subsequent appearance of flowering until 900-950 flowers m^{-2} had appeared. There after flowers appeared in short, but not in long days (Flohr *et al.*, 1990). Bell *et al.* (1991) conducted three separate sets of experiments. In the first set, they found that day length had positive effect on reproductive development and harvest index at h_1 i e , assessments made after 35 days after flower appearance. In his second set, he found that long day treatment reduced number of flowers in robust 33-1 and to lesser extent in cultivar white spanish. But, no effect of photoperiod on time to first flower was evident. In third set they had worked with groundnut cultivars Spanish, Virginia and Valencia types. The thermal time to flowering was lower in Spanish than Valencia and single Virginia type. This was supported Bagnall *et al.* (1991) whose work on Spanish, Virginia and Valencia types showed that the thermal time to first flower appearance was little affected by photoperiods but temperature had a major effect on time to first flower. Number of flowers produced was significantly enhanced in short day photoperiods. This was true

with his second set of experiment, which he carried along with Bagnall and King (1991). They had also showed that flower number was doubled in 12 hr than that of 16hrs treatment of 60-70 days from emergence. Bagnall *et al* (1991) also showed that rate of emergence in all cultivars was positively associated with mean air temperature, with all sowing dates characterised by sub-optimum temperature for this developmental stage. For all cultivars, the rate of development from emergence to flowering was positively associated with mean air temperature during the period. Temperatures experienced in all sowing were also in sub-optimal range for this developmental stage. A sub-set of six cultivars showed an additional positive response in the rate of flowering development to mean day length during the same period, although temperature is the dominant factors.

The results of Wallace *et al.* (1993) laid importance on the fact that photoperiod and temperature were the primary environmental factors that control over time to flowering and maturity, cultivar adaptation and yield.

Beside these environmental, seasonal and genotypic variance which play a crucial role in flowering regulation in groundnuts, one more factor that plays a crucial role in flowering, is growth regulators. Lee (1990) showed that seed treatments of groundnuts with Gibberellins or Indole acetic acid of concentrations 50, 100, 200 ppm showed increased number of flowers. Experiments of Flohr (1989) indicated that the photoperiod might influence the reproductive efficiency in groundnuts by changing hormonal balance. A higher Gibberellin content and/or a change in gibberellin metabolism during pegging and podding under long day (LD) appears to be related to a reduction of reproductive development and growth, because blocking

Gibberellic acid synthesis with PP333 (anti-gibberellin) during those growth phases reversed the effects of long days.

PHOTOSYNTHESIS:

The product of carbon fixation comprises a major part of dry matter and hence net CO_2 assimilation is the principle factor determining productivity.

According to Pallas and Smith (1974) photosynthetic rates of groundnut, a C_3 plant is higher than other C_3 plant like tomato. They also revealed that groundnut photosynthetic rate saturation occurs near full sunlight (slightly lesser than full sunlight). Trachtenberg and Mc Cloud (1976) found maximum photosynthetic rate of 77mgCO_2 dm^{-2} hr^{-1}in individual leaf. According to Bhagasari and Brown (1976) photosynthetic rates varied from 24-37 mgCO_2 dm^{-2} hr^{-1}.

Photosynthesis varied with age of the leaf and the top three leaves showed higher photosynthetic rates (Sastry *et al*., 1980). In third leaf, the youngest fully expanded leaf on the branch, the apparent photosynthetic rates were higher 8th lowest and 5th exhibited intermediate (Henning *et al*., 1979).

Photosynthetic rates not only dependent on position of leaf but also the intensities of light it is receiving.

Light:

Photosynthetic effectiveness of wheat reaches a slight maximum near 4400^{0}A and decreases greatly between 4400^{0}A and 4000^{0}A (Parker, 1946). 4000^{0}A , the maximum effectiveness for stopping floral initiation apparently takes place at shorter wavelengths.

The intercepted radiation does not only influence reproductive structure, but also have linear relation with crop biomass (Monteith, 1977). While Piara Singh *et al.* (1994) working for evaluation of PNUTGRO model, showed that 40 plants per m^{-2} with spacing of 60 cm between row showed 80% interception, but it was found lowest for 10 plants per m^{-2}. Bennett *et al.* (1993) showed that percentage of interception varies according to age and LAI. Ninety five percent of solar radiation interception was found at LAI of 4.0, 57 days after sowing (DAS) and it was found constant up to 127 and 141DAS depending on genotypes and than declined.

To be more precise in relating radiation towards development of biomass, radiation use efficiency (RUE) was used. It was shown that RUE in the warm environments was 39% more than that of cooler environments and was found out to be 0.8 to near 1.4 g M J^{-1} for peanut grown under optimal conditions (Bell *et al.*, 1987, Stirling *et al.*, 1990, Wright *et al.*, 1992, Bell *et al.*, 1992).

Single leaflet carbon exchange ratio: Single leaflet carbon exchange ratio (CER) declined early stable values over most of the growing season, ranging between 25 and 35 μ mol CO_2 m^{-2} sec^{-1} before declining sharply during the late seed filling period (Benett *et al.*, 1993).

Groundnuts phenology and effect of photoperiod on it:

Groundnut phenology was studied by Bouffile (1947) and Bolhuis (1958) and De Grout (1959) who showed in (pot experiments) that reducing the number of flowers per plant resulted in increased pod set percentage, which reached 66.6% in one case. Goldin *and* Har-tZook (1966) had similar conclusions that the

formation and development of pods may be inhibited by flowering and vegetative growth.

Photoperiods considerably manipulate the phenology of groundnuts. Duncan (1978) showed that differences in 3- physiological processes explain most of the yield variation among 5- peanut cultivars; the partitioning, the length of filling period and rate of fruit establishment, where partitioning ranges from 41% - 98%.

According to Wynne *et al.* (1973) who concluded that short day treatments were favourable for producing more fruit than long days but the decrease in plant height occurs in short day treatments. Shot day treatment also increase number of pegs, peg growth, fruit number, fruit weight, seed weight and increase in seed weight per plant (Emery., 1981). Witzenberger *et al.* (1985) Evaluated 6 groundnut cultivars in short day (normal winter / spring day at Hyderabad) and long day (extending day to 22 hr) by artificial lightening. There was increase in pod yield in short day conditions in 4-cultivars but, slight increase in yield under long day conditions were seen in TMV-2 and Robut 33-1. TMV-2 had accumulated higher vegetative dry matter in the long day treatment.

Photoperiod such as long day (15-16 hr) increased Crop growth rates (CGR) and generally decreased partitioning and duration of the crops effective pod filling stage. however yield difference in genotypes varied due to partitioning in some and due to pod filling in others (Witzenberger, 1988)

Photoperiods also used as tool for genotype selection and sensitiveness. All hybrids exceeding mid-parent value of fruit for short day treatment, while only two of the six crosses exceeded mid- parent value for fruit yield under long

days (wynne *et al.*, 1974). Genotypes were classified as being sensitive to day length if extended day length treatment changed harvest index (HI) by greater than 75% (ICRISAT annual report, 1988)

Bagnall *et al.* (1991) flower, peg and pod number were consistently increased by Short day treatment for a range of peanut (Arachis *hypogaeae* L.) varieties, therefore the species regarded as facultative short day plant (SDP). Flower and peg numbers at 60-70 days from emergence were approximately doubled by 12 hr days compared to plants of 16 hr days. Peg numbers were highly correlated to flower number; the ratio was independent of differing photoperiod treatments, suggesting that there was no major effect of day length on flower abortion. However, pod number and therefore yield, was more influenced by photoperiod than was flower or peg formation.

Photoperiod was not only the single factor affecting groundnut phenology but also, temperature has profound influence on it. So, the photothermal concept gaining importance. The latest researches were based upon cumulative thermal time as basis, instead of calendar days. Photoperiod responses were significant at higher temperature. This was evident when photoperiod sensitive Valencia Cultivar NcAc-17090 was lacking photoperiod response and the occurrence of strongest photoperiodic response in relatively insensitive cultivar Robut 33-1 was surprising. The mean daily temperature during treatment period was 26^0C. Photoperiods did not show significant response when daily heat unit accumulation was less than $340\text{-}350^0$Ch and less than 16 h and 17-h photoperiod pegs and pods and total pod weight/plant reduced compared to short day (Bell *et al.* 1991).

Flohr *et al.* (1990) worked out physiological basis for responses to day length in groundnut genotypes NcAc-17090. Longdays increased the thermal time between the initiation of each peg and pod and thermal time required for each fruit to mature. Partitioning in long days decreased than short days. Bell and Harch (1991) showed that the reproductive development and harvest index (HI) at h_1 (35 days after first flower appearance) were positively associated with day length during emergence to flowering period for most cultivars. Similarly, reproductive development and HI at h_2 (65 days after first flower appearance) were positively related with day length and negatively related h_1 and h_2 period. Nigam *et al.* (1994) subjected three groundnut genotypes namely TMV-2, NcAc-17090 and VA 81B to 22/18^{0}C , 26/22^{0}C and 30/26^{0}C day/night temperature regimes and each to 12 h (long) and 9 h (short) photoperiods and found that partitioning of dry matter to pods was not significantly affected by photoperiod under low temperature regimes, but at higher temperature regimes, partitioning to pods was significantly greater under short day condition. Photoeriodic effect on total dry matter was significant with genotypes producing total 32-72 % dry matter under long day (12 h) than short day (9 h) and long day treatments also induced lower pod to peg ratio(PPR) indicating lesser peg conversion to pods. Thus PPR could be used an indicator of genotypic sensitivity to photoperiod in groundnuts. The results also showed lack of relationship between leaf area and pod weight (or) pod number, suggesting that pod development is controlled by factors other than carbon assimilation (Nigam *et al.*, 1998)

Wallace *et al.* (1993) reported that photoperiod gene control over partitioning precedes and was causal of the photoperiod gene control over days to flowering and maturity. So, partitioning and translocation was of utmost importance in groundnut.

Growth rates and partitioning:

Williams *et al.* (1975) while studying partitioning growth of groundnut at three altitudes in Rhodesia, reported that CGR was lowest at hottest site (Mean daily temperatures (25- 26^{0}C) but the maximum yield of kernel was achieved at intermediate temperature (20.8^{0}C). Maximum CGR in groundnut genotypes grown on grasslands (17.9^{0}C) was 88 g m^{-2} wk^{-1}, at Messa (20.10C) 120 g m^{-2} wk^{-1} and pannure (23.3^{0}C) 194 g m^{-2} wk^{-1}. Samarasinghe and Tannae (1989) worked on groundnut cultivars chico, pronto, early bunch, McRan and pronto, early bunch .In McRan CGR increased untill 52 days after sowing, decreasing before pod filling and then increased to high levels due to increased demand for assimilates during rapid seed development

Polara *et al.* (1991) carried out pot trials with groundnut cultivars TG-17 in a clay soil and his results showed that dry matter and nutrient accumulation were highest in shoots, followed by pods and roots. But, yields were highest when cultivars showed less partitioning of dry matter in to leaves during pod growth. Higher pod yields in bunch type (TAG-24) was associated with reduced plant dry matter and improved harvest index in relation to the source variety, spanish improved (Bhatia *et al*., 1991) Tsai *et al.*, (1987) worked with Virginia groundnuts which were grown in Pintung area. The results laid importance on the fact that pod dry matter depended on current assimilation rather remobilization of resources but source of photosynthates did not appear to be limiting factor.

Translocation:

Accumulation of assimilates in photosynthetic tissue due to slow translocation may cause reduction in photosynthetic rates (Pn) of plant leaves (Neales

and Incoll 1968). Chatterton (1973) presented evidence on the basis of diurnal negative correlation between Pn and specific leaf weight (SLW) of alfalfa that Pn may be reduced due to accumulation of assimilates in leaves. Hartt (1963) reported that a decrease in Pn of detached leaves of sugarcane was associated with an increase in sucrose content. Hofstra and Nelson (1969) found that C_4 species, such as tropical grass, exported more than 70% of assimilated ^{14}C in six hours of translocation as compared to 45 - 50 % for C_3 species which have lower Pn than C_4 species. A direct relationship between photosynthesis and traslocation has not been observed in genotype comparisons. Evans and Dun stone (1970) reported that wild diploid species of wheat had higher rates of Pn but lower translocation rates than modern hexaploid cultivars of *Triticum aestivum* L.

Though partitioning and translocation are the important factors governing yield variance, but there are factors, which also contribute for yield variance. Bell *et al.* (1994) showed that groundnut nitrogen uptake during reproductive growth was insufficient to meet the demands of developing pods and nitrogen was remobilised from vegetative plant parts. But, there was negative correlation between specific leaf area (SLA) and leaf nitrogen content per unit leaf area (SLN) which in turn negatively correlated with carbon isotope discrimination (DELTA). The results suggested that SLA can be used a surrogate for DELTA (Wright *et al.*, 1994)

Groundnut protein profiles:

Though, there were some works on the physiological changes during different photoperiod treatments, but these were confined to non-leguminous

crops and plants. Very limited information is available on the physiological and molecular approaches of photoperiod sensitivity.

Shokarii *et al.*, (1991) laid importance on 36 kDa polypetide, which was present as early in embryogenesis stage and also present all over cotyledon and surface seed also. But, the function of 36 kDa was not known. Bianchi-Hall (1994) analysed 34 cultivars of groundnut and results showed that, it was possible to differentiate between sub-species but not to associate a particular profile with only one specific cultivar. Within sub-species, cultivars in more than one group and most cultivars that grouped together were genetically related. Phylogenetic relationship was established through SDS-PAGE analysis and was related to morphological classification, when 19 accessions of ground seed protein profiles analysed through SDS-PAGE (Singh *et al.*, 1994).

Effect of photoperiod on protein profiles:

Photoperiod was shown to have considerable qualitative and quantitative effects on protein metabolism under controlled environmental conditions, with exposure top 8h of light resulted in 20% increase of 32 kDa protein in bark of *populus deltoides* Bartr ex Marsh. After 17 days exposure, the 32-kDa protein accumulated nearly half of the total soluble protein. In field conditions, such changes in protein were observed under day length of 14.1 h (Gary, 1991). When *Pharbatis nil choisy* cv violet subjected to short day, the intensity of one polypetide spot of molecular mass 22-kDa increased in short day treatment (Michiyuki ono *et al.*, 1993).

CHAPTER III

Materials and methods

3.1 Field experiment: A Field experiment was conducted on alfisols at ICRISAT centre, Patancheru, near Hyderabad, Andhra pradesh, INDIA during the rabi season (Dec-April) 1997-98 to investigate the effect of photoperiod on growth and apportioning of dry matter to various growing organs in selected groundnut genotypes

3. 1.1 Experimental design and layout

The experiment was designed as a split-plot with three photoperiod treatments as main and nine genotypes as sub treatments. Each treatment was replicated thrice (Fig-1). Soil characteristics were given in Table-1a and 1b

Main treatments : Photoperiods

1. Short day (SD) with day length of 8 hr
2. Normal day (ND)
3. Long Day (LD) day length of 16 hr

Sub-treatments : Nine Genotypes:

1) NC Ac 17090 2) ICGV 86534

3) ICGV 86031 4) ICGV 86015

5) ICGV 87128 6) ICGMS 42

7) TAG 24 8) TMV 2

9) ICGV 88438

The genotypic characteristics are described briefly in Table-1c.

Table:1a Soil mechanical analysis.

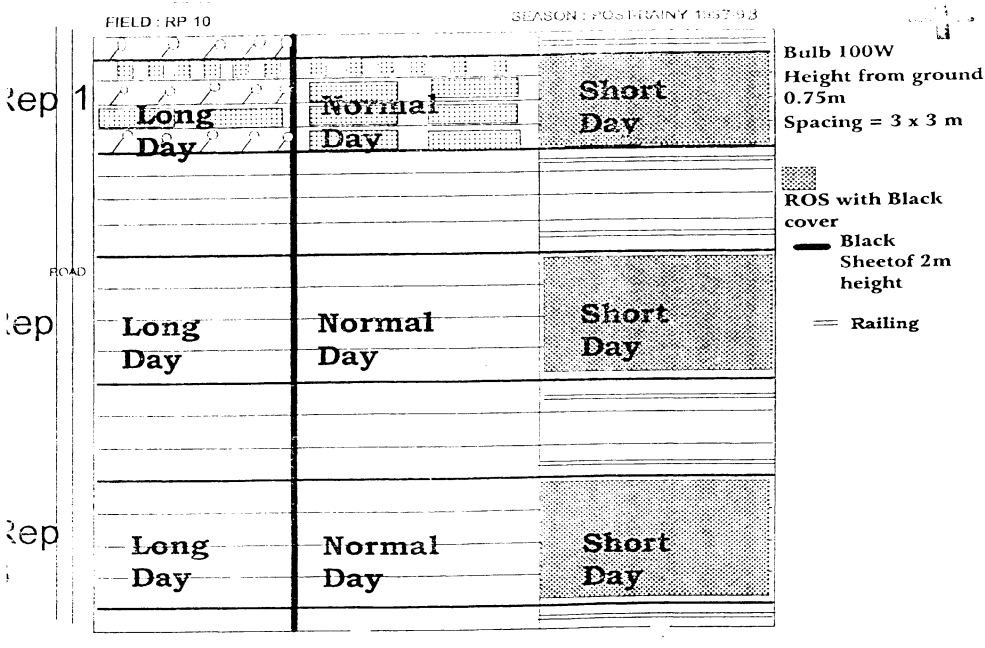
Soil texture	Percentage
Sand	73
Silt	8 4
Clay	18 6
Classification	Lithic Rhodustalf

Table:1b Chemical Analysis of soil

Soil character	Value
Soil reaction pH	5 9
Electrical conductivity(dsm^{-1})	0 18
Organic carbon(%)	0 99
Available nitrogen($kg\ ha^{-1}$)	180 16
Available phosphorus($kg\ ha^{-1}$)	15 75
Available potassium($Kg\ ha^{-1}$)	526 61

Tabe : 1 **Characteristics of genotypes used in the study**

Genotypes	Taxonomic grouping	Origin	Branching pattern	Release status	Duration
ICGMS 42	*Arachis hypogaea* subsp *hypogaea*	ICRISAT,India	Sequential	Released, 1990	100-110
ICGV 86564	Spanish bunch	ICRISAT,India	Sequential	Released	100-110
ICGV 86031	Spanish bunch	ICRISAT,India	Sequential	Released in 1982	105-110
ICGV 86015	Spanish bunch	ICRISAT,India	Sequential	It is under consideration for release as BARD 92 in Pakistan and Hung-Loc 25(HL 25) in Vietnam	100-105
ICGV 87128	Might be spanish	ICRISAT,India	Sequential	Released	120
ICGV 88438	Spanish bunch	ICRISAT,India	Sequential	Released	100-110
NC Ac 17090	*Arachis hypogaea* sub.*fastigata* var. *fastigata*	Peru	Sequential	Under consideration for release	100-110
TAG 24	Spanish bunch	BARC,Bomabay	Sequential	Released by BARC, Trombay	100-105
TMV 2	*Arachis hypogaea* sub.fastigata var. vulgaris	India	Sequential	Released	100-110


FIELD : RP 10
SEASON : POST RAINY 1997-98
Rep 1
Long Day
Normal Day
Short Day
ROAD
Rep
Long Day
Normal Day
Short Day
Rep
Long Day
Normal Day
Short Day
Bulb 100W
Height from ground 0.75m
Spacing = 3 x 3 m
ROS with Black cover
Black Sheetof 2m height
Railing

3.2 Crop management: Experimental block was disc- ploughed to attain a fine tilth and a basal dose of 100 kg ha^{-1} Di Ammonium Phosphate (DAP) (18 % N and 20 % P) was incorporated into the top soil at the time of land preparation. The field was prepared into broad beds of 1.5-m width with furrows of 30 cm on either side of the bed. Sowing of the experiment was done on 5th Dec. 199. Before sowing the seeds were treated with Thiram and Captan @ 3 g Kg^{-1} of seeds to prevent seedling diseases. A seed rate of 110 Kg $ha^{-1}$was used and the seeds were hand sown in furrows opened at 30 cm interval on the broad beds, with a seed to seed distance of 10 cm within the a row. After sowing, the field was uniformly irrigated to field capacity using sprinklers to ensure sufficient soil moisture for seed germination and crop establishment. Plants were thinned at 20 -25 days after sowing (DAS) to achieve a plant population of 33plants m^2. The crop was maintained pest and disease free by following all prophylactic measurements. There was a severe problem of pest especially *Spodoptera litura* during 52 DAS to 78 DAS in the growing season. Despite of intensive pest control measures, there was considerable damage in some plots by *Spodoptera litura*. However except this pest attack, there was no major problem to crop growth. Gypsum was applied @ 250 - 500 Kg ha^{-1} during pegging at DAS to favour pod filling.

3.3 Treatments

As described earlier, the three photoperiod (short day, normal day and long day) treatments consisted the main and nine genotypes as sub-treatments. Size of the sub-treatments (genotypes) was 6 m^{-2} (4m x 1.5 m).

3.3.1 Imposition of photoperiod treatments:

The photoperiod treatments were imposed from 03 DAS to final harvest. The day length in short and long day treatments was adjusted depending on the normal day length

Including civil twilight at dawn and dusk. The detailed time schedule of day length treatment imposition during the growing season is furnished in the Table -2

The information about the daily sunrise and sunset times were collected from meteorological observatory situated at 1 km distance within a radius of 1 km from the experimental site. The timings of short day and long day were adjusted for a period of 15 days as shown in Table-2 and in Fig-2

3.3.1.1 Short day: The short day of 8-hr photoperiod was achieved by using portable rainout shelter (Chauhan *et al.*, 1997). The rain out shelters (ROS) were originally designed and fabricated at ICRISAT centre as a tool to conduct drought experiments in the field. However, the ROS were used in the present investigation to impose short day by covering the ROS with black cloth to prevent entry of sun light on the experimental plots. The ROS covered an area of 7.2x15m. ROS were operated in such a manner (as presented in Table-2) to achieve a day length of 8 hr during experimental period. ROS was pushed over the experimental plots. . After 15 minutes, the side curtains were pulled down and tied, so that 100% darkness was achieved under shelter. Similarly while removing ROS, first the curtains were lifted up and left as such for 15 minutes after which the ROS were pushed back to their parking place (Plate-1).

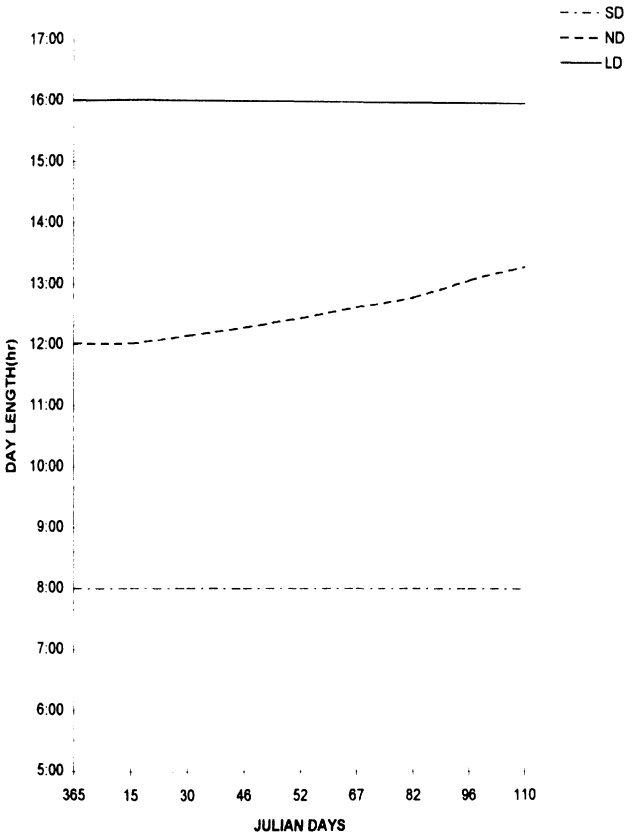


Fig : 2 PHOTOPERIOD AT HYDERABAD(18^0 N Lat)

1:Short day (SD) photoperiod imposition in groundnut (Black out shelters over SD plots).

Table :2 Day length for different photoperiod treatments

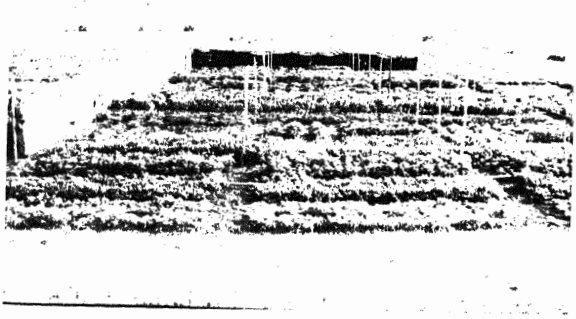
	Short day		Normal day		Long day	
	Operating time of ROS				Time of artificial lighting	
Calendar date	Closing time	Opening time	Sun rise	Sun set	on	off
1.Dec15-Dec31	16:30h	8:00h	06:06h	18:16h	18:16h	22:16h
2. Jan01-Jan15	16:30h	8:00h	06:10h	18:20h	18:20h	22:16h
3. Jan16-Jan30	16:30h	8:00h	06:16h	18:25h	18:25h	22:16h
4. Jan31-Feb14	16:30h	8:00h	06:14h	18:31h	18:31h	22:14h
5. Feb15-Mar01	16:30h	8:00h	06:09h	18:36h	18:36h	22:09h
6. Mar02-Mar16	16:30h	8:00h	06::00h	18:38h	18:38h	22:00h
7. Mar17-Mar31	16:30h	8:00h	05:51h	18:39h	18:39h	21:51h
8. Apr01-Apr15	16:30h	8:00h	05:41h	18:46h	18:46h	21:41h
9. Apr16-Apr30	16:30h	8:00h	05:35h	18:54h	18:54h	21:35h

3.3.1.2 Normal day:

Normal day treatment consist of exposing the genotypes to natural day length prevailed during the season. The timing of sunrise and sunset during the season are presented in the Table-2

3.3.1.3 Long day:

Long day treatment of 16 hr was imposed by providing artificial light (for appropriate time) following the sun set to stimulate extension of civic light affect. The long day treatment was imposed from 03 DAS to final harvest. The artificial illumination was supplied by 40 W incandescent tungsten filament lamps arranged in grid over the field at a spacing of 3 x 3 m. All plants under the lamps were exposed to artificial light of about 60 Lux incident at canopy level (Marie-Lusie flohr; 1990). These bulbs were attached to an automatic timer, which was programmed to switch on and off at specified time as detailed in Table-2. Before the commencement of the long day treatment a black curtain was raised to a height of 6 feet to protect neighbouring treatments from artificial lightening (Plate-2).



2: Long day (LD) photperiod imposition in groundnut (Taken before sunset).

3.4 OBSERVATIONS AND MEASUREMENTS

3.4.1 Non-destructive measurements

3.4.1.1 **Emergence:** Number of seedlings emerged in each plot was recorded at 2 or 3 day interval the days starting form date of first irrigation after sowing. The time taken for 50% of the seedling to emerge in each plot was determined, starting from date of first irrigation after sowing.

3.4.1.2 **Date to first flower:** In each plot, the date on which 1st flower appeared was noted and recorded, taken as date to first flower appearance for that genotype.

3.4.1.3 **50% flowering:** Date on which 50% of the plants in each plot flowered was recorded as date to 50% flowering.

3.4.1.4 **Rate of flowering:** Five plants in each plot were randomly selected and tagged to make flower counts on daily basis. In total 405 plants were tagged and fresh flowers that appearance was recorded at 10AM daily. Until flowering ceased.

3.4.1.5 **Gas exchange measurements:** The measurements of gas exchange were made at 20 days interval starting from 40 DAS until 100 DAS, during 11:00 to 13:00hrs, using a LCA4 (Leaf chamber analyser-4, Halmagroup company, England) were taken on third or fourth leaf from the main shoot apex. In each plot five plants were sampled and in each plant, 3rd and 4th leaf from the apex of main axis were used to make the gas exchange measurements. Before making the measurement, the instrument was stabilised for a while and programmed to log required parameters in specific datafile. After the measurements, the data is down loaded into computer for further analysis. The leaf chamber consisted of 6.25 cm^2 area, on which photosynthetic rate was measured. For measuring the gas

exchange parameter, the leaf chamber was clamped on to the sampled leaf with solar radiation sensor facing perpendicular to the sunrays. The difference of incoming and outgoing CO_2 gas from the leaf chamber was monitored in the LCD display. When the differential reached a stable value the record button was pressed to record various physiological parameters i.e. photosynthesis, and leaf surface temperatures.

3.5 LIGHT INTERCEPTION

Fractional light intercepted (LI) by the canopy was measured at mid-day by using a Accupar (Degagon instruments Washington, USA) at 20, 40, 60, 80, 100 DAS. The Accupar consisted of a line quantum sensor of one-meter length attached to a data logger. The Accupar readings were recorded by placing the sensor above the canopy (I_0) to record the incident solar radiation and the radiation below the canopy at the ground level (I_1). For recording the I_1, the Accupar was below the canopy across rows at the ground level. The fractional radiation intercepted (LI) by the canopy at a given time was calculated using the following equation.

$$LI\ (\%) = [(I_0 - I_1) / I_0] \times 100$$

Where,

I_0 is total incoming radiation (measured above the canopy)

I_1 is remaining radiation that reached at the ground level, after being intercepted by the canopy (measured below the canopy at ground level).

3.6 DESTRUCTIVE MEASUREMENTS

3.6.1 GROWTH ANALYSIS

Plants were harvested from a ground area of 0.6 m^2 [1.2-m (4rows)-x 0.5 m (length)] from each plot starting at 40 DAS and at every 20-day interval. After harvest, roots were separated

and discarded. Plants were washed to remove soil particles, and a sub-sumaple of three plants was picked at random for detailed analysis for growth components. The rest of the plants were treated as a bulk sample.

The scheme for growth analysis is shown in fig-3.

As shown in the scheme, in the bulk sample plants, were dissected into leaves, stems immature and mature pods. These components were oven-dried at 80^0C for 48h before recording their weights. The immature and mature pods were shelled, kernel numbers and weights were determined after oven drying.

3.6.2 Sub-sample measurements:

Sub-sample plants were separated into leaves, stems, roots and reproductive structures and roots were discarded. The main stem length and number of branches were recorded. From the leaves, a grab sample was taken for leaf area measurement. The leaf area was measured using a LI-3100 automatic leaf area meter (LI-COR, Inc., Lincoln, NE). Total leaf area was calculated as the product of the leaf area /dry weight ratio of the leaf sub-sample and the total leaf weight (subsumable leaf weight plus bulk sample leaf weight). The leaf area index (LAI) was calculated as the ratio of the total leaf area to the ground area ($0.6 m^{-2}$). Reproductive parts were divided into aerial pegs, sub-terranean pegs, juvenile pods, immature pods and mature pods as described by Williams *et al.* (1975). The numbers in each class were counted and weights recorded after oven drying. The pods were shelled and the kernel weights were determined. The pod weights were adjusted for higher energy content by multiplying a coefficient of 1.65 as suggested by Duncan *et al.* (1978).

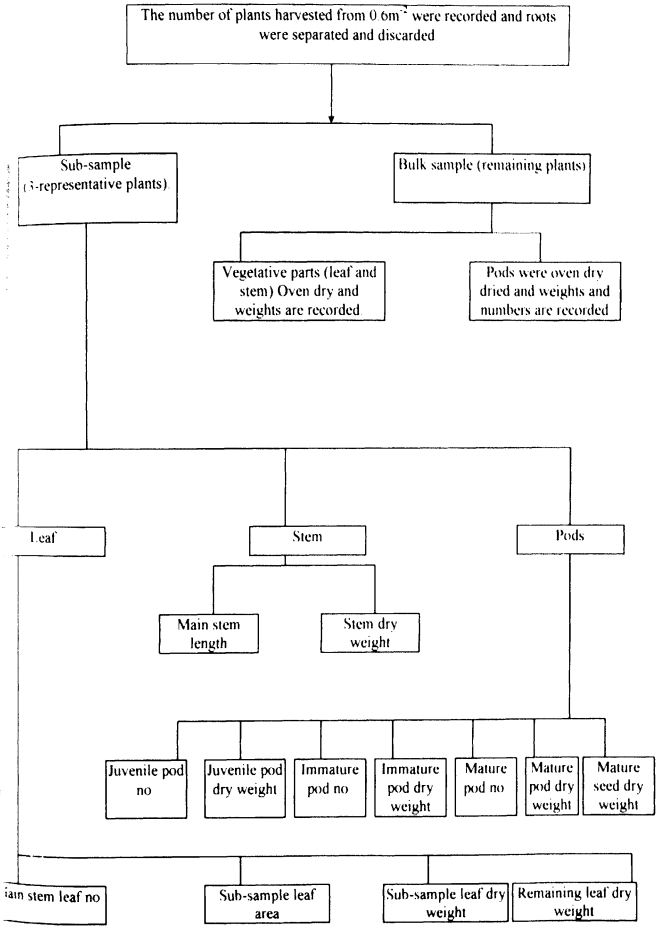


Fig: 3 Scheme for growth analysis

3.7 Computation of components of crop Growth rates and development:

1. Specific leaf area (SLA) = Sub -sample leaf area/sub sample leaf dry weight
2. Total leaf weight = Sub sample leaf dry weight +remaining leaf dry weight +bulk leaf dry weight
3. Total leaf area = Total leaf dry weight x SLA
4. Leaf area index (LAI) = Total leaf area /LF where, LF is ground area harvested (0 $6m^2$)
5. Total stem weight m^{-2} = 3-plant stem dry weight + bulk stem dry weight/(LF)
6. Total pod weight m^{-2} = 3-plant juvenile pod dry weight +3-plant Imature pod dry weight +3-plant mature pod dry weight + bulk pod dry weight/LF
7. Total seed weight m^{-2} =3-plant Imature seed dry eight +3-plant mature seed dry weight + bulk seed dry weight/ LF
8. Total Vegetative weight m^{-2} = Total stem dry weight m^{-2} + Total leaf dry weight m

9. Adjusted biomass = Total vegetative weight m^{-2} + (Total pd weight m^{-2}x1 65)
10. Aerial peg no m^{-2} = Total plant number x (3plants total aerial peg number /3)/LF
11. Subterranean peg no. m^{-2} = Total plant no. x (3plants Total Subterranean peg no /3)/LF
12. Juvenile pod no. m^{-2}= Total plant no. x (3plants Total Juvenile peg no /3)/LF
13. Juvenile pod weight m^{-2} = Total plant no. x (3plants Total juvenile pod peg no /3)/LF
14. Immature pod no. m^{-2} = Total plant no. x (3plants Total Immature pod no /3)/LF
15. Immature pod weight m^{-2} = Total plant no. x (3plants Total Immature pod weight no /3)/LF
16. Mature pod no. m^{-2} = Total plant no. x (3plants Total Mature pod no /3)/LF

17. Mature pod weight m-2 = Total plant no. x (3plants Total Mature pod weight no. /3)/LF

18. Total reproductive structure no. = Aerial peg no. m^{-2} + subterranean peg no. m^{-2} + juvenile pod no. m^{-2} + Immature pod no. m^{-2}+Mature pod no. m^{-2}

19. Sub-terranean peg ratio = subterranean peg no. m^{-2} +Juvenile pod no. m^{-2} +Immature pod no. m^{-2}+Mature pod no. m^{-2}/ (Total Reproductive structure no.)

20. Mature pod ratio = Mature pod no./(Juvenile pod no. m^{-2} + Immature pod no. m^{-2}+Mature pod no. m^{-2})

21. Peg to pod ratio = Mature pod no./(Total Reproductive structure no.)

3.7.1 Computation of growth rates:

Growth rates were computed by regressing a given growth parameter against the DAS from the sequential growth analysis data. The slope of regression indicated the rate of growth of the given variable per day. The 'X' and 'Y' coefficients used in computation of growth rates using regression analysis is given in the Table 4

Table : 3 Cumulative thermal time on ten day interval.

Year	Month	Date	Max	Mi	DA.E	Tht	Cthtime
1997	12	8	27.8	19	0	13	0
1997	12	18	25.4	20	10	13	121.5
1997	12	28	30.1	18	20	14	256.85
1998	1	7	27.6	12	30	9.9	371.7
1998	1	17	32.8	15	40	14	485.85
1998	1	27	30.2	19	50	15	624.35
1998	2	6	31.4	18	60	15	770.25
1998	2	16	32.4	18	70	15	900.35
1998	2	26	34.8	19	80	17	1048.7
1998	3	8	33.9	17	90	15	1215.6
1998	3	18	34.6	17	100	16	1386.7
1998	3	28	35.2	21	110	18	1569
1998	4	7	38.1	23	120	20	1762.5
1998	4	17	37.6	25	130	21	1974.6

Courtesy- ICRISAT meteorological data.

Table :4 Regression components used in computation of crop growth or developmental rates

Growth rate	Y	X
Crop growth rate(g m^{-2} day)	Adjusted biomass wt. m^{-2}	DAS
Pod growth rate (g m^{-2} day)	Total Pod wt. m^{-2}	DAS
VGR(g m^{-2} day)	Vegetative wt. m^{-2}	DAS
Peg addition rates (g m^{-2} day)	Total Reproductive structure m^{-2}	DAS
seed growth rate(g m^{-2} day)	Seed wt. m^{-2}	DAS

3.7.2 Computation of thermal time:

The thermal time is calculated as,

Thermal time = (Maximum temperature + Minimum temperature)/2 - T_b

Where, T_b is the base temperature below which germination process is inhibited T_b was taken as 10^0C (Ahmed *et al.*, 1984). The thermal time accumulated during the growing season is presented in the Table: 3

The growth rate per unit thermal time was computed by replacing "DAS" in Table: 3 with cumulative thermal time at respective DAS

Observation at final harvest:

At final harvest a net plot area of 1.5 m X 1.5 m was harvested. The roots were separated and discarded. After picking of the pods, the shoots and pods were oven dried at 80 ^{0} C before recording of the dry weights. The total dry matter (TDM) was computed after adjusting the pod weights for the high-energy content using a factor of 1.65. The TDM was calculated as follows

TDM = Shoot weight + (Pod weight X 1.65)

TDM was expressed per hectare basis.

3.8 Statistical Analysis

Experimental data were subjected to analysis of variance using a standard split-plot design analysis as described by Gomez and Gomez (1984) and using the GENSTAT Package (Genstat manual, 1983) in a VAX mainframe Computer system at ICRISAT Centre

SEPARATION OF PROTEINS ON SODIUM DODECYL SULPHATE (SDS) - POLY ACRYLAMIDE GEL ELECTROPHORESIS (PAGE)

Known weight of tissue was sampled and frozen in liquid nitrogen. The tissue was ground in 1:4 (tissue weight: buffer volume) extraction buffer, and the extract was centrifuged at 5,000 rpm for 20 min at 4° C, and 100 µl of supernatant was used for protein analysis

Reagents used in the extraction buffer were Tris buffer 8.0 pH (Tris 50 mM, EDTA 2 mM, 2- mercaptoethanol 5 mM, PMSF 1 mM, PVPP - 0.5%)

3.9 Protein was quantified by using the method as described by Lowry *et al* (1951)

Reagent A: 20g sodium carbonate and 4g of sodium hydroxide are dissolved in distilled water by stirring and then 0.2g of sodium-potassium tartarate is added and the volume is made upto 1 litre.

Reagent B: 0.5g $CUSO_4$ $5H_2O$ is dissolved in 100ml of distilled water

Reagent C: 50ml of reagent A and 1ml of reagent B are prepared fresh before use

Folin's reagent: Diluted to 1N before use

3.9.1 Procedure:

Protein solution (0.1ml) was taken and the volume was made upto 1ml with distilled water and thoroughly mixed with 5ml of Lowry's reagent. After 10 minutes 0.5ml of the Folin's reagent was added and shaked immediately with the vortex mixer. After 30 minutes absorbance reading was measured at 630 nm. Blank is also run.

Standard curve of protein was developed using a range of concentrations of using Bovine Serum albumin (BSA).

The proteins were concentrated by trichloro- acetic acid (TCA) precipitation. Known volume of the extract was taken in a centrifuge tube, TCA (100%) was added equal to 1/10 volume of extract and kept on ice for 1 hr., centrifuged at 12,000 rpm for 10 minutes, supernatant was then discarded and chilled acetone was added and centrifuged again at 12,000 rpm for 10 min and acetone is decanted the traces of acetone were removed by drying.

Sample containing 100 µl of total protein was dissolved in sample buffer containing 50 mM Tris - Hcl (pH 6.8), 1-% (v/v) SDS, 2% (v/v) 2- mercaptoethanol, 12.5% Glycerol and 0.05% stacking dye. The protein samples were denatured in boiling water for 4 min. After cooling, 100µg of protein is used for loading into the wells.

Gels containing 12. 5 % resolving gel and 3 % Stacking gel were prepared from acrylamide stock containing bis. The Composition of 30 ml resolving gel was 12.5 ml of 30 % Acrylamide with bis, 0.3 ml of 10 % SDS, 7.5 ml of 1.5 M Tris HCl buffer (P^H 8.8), 9.6 ml of water, 0.1 ml of 10 % Ammonium Per Sulphate. The contents were degassed for 2 min. The gels were chemically polymerised by the addition of 0.025 % TEMED by volume. The mixture was poured in gel moulds overlaid with water and was left undisturbed for an hour to get satisfactory polymerisation. The stacking gel contained 1.67 ml of stock Acrylamide (30 %) with Bis, 1.25 ml 0.5 M Tris Hcl Buffer (P^H 6.8), 0.1 ml of 10 % SDS, 0.05 ml of 10 % Ammonium per sulphate and 6.9 ml of water. The gel was exactly polymerised like resolving gel after the addition of 0.025 % of TEMED. The combs were inserted on top of the resolving gel after removing the layer of water. Stacking gel was poured over resolving gel and left undisturbed for about half an hour. Then combs were removed and sample was applied into the wells along with a standard mixture. Electrophoresis was carried out using LKB 2001 Vertical unit for 2 X 1.5-mm gels at a constant current of 60 milliamperes, until

the bromophenol blue marker reached the bottom of the gel (approximately 5 hr). Gels were removed and fixed in 10% Acetic acid for 10 - 15 min. and stained overnight with 1 % Coomassie Brilliant blue dye and destained by repeated washing with 7 % Acetic acid in 50 % Methanol. The gels were scored and the differences in protein banding patterns were noted.

^{14}C TRANSLOCATION STUDIES

Influence of photoperiod on the current translocation of photosynthates to various plant parts was investigated in four selected genotypes (ICGMS 42, NC Ac 17090, ICGV 87128 and TMV 2) during the pod filling phase. The ^{14}C studies consist of four major steps. I e.

3.10 Generation of $^{14}CO_2$ gas in the laboratory.

3.10.1 $^{14}CO_2$ feeding in the field.

3.10.2 Processing of plant material for ^{14}C counting.

3.10.3 ^{14}C counting using liquid scintillation counter.

3.10 Generation of ^{14}C gas:

In the laboratory, 2N Hcl was taken in a 'U' tube and another end was closed with a rubber stopper .1ml of radio active Sodium bicarbonate with radio activity 100µCi was injected into the U-tube containing 2N Hcl , to yield 10 ml of $^{14}Co_2$ gas The gas was sucked into a syringe by inserting the needle through the rubber stopper. After suction, the tip of the needle was tightly closed with rubber stopper to avoid gas leakage The syringe was taken into the field for ^{14}C feeding.

3.10.1 ^{14}C feeding in the field:

^{14}C-labelling of plants was carried out as described by Kumarasinghe (1990) and Mahalakshmi, Sivaramakrishnan and Bidinger (1993) but with some modifications All precautions were taken to avoid radioactive contamination The $^{14}CO_2$ feeding was done when crop was 71-day old (during pod filling phase), with Four randomly selected plants in one replication. Thus there were a total of 48 (4 genotypes x 4 plants x 3 treatments),

for ^{14}C translocation studies. The ^{14}C feeding was done during 10:00 to 12:00 hr when there was full sunshine.

Plastic petriplates (70mm diameter) were used as ^{14}C chamber to accommodate single leaves (with four leaflets). About 1 mm constriction was made in the edges of upper and lower corners of the petriplates to position petiole so that, leaf (with 4-leaf lets) can be accommodated in the petriplate. On the upper cover of the petriplate a perforation of 1-cm diameter was made and sealed with rubber stopper. The fully expanded and undamaged third leaf or fourth leaf from the apex of the main stem was selected for ^{14}C feeding. The sampled leaf was held in petriplate as shown in the plate no-

The leaf was carefully placed in petriplate with petiole Passing through constriction made in the edges of the petriplate. The upper lid was closed and the borders were sealed with a parafilm. One ml of radioactive $^{14}CO_2$ gas was injected through the rubber stopper on the upper lid of the petriplate. After 1 ½ minutes, the leaf was freed and petriplate was opened to release the residual $14CO_2$. Radioactivity was checked with Greiger-Muller open widow radioactivity counter. The fed leaf was tagged.

3.10.2 Processing of plant material:

After 48 hours of feeding, the plants were harvested and washed in glass houses specially meant for handling radiocative plant material. The plants were separated into fed leaf, remaining leaf, stem, aerial pegs, sub-terranean pegs, immature pods and roots. The dry weights of all parts and leaf area of fed leaf was taken in RadioIsotope Laboratory ICRISAT, oven dried and stored until further analysis.

The dried plant material was ground to pass a 20-mesh screen. The sample grinding was done in a mechanical grinder and after each sample the grinder was thoroughly with

vacuum cleaner. Face mask, apron and gloves were always worn while handling the radioactive material. A known weight of tissue 50mg for fed leaf and 100mg for other parts are taken in ceramic boats for biological oxidation followed by counting using scintillation counter.

Before going for oxidation followed by counting, following materials is kept ready-

3.10.2.1 Cocktail solution.

3.10.2.2 Biological oxidiser (R J Harvey, USA)

3.10.3.1 Liquid scintillation counter (BECKMAN, LS-6500)

3.10.2.1 COCKTAIL SOLUTION:

It was prepared in the following ratio;

a. Carbosorb-1litre.

b. Toulene - 2 litres.

c. PPO(2,5-diphenyloxazole)- 8gm

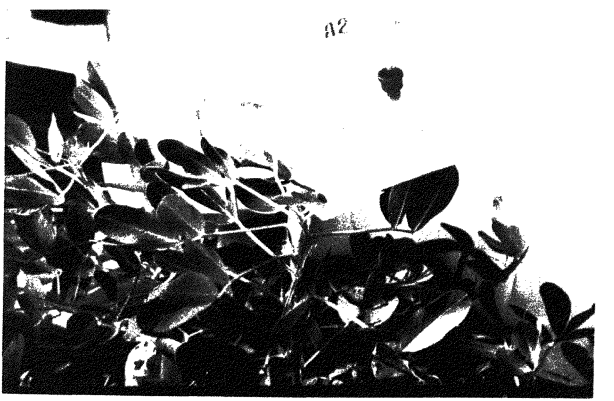
d. POPOP(1,4-bis2-(5-phenyloxazole)-benzene-1gm

To one 1litre of Carbosorb, PPO and POPOP were added slowly stirring it on magnetic stirrer. After dissolving the PPO AND POPOP, 2 litres of Toulene was added AND the cocktail was stored in a brown coloured bottle at -20^0C. The whole operation was done under fumehood chamber and following all necessary protocols

3.10.2.2 Biological oxidiser:

Following steps were followed for biological oxidation of the material.

a. The oxidiser was programmed for 2-minutes to enable the combustion of the plant sample.



3: ^{14}C feeding using $^{14}CO_2$ in greenhouse.

b. The oxygen and nitrogen gas flow into the biological oxidiser was fixed at 300cc/min.

c. The temperature of catalyst zone kept in such a manner that did not exceed 680^0C and that of combustion zone 900^0C

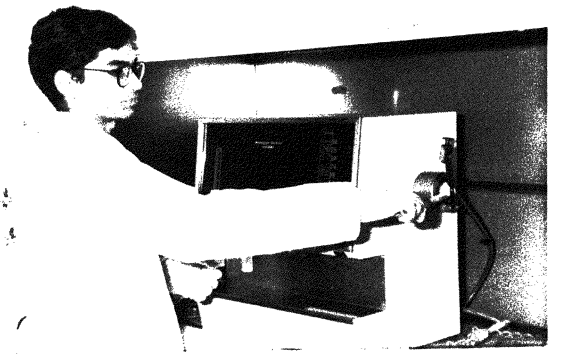
d. The cocktail suction should be of 15ml.

Fifty-mg mannitol as standard and 50mg of mannitol plus known quantity of radioactive standard was taken in ceramic boats. After setting up the biological oxidiser, the mannitols and the radioactive samples were inserted into oxidising chamber using ladle; of glass ladle, after combustion the samples were added to the vial containing cocktail which absorbed radioactive carbon. As mentioned earlier, in case plant samples, 50 mg of fed leaf and 100 mg of other plant parts were taken for oxidation process (Biological Oxidiser shown in Plate-3).

3.10.3 ^{14}C counting using liquid scintillation counter.

3.10.3.1 Liquid scintillation counter:

BECKMAN, LS-6500 liquid scintillation counter was used to count the ^{14}C disintegration in the sample by using the mannitols plus sample with known radioactivity (Plate-4). The efficiency of counting was found to be more than 98%. Than mannitol counts were used as background counts. The scintillation counter was programmed to automatically deduct the background counts while counting the radioactive plant samples and report radioactivity obtained in DPM (Disintegrations per minute). Total radioactivity in each plant part was calculated using the sample dry weight and the organ dry weight. The distribution of



4: Biological oxidiser (RJ Harvey, USA)

radioactivity among different parts at various harvests was expressed as percent of the total radioactivity recovered recorded in the plant.

CHAPTER IV
Results

During the post rainy season of 1997-98, field experiment was conducted to investigate the genotype variation in sensitivity of 9-selected groundnut genotype to photoperiod. As described in Material and Methods chapter three photoperiod regimes were imposed, i.e. short day (SD), normal day (ND), long day (LD) the details of the photoperiod regimes and details of methodologies followed to impose this treatment is explained in detail in material and methods.

The summary of climate prevailed during growing season (Dec-97-April-98) is as follows- the mean maximum temperatures ranged from 25.2 to 41.8 ^{0}C while mean temperatures 19.1to 32.45 ^{0}C . The solar radiation ranged from 6.4 to 25.5 MJ m^{-2} d^{-1} There was a gradual increase in mean temperatures from sowing time (23.4 ^{0}C'd) to final harvest (29.3 ^{0}C'd), which also resulted in open pan evaporation from 4.5 mm d^{-1} (Dec-97) to 10.5 mm d^{-1} (April-98) In general there was no rainfall during the growing season except for three events of rain at 25.4 mm (01 DAS), 2.5 mm (10DAS) and 29.6 mm (166DAS). The effect of photoperiod on crop growth and development is presented in the following major headings,

4.1 Crop phenology.

4.2 Crop growth rates and partitioning.

4.3 Reproductive development.

4.4 Physiological parameters such as light interception and photosynthesis and translocation of current photosynthates (measured by using $^{14}Co_2$).

4.5 Protein profiles (apical meristem)

4.1 Effect of photoperiod on crop phenology:

4.1.1 Emergence:

As, presented in Table-5, in all the genotypes 50% of the plants in all the plots emerged by 7 to 8 days after first irrigation. Photoperiod did not influence the days to 50% emergence. TAG 24,NC Ac 17090 emerged one day earlier (7days) while rest of the genotypes showed 50% emergence by 8th day. The thermal time for emergence ranged from 82 to 104 ^{0}Cd(Table-5). The Photoperiods did not influence thermal time to emergence however, genotypic variation in the thermal time for emergence was significant at any given level of photoperiod. For example genotypes (TAG 24,NC Ac 17090) showing short thermal for emergence time 82-86^{0}Cd compared to most of the genotypes which had relatively longer thermal time for emergence (95-109^{0}Cd).

4.1.2 Flowering: The days to first flower appearance ranged from 30 to 42 DAS (Table-5). There was no significant effect of photoperiod on first flower appearance. In all the 3-main treatments first flower appearances noted at 37 or 38 days. However the genotypic difference was significant with TAG 24 and NC Ac17090 being the earliest in the first flower appearance while in rest of the genotypes the first flower appearance was delayed by 3 to 10 days. Thermal time for first flower appearance ranged from 398^{0}Cd to 508^{0}Cd . Photoperiod treatment did not influence thermal time to first flower appearance. However, genotypic differences were significant for e g TAG 24. First flower appearance in TAG 24 occurred at about 380 to 390 ^{0}Cd. While, ICGV 86564, ICGV 88438 recorded longest thermal requirement for flower initiation ranging from 480 to 500 ^{0}Cd.

Table: 5 Days to emergence(DEM),flower initiation(FI) and 50% flowering(50%F) under Short day(SD), Normal day(ND), Long day(LD) photoperiod conditions in groundnut.

Genotype	DEM				FI				50%F			
	SD	ND	LD	Mean	SD	ND	LD	Mean	SD	ND	LD	Mean
ICGV 88438	8	8	9	8	40	41	41	40	43	43	43	43
ICGV 87128	8	8	8	8	36	38	38	38	42	42	43	42
ICGV 86015	8	8	8	8	36	36	38	37	42	42	42	42
ICGMS 42	8	8	8	8	39	40	42	40	44	44	44	44
TMV 2	8	8	8	8	37	38	38	38	42	42	43	42
ICGV 86031	8	8	8	8	37	37	38	37	42	42	42	42
ICGV 86564	8	8	8	8	41	40	42	41	45	44	44	44
TAG 24	7	7	7	7	33	30	30	31	38	41	41	40
NC Ac 17090	7	7	7	7	36	36	36	36	41	42	42	42
Mean	8	8	8		37	37	38		42	42	43	
SEM(±)	0.1				0.3				0.2			
CV%	5.4				3				3.3			

Analysis of variance				
Source of variation	df	DEM	FI	50%F
MT(Photoperiods)	2	NS	NS	NS
ST(Genotypes)	8	**	**	**
MTXST	16	NS	NS	NS

* significant at P=0.05

** significant at P=0.01

4.1.3 Days to 50% flowering:

Days to flowering of 50% of the plants flowered ranged from 40 to 44 days amongst genotypes with TAG 24 showing earlier flowering (40DAS), where as for rest of the genotypes 50% flowering occurred during 42-44 DAS (Table-5). The photoperiod treatment did not have significant influence in time to 50% flowering.

Thermal time for 50% flowering ranged from 460 to 540 ^{0}Cd(Table-6). The mean thermal time upto 50% flowers ranged from 516 to 522 ^{0}Cd amongst the three photoperiod treatment suggested lack of influence of photoperiod on thermal time to flowering. However genotypes varied significantly in the thermal time to required flowering, with TAG 24 having 494 ^{0}cd compared to 544 ^{0}Cd in ICGMS 42.

4.1.4 Flower addition rate:

The rate of flower addition was calculated on thermal time basis by regressing the cumulative flowers with thermal time. The results have shown that the total number of flowers produced per plant ranged from 35 to 95 representing a significant variation among genotypes (Table-7). The time by which the flowering ceased was also varied significantly among genotypes. Genotypes showing inhibition of flowering by thermal time (Table-7). It was quite clear that cumulative flowering across the photoperiod treatments showed a steady increase, but in short day the cessation was quicker followed by normal day (ND) and long day (LD). Similarly, the fresh flower appearance on daily basis showed that SD showing higher peaks quite early as compared to ND and LD. For NC Ac 17090 there is distinct pattern of cumulative flowering among the treatments in short day followed by ND and LD. But the fresh flower

Table:6 Thermal time to days to emergence(DEM),flower initiation(FI) and 50% flowering(50%F) under Short day(SD), Normal day(ND), Long day(LD) photoperiod conditions in groundnut.

Genotype	DEM				FI				50%F			
	SD	ND	LD	Mean	SD	ND	LD	Mean	SD	ND	LD	Mean
ICGV 88438	100.07	100.07	104.53	**101.56**	481	495	495	**490**	531.1	522.1	531.1	**528.1**
ICGV 87128	95.6	95.6	91.28	**94.16**	437	458	463	**453**	512.8	517.5	522.1	**517.5**
ICGV 86015	95.6	95.6	95.6	**95.6**	437	437	454	**443**	512.8	512.8	517.5	**514.4**
ICGMS 42	95.75	100.07	109	**101.61**	476	481	508	**489**	547.7	539.4	543.8	**543.6**
TMV 2	100.07	95.6	95.6	**97.09**	441	458	458	**453**	512.8	517.5	522.1	**517.5**
ICGV 86031	100.07	95.6	95.6	**97.09**	441	449	454	**448**	512.8	512.8	512.8	**512.8**
ICGV 86564	100.07	100.07	95.6	**98.58**	499	481	508	**496**	547.7	539.8	543.8	**543.8**
TAG 24	82.65	82.65	82.93	**82.74**	398	375	375	**764**	459.6	494.6	494.4	**482.9**
NC Ac 17090	86.97	82.65	86.97	**85.53**	429	429	429	**429**	503.6	512.8	512.8	**509.8**
Mean	**95.2**	**94.21**	**95.23**		**449**	**451**	**460**		**515.7**	**518.8**	**522.3**	
SEM(±)	**0.765**				**8.59**				**2.11**			
CV%	**6.1**				**3.2**				**3.4**			

Analysis of variance				
Source of variation	df	DEM	FI	50%F
MT(Photoperiods)	2	NS	NS	NS
ST(Genotypes)	8	**	**	**
MTXST	16	NS	NS	NS

* significant at P=0.05

* * significant at P=0.01

Table : 7 Total flowers(Tflow) produced by genotypes under short day(SD),normal day(ND),long day(LD) photoperiod conditions.Values in parantheses indicate Days after sowing at which flowering ceased(NDAS) in groundnut.

Genotype	SD	ND	LD	Mean
ICGV 88438	62(103)	64(116)	69(123)	**65(114)**
ICGV 87128	50(66)	88(107)	74(108)	**71(94)**
ICGV 86015	39(62)	73(107)	67(106)	**59(92)**
ICGMS 42	57(92)	74(116)	76(121)	**69(109)**
TMV 2	51(77)	72(104)	67(106)	**63(96)**
ICGV 86031	40(80)	80(115)	76(121)	**66(105)**
ICGV 86564	52(106)	63(120)	61(121)	**59(116)**
TAG 24	35(71)	43(95)	38(70)	**38(79)**
NC Ac 17090	40(80)	73(113)	95(114)	**69(103)**
Mean	**47(82)**	**70(110)**	**69(110)**	
SEM(±)		**1(1)**		
CV%		**15.6(7.1)**		

Analysis of variance		
Source of variation	**d.f**	**Tflow(NDAS)**
MT (Photoperiods)	2	**(**)
ST (Genotypes)	8	**(**)
MT x ST	16	**(**)

* significant at P =0.05

* * significant at P =0.01

appearance was quite consistent with similar peaks at same days after sowing was seen in TMV 2, TAG 24, ICGV 86031, ICGV 87128, ICGV 86015.

The photoperiod treatment showed effects on rate of flowering addition per unit thermal time (Table-8). In general there was a reduction in the rate of flower addition per thermal time as the length of the photoperiod increased. For example, the mean rate of flower addition in short day is 0.092 $^0Cd^{-1}$, 0.081 $^0Cd^{-1}$ in normal day and 0.072 $^0Cd^{-1}$ in long day. The genotypic variation in the rate of flower addition was also significant with ICGV 86564 having the least rate of flower addition, i.e. 0.061 $^0Cd^{-1}$ compared to 0.119 $^0Cd^{-1}$ in TAG 24. However, the genotypic x photoperiod interaction was also significant but ICGV 86564 showing the least change in the rate of flowering addition (0.061-0.062 $^0Cd^{-1}$,with change in photoperiod). In most of the genotypes there was a reduction in rate of flower addition. Only one genotype NC Ac 17090 showed in the rate of flower addition from short day (0.059 $^0Cd^{-1}$) to long day (0.96 $^0Cd^{-1}$) (Table-8). There was a strong correlation (0.63*) among normal day and short day in the rate of flower addition. However the correlation between normal day and long day, short day and long day were not significant.

The thermal time requirement for production of first 25 flowers was calculated. Since it has been shown in earlier studies that the time to produce 25 flowers was an important indicator of genotypic maturity (Upadhyaya *et al.*, 1994). The present study was shown that the photoperiod had significant effect on thermal time to production of first 25 flowers. It was apparent that the thermal time to produce flowers increased with increase in day length. For e.g. The thermal time to 25 flowers was 740 ^{0}cd in short day, 780 ^{0}Cd in normal day and 842 ^{0}cd in long day. The genotypic variation in thermal time requirement to produce first 25 flowers was

Table : 8 Rate of flower addition (b) per unit thermal time under Shortday(SD), Normalday(ND), Longday(LD) photperiod conditions in groundnut.

Genotype	SD	ND	LD	Mean
ICGV 88438	0.073	0.062	0.066	**0.067**
ICGV 87128	0.142	0.099	0.076	**0.106**
ICGV 86015	0.118	0.071	0.067	**0.085**
ICGMS 42	0.085	0.074	0.072	**0.077**
TMV 2	0.094	0.070	0.067	**0.077**
ICGV 86031	0.073	0.068	0.063	**0.068**
ICGV 86564	0.062	0.062	0.061	**0.061**
TAG 24	0.119	0.159	0.078	**0.119**
NC Ac 17090	0.059	0.061	0.096	**0.072**
Mean	**0.092**	**0.081**	**0.072**	
SEM(±)		**0.0086**		
CV %		**18.2**		

Analysis of variance		
Source of variation	**d.f**	**b**
MT (Photoperiods)	2	*
ST (Genotypes)	8	**
MT x ST	16	**

Correlations	
ND-SD	**0.63**
ND-LD	**0.23**
SD-LD	**0.03**

* significant at P 0.05

* * significant at P 0.01

also significant with TAG 24 showing the least thermal time (630 ^{0}Cd). While, ICGV 86564 having the greatest thermal time requirement for production of 25 flowers (1022 ^{0}Cd). However, the genotypic x photoperiod interaction was not significant (table-9a).

4.1.5 Effect of photoperiod on main stem length (MSTL) and leaf area index(LAI) :

Main stem length was recorded at 40,60,80,100 and final harvest. Main stem length showed a consistent increase from 40 DAS to final harvest. The photoperiod treatments were significant at 80, 100 DAS however the MSTL were increased from SD to LD between 60 to 100 DAS. The genotypic variance was found to be significant at all the stages and the length varied from 4.9 cm (40 DAS) to 27.5 cm (final harvest). Interaction between was also found out to be significant, showing that photoperiod has profound influence on MSTL (Table-9b)

The leaf area index (LAI) also varied across the treatments from SD to LD with photoperiod remaining significant at 80 and 100 DAS, However the genotypic variance were found to be significant between 40 to 100 DAS. The interaction between genotype and photoperiod were significant between 40 to 100 DAS with 0.5 to 4.9 respectively. Thus the results indicated that LAI were also influenced by photoperiods (Table-9b). Effect of photoperiod on crop growth was shown in plate 6a, 6b, 7a, 7b, 8a, 8b, and 9a, 9b)

4.2 Effect of photoperiod on Crop growth rates (CGR):

CGR was analysed using sequential growth analysis (Table-10). The growth rates were completed by regressing growth variable with time (days) at which the growth analysis was conducted. The CGR in present the experiment ranged from 6g m^{-2} d^{-1} to 20g m^{-2} d^{-1}. In general CGR was less under short day conditions (8.33 g m^{-2} d^{-1}) compared to normal day (13.3 g m^{-2} d^{-1}) and 10.3 g m^{-2} d^{-1} in long day, resulting in significant (P 0.05) effects of photoperiods on crop growth. However, the genotypic differences were significant with respect to

Table : 9a Thermal time to 25 flowers under shortday(SD), Normalday(ND), Longday(LD) photperiodic conditons in groundnut.

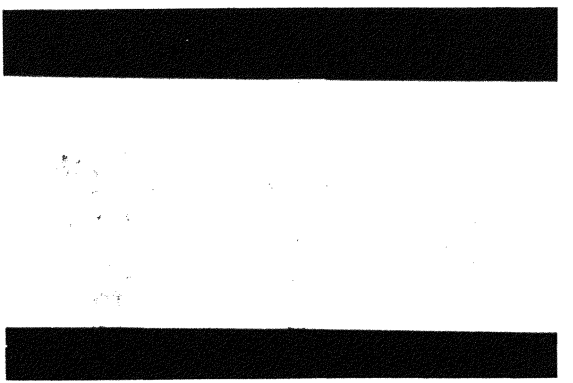
Genotype	SD	ND	LD	Mean
ICGV 88438	850.9	953.3	977.4	**927.2**
ICGV 87128	639.3	672.5	790.5	**700.8**
ICGV 86015	682	702.6	813.7	**732.8**
ICGMS 42	843.7	888.5	916.6	**882.9**
TMV 2	647.6	727.2	788.1	**720.9**
ICGV 86031	697.9	742.3	806.8	**749**
ICGV 86564	983.5	1030.5	1051.5	**1021.8**
TAG 24	611.9	590.6	711.7	**638**
NC Ac 17090	730.9	725.1	729.6	**728.5**
Mean	**743.1**	**781.4**	**842.9**	
SEM(±)		**34.89**		
CV%		**7.9**		

Analysis of variance		
Source of variation	d.f	Y25
MT (Photoperiods)	2	**
ST (Genotypes)	8	**
MT x ST	16	NS

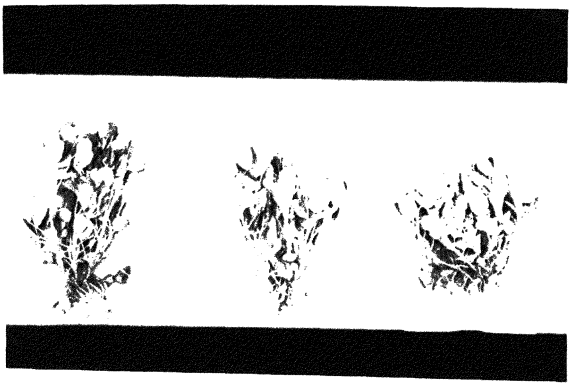
Correlations	
ND-SD	0.97
ND-LD	0.96
SD-LD	0.92

* significant at P=0.05
* * significant at P=0.01

6a:Genotype NC Ac 17096 under long day (LD), normal day (ND), short day (SD) photoperiods.

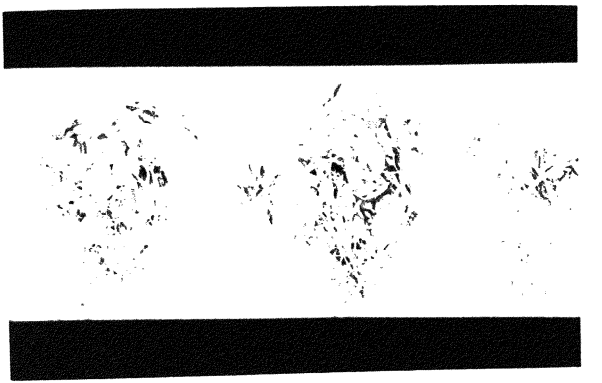


6b:Genotype TMV 2 under long day (LD), normal day (ND), short day (SD) photoperiods.



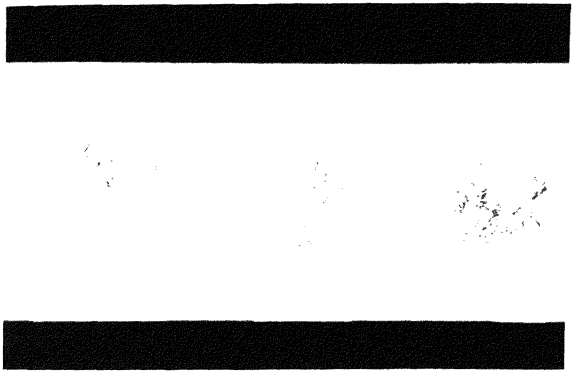
Phenotype KAV 8a051 under long day (LD), Normal day (ND), short day (SD) photoperiods.

Phenotype KAV 2a under long day (LD), normal day (ND), short day (SD) photoperiods.



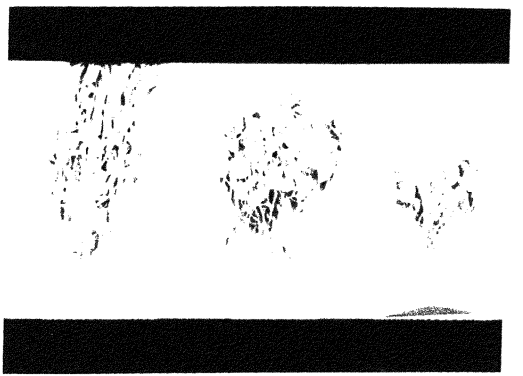
8a:Genotype ICGV 86435 under long day (LD), normal day (ND), short day (SD) photoperiods.

8b:Genotype ICGV 86564 under long day (LD), normal day (ND), short day (SD) photoperiods.



9a:Genotype ICGV 86015 under long day (LD), normal day (ND), short day (SD) photoperiods.

9b:Genotype ICGV 87128 under long day (LD), normal day (ND), short day (SD) photoperiods.



1d: Genotype IC356S-s2 under long day (LD), normal day (ND), short day (SD) photoperiods.

Table :9b Main stem length(MSTL),leaf area index(LAI) under short day(SD),normal day(ND),long day(LD) photoperiod regimes in groundnut.

		MSTL				LAI			
45	Genotype	SD	ND	LD	Mean	SD	ND	LD	Mean
40	ICGV 88438	7.3	9.2	4.1	**6.9**	0.5	0.6	0.5	**0.5**
	ICGV 87128	6.7	5.3	5.4	**5.8**	0.6	0.4	0.5	**0.5**
	ICGV 86015	6.1	6.1	5.4	**5.9**	0.5	0.5	0.5	**0.5**
	ICGMS 42	4.1	6.2	5.8	**5.4**	0.5	0.5	0.6	**0.5**
	TMV 2	4.0	4.9	6.3	**5.0**	0.4	0.4	0.4	**0.4**
	ICGV 86031	6.5	7.2	6.9	**6.9**	0.5	0.4	0.4	**0.4**
	ICGV 86564	6.3	5.9	6.5	**6.2**	0.5	0.6	0.5	**0.5**
	TAG 24	4.6	4.6	5.5	**4.9**	0.3	0.4	0.4	**0.4**
	NC Ac 17090	5.8	5.2	5.2	**5.4**	0.6	0.4	0.5	**0.5**
	Mean	**5.7**	**6.1**	**5.7**		**0.5**	**0.5**	**0.5**	
	SEM(±)		**0.22**				**0.04**		
	CV%		**15**				**18.3**		
60	ICGV 88438	10.4	15.1	15.5	**13.6**	2.3	2.3	2.5	**2.4**
	ICGV 87128	10.6	9.9	14.2	**11.6**	1.6	1.7	2.1	**1.8**
	ICGV 86015	9.7	9.6	13.7	**11.0**	1.7	1.8	1.7	**1.8**
	ICGMS 42	9.7	10.4	12.4	**10.8**	2.2	2.1	2.4	**2.2**
	TMV 2	13.3	10.5	11.9	**11.9**	1.4	1.4	2.0	**1.6**
	ICGV 86031	8.9	11.3	10.8	**10.4**	1.4	1.4	1.8	**1.5**
	ICGV 86564	10.7	8.7	9.6	**9.7**	1.8	2.0	1.9	**1.9**
	TAG 24	9.6	13.4	11.2	**11.4**	1.1	1.2	1.5	**1.3**
	NC Ac 17090	9.5	8.3	10.7	**9.5**	1.9	1.9	2.1	**2.0**
	Mean	**10.3**	**10.8**	**12.2**		**1.7**	**1.8**	**2.0**	
	SEM(±)		**0.72**				**0.07**		
	CV%		**21.5**				**17.4**		
80	ICGV 88438	13.5	15.8	17.9	**15.7**	2.8	3.3	4.4	**3.5**
	ICGV 87128	7.9	10.4	12.9	**10.4**	1.8	2.1	2.7	**2.2**
	ICGV 86015	8.6	11.2	11.9	**10.6**	1.7	2.5	2.4	**2.2**
	ICGMS 42	9.4	10.4	23.8	**14.5**	2.6	4.3	4.4	**3.8**
	TMV 2	13.3	19.9	21.6	**18.3**	2.4	2.7	2.8	**2.6**
	ICGV 86031	11.7	13.9	13.4	**13.0**	2.0	3.4	2.8	**2.7**
	ICGV 86564	13.0	14.6	23.3	**17.0**	3.1	5.2	3.7	**4.0**
	TAG 24	6.0	7.4	8.2	**7.2**	1.0	1.3	2.5	**1.6**
	NC Ac 17090	15.2	22.1	35.1	**24.1**	2.3	3.0	3.6	**3.0**
	Mean	**11.0**	**14.0**	**18.7**		**2.2**	**3.1**	**3.3**	
	SEM(±)		**1.18**				**0.11**		
	CV%		**13.5**				**21.7**		
100	ICGV 88438	14.4	24.4	21.0	**19.9**	3.0	4.6	4.1	**3.884**
	ICGV 87128	9.7	12.2	13.2	**11.7**	1.8	2.5	2.3	**2.208**
	ICGV 86015	9.2	11.5	12.1	**10.9**	1.2	2.2	2.5	**1.978**
	ICGMS 42	10.4	15.0	29.9	**18.5**	2.5	4.2	4.7	**3.808**
	TMV 2	13.5	23.5	25.2	**20.7**	2.1	2.8	3.4	**2.741**
	ICGV 86031	13.3	18.1	16.9	**16.1**	2.1	3.6	3.0	**2.918**
	ICGV 86564	13.1	19.4	30.0	**20.8**	3.0	4.6	4.8	**4.119**
	TAG 24	6.1	8.2	8.6	**7.6**	0.8	1.3	3.0	**1.727**
	NC Ac 17090	15.9	26.7	42.4	**28.3**	2.5	3.4	3.4	**3.083**
	Mean	**11.7**	**17.7**	**22.2**		**2.1**	**3.2**	**3.5**	
	SEM(±)		**1.01**				**0.13**		
	CV%		**17.2**				**18.1**		
	ICGV 88438	X	22.7	26.3	**24.5**	X	2.7	3.8	**3.3**
	ICGMS 42	X	14.9	30.1	**22.5**	X	2.8	4.9	**3.8**
	ICGV 86031	X	18.5	18.1	**18.3**	X	3.4	3.4	**3.4**
	ICGV 86564	X	23.6	31.5	**27.5**	X	4.1	2.9	**3.5**
	Mean	**X**	**19.9**	**26.5**		**X**	**3.3**	**3.8**	
	SEM(±)		**1.60**					**0.01**	
	CV%		**11.6**					**30.9**	

Table9b continued ...

DAS	Analysis of variance			
40	Source of variation	d.f	MSTL	LAI
	MT (Photoperiods)	2	NS	NS
	ST (Genotypes)	8	**	**
	MT x ST	16	**	NS
60	MT (Photoperiods)	2	NS	NS
	ST (Genotypes)	8	*	**
	MT x ST	16	NS	NS
80	MT (Photoperiods)	2	*	**
	ST (Genotypes)	8	**	**
	MT x ST	16	**	*
100	MT (Photoperiods)	2	**	**
	ST (Genotypes)	8	**	**
	MT x ST	16	**	*
FH	MT (Photoperiods)	1	NS	NS
	ST (Genotypes)	3	**	NS
	MT x ST	3	**	NS

* significant at P=0.05
* * significant P=0.01

Table:10 Crop growth rates (CGR) gm m^{-2} d^{-1} under Shortday(SD), Normalday(ND) ,Longday(LD) photoperiod conditions.

Genotype	SD	ND	LD	Mean
ICGV 88438	11.61	14.53	9.56	**11.9**
ICGV 87128	7.86	13.31	8.71	**9.96**
ICGV 86015	6.4	12.54	11.95	**10.3**
ICGMS 42	9.25	11.96	6.98	**9.4**
TMV 2	8.75	10.53	12.38	**10.55**
ICGV 86031	8.36	19.76	12.69	**13.6**
ICGV 86564	9.26	14.39	10.86	**11.5**
TAG 24	5.93	9.36	9.3	**8.2**
NC Ac 17090	7.25	13.66	10.03	**10.31**
Mean	**8.3**	**13.34**	**10.27**	
SEM(±)		**0.667**		
CV%		**18.6**		

Analysis of variance

Source of variation	d.f	CGR
MT (Photoperiods)	2	*
ST (Genotypes)	8	**
MT x ST	16	**

CGR. TAG 24 showing the least CGR (8.2 g m^{-2} d^{-1}) compared to 11.9 g m^{-2} d^{-1} in ICGV 88438. The photoperiod x genotype interaction was also significant for CGR (Table-10).

4.2.1 Vegetative growth rates (VGR):

VGR ranged from 0.72 g m^{-2} d^{-1} (SD) to 5.43 g m^{-2} d^{-1} (LD) amongst genotypes and treatments (Table-11). The photoperiod treatments were significant (P 0.01), with short day having the minimum (1.205 g m^{-2} d^{-1}), when as normal day and long day have 2.99 and 3.565 g m^{-2} d^{-1} respectively. However, the genotypic variance was also found to be significant with VGR. TAG 24 showing the least, i.e. 1.323 g m^{-2} d^{-1} compared to 4.385 g m-2 d-1 in ICGV 86564. While, the photoperiod and genotypic interaction was a general increase in VGR as day length were increased.

4.2.3 Pod growth rates (PGR):

PGR ranged from 4 to 10.7 g m^{-2} d^{-1} amongst genotype and treatments (Table-12). The photoperiod treatments were significant (P 0.05), with short day and long day having comparative PGR (5.6-5.8 g m^{-2} d^{-1}) compared to 8.8 g m^{-2} d^{-1} under normal day conditions. The mean PGR ranged from 5.3-7.7 g m^{-2} d^{-1}. However, the genotypic variation was not found to be significant. The photoperiod x genotype interaction was significant with some genotypes showing very little change in PGR (TMV 2), where as some genotypes showing significant differences in PGR with change in photoperiod. In general there was an increase in PGR under normal conditions, compared to short day and long day.

A comparative analysis of VGR and PGR has shown that the influence of photoperiod was more on PGR (Fig-4). It was clear from this analysis, that VGR increased along the photoperiods, where as PGR were significantly influenced by short day and long day conditions. Indicating that photoperiod influence was very important on reproductive growth.

Table :11 Vegetative growth rates(VGR) g m^{-2} d^{-1} under short day(SD),normal day(ND),long day(LD) photoperiodic conditions in groundnut.

Genotype	SD	ND	LD	Mean
ICGV 88438	3.033	5.018	4.719	**4.257**
ICGV 87128	1.462	1.245	1.675	**1.461**
ICGV 86015	0.301	2.253	1.739	**1.431**
ICGMS 42	1.279	3.872	5.421	**3.524**
TMV 2	0.72	2.536	3.06	**2.106**
ICGV 86031	0.699	4.037	2.493	**2.41**
ICGV 86564	2.622	5.107	5.425	**4.385**
TAG 24	0.253	0.422	3.294	**1.323**
NC Ac 17090	0.479	2.241	4.259	**2.326**
Mean	**1.205**	**2.97**	**3.565**	
SEM(±)		**0.2189**		
CV%		**24.6**		

Analysis of variance		
Source of variation	d.f	VGR
MT (Photoperiods)	2	**
ST (Genotypes)	8	**
MT x ST	16	**

* significant at P=0.05
* * significant at P=0.01

Table: 12 Pod growth rates (PGR) gm m^{-2} d^{-1} under Shortday(SD) Normalday(ND), Longday(LD) photperiod conditions in groundnut

Genotype	SD	ND	LD	Mean
ICGV 88438	7.55	10.4	4.16	**7.37**
ICGV 87128	5.39	10.74	5.51	**7.21**
ICGV 86015	4.77	9.51	8.73	**7.67**
ICGMS 42	6.84	7.11	2.87	**5.6**
TMV 2	6.55	6.96	7.94	**7.15**
ICGV 86031	6.08	8.18	7.79	**7.35**
ICGV 86564	5.73	9.24	4.52	**6.5**
TAG 24	4.18	6.96	4.74	**5.29**
NC Ac 17090	5.69	9.91	4.09	**6.56**
Mean	**5.86**	**8.78**	**5.59**	
SEM(±)		**0.402**		
CV%		**26.7**		

Analysis of variance

Source of variation	d.f	PGR
MT (Photoperiods)	2	**
ST (Genotypes)	8	NS
MT x ST	16	**

* significant at P=0.05

* * significant at P=0.01

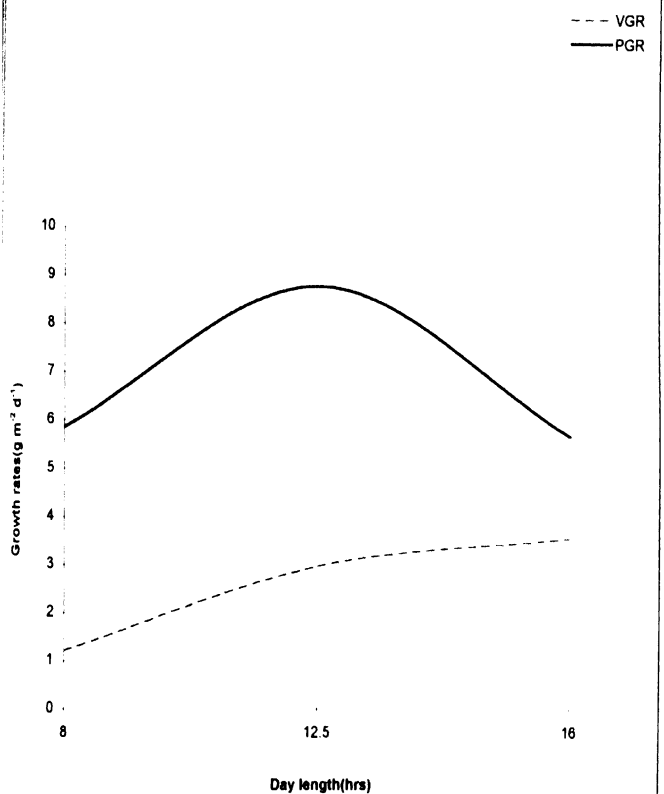


Fig :4 Effect of photoperiod on VGR and PGR

4.2.4 Seed growth rates (SGR):

SGR showed that there was no significant influence of photoperiod on the seed growth rates (Table-13), although normal day treatment had higher seed growth rates 4.87 g m^{-2} d^{-1} compared to 4.35 g m^{-2} d^{-1} in short day, 4.07 in g m^{-2} d^{-1} in long day. However, photoperiod effects as well as genotypic effect were not significant. Photoperiod x genotype was significant (P=0.01). The photoperiod x genotype has resulted because of some genotype showing some reduction in seed growth rates with increase in day length (ICG 88438,ICGV 86564,ICGMS 42). Where as in other genotypes there was increase in seed growth rates with increase in day length for e.g. ICGV 86015. In some genotypes the seed growth rates were marginally greater in normal day compared to that in short day and long day (ICGV 87128,TAG 24)(Table-13)

4.2.5 Partitioning:

Partitioning of dry matter to pods was calculated as the ratio of PGR to CGR (Table-14). The analysis of partitioning of dry matter to pods has shown that the photoperiod treatments had significant influence on partitioning with short day treatment showing the greatest partitioning (0.714) followed by normal day (0.675) and long day (0.527). The partitioning ranges from 0.55 to 0.75 representing a significant variation among genotypes. The partitioning was greatest in ICGV 86015 and ICGV 87128 (0.701 and0 .74) and least in ICGV 86564(0.56). There was a significant interaction of photoperiod x genotype, for e.g. in some genotypes the partitioning was stable across the three photoperiod regimes (ICGV 86015, ICGV 87128),

where as in some sensitive genotypes for e.g. NC Ac 17090 and ICGV 88438 the partitioning reduced with increase in day length (Fig-5). The magnitude of sensitivity varied amongst genotypes (Fig-6). Insensitive genotypes such as ICGV 86015, ICGV 87128, TMV 2

Table: 13 Seed growth rates (SGR) gm m^{-2} d^{-1} under Shortday(SD), Normalday(ND),Longday(LD) photoperiod conditions in groundnut.

Genotype	SD	ND	LD	Mean
ICGV 88438	5.89	4.33	3.48	**4.57**
ICGV 87128	4.06	6.32	5.45	**5.28**
ICGV 86015	3.44	4.87	5.65	**4.65**
ICGMS 42	5.25	4.66	1.46	**3.79**
TMV 2	4.87	3.99	6.86	**5.24**
ICGV 86031	4.27	5.74	4.19	**4.73**
ICGV 86564	4.12	3.13	2.77	**3.34**
TAG 24	3.32	5.01	3.16	**3.83**
NC Ac 17090	3.95	5.77	3.57	**4.43**
Mean	**4.35**	**4.87**	**4.07**	
SEM(±)		**0.517**		
CV%		**31**		

Analysis of variance		
Source of variation	**d.f**	**SGR**
MT (Photoperiods)	**2**	NS
ST (Genotypes)	**8**	NS
MT x ST	**16**	**

* significant at P 0.05

* * significant at P- 0.01

Table : 14 Partitioning(part.) among genotypes under Shortday(SD), Normalday(ND), Longday(LD) photperiod conditions in groundnut.

Genotype	SD	ND	LD	Mean
ICGV 88438	0.651	0.699	0.398	**0.583**
ICGV 87128	0.694	0.807	0.632	**0.711**
ICGV 86015	0.747	0.771	0.721	**0.746**
ICGMS 42	0.739	0.611	0.415	**0.589**
TMV 2	0.755	0.652	0.64	**0.682**
ICGV 86031	0.726	0.424	0.616	**0.588**
ICGV 86564	0.622	0.642	0.412	**0.558**
TAG 24	0.704	0.742	0.495	**0.647**
NC Ac 17090	0.787	0.73	0.411	**0.643**
Mean	**0.714**	**0.675**	**0.527**	
SEM±		**0.0214**		
CV%		**17.4**		

Analysis of variance		
Source of variation	**d.f**	**Part.**
MT (Photoperiods)	2	**
ST (Genotypes)	8	**
MT x ST	16	*

* significant at P=0.05

* * significant P=0.01

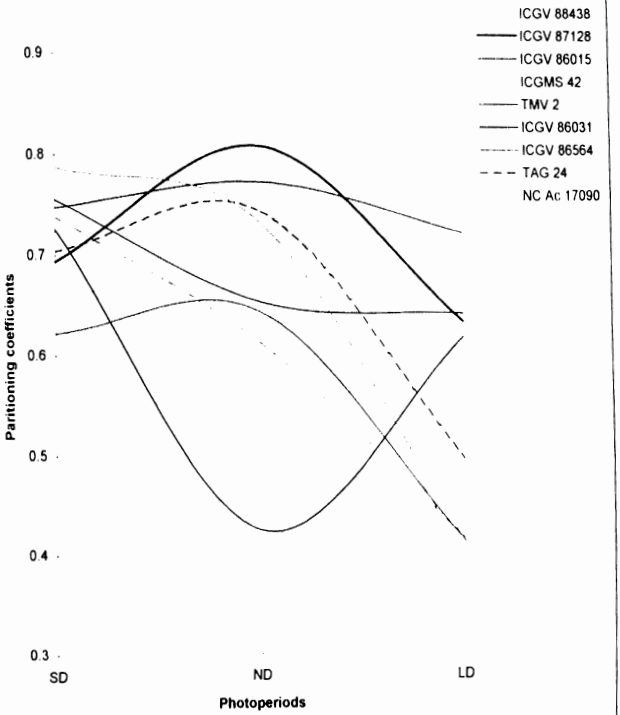


Fig : 5 Effect of short day(SD),Normal day(ND),long day(LD) photperiods on partitioning

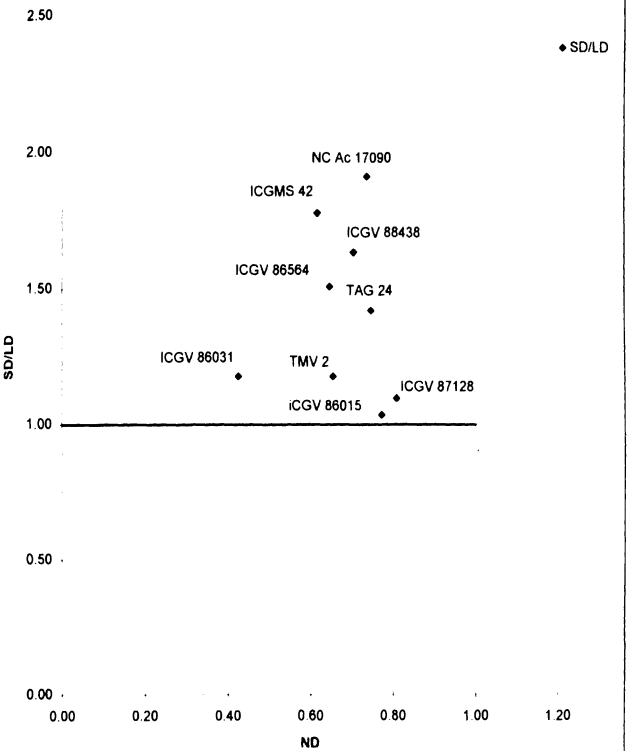


Fig : 6 Effect of photoperiod on partitioning

AND ICGV 86031 showed little change in the ratio of partitioning in short day and long day, although this genotype differed significantly in partitioning. It was apparent in Fig-5 that there insensitive genotypes were closure to the solid drawn line at '1' which represents little or no change in partitioning across short day and long day. The photoperiod sensitive genotypes such as NC Ac 17090, ICMS 42 , ICGV 88438 clustered at significant distance from the insensitive types.

In general there seems to be negative correlation between partitioning in normal day with SD/LD ratio. These results indicated that selection for higher partitioning under long day conditions likely to resulting selection for photoperiod insensitive types. However, there was one exception to these relationship with ICGV 86031 which had relatively low partitioning under normal day, It was showed relatively less sensitivity to photoperiod. For e.g. insensitive genotype which had very little or marginal change in partitioning compared to that of normal day (those genotypes which fall on with ratio of 1) can be selected as insensitive compared to this which show significant departure from 1. In this analysis it is clear that genotypes were relatively insensitive compared to sensitive genotypes.

Sequential growth analysis at 40,60,100 DAS has revealed that the aerial peg number and sub-terranean number did not differ significantly under influence of photoperiod, however juvenile pod number differed significantly with photoperiod regimes at 60 DAS only (Table-15). It was apparent from the analysis (Table-15) at 60 DAS although there was equally similar numbers of aerial and sub-terranean peg numbers across three photoperiod regimes, the juvenile pod number significantly greater in short day compared to long day at 60 DAS. However at 80 and 100 DAS there was drop in sub-peg number and an increase in juvenile pod number. However, the trend for having greater juvenile pod number in short day compared to long day conditions at 60, 80 and 100 DAS. At 60 DAS immature pod number ranged from 15 to 48.

Table : 15 Effect of short day(SD),normal day(ND),long day(LD) photoperiods on aerial peg number(Apegn),sub-terranean peg number(Spegn), Juvenile pod number(Jvpdn) in groundnut.

		Apegn				Spegn				Jvpdn			
DAS	Genotype	SD	ND	LD	Mean	SD	ND	LD	Mean	SD	ND	LD	Mean
40	ICGV 88438	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 87128	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86015	x	x	x	x	x	x	x	x	x	x	x	x
	ICGMS 42	x	x	x	x	x	x	x	x	x	x	x	x
	TMV 2	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86031	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86564	x	x	x	x	x	x	x	x	x	x	x	x
	TAG 24	x	x	x	x	x	x	x	x	x	x	x	x
	NC Ac 17090	x	x	x	x	x	x	x	x	x	x	x	x
	Mean	**x**	**x**	**x**		**x**	**x**	**x**		**x**	**x**	**x**	
	SEM(±)	**x**				**x**				**x**			
	CV%	**x**				**x**				**x**			
60	ICGV 88438	176.7	107	142.7	**142.1**	68	75	101.7	**81.7**	87	64	0	**50**
	ICGV 87128	94	137	189	**140.1**	133.3	200	190.7	**174.7**	472.7	331	430	**411**
	ICGV 86015	121	166.7	245.3	**177.7**	152.7	242.3	227.3	**207.4**	425	342	268	**345**
	ICGMS 42	126.3	95	89	**103.4**	93	98	104.3	**99**	113.3	81	0	**65**
	TMV 2	114	102	128	**114.7**	81	105.7	148.3	**112**	294.7	428	305	**343**
	ICGV 86031	106.7	197.7	142	**148.8**	82	99	103.7	**95**	304.7	285	253	**281**
	ICGV 86564	68	79	71	**73**	88	69	61	**73**	60	53	0	**38**
	TAG 24	94	167.3	113.7	**125.1**	135	174.3	159	**156**	384	472	280	**379**
	NC Ac 17090	88	104	90	**94**	83	94	151.3	**109**	151.7	228	0	**127**
	Mean	**109.9**	**128.3**	**134.5**		**101.8**	**128.6**	**138.6**		**254.7**	**254**	**171**	
	SEM(±)		**6.4**				**11.7**				**8.0**		
	CV%		**26.6**				**28.6**				**24.6**		
80	ICGV 88438	279.7	375.3	202	**285.7**	205	132	95	**144**	273	108	98	**160**
	ICGV 87128	57	94	175.3	**108.9**	49	79	158	**95**	304.7	160	401	**289**
	ICGV 86015	26	145.7	79	**84**	49	60	76	**61**	370	201	271	**281**
	ICGMS 42	190	202.3	308.7	**233.7**	134	116	136	**129**	239	121	126	**162**
	TMV 2	29	66	129.7	**75**	47	37	62	**49**	254.3	194	269	**239**
	ICGV 86031	60	223.7	183	**155.4**	15	41	48	**35**	296.7	234	222	**251**
	ICGV 86564	358.7	168.7	143.7	**223.7**	136	83	163	**127**	124	111	102	**112**
	TAG 24	30	42	49	**40**	102	49	44	**65**	216.7	399	281	**299**
	NC Ac 17090	79	67	212.3	**119.4**	22	23	53	**32**	141	125	217	**161**
	Mean	**123.1**	**154**	**164.8**		**84**	**69**	**93**		**247**	**184**	**221**	
	SEM(±)		**12.0**				**11.5**				**16.1**		
	CV%		**31.4**				**34.8**				**27.4**		
100	ICGV 88438	209.3	188.7	334.3	**244.1**	93	67	52	**71**	281	147	186	**205**
	ICGV 87128	28	94	64	**62**	108.7	43	112.3	**88**	280.7	176	237	**231**
	ICGV 86015	92	107	107.7	**102.2**	69	84	33	**62**	223.3	232	251	**236**
	ICGMS 42	242.7	212	262.3	**239**	135	127	73	**111.8**	218	143	114	**158**
	TMV 2	33	77	74	**61**	36	25	22	**28**	219.7	182	92	**164**
	ICGV 86031	61	213.7	195.7	**157**	27	55	34	**39**	205.7	316	241	**254**
	ICGV 86564	118.7	290.7	242	**217**	68	116.7	73	**86**	189.3	121	89	**133**
	TAG 24	15	44	52	**37**	72	64	90	**75**	238.7	207	263	**236**
	NC Ac 17090	71	69	197.7	**112.4**	14	30	43	**29**	104.7	111	127	**114**
	Mean	**97**	**144**	**170**		**69**	**68**	**59**		**218**	**182**	**178**	
	SEM(±)		**10.7**				**2.3**				**16.6**		
	CV%		**28.4**				**27.5**				**28.9**		
H	ICGV 88438	x	272	267	**269**	x	19	23	**21**	x	111	143	**127**
	ICGMS 42	x	234	241	**238**	x	6	63	**35**	x	215	129	**172**
	ICGV 86031	x	388	335	**361**	x	3	3	**3**	x	142	135	**138**
	Mean	**x**	**298**	**281**		**x**	**9.4**	**29.9**		**x**	**156**	**136**	
	SEM(±)		**3.8**				**9.3**				**5.9**		
	CV%		**32**				**108**				**42.4**		

Table: 15 continued...

DAS	Analysis of variance Source of variation	d.f	Apegn	Supn	Jvpd
40	MT (Photoperiods)	2	X	X	X
	ST (Genotypes)	8	X	X	X
	MT x ST	16	X	X	X
60	MT (Photoperiods)	2	NS	NS	**
	ST (Genotypes)	8	**	**	**
	MT x ST	165	**	NS	**
80	MT (Photoperiods)	2	NS	NS	NS
	ST (Genotypes)	8	**	**	**
	MT x ST	16	**	**	**
100	MT (Photoperiods)	2	*	*	NS
	ST (Genotypes)	8	**	**	**
	MT x ST	16	**	**	*
FH	MT (Photoperiods)	1	NS	NS	NS
	ST (Genotypes)	2	NS	NS	NS
	MT x ST	2	NS	NS	NS

* significant at P=0.05
* * significant P=0.01

Greater number of immature pods occurring under short day conditions (47) compared to 15 under normal day and 20 under long day conditions. However, maximum number of immature pods (Table-16) were recorded at 80 DAS with long day and normal day having up to 245 immature pods m^{-2} compared to 215 in short day. Mature pod number m^{-2} was greater at 80 DAS under short day (65) than to 37 in normal day and 28 in long day. The genotypes also varied significantly in number of mature pods, which ranged from '0' in ICGV 86564 to more than 140 in TAG 24. Similar trend was observed for mature pod production at 100 DAS as well as at final harvest with short day recording greatest number of mature pods. Genotypic sensitivity to photoperiod regimes was also apparent in mature pod m^{-2} at 100 DAS. For example relative insensitive genotypes ICGV 87128 and TMV 2 recorded high mature pod number in all the three photoperiod regimes where as the mature pod number reduced drastically with increase in photoperiod in sensitive types, like NC Ac 17090 and ICGV 88438.

The effect of photoperiod regimes on reproductive development was further illustrated by analysing the ratios of sub-terranean peg (it is the ratio between sub-terranean parts to that of reproductive structures), further analysed by examining (sub-terranean peg ratio (SPGR), mature pod ratio (MTPR) and total peg to pod ratio (PPR)). This data have clearly indicated the influence of photoperiod on SPGR, which was non-significant at 60,80,100 DAS although genotypic differences were significant at all, stages (Table-17). However, there was a trend for increase in SPGR under short day starting at 80 DAS and 100 DAS relative to normal day and long day. Genotype x photoperiod interaction was significant with some genotypes showing significant reduction in sub-terranean peg and with increased day length (ICG 88438,ICGMS 42,NC Ac 17090) where as, SPGR remained constant not in all the photoperiod regimes in some genotypes (TAG 24,ICGV 86564,ICGV 86031,TMV 2).

Table :16 Effect of short day(SD),normal day(ND),long day(LD) photperiods on Immature pod number(Impdn),Matpd(Mtpdn) in groundnut.

		Impdn				Mtpdn			
AS	Genotype	SD	ND	LD	Mean	SD	ND	LD	Mean
40	ICGV 88438	x	x	x	x	x	x	x	x
	ICGV 87128	x	x	x	x	x	x	x	x
	ICGV 86015	x	x	x	x	x	x	x	x
	ICGMS 42	x	x	x	x	x	x	x	x
	TMV 2	x	x	x	x	x	x	x	x
	ICGV 86031	x	x	x	x	x	x	x	x
	ICGV 86564	x	x	x	x	x	x	x	x
	TAG 24	x	x	x	x	x	x	x	x
	NC Ac 17090	x	x	x	x	x	x	x	x
	Mean	**x**	**x**	**x**		**x**	**x**	**x**	
	SEM(±)			**x**				**x**	
	CV%			**x**				**x**	
60	ICGV 88438	0	0	0	**0**	x	x	x	x
	ICGV 87128	32	29	0	**20**	x	x	x	x
	ICGV 86015	52	0	58	**37**	x	x	x	x
	ICGMS 42	0	0	0	**0**	x	x	x	x
	TMV 2	97	6	0	**34**	x	x	x	x
	ICGV 86031	26	0	31	**19**	x	x	x	x
	ICGV 86564	0	0	0	**0**	x	x	x	x
	TAG 24	130	71	92	**98**	x	x	x	x
	NC Ac 17090	88	30	0	**39**	x	x	x	x
	Mean	**47**	**15**	**20**					
	SEM(±)			**5.21**					
	CV%			**74.1**					
0	ICGV 88438	170.7	63	63.3	**99**	4	0	0	1
	ICGV 87128	278.7	316	486	**360.2**	67	44	0	**37**
	ICGV 86015	208	407.3	481	**365.4**	90	47	52	**63**
	ICGMS 42	137.3	138.3	28	**101.2**	45	0	0	**15**
	TMV 2	440	441	509.7	**463.6**	152.3	0	82	**78**
	ICGV 86031	228.3	336.7	250.3	**271.8**	37	24	23	**28**
	ICGV 86564	157.3	44.3	38.7	**80.1**	0	0	0	**0**
	TAG 24	114.3	138.7	168.7	**140.6**	140	166	96	**134**
	NC Ac 17090	201.7	230	179.3	**203.7**	48	57	0	**35**
	Mean	**215.1**	**235**	**245**		**65**	**38**	**28**	
	SEM(±)			**21.63**				**4.55**	
	CV%			**31.6**				**43**	
0	ICGV 88438	186.7	202.3	199.3	**196.1**	133.3	49.3	35.3	**73**
	ICGV 87128	107	185.7	120.3	**137.7**	246	303.3	352	**300.4**
	ICGV 86015	116.7	108.3	329.3	**184.8**	244.3	311.3	185	**246.9**
	ICGMS 42	48	96	47	**64**	263	183	89.3	**178.4**
	TMV 2	145.7	102.3	176	**141.3**	471	364.7	449.3	**428.3**
	ICGV 86031	133	275.7	284	**230.9**	184.7	133.3	106.3	**141.4**
	ICGV 86564	150.3	186.3	112	**149.6**	202	190	152	**181**
	TAG 24	108.3	150.3	221	**159.9**	200.7	177	239.7	**205.8**
	NC Ac 17090	102.7	236.3	270.7	**203.2**	199.7	116.7	61	**125.8**
	Mean	**122**	**171.5**	**195.5**		**238**	**203**	**186**	
	SEM(±)			**17.25**				**12.24**	
	CV%			**33.7**				**37**	
	ICGV 88438	x	86	134	**110**	x	387	231	**309**
	ICGMS 42	x	224	159	**192**	x	456	221	**339**
	ICGV 86031	x	161	256	**209**	x	700	469	**585**
	Mean	**x**	**157**	**183**		**x**	**515**	**307**	
	SEM(±)		**9.1**					**22**	
	CV%		**37**					**17.9**	

Table: 16 continued....

DAS	Source of variation	Analysis of variance d.f	lmpdn	Mtpdn
40	MT (Photoperiods)	2	x	x
	ST (Genotypes)	8	x	x
	MT x ST	16	x	x
60	MT (Photoperiods)	2	*	x
	ST (Genotypes)	8	**	x
	MT x ST	16	**	x
80	MT (Photoperiods)	2	NS	*
	ST (Genotypes)	8	**	**
	MT x ST	16	**	**
100	MT (Photoperiods)	2	NS	NS
	ST (Genotypes)	8	**	**
	MT x ST	16	**	NS
FH	MT (Photoperiods)	1	*	NS
	ST (Genotypes)	2	**	NS
	MT x ST	2	NS	NS

* significant at P=0.05
* * significant P=0.01

Table :17 **Effect of short day(SD),normal day(ND),long day(LD) photperiods on Subterranean peg to pod ratio(SPGR),Mature pod ratio(MTPR),total peg to pod ratio(PPR)**

		SPGR				MTPR				PPR			
AS	Genotype	SD	ND	LD	Mean	SD	ND	LD	Mean	SD	ND	LD	Mean
40	ICGV 88438	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 87128	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86015	x	x	x	x	x	x	x	x	x	x	x	x
	ICGMS 42	x	x	x	x	x	x	x	x	x	x	x	x
	TMV 2	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86031	x	x	x	x	x	x	x	x	x	x	x	x
	ICGV 86564	x	x	x	x	x	x	x	x	x	x	x	x
	TAG 24	x	x	x	x	x	x	x	x	x	x	x	x
	NC Ac 17090	x	x	x	x	x	x	x	x	x	x	x	x
	Mean	x	x	x		x	x	x		x	x	x	
	SEM(±)		x				x				x		
	CV%		x				x				x		
60	ICGV 88438	0 427	0 63	0 41	**0.489**	x	x	x	x	x	x	x	x
	ICGV 87128	0 867	0 843	0 887	**0.866**	x	x	x	x	x	x	x	x
	ICGV 86015	0 91	0 777	0 84	**0.842**	x	x	x	x	x	x	x	x
	ICGMS 42	0 577	0 73	0 43	**0.579**	x	x	x	x	x	x	x	x
	TMV 2	0 807	0 847	0 817	**0.823**	x	x	x	x	x	x	x	x
	ICGV 86031	0 743	0 79	0 733	**0.756**	x	x	x	x	x	x	x	x
	ICGV 86564	0 603	0 727	0 39	**0.573**	x	x	x	x	x	x	x	x
	TAG 24	0 983	0 91	0 827	**0.907**	x	x	x	x	x	x	x	x
	NC Ac 17090	0 7	0 717	0 58	**0.666**	x	x	x	x	x	x	x	x
	Mean	**0.735**	**0.774**	**0.657**		x	x	x		x	x	x	
	SEM(±)		**0.0297**				x					x	
	CV%		**19.2**				x					x	
80	ICGV 88438	0 893	0 443	0 583	**0.633**	0 0133	0	0	**0.004**	0 0067	0	0	**0.0022**
	ICGV 87128	0 927	0 952	0 853	**0.911**	0 1067	0 0867	0	**0.064**	0 09	0 0867	0	**0.0589**
	ICGV 86015	0 976	0 863	0 986	**0.942**	0 1333	0 07	0 063	**0.089**	0 1267	0 0567	0 06	**0.0811**
	ICGMS 42	0 747	0 65	0 497	**0.631**	0 1067	0	0	**0.036**	0 0567	0	0	**0.0189**
	TMV 2	0 817	0 913	0 877	**0.869**	0 18	0	0 097	**0.092**	0 14	0	0 0767	**0.0722**
	ICGV 86031	0 907	0 733	0 71	**0.783**	0 0633	0 04	0 043	**0.049**	0 0567	0 0267	0 03	**0.0378**
	ICGV 86564	0 487	0 477	0 827	**0.597**	0	0	0	**0**	0	0	0	**0**
	TAG 24	0 807	0 863	0 88	**0.85**	0 3	0 2367	0 177	**0.238**	0 1967	0 19	0 1433	**0.1767**
	NC Ac 17090	0 953	0 863	0 603	**0.806**	0 1233	0 1467	0	**0.09**	0 1067	0 12	0	**0.0756**
	Mean	**0.8349**	**0.751**	**0.755**		**0.1141**	**0.0644**	**0.042**		**0.0887**	**0.0533**	**0.0344**	
	SEM(±)		**0.0574**				**0.003**					**0.00556**	
	CV%		**20.9**				**25.8**					**38.8**	
100	ICGV 88438	0 843	0 703	0 55	**0.699**	0 2233	0 12	0 083	**0.142**	0 16	0 0767	0 0433	**0.0933**
	ICGV 87128	0 88	0 76	0 82	**0.82**	0 3867	0 4767	0 477	**0.447**	0 2933	0 3333	0 35	**0.3256**
	ICGV 86015	0 787	0 867	0 767	**0.807**	0 4167	0 4633	0 233	**0.371**	0 2967	0 3533	0 1733	**0.2744**
	ICGMS 42	0 703	0 797	0 553	**0.684**	0 4967	0 4267	0 353	**0.426**	0 28	0 2633	0 15	**0.2311**
	TMV 2	0 893	0 767	0 99	**0.883**	0 5633	0 5733	0 62	**0.586**	0 48	0 42	0 6	**0.5**
	ICGV 86031	0 797	0 783	0 727	**0.769**	0 3567	0 1867	0 17	**0.238**	0 2633	0 1333	0 1167	**0.1711**
	ICGV 86564	0 787	0 597	0 677	**0.687**	0 08	0 07	0 323	**0.158**	0 0533	0 0267	0 16	**0.08**
	TAG 24	0 963	0 863	0 83	**0.886**	0 3667	0 3433	0 333	**0.348**	0 31	0 2533	0 2433	**0.2689**
	NC Ac 17090	0 817	0 737	0 713	**0.756**	0 49	0 2567	0 137	**0.294**	0 39	0 1733	0 0933	**0.2189**
	Mean	**0.83**	**0.764**	**0.736**		**0.3756**	**0.3241**	**0.303**		**0.2807**	**0.2259**	**0.2144**	
	SEM(±)		**0.0243**				**0.00731**					**0.00799**	
	CV%		**16.7**				**25.2**					**32.3**	
H	ICGV 88438	x	0 677	0 653	**0.665**	x	0 857	0 487	**0.582**	x	0 433	0 287	**0.36**
	ICGMS 42	x	0 787	0 707	**0.747**	x	0 51	0 433	**0.472**	x	0 4	0 277	**0.338**
	ICGV 86031	x	0 723	0 72	**0.722**	x	0 703	0 55	**0.627**	x	0 51	0 397	**0.453**
	Mean	x	**0.729**	**0.693**		x	**0.623**	**0.483**		x	**0.448**		**0.32**
	SEM(±)	x		**0.0129**		x		**0.013**		x		**0.0098**	
	CV%	x		**9.7**		x		**11.4**		x		**13.6**	

Table 17 continued...

Analysis of variance					
DAS	Source of variation	d.f	SPGR	MTPR	PPR
40	MT (Photoperiods)	2	x	x	x
	ST (Genotypes)	8	x	x	x
	MT x ST	16	x	x	x
60	MT (Photoperiods)	2	NS	x	x
	ST (Genotypes)	8	**	x	x
	MT x ST	16	NS	x	x
80	MT (Photoperiods)	2	NS	**	**
	ST (Genotypes)	8	**	**	**
	MT x ST	16	**	**	**
100	MT (Photoperiods)	2	NS	**	**
	ST (Genotypes)	8	**	**	**
	MT x ST	16	NS	**	**
FH	MT (Photoperiods)	1	NS	*	*
	ST (Genotypes)	2	NS	**	*
	MT x ST	2	NS	NS	NS

Mature pod ratio has very clearly shown that the significant effects of photoperiod on this parameter at 80 DAS and 100DAS. It was apparent from analysis that mature pod ratio reduced linearly with increase in day length at both 80 DAS and 100 DAS at both stages genotypic effects as well as genotype x photoperiod interaction was highly significant. Although at 80 DAS, some genotypes have recorded zero MTPR. The genotypic effects become clearer at 100 DAS between the photperiod as well as between genotypes.

Similar trend was observed in total peg to pod ratio with this parameter that reducing as the photoperiod increased. The genotypic differences were also significant at 80 DAS and 100 DAS.

The partitioning of dry matter amongst leaves stems and pods were analysed to examine the influence of photoperiod and genotypic sensitivity in partitioning of dry matter across various organs. The analysis of stem to leaf under a given situation indicates the trend for allocation of assimilates produced in the leaves per unit leaf weight per unit area. The analysis of stem to leaf clearly indicated that the ratio was consistently greater in normal day and long day than in short day. The similar trend of greater stem to leaf was observed at all the growth stages (Table-18).

However, there were significant differences amongst genotypes for stem to leaf ratio at growth harvest. Although photoperiod x genotype interaction was not significant at 40 and 60 DAS. This interaction becomes significant at 80 and 100 DAS. This analysis indicated that the assimilates produced per leaf weight partitioned more into stems in long day and normal day compared to short day.

Specific leaf area (SLA) has very clear shown by that the significant effects of photoperiods on this parameter at 80DAS (Table-19). SLA increased upto 60 DAS and declined

Table :18 Stem to leaf ratio(ST/LF) under short day(SD),normal day(ND),long day(LD) photoperiodic conditions in groundnut.

DAS	Genotype	St/lf			
		SD	ND	LD	Mean
40	ICGV 88438	0.060	0.070	0.080	0.070
	ICGV 87128	0.053	0.057	0.073	0.061
	ICGV 86015	0.043	0.067	0.087	0.066
	ICGMS 42	0.043	0.063	0.063	0.057
	TMV 2	0.040	0.040	0.063	0.048
	ICGV 86031	0.067	0.083	0.087	0.079
	ICGV 86564	0.057	0.067	0.090	0.071
	TAG 24	0.037	0.060	0.057	0.051
	NC Ac 17090	0.043	0.053	0.077	0.058
	Mean	0.049	0.062	0.075	
	SEM(±)		0.0030		
	CV%		40		
60	ICGV 88438	0.207	0.350	0.307	0.288
	ICGV 87128	0.160	0.347	0.250	0.252
	ICGV 86015	0.173	0.337	0.273	0.261
	ICGMS 42	0.173	0.247	0.273	0.231
	TMV 2	0.123	0.213	0.253	0.197
	ICGV 86031	0.193	0.367	0.353	0.304
	ICGV 86564	0.173	0.320	0.293	0.262
	TAG 24	0.103	0.223	0.267	0.198
	NC Ac 17090	0.153	0.253	0.260	0.222
	Mean	0.162	0.295	0.281	
	SEM(±)		0.0110		
	CV%		16.4		
80	ICGV 88438	0.323	0.650	0.670	0.548
	ICGV 87128	0.170	0.343	0.423	0.312
	ICGV 86015	0.143	0.333	0.390	0.289
	ICGMS 42	0.280	0.527	0.610	0.472
	TMV 2	0.223	0.403	0.493	0.373
	ICGV 86031	0.317	0.610	0.560	0.496
	ICGV 86564	0.360	0.787	0.470	0.539
	TAG 24	0.103	0.210	0.553	0.289
	NC Ac 17090	0.183	0.443	0.590	0.406
	Mean	0.234	0.479	0.529	
	SEM(±)		0.0141		
	CV%		26.5		
100	ICGV 88438	0.530	1.213	1.217	0.987
	ICGV 87128	0.180	0.513	0.543	0.412
	ICGV 86015	0.187	0.443	0.453	0.361
	ICGMS 42	0.363	0.970	1.310	0.881
	TMV 2	0.297	0.610	0.687	0.531
	ICGV 86031	0.363	1.027	1.090	0.827
	ICGV 86564	0.443	1.213	1.490	1.049
	TAG 24	0.120	0.277	1.093	0.497
	NC Ac 17090	0.267	0.830	1.720	0.939
	Mean	0.3060	0.789	1.067	
	SEM(±)		0.0364		
	CV%		21.7		
FH	ICGV 88438	x	1.890	2.190	2.040
	ICGMS 42	x	1.410	1.890	1.650
	ICGV 86031	x	1.650	1.450	1.550
	Mean	x	1.650	1.850	
	SEM(±)		0.7300		
	CV%		34.2		

Table: 18 continued...

Analysis of variance			
DAS	**Source of variation**	**d.f**	**St/Lf**
40	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
60	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
80	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	*
100	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	**
FH	**MT (Photoperiods)**	**1**	NS
	ST (Genotypes)	**2**	NS
	MT x ST	**2**	NS

* significant at P=0.05
* * significant P=0.01

there after. The photoperiod effects were significant at all stages except final harvest. The photoperiod x genotype interaction was significant at 80 DAS. Genotypic differences were significant (P=0.01) at all stages except at final harvest.

4.3 Reproductive development:

The analysis of rate of peg addition (per day basis) have shown that the photoperiods treatments did not influence the rate of peg addition (Table-20), although there was significant genotypic variation for the trait. The rates of peg addition ranged from 9.9 pegs m^{-2} d^{-1} in ICGV 86564 to 14.8 pegs m^{-2} d^{-1}in TMV 2. The photoperiod x genotype interaction was also significant (P=0.01) with some genotype showing reduction in peg addition rates with increase in length of the day (ICGV 88438,ICGV 86564,ICGMS 42), where as in some genotypes there was an increase in peg addition rate with rise in day length (TAG 24,NC Ac 17090,ICGV 86015,ICGV 87128).

4.4 Effect of photoperiod on physiological parameters such as light interception, photosynthesis and translocation of current photosynthates:

4.4.1. Light interception :

Light interception values showed a consistent increase from 40 DAS to final harvest, which ranged from 58.3 to 79.6(Table-21a). The photoperiod treatments remained significant only at 40, 100 and 120 DAS, though there was trend for increase in interception was observed from short day (SD) to long day (LD) at all the stages. The genotypic variations were significant at 40,60,80 and 100 DAS. But, the interaction between genotype and photoperiod was significant at 40 and 60 DAS only.

Table : 19 Specific leaf area(SLA) under short day(SD),normal day(ND),long day(LD) photoperiodic conditions in groundnut.

DAS	Genotype	SLA			
		SD	ND	LD	Mean
40	ICGV 88438	173.7	168	161.7	167.8
	ICGV 87128	194.7	168.7	150.7	171.3
	ICGV 86015	199.7	177	161.3	179.3
	ICGMS 42	189.7	169	170.7	176.4
	TMV 2	205	172.3	158	178.4
	ICGV 86031	181	141	144.7	155.6
	ICGV 86564	180	163.7	160.3	168
	TAG 24	190.3	172.3	169	177.2
	NC Ac 17090	235.3	181	166	194.1
	Mean	194.4	168.1	160.3	
	SEM(±)	4.28			
	CV%	9.3			
60	ICGV 88438	235.3	190.7	208.7	211.6
	ICGV 87128	231	180	199.7	203.6
	ICGV 86015	230.7	179.3	196.3	202.1
	ICGMS 42	226.7	195.3	198.3	206.8
	TMV 2	244.3	202.7	215	220.7
	ICGV 86031	200.3	145.3	162.7	169.4
	ICGV 86564	226	181	201	202.7
	TAG 24	217.7	163	184.3	188.3
	NC Ac 17090	251.7	205.7	215.3	224.2
	Mean	229.3	182.6	197.9	
	SEM(±)	3.71			
	CV%	6			
80	ICGV 88438	218.3	188	201.7	202.7
	ICGV 87128	216.7	177.3	181.3	191.8
	ICGV 86015	214	186.3	183.7	194.7
	ICGMS 42	206	192	215.7	204.6
	TMV 2	223.7	193.3	190.3	202.4
	ICGV 86031	168	167.3	158	164.4
	ICGV 86564	216	195.3	200.3	203.9
	TAG 24	200	167.7	170	179.2
	NC Ac 17090	231.3	188.3	199.7	206.4
	Mean	210.4	184	189	
	SEM(±)	3.4			
	CV%	5.4			
100	ICGV 88438	199.3	164	154	172.4
	ICGV 87128	201.7	152	147.3	167
	ICGV 86015	179.7	167	167.7	171.4
	ICGMS 42	183.7	161	158.3	167.7
	TMV 2	186.3	165.3	169.7	173.8
	ICGV 86031	165	144	119.7	142.9
	ICGV 86564	197.3	157.3	155	169.9
	TAG 24	187.7	155.7	143.7	162.3
	NC Ac 17090	192	152	123	155.7
	Mean	188.1	157.6	148.7	
	SEM(±)	3.31			
	CV%	8.1			
FH	ICGV 88438	x	128.7	136.3	132.5
	ICGMS 42	x	128.3	141.7	135
	ICGV 86031	x	125.7	128	126.8
	Mean		127.6	135.3	
	SEM(±)	2.79			
	CV%	15.3			

Table : 19 continued...

Analysis of variance			
DAS	**Source of variation**	**d.f**	**SLA**
40	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
60	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
80	**MT (Photoperiods)**	**2**	*
	ST (Genotypes)	**8**	**
	MT x ST	**16**	*
100	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
FH	**MT (Photoperiods)**	**1**	NS
	ST (Genotypes)	**2**	NS
	MT x ST	**2**	NS

* significant at P=0.05
* * significant P=0.01

Table : 19 continued...

Analysis of variance			
DAS	**Source of variation**	**d.f**	**SLA**
40	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
60	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
80	**MT (Photoperiods)**	**2**	*
	ST (Genotypes)	**8**	**
	MT x ST	**16**	*
100	**MT (Photoperiods)**	**2**	**
	ST (Genotypes)	**8**	**
	MT x ST	**16**	NS
FH	**MT (Photoperiods)**	**1**	NS
	ST (Genotypes)	**2**	NS
	MT x ST	**2**	NS

* significant at P=0.05
* * significant P=0.01

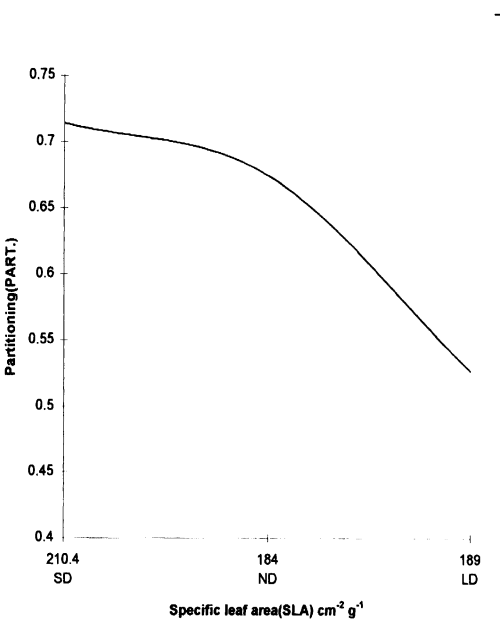


Fig : 7 Effect of short day(SD),normal day(ND),long day(LD) photoperiods on patitioning(PART.) and on specific leaf area(SLA)

Table: 20 Peg addition rates (PGAR) gm m-2 d-1 under Shortday(SD), Normalday(ND),Longday(LD) photoperiod conditions

Genotype	SD	ND	LD	Mean
ICGV 88438	14.18	9.3	8.69	**10.72**
ICGV 87128	12.81	13.14	17.62	**14.52**
ICGV 86015	12.54	13.05	16.67	**14.09**
ICGMS 42	16.11	11.88	8	**12**
TMV 2	17.17	13.75	13.67	**14.87**
ICGV 86031	10.81	14.22	11.91	**12.31**
ICGV 86564	11.41	10.91	7.62	**9.98**
TAG 24	9.87	10.8	14.78	**11.82**
NC Ac 17090	7.57	10.14	12.9	**10.2**
Mean	**12.5**	**11.91**	**12.43**	
SEM±		**0.538**		
CV%		**2.111**		

Analysis of variance		
Source of variation	**d.f**	**PGAR**
MT (Photoperiods)	2	NS
ST (Genotypes)	8	**
MT x ST	16	**

* significant at P=0.05
* * significant P=0.01

Table :21a Light interception by genotypes at 40,60,80,100 DAS(Days after sowing) under Short day(SD), normal day(ND), Long day(LD) phtoperiod conditions in groundnut.

	40DAS				60DAS				80DAS				100DAS			
Genotype	**SD**	**ND**	**LD**	**Mean**	**SD**	**ND**	**LD**	**Mean**	**SD**	**ND**	**LD**	**mean**	**SD**	**ND**	**LD**	**Mean**
ICGV 88438	61.37	57.54	61.92	**60.28**	59.36	63.45	63.27	**62.03**	64.93	66.79	65.42	**65.72**	69.95	79.52	82.31	**77.26**
ICGV 87128	59.15	60.23	63.87	**61.08**	62.03	61.57	65.7	**63.1**	65.66	65.93	69.29	**66.96**	74.68	73.79	77.81	**75.43**
ICGV 86015	61.17	64.96	60.32	**62.15**	60.99	66.99	63.04	**63.67**	61.35	68.67	67.55	**65.86**	69.74	73.98	77.96	**73.89**
ICGMS 42	62.51	60	65.66	**62.72**	64.56	64.6	68.04	**65.73**	67.76	69.07	71.31	**69.38**	71.99	78.62	80.92	**77.17**
TMV 2	54.95	59.81	65.92	**60.23**	61.15	61.81	66.69	**63.21**	64.66	65.42	68.88	**66.32**	72.6	76.37	82.33	**77.1**
ICGV 86031	63.7	58.28	59.38	**60.45**	60.65	64.65	60.9	**62.07**	59.05	67.79	67.22	**64.69**	72.92	80.65	69.45	**74.34**
ICGV 86564	60.01	62.73	59.35	**60.69**	61.81	68.32	61.13	**63.75**	65.45	71.81	65.83	**67.63**	73.12	83.46	81.45	**79.34**
TAG 24	41.74	44.04	46.15	**43.98**	42.51	46.34	51.57	**46.81**	46.34	52.34	53.74	**50.81**	48.83	55.76	61.81	**55.46**
NC Ac 17090	60.16	67.77	60.91	**62.95**	60.9	68.59	67.22	**65.57**	**65.94**	**70.64**	71.31	**69.3**	71.99	79.04	82.67	**77.9**
Mean	**58.31**	**59.48**	**60.39**		**59.33**	**62.92**	**63.06**		**62.35**	**66.47**	**66.73**		**69.53**	**75.69**	**77.41**	
SEM(±)		**0.124**				**0.94**				**1.56**				**0.484**		
CV%		**4.1**				**5**				**7.5**				**6.4**		

Analysis of variance					
Source of variation	**d.f**	**40DAS**	**60DAS**	**80DAS**	**100DAS**
MT (Photoperiods)	2	**	NS	NS	**
ST (Genotypes)	8	**	**	**	**
MT x ST	16	**	*	NS	NS

* significant at P=0.05

* * significant P=0.01

Table :21b Light interception by genotypes at 120 DAS(Days after sowing) and after final harvest(FH) under Short day(SD), normal day(ND), Long day(LD) photperiod conditions.

	120DAS			FH		
Genotype	**ND**	**LD**	**Mean**	**ND**	**LD**	**Mean**
ICGV 86564	77.19	80.03	**78.61**	77.1	84.3	**80.7**
ICGV 88438	75.05	79.52	**77.28**	77.9	79.5	**78.7**
ICGV 42	77.19	84.26	**80.73**	75.2	78.1	**76.6**
ICGV 86031	77.12	72.94	**75.03**	75	76.7	**75.9**
Mean	**76.64**	**79.19**		**76.3**	**79.6**	
SEM(±)		**0.358**			**0.85**	
CV%		**5.4**			**6.7**	

Analysis of variance			
Source of variation	**d.f**	**Fifth**	**Fh**
MT (Photoperiods)	1	*	NS
ST (Genotypes)	3	NS	NS
MT x ST	3	NS	NS

* significant at P=0.05

4.4.1.1 Radiation use efficiency(RUE) :

RUE ranged from 0.870 g MJ^{-1} m^{-2} to 0.615 g MJ^{-1} m^{2} (Table-22). The photoperiodic effects on RUE were on par with each other. The genotype ICGV 88438 recorded the highest RUE 0.838 g MJ^{-1} m^{-2} and the ICGV 87128 the least 0.651 g MJ^{-1} m^{-2} and others in between.

4.4.2. Photosynthesis(Pn) :

4.4.2.1 Leaf photosynthetic rates :

The Pn Values across treatments were significant from 60 DAS onwards to final harvest (Table-22). From the Fig-7, it was clear that irrespective of treatments Pn declined from 60 DAS onwards and this was very prominent in long day treatment. At 60 DAS, normal day has slightly higher Pn rate than in short day. The photoperiod x genotype interaction was significant, with short day and normal day varying significantly from long day. The genotypic difference was also significantly different and the rates varied from 6.44 µmol m^{-2} s^{-1} (final harvest) to 18.41µmol m^{-2} s^{-1} (60 DAS).

4.4.2.2 Surface leaf temperatures :

Photoperiods had significant influence on surface leaf temperatures (Table-23). The surface leaf temperatures of long day varied significantly from short day and normal day (Fig-9). Short day surface leaf temperatures were almost consistent throughout the growth period. Long day surface leaf temperatures declined sharply after 60 DAS onwards. The photoperiods x genotype interaction were significant at 40, 60 and 80 DAS. Genotypic variance was also found to be significant at 40, 100 and final harvest but not at 60 and 80 DAS.

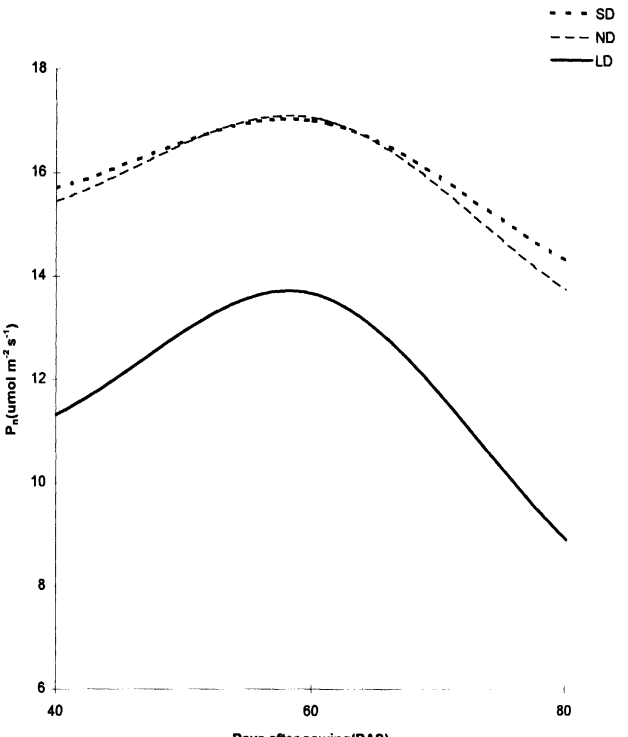


Fig : 8 Effect of photoperiod on leaf photosynthetic rates(Pn)

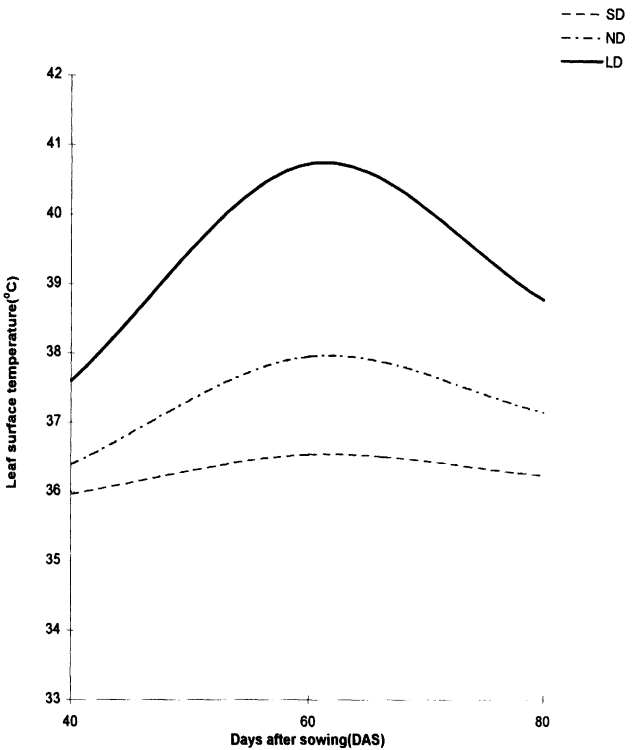


Fig : 9 Leaf surface temperature variation along short day(SD),Normal day(ND),Long day(LD) photoperiodic conditions

Table :22 Effect of short day(SD),normal day(ND),long day(LD) photoperiod on radiation use efficiency(RUE)g MJ^{-1} m^{-2} in groundnut.

Genotypes	SD	ND	LD	Mean
ICGV 88438	0.814	0.831	0.870	**0.838**
ICGV 87128	0.633	0.640	0.680	**0.651**
ICGV 86015	0.772	0.733	0.711	**0.739**
ICGMS 42	0.781	0.721	0.802	**0.768**
TMV 2	0.711	0.709	0.749	**0.723**
ICGV 86031	0.698	0.622	0.765	**0.695**
ICGV 86564	0.775	0.625	0.640	**0.680**
TAG 24	0.681	0.804	0.798	**0.761**
NC Ac 17090	0.696	0.615	0.743	**0.685**
Mean	**0.729**	**0.700**	**0.751**	

Table: 23 Effect of short day (SD), normal day (ND), long day (LD) photoperiod on leaf photsynthetic rates(Pn), Leaf temperatures(Lftemp) in groundnut.

S	Genotype	Pn				Lftemp			
		SD	ND	LD	Mean	SD	ND	LD	Mean
40	ICGV 87128	13.63	16.91	15.62	15.39	34.51	36.75	36.69	35.98
	ICGV 86015	16.32	14.41	15.55	15.43	35.99	37.8	37.69	37.16
	ICGMS 42	19.76	16.28	12.06	16.03	35.59	34.83	37.15	35.86
	TMV 2	15.13	19.3	11.35	15.26	36.48	36.68	38.64	37.26
	ICGV 86564	18.71	17.13	9.47	15.10	36.44	36.44	38.44	37.11
	NC Ac 17090	18.65	18.52	18.06	18.41	36.78	35.83	37	36.54
	Mean	17.03	17.09	13.68		35.96	36.39	37.6	
	Se M		0.843			0.215			
	CV%		22.6			2.4			
60	ICGV 87128	11.98	14	5.63	10.54	32.71	37.2	43.18	37.7
	ICGV 86015	13.4	14.26	3.72	10.46	35.46	36.83	41.73	38.01
	ICGMS 42	15.03	15.39	9.78	13.4	37.63	39.26	40.72	39.2
	TMV 2	16.79	13.67	10.82	13.76	37.61	38.12	39.56	38.43
	ICGV 86564	15.9	10.77	7.78	11.48	37.96	38.38	39.63	38.66
	NC Ac 17090	13.05	14.67	15.78	14.5	37.89	37.97	39.63	38.5
	Mean	14.36	13.79	8.92		36.54	37.96	40.74	
	Se M	0.865				0.181			
	CV%	23.2				3			
80	ICGV 87128	12.82	15.46	10.63	12.97	33.61	36.96	39.92	36.83
	ICGV 86015	14.87	14.32	9.63	12.94	35.74	37.31	39.7	37.59
	ICGMS 42	17.38	15.84	10.92	14.71	36.6	37.05	38.95	37.53
	TMV 2	15.97	16.49	11.09	14.52	37.05	37.41	39.09	37.85
	ICGV 86564	17.3	13.93	8.61	13.28	37.21	37.41	39.03	37.88
	NC Ac 17090	15.84	16.58	17.02	16.48	37.34	36.89	36.18	36.8
	Mean	15.7	15.44	11.32		36.26	37.17	38.81	
	Se M		0.895				0.056		
	CV%		13.6				2.6		
100	ICGV 86015	x	4.89	2.4	3.65	x	39.93	44.22	42.08
	ICGMS 42	x	8.15	2.67	5.41	x	39.71	42.94	41.33
	ICGV 86564	x	9.13	3.87	6.5	x	35.02	40.88	37.95
	NC Ac 17090	x	14.6	4.32	9.46	x	37.24	40.9	39.07
	Mean	x	9.19	3.32		x	37.98	42.23	
	Se M	0.67				0.239			
	CV%	31				2.8			
FH	ICGV 86564	x	10.95	1.92	6.44	x	38.68	43.76	41.22
	NC Ac 17090	x	9.84	5.99	7.91	x	38.09	39.17	38.63
	Mean	x	10.4	3.95			38.39	41.47	
	Se M		0.492				0.409		
	CV%		21.6				2.4		

		Analysis of variance		
DAS	Source of variation	d.f	Pn	Lftemp
40	MT (Photoperiods)	2	NS	*
	ST (Genotypes)	8	NS	**
	MT x ST	16	NS	*
60	MT (Photoperiods)	2	*	**
	ST (Genotypes)	8	*	NS
	MT x ST	16	*	**
80	MT (Photoperiods)	2	*	**
	ST (Genotypes)	8	**	NS
	MT x ST	16	*	**
100	MT (Photoperiods)	1	*	**
	ST (Genotypes)	3	**	**
	MT x ST	3	*	NS
FH	MT (Photoperiods)	1	*	*
	ST (Genotypes)	1	NS	*
	MT x ST	1	*	*

* significant at P=0.05

* * significant P=0.01

4.4.3 Translocation:

The translocation studies were done on 71 days old crop for four selected Genotypes (ICGV 87128,ICGMS 42,TMV 2,NC Ac17090). During the active pod filling phase, The ^{14}C was fed to fully expanded, mature 3rd or 4th leaf from the apex of main axis and the Proportion of the ^{14}C realised in various vegetative and reproductive [pegs (aerial and Subterranean pegs) and pods (immature and mature) and roots] growing organs. After feeding ^{14}C the plants were harvested after 48 hr and the ^{14}C was measured as described in material and methods, page no, in various organs of the plant.

The analysis has clearly shown that there was more ^{14}C in leaves and stems in long day treatment (Table-24) for example while the leaves in SD contained 25% of total ^{14}C and the leaves in long day had 34.5% of total ^{14}C. Similarly in stems in short day 19.85 was present as compared to 37.4% in long days. This effect was consistent for all the four genotypes .It was apparent that the ^{14}C label was more in stems in long days than that in the leaves in the short day.

Under short day conditions the ^{14}C translocated to pods was greater (63.5%) followed by leaves (25%), stems (19.8%) and roots (11.6%) (Fig-10a and10 b). Interestingly under long day treatment only 26% of ^{14}C was present in pods and greatest among all ^{14}C labelled was realised in stems (37.4%), leaves (34.5%) and roots (17.4%). The overall analysis clearly showed that short day conditions favoured translocation of current photosynthates to pods, while long day conditions favoured translocation of photosynthates to vegetative organs and roots. The ^{14}C translocated to pegs were similar in both short day and long day conditions. The greater translocation of ^{14}C to leaves, stems and roots under long day conditions was consistent and significant in all the four genotypes studied. However, the genotypic differences were apparent and significant in ^{14}C

Table : 24 Partitioning of ^{14}C into different organs under Short day(SD),Normal day(ND),Long day(LD) photperiodic conditions in groundnut.

Genotype	Leaf			Stem			Root			Peg			Pod		
	SD	LD	Mean	SD	LD	Mean	SD	LD	Mean	SD	LD	Mean	SD	LD	Mean
ICGV 87128	25.6	27.9	**26.7**	15.3	29	**22.1**	11.05	21.42	**16.23**	2.83	3.47	**3.15**	54.9	44.7	**49.8**
ICGMS 42	26.7	37.4	**32**	24.8	41.3	**33.1**	16.02	22.52	**19.27**	3.84	1.55	**2.69**	52.7	1.1	**26.9**
TMV 2	21.4	29.7	**25.5**	19.9	36.4	**28.2**	9.56	14.78	**12.17**	2.45	3.3	**2.88**	52.2	35	**43.6**
NC Ac 17090	26.3	43.1	**34.7**	19	42.9	**30.9**	9.83	11.82	**10.83**	2.21	1.36	**1.79**	54.5	0	**27**
Mean	**25**	**34.5**		**19.8**	**37.4**		**11.61**	**17.64**		**2.84**	**2.42**		**53.6**	**20.1**	
SEM(±)	**0.94**			**1.65**			**1.387**			**0.787**			**2.44**		
CV%	**21.9**			**22.7**			**26.2**			**74.2**			**18.9**		

Analysis of variance						
Source of variation	d.f	Leaf	Stem	Root	Peg	Pod
MT (Photoperiods)	1	**	**	NS	NS	**
ST (Genotypes)	3	*	*	**	NS	**
MT x ST	3	NS	NS	NS	NS	**

* significant at P=0.05

* * significant at P=0.01

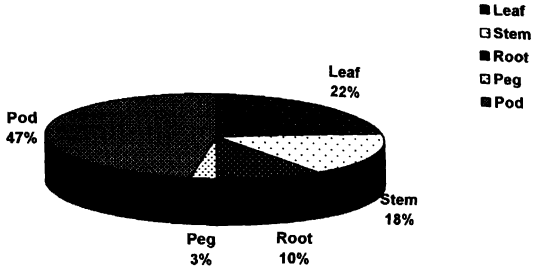


Fig :10a Effect of short day(SD) photoperiod on ^{14}C partitioning

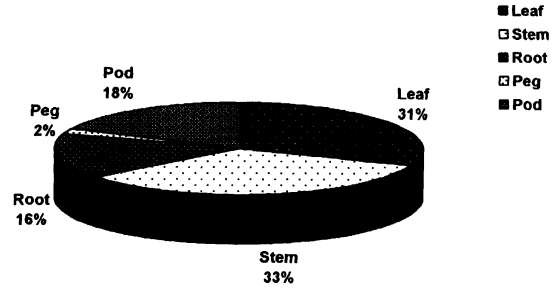
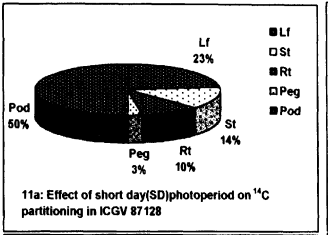


Fig :10b Effect of Long day(LD) photoperiod on ^{14}C partitioning

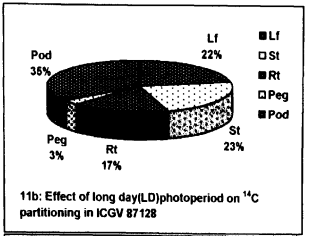
translocation. For example NC Ac 17090 and ICGMS 42 under long day conditions translocation was greatest to leaves and stems (Fig-11c, 11d, 11g, 11h) while translocation of ^{14}C was zero to pods. The relative insensitivity to photoperiod was apparent in ICGV 87128 and TMV 2 in which the translocation of ^{14}C to pods was more or less the same under long day conditions (Fig-11a, 11b, 11e, 11f). This data also indicate the genotypic variation in translocation of current photosynthate to roots. For example the ^{14}C realised in the roots was greatest for ICGMS 42 compared to NC Ac 17090 under both short day and long day conditions. Further, this analysis has also shown that the pegs are relatively weak in competing for current photsynthates compared to the pods and photoperiod had little influence in the translocation of ^{14}C to pegs.

4.5 Effect of photoperiod on protein profiles:

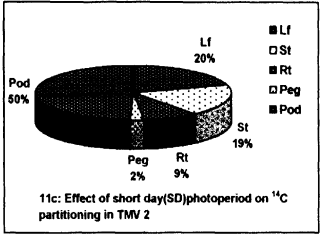
The data on photoperiod influence on protein profiles are presented in Table-25. Short day photoperiods induced new protein bands 45.7 and 41 kDa in ICGMS 42 and NC Ac 17090 (highly sensitive) and ICGV 86564(moderately sensitive), but these were absent in long days (Table-25) while the insensitive genotype TMV 2 showed no new protein addition. But genotypes differed quantitatively across the photoperiods. In ICGMS 42 in short day, 72.8 kDa was prominent and under long day it was 25.1 kDa (Plate-10). Similarly in NC Ac 17090 under short day 72.8kDa and under long day 24.2 kDa was prominent (Table-25). In case of ICGV 86564, 69.1 kDa under short day and 22.3 and 14.1 kDa under long day were prominent (Plate-10). In case of TMV 2 these were at close ranges between treatments, i.e. 24.2 and 22.3 kDa under short day and long day respectively were prominent.



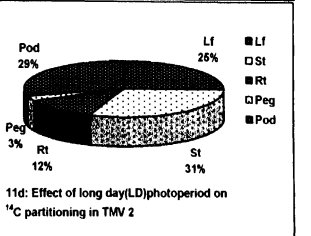
11a: Effect of short day(SD)photoperiod on ^{14}C partitioning in ICGV 87128



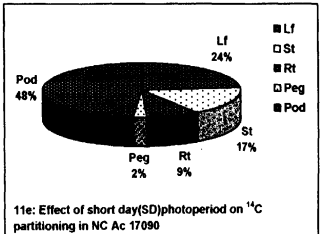
11b: Effect of long day(LD)photoperiod on ^{14}C partitioning in ICGV 87128



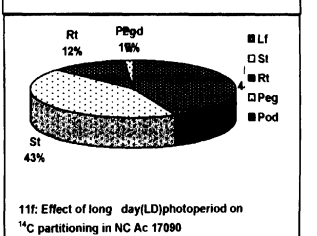
11c: Effect of short day(SD)photoperiod on ^{14}C partitioning in TMV 2



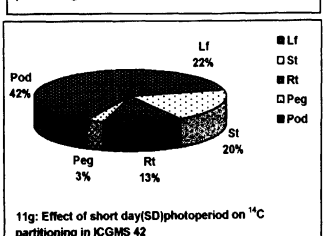
11d: Effect of long day(LD)photoperiod on ^{14}C partitioning in TMV 2



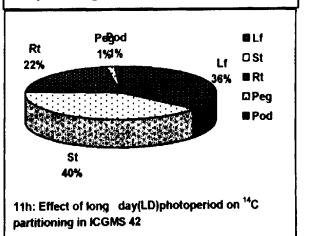
11e: Effect of short day(SD)photoperiod on ^{14}C partitioning in NC Ac 17090



11f: Effect of long day(LD)photoperiod on ^{14}C partitioning in NC Ac 17090



11g: Effect of short day(SD)photoperiod on ^{14}C partitioning in ICGMS 42



11h: Effect of long day(LD)photoperiod on ^{14}C partitioning in ICGMS 42

Table:25 Qualitative changes in protein profiles due to photoperiodic sensitivity.

Genotype	Characteristic of new protein bands(kDa)		Photoperiodic sensitivity
	Short day (SD)	Long day (LD)	
ICGMS 42	45.7 & 41	x	Highly sensitive
NC Ac 17090	45.7 & 42	x	Highly sensitive
TMV 2	x	x	Insensitive
ICGV 86564	45.7 & 42	x	Moderately sensitive

Table:26 Quantitative changes in protein profiles due to photoperiodic sensitivity.

Genotype	Quantitative differenceof protein bands		Photoperiodic sensitivity
	Short day (SD)	Long day (LD)	
ICGMS 42	72.8	25.1	Highly sensitive
NC Ac 17090	72.8	24.2	Highly sensitive
TMV 2	24.2	22.3	Insensitive
ICGV 86564	69.1	22.3 &14.1	Moderately sensitive

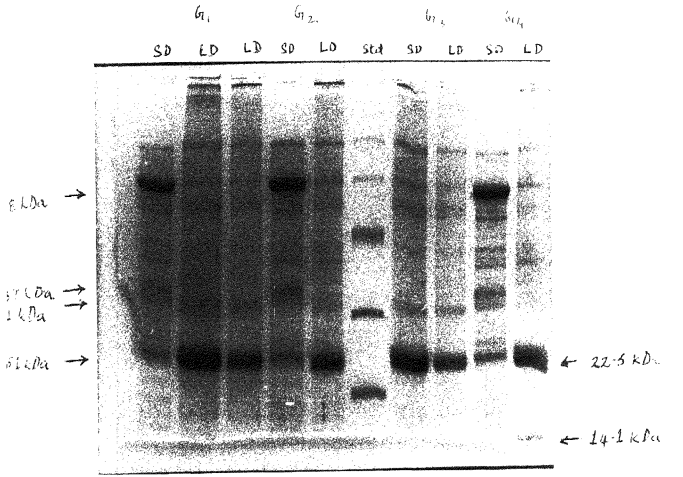


Fig: Effect of short day (Sd), long day (LD) photoperiods on groundnut apical meristem protein profiles

CHAPTER V

Discussion and conclusion

Groundnut is an important commercial, oil seed and food crop grown in wide range of climate extending from 40^0 N to 40^0 S latitude in the world. In India groundnut crop is grown from 8^0N to 28^0S latitude, which is characterised by significant variation in environment. In addition to various major environmental factors such as temperature, water deficit and soil type etc., photoperiod is yet another very important environmental factor, which influence adaptation of groundnuts. A large genotype x environment interaction for groundnut has been reported by a number of researchers (Branch and Hiberland, 1989). This large genotype x environment interaction is a major underlying factor for unstable performance of high yielding, improved genotypes across varied environments. When water deficit is not a limiting factor, temperature and photoperiod become the major climatic factor that influence groundnut genotypes behaviour (Leong and Ong, 1983, Witzenberger *et al.*, 1985, Bell *et al.*, 1991).

The present study aims at investigating the role of photoperiod on crop phenology, growth and partitioning of photosynthates in nine selected genotypes growing under three photoperiod regimes short day (SD), normal day (ND), long day (LD). The details of genotypes and method of imposition of photoperiod regimes has been described in detail in material and methods.

Most of the studies on effects of photoperiodism on plant species concentrate on time taken for initiation for flowering. Thus, as such traditionally

photoperiodism was associated with process of flower induction. In this sense groundnut has been classified as a day neutral plant with respect to time to flower (Bunting and, 1980, Leong and Ong, 1983). Almost all the earlier studies works on photoperiod responses in groundnut have been limited to growth chambers and very rarely, these investigation were rarely, these investigations were continued up to the end of the crops life. The present investigation was carried out so as to have a comprehensive study of photoperiod effects. In the field the present investigation showed that days to 50% emergence (DEM) was not influenced by photoperiod. Thermal time to first flower appearance occurred by 38 days after sowing in all photoperiod regimes Suggested that temperature rather than photoperiod control flowering time. These results are in support of the studies by various workers (Witzenberger *et al.*, 1985, Bagnall and king, 1991,Bell *et al.*, 1991, Nigam *et al.*, 1994). However, genotypic differences were significant within a given photoperiod regime. For example TAG 24, NC Ac 17090 were the earliest to flower, where as in other genotypes, first flower appearance was delayed by 3 to 10 days. The influence of temperature on the crop phenology is well documented in literature (Leong and Ong, 1983, Bagnall and King, 1991, Cox, 1979). To avoid confounding effects of temperature for various phenological events were calculated in thermal time in the present study assuming 10^0 C as the T_b (base temperature) for genotypes under study (Mohamed *et al.*, 1984). As mentioned earlier, thermal time for flower initiation was also not influenced by the photoperiod. However, genotypic differences in thermal time requirement for flower appearance varied significantly from 380^0 Cd to 500^0 Cd. Photoperiod did not influence days to 50% flowering, but genotypic difference were significant. This well supported by (Bell *et al.*, 1991, ICRISAT annual report, 1988).

However, Photoperiod treatments influenced rates of flower addition per unit thermal time with SD showing 0.092 flower per $^{0}Cd^{-1}$ compared to ND (0.081 flower $^{0}Cd^{-1}$) and 0.071 flower $^{0}Cd^{-1}$ in LD. There were very limited studies on this aspect, though there were several studies on other aspects of flowering. This aspect of our study is very important on the context of early maturing studies by (Upadhyaya *et al.*, 1994).

Thermal time to accumulation of first 25 flowers was greatly influenced by photoperiods. Thermal time taken for accumulation of 25 flowers in SD was 743.1 ^{0}Cd compared 781.4 ^{0}Cd ND and 842.9 ^{0}Cd LD. These results indicate the photoperiod (SD) may be influencing the genes associated with early maturity hence would have a lot of practical implication in genetic enhancement for early maturity in groundnut. In the present investigation, it was clear that SD promoting higher rate of flowering with less thermal time requirement for accumulation for 25 flowers.

The total number of flowers produced by genotypes also varied with photoperiod regimes. In SD the mean cumulative flower counts per plant were lower (47) compared to 70 in ND and LD. There is conflicting information about the effect of photoperiod on the flower addition. For example Emery *et al.* (1981) have shown that the rate of flower addition was faster in short day and it slowed down after reaching a peak, where as the LD resulted in continuous addition of flowers through out the growing season. Bagnall and King, 1991, while studying the effect of photoperiod in two genotypes, i.e., Early bunch, Robut 33-1 they found that SD promoted flowering in both the cultivars compared to continuous long days. In their cumulative flower number after 24 days of flowering were greater in SD than in LD by 70 to 80% in both the cultivars. In the present study cumulative flowering across the photoperiod treatments showed a

steady increase, although in SD the rate of increase was higher and cessation was quicker (Fig-12a, 12b, 12c, 12d, 12e, 12f). ND and LD there were continuous flowering until the end of the season. Similarly, the data on fresh flower appearance counted on daily basis showed higher peaks in SD quite early as compared to ND and LD (fig-12g, 12h, 12I, 12j). For NC Ac 17090 there was distinct pattern of cumulative flowering among the treatments in short day followed by ND and LD. But, the flower appearing was quite consistent with similar peaks in TMV 2, TAG 24, ICGV 86031, ICGV 87128, and ICGV 86015. The figures were of similar trend as that of Bell and Harch (1991).

The photoperiod regimes had a clear impact on the effective period of flowering (the time difference between flowering initiation and cessation). The effective period of flowering was 45 days in SD while it was 73 days in ND and 72 days in LD. Although earlier works have shown that photoperiod did not influence flowering, there is little information about effect of photperiod on pattern of flowering. Wynne and Emery (1974) found that SD resulted in production of fewer flowers than plants growing in LD. Over all analysis on influence of photoperiod on flowering suggested the following,

The important physiological events like time to first flower appearance, time to 50% flowering were not influenced by the photoperiod, however the number of flowers produced and rate of flower produced per unit thermal time were significantly influenced under SD. Plant physiological studies on crop have shown that the flowering is triggered by hormonal mechanisms (Ethylene production) where as rate of flowering is both influenced by both hormonal regulation and mobilisation of current photosynthate reserve (Wiiliams and Rao, 1983) Present studies have clearly shown that hormonal

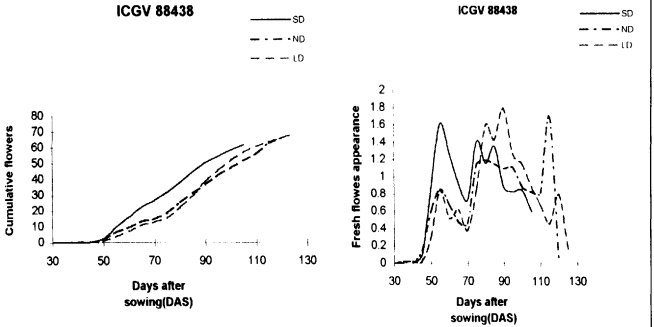


fig :12a Cumulative flowering under short day(SD),normal day(ND)long day(LD) photoperiodic conditions

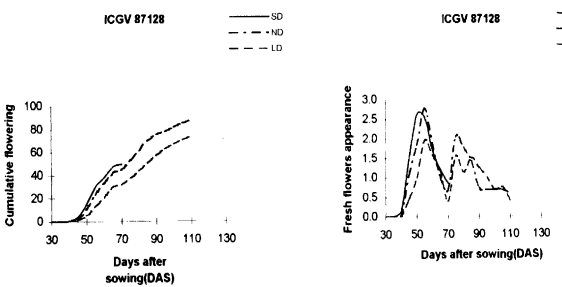
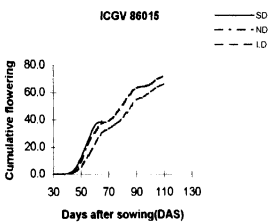


Fig : 12b Fresh flowers under short day(SD),normal day(ND) long day(LD) photoperiod conditions



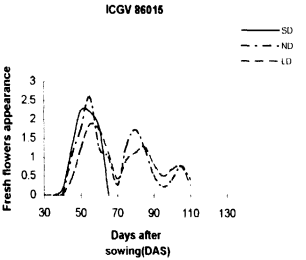
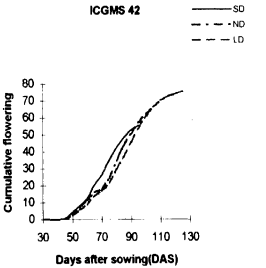


fig : 12c Cumulative flowering under short day(SD),normal day(ND)long day(LD) photoperiodic



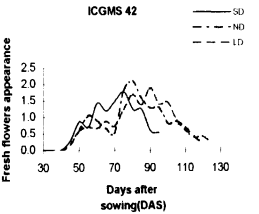
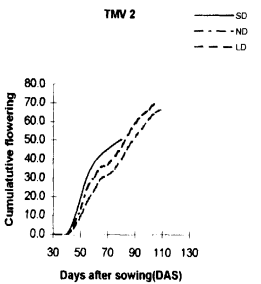


Fig : 12 d Fresh flowers under short day(SD),normal day(ND) long day(LD) photoperiod conditions



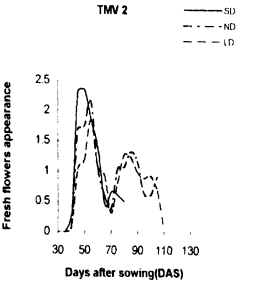
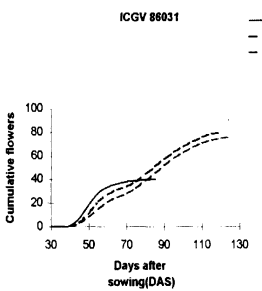


fig : 12e Cumulative flowering under short day(SD),normal day(ND)long day(LD) photoperiodic conditions



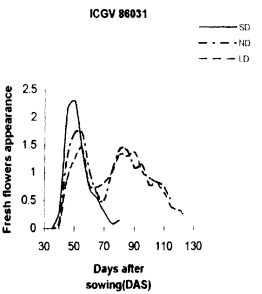
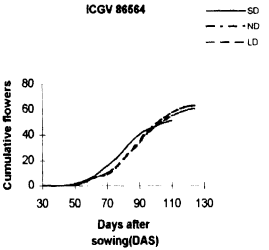


Fig : 12f Fresh flowers under short day(SD),normal day(ND) long day(LD) photoperiod conditions



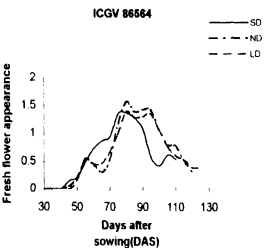
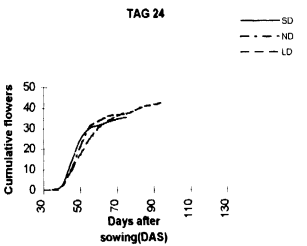


fig : 12g Cumulative flowering under short day(SD),normal day(ND),long day(LD) photoperiodic



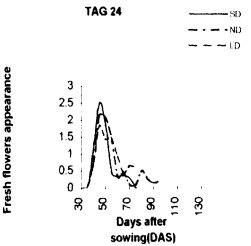


Fig : 12h Fresh flowers under short day(SD),normal day(ND) long day(LD) photoperiod conditions

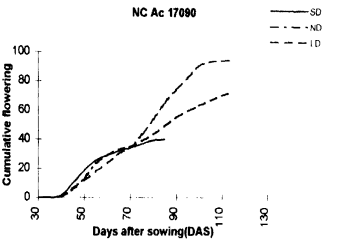


fig :12i Cumulative flowering under short day(SD),normal day(ND)long day(LD) photoperiodic

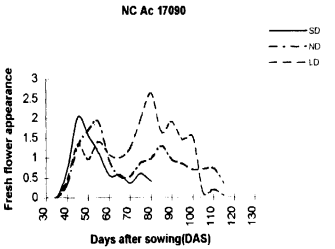


Fig : 12 j Fresh flowers under short day(SD),normal day(ND) long day(LD) photoperiod conditions

regulation played an important role under SD which led to greater rate of flower production within a short span of time. This finding is amply supported by the shorter thermal time taken for produce 25 flowers under three photoperiod regimes (Table-9). This investigation has clearly shown that, photoperiod regime had influenced on hormonal balance. It is possible that SD treatment may be promoting hormones like Cytokinins, Abscissic acid (ABA). Flohr (1989) suggested that LD increased active Gibberellin (GA) metabolism, which in reduced reproductive development while promoting vegetative growth in peanuts. It is possible that the GA to ABA ratio might be higher under LD condition. Early promotion of flowering and early cessation of flowers under SD might be due to the influence of SD flowering hormones. However, these hypotheses further basic studies to understand the molecular basis of photoperiod effects in groundnut.

Crop growth rates and partitioning:

Crop growth rate (CGR):

Sequential growth analysis of crop at different growth stages helped to understand the effects of photoperiod on the processes controlling yield and its components. A novel way is to use the physiological growth models to understand and interpret the yield differences occurring due to various treatment effects. The pod yield (Y) is function of crop growth rate (CGR) and duration of reproductive period (D) and the proportion of dry matter partitioned into pods over reproductive period (P).

Thus, **Y = CGR X D X P**

The growth analysis conducted in this study helped to compute the components, which in turn were used to investigate the photoperiod and genotype interaction. It was apparent from results (Table-10) that CGR values were lower in SD (8.3 g m^{-2} d^{-1}) compared with ND (13.3 g m^{-2} d^{-1}) and LD (10.3 g m^{-2} d^{-1}). Lower CGR values in SD were mainly due to lower interception of radiation by the foliage and apparently evident by lower LAI.The plants in SD were shorter and compact than those in ND and LD. This was supported by lower main stem length in SD (11cm) compared to ND (14cm) and LD (18.7cm) at 80 DAS. Leaf area index (LAI) were 2.1 in SD, 3.1 and 3.3 in ND and LD respectively. This is supported by finding of Wynne *et al.* (1973) and Flohr, (1990) who showed that plant height and LAI increased under LD. There is limited information on the effect of photoperiod on groundnut in canopy conditions, since most of the earlier studies dealt with isolated plants grown in controlled environmental condition in growth chambers. Earlier studies conducted at ICRISAT (Witzenberger *et al.*, 1988, Flohr, 1990) were dealt with comparisons of ND and LD only. They did not include the SD. Thus, the present study is first of its kind about the investigation on the effect of photoperiods on groundnut under canopy conditions in the field.

The works of Flohr (1990) shown that CGR rates were not different between ND and LD. These results are in contrast with that of present investigation where in the CGR was lower in LD compared to ND.

There were significant genotypic differences, which resulted in genotypic x photperiod interaction. Some genotypes showed stable or marginal change across photoperiod regimes, while some showed significant differences in the growth rates

across photoperiod regimes, it should be noted that. The variation in CGR due to genotypes or photoperiod regimes could also arise due to varied light interception by the canopy. In fact the data has clearly shown that light interception (LI) were lower in SD compared to ND and LD across various growth phases. The LI at DAS, ranged from 58 to 69 %in SD, 59 to 76 %in ND and 60 to 79% in LD. The physiological analysis of Radiation use efficiency (RUE) has shown that photoperiod regimes had only marginal effects on RUE (Table-22), which indicated that the mechanism of photosynthesis was not influenced by photoperiod treatments and the observed difference in CGR are mostly attribute to radiation interception by the canopy (Fig-13).

Vegetative growth rate (VGR):

Present study had very clearly shown that there was a in linear increase in VGR from 1.2 g m^{-2} d^{-1} in SD to 3.6 g m^{-2} d^{-1} as the day length increased (Table-11). This trend of increase VGR with photoperiod was seen in most of the genotypes, although the pattern of the change varied amongst genotypes. For example ICGV 87128 and ICGV 88438 showed very little change in VGR across photoperiod regimes. Where as ICGMS 42, NC Ac 17090 showed linear increase in VGR with increase in day length. There were also some genotypes, which showed marginal change between SD and ND, but greater change in LD. This analysis supports the earlier observation that the LD treatment may influence the hormones, which associated with the vegetative growth and development in general groundnuts (Flohr, 1989). However in some genotypes there was a little influence of photoperiod on vegetative growth promotion. Further studies are needed to examine the effects of photoperiod on growth hormone regulation in groundnut to interpret the genotype x photoperiod interaction.

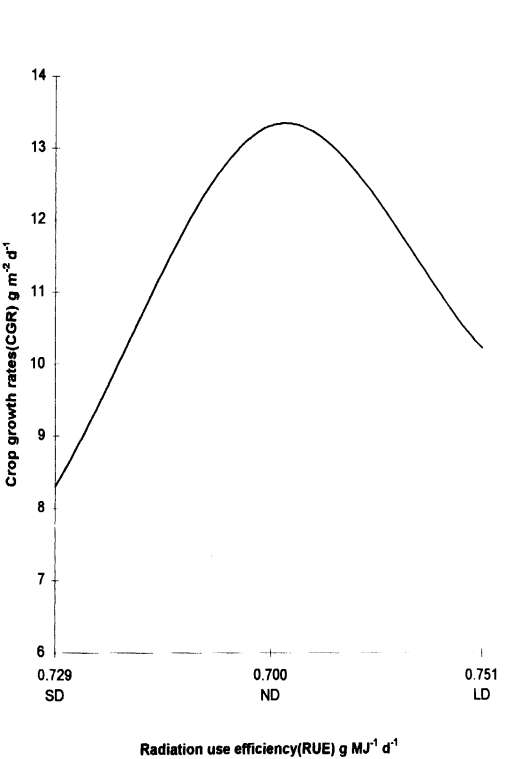


Fig :13 Radition use efficiency(RUE) and crop growth rates(CGR) under short day(SD),normal day(ND),long day(LD) photoperiod conditions

Pod growth rates (PGR):

The present study has shown that the extreme photoperiod treatments (SD and LD) resulted in similar PGR, although the PGR was greater in ND compared to other two photoperiods. Marie-Lusie Flohr (1990) has also showed the lower PGR under LD condition is compared to ND. However, the difference in PGR between SD and ND were significant enough in the present study. These differences basically were because of lower light interception by the canopy in SD in addition to other effects of the photoperiod. It is well established that PGR is closely associated with the CGR. The pod filling in groundnut is dependent on the availability of translocation of current photosynthates to the growing pods. The genotypic differences in the PGR in addition to the uptake of nutrient by the pods arise from two major factors i.e.

1. Sink potential of the growing pod in comparison with other competing organs such as stem, leaves and roots.
2. Uptake of calcium and other nutrient from ambient soil medium.

In the present study the calcium was applied as gypsum to all the treatments at the rate of during pod filling period (60DAS), hence the observed differences due to photoperiod effects could be associated with the sink potential of the reproductive structures.

Seed growth rates (SGR) and partitioning:

In spite of significant effects of photoperiod on CGR and PGR the influence of photoperiod on seed growth rates (SGR) was minimal. In fact the mean SGR was 4.35 g m^{-2} d^{-1} in SD, 4.87 g m^{-2} d^{-1} ND and 4.07 g m^{-2} d^{-1} in LD. This

observation suggested that the action of photoperiod could be earlier to the seed development.

The analysis of dry matter partitioning has clearly shown that the SD treatment had resulted in greater dry matter allocation to pods in SD (0.71) compared to ND (0.67) and LD (0.52). Thus, a clear inverse relationship between partitioning and the day length was evident in the present study. This results reconfirmed the earlier findings of (Marie-LSusie Flohr, 1990, Nigam *et al.*, 1994). However, the genotypic differences and interaction of genotype x photoperiod were also significant. The genotypic differences in partitioning is well Known (Duncan *et al.*, 1978). However, the photoperiod seem to manipulate the partitioning of dry matter in some genotypes ICGV 88438, ICGV 86015 and TAG24, while, in some others (ICGMS 42, NC Ac 17090) the partitioning reduced with increase in day length. The sensitivities were apparent from fig-5, in which genotypes ICGV 87128, ICGV 86015, TMV 2 and ICGV 86031 were insensitive and ICGMS 42, NC Ac 17090, ICGV 88438, ICGV 86564,TAG 24 were sensitive. The present study illustrated significant role of photoperiod in adaptation of groundnuts in varied environments. The sensitivity of genotypes to photperiod is major factor, which could be contributing to the genotype x photoperiod interaction. The influence of photoperiod and genotypic sensitivity to photoperiod was further illustrated in the bi-plot showing the relative sensitivities of genotypes to photoperiod (Fig-6). It was apparent that in 4-genotypes (ICGV 86015, ICGV 87128,TMV 2, ICGV 86031) the partitioning was stable across photoperiod regimes although these genotypes showed variability for partitioning among themselves. The degree of sensitivity in other genotypes was apparent from their deviation from SD/LD ratio of one. The present study has shown that NC Ac

17090 was the most sensitive of all the genotypes studied. This observation supports the earlier work of Flohr, (1990). Which showed the photoperiod sensitivity of this particular genotype.

Screening tools for photoperiodic sensitivity in groundnut:

Though, partitioning has been projected as the most reliable method for screening genotypes for photoperiod sensitivity, there has been quest for searching new tools to screen out genotype for photoperiod sensitivity as early in the crops life as possible to enable rapid and reliable selection. This will also enable allied fields to carry out further research at quicker pace (especially biotechnological work). In the present study, it was found that sub-terrain peg ratio (SPGR), mature pod ratio (MTPR), peg to pod ratio (PPR) were promising indicators of photoperiod sensitivity. SPGR showed a decreasing trend with increase in photoperiod, although genotypic difference was apparently significant. MTPR and PPR also decreased as day length increased and the results recorded at 100 DAS can give clear about sensitivity of genotype to photoperiod. These results have been clearly supported by works of Nigam *et al.* (1998) who showed that pod to peg ratio was lower in LD than in SD and than the PPR could be used as an indicator of genotypic sensitivity to photperiod in groundnut.

In our endeavour to search for alternatives for screening photoperiod sensitivity, we got very promising results from Stem to leaf ratio (STLF). The photoperiod treatments had significant effect on STLF right from pre-flowering stage. But, from results (Table-19) it was clear that dry matter partitioning was more to stem in ND and LD than in SD. One of the special features of these ratios is that it is very prominent from very early stages, i.e. 40 DAS onwards. The non-significant interaction between

photoperiod x genotype at early stages 40 and 60 DAS further supports the use of this parameter as a potential tool to assess photoperiod sensitivity in groundnut genotypes. Probably, this work is first of its kind to assess photoperiod sensitivity from quite early stage onwards.

Photoperiod did not have significant influence on the aerial peg number and sub-terranean peg numbers and peg addition rates as though genotypic variability were significant. However, photoperiod did influence the juvenile pod number immature pod number, mature pod number, showing that photoperiod effect on reproductive structure is more prominent. These results were well supported by (Wynne *et al.*, 1973, Bell and Harch, 1991, Bell *et al.*, 1991A, Bell *et al.*, 1991B).

Physiological basis for photoperiod sensitivity:

The physiological basis of genotypic variation in sensitivity to photoperiod was further investigated by studying photosynthetic rate (P.n.) and translocation of photosynthates by using ^{14}C techniques.

Photosynthesis:

The spot measurement of photosynthetic rates (Pn) was measured on single leaves at different growth stages (Table-22). The results shown that the Pn was comparable between SD and ND at all growth stages while the LD treatment in general resulted in lower Pn than SD and ND. The lower Pn rates in LD could be because of the feed back inhibition occurring in the leaves due to higher retention of starch in leaves, consequent to lower translocation of current photosynthates to competing sinks. In the current study of starch content in leaves was not measured, but indirect evidences such as low SLA in LD compared to SD and ND suggested that leaves were relatively thicker in LD (Table-

19). The major variant in specific leaf area (SLA) is the leaf weight, which is constituted by starch and other mineral elements in the leaf. The lower SLA (thicker leaf) in general indicates presence of high leaf nitrogen and starch contents (Nageswara Rao *et al.*, 1994). It was clear in present study that low SLA could have resulted low in Pn under LD. Low translocation of starch from the leaves might have resulted in reduction of photosynthetic rates (Pn). This conclusion is well supported by Neales and Incoll (1968) who showed that that accumulation of photosynthates in leaves can result in reduction of Pn. Chatteron (1972) had similar results in Alfalfa that negative correlation exits between Photosynthetic rate (Pn) and specific leaf weight (SLW). The relationship between Pn and SLA should be interpreted with a caution. The relationship could be either positive or negative depending whether SLA playing a active or passive role as the time of 'Pn' measurement. In the 'active role' low SLA leaves would have higher photosynthetic capacity because of higher nitrogen content and current photosynthates could be actively having mobilised to competing sinks.

In the passive role, leaves themselves may be acting as sinks for photsynthates. Under certain conditions, because of low or lack of mobilisation of assimilates from leaves. Under these conditions, the photosynthetic rate (Pn) will be low because of feed back inhibition of the process.

Higher Pn rates in SD and ND could be resulting due to higher demand for photosynthates for other growing organs i.e. pods and stems.

Effect of photperiod on translocation of current photosyntahtes was further illustrated in ^{14}C translocation studies, conducted in SD and LD. This data clearly showed that leaves and stems of plants under LD contained more photsynthates ^{14}C (34-37%),

while under SD, the leaves and stems had significantly less ^{14}C (19—25%). Further the studies also indicated that translocation of ^{14}C to pods were significantly greater under SD than that in LD. In present investigation the genotypes ICGV 87128, TMV 2 translocated more photsynthates to reproductive structure (pods) (Fig-11a, 11b, 11c, 11d). Which ranged from 35-50% and 29-50% ICGV 87128,TMV 2 respectively in SD and LD respectively. But, ICGMS 42 and NC Ac 17090 showed low translocation of photosynthates (nearly zero) to pods under LD. The results were supporting earlier observation that ICGMS 42, NC Ac 17090 were sensitive one and ICGV 87128, TMV 2 were relatively insensitive one. It was clear that irrespective of genotypes, LD conditions resulted in greater translocation of photosynthate to leaves, stems and roots, while SD translocation was greater to reproductive structure (pods).

The analysis also highlights physiological basis for photoperiod effects on translocation of photsynthates. Lower Pn rates observed under LD were also supported by stagnation of carbon compounds in the leaves and stems, while there was enhanced flow of ^{14}C to growing pods under SD. There is very limited information about effect photoperiod translocation of current photsynthates.

Molecular basis for photoperiod sensitivity:

Molecular basis for photoperiod sensitivity was investigated in four selected genotypes by examining protein profiles in leaves using SDS-PAGE. The results shown both qualitative and quantitative changes in protein banding pattern. The qualitative changes included appearance of two new bands (45.7 and 41 kDa) under SD in sensitive genotypes (Table-24). These additional bands are absent in relatively insensitive genotypes (TMV 2), shown in (plate-10). The qualitative differences in protein bands

were apparent with sensitive genotype (ICGMS 42, NC Ac 17090, and ICGV 86564) producing greater intensity of specific proteins under SD and LD treatments. Characteristically, in sensitive genotypes intensity showed prominent bands at 69 to 72 kDa while, insensitive genotype (TMV 2) showed prominent band 24 kDa in SD, in LD all the four genotypes showed high intensity protein bands 20-25 kDa (Plate-10)

There is no information about the effect of photoperiod on changes in protein metabolism in groundnut. All the previous works of Gary *et al.* and Michiyukiono *et al.* (1993) have shown the effect of photoperiod on protein metabolism in tree species under controlled environmental conditions. Further investigation is necessary to characterise the changes in the protein and identify molecular markers associated with photoperiod sensitivity in groundnuts.

It is clear from our studies that photoperiod played significant role in altering groundnut phenology and physiology. The photoperiodic responses in selected nine genotypes studied in under canopy conditions enabled us to understand the physiological and molecular basis responsible for variation among genotypes. This kind of basic and strategic study is important to predict the response of unpredictable legume under varied environmental conditions.

A spin off from present investigation was identification of alternate tools to assess photoperiodic sensitivity, which will be faster, effective, economical and have wider range of acceptance. Our investigation showed that mature pod ratio (MTPR), sub-terranean peg ratio (STPR), peg to pod ratio (PPR) and stem to leaf ratio (STLF) can be used as potential indicator of photperiodic sensitivity. Never the less, STLF ratio appears

to be by far preferable because this trait could be assessed at early stage in crop life. Other physiological parameters such as MTRP and PPR could also be used as selection tools but it should be noted that these variables might have confounding effects arising from other factors such as drought, soil nutrient etc. In addition to the photoperiods and temperature.

Our investigation also searched for molecular basis for photoperiodic sensitivity. This will be a effective tool for breeders and bio-technologist to know the photoperidic (in) sensitivity at very early stages of their cross and to assess the heritability of insensitive genes. It also provides a basis for identifying molecular markers associated with photoperiodic sensitivity in groundnuts.

CHAPTER VI
Summary

A field experiment was conducted on alfisols at ICRISAT centre, Patancheru, near Hyderabad, Andhra pradesh, INDIA during the rabi season (Dec-April) 1997-98 to investigate the effect of photoperiod on growth and apportioning of dry matter to various growing organs in nine selected groundnut genotypes.

In our investigation we have conducted growth analysis, spot measurements of Pn photosynthetic rates, leaf temperature and radiation interception. Beside these, we have conducted ^{14}C translocation studies and also carried out SDS-PAGE.

Photoperiod failed to influence days to 50% emergence, flowering initiation and days to 50% flowering. However, the rate of flowering, thermal time to accumulation of first 25 flowers varied significantly under different photoperiod. The thermal time to accumulation first of 25 flowers was least in short day (SD), i.e. 743 ^0Cd was highest in Long day (LD) 842.9 ^0Cd. Rate of flowering decreased with increase day length 0.092 $^0Cd^{-1}$(SD) to 0.71 $^0Cd^{-1}$(LD). Cumulative flowering also varied significantly under photoperiod influence. SD is having 42 flowers where as ND and LD having 70 each. Days to flower cessation also varied with photoperiod SD flowering cessation occurred in 82 days. Where as it took 110 days under ND and LD.

Photoperiods also influenced main stem length and leaf area index (LAI). In SD the main stem length ranged from (5.7-11.7cm), in ND (6.1-19.9cm) and in LD (5.7-7.3cm), where as LAI ranged from (0.5-2.1) in SD, ND and LD (0.5-3.8) with photoperiod treatments remaining significantly different from each other at 80 DAS and 100 DAS.

The CGR values varied from 8.3 g m^{-2} d^{-1} in SD to that of ND (13.3 g m^{-2} d^{-1}) and LD (10.3 g m^{-2} d^{-1}). VGR varied from 1.2 g m^{-2} d^{-1} to 3.6 g m^{-2} d^{-1} in LD. VGR increased with

increase in day length. PGR was greatest in ND (8.78 g m^{-2} d^{-1}). But, SD and LD showed similar PGR, i.e. 5.86 and 5.59 g m^{-2} d^{-1} respectively. Photoperiod had minimal effect on SGR, In (SD (4.35 g m^{-2} d^{-1}), ND (9.87 g m^{-2} d^{-1}) LD (4.07 g m^{-2} d^{-1})).

Partitioning of dry matter was found highest in SD (0.714) followed by ND (0.675) and LD (0.527). From Fig-5 and 6, it is quite clear that NC Ac 17090 AND ICGMS 42 were highly sensitive, where as ICGV 88438, ICGV 86564, TAG 24 were moderately sensitive and ICGV 86015, ICGV 87128, TMV 2, ICGV 86031 were insensitive. So, selection for higher partitioning in LD conditions likely to result selection for photoperiod insensitive types.

Photoperiod is having profound influence on reproductive structures. Juvenile pod number, immature pod number, mature pod numbers varied significantly and were greater in number under SD conditions. However, photoperiods failed to influence aerial peg number, sub-terranean peg number and peg addition rates. But, it influenced the sub-terranean peg ratio (STPGR), mature pod ratio (MTPR) and peg to pod ratio (PPR). These ratios decreased with increase in day length.

Transloaction studies with ^{14}C showed that, leaves and stems of plants accumulated more photsynthates in LD (31% in leaves and 33% in stems) while in SD it was 22% in leaves and 18% stems. SD favoured more photosynthate translocation to pods (47%) compared to LD (18%). Genotypes ICGV 87128, TMV 2 translocated more photosynthates to reproductive structures, while, ICGMS 42 and NC Ac 17090 translocation greatly decreased by LD conditions.

Our molecular investigations showed that genotypes varied in their photoperiodic sensitivity, with new band additions (45.7 and 41 kDa) under SD was seen in sensitive types

(ICGMS 42, NC Ac 17090, ICGV 86564), while SD failed to produce new band addition in insensitive type, i.e. TMV 2. Quantitative variation was also found. Sensitive genotypes showing prominent bands at 69-72 kDa, while insensitive type (TMV 2) showed prominent band at 24 kDa in SD. IN LD all four genotypes showed high intensity bands between 20-25 kDa.

So, present investigation revealed the following essential features:

1. Photoperiods failed to influence days to 50% emergence, days to flower initiation and days to 50% flowering.
2. Photoperiods did influence rate of flowering, days to accumulation of 25 flowers and days to flower cessation.
3. Photoperiods have tremendous effect on partitioning. NC Ac 17090, ICGVGMS 42 were sensitive. While, ICGV 88438, ICGV 86564, TAG 24 were moderately sensitive and ICGV 86015,ICGV 87128, TMV 2, ICGV 86031 were insensitive.
4. Sub-terranean peg ratio (STPGR), mature pod ratio (MTPR), peg to pod ratio (PPR), stem to leaf (STLF) were reduced under LD.
5. Translocation to pods in LD were reduced and were more to stems and leaves under LD, while SD promoted more dry matter translocation to pods (42%).
6. Genotypes differed qualitatively and quantitatively in response to photoperiods. The protein bands of sensitive once differed from that of insensitive ones. However, under LD the intensity of protein bands were seen at low molecular weight and of similar nature in all the four genotypes.

The above results have helped us to understand the physiological and molecular basis for photoperiod sensitivity. These also helped us to understand the importance of the fact that,

1. There is significant effect of photoperiod on groundnut, although the degree of sensitivity varied with genotypes.
2. Crop phenological events upto flowering and pod set were less affected due to photoperiod compared to post-reproductive growth processes.
3. The effect of photoperiod was significant on partitioning of photosynthates to reproductive structures with long day favouring translocation of current photosyntahte to vegetative structures (leaves and stems) while short day promoted translocationm of photosynthates to pod.
4. Above analysis indicate that photoperiod seems to regulate the translocation of current assimilate from leaves to either vegetative or reproductive growth.
5. This study showed that SD seems to hasten the maturity by making growing pegs (pods) as competing sinks to photosynthates.
6. The present investigation showed that photoperiod sensitivity can be assessed by leaf to stem ratio, peg to pod ratio and partitioning of assimilate to pods.
7. The growth analysis helped to compute the model components, which in turn were used to investigate the photoperiod and genotypic interaction towards photoperiod sensitivity.
8. The present investigation also showed that photoperiod sensitivity could be assessed through molecular means (SDS-PAGE).

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