SEASONALITY - ITS PHYSIOLOGICAL IMPACT ON PIGEONPEA

THESIS SUBMITTED IN PART FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (AGRICULTURE) IN CROP PHYSIOLOGY TO THE TAMIL NADU AGRICULTURAL UNIVERSITY

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By

K. BALAKRISHNAN

DEPARTMENT OF CROP PHYSIOLOGY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
COIMBATORE - 641 003

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CERTIFICATE

This is to certify that the thesis entitled "SEASONALITY - ITS PHYSIOLOGICAL IMPACT ON PIGEONPEA" submitted in part fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) IN CROP PHYSIOLOGY to the Tamil Nadu Agricultural University, Coimbatore is a record of **bona fide** research work carried out by Mr. K. BALAKRISHNAN under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Date :

Place : Coimbatore-3

(Dr. N. NATARAJARATNAM)
Chairman

APPROVED

Chairman : (Dr. N. NATARAJARATNAM)

Members : (Dr. M. MOOSA SHERIFF)

(Dr. T. S. MANICKAM)

(Dr SP. PALANIAPPAN)

ABSTRACT

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BY

K.BALAKRISHNAN

Degree: DOCTOR OF PHILOSOPHY IN CROP PHYSIOLOGY

Chairman : Prof. N.NATARAJARATNAM,Ph.D.,
Head, Department of Crop Physiology
Tamil Nadu Agricultural University
Coimbatore -641 003.

Studies were conducted in six pigeonpea cultivars comprising three long duration and three short duration types viz., CO.5, CORG 5, UPAS 120, CORG 11, PLS 361/1 and SA 1 in three different sowings namely 21st February, 21st June and 21st September to gather information on the physiological basis of yield variation due to seasonality. Stability analysis was also resorted to identify the relative stability of cultivars or physiological/morphological attributes over sowings. Path coefficient analysis was undertaken to identify the most important yield component which contributed to the yield.

Sowing dates had greatly influenced the phenological development of the crop. The grain filling period remained unaffected by different sowing dates even though the duration of crops varied.

Higher growth was observed in February sowings as compared to the June and September sowings. The higher

expression of the growth was contributed by LAI, CGR, LAD and quicker canopy development which were more in February sowings whereas NAR, LWR and LAR were higher in September sowings. Similar trend was also noticed in long and short duration cultivars. Favourably higher growth in February sowings was due to the higher cumulative heat units, photothermal units, heliothermal units and sunshine hours noticed in February sowing than that of others.

February sowings also recorded comparatively higher chlorophyll content, photosynthetic rate per unit leaf area, transpiration rate than the other two. The leaf water potential was lower in February (low water content) than the other two sowings.

The number of seeds per plant which represented sink size was found to be the main contributing factor for the grain yield. The highest pod number per plant which contributed higher number of seeds per plant was recorded in February sowings followed by June and September sowings. This trend was reflected in grain productivity too. Low HI was observed in February sowings as compared to September sowings. The yield reduction in September sowings was mainly due to the reduced sink size which had been monitored by the source size (LAI). It is pertinent to remember that the rate of grain filling per plant was reduced in September sowings while the rate of filling per seed remained unaffected. The main defect appeared to be the reduced sink size modulated by the pod number per plant through total number of seeds per plant.

Among the long duration cultivars, SA 1 could show comparatively higher yield than the others because it was able to stabilise the ILA, number of branches, LAI, number of pods per plant, number of seeds per pod and 1000-grain weight. As regards the short duration cultivars, CORG 5 was found to be the higher yielder because it could fix photosynthetic rate, 1000-grain weight and HI. In general, DMA and grain yield were found to be highly unstable in all the cultivars studied.

This study also brought out newer concepts for pigeonpea improvement. The DMA and HI were identified for yield stability over seasons. Based on this study, the strategies for further crop improvement in pigeonpea were suggested.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Pigeonpea happens to be a major source of vegetable protein for the population of Indian sub continent. This grain legume is cultivated nearly in fifty countries spread over the world. The production of this crop extends from Australia to South America covering countries like Laos, Thailand to Argentina, Paraguay and Venezuela.

Eventhough the crop is covering the whole world, ninety per cent of its production is in India. Compared to India, the productivity appears to be comparatively high in Trinidad and Dominican Republic wherein the average yield trends are 1667 and 2194 $kg.ha^{-1}$ respectively. The average Indian productivity is only about 675 $kg.ha^{-1}$. Hence the necessity to increase the yield is acutely felt in the light of increasing population pressure. But the information on the physiological constraints for the increased productivity is very meagre. Realising this major lacunae, the crop had been recognised as mandate crop in ICRISAT (International Crop Research Institute for the Semi-Arid Tropics), Hyderabad. In addition, very active and fruitful research efforts are in evidence in Australia and West Indies for increasing the productivity.

A major problem towards productivity increase is the reaction of crop to the varying agro-climatic situations.

The yield response is very sensitive to the changing weather parameters that exist in different seasons peculiar to these agro-climatic regions. For understanding the productivity constraints in such of those situations mentioned above, it is paramount to delineate the physiological mechanisms which are responsible for such a behaviour pattern in these plants.

Keeping the above concept in view, the following objectives have been earmarked in the experiments to be undertaken.

(1) To estimate and measure the variations in the yield in different seasons with emphasis on the identification of the weather parameters contributing for increased yield.

(2) To delineate the phenotypic characters whose expressivity is monitored by environmental variations

(3) The underlying physiological mechanisms which influence the yield variations will also be recognised. The relationship of the altered physiological reactions to the yield differences through the phenotypic characters will be perceived.

(4) To measure the degree of stability of various physiological and growth attributes that contribute towards increase or decrease in the yield expression over seasons through suitable statistical tools.

(5) To draw out necessary inferences for the existing productivity levels and also suggest suitable strategies for the future crop improvement.

The author will feel extremely gratified if this kind of new approach could elicit sufficient information from the crop indicating reasons for the low productivity. Further he will deem it a reward, if this study can stimulate similar interest in the physiological functioning of other crops where productivity plateau had already come into existence making it difficult to achieve further break throughs.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The contributions of earlier researchers on the physiological analysis of pigeonpea (*Cajanus cajan* (L.)Millsp) and its response to different dates of sowing as influenced by day length, temperature and solar radiation are reviewed in this chapter. For this purpose, presentation of major trends of thoughts have also been attempted. For convenience, the literature surveyed is given under different headings.

Phenological development

Phenology: Phenology is the study of the timing of recurring natural phenomena in plants, especially in relation to climatic conditions (Larcher, 1980). Photoperiod is one of the factors in the environment which determines the area of adaptation of crops. Temperature also had been known to affect the adaptability of a variety. Therefore, it was essential to integrate the influence of photoperiod and temperature to fully understand the effect of environment on flowering (Wallis et al., 1980). The pigeonpea is a quantitatively short day plant, and its phenology is strongly influenced by photoperiod (Spence and Williams, 1972).

The rate of development of the floral primordia in pigeonpea increased with increase in both day length and temperature (Turnbull et al., 1980). Datta and Aretideb (1970) observed that flowering period appeared to be influenced by weather conditions. With regard to variation in photoperiod and temperature, Summerfield and Minchin (1976) observed that photoperiod and temperature in the arid and humid tropics varied significantly. Day length also varied regularly with latitude and year (Lawn, 1980). Phenology and vegetative growth were influenced by photoperiod x temperature interactions and thus sowing date and latitude (Wallis et al., 1980) seemed to dominate the above parameters.

Photoperiod

The most significant contribution to be made to pigeonpea improvement in the short term is the prediction of crop phenology in particular environments (Lawn, 1980). Phenology in short day pulses depended on sowing date and cultivar maturity type (Lawn et al., 1977). Though a combination of photoperiodic and temperature effects, the time of flowering and maturity of pigeonpea cultivars could be varied according to the date of planting (Derieux 1971; Akinola and Whiteman, 1974). Significant influence of date of sowing on the phenology of pigeonpea was also reported by many authors (Riollano et al., 1962; Gooding 1960; Wallis et al., 1975; Abrams, 1975; Gowda and Kaul, 1982). Generally, the late maturing cultivars are more sensitive to shorter day length than early maturing types (Byth, 1968; Anon., 1976). Day length had a dominant influence on growth and yield, but part of this effec could have been a reponse to radiation rather than photoperiod (Hammerton, 1976). Early flowering under shorter day length conditions led to the reduced number of floral buds developed per plant (Wallis *et al*., 1980).

Temperature

There were evidences that overall growth was influenced by temperature variations experienced in different sowing dates (Akinola and Whiteman, 1975). The growth was depended upon the interaction of temperature with sowing dates (Fuki, 1963; Sheldrake and Narayanan, 1979a; Lawn and Byth, 1977; Green *et al*., 1979; Wallis *et al*., 1979a; Kay, 1979). Phenology was also influenced by photoperiod x temperature interactions. A wide range of phenology in extremely diverse production system were possible in pigeonpea (Saxena *et al*., 1980). The rate of ontogenic development in pulses was reported to be generally sensitive to temperature. The most favourable temperature range for crop growth is 19°-29°C but it can tolerate temperature oscillation between 10°C and 40°C (Pathak, 1970). Temperature was the dominant factor influencing the number of days from emergence to floral initiation, accounting for approximately 60 per cent of the total variations compared to 10 per cent due to photoperiod. Increasing either the day or the night temperature delayed floral initiation. The greatest delay was caused by the most widely divergent day/night temperature combinations. The tested combination was 32/16°C for day and night temperature respectively (Turnbull *et al*., 1980).

The cool temperature coupled with decreasing day length seemed to overcome the effects of long delay in sowing (Venkataraman and Sheldrake, 1981). Pigeonpea could tolerate a wide range of temperature from 19° to 43°C (de Jabrun *et al.*, 1981) and with relatively poor growth when temperature was below 22°C. Temperature above 36°C was found to be sub-optimal (Chauhan *et al.*, 1982). Higher growth in May and June might be attributed to both higher solar radiation and temperature, while the greatly reduced growth in the winter season might have stemmed mainly from low temperature (Anon, 1982). At ICRISAT Centre (Hyderabad) pigeonpea cultivars flowered and matured about a month earlier than at Hissar. The differences in phenology stemmed from shorter day length and cooler climate at ICRISAT from June to September (Wallis *et al.*, 1984). The diurnal variation in temperature, heavy overcast sky, high humidity and day length sensitivity of the cultivar during the growing season also played their roles in deciding the yields (Asedima, 196?).

Temperature-Photoperiod interaction

Under relatively cool conditions, an important effect of temperature on flowering seemed to be reduction in the requirement of short days. Thus in monthly planting trials carried out at Hyderabad (elevation 500 M) and at Mahabaleswar (elevation 2000 M) both at same latitude, under same long day conditions, cultivar which did not flower at the former flowered under the cooler conditions at the latter (Anon., 1976). It was found that short photoperiods reduced overall vegetative growth, days to flowering, pod filling and ripening (Wallis et al., 1975). The phenological development of pigeonpea cv. Royes was affected by photoperiod. The effect was manifested as reduced vegetative growth. Plant height decreased markedly (from 217 to 73 cm) as sowings were delayed (Wallis et al., 1979 a,b). The major benefit of the photoperiod sensitivity was that late sowing could be used to restrict vegetative growth and induce synchronisation of flowering. These advantages could also be gained by the use of early maturing lines that are sensitive to photoperiod at different latitudes (Wallis et al., 1980). Days to flowering and maturity varied according to the sowing date due to its variations in photoperiod x temperature interactions (Ariyanayagam, 1976). Apart from photoperiod, other factors also influenced the flowering and fruiting (Pathak, 1970; Lawn and Byth, 1973; Iswaran, 1976).

Date of sowing

The time of sowing had shown its effect on vegetative and reproductive phases of the crop and it was an important factor influencing crop duration (Dhingra et al., 1980). Venkataraman and Green (1979) reported that days to 50 per cent flowering decreased from September to November sowings. The reproductive phase was shortened to November sowings. The reproductive phase was shortened from 76 days in September sowing to 59 and 39 days in the October and November sowings respectively. The duration of both flowering and podding was shorter in the September sown crop than in the June sown crop (Roy Sharma *et al*., 1980). The crop planted during longer days of May and June took more time to flower and mature, while those planted in September and October flowered and matured earlier (Lawn, 1980). Experiment conducted in India had also shown that pigeonpea could be cultivated even in Rabi season (Roy Sharma *et al*., 1980; Sharma *et al*., 1981).

Growth and Dry Matter Accumulation

Root

Inforzato (1947) studied the root system of pigeonpea and found that two year old plant recorded root weight of 1,237.04 g per plant of which 90.67 per cent was found in the top 30 cm of the soil. The weight of the aerial plant was 17,200 g per plant. The maximum rooting depth observed was 2.95 m with plant height of 4.5 m. Plant height which ranged from 0.9 to 4.5 m was recorded in Trinidad (Riollano *et al*., 1962). The rooting system developed with a tap root was traced to a depth of more than 2 m. However, most of the roots remained in top 30 cm layer (Sheldrake and Narayanan, 1979). Pigeonpea had a well developed root system compared to other legumes and this system used in moisture upto 110 cm (Reddy and Rao, 1980) and even upto 180 cm depth in certain cases (Rivera *et al*., 1983).

Shoot

Planting date influenced the plant height to a greater extent. Planting at May-June recorded 1.5 M height whereas December planting recorded only 1 m (Riollano,1964). May 20 planting recorded higher plant height (220 cm) than June 5 plantings (140 cm) (Singh et al., 1971). The average height of the plants was observed as 1.07 m in September sown plants as against 2.85 m in June sown plants (Roysharma et al., 1980). The summer sown crop produced more vegetative growth because of the long day conditions of the summer months (Narayanan et al., 1981). The longer vegetative phase and taller plants with more branching resulted in higher growth in April planted crop than June planted crop (Panwar and Yadav, 1980).

Dry matter Accumulation

With regard to dry matter production, the traditional long duration variety recorded a total DMA of 15 t. ha^{-1} (Jain, 1975). Dry matter yield as high as 23 t. ha^{-1} had been reported from Australia for a long duration cultivars cv.UQI (Akinola and Whiteman, 1974). Dry matter accumulation was more in the leaves during first 70 days; thereafter the comparative increase was more in the stem. However, after pod development, drymatter accumulation in both stem and leaves declined due to leaf senescence and translocation of minerals and photosynthates to reproductive parts (Dhingra et al.,1980). In all the three maturity groups viz., early, medium and late the dry matter accumulation was negligible until 4-5 weeks after planting. The growth picked up after 6 weeks and increased rapidly (Gowda and Kaul, 1978). Drymatter accumulation of the stem increased after flower bud initiation, reflecting continued production of new branches and thickening of existing stems (Narayanan and Sheldrake, 1976).

Effect of sowing dates on dry matter accumulation

Because of pigeonpea's are photoperiod sensitivity, its DMP was greatly influenced by the time of planting. The dry matter yield declined with a delay in sowing beyond September (Akinola and Whiteman, 1974). April-May planting of indeterminate cultivar recorded more DMA than September-October plantings under Puerto Rico conditions (Abrams and Julia, 1973). The dry matter accumulation of indeterminate types outyielded the determinate types in all cases (Anon., 1978; Hammerton, 1977). Venkataraman and Sheldrake (1981) reported that higher DMA (2344 $kg.ha^{-1}$) was recorded in September sown crop than November sown crop (1515 $kg.ha^{-1}$). April-May plantings recorded more DMA than November and December plantings. The dry weight of the late plantings were only a tenth of the fomer (Chauhan *et al.*, 1982).

With respect to shoot/root ratio, Sheldrake and Narayanan (1977) reported that the ratio was 4.0 in blacksoil maturity groups viz., early, medium and late the dry matter accumulation was negligible until 4-5 weeks after planting. The growth picked up after 6 weeks and increased rapidly (Gowda and Kaul, 1978). Drymatter accumulation of the stem increased after flower bud initiation, reflecting continued production of new branches and thickening of existing stems (Narayanan and Sheldrake, 1976).

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With respect to shoot/root ratio, Sheldrake and Narayanan (1977) reported that the ratio was 4.0 in blacksoil and 3.5 in red soils. It also ranged from 3-11 during the crop season (awson and Constable 1980) at different stages of crop growth.

Pattern of dry matter accumulation

The dominance of stem growth led to reduced supply of photoassimilates to pod setting and ultimately seed production. More than 47 per cent of the total DMA was produced after flowering (Pandey, 1980). Dry matter accumulation and leaf area development was very slow upto 7 weeks sowing after and thereafter increased steadily (Chopra and Sinha, 1980). Leaf drymatter might reach its maximum between flowering and pod development. It also depended upon the rate of new leaf growth and senescence of old leaves. The low DMA and leaf area in initial phase, may reflect an initial high investment in the root development (Lawn, 1980). The rate of dry weight increase in leaves declined as the pod development started owing to leaf senescence and abscission (Narayanan and Sheldrake, 1976; 1979) Tayo (1983 a,b) studied the leaf number and recorded 300 leaves per plant. The number of branches were also found to be 30 per plant. Tayo and Togun (1984) observed 400 leaves at 15 weeks after sowing and decreased to 100 at maturity. Hughes and Keatinge (1983) obtained a linear relationship between the maximum amount of dry matter accumulation by the crop and the amount of solar radiation intercepted.

Growth Analysis

Leaf Area Index (LAI): Several procedures have been developed to analyse and interrelate the changes in plant size and structure which occur during growth and development. Perhaps the best known method, which we call traditional plant growth analysis arose from work by Gregory (1918); Blackman (1919) and Briggs et al. (1920 a,b). Subsequent refinement was initiated with major contributions by Williams (1946) and Watson (1952); Hughes and Freeman (1967).
Wilson (1981) had established traditional plant growth analysis as a standard approach to the study of plant growth and productivity. Recent reviews of the procedures were made by Kvet et al. (1971), Evans (1972), Hunt (1978) and Jolliffe et al. (1982). With regard to pigeonpea in particular, the optimum LAI was found to be 7.00, but for other large leaved tropical pulses it was from 3.0 to 4.0 (Rachie and Roberts, 1974). The changes in LAI with time closely paralled the changes in leaf dry weight. The maximum LAI recorded at Hyderabad was 12.7 (Sheldrake, 1984). A similar maximum has been found in Australia also (Wallis et al., 1975). An LAI of 3.28 was found to be critical for medium duration cultivars (Sheldrake and Narayanan, 1979). Keatinge and Hughes (1980) reported that the peak LAI values ranged from 0.34 to 12.5 in 24 locations. Maximum LAI values also ranged from 13 to 16 have been reported from Australia (Wallis et al., 1975). The

leaf area development in pigeonpea remained low during the early vegetative growth stage and increased sharply with advancement of crop age. The maximum LAI was attained just after flowering (Pandey, 1980). A typical leaf area development pattern for a medium-duration cultivar showed that after the first 30 days of growth LAI was barely 0.5 (Saxena et al., 1983). The maximum LAI was normally achieved after bud initiation and nearly coincided with the time of maximum CGR (Sheldrake and Narayanan, 1979; Natarajan and Willey, 1980). The leaf area increased upto flowering and thereafter decreased towards maturity (Tayo, 1982 a,b; Gowda and Kaul, 1982; Hegde and Saraf, 1982a; Tayo, 1983). Pigeonpea, besides being slow in canopy development was inefficient in the use of intercepted radiation for dry matter production (Hughes et al., 1980).

Crop Growth Rate (CGR)

Dry matter production and CGR in the earlier stages of growth were very slow. The peak CGR of 7.65 $g.m^{-2}$ day was attained between 80 and 100 days after sowing in a variety with 160 days duration (Saxena et al., 1983). Work done in Australia with longer duration pigeonpea showed three distinct growth phases; an initial lag phase upto 84th day; a grand period of growth phase lasting until 168th day, and a final slow phase of dry matter production. In this study, a maximum value of CGR reached as high 18 $g.m^{-2}$ day^{-1}, whereas, the medium duration cultivars ST-1, 1 CP-1 and HY-3C produced

8.9, 13.7 and 7.5 $g.m^{-2}day^{-1}$ (Sheldrake and Narayanan,1979b). The CGR was low during the first two months, reaching maximum at pod flowering and declined afterwards (Pandey,1980).

Experiment conducted at ICRISAT, Hyderabad revealed that the June sowing recorded higher CGR (8 $kg.ha^{-1}.day^{-1}$) than December sowings (1 $kg.ha^{-1}.day^{-1}$). The reasons were coincided with high temperature and solar radiation (Anon, 1982). Initially, CGR was very low which progressively increased and reached the peak value around flowering time. Thenceforth, there was gradual decline in CGR upto harvest (Hegde and Saraf,1982a). CGR increased upto 15 weeks after sowing (22.61 $g.m^{-2}.day^{-1}$) and decreased at maturity stage (10.06 $g.m^{-2}.day^{-1}$) (Tayo,1982b).

Net Assimilation Rate (NAR), Relative Growth Rate (RGR) Absolute Growth Rate (AGR) and Leaf Area Duration (LAD)

The net assimilation rate (NAR) decreased with growth period and the values were around 30 $g.m^{-2}.week^{-1}$. at the time of flowering (Sheldrake and Narayanan, 1979b). NAR reached maximum 75 to 85 $g.m^{-2}.week^{-1}$. at 30 days after sowing (Rowden et al., 1981). With regard to NAR and RGR, they decreased as time trend (Hegde and Saraf,1982a). Experiment conducted at Nigeria showed that CGR, NAR and RGR did not show any regularity with growth period. But LAR showed declining trend towards maturity. The variation in NAR, CGR might be attributed to the outgrowth of new leaves (Tayo,1982a). Higher LAI and longer crop duration influenced the LAD and dry matter production (Hegde and Saraf,1982a). The LAR showed declining trend towards maturity (Tayo,1982a). With regard to absolute growth rate, it increased upto 95 days after sowing (9.5 $g.plant^{-1}.week^{-1}$) and decreased at (164 days) maturity (2.4 $g.plant^{-1}.week^{-1}$) (Hegde and Saraf,1982a). Rawson and Constable (1980) calculated that SLW should be 4.0 $mg.cm^{-2}$ for achieving maximum yield. It also ranged from 4.75 to 8.40 $mg.cm^{-2}$ (Sharma and Saxena,1983). SLA is a much more variable parameter than LWR; in other words, leaf area is more plastic than leaf weight (Fitter and Hay,1981). The changes in SLA must imply an important anatomical changes in the mesophyll and palisade layers (Hiesey et al.,1971). SCA also responded to environmental changes. SLA changed from 4.9 to 12.7 $dm^{-2}.g^{-1}$, for plants growing under high solar radiation to low solar radiation (Hughes, 1959). LWR was susceptible only to changes in temperature, day length and soil factors and not to changes in the light intensity (Evans, 1972). Solar radiation showed a large association with AGR, RGR, SLW whereas temperature influenced strongly LAR, LWR, LAD and SLA during both kharif and rabi seasons (Singh et al., 1972).

Leaf senescence and its fall

Leaf shedding: The leaf senescence is an important physiological parameter which decides the yield in pulses. Leaf senescence permits recovery and retranslocation of the bulk of the nutrients from the senescenced leaf and their phenomen brings about shedding of ineffective leaves (Leopold, 1961). Narayanan and Sheldrake (1976) reported that about 2 $t.ha^{-1}$ of the dry matter was lost from the medium duration cultivars due to the fallen leaves. Experiment conducted at ICRISAT revealed that fallen material constituted 25 per cent of the total dry matter production of 8.4 $t.ha^{-1}$ (Sheldrake and Narayanan, 1979). The total leaf fall might be as high as 1.8 to 2.1 $t.ha^{-1}$ (Pandey, 1980). Leaf shedding is a varietal character and it varies from variety to variety. It ranged from 109.36 to 24.41 $kg.ha^{-1}$ of leaf dry weight (Madhusudana Rao et al., 1980). A maximum of 3100 $kg.ha^{-1}$ fallen leaves had also been reported (Chauhan et al., 1984).

Influence of sowing dates on leaf shedding

With regard to influence of sowing dates on leaf fall, Roy Sharma et al. (1980) reported that the quantity of leaf fall was appreciably higher in the June sown crop (6370 $kg.ha^{-1}$) than in the September sown crop (2350 $kg.ha^{-1}$). Comparing September and November plantings, September planting recorded higher fallen leaf dry weight than the November plantings (Venkataraman and Sheldrake, 1981). One of the earliest changes associated with foliar senescence was the loss of total soluble protein (Kar and Mishra, 1977), disturbed chloroplast metabolism (Harkman, 1979) and decreased photosynthetic carbon metabolism (Wittenbach et al., 1980). Physiological basis of senescence might be attributed to decreased effectiveness of the photosynthetic apparatus, diminishing auxin supply and less efficient synthesis of RNA and protein (Meyer, 1918; Leopold, 1961). But the precise biochemistry of leaf senescence processes was uncertain (Nooden and Thompson, 1984) in this crop plant.

Nutrient content in fallen leaves

The nitrogen content of fallen leaves ranged from 1.36 to 1.56 per cent in five pigeonpea cultivars studied (Sheldrake and Narayanan, 1977). The content of nitrogen declined from 4.5 to 1.5 per cent in the senescenced leaves (Sheldrake, 1979). The senescenced leaves contained 1.3 per cent N and thus removed 40 kg N. ha^{-1} (Chauhan et al., 1984). The removal of nitrogen through fallen leaves also ranged from 24 to 30 kg N.ha^{-1} (Pandey, 1980). The senescenced leaves contained lower Ca, Mg, N, P, K and chlorophyll than the intact leaves. The imbalance was due to the remobilisation of the nutrients (Deshpande and Nimbalkar, 1981). The phosphorus content of the fallen leaves declined to 0.30 to 0.06 per cent from intact leaves and it has also been estimated that 1.3 to 5.0 kg P.ha^{-1} was removed in the form of fallen leaves (Sheldrake and Narayanan, 1977). The percentage of phosphorus declined from 0.3 to 0.1 per cent in the senescenced leaves (Sheldrake, 1979).

The reason for leaf senescence might also be attributed to the source response to the sink demand (Sheldrake, 1979).

Leaf senescence appeared to be partly due to both leaf age and degree of shading (Lawn, 1980) and it enhanced progressively after flowering (Pandy, 1980). During the reproductive phase, the rate of leaf fall exceeded the rate at which new leaves were produced and thus LAI declined sharply (Pandey, 1980).

Yield components

Association of yield components

Dasappa and Mahadevappa (1970) found that number of pods per plant was the main component of grain yield. Seed yield was positively correlated with plant spread, length of main branch and number of pods per plant. (Munos and Abrams (1971) Beohar and Nigams, 1972; Ganguli and Srivastava, 1972; Joshi, 1973). Raju and Chandra (1972) concluded that improvement was needed for the characters like plant spread, number of branches and 100 grain weight. Yield showed significant and positive association with plant height, secondary branches and pod length (Singh et al., 1972). The number of clusters per plant was identified as the main yield component in pigeonpea (Singh and Malhotra, 1973; Malhotra and Sodi, 1977). Work done at Puerto Rico revealed that grain yield differences in pigeonpea resulting from agronomic manipulation were largely manifested through differences in the pod number and pod bearing branches per plant rather than seed number per pod and 100 seed weight (Abrams and Julia, 1973). Pods per plant had direct effect on yield (Veeraswamy et al., 1975; Dani, 1979; Malik et al., 1981; Pahuja et al., 1981; Rowden et al., 1981; Venkateswaralu and Jagmohan Rao, 1984; Balyan and Sudhakar, 1985). The grain yield was positively correlated with the weight of pod per plant (Mukewar and Muley, 1974). It was also observed that number of primary branches and cluster per plant were the main yield components (Ramanujam, 1975; Ram et al., 1976 a,b). Path coefficient analysis revealed that the plant height and number of secondary branches had direct influence on seed yield (Reddy and Rao, 1980). Seeds per pod had positive correlation with yield (Dahiya et al., 1974; Kumar and Haque, 1973; Reddy and Rao, 1980; Singh et al., 1981; Singh et al., 1982; Bhowmik et al., 1983; Wanjari and Ansari, 1983; Balyan and Sudhakar, 1985). The number of leaves per plant also had positive association with seed yield (Ramanujam, 1975; Kumar and Haque, 1973; Ganguli and Srivastava, 1972; Saxena and Sharma, 1981). Seed yield was also found to have positive association with 100-seed weight (Pankaja Reddy et al., 1975; Vikhe et al., 1983; Jag Shoran 1982; Bhingra et al., 1983; Suresh Kumar, 1983; Jag Shoran, 1985; Balyan and Sudhakar, 1985). Dry matter production was also positively and significantly correlated with grain yield (Ahlawat et al., 1981; Kehringe et al., 1983) and harvest index (Singh et al., 1981; Dumbre and Deshmukh, 1983). Seed yield was also correlated with chlorophyll content (Ramanujam, 1975).

On the contrary, there were reports to indicate that grain yield was negatively correlated with plant height, 100 grain weight and days to maturity (Mukewar and Muley, 1974; Singh et al., 1981). Seeds of the longer duration cultivars were large and heavier than the short duration cultivars (Rathinaswamy et al., 1973). Experiment conducted at ICRISAT revealed that the seeds per pod ranged from 2.0 to 2.89 and 100 seed weight ranged from 5.3 to 6.8 g. They also noted that 100 seed weight of cultivars grown in the rabi season were lower than those of same cultivars grown in the kharif season (Sheldrake and Narayanan, 1977). Seed number per pod ranged from 2.6 to 3.5 and 100 seed weight ranged from 7.3 to 16.3 g among cultivars studied (Anon.,1980).

Effect of sowing dates in yield component

April planted crop recorded more number of branches, more number of pods, and bigger size of grains than those of June sown crop (Panwar and Yadav, 1980). Comparing September and November sowings, September sowing recorded higher 100-seed weight (8.2 g) than (7.5 g) November sowings (Venkataraman and Sheldrake, 1981). Chauhan et al. (1982) recorded higher 100 seed weight in April sown crop than the subsequent sowings.

Although there were large variations among cultivars in seed size and seed number per pod, within a given cultivar these were remarkably constant; the most important variable determining yield was pod number per plant rather than pod number per unit area (Hammerton,1971; Akinola and Whiteman, 1974 ; Rao and Willey,1980; Rowden et al., 1981).

Influence of sowing dates on yield

Sowing time has profound effect on the productivity of pigeonpea. Timely sowing must be ensured to get maximum returns from the applied inputs. The earliest reports from West Bengal indicated that early planting on 10th May in 1951 and 1952 recorded higher yields than the subsequent plantings (Anon., 1953). It was also found that mid March sowing gave the highest grain yield of 832 $kg.ha^{-1}$ (Premsekhar and Subramaniam,1961). The reduced grain and straw yields were noticed when the sowings were delayed beyond July (Riollano et al., 1962). Seed yields were higher in the crop sown on May 20 and declined with successive late sowings (Singh et al., 1971). Derieux (1970) stated that the late sowing of day length-insensitive and shortday variety reduced the yield. He also studied the photoperiodism in 200 sources of pigeonpea collected from all over the world with reference to yield (Derieux, 1971). Environmental factors had the greatest influence on seed yield per plant (Ganguli and Srivastava,1969). Date of planting significantly influenced the yield attributes (Dahiya et al., 1974; Veeraswamy et al.,1975; Wallis, 1976). It was observed that higher grain yield was recorded in May 20 plantings than successive plantings (Saxena and

Yadav, 1975). When pigeonpea was grown in the cool post-rainy season, it matured sooner and its growth much lesser and yield were also less than Kharif season (Narayanan and Sheldrake, 1979; Roy Sharma et al., 1980). Planting after June had a tendency to mature early. Higher yield was recorded in June planting than the subsequent plantings (Faroda and Singh, 1980; Sandhu et al., 1981). Delayed sowing beyond August reduced the yield but HI increased (Sinha and Bhattacharya, 1982). The per plant yield of post rainy season pigeonpea was drastically reduced because of their sensitivity to the short days (Madhusudana Rao et al., 1983). September sown crop recorded higher yield (786 $kg.ha^{-1}$) than (430 $kg.ha^{-1}$) November sowings (Venkataraman and Sheldrake, 1981). Experiment conducted at Maharashtra revealed that more grain yield was recorded in rainy season than winter season crop (Jadhav and Narkar, 1983). Tayo (1983a) also recorded more yield in April plantings than June plantings. Pigeonpea could be successfully grown as post rainy season crop in Maharashtra tracts preferably seeded before 20th September (Kayande, 1983; Ikramullah and Yogeswara Rao, 1983). Optimum period for sowing photosensitive varieties was found to be September-October. Further delay resulted in reduced growth and yield (Chandra et al., 1983). Pigeonpea would not flower if planted beyond November, as almost all the varieties are highly photosensitive (Venkateswarlu and Jagan Mohan Rao, 1984). Early sowings (March, April and May) of varieties UPAS 120 and T 21 produced 8 and 57 per cent higher grain yield and DMA respectively than the June sowings (Dahiya, 1985).

Per day productivity

With regard to per day productivity, Singh *et al.* (1971) reported 8.4 kg.ha.day^{-1} in the crops of 162 days duration. Narayanan and Sheldrake (1979) noted 12.8 kg.ha^{-1}.day^{-1} in 133 days duration crop; Akinola and Whiteman (1975) observed 9.5 kg.ha^{-1}.day^{-1} in the 294 days crop duration. Wallis *et al.* (1979) and Rowden *et al.* (1981) recorded 21.9 kg.ha^{-1}.day^{-1} and 12.4 kg.ha^{-1}.day^{-1} respectively in the crop of 105 days duration. Time of sowing was also having its influence on per day productivity. In this regard, Venkataraman and Sheldrake (1981) found that 14.88 and 12.41 DMP kg.ha^{-1}.day^{-1}, 5.02 and 3.55 seed yield kg.ha^{-1}.day^{-1} respectively in September and November sown crops in 16 pigeonpea cultivars. In North India, early cultivars often gave 1.5 to 2.0 t.ha^{-1} and sometimes over 3.6 t.ha^{-1} (Manjhi *et al.*, 1973; Ahlawat, 1981). In traditional cropping systems, the highest yields, exceeding 4 t.ha^{-1} was obtained in North India (Singh and Kush, 1981). Recently high yields of 4.5 t.ha^{-1} have been obtained with selected lines of early maturing (110 days) day neutral pigeonpea (Wallis *et al.*, 1980). An exceptional yield of 5 t.ha^{-1} was also reported in India (Rachie and Roberts, 1974). However, Rawson and Constable (1980) predicted that the yield should be 2.7 t. ha^{-1} from 264 pods per plant with HI of 22 per cent.

Harvest Index

The term "harvest index" was proposed by Donald (1962) for the ratio of grain yield to biological yield. Other definitions like "migration coefficient" (Beren,1920) or coefficient of effectiveness (Nichiporovich, 1956) are identifical in meaning with harvest index, but HI is accepted and used by plant breeders and physiologist (Kertesz,1984). Experiment conducted at Australia revealed that harvest index was lower in the plants grown in the normal season than in plants grown in the cool post-rainy season where the plants were smaller and mature sooner (Akinola and Whiteman,1974). The low harvest index in pulses appeared to be responsible for low yield and not the photosynthetic capacity (Jain, 1975). The importance of a favourable harvest index for high yields in pulses had also been recognised by Swaminathan (1973), Jain (1975) and Sharma and Green (1975). The harvest index ranged from 12 to 30 per cent in several early and medium maturity pigeonpea cultivars (Ariyanayagam, 1975). The ideal plant in pigeonpea would be one with medium spread, early maturity and high yield. This ideal plant type combined with photoperiod insensitivity and high harvest index would give desired results in improving the yield (Kapoor, 1977).

Association of grain yield and Harvest Index

Cultivar differences in harvest index may be influenced by the dry matter partitioned into seeds in the reproductive phase (Narayanan and Sheldrake, 1976). Grain yield increase was accompanied by an increase in both total dry matter production and harvest index (Chopra and Sinha,1980) Ram et al. (1976a) also observed a positive and significant association of HI with grain yield at phenotypic level. Singh et al. (1981) and Marekar (1982) obtained a positive correlation between grain yield and HI. The association of HI, grain yield with total dry matter production was also studied by Khapre and Nerkar (1985). Studies at ICRISAT revealed that harvest index was higher in determinate cultivars (31.5 per cent) than in indeterminate cultivars (19.2 per cent) (Venkataraman and Green, 1979).

Effect of sowing dates on harvest index

As in most grain legumes, HI in pigeonpea was strongly influenced by environment (Saxena et al., 1983). As early as 1923, it was reported that under shorter day lengths, more DMP was partitioned into seed (Garner and Allard, 1923) in pigeonpea particular (Lawn, 1980). Low HI in pigeonpea was also recorded by Willey et al. (1980). The harvest index of rabi pigeonpea was higher (35 per cent) than in the kharif (28 per cent) season (Sheldrake and Narayanan, 1977). Venkataraman and Sheldrake (1981) recorded higher harvest index (34 per cent) in September than in November (28 per cent) sowings. Late plantings, which produced smaller plants with less vegetative growth resulted in high HI (Anon., 1978). Katiyar and Sarial (1985) indicated that the variances in harvest index due to genotypes and environments were highly significant. Among cultivars tested, HI ranged from 8 to 39 per cent (Tayo and Togun, 1984). The harvest index decreased from 33 to 26 per cent owing to the added fall n leaf materials among cultivars studied (Sheldrake and Narayanan, 1979). For high and stable grain production, a balanced partitioning of dry matter to grain must be achieved and this will be reflected in the HI (Singh and Kush, 1980). In general, improved HI represented increased physiological capacity to mobilise and translocate photosynthetic products to organs of commercial value. For selection, not only HI but also a number of physiological and quantitative characteristics should be considered as criteria (Kertesz, 1984).

Pod set

The pod setting percentage in pigeonpea cultivars ranged from 10 to 12 per cent (Derieux, 1969; 1970). A record of 42 per cent was also observed in ICRISAT, Hyderabad (Anon., 1974). In Caribbean area pod setting percentage was 3.6 to 17.6 per cent whereas in Guadeloupe the percentage was 4 to 19.1 per cent. In Jamaica and Trinidad, the above percentage was 2.20 to 63 per cent and approximately

35 per cent respectively (Derieux, 1970; Hammerton, 1974; Ariyanayagam, 1975). It also ranged from 15.0 to 19.0 per cent in rabi season under Indian conditions (Sheldrake and Narayanan, 1977). Abscission had been noted to occur mostly within 4-9 days of flower opening in Jamaica (Hammerton, 1974). The great majority of flowers as many as 90 per cent were shed without setting pods (Pathak, 1970; Sheldrake et al., 1979; Tayo, 1980; Singh et al., 1984; Pandey and Singh, 1981).

Effect of environment on pod sett

With regard to environmental influence on pod setting, experiment conducted at ICRISAT revealed that no pod set occured at night temperature below 7°C during the reproductive phase but at 15°C pod set was normal which suggested that the critical night temperature for this cultivar was between 7 and 15°C (Anon., 1983). Pod set appeared to be normal when weekly mean minimum temperatures was over 15°C (Saxena et al., 1985). Pod set is probably dependent on supply of assimilates and nutrients and also some auxin factors. The abscission promoting auxins were responsible for flower drop and might be localised. The perennial nature of pigeonpea could also be a reason for such behaviour (Sheldrake, 1979). The reasons for flower drop were primarily physiological and could not be accounted for in terms of pest attack or inadequate pollination (Sheldrake, 1984).

Microclimatology and physiological parameters

Leaf temperature: Microclimatology deals with the studies on the principles of interactions between plants and environmental factors (Kakde, 1985). The work done on microclimate of pigeonpea is very limited. Spence and Fordham (1973) and Taitt and Spence (1976) studied the microclimate of pigeonpea. The leaf temperature was measured in crop plants as early as 1915 (Ehlers, 1915; Miller and Saunders, 1923; Ansari and Loomis, 1959). Clum (1926) attempted to correlate leaf temperature with transpiration. Jackson (1981) reviewed the leaf temperature of plants in relation to water stress conditions. Experiment conducted at Czechoslovakia revealed that both maintenance and dark respiration rates were increased with leaf temperature. The leaf temperature ranged from 15-62°C (Kase and Catsky, 1984).

Leaf water potential

Rawson and Constable (1980) reported that the -50 bar water potential was severe enough to result in tip death of the branches in pigeonpea. They also added that photosynthesis was reduced at -20 bar leaf water potential. The changes in transpiration rate was also associated with leaf water potential. Transpiration rate was reduced under the leaf water potential changed from -13.0 to 18.0 bars (Ramesh Babu et al., 1982) and it also ranged from -1.5 to -31.6 bars (Ramesh Babu et al., 1983).

While studying the diurnal variation on leaf water potential, it was revealed that LWP was high in the morning and low in the evening (Singh et al., 1983; Singh et al., 1984).

Transpiration

The stomatal resistances affected photosynthesis to much lesser extent than transpiration in pigeonpea (Spence and Fardham, 1973). Older leaves recorded lesser transpiration rate than younger leaves (Rawson and Constable, 1980). Transpiration rate increased from seedling to flowering phase in pigeonpea. This might be attributed to the stomatal development and position of the leaves (Joshi, 1983). Ramesh Babu et al. (1982) measured the transpiration rate in pigeonpea and found that it ranged from 1.8 to 15.1 ($mg.dm^{-2}.min^{-1}$). Increased transpiration was also associated with increased DMA (Onium, 1983). Since, there was a change in meteorological factors during growth, the differences in water potential and solute potential could be due to changes in temperature and humidity rather than the developmental effects (Agarwal et al., 1984). The leaf conductance was strongly affected by growth conditions and changed with leaf age. It increased with leaf emergence to maturity and declined to a very low value as the leaf senescenced (Jones, 1983).

Chlorophyll content

Deshpande and Nimbalkar (1981) recorded lesser content of chlorophyll in senescent leaves than the intact leaves. It could also be attributed to the disturbed chloroplast structure in the senescent leaves. A maximum chlorophyll content of 3.544 $mg.g^{-1}$ at active pod filling stage had also been reported (Luthra et al., 1983). With regard to varietal variations, the chlorophyll content ranged from 2.20 to 3.94 $mg.g^{-1}$ in different varieties (Joshi and Nimbalkar, 1984).

Photosynthesis

Like all legumes, pigeonpea is a C_3 plant (Saxena et al., 1983). The photosynthetic activity was more pronounced during the vegetative phase of crop growth and declines as pod begin to develop (Sinha, 1970). This drop was associated with a fall in leaf N and loss of RUBP activity (Jain, 1975). Genotypic differences in the relative rates of photosynthesis of pigeonpea leaves measured by ^{14}C fixation had been observed (Pandey et al., 1976). Rawson and Constable (1980) suggested young fully expanded leaves in pigeonpea for measuring the photosynthetic rate and found that it ranged from 20.0 to 25.0 (mg $CO_2.cm^{-2}.S^{-1}$). The reason for low photosynthetic rate might be attributed to its saturation at low light intensity. Luthra et al. (1983) compared the photosynthesis in leaf, pod wall, andseed and found that leaf photosynthesis was 4-12 times higher than the pod wall and 7-9 times more than the seed. RUBP and PEPC activity was more in pod wall than in the seeds. The low amounts of PEPC enzyme (activity ranging from 0.04 to 0.11 μ mol. $CO_2.dm^{-2}.min^{1}$) had been reported (Cheema and Pandey, 1980). Experiment conducted with $^{14}CO_2$ revealed that after 48 hours period of translocation period the percentage of photosynthetically fixed $^{14}CO_2$ that accumulated in seeds, pod walls and stems were 59, 21 and 15 per cent respectively (Tim et al., 1984). Joshi and Nimbalkar (1984) recorded that the rate of $^{14}CO_2$ assimilation ranged from 7.67 to 8.17 ($S^{-1}mg^{-1}$ (FM) . They also found that saccharose as the photosynthetic product. The reason for low photosynthetic rate in pigeonpea leaves might be attributed to its higher rates of respiration (Luthra et al., 1963).

Light interception and Canopy Productivity

Monteith's (1972) analysis of crop productivity showed the importance of solar radiation interception as a major determinant of dry matter production. Work done on pigeonpea revealed that the rate of dry matter production was proportional to intercepted radiation (Natarajan and Willey, 1980; Hughes et al., 1981; Hughes and Keatinge, 1983). The theoretical basis for the attenuation of light within a canopy had been provided by Monsi and Saeki (1953) who presented a relationship analogous to the Beer-Lambertson Law. $I = I_o e^{-kL}$ where I_o is the intensity of the incident radiation.

I is the intensity after passage through a canopy of a given leaf area index (L), while K is the extinction coefficient. Verhagen et al. (1963) related light extinction coefficient to leaf area index, where K value was low, the intensity of light available at depths in the foliage was high (Williams and Joseph, 1970).

Light extinction coefficient

Plants with prostrate leaf arrangements have higher extinction coefficient (k) within the canopy than those with erect leaves (Cooper and Breese, 1971). The K value also depended on specific properties of the foliage, of which leaf inclination, leaf size, reflective and absorptive properties and vertical spacing or distribution were the most important (Verhagen et al., 1963). Light transmission ratio (LTR) decreased with increasing leaf area index in rice (Anon., 1969). With regard to pigeonpea, LAI and light interception were linearly related (Wallis et al., 1975). The efficiency of radiation interception by the crop was largely a function of LAI (Shibles and Weber, 1965; 1966). Rowden et al. (1981) recorded low extinction coefficient (k=0.3) suggesting that canopy structure was efficient in allowing light penetration at critical LAI. Work done at Trinidad revealed that pigeonpea inefficiently used the intercepted solar radiation for dry matter production. A mean intercepted light use efficiency of 0.91 and 1.08 per cent was observed with short duration and medium duration pigeonpea cultivars respectively was recognised for the period upto maximum dry matter production (Hughes et al., 1980; Natarajan and Willey, 1979).

Heat unit concept

Reaumer (1735) was credited with the first enunciation of the heat unit concept. He found that sum of mean daily air temperature required by a species to reach maturity was constant from year to year. Boussingault (1837) followed the same method and called the calculated heat requirements 'degree days'. Plant development is inhibited by temperature below a certain level, referred to as base temperature and this temperature is substracted from daily mean temperature before carrying out the summation. Plant development was also inhibited at temperature higher than optimum (Gilmore and Rogers, 1958).

An equation was developed to determine degree days for conditions when base temperature was above daily minimum and optimum was less than daily maximum temperature (Baskerville and Emin, 1969). Nuttonson (1948, 1955) pioneered studies on the effect of temperature and photoperiod together on plant development. Degree days were multiplied by average photoperiod of the phenological phases to obtain photothermal index. The degree day methods were shown to fail when the differences in developmental phases arise due to soil moisture (Idso et al., 1978; Iwata, 1984).

Heat units and crop growth

Correlation between dry matter production and sum of air temperature was obtained in soybean (Holmes and Robertson, 1959; Uchijma, 1975; Rajput, 1980), and also in wheat (Chakravarthy and Sashtry, 1983 a, b, c). A positive significant correlation was showed in pigeonpea between accumulated temperature units, seed yield and DMP (Chi-Chu Wang, 1979; Dhingra et al., 1980). In mustard, similar results had been obtained by Ravindra (1985). Uchijima (1975) concluded that the sum of air temperature was highly responsible for the accumulation of dry matter of crop stand. He also obtained a relation between accumulation of dry matter and sum of solar radiation which followed a sigmoid pattern. The poor dry matter accumulation in the earlier stages was attributed to poor capture of solar radiation by the crop canopy (Iwata and Okubo, 1969).

Nutrient uptake

Plant species differed extensively in the uptake, translocation, accumulation and use of mineral elements. If this were not so, the great diversity of plants now known would not exist. Diversity among genotypes, cultivars, varieties, lines, inbreds etc. within a plant species for mineral element, uptake, translocation, distribution, and use had been recognised for many years. Numerous reviews had been written on the subject (Antonovics et al., 1971; Brown, 1963, Epstein,1972; Lauchli,1976; Milliken,1961; Murray and Benson,1976; Saric,1981; Vose,1963; Brown et al., 1972; Brown 1978). Large differences among genotypes for mineral elements should be recognised (Clark, 1983). Many differences were under genetic control but their expression might be altered dramatically when the plants were grown under different environments. These genotype differences helped to explain plant adaptations to many mineral stress conditions noted throughout the world (Devine,1982; Jung,1978; Rorison, 1969; Wright,1976). These differences provided the basis for better adaptation and survival under unique mineral stress conditions (Clark, 1983).

Nutrient content

Bajani and Patel (1956) analysed the nutrient contents of pigeonpea leaves and found that 1.12 N, 0.36 P, 0.72 K and 0.48 Ca per cent at harvest stage. The uptake of total phosphorus was found to be 160 mg.plant^{-1} (Sheldrake and Narayanan, 1979b). The phosphorus content in the leaf, stem, grain and husk were 0.194, 0.124, 0.375 and 0.104 per cent respectively (Hegde and Saraf, 1982b). They also found out that the potassium content in the leaf stem, grain and husk were 0.5, 0.27, 1.22 and 0.33 per cent respectively. Seeds were richer in NPK than the other tissues (Metha and Khatri, 1962). The chemical analysis of the seed revealed that the protein, fat, ash, CaO, MgO and Fe content were 22.31, 1.45, 3.21, 0.128, 0.205 per cent and 7.62 mg/g respectively at harvest stage (Pant and Kapur, 1963).

Nutrient uptake in different crop compounds

The nutrient uptake of N, P, K, Ca and Mg were found to be 13.15, 4.98, 4.5, 5.4 and 2.2 $kg.ha^{-1}$ respectively in a variety of pigeonpea with the DMP of 1825 $kg.ha^{-1}$ (Metha and Khatri, 1962). Experiment conducted at Trinidad revealed that the total NPK, Ca and Mg contained in a pigeonpea variety yielding 5200 $kg.ha^{-1}$ of green pods were 198, 17, 53, 43 and 31 $kg.ha^{-1}$ respectively (Dalal,1980). Studies on nutrient uptake in pigeonpea revealed that the total NPK, Ca and Mg were found to be 216, 12, 168, 54 and 19 $kg.ha^{-1}$ respectively in a variety of 147 days of duration with 12340 $kg.ha^{-1}$ of DM. On an average 109 kg N and 14 kg $P.ha^{-1}$ were removed by a crop of medium duration pigeonpea cultivar (Singh et al., 1983).

Nitrogen

Experiment conducted at ICRISAT revealed that the nitrogen content of the stem at harvest was 0.53 per cent (Sheldrake and Narayanan, 1977). Sheldrake and Narayanan (1979) reported that the uptake of N was 2.5 $g.plant^{-1}$ in a variety with 160 days of duration. Calculations had shown that the remobilisation from the leaves could be account for most of nitrogen in the seeds and for at least half the phosphorus (Sheldrake and Narayanan, 1979b; Irizarry and Rivera, 1983). Hegde and Saraf (1982) found that the N content in the leaf, stem, grain, and husk were 2.83, 0.96, 3.21 and 0.89 per cent respectively at harvest stage. The N content in the grain ranged from 3.5 to 12.9 per cent (Sheldrake and Narayanan, 1977). The amount of N in the root system was estimated to be 10 kg. ha^{-1} (Sheldrake and Narayanan, 1979b). The total uptake of nitrogen and phosphorus ranged from 72 to 216 kg.ha^{-1} and 10 to 24 kg.ha^{-1} respectively at harvest stage (Ahlawat, 1981). Although pigeonpea accumulated upto 301 kg. N ha^{-1} only 21-49 per cent was utilised for seed development. The low yield in pigeonpea might also be attributed to the poor utilization of accumulated nitrogen (Sinha et al., 1983).

Phosphorus and Potassium

With regard to phosphorus, Sheldrake and Narayanan (1977) found that the total phosphorus uptake by above ground parts of the plant grown in black soil was 5.6 kg/ha. Measurements on field grown plants had shown that N, P and K uptake took place throughout the vegetative phase and continued during the reproductive phase (Natarajan and Willey, 1980). The percentage content of these elements in the various vegetative organs declined towards reproductive phase (Sheldrake and Narayanan, 1979b; Ahlawat, 1981; Chauhan and Singh, 1981).

Protein content

The protein content of most legumes is within the range of 18-25% with a few exceptions (36-40 per cent in soybean). Over 200 varieties of pigeonpea had been analysed for protein content which was found to range from 16.1 to 30 per cent (Abrams, 1975). The perennial pigeonpea types had bigger and heavier seeds than the annuals and vice-versa for protein contents (Rathinaswamy et al. 1973). It had also been reported that early maturing cultivars had higher seed protein (20.62 to 25.5 per cent) than late maturing ones (19.95 to 21.75%) (Tripathi, 1975). The protein content of the pigeonpea cultivars also ranged from 17.9 to 25 per cent (Singh et al., 1970; Sharma et al., 1976; Tetteh, 1976; Geervani, 1980). With regard to influence of sowing date in protein content, experiment conducted at Meerut with three dates of sowing viz., June 7, 22 and July 7 revealed that June 22 planting recorded more protein content than the other plantings (Singh et al., 1981). However, Singh et al. (1971) found that protein content of seed was not at all affected by dates of sowings.

Genotype x Environmental Interactions

Stability parameters for comparing varieties under different environments had been formulated by Eberhart and Russell (1966). The variation arising from the lack of correspondence between the genetic and non-genetic effects is also known as genotype x environment interaction (Verma and Gill, 1975). Frey (1964) found that mean squares due to strain x environment interaction was highly significant for the group of lines selected under non stress conditions. A study with 21 sorghum hybrids at seven locations over two years indicated differential response of genotypes grown under different environmental conditions for yield (Liang and Walter, 1966). Evaluation of sorghum varieties and hybrids was carried out in a series of East African environments during 1966 to 1970 by Majisu and Doggett (1972). Genotype x environment interaction was significant for all years and genotypes usually differed significantly in their regression on environments. Two varieties had mean yield above the grand mean and the regression coefficient was close to unity, but their mean square deviations were undesirably large. Some genotypes showed evidence of good yield stability but their superiority over local environment was in doubt. Significantly large portion of G x E interaction was accounted for by the linear component. The non-linear component was not significant and its magnitude was considerably smaller than that of linear component (Palaniswamy et al., 1978). In maize, stability was genetically controlled (Scott, 1967). Significant G x E interaction was observed for number of grains/plant, plant height and yield (Mall et al., 1978). Generally, more than 80 per cent of the yield variation for individual varieties was due to linear regression response

(Langer *et al.*, 1979). In smooth brome grass, G x E interaction was significant for plant height, tiller density, tiller dry weight, leaf area and forage yield (Tan *et al.*, 1976, 1977; 1978; 1979; Walton, 1976).

With regard to pigeonpea, Ramanujam (1975) studied the linear and non linear component of G x E interaction. He also showed that large proportion of genotypes showed more linear components than non linear components respectively for the following traits namely, yield per plant (73.61 per cent; 26.39 per cent), number of pods per plant (77.43 per cent, 22.57 per cent), number of seeds per pod (48.98 per cent; 51.02 per cent), number of primary branches per plant (34.21 per cent; 65.79 per cent) and seed size (78.99 per cent; 20.01 per cent). Importance of studying the G x E for physiological traits for crop improvement was stressed by Lawn (1980). Over 100 genotypes of pigeonpeas were evaluated in five environments. The G x E interactions were found significant in the case of pods per plant, branches per plant and 1000-grain weight. The linear component of the G x E was found to be significant only for days to maturity and grain yield per plant. However, its non-linear component was significant for almost all the characters (Jag shoran *et al.*, 1981). The magnitude of range for phenotypic variability was high for all characters except seeds per pod (Jag Shoran, 1983). Jag Shoran (1985) found that the relationship between linear and non linear responses were observed to be character specific in pigeonpea. He also added that a stable variety could be defined as one with unit regression (bi=1) and low deviation from linearity (S^2di = 0).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Investigations outlined in the thesis were carried out during 1984-85 in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, to collect specific as well as comprehensive information the possible effects of different dates of sowing on the growth and physiology of pigeonpea. A brief account of the methodologies adopted and materials utilised are elucidated in the following pages.

Field Experiments

The experiment was laid out under field conditions in the 'B' block of the New Area, Millet Breeding Station. The details are given below:

Design of experiment : Randomised Blocks design

Cultivars (Six) : Short duration

V_1 - CO 5

V_2 - CORG 5

V_3 - UPAS 120

Long duration

V_4 - CORG 11

V_5 - PLS 361/1

V_6 - A 1

The seeds were obtained from the Professor of Pulses, School of Genetics, Tamil Nadu Agricultural University, Coimbator

Treatments (Date of sowing)	:	Three
		D_1 - 21-2-1984
		D_2 - 21-6-1984
		D_3 - 21-9-1984
Replications	:	Three
Plot size	:	3.6 x 2.25 M
Spacing	:	45 x 30 cm (short duration) 45 x 45 cm (long duration)

Field Location

The experimental field was situated at 11°02" N latitude, 76.57"E longitude and at an altitude of 426.76 M above mean sea level. The mean average rainfall was about 631 mm, while the mean maximum and minimum temperatures were 30°C and 26°C respectively.

Soil properties

The soil was analysed for its physical and chemical constituents before sowing and the data are presented below. The same field was used for cultivation in all the three seasons. So, the variation due to soil was eliminated in the present study.

Physical and Chemical analysis of soil

Soil type : Clay loam

1. Physical properties		Contents
Sand	:	49.92 (per cent)
Coarse sand	:	36.41 (per cent)

Fine sand	:	13.51 (per cent)
Clay	:	38.17 (per cent)
Silt	:	12.80 (per cent)
Volume of expansion	:	36.25 (per cent)
Maximum water holding capacity	:	37.66 (per cent)
Pore	:	40.56 (per cent)
Apparent density	:	1.62
Absolute specific gravity	:	2.66

Chemical properties

pH	:	7.4
EC	:	0.210
CEC	:	5.20
Available P (kg/ha)	:	7.12
Available N (organic carbon method)	:	0.092 per cent
Exchangeable potassium	:	0.09 per cent
Exchangeable calcium	:	4.22 per cent
Exchangeable Magnesium	:	2.01 per cent
Exchangeable sodium	:	0.114 per cent
Exchangeable SAR	:	0.060
ESP	:	0.270

Seed treatment

Before sowing, the seeds were treated with Bavistin @ 2 g/kg in a polythene bag to ensure a uniform coating over the seed. After 12 hours of bavistin treatment, the seeds were once again treated with Rhizobium peat culture. The inoculum was obtained from the Department of Agricultural Microbiology, Tamil Nadu Agricultural University, Coimbatore. Jaggery (125 g) was boiled with 500 ml of water and cooled. It was used as adhesive to inoculate the *Rhizobium* with seeds. The treated seeds were dried under shade for thirty minutes before sowing.

Fertiliser doses

Fertiliser was basally applied at the rate of 20:40:0 (N:P:K) as urea, superphosphate and muriate of potash respectively at the time of seeding.

Weather conditions data

The experiment was conducted from 21-2-84 to 26-2-85. The metereological data of maximum, minimum temperature, relative humidity, sunshine hours, solar radiation, evaporation and rainfall were recorded at the Meteorological Observatory, Tamil Nadu Agricultural University, Coimbatore. The data on day length at 11°N latitude were calculated from the table published by C.P.Casella and Co. The monthly total and mean of the meteorological observations were worked out and presented in Table 1, 1a.

Stages of sampling

Samples were drawn at six stages namely, 30, 40, 50 days after sowing, first flowering, 50% flowering and harvest stages for studying growth and development. The various physiological measurements were made at 50 days after sowing,

Table 1. *Meteorological observations (Monthly total and mean)*

Year and Months	Temperature (°C)				Relative humidity (%)				Rainfall (mm)		Sunshine hours		Evaporation (mm)		Solar radiation			
	Maximum		Minimum		07-22		14-22								(cal.cm^{-2}. min^{-1})		Day length (Hours)	
	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	No. rainy days	Total	Mean	Total	Mean	Total	Mean	Total	Mean
1984																		
February	858.5	29.6	592.0	20.4	2612	90.0	1435	49.0	53.8	3	182.5	6.3	112.0	4.4	6018.6	207.53	342.16	11.48
March	997.9	32.1	613.5	19.9	2695	86.9	1256	40.2	121.7	6	263.2	8.4	130.0	4.2	7130.2	230.0	315.23	12.06
April	1021.6	34.0	685.4	22.8	2676	89.2	1353	45.1	53.8	5	247.5	8.3	150.2	5.0	6954.0	231.80	372.50	12.25
May	1107.6	35.7	729.0	23.5	2595	83.7	1201	38.7	53.4	5	292.6	9.4	193.0	6.2	7802.6	251.72	393.15	12.51
June	926.7	30.8	687.7	22.9	2230	74.0	1604	53.0	41.0	4	100.9	3.3	198.2	6.6	6144.8	204.82	383.10	12.46
July	939.5	30.3	699.4	22.3	2495	80.4	1718	50.4	43.5	4	137.8	4.4	171.0	5.1	6382.0	205.87	392.24	12.39
August	976.6	31.5	676.5	21.8	2471	80.0	1539	50.0	8.1	1	196.5	6.3	224.4	7.2	7036.0	226.96	384.09	12.23
September	954.2	31.8	653.0	21.7	2551	85.0	1516	50.0	82.6	6	204.8	6.8	150.4	5.3	6598.0	219.93	364.30	12.09
October	916.4	29.6	624.2	20.1	2713	87.0	1709	55.0	290.3	9	233.8	8.0	119.2	3.8	6949.4	224.17	368.17	11.52
November	877.6	29.2	598.2	19.9	2658	89.0	1600	53.0	86.2	5	217.7	7.2	94.8	3.1	6160.2	205.34	348.50	11.37
December	900.0	29.0	516.4	16.6	2800	90.0	1422	45.0	40.5	2	287.7	9.2	120.0	3.8	6918.2	223.16	357.20	11.30
1985																		
January	892.0	28.7	591.4	19.1	2776	89.0	1588	51.0	70.4	4	218.9	7.1	109.8	3.5	6297.8	203.15	358.27	11.33
February	905.0	32.3	532.0	19.0	2256.	81.0	980	35.0	-	-	245.4	8.5	145.2	5.1	6614.4	236.23	330.22	11.47

Table 1a. Mean meteorological observation during the cropping period

te of wing	Cultivars	Temperature (°C) Max.	Temperature (°C) Min.	Relative humidity (%) Max.	Relative humidity (%) Min.	Sun-shine hours	Evaporation (mm)	Solar radiation ($Cal.cm^2.min^{-1}$)	Range of temperature (°C) Max.	Range of temperature (°C) Min.
	Short duration									
	CO 5	33.26	22.0[illegible]	84.15	47.57	7.64	5.40	10[illegible].11	37.0	16.5
	CORG 5	33.01	22.14	83.[illegible]	44.28	7.44	5.53	101.28	37.0	16.5
	UPAS 120	33.16	22.0	83.85	47.33	7.74	5.[illegible]	106.38	37.0	16.5
	Mean	33.21	22.0[illegible]	8[illegible].74	4[illegible].73	7.62	5.44	[illegible]	37.0	16.5
	Long duration									
	CORG 11	33.37	22.09	82.70	46.64	6.93	5.93	94.23	37.0	16.5
	PLS 361/1	[illegible]	22.00	82.62	46.85	6.92	5.80	93.09	37.0	16.5
	SA 1	32.29	22.01	82.91	47.45	6.80	5.69	91.68	37.0	16.5
	Mean	32.67	22.02	82.74	46.98	6.88	5.81	93.26	37.0	16.5
	Grand mean	32.94	22.09	83.24	45.36	7.25	5.63	98.79	37.0	16.5
	Short duration									
	CO 5	30.84	22.01	81.92	53.44	5.7[illegible]	5.80	74.32	33.5	17.8
	CORG 5	30.81	21.79	81.94	52.81	5.81	5.86	76.35	33.5	14.0
	UPAS 120	30.96	22.13	81.73	53.61	5.57	5.87	70.95	33.5	18.2
	Mean	30.87	21.97	81.86	53.28	5.71	5.84	73.87	33.5	16.67
2	Long duration									
	CORG 11	30.34	20.78	84.34	52.79	6.53	5.01	83.85	33.5	11.7
	PLS 361/1	30.27	20.68	84.40	52.48	6.59	5.00	84.51	33.5	11.7
	SA 1	30.23	20.54	84.56	52.30	6.68	4.98	86.05	33.5	11.7
	Mean	30.28	20.67	84.44	52.52	6.60	4.99	84.80	33.5	11.7
	Grand mean	30.58	21.32	83.15	52.90	6.16	5.42	79.34	33.5	11.19
	Short duration									
	CO 5	29.34	19.50	89.27	53.45	7.55	3.33	94.63	33.0	11.7
	CORG 5	29.29	19.46	89.35	53.14	7.58	3.37	94.50	33.0	11.7
	UPAS 120	29.47	19.37	89.17	52.22	7.72	3.49	98.91	33.0	11.7
	Mean	29.36	19.44	89.26	52.94	7.62	3.39	96.01	33.0	11.7
D_3	Long duration									
	CORG 11	29.61	19.12	88.86	50.52	7.69	3.62	97.31	34.0	11.7
	PLS 361/1	29.73	19.22	88.39	49.97	7.75	3.69	99.00	34.0	11.7
	SA 1	29.84	19.16	90.75	49.24	7.84	3.76	100.76	34.0	11.7
	Mean	29.73	19.16	89.33	49.91	7.76	3.69	99.02	34.0	11.7
	Grand mean	29.55	19.30	89.29	51.43	7.69	3.54	97.52	33.5	11.7

first flowering, 50% flowering and harvest stages. Yield and yield components were analysed at the time of harvest stage.

Growth attributes

Shoot height

The shoot length of the plant was measured from the ground level to the growing tip at different stages and the average was worked out for five plants randomly in each replications and expressed in cm.

Root length

The distance from the base to the longest root was measured at different stages and the average was expressed in cm.

Number of primary branches

The number of branches were counted at all stages by destructive analysis and the average was expressed as number per plant.

Leaf number

Five plants from each replication were removed at random and the trifoliate leaf was counted as a single unit. The number of leaves per plant was arrived at through working out the mean of five plants.

Leaf Production Rate (LPR)

The rate of leaf production was arrived at by using the following formula and expressed as number of leaves per day.

$$LPR = \frac{\text{Number of leaves at second stage} - \text{Number of leaves at first stage}}{\text{Time interval}}$$

Leaf Area

For leaf area measurements, the weight to area relationship was utilised. Fifty leaves of the sampled plants were taken from different positions at random and their area was recorded using the Licor-model 3100 Conveyer belt leaf area meter. These were finally weighted after drying. The rest of the leaves were kept in an oven and their area was computed on the basis of area to weight ratio at all stages and the average was expressed in cm^{-2} per plant.

Dry Matter Accumulation (DMA)

For estimating the dry matter accumulation of stem, leaf and root, the entire plant was pulled out with least root damage. The whole plant was separated into leaf, stem, root and dried at 80 ± 1°C for 24 hours and the dry weight of the stem, root and leaf were weighed and expressed in $g.m^{-2}$.

Shoot/Root ratio

Shoot/root ratio was calculated by both length and dry weight method.

Leaf/Stem Ratio

Leaf/stem ratio was arrived at by dividing the leaf dry weight by stem dry weight. The root weight was not included in the stem dry weight.

Individual Leaf Area (ILA)

ILA was calculated by using the following formula and expressed in cm^{-2}. $leaf^{-1}$.

$$ILA = \frac{\text{Total leaf Area}}{\text{Total leaf number}}$$

Individual Leaf Weight (ILW)

ILW was arrived at by using the following formula and expressed in mg. $leaf^{-1}$.

$$ILW = \frac{\text{Total leaf weight}}{\text{Total leaf number}}$$

Growth analysis Components

Leaf Area Index (LAI)

The leaf area index was calculated by employing the formula of Williams (1946).

$$LAI = \frac{\text{Leaf area of a plant}}{\text{Land area occupied}}$$

Leaf Area Ratio (LAR)

The LAR was arrived at by using the formula of Radford (1967) and the values expressed in $cm^{-2}.g^{-1}$.

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

Leaf Weight Ratio (LWR)

The LWR was calculated by employing the formula suggested by Kvet *et al.* (1971) and expressed as $g.g^{-1}$.

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

Absolute Growth Rate (AGR)

The AGR was calculated by using the formula suggested by Kvet *et al.* (1971) and expressed in $g.\ plant^{-1}.day^{-1}$.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

where W_1 and W_2 are the plant dry weights at t_1 and t_2 respectively.

t_1 and t_2 are time interval in days.

Leaf Area Duration (LAD)

The LAD was determined by using the formula suggested by Power *et al.* (1967) and expressed in days.

$$LAD = \frac{Li\ (Li + 1)}{2} \times t_2 - t_1$$

Where

Li = Leaf area index at the first stage
Li+ 1 = Leaf area index at the second stage
t_2+ t_1= Time interval between stages

Specific Leaf Weight (SLW)

The SLW was arrived at by using the formula suggested by Pearce *et al.* (1968) and expressed in $g.cm^{-2}$.

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

Specific Leaf Area (SLA)

The following formula suggested by Kvet *et al.* (1971) was employed and expressed in $cm^{-2}.g^{-1}$.

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

Relative Growth Rate (RGR)

The RGR was determined by utilising the formula suggested by Williams (1946) and expressed in $g.g^{-1}\ day^{-1}$.

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

where W_1 and W_2 are where plant dry weights at t_1 and t_2 respectively

t_1 and t_2 are time interval in days.

Net Assimilation Rate (NAR)

The method proposed by Gregory (1918) and modified by Williams (1946) was employed for calculating the NAR and it was calculated based on leaf dry weight basis and the values were expressed in $g.g^{-1}.day^{-1}$.

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e l_2 - \log_e l_1)}{(l_2 - l_1)}$$

where, W_1 and W_2 are leaf dry weights of whole plant at t_1 and t_2 respectively. L_1 and l_2 are leaf dry weights at t_1 and t_2 respectively

t_1 and t_2 are time in days.

Crop Growth Rate (CGR)

From the dry weight of whole plant, CGR was arrived at using the formula suggested by Watson (1958) and expressed in $g.m^{-2}.day^{-1}$.

$$CGR = \frac{W_2 - W_1}{P\ (t_2 - t_1)}$$

where, W_1 and W_2 are the whole plant dry weight at t_1 and t_2 respectively.

t_1 and t_2 are time in days

P is the ground area in which W_1 and W_2 have been estimated.

Dry Matter Efficiency (DME)

The dry matter efficiency was calculated by means of the formula suggested by Krishnamurthy et al. (1973).

$$DME = \frac{\text{Seed yield}}{\text{Total DMP}} \times \frac{100}{\text{Duration of genotypes}}$$

Unit Area Efficiency (UAE)

The UAE for seed yield and total DMP were calculated by using the following formula and the values are expressed $g.m^{-2}.day^{-1}$.

$$UAE\ (Seed\ yield) = \frac{Seed\ yield}{Land\ area} \times \frac{1}{Duration\ of\ genotype}$$

$$UAE\ (Total\ DMP) = \frac{Total\ DMP}{Land\ area} \times \frac{1}{Duration\ of\ genotype}$$

Fallen leaves and Reproductive parts

Six plants in each replication were marked on 30th day after sowing. The fallen leaves and reproductive parts were collected at weekly intervals in between rows of the plants and the cumulative weights were obtained ($g.plant^{-1}$) at specified stages. The leaves were free from any foliar disease.

Yield and Yield components

Five plants from each replication were removed from the soil at harvest stage and analysed for the following components.

Number of primary branches

The number of primary branches were counted and the mean value expressed as numbers per plant.

Number of pods per plant

All the pods picked in each replication were counted and expressed as number of pods per plant.

Number of seed per pod

Seeds were removed from the randomly selected 30 pods. The seeds were counted and the average was worked out and expressed as number of seed per pod.

1000 seed weight

After drying and thrashing, the seeds were separated from the husk. Randomly picked 1000 seeds were counted from each replication and the mean was expressed in g.

Dry weight of pods

Before separating the seeds from the pods, the pods were weighed and expressed as g. plant^{-1}.

Pod set

Before picking the pods from the selected plants, the scars on the racemes, representing the abscission zone of fallen buds, flowers and pods were counted and from these data the percentage of pod set was calculated by using the formula formulated by Sheldrake and Narayanan (1977).

$$\text{Percentage of pod set} = \frac{\text{Number of pods per plant}}{\text{Scar number per plant} + \text{Number of pods per plant}} \times 100$$

Harvest Index (HI)

Harvest Index was calculated by using the following formula and expressed in percentage

$$HI = \frac{\text{Grain yield}}{\text{Total phytomass}} \times 100$$

This was also calculated taking into account fallen leaf dry weight and reproductive weight materials added to total DMP (Total phytomass)

HI was also calculated on energy basis from the following formula

$$HI = \frac{\text{Energy content of economic yield}}{\text{Energy content of phytomass}} \times 100$$

For calculating energy value, the energy content of seed and DMP were considered as 4.45 and 3.96 (K.cal.g seed^{-1}) respectively (Sinha and Swaminathan, 1984).

NHI (Nitrogen harvest index) was calculated by the following formula adopted by Spiertz (1982).

$$NHI = \frac{\text{Nitrogen uptake by Grain}}{\text{Nitrogen uptake by phytomass}} \times 100$$

Yield of Grain and Husk

After threshing and drying, the grain and husk were weighed and expressed in g.m^{-2} and g.plant^{-1}.

Physiological Analysis

Chlorophyll

The chlorophyll a, b and total were estimated in a fully expanded young leaf in the main branch at specified stages by employing the methods of Yoshida et al. (1971).

Photosynthetic rate

The photosynthetic rate was measured in Infra red Gas Analyser (IRGA) model 225-2B-SS Gas Analyser (Meidner, 1984) manufactured by Analytical Development Company, Hoddesdon, England employing differential measurement technique. The instrument was allowed to warm up initial adjustments made and set to read CO_2 concentration at 300 ppm. The leaves were excised under water and placed inside a plexiglass chamber with a replacement top which was connected to the instrument. The top of the chamber was tightly closed and the rate was expressed in mg $CO_2.dm^{-2}.hr^{-1}$.

Stomatal Diffusive Resistance (CO_2)

The stomatal diffusive resistance for CO_2 was arrived at by multiplying the stomatal diffusive resistance for water with 1.7 (Lamoreaux and Chaney, 1970).

Stomatal Diffusive Resistance (H_2O)

The stomatal diffusive resistance (water) was measured with a pre-caliberated LI-1600 Auto steady state porometer, LI-COR, Lin Coln, Nebraska, 68504 (USA). This was measured in a fully expanded young leaf at 12-14 hours and expressed in $S.cm^{-1}$.

Leaf Water Potential

The leaf water potential was measured using pressure bomb apparatus at selected physiological stages in a petiole of fully expanded young leaf in the main branch (Meidner,1984) and expressed in MPa.

Transpiration rate

The transpiration rate was measured at selected physiological stages in a fully expanded young leaf with the help of LI-1600 Auto Steady State Porometer, LI-COR. Lincoln Nebraska, 68504-USA and expressed in $\mu g.\ cm^{-2}.s^{-1}$.

Leaf temperature and humidity

The leaf temperature and relative humidity was measured at selected stages in a fully expanded young leaf by using the LI-1600 Auto Steady State Porometer, LI-COR,Lincoln, Nebraska 68504 USA. The temperature was expressed in celesius and relative humidity as percentage. All the above measurements were recorded at 12-14 hours with Steady State Porometer.

Light Interception and Canopy growth

Light Interception (per cent)

The light penetration in the middle of the canopy at 12-14 hours was measured by Integrating quantum Radiometer/

photometer, LI-COR - inch LI 18813 and expressed in lux Palaniappan, 1984).

$$\text{Light interception} = \frac{\text{Light intensity at the top of the canopy}}{\text{Light intensity at the middle of the canopy}} \times 100$$

Light extinction coefficient (k)

The k value was worked out by using the formula adopted by Monsi and Saeki (1953).

$$I = I_o \, e^{-KL}$$

where $$K = \frac{1}{L} \log e \left(\frac{I}{I_o} \right)$$

I = Light flux density to a horizontal surface below L units of leaf area index

I_o = Light flux density above the canopy

e = the base to the natural logarithms

k = extinction coefficient

Heat Unit Concept

Cumulative sunshine hours, evaporation and Solar Radiation

The cumulative sunshine hours, evaporation and solar radiation at various stages were calculated by summation of daily recorded values.

Cumulative day length

The cumulative day length (at 11°N latitude) was calculated at different selective stages by referring to the table published by C.F.Casella and Co., London and furnished in Appendix.

Accumulated Heat Unit

The total of cumulative heat unit for each pheno-phases was calculated as a summation of the daily mean temperature during the crop period (Dhingra et al., 1981).

Growing Degree Days (GDD)

GDD or accumulated day degrees is also called "effective heat unit". This is an arithmetic accumulation of daily mean temperatures above certain threshold temperature. This was computed as follows (Iwata, 1984).

$$\text{Degree days} = \frac{(\text{Maximum} + \text{Minimum})}{2} - \text{base temperature}$$

The temperature 15°C was considered as base temperature (Johansen, 1984) for pigeonpea for calculating the degree days.

Photothermal Units (PTU)

For different stages of growth, accumulated photothermal units were calculated by employing the formula of Major et al. (1975).

PTU = Growing Degree days x Mean day length

Heliothermal unit (HUT)

The product of degree days and hours of bright sunshine hours was termed as heliothermal units (Rajput, 1982; Sastry and Chakravarthy, 1982).

HTU = Growing degree days x Number of bright sunshine hours

Heat Unit Efficiency (HUE)

To compare the performance of the variety taken under different dates of sowing with respect to utilisation of heat in terms of day degrees during the crop growth, the HUE was calculated as GDD accumulated to produce unit amount of dry matter per unit area (Rajput, 1980)

$$HUE = \frac{DMP\ g^{-1}.m^{-2}}{GDP}$$

Nutrient Analysis

A quantity of 500 mg of the dried and powdered sample was taken in a pyrex flat bottomed flask and digested with a mixture of sulphuric acid, nitric acid and perchloric acid (2:9(1). Initially, it was digested in a cold state and then heated over sand bath until an ashy white digest was obtained. The digest was filtered and made up to a known volume. This triple acid aliquot was used for the estimation of phosphorus, potassium, calcium and magnesium.

Phosphorus was estimated by employing the method formulated by Jackson (1962).

Potassium was estimated with the help of digitel flame photometer

Calcium and Magnesium were estimated by Versenate titration met od (Jackson, 1962).

The total nitrogen was estimated by employing the method of Humphries (1956).

The protein content was estimated by following the method of Lowry et al. (1951) and the values were expressed as percentage g. plant^{-1} and g.m^{-2}.

Stability Analysis

Stability analysis was worked out by the model suggested by Eberhart and Russel (1966). This model was used in this study to analyse the genotype x environment interaction. Considering three seasons as specific environments, or certain biomass and yield components were studied for their stability over seasons. Biomass components include, photosynthesis, LAI at 50% flowering, leaf-stem ratio, stem weight, Individual leaf size and total DMP at harvest stage. Yield components include, number of pods per plant, number of branches per plant, number of seeds per pod, 1000-seed weight, HI and grain yield.

Following the methodology elaborated by Eberhart and Russell (1966) three parameters of stability namely mean, regression coefficient (b) and mean square deviation ($S^{-2}d$) were estimated for each cultivar.

The linear model proposed by the above authors was

$$Y_{ij} = U_i + b_i I_j + \delta_{ij} + e_{ij}$$

where

Y_{ij} = mean performance of i^{th} variety/family in j^{th} environment

U_i = average performance of i^{th} variety/family over all environments

bi = regression coefficient that measures the response of the ith variety to varying environment

δ_{ij} = the deviation from regression of the i^{th} variety at j^{th} environment

I_j = environmental index, as the deviation of the mean of all varieties in j^{th} environment from grand mean and

$$\sum_{j=1}^{n} I_j = 0$$

(a) The regression coefficient for each variety was estimated as follows

$$bi = \sum_{j=1}^{n} Y_{ij} \; I_j \; / \; \sum_{j=1}^{n} I_j^2$$

(b) The mean square deviation from linear regression (S^2d) for each variety was estimated as follows.

$$S^2d = \left[\sum_j d^2_{ij} / (n-2)\right] - (Se^2/r)$$

where $$\sum_j d^2_{ij} = \left[\sum_j Y^2_{ij} - \frac{Y_i^2}{t}\right] - \frac{\left(\sum_j Y_{ij} I_j\right)^2}{\sum_j I_j^2}$$

Statistical Analysis

The data collected during the course of experiments were subjected to detailed statistical scrutiny following the analytical procedures of Panse and Sukhatme (1961) to bring out cultivars stages, sowings and their interaction effects. Correlation coefficient of characters was also worked out wherever necessary. The analysis was carried out in both HCL Micro 2200 and [illegible] 100 [illegible] micro computer systems.

EXPERIMENTAL RESULTS

CHAPTER IV

RESULTS

The present investigation was mainly aimed at finding out the growth and physiological responses of short and long duration cultivars of pigeonpea to three different dates of sowing as influenced by varying environmental situations. The genotype x environment interaction was studied not only for morphological characters but also for physiological parameters through stability analysis. The data from field and laboratory experiments are presented in this chapter after statistical analysis and also diagrammatically represented wherever necessary.

Phenological Development

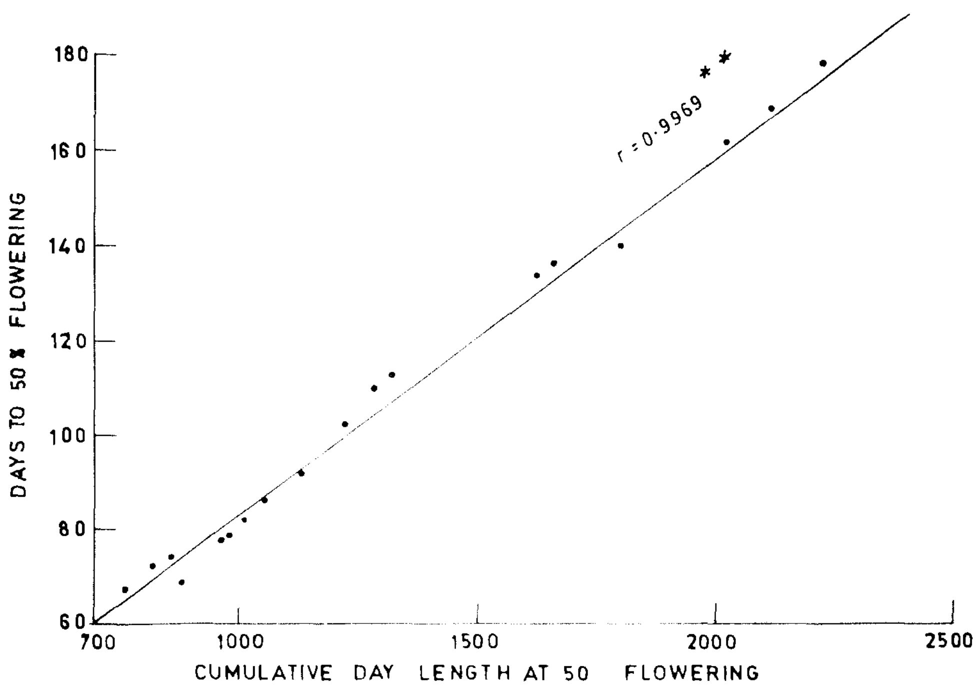
Days to first flowering, 50% flowering and harvest were recorded for all the varieties in all the three different dates of sowing and the data are presented (Table 2; Fig.1). It was observed that days to first flowering, 50% flowering and harvest were decreased from D_1 to D_3 progressively in both groups of varieties. The number of days to flowering was greatly reduced in long duration than in short duration cultivars. In the case of first flowering, the days to first flowering in short duration cultivars got reduced from D_1 (67.6) to D_2 (63.3) and a further decrease was also noticed from D_2 to D_3 (61.3), whereas for long duration cultivars it

Table 2: Phenological observation

Date of sowing	Cultivars	Date at first flowering		Date at 50% flowering		Date at harvest		Grain filling period
	Short duration							
	CO 5	28-4-84	(68)	1[illegible]-5-84	(86)	2[illegible]-6-84	(123)	37.0
	CORG 5	1-5-84	(71)	22-5-84	(92)	3-7-84	(134)	42.0
	UPAS 120	24-4-84	(6[illegible])	13-5-84	(83)	19-6-84	(120)	37.0
	Mean		(67.6)		(87.0)		(125.7)	38.7
21-2-84 (D_1)	**Long duration**							
	CORG 11	29-6-84	(130)	31-7-84	(162)	17-9-84	(210)	48.0
	PLS 361/1	7-7-84	(138)	7-8-84	(169)	25-9-84	(218)	49.0
	SA 1	10-7-84	(141)	16-8-84	(178)	1-10-84	(224)	46.0
	Mean		(136.3)		(169.7)		(217.3)	47.7
	Short duration							
	CO 5	25-8-84	(66)	6-9-84	(78)	15-10-84	(117)	39.0
	CORG 5	24-8-84	(65)	7-9-84	(79)	19-10-84	(121)	42.0
	UPAS 120	18-8-84	(59)	28-8-84	(69)	7-10-84	(109)	40.0
	Mean		(63.3)		(75.3)		(115.7)	40.3
	Long duration							
21-6-84 (D_2)	CORG 11	15-10-84	(117)	1-11-84	(134)	16-12-84	(179)	45.0
	PLS 361/1	19-10-84	(121)	3-11-84	(136)	19-12-84	(182)	46.0
	SA 1	22-10-84	(124)	6-11-84	(139)	23-12-84	(186)	47.0
	Mean		(120.7)		(136.3)		(182.3)	46.0
	Short duration							
	CO 5	23-11-84	(64)	1-12-84	(73)	10-1-85	(112)	39.0
	CORG 5	22-11-84	(63)	3-12-84	(74)	10-1-85	(118)	44.0
	UPAS 120	16-11-84	(57)	25-11-84	(66)	1-1-85	(103)	37.0
	Mean		(61.3)		(71.0)		(111.0)	40.0
	Long duration							
21-9-84 (D_3)	CORG 11	18-12-84	(89)	2-1-85	(104)	14-2-85	(147)	43.0
	PLS 361/1	21-12-84	(92)	8-1-85	(110)	21-2-85	(154)	44.0
	SA 1	25-12-84	(96)	10-1-85	(112)	26-2-85	(159)	47.0
	Mean		(92.3)		(108.7)		(153.30)	44.7

Values in parenthesis indicate days after sowing

DAYS TO 50 % FLOWERING



decreased from D_1 (136.3) to D_2 (120.7) and from D_2 to D_3 (92.3). In the case of 50% flowering and harvest stages also, a similar trend was noticed.

Growth and Dry Matter Accumulation

Shoot height (cm)

Data on shoot height are presented in the Table 3. Shoot height increased as time trend in both short and long duration cultivars. Significant differences could be noticed among cultivars, sowings and also among stages. There were drastic reductions in the plant height from (132.7) in D_1 (first sowing) to (72.5) in D_3 (third sowing). Comparing the two groups, long duration cultivars recorded higher plant height (135.16) than the short duration (73.3) ones.

Root length (cm)

Data on root length (Table 4) revealed that it increased as time trend. Significant differences could be noticed among cultivars, stages and also sowings. Root length was reduced progressively from D_1 (52.3) to D_3 (25.0). Here too, long duration cultivars recorded longer root length (50.4) than the short duration ones (21.4).

Number of branches

The number of branches per plant increased as age advanced (Table 5). The differences among cultivars sowings

Table 3. Shoot height (cm)

Cultivar Mean					Stage Mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	84.5	63.8	57.7	69.3	30	25.4	25.0	24.6	25.0
CORG 5	93.4	71.6	58.2	77.4	40	50.2	42.3	34.7	42.4
UPAS 120	75.2	64.7	52.4	64.1	50	86.9	65.2	54.1	68.7
Mean	84.4	67.4	56.1	70.3	First flowering	204.0	144.3	96.0	148.1
Long duration									
CORG 11	174.2	134.8	87.2	132.0	50% flowering	213.3	162.6	111.1	162.3
PLS 361/1	180.2	135.5	87.7	134.5					
SA 1	188.9	135.9	95.2	139.0	Harvest	216.9	168.9	114.9	166.9
Mean	181.1	135.4	89.0	135.1					
Grand mean	132.7	101.4	72.5						

	SE	CD
Cultivar	0.865	2.422**
Season	0.612	1.713**
Stage	0.865	2.422**
Cultivar x Stage	2.119	5.931**
Cultivar x Season	1.498	4.193**
Season x Stage	1.498	4.193**

Table 4. Root length (cm)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	31.4	7.6	9.2	16.0	30	8.6	23.2	21.9	17.9
CORG 5	34.9	19.5	13.0	22.5	40	19.1	26.4	23.3	22.9
UPAS 120	32.5	24.2	20.3	25.7	50	30.3	21.3	24.0	25.2
Mean	32.9	17.1	14.1	21.4	First flowering	81.8	37.1	27.4	48.8
Long duration									
CORG 11	70.6	40.7	29.6	46.9	50% flowering	87.6	36.0	29.9	51.1
PLS 361/1	73.7	43.0	36.2	50.9					
SA 1	72.8	46.9	40.3	53.3	Harvest	88.3	37.9	28.5	51.5
Mean	72.4	43.5	26.4	50.4					
Grand mean	52.3	30.3	25.0						

	SE	CD
Cultivar	0.267	0.746**
Season	0.189	0.528**
Stage	0.267	0.746**
Cultivar x Stage	0.653	1.828**
Cultivar x Season	0.462	1.293**
Season x Stage	0.462	1.293**

Table 5. Number of branches (No.plant^{-1})

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	8.30	6.96	4.00	6.42	30	-	-	-	-
CORG 5	8.14	6.54	3.92	6.20	40	5.03	7.51	2.60	3.71
UPAS 120	7.28	5.40	3.08	5.25	50	8.61	5.95	3.47	6.01
Mean	7.90	6.30	3.67	5.95	First flowering	13.90	9.09	5.40	9.46
Long duration									
CORG 11	14.22	8.05	6.10	9.46	50% flowering	15.52	9.90	6.45	10.62
PLS 361/1	15.54	9.66	6.44	10.55					
SA 1	17.46	9.82	6.48	11.25	Harvest	16.05	10.23	7.08	11.12
Mean	15.74	9.17	6.34	10.42					
Grand mean	11.82	7.74	5.00						

	SE	CD
Cultivar	0.160	0.499**
Season	0.113	0.318**
Stage	0.160	0.499**
Cultivar x Stage	0.357	1.106**
Cultivar x Season	0.277	0.779**
Season x Stage	0.620	1.742**

and stages were found to be significant. Clear cut differences could be observed with reference to sowing dates(D_1-11.82; D_2-7.74; D_3-5.0). Even here, long duration cultivars recorded more (10.42) branch number (5.95) than the short duration cultivars.

Number of leaves

The number of leaves per plant increased to maximum (678.25) at 50% flowering and declined (483.72) at later stages(Table 6). It was found to be significant in cultivars, stages and also in different sowing dates. The highest leaf number was recorded in D_1 (662.74) followed by D_2 (161.22) and D_3 (97.14) respectively. The long duration cultivars recorded more leaf number (431.65) as compared to short duration cultivars (70.20).

Leaf production rate

Data on rate of leaf production are presented in Table 7. The rate of leaf production (number of leaves per day) reached maximum in between 50th day and first flowering (8.62) and thereafter declined. The negative rate between 50% flowering and harvest stage might be attributed to the rate of leaf shedding exceeding the rate of leaf production. The rate was maximum in D_1 (4.18) followed by D_2 (1.70) and D_3 (1.58). There were significant differences that could be noticed between short (1.85) and long duration cultivars (3.29).

Table 6. Number of leaves per plant

Cultivar Mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	152.72	61.6	39.7	84.70	30	7.3	7.6	6.8	7.26
CORG 5	151.50	64.7	31.1	82.47	40	20.4	14.7	11.0	15.37
UPAS 120	71.22	31.8	27.3	43.43	50	102.1	32.9	24.5	53.18
Mean	125.1	52.7	32.7	70.20	First flowering	1350.6	312.5	150.1	604.42
Long duration					50% flowering	1456.3	354.3	224.10	678.25
CORG 11	1122.8	270.7	161.4	181.66	Harvest	1039.6	245.4	166.2	483.72
PLS 361/1	1080.3	259.6	170.9	506.29					
SA 1	1389.8	278.7	152.4	606.99					
Mean	1200.3	269.7	161.6	431.65					
Grand mean	662.74	161.22	97.14						

	SE	CD
Cultivar	1.618	4.259**
Season	1.144	3.203**
Stage	1.618	4.259**
Cultivar x Stage	3.964	11.095**
Cultivar x Season	2.803	7.845**
Season x Variety	2.803	7.845**

Table 7. Leaf production rate (No. of leaves per day)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	3.71	1.69	1.48	2.29	30	-	-	-	-
CORG 5	3.45	1.74	0.32	2.04	40	1.30	0.71	0.42	0.81
UPAS 120	1.84	0.99	0.70	1.18	50	8.16	1.83	1.35	3.78
Mean	3.00	1.47	1.05	1.83	First flowering	16.85	5.53	3.48	8.62
Long duration									
CORG 11	5.99	1.89	2.68	3.52	50% flowering	3.58	2.86	5.11	3.85
PLS 361/1	5.89	1.96	2.64	3.49					
SA 1	4.25	1.94	2.45	2.88	Harvest	-8.95	-2.39	-1.29	-4.21
Mean	5.37	1.93	2.59	3.29					
Grand mean	4.18	1.70	1.58						

Leaf area (cm^{-2}. $plant^{-1}$)

Data on leaf area are presented in Table 8. The leaf area increased upto 50% flowering and declined thereafter. Significant differences could be noticed among cultivars, stages and sowings. A drastic reduction in leaf area could be observed from D_1 (12030.40) to D_3 (1144.64) progressively. The long duration cultivars recorded higher leaf area (9385.80) than short duration cultivars (912.80).

Leaf weight ($g.m^{-2}$)

The leaf weight increased as time trend upto 50% flowering (355.6) and declined at harvest stage (233.3) (Table 9). Statistical scrutiny revealed that the differences among cultivars sowings and stages were significant. A progressive reduction in leaf weight was noticed from D_1 to D_3. As in the previous cases, long duration cultivars recorded more leaf weight (267.3) than short duration cultivars (42.4).

Stem weight ($g.m^{-2}$)

Stem weight also increased as time trend but a slight decreased was noticed at harvest stage (Table 10). Differences among cultivars, sowings and stages were found to be significant. During the first sowing (D_1) the recorded stem weight was more than the D_2 by ten times while D_3 recorded three and half times that of D_2 (2235.3 in D_1; 213.6 in D_2;

Table 8. Leaf area (cm^{-2}. $plant^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	2266.6	721.0	399.7	1121.77	30	55.7	77.3	34.4	55.79
CORG 5	2305.5	859.7	324.7	1163.33	40	297.5	205.0	112.6	205.06
UPAS 120	1040.4	369.9	220.2	453.53	50	1630.7	479.9	349.0	819.89
Mean	1870.8	650.2	307.5	912.80	First flowering	24606.5	4445.7	1958.3	10336.82
Long duration									
CORG 11	19116.4	4061.2	1924.0	8367.19	50% flowering	27037.4	5109.8	2575.7	11834.27
PLS 361/1	24037.0	3758.6	1939.9	9911.83					
SA 1	23416.4	3867.9	2001.3	9708.59	Harvest	17704.5	3240.7	1837.7	7594.35
Mean	22189.9	3895.9	1981.7	9355.80					
Grand mean	12030.4	2273.0	1144.6						

	SE	CD
Cultivar	11.126	31.143**
Season	7.867	22.021**
Stage	11.126	31.143**
Cultivar x Stage	27.254	76.284**
Cultivar x Season	19.271	53.941**
Season x Stage	19.271	53.941**

Table 9. Leaf weight ($g.m^{-2}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	91.60	34.94	17.14	47.9	30	2.26	1.97	1.41	1.8
CORG 5	88.47	43.35	15.46	49.0	40	9.42	6.68	3.59	6.5
UPAS 120	61.50	18.41	10.79	30.2	50	56.69	17.86	10.17	28.2
Mean	80.50	32.20	14.50	42.4					
Long duration									
CORG 11	609.53	97.55	54.89	253.9	First flowering	722.47	124.36	61.83	302.8
PLS 361/1	633.35	105.45	54.68	264.9					
SA 1	685.29	99.06	63.38	282.9	50% flowering	837.45	146.51	83.07	355.6
Mean	643.1	100.7	57.6	267.3					
Grand mean	361.8	66.4	36.1		Harvest	542.45	101.39	56.27	233.3

	SE	CD
Cultivar	0.865	2.421**
Season	0.612	1.711**
Stage	0.865	2.421**
Cultivar x Stage	2.118	5.929**
Cultivar x Season	1.498	4.193**
Season x Stage	1.498	4.193**

Table 10. Stem weight (g. m^{-2})

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	149.06	46.18	26.67	73.9	30	0.39	0.98	0.78	0.92
CORG 5	179.58	58.31	21.32	86.4	40	5.32	4.42	2.51	4.10
UPAS 120	85.66	28.61	13.49	42.5	50	39.26	15.23	8.49	20.90
Mean	138.10	44.4	20.49	67.6	First flowering	4238.20	337.24	75.54	1563.70
Long duration									
CORG 11	4110.69	334.33	92.38	1512.5	50 % flowering	4622.41	474.61	140.75	1745.90
PLS 361/1	4344.39	418.20	88.43	1617.0					
SA 1	4542.34	395.76	119.26	1685.7	Harvest	4505.53	448.92	129.47	1694.60
Mean	4332.5	427.13	100.02	1605.1					
Grand mean	2235.3	213.6	60.3						

	SE	CD
Cultivar	1.377	3.855**
Season	0.974	2.726**
Stage	1.377	3.855**
Cultivar x Stage	3.374	9.444**
Cultivar x Season	2.386	6.677**
Season x Stage	2.386	6.677**

60.3 in D_3). Lower weight was recorded (67.6) in short duration cultivars as compared to the long duration varieties (1605.10).

Root weight ($g.m^{-2}$)

Data on root weight are tabulated in Table 11. It increased up to 50% flowering (278.4) and then declined at harvest stage (255.9). Here too, significant differences could be observed between cultivars, stages and sowings. Different sowing dates induced differences which were clearly demonstrated (341.3 in D_1; 42.5 in D_2; 13.3 in D_3). As in the previous cases, long duration cultivars recorded more root weight (246.0) than short duration cultivars (18.7).

Reproductive parts weight ($g.m^{-2}$)

The weight of the reproductive parts recorded from first flowering to harvest revealed that this parameter increased with maturity (Table 12). Significant differences could be observed in all the levels. A drastic reduction from D_1 (508.3) to D_2 (171.3) and from D_2 to D_3 (121.1) could also be observed. Here too, short duration cultivars (157.6) showed lesser values to the extent of three times than that of the long duration cultivars (376.1).

Dry Matter Accumulation ($g.m^{-2}$)

The mean total dry matter accumulation over stages increased as the life cycle advanced (Table 13). Upto 50th

Table 11. Root weight ($g.m^{-2}$)

Cultivar mean | Stage mean

Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	35.95	13.81	5.33	18.4	30	0.35	0.41	0.21	0.32
CORG 5	43.01	14.95	6.02	21.3	40	1.84	0.79	1.04	1.20
UPAS 120	37.53	6.48	5.19	16.4	50	11.71	4.25	2.56	6.10
Mean	38.80	11.80	5.50	18.7	First flowering	661.07	76.49	18.82	252.10
Long duration									
CORG 11	593.61	78.41	20.84	230.9	50% flowering	709.54	94.96	30.63	278.40
PLS 361/1	725.75	73.88	20.33	273.3					
SA 1	611.83	67.59	22.09	233.8	Harvest	663.15	78.21	26.55	255.90
Mean	543.70	73.40	21.10	246.0					
Grand mean	341.3	42.50	13.30	132.40					

	SE	CD
Cultivar	1.178	3.299**
Season	0.833	2.333**
Stage	1.178	3.299**
Cultivar x Stage	2.887	8.083**
Cultivar x Season	2.042	5.715**
Season x Variety	2.042	5.715**

Table.12: Reproductive part weights (g. m⁻²)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	228.8	151.7	108.6	163.0	30	-	-	-	-
CORG 5	245.5	173.2	112.7	177.1	40	-	-	-	-
UPAS 120	167.4	143.3	87.5	132.9	50	-	-	-	-
Mean	213.9	156.1	102.9	157.6					
Long duration									
CORG 11	762.6	181.6	147.2	363.8	First flowering	221.1	29.9	10.8	82.3
PLS 361/1	788.2	172.6	112.7	357.8					
SA 1	857.2	205.6	157.9	406.9	50% flowering	341.4	54.0	47.7	147.7
Mean	802.6	186.6	139.3	376.1					
Grand mean	508.3	171.3	121.1		Harvest	962.4	429.9	304.9	565.7

	SE	CD
Cultivar	2.83	8.02**
Season	2.00	5.67**
Stage	2.00	5.67**
Cultivar x Stage	4.91	14.04**
Cultivar x Season	4.91	14.04**
Season x Variety	4.91	14.04**

Table 13. Total dry matter accumulation ($g.m^{-2}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	391.3	170.5	91.7	217.85	30	3.6	3.0	2.4	3.00
CORG 5	426.7	203.0	98.2	243.35	40	16.7	11.9	7.1	11.90
UPAS 120	267.3	125.3	71.3	154.64	50	107.6	37.4	20.3	55.06
Mean	362.4	166.3	87.1	205.28	First flowering	5842.7	568.1	166.9	2192.58
Long duration									
CORG 11	5695.1	600.7	241.7	2179.17	50% flowering	6527.2	790.5	294.9	2530.86
PLS 361/1	6114.1	683.8	219.8	2339.25					
BA 1	6287.1	668.9	283.6	2413.27	Harvest	6686.1	1061.2	514.8	2754.03
Mean	6032.1	651.1	248.4	2310.56					
Grand mean	3197.30	408.72	167.75						

	SE	CD
Cultivar	25.97	58.66**
Season	18.37	41.46**
Stages	25.97	58.66**
Cultivar x Sowing	44.98	101.62**
Cultivar x Stages	62.62	143.75**
Sowing x Stages	44.98	101.62**

day, a slight increase alone could be observed. Afterwards, the increase was impressive up to harvest stage. Differences were found to be significant at all levels. The effect of different sowing dates on the total dry matter accumulation was well established. The total dry matter accumulation decreased progressively from D_1 (3197.30) to D_2 (408.72) and from D_2 to D_3 (167.75). With regard to varietal groups, long duration cultivars as a group exceeded by nearly 9 times over short duration group. The pooled analysis of the total dry matter accumulation also revealed that the differences were significant at all levels.

S/R ratio (length)

Data on S/R ratio by length are tabulated in Table 14. Shoot/Root ratio by length decreased progressively excepting at 50th and first flowering stages. Differences were found to be significant at all levels. Second sowing (D_2) recorded the highest ratio (3.19) followed by D_3 (2.83) and D_1 (2.62) respectively. With regard to groupings, only a slight difference could be observed between long duration (3.07) and short duration cultivars (2.69).

S/R ratio (weight)

Shoot/Root by weight was also worked out and the data are presented in Table 15. It decreased as time trend upto 50% flowering and then a sudden increase was noticed at

Table 14. Shoot-Root ratio (Length)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	2.71	2.77	2.61	2.69	30	2.88	3.32	2.65	2.95
CORG 5	2.70	2.71	2.62	2.67	40	2.61	2.16	2.66	2.47
UPAS 120	2.49	3.06	2.60	2.72	50	2.86	2.97	2.67	2.83
Mean	2.63	2.85	2.61	2.69	First flowering	2.52	3.59	3.27	3.13
Long duration									
CORG 11	2.55	3.71	3.05	3.10	50% flowering	2.43	3.67	2.96	3.02
PLS 361/1	2.64	3.52	3.02	3.06					
SA 1	2.65	3.41	3.09	3.05	Harvest	2.43	3.48	2.77	2.89
Mean	2.61	3.47	3.05	3.07					
Grand mean	2.62	3.19	2.85						

	SE	CD
Cultivar	0.033	0.092**
Season	0.023	0.065**
Stage	0.033	0.092**
Cultivar x Stage	0.081	0.226**
Cultivar x Season	0.057	0.159**
Season x Stage	0.057	0.159**

Table 15. Shoot-root Ratio (Weight)

Cultivar mean

Cultivars	D_1	D_2	D_3	Mean
Short duration				
CO 5	9.36	10.95	12.23	10.84
CORG 5	8.47	11.09	11.16	10.24
UPAS 120	7.15	14.69	9.89	10.57
Mean	8.33	12.24	11.09	10.55
Long duration				
CORG 11	8.94	8.41	9.46	8.94
PLS 361/1	8.19	8.29	8.31	8.46
SA 1	9.37	9.11	9.75	9.41
Mean	8.60	8.60	9.37	8.94
Grand mean	8.55	10.42	10.23	

Stage mean

Stages (Days after sowing)	D_1	D_2	D_3	Mean
30	9.94	7.02	10.48	9.11
40	8.17	13.40	5.75	9.11
50	3.19	7.82	6.92	7.64
First flowering	7.31	7.12	8.00	7.47
50 flowering	7.75	8.28	8.61	8.21
Harvest	10.23	18.91	21.65	16.93

	SE	CD
Cultivar	0.091	0.255**
Season	0.064	0.180**
Stage	0.091	0.255**
Cultivar x Stage	0.223	0.624**
Cultivar x Season	0.157	0.411**
Season x Stage	0.157	0.411**

the harvest stage. Significant differences were demonstrated among cultivars stages and also in sowings. Here also, second sowing (D_2) recorded the highest ratio (10.42) followed by D_1 (10.23) and D_3 (8.58). Slightly difference could be observed between short duration cultivars (10.55) and long duration cultivars (8.94).

Leaf/Stem ratio

Generally, the leaf/stem ratio decreased as time trend (Table 16). Significant differences could be noticed among cultivars and stages but not in respect of sowings. There was not much difference that could be noticed between D_1 (1.07) and D_3 (1.08). But D_2 recorded lesser value than the other two. The short duration cultivars recorded higher value (1.18) than the long duration cultivars (0.92).

Individual leaf Area (ILA) ($cm^{-2}.leaf^{-1}$)

The individual leaf area was worked out and the data were presented (Table 17). It increased upto 50th day (14.7) and decreased at harvest stage (12.4). There were variations among cultivars and stages. There was slight difference among sowing dates (14.7 in D_1; 13.0 in D_2; 10.1 in D_3). Comparatively, long duration cultivars recorded higher area (13.6) than the short duration ones (11.5).

Table 16. Leaf-Stem Ratio

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	1.22	1.21	1.25	1.23	30	2.25	1.98	1.82	2.02
CORG 5	1.29	1.17	1.13	1.19	40	1.73	1.51	1.43	1.56
UPAS 120	1.19	1.08	1.13	1.13	50	1.43	1.16	1.20	1.26
Mean	1.23	1.15	1.17	1.18	First flowering	0.44	0.49	0.92	1.92
Long duration									
CORG 11	0.88	0.85	0.99	0.91	50 flowering	0.35	0.43	0.59	1.53
PLS 361/1	0.93	0.82	1.01	0.92					
SA 1	0.96	0.89	0.99	0.94	Harvest	0.36	0.45	0.55	1.21
Mean	0.92	0.85	0.99	0.92					
Grand mean	1.07	1.00	1.08						

	SE	CD
Cultivar	0.093	0.261**
Season	0.066	0.104NS
Stage	0.093	0.261**
Cultivar x Stage	0.228	0.639NS
Cultivar x Season	0.165	0.452**
Season x Stage	0.165	0.452**

Table 17. Individual Leaf Area $(cm^{-2}.leaf^{-1})$

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	13.9	11.7	9.4	11.6	30	7.5	10.1	4.9	7.5
CORG 5	14.2	13.0	9.7	12.3	40	14.7	13.8	9.9	12.8
UPAS 120	13.0	11.4	7.8	10.7	50	15.8	14.6	13.6	14.7
Mean	13.7	12.0	8.9	11.6	First flowering	17.3	13.4	12.1	14.3
Long duration									
CORG 11	14.4	14.7	10.6	13.2	50 flowering	17.2	14.0	10.5	13.9
FLS 361/1	18.3	13.4	11.3	14.3					
SA 1	14.5	13.8	11.8	13.3	Harvest	15.8	11.9	9.5	12.4
Mean	15.7	13.9	11.2	13.6					
Grand mean	14.7	13.0	10.1						

Individual leaf weight (ILW) (mg.leaf^{-1})

The individual leaf weight also followed a similar trend as that of ILA as far as time trend was concerned (Table 18). A maximum of 83.1 at 50th day decrease was found to 78.5 towards maturity. With regard to sowing dates, a progressive reduction was noticed from D_1 (84.3) to D_2 (73.5) and D_2 to D_3 (59.9). Similar to ILA, long duration cultivars recorded higher leaf weight (75.6) than the short duration cultivars (69.6).

Growth Analysis

Leaf Area Index (LAI)

The leaf area index was calculated based on leaf area and the data are presented (Table 19). It increased upto 50% flowering and declined thereafter. Differences between cultivars, sowings and stages were found to be significant at all levels. First sowing (D_1) recorded seven times more LAI than D_2. The D_2 recorded two times higher LAI than D_3. Here too the mean LAI was higher in the case of long duration group (4.606) than the short duration ones (0.699).

Net Assimilation Rate (NAR)(g.g^{-1}. day^{-1})

The net assimilation rate was worked out based on the leaf weight (Table 20). NAR decreased on time trend (0.2294 at 30th day to 0.0772 at harvest stage). Significant difference

Table 18. Individual Leaf weight (mg. leaf^{-1})

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	75.8	70.3	56.1	67.4	30	50.6	42.8	34.0	42.4
CORG 5	76.9	81.8	59.5	72.7	40	76.3	75.1	54.3	68.6
UPAS 120	80.4	74.6	50.8	68.6	50	89.7	90.3	69.3	83.1
Mean	77.7	75.6	55.5	69.6					
Long duration					First flowering	99.7	74.1	71.0	81.6
CORG 11	89.6	70.6	61.5	73.9					
PLS 361/1	95.4	74.3	60.6	76.4	50% flowering	99.9	79.7	64.8	81.4
SA 1	88.7	70.1	71.0	76.6					
Mean	91.2	71.6	64.4	75.6	Harvest	89.7	79.8	66.1	78.5
Grand mean	84.3	73.5	59.9						

Table 19. Leaf Area Index (LAI)

Cultivar Mean					Stage Mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (days after sowing)	D_1	D_2	D_3	Mean
<u>Short duration</u>									
CO 5	1.71	0.54	0.27	0.842	30	0.034	0.046	0.0021	
CORG 5	1.71	0.63	0.24	0.858	40	0.17	0.12	0.0006	
UPAS 120	0.76	0.27	0.16	0.599	50	0.98	0.28	0.202	
Mean	1.39	0.40	0.22	0.699	First flowering	12.54	2.32	1.025	
<u>Long duration</u>									
CORG 11	9.43	2.00	0.34	4.128	50% flowering	14.25	2.73	1.345	
PLS 361/1	11.85	1.85	0.96	4.001					
SA 1	11.51	1.90	1.02	4.810	Harvest	8.98	1.70	0.950	
Mean	10.93	1.91	0.97	4.606					
Grand mean	6.15	1.20	0.60						

	SE	CD
Cultivar	0.135	0.377**
Season	0.095	0.266**
Stages	0.135	0.377**
Cultivar x Stages	0.329	0.923**
Cultivar x Season	0.233	0.652**
Season x Stage	0.233	0.652**

Table 20. Net Assimilation Rate (NAR) ($g.g^{-1}.day^{-1}$)

Cultivar mean / Stage mean

Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.1769	0.1911	0.1924	0.1869	30–40	0.2619	0.2233	0.2030	0.2294
CORG 5	0.1591	0.1855	0.1990	0.1812	40–50	0.3739	0.2236	0.2086	0.2287
UPAS 120	0.1858	0.2392	0.2594	0.2268	50-First flowering	0.1186	0.2314	0.1637	0.1712
Mean	0.1739	0.2052	0.2156	0.1983					
Long duration									
CORG 11	0.1478	0.1416	0.1542	0.1464	First flowering to 50% flowering	0.0561	0.1204	0.3078	0.1307
PLS 361/1	0.1324	0.1608	0.1412	0.1448					
SA 1	0.1736	0.1494	0.1478	0.1569	50% flowering to Harvest	0.0205	0.0858	0.1253	0.0772
Mean	0.1498	0.1506	0.1477	0.1494					
Grand mean	0.1619	0.1779	0.1816						

	SE	CD
Cultivar	0.00165	0.00463**
Season	0.00117	0.00328**
Stage	0.00165	0.00467**
Cultivar x Stage	0.00369	0.01034**
Cultivar x Season	0.00286	0.00804**
Season x Stage	0.00286	0.00804**

could be noticed among cultivars, sowings as also in stages at all levels. In contrast to LAI, the highest NAR value was recorded in D_3 (0.1816) followed by D_2 (0.1779) and D_1 (0.1619). The short duration cultivars recorded higher NAR (0.1983) than long duration cultivars (0.1494).

Crop Growth Rate (CGR) ($g.m^{-2}.day^{-1}$)

In contrast to NAR, CGR increased upto the stage between 50th day and first flowering and declined thereafter (Table 21). Significant differences could be noticed between cultivars, sowings and stages at all levels. The maximum CGR was recorded in D_1 (22.20) followed by D_2 (7.43) and D_3 (4.14). The long duration cultivars recorded higher CGR (16.24) than the short duration cultivars (6.27).

Relative Growth Rate (RGR) ($g.g^{-1}.day^{-1}$)

Similar to NAR, RGR also decreased as time trend (Table 22). Differences were found to be significant at all levels excepting for cultivar x stage interaction. Here too, the maximum RGR was recorded in D_1 (0.084) followed by D_3 (0.072) and D_2 (0.071) respectively. In contrast to other parameters, short duration cultivars recorded higher RGR (0.084) than the long duration cultivars (0.067).

Absolute Growth Rate (AGR) ($g.plant^{-1}. day^{-1}$)

Data on absolute growth rate revealed that it increased upto first flowering and declined thereafter (Table 23). Differences among cultivars sowings and stages

Table 21. Crop Growth Rate (CGR) ($g.m^{-2}.day^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	10.61	5.78	3.42	6.60	30–40	1.31	0.85	0.47	0.87
CORG 5	10.47	7.06	3.48	7.00	40–50	9.08	2.55	1.31	4.31
UPAS 120	7.83	4.75	3.05	5.21	50–First flowering	73.41	11.92	4.34	29.89
Mean	9.63	5.86	3.31	6.27					
Long duration									
CORG 11	35.78	6.07	4.98	15.61	First flowering–50% flowering	23.34	15.18	9.36	15.96
PLS 361/1	34.80	10.30	3.94	16.35					
SA 1	33.73	10.64	5.94	16.77					
Mean	34.77	9.00	4.95	16.24	50% flowering to Harvest	3.86	6.65	5.19	5.23
Grand mean	22.20	7.43	4.14						

	SE	CD
Cultivar	0.248	0.697**
Season	0.175	0.492**
Stage	0.248	0.697**
Cultivar x Stage	0.552	1.557**
Cultivar x Season	0.425	1.196**
Season x Stage	0.425	1.196**

Table 22. Relative Growth Rate (RGR) ($g.g^{-1}.day^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.091	0.083	0.078	0.084	30–40	0.1535	0.128	0.108	0.129
CORG 5	0.089	0.086	0.077	0.083	40–50	0.1860	0.114	0.105	0.134
UPAS 120	0.088	0.081	0.084	0.084	50-First flowering	0.0641	0.073	0.070	0.069
Mean	0.088	0.083	0.079	0.084					
Long duration									
CORG 11	0.080	0.060	0.067	0.069	First flowering to 50% flowering	0.0131	0.032	0.062	0.035
PLS 361/1	0.077	0.063	0.065	0.068					
SA 1	0.079	0.057	0.063	0.066	50% flowering to Harvest	0.0038	0.012	0.017	0.011
Mean	0.078	0.060	0.065	0.067					
Grand mean	0.082	0.071	0.072						

	SE	CD
Cultivar	0.00102	0.00286**
Season	0.00072	0.00202**
Stage	0.00102	0.00286**
Cultivar x Stage	0.00228	0.00639**
Cultivar x Season	0.00176	0.00496**
Season x Stage	0.00176	0.00496**

Table 23. Absolute Growth Rate (AGR) (g.plant^{-1}.day^{-1})

Cultivar Mean					Stage Mean				
Cultivars	D_1	D_2	D_3	Mean	Stage (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	1.432	0.743	0.461	0.878	30-40	0.216	0.142	0.079	0.145
CORG 5	1.415	0.831	0.470	0.905	40-50	1.493	0.417	0.227	0.712
UPAS 120	1.077	0.635	0.411	0.707	50-First flowering	14.265	1.930	0.789	5.661
Mean	1.308	0.736	0.447	0.830					
Long duration									
CORG 11	7.255	1.237	1.009	3.167	First flowering to 50% flowering	4.308	2.560	1.648	2.858
PLS 361/1	7.038	2.088	0.788	3.305					
SA 1	6.821	1.878	1.202	3.300	50% flowering - Harvest	0.582	1.130	0.865	0.859
Mean	7.038	1.734	0.999	3.257					
Grand mean	4.173	1.233	0.724						

	SE	CD
Cultivar	0.0585	0.1644**
Season	0.0414	0.1164**
Stage	0.0585	0.1644**
Cultivar x Stage	0.1309	0.3679**
Cultivar x Season	0.1014	0.2850**
Season x Stage	0.1014	0.2850**

were found to be significant at all levels. The highest value was recorded in D_1 (4.173) followed by D_2 (1.223) and D_3 (0.724). Comparing the two groups, long duration cultivars recorded higher growth rates (3.257) than the short duration cultivars (0.830).

Leaf Area Duration (LAD) (Days)

Data on LAD were calculated and presented in the Table 24. The leaf area duration increased as time trend excepting for a slight decrease in between first and 50% flowering. Differences were significant at all levels. A progressive reduction in LAD was noticed from D_1 (300.93) to D_2 (45.93) and D_2 to D_3 (18.10). The long duration cultivars recorded (226.05) higher LAD than the short duration cultivars (17.25).

Specific Leaf Area (SLA) ($cm^{-2}.g^{-1}$)

The specific leaf area (SLA) increased upto 50th day and thereafter decreased (Table 25). Differences were found to be statistically significant at all levels excepting variety x stage interaction. With regard to sowing dates, the maximum SLA was noticed in D_2 (183.00) followed by D_1 (170.80) and D_3 (170.00) respectively. Long duration cultivars recorded higher value (183.3) than the short duration cultivars (165.80).

Table 24. Leaf Area Duration (LAD) (Days)

Cultivar Mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	42.53	12.13	5.72	20.11	30–40	1.06	0.84	0.43	0.77
CORG 5	47.71	15.67	5.49	22.95	40–50	5.81	2.08	1.34	3.07
UPAS 120	17.84	5.35	2.93	8.71	50–First flowering	524.80	77.05	21.83	207.89
Mean	36.03	11.05	4.71	17.25					
Long duration									
CORG 11	473.66	78.75	29.51	193.97	First flowering–50% flowering	429.05	37.78	18.03	161.62
PLS 361/1	606.66	86.58	31.45	241.56					
SA 1	617.21	77.15	33.51	242.63					
Mean	565.84	80.12	31.94	226.05	50% flowering – Harvest	543.86	100.26	50.54	231.55
Grand mean	300.93	45.93	18.10						

Table 25. Specific leaf area ($cm^{-2}.g^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	181.3	177.0	164.3	174.2	30	152.4	238.7	146.9	179.3
CORG 5	184.5	164.9	162.6	170.6	40	191.9	184.1	184.8	186.9
UPAS 120	141.8	159.6	156.3	152.5	50	175.0	163.7	200.9	179.8
Mean	169.2	167.2	161.1	165.8	First flowering	172.6	180.4	175.1	176.0
Long duration									
CORG 11	161.9	213.3	170.5	181.9	50% flowering	168.7	175.8	159.8	167.8
PLS 361/1	184.1	183.6	187.9	185.2					
SA 1	171.0	199.4	178.4	182.9	Harvest	163.8	154.3	152.4	156.8
Mean	172.3	198.8	178.9	183.3					
Grand mean	170.8	183.0	170.0						

	SE	CD
Cultivar	2.070	5.793**
Sowing	1.464	4.097**
Stage	2.070	5.793**
Cultivar x Stage	5.070	14.192NS
Cultivar x Sowing	3.585	10.035**
Sowing x Stage	3.585	10.035**

Specific Leaf Weight (SLW) ($g^{-1}.cm^{-2}$)

With regard to SLW, it increased as time trend from 40th day onwards till harvest. Differences among cultivars, (Table 26) sowings and stages were found to be significant at all levels. Sowing date differences were clearly demonstrated. The maximum SLW was noticed in D_3 (0.0061) followed by D_1 (0.0060) and D_2 (0.0057) respectively. Comparing the two groups of cultivars, short duration group recorded higher SLW (0.0060) than long duration ones (0.0055).

Leaf Weight Ratio (LWR) ($g.g^{-1}$)

With regard to time trend, LWR showed fluctuating trends. However, the reproductive stages recorded lesser values than the vegetative stages (Table 27). Differences among cultivars, sowings and stages were found to be significant at all levels excepting cultivar x stage interaction. There was not much difference among different dates of sowings (0.369 in D_1; 0.365 in D_2; 0.380 in D_3). Long duration cultivars recorded lesser value (0.355) than the short duration cultivars (0.393).

Leaf Area Ratio (LAR)(cm^{-2}. g^{-1})

The leaf area ratio decreased as time trend. Differences at cultivar and stage levels were found to be significant in all the three dates of sowings (Table 28). The highest LAR was recorded in the D_2 (69.8) followed by D_3 (68.0) and D_1 (63.5). Similar to LWR, short duration

Table 26. Specific Leaf Weight ($g.cm^{-2}$)

Cultivar mean | Stage mean

Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.0056	0.0060	0.0065	0.0060	30	0.0066	0.0041	0.0069	0.0058
CORG 5	0.0055	0.0063	0.0063	0.0060	40	0.0053	0.0055	0.0055	0.0054
UPAS 120	0.0073	0.0063	0.0065	0.0060	50	0.0057	0.0062	0.0050	0.0056
Mean	0.0055	0.0063	0.0064	0.0060	First flowering	0.0059	0.0055	0.0057	0.0057
Long duration									
CORG 11	0.0063	0.0048	0.0059	0.0057	50 flowering	0.0061	0.0057	0.0063	0.0060
PLS 361/1	0.0054	0.0054	0.0054	0.0054					
SA 1	0.0059	0.0051	0.0059	0.0056	Harvest	0.0064	0.0070	0.0069	0.0067
Mean	0.0058	0.0051	0.0057	0.0055					
Grand mean	0.0060	0.0057	0.0061						

	SE	CD
Variety	2.327×10^{-10}	6.514×10^{-10}**
Season	1.646×10^{-10}	4.606×10^{-10}**
Stage	2.327×10^{-10}	6.514×10^{-10}**
Variety x Stage	5.701×10^{-10}	15.957×10^{-10}**
Variety x Season	4.301×10^{-10}	11.283×10^{-10}**
Season x stage	4.301×10^{-10}	11.283×10^{-10}**

Table 27. Leaf Weight Ratio (g. g^{-1})

Cultivar Mean					Stage Mean				
Cultivars	D_1	D_2	D_3	Mean	Stage (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.407	0.390	0.407	0.401	30	0.412	0.418	0.479	0.436
CORG 5	0.404	0.434	0.417	0.418	40	0.445	0.427	0.491	0.454
UPAS 120	0.394	0.339	0.351	0.361	50	0.331	0.384	0.345	0.361
Mean	0.401	0.387	0.391	0.393	First flowering	0.385	0.263	0.294	0.395
Long duration									
CORG 11	0.332	0.345	0.386	0.354	50% flowering	0.303	0.263	0.234	0.286
PLS 361/1	0.338	0.339	0.393	0.356					
SA 1	0.359	0.343	0.383	0.355	Harvest	0.318	0.307	0.318	0.314
Mean	0.336	0.342	0.389	0.365					
Grand mean	0.369	0.365	0.389						

	SE	CD
Cultivar	0.0114	0.0319**
Season	0.0081	0.0225**
Stage	0.0114	0.0319**
Cultivar x Stage	0.0279	0.0782NS
Cultivar x Season	0.0197	0.0553**
Season x Stages	0.0197	0.0553**

Table 28. Leaf Area Ratio (cm^{-2}. g^{-1})

Cultivar Mean					Stage Mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	73.4	75.9	68.9	72.7	30	94.3	143.0	85.8	167.1
CORG 5	74.7	78.7	72.4	75.2	40	107.1	103.2	92.9	101.0
UPAS 120	59.5	56.8	59.6	58.6	50	91.3	77.5	103.1	90.6
Mean	69.2	70.5	66.9	68.8	First flowering	39.1	44.1	67.1	50.3
Long duration									
CORG 11	55.7	72.9	64.0	64.2	50% flowering	33.3	37.4	42.9	37.8
PLS 361/1	64.0	64.2	73.5	67.2					
SA 1	53.7	70.7	69.9	64.7	Harvest	16.0	14.3	16.1	15.5
Mean	57.8	69.3	69.1	65.4					
Grand mean	63.5	69.8	68.0						

cultivars recorded higher value (68.8) compared to the long duration cultivars (65.4).

Fallen leaves(g. plant^{-1})

The fallen leaves were collected at selected stage and the data on their weights are presented in the Table 29. With regard to time trend, the maximum weight was recorded in between 50th day and first flowering (7.54) and decreased in between first and 50% flowering (4.53) and increased thereafter (4.83). Differences were found to be significant at all levels. The total fallen material was also computed for all the stages and the data revealed that the maximum fallen material was recorded in D_1 (28.39) followed by D_2 (16.21) and D_3 (8.74). Differences due to sowing dates were clearly demonstrated. First sowing (D_1) recorded the maximum (11.35) followed by D_2 (6.48) and D_3 (3.39). Here too, long duration cultivars recorded higher fallen leaf material (10.84) than the short duration cultivars (3.31).

Yield and its components

Yield components

With regard to yield components (Table 30) the 1000-seed weight did not indicate any marked variation among sowing dates. The number of seed per pod also followed the above trend. But number of pods per plant decreased drastically from D_1 (587.37) to D_2 (301.40). Further decrease was also

Table 29. Fallen leaves (g. $plant^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	4.63	3.40	1.87	3.30	30	-	-	-	-
CORG 5	4.33	3.21	2.04	3.19	40	-	-	-	-
UPAS 120	5.06	3.40	1.91	3.45	50	1.36	0.81	0.46	0.87
Mean	4.67	3.34	1.94	3.31	First flowering	12.97	6.18	3.48	7.54
Long duration									
CORG 11	16.59	9.39	4.24	10.07	50% flowering	7.07	4.04	2.47	4.53
PLS 361/1	18.00	9.50	4.94	10.84					
SA 1	19.46	9.98	5.38	11.61	Harvest	6.99	5.18	2.33	4.83
Mean	18.04	9.62	4.85	10.84					
Grand mean	11.35	6.48	3.39						

	SE	CD
Cultivar	0.174	0.489**
Season	0.123	0.346**
Stage	0.174	0.489**
Cultivar x Stage	0.389	1.096**
Cultivar x Season	0.301	0.849**
Season x Stage	0.301	0.849**

Table 30. Yield and yield components

	Grain yield (g.plant)	Husk yield (g.plant)	1000 seed weight (g)	No. seed/ pod	No.pod/ plant	Pod sett (per cent)	DMS	HI	HIP	Pod weight (g plant^{-1})	Grain yield (g.m^{-2})
I sowing											
Mean	108.12	71.48	74.11	2.77	587.37	11.85	0.150	20.53	18.38	179.60	584.44
SE	1.173	12.54	1.569	0.416	21.331	6.913	0.00601	0.507	1.183	7.875	46.485
CD	4.26**	45.59**	5.708**	1.518	77.557**	2.356	0.02186	1.486	4.302**	28.636**	169.017**
II sowing											
Mean	40.57	33.81	78.71	3.28	301.48	14.18	0.216	27.66	25.16	74.48	234.92
SE	0.748	0.903	1.502	0.461	38.601	1.133	0.0137	2.943	2.160	3.268	17.664
CD	2.718**	3.282**	5.463**	1.677	140.353**	4.118	0.0499	10.704**	7.854**	11.883**	64.228**
III sowing											
Mean	23.15	29.26	74.91	2.94	184.52	16.65	0.210	26.43	23.50	52.43	130.85
SE	2.498	0.762	1.492	0.417	16.517	0.987	0.00643	1.818	1.505	4.023	8.928
CD	9.085**	2.770**	5.424**	1.518	60.058**	3.589	0.02338**	6.612**	5.474**	15.627**	32.462**
Pooled analysis											
CO 5	27.83	23.12	77.03	2.88	178.73	15.04	0.282	32.83	29.66	50.95	205.96
CORG 5	31.74	26.77	78.58	2.85	193.10	14.52	0.270	33.26	30.33	58.53	234.92
UPAS 120	22.81	19.48	57.08	2.82	127.50	14.37	0.327	36.20	31.33	42.29	168.84
Mean	27.46	23.12	70.89	2.85	166.44	14.64	0.293	34.09	30.34	50.59	203.24
CORG 11	82.02	66.05	78.91	2.98	525.93	13.07	0.100	16.26	15.17	148.27	405.19
PLS 361/1	84.94	58.25	82.64	3.14	517.47	14.07	0.085	14.70	13.27	143.19	419.59
SA 1	94.31	75.47	81.23	3.23	604.60	13.93	0.087	15.45	14.33	169.78	465.90
Mean	87.09	56.59	80.92	3.17	549.13	13.36	0.091	15.47	14.21	153.74	430.27
Grand mean	57.28	44.85	75.91	2.98	357.79	14.23	0.192	24.87	22.35	102.17	316.74
Sowing SE	0.674	2.968	0.621	0.176	11.000	0.403**	0.00384	0.824	0.680	2.222	11.908
CD	2.031**	8.947**	1.872**	0.531	33.453**	1.214	0.01158	2.484**	2.051**	6.697**	35.888**
Cultivars											
SE	0.953	4.198	0.878	0.249	15.698	0.569	0.00544	1.165	0.962	3.143	16.842
CD	2.872**	12.654**	0.648**	0.752	47.309**	1.716	0.01638	3.517**	2.899**	9.472**	50.754*
Sowing x Cultivar											
SE	1.651	7.272	1.522	0.432	27.190	0.986	0.00942	2.019	1.667	5.444	29.169
CD	4.976	21.917**	4.596	1.302	81.942**	2.972	0.02838**	6.085	5.023**	16.405**	87.908**

observed in D_3 (184.52). The pod weight per plant also was reduced progressively from D_1 to D_3. Pod setting also was influenced by dates of sowing. The maximum pod set was observed in D_3 (16.65) followed by D_2 (14.18) and D_1 (11.85). Difference among cultivars with regard to pod setting percentage did not show any significance. The effect of sowing dates on harvest index (HI) was well demarcated. The mean HI was found to be maximum in D_2 (26.77), followed by D_3 (26.43) and D_1 (20.53) respectively. When the fallen leaf material and other parts were added to the total dry matter production for calculating the HI, it was further reduced (20.53 to 18.30 in D_1; 27.66 to 25.16 in D_2; 26.53 to 25.30 in D_3). The dry matter efficiency (DME) was also computed and the data revealed that the maximum was recorded in D_2 (0.216) followed by D_3 (0.210) and D_1 (0.150). All the above yield components showed significance for cultivar differences excepting number of seed per pod and pod setting percentage.

Yield

Yield of grain and husk were measured and the data were computed both in terms of g. plant^{-1}, and g.m^{-2} (Table 30). The mean data for the sowings over cultivars revealed that the yield tended to decrease from first sowing (D_1) to third sowing (D_3) progressively. The grain yield per plant was maximum in D_1 (108.12) followed by D_2 (40.37) and

D_3 (23.15). A similar trend was noticed in grain yield expressed in $g.m^{-2}$.

In the pooled analysis of the yield and yield components revealed that the grain yield, husk yield, number of pods per plant and pod weight registered higher value in long duration cultivars in contrast to short duration cultivars. There was not much difference between the two groups of cultivars with respect to 1000-seed weight, number of seeds per pod and pod set percentage. However, short duration cultivars recorded higher values in the case of DMS and HI. Differences were found to be significant in all the parameters excepting number of seeds per pod. The mean value of yield and yield components over sowings and cultivars were as follows: grain yield (57.28), husk yield (44.85), 1000 grain weight (75.91), number of pods per plant (357.79), pod setting percentage (14.23), HI (24.87), HI including fallen leaves (22.35), and DMS (0.192).

Perday Productivity ($g.m^{-2}.day^{-1}$)

Grain productivity

The biomass and grain productivity in terms of unit area efficiency (UAE) expressed in $g.m^{-2}.day^{-1}$ revealed that the former and latter were decreased from D_1 to D_2 and D_2 to D_3 respectively (Table 31). In the case of grain productivity, there was a marked difference (1.58) between long duration (3.97

Treatment (Date of sowing)	Cultivars	Biomass productivity (UA)			Grain productivity (UAE)			HIS
		$g.m^{2}$	$g.m^{-2}.day^{-1}$	$K\ Cal.m^{-2}day^{-1}$	$g.m^{-2}$	$g.m^{-2}day^{-1}$	$K\ Cal.m^{-2}day^{-1}$	
D_1	CO 5	982.59	7.98	31.60	304.88	2.47	10.99	34.77
	CORG 5	1110.02	8.28	32.79	354.46	2.64	11.75	25.83
	UPAS 120	655.04	5.45	21.58	248.49	2.07	9.21	42.67
	Mean	915.88	7.24	28.65	302.61	2.39	10.65	37.75
	CORG 11	11859.95	56.48	223.66	793.36	3.77	16.77	7.49
	PLS 361/1	12590.58	57.75	228.69	883.03	4.05	18.02	7.87
	SA 1	12919.59	57.68	228.41	922.19	4.11	18.29	8.01
	Mean	12456.70	57.30	226.92	866.19	3.97	17.69	7.79
D_2	CO 5	545.74	4.64	18.37	213.86	1.83	8.14	44.31
	CORG 5	636.52	5.26	20.85	226.44	1.87	8.32	39.34
	UPAS 120	423.85	3.89	15.40	183.52	1.68	7.48	48.57
	Mean	534.70	4.59	18.20	207.94	1.79	7.98	44.27
	CORG 11	1402.96	7.84	31.05	245.02	1.38	6.14	19.77
	PLS 361/1	1679.60	9.23	36.67	248.96	1.36	6.05	16.49
	SA 1	1680.59	9.04	35.79	291.95	1.56	6.94	19.39
	Mean	1587.72	8.70	34.50	261.97	1.43	6.37	18.55
D_3	CO 5	340.86	3.04	12.04	99.16	0.885	3.94	32.77
	CORG 5	376.43	3.19	12.63	123.87	1.05	4.67	36.97
	UPAS 120	267.50	2.59	10.25	74.52	0.723	3.22	31.41
	Mean	328.26	2.94	11.64	99.18	0.886	3.94	33.71
	CORG 11	704.49	4.79	18.96	177.19	1.205	5.36	28.27
	PLS 361/1	573.73	3.73	14.77	126.80	0.823	3.66	24.78
	SA 1	825.47	5.19	20.55	183.57	1.150	5.12	24.91
	Mean	701.23	4.57	18.09	162.52	1.059	4.71	25.98

and short duration cultivars (2.39). But in the case of D_2, the difference (0.36) narrowed down, (1.79) for short duration cultivars and (1.43) for long duration cultivars whereas in the case of D_3, the gap (0.173) still got reduced and there was not much difference among two groups of cultivars.

Biomass productivity

With regard to biomass productivity (UAE) marked difference could be noticed among two groups of cultivars in all the three sowings (Table 31). In the case of first sowing difference (50.46) could be observed between short duration cultivars (7.24) and long duration cultivars (57.30). In the case of D_2, the above gap narrowed down to 4.11 between short duration cultivars (4.54) and for long duration cultivars (8.70), whereas in the case of D_3, the gap further narrowed down to 1.63 between short duration cultivar (2.94) and for long duration cultivars (4.54).

The harvest index (HI) calculated on energy relationship revealed improvement of HI over the traditional method of assessing the HI. However, increase in HI was noticed from D_1 to D_2 and a decrease from D_2 to D_3. The above trend was noticed in short duration cultivars. On the contrary, the HI for long duration cultivars increased from D_1 to D_3 progressively.

Path Analysis of Yield components

Path analysis was undertaken for evaluating the relative contribution of each character-both direct and indirect to yield. The yield and yield components on three sowings were subjected to the correlation coefficients and path coefficients. The data were presented in Tables 32 and 33.

Data on simple correlation of grain yield with yield components revealed that seed yield had a high positive significant correlation with number of pods per plant (r = 0.9769*) and pod setting percentage (r = 0.5298**). On the contrary, DMS (r = -0.6951**) and HI (r = -0.7669**) had high negative significant correlation with grain yield. The other two components namely 1000-seed weight and number of seeds per pod had weak positive association with grain yield. Among the yield components, 1000-grain weight was positively correlated with number of pods per plant (r = 0.3557*). But pod setting percentage and number of seeds per pod had weak positive association with number of pods per plant. However DMS and HI had negative association. The number of seed per pod had only weak positive association with number of pods per plant and pod set had shown negative association with DMS and HI. The number of pods per plant had significant and positive correlation with HI and showed negative correlation

Table 32. Simple correlation between yield and yield components in pigeonpea

Parameters		Y Seed yield g. plant^{-1}	X_1 1000 seed weight (g)	X_2 No. of seed/pod	X_3 No. of pod/plant	X_4 Pod sett (%)	X_5 DMI	X_6 HI
Seed yield (g.plant^{-1})	Y	1	0.2475	0.0491	0.9758**	0.5288**	-0.6951**	-0.7669**
1000-seed weight	X_1		1	0.2663	0.3357*	0.0281	-0.5901**	-0.4645**
No. of seed/pod	X_2			1	0.1596	0.1172	-0.2179	-0.1291
No. of pod/plant	X_3				1	-0.5088**	-0.7761**	0.8393**
Pod sett (%)	X_4					1	0.2576	0.3402*
DME	X_5						1	0.8592**
HI	X_6							1

** Significant at P = 0.01

* Significant at P = 0.05

Table 33. Direct and Indirect effect of different characters on grain yield

Parameters	100 seed weight	No. of seed/pod	No. of pod/plant	Pod sett (%)	DMS	HI	Correlation with seed yield
1000 seed weight	-0.0229	-0.0276	0.3904	0.0004	0.0289	0.0637	0.2475
No. of seed/pod	-0.0061	-0.1039**	0.1859	0.0019	-0.0107	-0.0177	0.0491
No. of pod/plant	-0.0077	-0.0166	1.1629**	-0.0083	-0.0380	-0.1511	0.9769**
Pod sett (%)	0.0006	-0.0121	-0.5917	0.0164	0.0126	0.0467	0.5288**
DMS	0.0135	0.0227	-0.9025	0.0042	0.0490	0.1179	-0.6951**
HI	0.0107	0.0134	-0.9761	0.0055	0.0421	0.1372*	-0.7669**

R^2 = 0.9773 * Significant at P = 0.05

Residual = 0.1505 ** Significant at P = 0.01

with pod set and DMP whereas pod setting percentage had positive association with DMP and HI. A highly significant positive correlation (r=0.8592**) was established between DMP and HI.

The partial regression coefficients (Table 34) were highly significant for the number of pods per plant (19.18**) and HI (2.09**) but not significant for DMP (0.7762) and pod setting (0.4759). It showed highly negative effect for 1000-grain weight (-0.6294) and a significant negative effect for number of seeds per pod (-3.47**).

The number of pods per plant had the highest positive direct effect (1.1629**) on grain yield followed by HI (0.1372), DMP (0.0490) and pod sett (0.0164). But number of seeds per pod and 1000 grain weight had weak negative effect on grain yield. Almost all the characters affected the yield indirectly.

Physiological Analysis

Chlorophyll content ($mg.g^{-1}$)

1. Chlorophyll a: The chlorophyll a, b and total were analysed in a fully expanded young leaf at 50th day, first flowering, 50% flowering and harvest stages (Table 35). With regard to chlorophyll a, it increased upto 50% flowering and thereafter decreased. Differences were found to be significant at all levels except cultivar x stage in interaction. However

Table 34. Partial Regression

Variable	Partial regression	SE of partial regression	T
1000-seed weight	-0.1365	0.2168	-0.6294
No. of seed/pod	-11.09	3.19	-3.47**
No. of pod/plant	0.2166	0.0112	19.18**
Pod sett (%)	0.3461	0.7219	0.4759
DMG	24.04	30.98	0.7762
HI	0.6685	0.3188	2.09*

Table 35. Chlorophyll a (mg.g^{-1})

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.95	0.81	0.83	0.86	30	-	-	-	-
CORG 5	0.98	0.86	0.83	0.89	40	-	-	-	-
UPAS 120	0.90	0.74	0.75	0.79	50	0.66	0.62	0.62	0.63
Mean	0.94	0.80	0.80	0.85	First flowering	1.29	1.17	1.12	1.19
Long duration									
CORG 11	0.82	0.79	0.93	0.85	50% flowering	1.53	1.25	1.20	1.33
PLS 361/1	1.09	0.91	0.90	0.97					
SA 1	1.05	0.91	0.96	0.97	Harvest	0.39	0.31	0.51	0.40
Mean	0.98	0.87	0.93	0.93					
Grand mean	0.97	0.84	0.86						

	SE	CD
Cultivar	0.039	0.110**
Season	0.027	0.078**
Stage	0.032	0.090**
Cultivar x Stage	0.078	0.221NS
Cultivar x Season	0.067	0.191**
Season x Variety	0.067	0.191**

first sowing recorded the maximum content of chlorophyll a (0.97) followed by D_3 (0.86) and D_2 (0.84). There was not much difference between two groups of cultivars.

2. Chlorophyll b: The chlorophyll b increased upto 50% flowering and declined thereafter (Table 36). Significant differences could be noticed at all levels excepting cultivar x stage interaction. The chlorophyll b was maximum in D_1 (0.65) followed by D_2 (0.56) and D_3 (0.55) respectively. Comparing the two groups of cultivars, long duration cultivars recorded slightly higher value than the short duration cultivars.

3. Total chlorophyll: Similar to chlorophyll a and b, the total chlorophyll also increased upto 50% flowering and decreased in the harvest stage (Table 37). Differences were found to be significant at all levels except cultivar x stage interaction. Date of sowing differences were clearly demonstrated. The highest chlorophyll content was recorded in D_1 (1.63) followed by D_3 (1.42) and D_2 (1.39) respectively. Long duration cultivars recorded slightly higher chlorophyll content (1.56) than the short duration cultivars (1.40).

Stomatal Resistance for CO_2 ($S.cm^{-1}$)

Data on stomatal resistances were presented in Table 38. The stomatal resistances (CO_2) increased as time trend. There were variations among cultivars and stages in all

Table 36. Chlorophyll b (mg. g^{-1})

Cultivar mean					Stage mean				
Cultivar	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.64	0.55	0.48	0.56	30	-	-	-	-
CORG 5	0.65	0.54	0.55	0.58	40	-	-	-	-
UPAS 120	0.60	0.49	0.51	0.53	50	0.41	0.38	0.40	0.39
Mean	0.63	0.53	0.51	0.55	First flowering	0.79	0.65	0.68	0.71
Long duration									
CORG 11	0.64	0.56	0.59	0.59	50 flowering	1.15	1.03	0.81	0.99
PLS 361/1	0.60	0.62	0.55	0.62					
SA 1	0.67	0.61	0.64	0.64	Harvest	0.23	0.19	0.32	0.25
Mean	0.66	0.59	0.59	0.62					
Grand mean	0.65	0.56	0.55						

	SE	CD
Cultivar	0.019	0.055**
Season	0.014	0.039**
Stage	0.016	0.045**
Cultivar x Stage	0.039	0.109NS
Cultivar x Season	0.033	0.094**
Season x Stage	0.033	0.074**

Table 37. Total chlorophyll ($mg.g^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	1.59	1.35	1.31	1.42	30	-	-	-	-
CORG 5	1.62	1.39	1.35	1.45	40	-	-	-	-
UPAS 120	1.50	1.24	1.26	1.33	50	1.08	0.99	1.03	1.03
Mean	1.57	1.32	1.31	1.40	First flowering	2.08	1.81	1.80	1.89
Long duration									
CORG 11	1.59	1.36	1.52	1.49	50% flowering	2.76	2.28	1.99	2.43
PLS 361/1	1.77	1.53	1.46	1.58					
SA 1	1.72	1.52	1.59	1.61	Harvest	0.62	0.51	0.83	0.65
Mean	1.69	1.47	1.52	1.56					
Grand mean	1.63	1.39	1.42						

	SE	CD
Cultivar	0.0281	0.0794**
Season	0.0198	0.0562**
Stage	0.0229	0.0648**
Cultivar x Stage	0.0561	0.1588NS
Cultivar x Season	0.0486	0.1376**
Season x Stage	0.0486	0.1376**

Table 38. Stomatal Resistance for CO_2 ($S.cm^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	0.851	1.007	1.122	0.993	30	-	-	-	-
CORG 5	0.926	0.969	1.190	1.028	40	-	-	-	-
UPAS 120	1.003	0.995	1.054	1.017	50	0.626	0.612	0.663	0.634
Mean	0.926	0.990	1.056	1.013	First flowering	0.767	0.893	0.810	0.823
Long duration									
CORG 11	0.909	0.935	0.998	0.947					
PLS 361/1	0.935	1.075	1.020	1.010	50% flowering	1.031	1.114	1.334	1.159
SA 1	1.020	1.058	1.096	1.058	Harvest	1.343	1.408	1.513	1.421
Mean	0.955	1.023	1.038	1.005					
Grand mean	0.941	1.007	1.080						

the three sowings. Sowing date differences were clearly demarcated. Third sowing recorded maximum (1.080) followed by D_2 (1.007) and D_1 (0.941). Not much difference could be observed among the two groups of cultivars.

Photosynthetic rate (mg CO_2.dm^{-2}.hr^{-1})

The photosynthetic rate was measured in a fully young matured leaf at selected stages (Table 39). Data on photosynthetic rate revealed that it increased as time trend upto 50% flowering stage and declined thereafter. Statistical analysis showed that the differences were significant at all levels excepting among cultivars. There was also significant differences for cultivar x stage interaction in D_1 and D_3 sowings. Not much difference could be noticed between D_1 (17.85) and D_2 (17.26). But D_3 recorded lower photosynthetic rate (15.25) than the previous two sowings. There were no clear differences in photosynthetic rate among two groups of cultivars.

Stomatal Resistance for water vapour (S.cm^{-1})

Data on stomatal resistance revealed that it increased as time trend (Table 40). Differences were found to be significant at all levels. The maximum resistance was recorded in D_3 (0.64), followed by D_2 (0.59) and D_1 (0.56). There was not much difference among the two groups of cultivars.

Table 39. Photosynthetic rate (mg CO_2.dm^{-2}.hr^{-1})

Cultivar mean					Stage mean				
cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	18.55	16.83	15.08	16.82	30	-	-	-	-
CORG 5	20.13	18.53	15.63	18.09	40	-	-	-	-
UPAS 120	16.78	16.65	15.05	16.16	50	14.00	13.06	10.57	13.07
Mean	18.48	17.33	15.25	17.02	First flowering	21.73	20.20	16.77	19.57
Long duration									
CORG 11	17.97	17.40	15.35	16.91	50% flowering	24.65	23.03	20.63	22.77
PLS 361/1	16.73	16.95	15.13	16.27					
SA 1	16.98	17.25	15.28	16.50	Harvest	10.23	11.36	13.02	11.74
Mean	17.23	17.20	15.25	16.56					
Grand mean	17.85	17.26	15.25						

	SE	CD
Cultivar	0.281	0.795NS
Season	0.198	0.562**
Stage	0.229	0.649**
Cultivar x Stage	0.562	1.591**
Cultivar x Season	0.487	1.377**
Season x Stage	0.487	1.377**

Table 40. Stomatal resistance for water vapour ($S.cm^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
<u>Short duration</u>									
CO 5	0.51	0.59	0.66	0.58	30	-	-	-	-
CORG 5	0.55	0.57	0.70	0.61	40	-	-	-	-
UPAS 120	0.59	0.58	0.62	0.59	50	0.36	0.36	0.39	0.37
Mean	0.55	0.58	0.66	0.59	First flowering	0.45	0.53	0.48	0.48
<u>Long duration</u>									
CORG 11	0.54	0.55	0.58	0.55	50% flowering	0.61	0.66	0.79	0.68
PLS 36 1/1	0.55	0.63	0.60	0.59					
SA 1	0.60	0.62	0.65	0.62	Harvest	0.79	0.83	0.89	0.84
Mean	0.56	0.60	0.61	0.58					
Grand mean	0.56	0.59	0.64						

	SE	CD
Cultivar	0.00533	0.01508**
Season	0.00376	0.01077**
Stage	0.00435	0.01231**
Cultivar x Stage	0.01066	0.03017**
Cultivar x Season	0.00923	0.02613**
Season x Stage	0.00923	0.02613**

Transpiration rate ($\mu g. cm^{-2}.s^{-1}$)

Data on transpiration rate revealed that it decreased as time trend (Table 41). Significant difference could be noticed among cultivars sowing dates and also in stages. The highest transpiration rate was recorded in D_1 (40.25) followed by D_2 (35.3?) and D_3 (31.03). There was not much difference between the two groups.

Leaf Water Potential (-MPa)

Data on leaf water potential revealed that it decreased as time trend (-0.656 MPa in 50th day to -1.253 MPa at harvest) (Table 42). Differences were found to be significant at all levels excepting for cultivar x stage interaction. The mean water potential of cultivars over sowing dates indicated that it increased from D_1 (1.235) to D_2 (0.912) and a further increase from D_2 to D_3 (0.655) was also observed. In contrast to transpiration rate, long duration cultivars recorded higher leaf water potential (0.835) than the short duration cultivars (0.1038).

Leaf temperature (°C)

The leaf temperature decreased upto 50% flowering and then a slight increase was observed at the harvest stage (Table 43). Differences were found to be significant at all levels except cultivar x stage interaction. A progressive reduction in leaf temperature was noticed from

Table 41. Transpiration Rate ($\mu g.cm^{-2}.S^{-1}$)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	35.88	33.44	31.02	33.11	30	-	-	-	-
CORG 5	39.47	34.87	31.92	35.42	40	-	-	-	-
UPAS 120	41.51	36.05	32.26	36.61	50	44.52	37.51	37.05	39.69
Mean	38.95	34.78	31.73	35.04	First flowering	45.42	38.11	35.80	39.77
Long duration									
CORG 11	43.61	37.03	31.43	37.35	50% flowering	46.43	38.57	30.44	38.48
PLS 361/1	41.16	34.83	31.15	35.71					
SA 1	39.87	35.74	28.40	34.67	Harvest	23.63	27.12	20.85	24.19
Mean	41.55	35.86	30.33	35.91					
Grand mean	40.25	35.33	31.03						

	SE	CD
Cultivar	0.346	0.979**
Season	0.245	0.693**
Stage	0.283	0.800**
Cultivar x Stage	0.693	1.960**
Cultivar x Season	0.599	1.697**
Season x Stage	0.599	1.697**

Table 42. Leaf Water Potential (-MPa)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	1.29	1.04	0.68	1.00	30	-	-	-	-
CORG 5	1.46	0.99	0.74	1.06	40	-	-	-	-
UPAS 120	1.40	0.97	0.78	1.05	50	0.93	0.71	0.33	0.67
Mean	1.38	1.00	0.73	1.04	First flowering	1.07	0.84	0.52	0.81
Long duration									
CORG 11	1.14	0.85	0.61	0.87	50% flowering	1.40	0.96	0.76	1.04
PLS 361/1	1.12	0.86	0.62	0.87					
SA 1	1.00	0.82	0.50	0.77	Harvest	1.54	1.18	1.04	1.25
Mean	1.08	0.84	0.57	0.84					
Grand mean	1.24	0.92	0.66						

	SE	CD
Cultivar	0.174	0.0492**
Season	0.123	0.0348**
Stage	0.142	0.0402**
Cultivar x Stage	0.348	0.0984NS
Cultivar x Season	0.301	0.0853**
Season x Stage	0.301	0.0853**

Table 43. Leaf Temperature (°C)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	31.47	32.67	27.95	30.69	30	-	-	-	-
CORG 5	31.95	31.05	28.05	30.35	40	-	-	-	-
UPAS 120	32.70	31.30	28.48	30.82	50	31.13	32.48	28.47	30.69
Mean	32.04	31.67	28.16	30.62	First flowering	30.45	28.73	26.55	28.57
Long duration									
CORG 11	30.25	31.08	27.53	29.62	50% flowering	30.17	28.83	25.57	28.19
PLS 361/1	30.00	29.50	26.53	28.34					
SA 1	29.80	29.55	26.68	28.67	Harvest	32.90	33.38	29.55	31.94
Mean	30.28	30.04	26.91	29.07					
Grand mean	31.16	30.85	27.54						

	SE	CD
Cultivar	0.317	0.899**
Season	0.255	0.636**
Stage	0.259	0.734**
Cultivar x Stage	0.636	1.738NS
Cultivar x Season	0.550	1.557**
Season x Stage	0.550	1.557**

D_1 (31.16) to D_2 (30.85) and from D_2 to D_3 (27.54). Short duration cultivars recorded relatively higher leaf temperature (30.62) as compared to long duration cultivars (27.09).

Leaf Relative Humidity (per cent)

In contrast to leaf temperature the leaf relative humidity increased upto 50% flowering (31.81) and decreased at harvest stage (24.37) (Table 44). Differences were found to be significant at all levels except for cultivar and also cultivar x stage interaction. The highest relative humidity was recorded in D_3 (32.54) followed by D_2 (27.39) and D_1 (22.90). Here too, not much difference could be observed between the two groups of cultivars.

Light interception and canopy growth

Data on light interception and extinction coefficient (k) calculated at 50th day and first flowering were tabulated (Table 45). With regard to 50th day, the percentage of light interception decreased progressively from D_1 to D_3. While for k value, an opposite trend was noticed. A similar trend has also been noticed in first flowering also. Comparing these two stages, the light interception was considerably increased, while k value decreased at flowering stage in all the three sowings. Comparing the cultivar groups, the long duration cultivars had registered higher light interception and lower k values than the short duration cultivars in all the three sowing

Table 44. Leaf Relative Humidity (per cent)

Cultivar mean					Stage mean				
Cultivars	D_1	D_2	D_3	Mean	Stages (Days after sowing)	D_1	D_2	D_3	Mean
Short duration									
CO 5	29.45	26.13	30.50	28.69	30	-	-	-	-
CORG 5	27.73	25.73	33.40	29.65	40	-	-	-	-
UPAS 120	27.00	25.35	35.25	29.19	50	27.96	28.05	32.05	29.62
Mean	28.06	25.74	33.73	29.17	First flowering	29.13	29.90	34.88	31.30
Long duration									
CORG 11	27.50	28.80	31.10	29.13	50 flowering	31.62	26.77	37.03	31.81
PLS 361/1	26.90	28.00	30.58	28.53					
SA 1	28.85	30.33	32.25	30.48	Harvest	22.90	24.03	26.18	24.37
Mean	27.75	29.04	31.34	29.38					
Grand mean	27.90	27.39	32.54						

	SE	CD
Cultivar	0.406	1.149NS
Season	0.287	0.813**
Stage	0.332	0.930**
Cultivar x Stage	0.813	2.299NS
Cultivar x Season	0.704	1.991**
Season x Stage	0.704	1.991**

Treatment (Date of sowing)	Cultivar	50th day				First flowering			
		At canopy level	Below the canopy	Light intercepted (per cent)	K value	At canopy level	Below the canopy	Light intercepted (per cent)	K value
D$_1$	CO 5	85200	7200	[illegible]	[illegible]	[illegible]	4100	94.5	0.92
	CORG 5	85200	6200	[illegible]	[illegible]	[illegible]	4300	93.6	0.89
	UPAS 120	85200	8400	90.2	[illegible]	71000	5400	92.7	1.91
	Mean	85200	[illegible]	[illegible]	[illegible]	[illegible]	4800	93.5	1.24
	CORG 11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	98.1	0.20
	PLS 361/1	85200	[illegible]	[illegible]	[illegible]	[illegible]	1300	[illegible]	0.16
	SA 1	85200	[illegible]	[illegible]	[illegible]	[illegible]	1200	98.3	0.17
	Mean	85200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.17
D$_2$	CO 5	72800	[illegible]	[illegible]	[illegible]	[illegible]	5100	92.6	3.13
	CORG 5	72800	11000	[illegible]	[illegible]	[illegible]	5500	91.9	2.47
	UPAS 120	72800	17000	[illegible]	[illegible]	[illegible]	7100	89.6	5.29
	Mean	72800	14066	80.8	[illegible]	[illegible]	[illegible]	91.4	3.63
	CORG 11	72800	10200	[illegible]	[illegible]	[illegible]	4400	93.6	0.64
	PLS 361/1	72800	[illegible]	87.1	7.31	[illegible]	4300	96.3	0.74
	SA 1	72800	11000	[illegible]	7.25	[illegible]	4400	93.6	0.71
	Mean	72800	10200	[illegible]	[illegible]	[illegible]	4533	93.4	0.69
D$_3$	CO 5	72000	18200	[illegible]	[illegible]	[illegible]	12000	79.9	3.42
	CORG 5	72000	21600	70.0	[illegible]	[illegible]	11200	81.3	4.29
	UPAS 120	72000	23300	[illegible]	[illegible]	[illegible]	[illegible]	72.7	6.28
	Mean	72000	[illegible]	70.8	[illegible]	[illegible]	12467	79.2	4.66
	CORG 11	72000	15300	[illegible]	7.13	[illegible]	9000	83.5	1.06
	PLS 361/1	72000	14200	[illegible]	7.04	[illegible]	10000	81.7	1.02
	SA 1	72000	13600	81.1	[illegible]	[illegible]	8400	84.6	1.06
	Mean	72000	14700	79.6	7.15	[illegible]	9133	83.3	1.05

Meteorological Observations

Solar Radiation (K cal.cm^{-2}.day^{-a})

Data on cumulative solar radiation at 30, 40 and 50 days after sowing, first flowering, 50% flowering and harvest stages were calculated (Table 46). The cumulative solar radiation increased as time trend in all the three sowings. The long duration cultivars accumulated higher solar radiation than the short duration cultivars. Comparing the sowing dates, first (D_1) sowing recorded the highest value (16680.32) followed by D_3 (12918.04) and D_2 (12010.40) sowings.

Evaporation (mm)

Data on cumulative evaporation revealed that it increased as time trend (Table 47). Here too, D_1 recorded the maximum (974.1) cumulative evaporation followed by D_2 (787.8), and D_3 (471.6). The cumulative evaporation was more in long duration cultivars than short duration cultivars.

Heliothermal units

The cumulative heliothermal units increased as time trend (Table 48). Even here, D_1 sowing accumulated more heliothermal units (2747803.8) than the other two sowings (D_2-1599113.4, D_3-1300317.7). The long duration groups accumulated higher units than the short duration groups.

Table 46. Cumulative Solar Radiation (k cal. $cm^{-2}.day^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flo-wering	Harvest
	CO 5	3166.7	4722.6	5709.5	7836.1	10410.6	12928.3
	CORG 5	3166.7	4722.6	5709.5	8287.5	10439.0	13571.0
D_1	UPAS 120	3166.7	4722.6	5709.5	7387.9	10394.4	12790.0
	Mean	3166.7	4722.6	5709.5	7837.2	10414.7	13096.43
	CORG 11	3166.7	4722.6	5709.5	13560.3	15123.8	19787.5
	PLS 361/1	3166.7	4722.6	5709.5	13944.4	15555.0	20469.2
	SA 1	3166.7	4722.6	5709.5	14411.4	16661.7	20535.8
	Mean	3166.7	4722.6	5709.5	13972.0	15780.2	20264.2
	Grand mean	3166.7	4722.6	5709.5	10904.6	13097.5	16680.32
	CO 5	1627.7	4722.6	2941.3	4340.1	5554.7	8695.0
	CORG 5	1627.7	4722.6	2941.3	4290.3	5743.2	9238.5
	UPAS 120	1627.7	4722.6	2941.3	3912.3	4656.5	7733.6
D_2	Mean	1627.7	4722.6	2941.3	4180.9	5318.13	8555.7
	CORG 11	1627.7	4722.6	4722.6	7582.3	10779.8	15008.6
	PLS 361/1	1627.7	4722.6	4722.6	9234.2	11145.4	15381.4
	SA 1	1627.7	4722.6	4722.6	9665.8	11302.0	16005.3
	Mean	1627.7	4722.6	2941.3	8827.4	11075.7	15366.1
	Grand mean	1627.7	4722.6	2941.3	6504.2	8196.9	12010.4
	CO 5	2670.0	3537.2	4806.0	5875.2	5650.4	10599.1
	CORG 5	2670.0	3537.2	4806.0	5883.0	5560.4	11151.0
	UPAS 120	2670.0	3537.2	4806.0	5519.6	5297.1	10188.1
D_3	Mean	2670.0	3537.2	4806.0	5759.3	5502.6	10646.07
	CORG 11	2670.0	3537.2	4806.0	8349.7	8934.6	14304.6
	PLS 361/1	2670.0	3537.2	4806.0	8805.7	8806.1	15247.0
	SA 1	2670.0	3537.2	4806.0	9359.3	9237.8	16020.8
	Mean	2670.0	3537.2	4806.0	8838.2	8992.8	15190.8
	Grand mean	2670.0	3537.2	4806.0	7298.8	7247.7	12918.04

Table 47. Cumulative evaporation (mm)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing) 30	40	50	First flowering	50% flowering	Harvest
	CO 5	120.0	173.0	222.8	270.4	415.1	664.6
	CORG 5	120.0	173.0	222.8	338.2	452.2	741.2
	UPAS 120	120.0	173.0	222.8	257.0	400.0	654.4
D_1	Mean	120.0	173.0	222.8	288.5	423.7	686.7
	CORG 11	120.0	173.0	222.8	713.4	891.4	1245.2
	PLS 361/1	120.0	173.0	222.8	765.6	945.6	1264.6
	SA 1	120.0	173.0	222.8	787.0	1023.8	1274.8
	Mean	120.0	173.0	222.8	755.3	953.5	1261.5
	Grand mean	120.0	173.0	222.8	520.9	688.6	974.1
	CO 5	181.4	236.4	314.8	442.8	520.9	679.6
	CORG 5	181.4	236.4	314.8	437.0	527.8	709.6
	UPAS 120	181.4	236.4	314.8	377.2	446.2	640.8
D_2	Mean	181.4	236.4	314.8	419.0	498.3	676.7
	CORG 11	181.4	236.4	314.8	679.6	751.6	859.9
	PLS 361/1	181.4	236.4	314.8	709.6	759.2	910.3
	SA 1	181.4	236.4	314.8	726.4	761.6	926.3
	Mean	181.4	236.4	314.8	705.2	757.5	898.6
	Grand mean	181.4	236.4	314.8	562.1	627.9	787.8
	CO 5	102.4	136.4	166.50	211.2	238.4	393.2
	CORG 5	102.4	136.4	166.50	208.2	238.4	377.6
	UPAS 120	102.4	136.4	166.50	190.4	219.6	359.0
D_3	Mean	102.4	136.4	166.50	203.3	232.1	376.6
	CORG 11	102.4	136.4	166.50	298.1	359.0	532.4
	PLS 361/1	102.4	136.4	166.50	311.7	367.2	569.2
	SA 1	102.4	136.4	166.50	326.5	373.2	597.8
	Mean	102.4	136.4	166.50	312.1	366.5	566.5
	Grand mean	102.4	136.4	166.50	257.7	299.3	471.6

Table 46. Cumulative Heliothermal units

Treatment (Days of sowing)	Cultivars	Stages (days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	75746.16	[illegible]	[illegible]	461719.24	[illegible]	1469907.00
	CORG 5	75746.16	148978.44	[illegible]	510678.76	[illegible]	1690062.90
	UPAS 120	75746.16	148978.44	238376.0	403214.16	747046.48	1411377.60
D_1	Mean	75746.16	148978.44	[illegible]	[illegible]	[illegible]	1520642.50
	CORG 11	75746.16	148978.44	[illegible]	609431.40	2245012.70	[illegible]
	PLS 361/1	75746.16	148978.44	[illegible]	770618.00	[illegible]	[illegible]
	SA 1	75746.16	148978.44	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	75746.16	148978.44	238376.0	1744337.2	[illegible]	[illegible]
	Grand mean	75746.16	148978.44	238376.0	1101470.6	[illegible]	2747803.80
	CO 5	44960.03	83275.89	134515.81	260503.32	[illegible]	904376.20
	CORG 5	44960.03	83275.89	134515.81	251258.74	[illegible]	967175.00
	UPAS 120	44960.03	83275.89	134515.81	215249.30	291519.48	767371.40
D_2	Mean	44960.03	83275.89	134515.81	243003.81	361345.49	879641.87
	CORG 11	44960.03	83275.89	134515.81	904376.20	1248067.40	2226115.30
	PLS 361/1	44960.03	83275.89	134515.81	967175.00	1296372.20	2308370.00
	SA 1	44960.03	83275.89	134515.81	1035967.50	1506897.60	2421272.80
	Mean	44960.03	83275.89	134515.81	969172.90	1350445.70	2318586.00
	Grand mean	44960.03	83275.89	134515.81	606088.36	855895.61	1599113.90
	CO 5	61889.12	85758.88	191875.37	300317.44	363074.61	884900.30
	CORG 5	61889.12	85758.88	191875.37	292698.00	376370.28	981982.10
	UPAS 120	61889.12	85758.88	191875.37	251444.48	315408.66	765300.48
D_3	Mean	61889.12	85758.88	191875.37	281486.64	351617.85	877394.29
	CORG 11	61889.12	85758.88	191875.37	556529.92	773738.68	555359.90
	PLS 361/1	61889.12	85758.88	191875.37	595983.13	851760.88	1737981.90
	SA 1	61889.12	85758.88	191875.37	653290.54	884900.30	1876375.80
	Mean	61889.12	85758.88	191875.37	601934.53	836799.95	1723239.20
	Grand mean	61889.12	85758.88	191875.37	441710.59	594208.90	1300316.70

Growing degree days

Data on growing degree days are presented (Table 49). It increased as time trend in all the three sowings. However, the highest growing degree days were noticed in D_1 (2120.25) followed by D_2 (1625.65) and D_3 (1240.37). As in the previous cases, the long duration cultivars accumulated more degree days than the short duration cultivars.

Photothermal units

Data on cumulative photothermal units revealed that the parameter values increased as time advanced (Table 50). Similar to growing degree days, the highest accumulation was noticed in D_1 (58775.56) followed by D_2 (46791.5) and D_3 (42720.6). The long duration cultivars accumulated higher units than the short duration ones.

Day length (hours)

Data on cumulative day length revealed that it increased as time trend (Table 51). The highest accumulation of day length was noticed in D_1 (2133.62) and followed by D_2 (1820.37) and D_3 (1545.12). Similar to the other parameters, the long duration cultivars accumulated more day length than the short duration cultivars.

Heat units

Data on accumulated heat unit also revealed that it increased as time trend (Table 52). Similar to other parameters first sowing (D_1) accumulated the highest heat units (4795.04)

Table 49. Growing degree days

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	319.2	437.40	574.40	811.60	1072.80	1552.50
	CORG 5	319.2	437.40	574.40	855.60	1162.90	1685.70
	UPAS 120	319.2	437.40	574.40	758.40	1031.70	1518.10
D_1	Mean	319.2	437.40	574.40	808.50	1089.10	1585.40
	CORG 11	319.2	437.40	574.40	1639.60	2005.55	2569.60
	PLS 361/1	319.2	437.40	574.40	1735.90	2088.95	2665.70
	SA 1	319.2	437.40	574.40	1773.00	2199.05	2729.90
	Mean	319.2	437.40	574.40	1716.20	2097.80	2655.10
	Grand mean	319.2	437.40	574.40	1262.40	1595.50	2120.25
	CO 5	347.45	464.45	560.95	768.90	909.60	1343.00
	CORG 5	347.45	464.45	560.95	756.90	921.40	1375.00
	UPAS 120	347.45	464.45	560.95	704.35	802.20	1264.00
D_2	Mean	347.45	464.45	560.95	743.40	877.70	1327.30
	CORG 11	347.45	464.45	560.95	1343.00	1506.60	1902.50
	PLS 361/1	347.45	464.45	560.95	1375.00	1527.30	1922.20
	SA 1	347.45	464.45	560.95	1406.80	1558.00	1947.30
	Mean	347.45	464.45	560.95	1374.90	1530.60	1924.00
	Grand mean	347.45	464.45	560.95	1059.20	1204.20	1625.25
	CO 5	307.60	411.60	509.90	646.40	715.70	1046.60
	CORG 5	307.60	411.60	509.90	636.30	731.10	1097.80
	UPAS 120	307.60	411.60	509.90	590.80	665.70	962.40
D_3	Mean	307.60	411.60	569.90	624.50	700.80	1035.60
	CORG 11	307.60	411.60	509.90	838.40	972.40	1374.60
	PLS 361/1	307.60	411.60	509.90	857.90	1028.20	1456.45
	SA 1	307.60	411.60	509.90	886.30	1046.40	1504.35
	Mean	307.60	411.60	509.90	861.10	1015.70	1445.10
	Grand mean	307.60	411.60	509.90	742.80	858.30	1240.37

Table 50. Cumulative Photothermal Units

Treatment (Days of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flo-wering	Harvest
	CO 5	9588.19	12798.72	16305.36	23420.08	30190.13	42878.67
	CORG 5	9588.19	12798.72	16305.36	24519.58	32200.27	46503.05
	UPAS 120	9588.19	12798.72	16305.36	22028.09	28921.34	41931.79
D_1	Mean	9588.19	12798.72	16305.36	23322.78	30437.25	43797.85
	CORG 11	9588.19	12798.72	16305.36	45281.21	55388.93	71416.31
	PLS 361/1	9588.19	12798.72	16305.36	47975.54	58067.18	74007.49
	SA 1	9588.19	12798.72	16305.36	48982.46	61079.45	75836.08
	Mean	9588.19	12798.72	16305.36	47644.40	58178.48	73753.29
	Grand mean	9588.19	12798.72	16305.36	35483.59	44307.96	58775.56
	CO 5	9895.39	13185.00	16510.29	21680.15	25575.26	37833.12
	CORG 5	9895.39	13185.00	16510.29	21253.12	25905.16	38920.59
	UPAS 120	9895.39	13185.00	16510.29	19508.41	22829.88	35459.28
D_2	Mean	9895.39	13185.00	16510.29	20813.89	24770.10	37404.33
	CORG 11	9895.39	13185.00	16510.29	37833.12	42667.24	55346.99
	PLS 361/1	9895.39	13185.00	16510.29	38920.59	43389.70	56081.41
	SA 1	9895.39	13185.00	16510.29	39765.90	44274.56	57107.72
	Mean	9895.39	13185.00	16510.29	38839.87	43443.83	56178.70
	Grand mean	9895.39	13185.00	16510.29	29826.88	34106.97	46791.50
	CO 5	8708.74	11683.98	14514.05	18441.47	20237.54	31110.51
	CORG 5	8708.74	11683.98	14514.05	18153.32	20933.30	32692.92
	UPAS 120	8708.74	11683.98	14514.05	16525.50	1900.74	28609.43
D_3	Mean	8708.74	11683.98	14514.05	17706.76	14357.19	30804.29
	CORG 11	8708.74	11683.98	14514.05	24841.96	28920.01	40652.89
	PLS 361/1	8708.74	11683.98	14514.05	25578.05	30558.26	42936.96
	SA 1	8708.74	11683.98	14514.05	26606.75	31103.66	44571.95
	Mean	8708.74	11683.98	14514.05	25675.59	30193.97	42720.60
	Grand mean	8708.74	11683.98	14514.05	21691.18	22275.58	36762.45

Table 51. Cumulative day length

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	362.36	482.29	606.00	630.17	1052.35	1529.28
	CORG 5	362.36	482.2	606.00	867.46	1142.04	1670.06
	UPAS 120	362.36	482.29	606.00	730.13	1013.32	1489.24
D_1	Mean	362.36	482.29	606.00	[illegible]	1069.59	1562.86
	CORG 11	362.36	482.29	606.00	1618.57	2024.08	2616.21
	PLS 361/1	362.36	482.29	606.00	1721.08	2112.48	2712.46
	SA 1	362.36	482.29	606.00	1759.24	2223.70	2784.48
	Mean	362.36	482.29	606.00	1699.63	2119.8[illegible]	2704.38
	Grand mean	362.36	482.29	606.00	1262.79	1594.74	2133.62
	CO 5	382.00	507.40	632.54	830.29	977.47	1448.08
	CORG 5	382.00	507.40	632.54	818.10	990.01	1495.32
	UPAS 120	382.00	507.40	632.54	744.10	879.45	1353.00
D_2	Mean	382.00	507.40	632.54	797.49	948.96	1432.13
	CORG 11	382.00	507.40	632.54	1448.08	1640.42	2170.26
	PLS 361/1	382.00	507.40	632.54	1495.32	1672.04	2204.59
	SA 1	382.00	507.40	632.54	1531.07	1707.07	2251.00
	Mean	382.00	507.40	632.54	1479.49	1673.17	2208.60
	Grand mean	382.00	507.40	632.54	1138.49	1311.07	1820.37
	CO 5	358.50	476.40	593.36	756.14	837.49	1309.17
	CORG 5	358.50	476.40	593.36	744.41	860.53	1378.41
	UPAS 120	358.50	476.40	593.36	675.05	775.27	1205.47
D_3	Mean	358.50	476.40	593.36	725.34	825.76	1297.68
	CORG 11	358.50	476.40	593.36	1044.45	1217.17	1707.06
	PLS 361/1	358.50	476.40	593.36	1079.17	1286.17	1799.48
	SA 1	358.50	476.40	593.36	1125.17	1309.17	1871.12
	Mean	358.50	476.40	593.36	1082.93	1270.84	1792.55
	Grand mean	358.50	476.40	593.36	904.14	1048.30	1545.12

Table 52. Cumulative Heat Units

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3500.3
	CORG 5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3746.5
	UPAS 120	795.70	[illegible]	[illegible]	1830.2	[illegible]	3175.8
D1	Mean	795.70	[illegible]	[illegible]	[illegible]	2489.5	3474.2
	CORG 11	795.70	1063.9	[illegible]	3630.40	4476.35	5820.4
	PLS 361/1	795.70	1063.9	[illegible]	3900.5	4724.75	6036.5
	SA 1	795.70	1063.9	[illegible]	[illegible]	[illegible]	6190.7
	Mean	795.70	1063.90	1350.9	3652.0	4741.7	6015.87
	Grand mean	795.70	1063.90	1350.9	2091.7	3614.6	4795.04
	CO 5	795.45	1062.45	1332.55	1756.90	2072.60	3090.0
	CORG 5	795.45	1062.45	1332.55	1729.90	2134.40	3187.6
	UPAS 120	795.45	1062.45	1332.55	1578.35	1845.20	2897.0
D2	Mean	795.45	1062.45	1332.55	1688.38	2005.70	3060.2
	CORG 11	795.45	1062.45	1332.55	3096.00	3474.60	4590.50
	PLS 361/1	795.45	1062.45	1332.55	3187.60	3565.30	4650.20
	SA 1	795.45	1062.45	1332.55	3259.50	3641.50	4735.30
	Mean	795.45	1062.45	1332.55	3181.03	3573.60	4657.60
	Grand mean	795.45	1062.45	1332.55	2434.71	3575.60	3858.60
	CO 5	752.70	1011.60	1259.90	1606.40	1791.70	2726.60
	CORG 5	752.70	1011.60	1259.90	1581.30	1841.10	2857.80
	UPAS 120	752.70	1011.60	1259.90	1437.00	1655.70	2537.40
D3	Mean	752.70	1011.60	1259.90	1541.60	1764.20	2700.60
	CORG 11	752.70	1011.60	1259.90	2173.40	2532.40	3578.60
	PLS 361/1	752.70	1011.60	1259.90	2237.80	2678.20	3766.40
	SA 1	752.70	1011.60	1259.90	2327.80	2726.60	3889.35
	Mean	752.70	1011.60	1259.90	2246.30	2645.73	3744.78
	Grand mean	752.70	1011.60	1259.90	1893.90	2204.96	3222.69

and followed by D_2 (3058.6) and D_3 (3222.7). As expected, the long duration varieties accumulated higher units than the short duration cultivars.

Sunshine hours

Data on cumulative sunshine hours values are calculated and presented in Table 53. It increased as time trend. Among sowing dates, first sowing (D_1) recorded the maximum sunshine hours (1227.12) followed by D_3 (1017.88) and D_2 (933.05). Similar to heat units, in the case of sunshine hours too, long duration cultivars accumulated the more sunshine hours as compared to the short duration cultivars.

Heat unit efficiency.

Data on heat unit efficiency are presented in the Table 54. There were variations between stages and cultivars in all the three sowings. With regard to first sowing (D_1), in short duration varieties, it increased as time trend upto 50 per cent flowering and thereafter declined whereas in long duration cultivars it increased upto first flowering and thereafter decreased. In the case of D_2, it increased throughout the growth period, as time trend for short duration cultivars. But in long duration cultivars it increased upto 50% flowering and thereafter declined except in SA 1 where it increased upto harvest stage. With respect to third sowing (D_3), it increased as time trend for both group of cultivars except PLS 361/1 where a declining trend was noticed at harvest stage. Comparing two groups of varieties,

Table 53. Cumulative sunshine hours

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing) 30	40	50	First flowering	50% flowering	Harvest
	CO 5	237.30	340.60	415.00	568.90	743.30	946.80
	CORG 5	[illegible]	340.60	415.00	597.10	800.20	997.00
	UPAS 120	237.30	340.60	415.00	534.20	710.40	929.70
D_1	Mean	237.30	340.60	415.00	566.70	752.60	957.83
	CORG 11	237.30	340.60	415.00	981.60	1119.40	1455.40
	PLS 361/1	237.30	340.60	415.00	1020.00	1165.40	1508.90
	SA 1	237.30	340.60	415.00	1045.10	1229.30	1524.90
	Mean	237.30	340.60	415.00	1015.60	1171.36	1496.40
	Grand mean	237.30	340.60	415.00	791.20	916.90	1227.12
	CO 5	129.40	179.30	239.80	338.80	427.70	673.40
	CORG 5	129.40	179.30	239.80	334.60	437.90	703.40
	UPAS 120	129.40	179.30	239.80	305.60	363.40	607.10
D_2	Mean	129.40	179.30	239.80	326.30	409.70	661.30
	CORG 11	129.40	179.30	239.80	573.40	828.40	1170.10
	PLS 361/1	129.40	179.30	239.80	703.40	848.80	1200.90
	SA 1	129.40	179.30	239.80	736.40	967.70	1243.40
	Mean	129.40	179.30	239.80	704.40	881.50	1204.80
	Grand mean	129.40	179.30	239.80	326.30	645.60	933.05
	CO 5	201.20	278.80	376.30	464.60	507.30	845.50
	CORG 5	201.20	278.80	376.30	460.00	514.80	894.50
	UPAS 120	201.20	278.80	376.30	425.60	473.80	795.20
D_3	Mean	201.20	278.80	376.30	450.10	498.60	845.06
	CORG 11	201.20	278.80	376.30	663.80	795.70	1131.50
	PLS 361/1	201.20	278.80	376.30	694.70	828.40	1193.30
	SA 1	201.20	278.80	376.30	736.60	845.50	1247.30
	Mean	201.20	278.80	376.30	698.40	823.20	1190.70
	Grand mean	201.20	278.80	376.30	529.30	660.90	1017.88

Table 54. Heat Unit Efficiency

Treatment (Date of sowing)	Cultivar	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
D1	CO 5	0.0121	0.0449	0.2296	0.5834	0.6856	0.6329
	CORG 5	0.0129	0.0481	0.2258	0.5681	0.7067	0.6685
	UPAS 120	0.0118	0.0332	0.1780	0.4416	0.4783	0.4315
	Mean	0.0123	0.0421	0.2111	0.5310	0.6238	0.5743
	CORG 11	0.0085	0.0315	0.1385	6.4025	5.8424	4.6155
	PLS 361/1	0.0111	0.0375	0.1712	6.6036	5.9899	4.7232
	SA 1	0.0107	0.0334	0.1806	6.6560	5.8582	4.7323
	Mean	0.0161	0.0341	0.1634	6.5540	5.8968	4.6903
	Grand mean	0.0112	0.0381	0.1873	3.5425	3.2603	2.6323
D2	CO 5	0.0090	0.0292	0.0729	0.2101	0.2859	0.4049
	CORG 5	0.0080	0.0301	0.0863	0.2477	0.3571	0.4629
	UPAS 120	0.0121	0.0236	0.0645	0.1494	0.2134	0.3353
	Mean	0.0097	0.0276	0.0745	0.2024	0.2854	0.4010
	CORG 11	0.0088	0.0241	0.0591	0.7581	0.7538	0.7374
	PLS 361/1	0.0085	0.0244	0.0608	0.7038	0.9218	0.8738
	SA 1	0.0105	0.0225	0.0559	0.6886	0.8465	0.8630
	Mean	0.0093	0.0237	0.0586	0.7168	0.8407	0.8047
	Grand mean	0.0095	0.0256	0.0666	0.4596	0.5631	0.6129
D3	CO 5	0.0087	0.0193	0.0427	0.0884	0.1677	0.3257
	CORG 5	0.0084	0.0185	0.0269	0.0781	0.1905	0.3429
	UPAS 120	0.0076	0.0167	0.0416	0.0584	0.1436	0.2779
	Mean	0.0082	0.0182	0.0371	0.0736	0.1673	0.3155
	CORG 11	0.0068	0.0154	0.0406	0.3376	0.4460	0.5129
	PLS 361/1	0.0074	0.0178	0.0462	0.3299	0.4170	0.3939
	SA 1	0.0081	0.0166	0.0405	0.3319	0.5277	0.5487
	Mean	0.0074	0.0166	0.0424	0.3331	0.4636	0.4852
	Grand mean	0.0078	0.0174	0.0265	0.2034	0.3158	0.4004

long duration cultivars recorded higher values than the short duration cultivars.

Relationship between Dry matter accumulation and Meteorological parameters

The correlation and linear regression was worked out between dry matter accumulation at different stages with various meteorological parameters namely, cumulative solar radiation, evaporation, heliothermal unit, growing degree days, photothermal units, day length, heat units and sunshine hours and the data are presented in the Table 55. The cumulative solar radiation, growing degree days and sunshine hours were positively correlated with dry matter accumulation in all stages. But 'r' value was significant only from 50th day onwards till harvest. The maximum positive correlation was obtained for cumulative solar radiation at first flowering (r=0.8534**), for growing degree days at harvest (r=0.8964**) and for sunshine hours at first flowering (r=0.8197**). The cumulative evaporation and day length were also positively correlated with dry matter accumulation but significance was noticed only from first flowering onwards. The maximum positive correlation was obtained at harvest stage for both parameters (evaporation r=0.8645**; day length r=0.8435**). The heliothermal units showed positive and significant correlation from 40th day onwards. The maximum 'r' value was obtained in harvest stage (r=0.9161**). The photothermal units and heat

Table 55. Correlation and linear regression of [illegible] at different stages with meteorological parameters

Parameters						
Cumulative solar radiation	Y =3.057 + 0.000015X r = 0.01534	Y= 5.71 +0.[illegible] r= 0.4267	Y= [illegible] r= 0.[illegible]**	Y= -7[illegible]6.35+1.[illegible] r = 0.8634**	Y= -71[illegible].[illegible]+1.02[illegible] r = 0.8269**	Y= -3985.41+9.18X r = 0.7365**
Cumulative evaporation	Y =2.124 + 0.0072X r = 0.3838	Y= 5.702+0.0[illegible] r= 0.3287	Y= [illegible].15 + 0.0294X r= 0.4564	Y =-[illegible]23.[illegible]+1[illegible].15X r = 0.6[illegible]98**	Y =-[illegible]2[illegible]5.[illegible]+14.4[illegible]X r = 0.[illegible]026**	Y =-7253.60+13.42X r = 0.8645**
Cumulative Helio-thermal units	Y = 2.70+0.0000064X r = 0.1271	Y= 0.393+0.000109X r= 0.7707**	Y= -6[illegible].18+0.000638X r= 0.6386**	Y = -2920.40+ 0.00713 X r = 0.9142**	Y =-31[illegible]2.18+5.54X r = 0.9154**	Y =4300.10+3.45X r = 0.9161**
Growing degree days	Y = -2.24 + 1.6438X r = 0.4322	Y= -26.64+0.0[illegible] r= 0.4435	Y=-532.88+1.072X r= 0.7559**	Y = -6[illegible]94.91+8.69X r = 0.836[illegible]**	Y=-7[illegible]90.71+8.30X r = 0.[illegible]918**	Y =-9714.22+7.50X r = 0.8964**
Cumulative photo-thermal units	Y =-5.142+0.00087X r = 0.6924**	Y= -42.99+0.00[illegible]37X r= 0.6495**	Y= -328.94+0.0243X r= 0.5538**	Y =-6898.41+0.[illegible]X r = 0.8201**	Y =-[illegible]749.16+2.47X r = 0.8[illegible]2**	Y=-10149.37+2.72X r= 0.8807**
Day length (Cumulative)	Y = -4.694+0.02118X r = 0.3425	Y= -13.44 + 0.0518X r= 0.1627	Y= 78.12 +(-0.037X) r= 0.7547**	Y =-702[illegible].37+8.35X r = 0.7634**	Y=-8[illegible]21.79+8.23X r= 0.8108**	Y=-10978.33+7.49X r = 0.8435**
Cumulative heat units	Y =-15.603+0.02393X r = 0.7599**	Y=-135.00+0.1404X r= 0.7973**	Y=-235.754+0.753X r= 0.7547**	Y=-7252.73+3.22X r = 0.8145**	Y=-8265.98+3.76X r = 0.8672**	Y=-10848.98+3.44X r = 0.8735**
Cumulative sunshine hours	Y = 3.026+0.00036X r = 0.0463	Y= 5.39 + 0.0222X r= 0.3445	Y =-55.20 + 0.263X r = 0.5029*	Y = -7307.48+15.15X r = 0.8197**	Y =-76[illegible]3.85+13.51X r = 0.7768**	Y =-3942.11+11.98X r = 0.7543**

units were positively and significantly correlated with Dry matter accumulation at all stages. But maximum 'r' value was noticed at harvest stage (photothermal unit r=0.8807**; heat units r = 0.8735**). Comparing all the meteorological parameters for 'r' value, the cumulative heliothermal units were well correlated with dry matter accumulation at harvest stage (r=0.9161**).

Nutrient uptake

Contents of nitrogen, phosphorus, potassium, calcium and magnesium were analysed at the harvest stage in stem, root, leaf grain, husk and fallen leaf materials. The total uptake was computed based on the individual organ uptake and the data are presented. Statistical analysis was resorted for studying the uptake pattern in different plant organs and also the total uptake of all nutrients. Apart from this, pooled analysis was also undertaken for all the three sowings.

Nitrogen ($g.plant^{-1}$)

Comparing all the plant components, stem recorded the maximum (3.90) followed by seeds (3.59) (Table 56). This trend was noticed in the first sowing (D_1). But in the case of second (D_2) and third sowings (D_3), seeds registered the maximum uptake followed by stem. Generally, in all the plant components, progressive decrease in uptake was noticed from D_1 to D_3. Significant differences could be noticed among the sowing dates. Pooled analysis over three sowings revealed that seeds removed

Table 56. Nitrogen uptake (g.plant^{-1})

	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf
<u>I sowing</u>						
Mean	3.59	0.334	1.826	3.908	0.268	0.295
SE	0.0564	0.00728	0.032	0.0510	0.00068	0.0035
CD	0.2050**	0.00265**	[illegible]	0.1855**	0.00247**	0.0127**
<u>II Sowing</u>						
Mean	[illegible]	0.179	[illegible]	0.421	0.0309	0.213
SE	0.0135	0.00624	0.0403	0.00614	0.00032	0.0225
CD	0.0491**	0.02269**	0.1467**	0.02234**	0.00116**	0.0820**
<u>III Sowing</u>						
Mean	0.779	0.145	0.162	0.161	0.00795	0.120
SE	0.0510	0.00167	0.0402	0.00640	0.00018	0.0014
CD	0.1823**	0.00593**	0.1464**	0.02327**	0.00067**	0.0050**
<u>Pooled analysis</u>						
CO 5	0.870	0.153	0.197	0.0716	0.0101	0.089
CORG 5	1.004	0.167	0.193	0.1013	0.0117	0.097
UPAS 120	0.692	0.125	0.087	0.0586	0.0064	0.104
Mean	0.855	0.148	0.159	0.0772	0.0094	0.096
CORG 11	2.857	0.330	1.2[illegible]	2.631	0.1805	0.294
PLS 361/1	2.122	0.244	1.507	2.382	0.2382	0.358
SA 1	2.877	0.297	1.336	3.736	0.1674	0.315
Mean	2.[illegible]	0.290	1.369	2.916	0.1713	0.322
Grand mean	1.878	0.219	0.764	1.497	0.0132	0.209
<u>Sowing</u>						
SE	0.0181	0.00229	0.1497	0.01220	0.00018	0.0054*
CD	0.0544**	0.00691**	0.4512**	0.03677**	0.00055**	0.0162**
<u>Cultivar</u>						
SE	0.0256	0.00324	0.2117	0.01726	0.00026	0.0076
CD	0.0770**	0.00977**	0.6381**	9.05201**	0.00077**	0.0229**
<u>Sowing x Cultivar</u>						
SE	0.0443	0.00562	0.3667	0.02989	0.00044	0.0132
CD	0.1333**	0.01692**	1.1052**	0.09008**	0.00134**	0.0398**

Table 57. Phosphorus uptake (g^{-1} $plant^{-1}$)

	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf
I sowing						
Mean	0.363	0.084	0.244	1.379	0.088	0.029
SE	0.00197	0.00169	0.00136	0.03905	0.00750	0.00163*
CD	0.00718	0.00425**	0.00496**	0.1420**	0.02727**	0.00593**
II sowing						
Mean	0.118	0.037	0.038	0.109	0.0077	0.018
SE	0.00126	0.00152	0.00151	0.00266	0.00197	0.00067
CD	0.00459**	0.00551**	0.00547**	0.00967**	0.00717**	0.00247**
III sowing						
Mean	0.064	0.029	0.018	0.027	0.0023	0.0076
SE	0.00154	0.00393	0.00141	0.00105	0.00015	0.00015
CD	0.00563**	0.01429**	0.00514**	0.00381**	0.00055**	0.00055**
Pooled analysis						
CO 5	0.087	0.024	0.025	0.028	0.0028	0.0086
CORG 5	0.091	0.027	0.020	0.033	0.0038	0.0085
UPAS 120	0.060	0.021	0.009	0.016	0.0025	0.0094
Mean	0.0791	0.024	0.018	0.025	0.0030	0.0088
CORG 11	0.285	0.075	0.169	0.922	0.0574	0.0252
PLS 361/1	0.281	0.069	0.191	1.079	0.0793	0.0267
SA 1	0.286	0.084	0.186	0.957	0.0508	0.0319
Mean	0.284	0.076	0.182	0.985	0.0625	0.0279
Grand mean	0.181	0.050	0.100	0.505	0.033	0.018
Sowing						
SE	0.00066	0.00103	0.00058	0.00923	0.00183	0.00042
CD	0.00199**	0.00310**	0.00176**	0.02781**	0.00551**	0.00126**
Cultivar						
SE	0.00094	0.00146	0.00083	0.01305	0.00258	0.00059
CD	0.00282**	0.00439**	0.00248**	0.03934**	0.00779**	0.00178**
Sowing x Cultivar						
SE	0.00162	0.00252	0.00143	0.02261	0.00447	0.00102
CD	0.00489**	0.00761**	0.00431**	0.06814**	0.01349**	0.00308**

Table 58. Potassium uptake ($g.plant^{-1}$)

	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf
I sowing						
Mean	1.406	0.509	1.186	5.560	0.363	0.114
SE	0.06505	0.00973	0.00372	0.806	0.01118	0.00774
CD	0.23653**	0.01375**	0.01354**	2.932**	0.04067**	0.02813**
II Sowing						
Mean	0.619	0.231	0.227	0.469	0.051	0.077
SE	0.00961	0.00717	0.01551	0.00066	0.00245	0.01272
CD	0.03493**	0.02608**	0.05641**	0.00241**	0.00891**	0.04625**
III Sowing						
Mean	0.392	0.200	0.134	0.189	0.019	0.041
SE	0.00368	0.00331	0.00151	0.04045	0.00159	0.00161
CD	0.01341**	0.01204**	0.00547**	0.14709**	0.00580**	0.00586**
Pooled mean						
CO 5	0.365	0.163	0.118	0.138	0.016	0.031
CORG 5	0.425	0.192	0.126	0.182	0.019	0.030
UPAS 120	0.311	0.120	0.056	0.064	0.012	0.029
Mean	0.367	0.158	0.100	0.128	0.015	0.030
CORG 11	1.163	0.452	0.786	4.044	0.253	0.101
PLS 361/1	1.136	0.407	0.976	3.910	0.301	0.129
SA 1	1.435	0.546	1.031	4.098	0.264	0.144
Mean	1.245	0.468	0.931	4.017	0.273	0.125
Grand mean	0.306	0.313	0.515	2.072	0.144	0.063
Sowing						
SE	0.01552	0.00295	0.00378	0.190	0.00272	0.00353
CD	0.04678	0.00890**	0.01138**	0.574**	0.00821**	0.01064**
Cultivar						
SE	0.02195	0.00418	0.00534	0.269	0.00385	0.00499
CD	0.06616**	0.01259**	0.01138**	0.811**	0.01161**	0.01505**
Sowing x Cultivar						
SE	0.03803	0.00723	0.00925	0.466	0.00667	0.00865
CD	0.11459**	0.02181**	0.02788**	1.405**	0.02011**	0.02606**

the highest N (1.878) followed by stem (1.497), leaf (0.764), pod wall (0.219), fallen leaves (0.209) and root (0.0132). Here too, long duration cultivars recorded higher nitrogen uptake than the short duration cultivars.

Phosphorus (g.plant^{-1})

Similar to nitrogen, phosphorus was more in the stem (1.379) and followed by seed (0.363) (Table 57). This was noticed in the case of first sowing. But in the case of D_2 and D_3, the seed (0.118, 0.064) exceeded the stem uptake (0.109, 0.027). The cultivar differences in all the three sowings in all the plant components were found to be significant. Pooled analysis over the sowings revealed that the maximum phosphorus uptake was noticed in the stem (0.505), followed by grain (0.181), leaf (0.111), pod wall (0.050), roots(0.033) and fallen leaves (0.018). Here too, long duration cultivars recorded higher phosphorus uptake than the short duration cultivars.

Potassium (g. plant^{-1})

Sowing differences were clearly demarcated (Table 58). With regard to first sowing (D_1), stem recorded the maximum uptake (5.560) followed by grain (1.406) and leaf (1.186). In the case of second and third sowing, seeds registered the maximum uptake followed by stem. Statistical analysis was found to be significant for all the components in all the three sowings. Pooled analysis showed that the mean potassium uptake was more in stem (2.072), followed by seed (0.806), leaf (0.515), husk (0.313), root (0.144) and fallen leaf (0.063). Even here long duration cultivars recorded higher uptake than the short duration cultivars.

Calcium uptake (g.plant^{-1})

Data on calcium uptake are presented in Table 59. Sowing differences were influencing the calcium uptake in all the three sowing dates. Calcium uptake was maximum in the stem in the case of D_1, in leaf in D_2 and fallen material in D_3. Cultivar differences were found to be significant for all components. Pooled analysis revealed that the highest mean calcium uptake was recorded in stem (2.561), followed by root (0.270), fallen material (0.204), grain (0.087) and husk (0.087).

Magnesium uptake (g. plant^{-1})

There were significant differences in magnesium uptake among different sowing dates (Table 60). In the case of first sowing, stem accumulated maximum (1.957), followed by leaf (0.388) and seed (0.239). With regard to second sowing, the highest was noticed in the stem (0.199), followed by husk (0.130) and leaf (0.069) whereas in the case of third sowing, husk recorded the maximum uptake (0.089) followed by stem (0.043), leaf (0.043) and grain (0.039). The differences were found to be significant at all levels. The pooled

Table 59. Calcium uptake ($g.plant^{-1}$)

	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf
I sowing						
Mean	0.171	[illegible]	[illegible]	[illegible]	0.695	0.310
SE	[illegible]	[illegible]	[illegible]	[illegible]	0.12356	0.00147
CD	[illegible]**	[illegible]**	[illegible]**	[illegible]**	[illegible]**	0.00535**
II sowing						
Mean	[illegible]	[illegible]	[illegible]	0.081	0.088	0.194
SE	0.00107	[illegible]	0.01513	0.03945	0.00383	0.00819
CD	0.00376**	[illegible]**	0.05505**	0.14345**	0.01392**	0.02978**
III sowing						
Mean	0.034	[illegible]	0.059	0.167	0.028	0.109
SE	0.00126	0.00137	0.01248	0.01962	0.00084	0.01318
CD	0.00459**	0.00497**	[illegible]**	0.07134**	0.00305**	0.04794**
Pooled analysis						
CO 5	0.043	0.044	0.068	0.145	0.027	0.081
CoRG 5	0.045	0.054	0.070	0.182	0.037	0.085
UPAS 120	0.033	0.037	0.034	0.073	0.027	0.098
Mean	0.040	0.045	0.057	0.133	0.030	0.088
CoRG 11	0.124	0.137	0.434	5.108	0.537	0.310
PLS 361/1	0.136	0.114	0.517	4.626	0.491	0.325
SA 1	0.152	0.136	0.597	5.232	0.491	0.325
Mean	0.137	0.129	0.516	4.988	0.510	0.320
Grand mean	0.089	0.087	0.286	2.561	0.270	0.204
Sowing						
SE	0.00368	0.00182	0.01234*	0.24295	0.02914	0.00367
CD	0.01108**	0.00549**	0.03729**	0.73219**	0.08781**	0.01107**
Cultivar						
SE	0.00519	0.00257	0.01750	0.34359	0.04121	0.00519
CD	0.01567**	0.00776**	0.05274**	1.03558**	0.12418**	0.01567**
Sowing x Cultivar						
SE	0.00901	0.00446	0.03031	0.59512	0.07137	0.00900
CD	0.02714**	0.01344**	0.09135**	1.79352	0.21509**	0.02713**

Table 60. Magnesium uptake (g.plant^{-1})

	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf
I sowing						
Mean	0.279	0.187	0.389	1.957	0.218	0.061
SE	0.01211	0.01040	[illegible]	0.3986	0.00488	0.00388
CD	0.04400**	0.03675**	0.00274**	1.4495**	0.01777**	0.01411**
II sowing						
Mean	0.076	0.103	0.068	0.199	0.024	0.033
SE	0.01197	0.00306	0.00147	0.01367	0.00117	0.00098
CD	0.04355**	0.01112**	0.00535**	0.04972**	0.00425**	0.00357**
III Sowing						
Mean	0.079	0.083	0.043	0.047	0.0053	0.024
SE	0.00186	0.00558	0.00319	0.00054	0.00121	0.00147
CD	0.00675**	0.02031**	0.01159**	0.00199**	0.00440**	0.00535**
Pooled analysis						
CO 5	0.085	0.063	0.029	0.037	0.006	0.022
CORG 5	0.056	0.077	0.032	0.044	0.008	0.021
UPAS 120	0.046	0.057	0.018	0.017	0.005	0.021
Mean	0.062	0.065	0.026	0.032	0.006	0.021
CORG 11	0.114	0.172	0.272	1.184	0.135	0.057
PDS 361/1	0.172	0.156	0.311	1.437	0.182	0.055
SA 1	0.216	0.221	0.337	1.688	0.158	0.058
Mean	0.164	0.183	0.306	1.436	0.158	0.057
Grand mean	0.116	0.124	0.166	0.734	0.083	0.039
Sowing						
SE	0.00287	0.00160	0.00085	0.09402	0.00122	0.00101
CD	0.00865**	0.00484**	0.00255**	0.28335**	0.03367**	0.00303**
Cultivar						
SE	0.00406	0.00227	0.00119	0.13297	0.00172	0.001422
CD	0.12237**	0.00684**	0.00361**	0.40073**	0.00519**	0.00428**
Sowing x Cultivar						
SE	0.00703	0.00393	0.00207	0.23031	0.00298	0.00246
CD	0.02119**	0.01184**	0.00625**	0.69408**	0.00899**	0.00742**

Table 61. Total uptake (g.plant^{-1})

Treatments	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
I sowing					
Mean	10.224	2.187	9.135	8.839	3.049
SE	0.212	0.0394	0.531	0.005715	0.01732
CD	0.772**	0.1433**	1.928**	[illegible]**	0.06296**
II sowing					
Mean	[illegible]	[illegible]	1.073	1.207	0.498
SE	0.0938	0.0014	0.0399	0.06289	0.01341
CD	0.3410**	0.0778**	0.1453**	0.19233**	0.04876**
III sowing					
Mean	1.371	0.149	0.975	0.448	0.242
SE	0.0175	0.00295	0.00467	0.04046	0.01548
CD	0.0638**	0.01072**	0.01696**	0.14717**	0.05631**
Pooled analysis					
CO 5	1.392	0.1764	0.831	0.408	0.213
CORG 5	1.583	0.1847	0.976	0.471	0.238
UPAS 120	1.073	0.1179	0.593	0.303	0.163
Mean	1.349	0.1593	0.800	0.394	0.205
C BG 11	7.553	1.4903	6.798	6.649	1.985
ILL 361/1	7.718	1.7248	6.851	6.222	2.313
SA 1	9.059	1.5971	7.517	6.934	2.667
Mean	8.110	1.6061	7.055	6.601	2.321
Grand mean	5.147	0.879	3.927	3.498	1.263
Sowing					
SE	0.0548	0.01059	0.1254	0.01556	0.00632
CD	0.1635**	0.03193**	0.3779**	0.047483**	0.01905**
Cultivars					
SE	0.0775	0.01498	0.1774*	0.02228	0.00894
CD	0.2338**	0.04516**	0.5345**	0.067151**	0.02695**
Sowing x Cultivar					
SE	0.1344	0.02595	0.3072	0.03859	0.01549
CD	0.4049**	0.078214**	0.9257**	0.11631**	0.04667**

Table 62. Protein analysis

	Protein (per cent)	Protein yield g.plant^{-1}	Protein (g.m^{2})	Nitrogen harvest index (Per cent)
I sowing				
Mean	18.16	20.61	110.19	47.22
SE	0.494	1.959	1.124	1.124
CD	1.794**	7.123**	4.089**	4.088**
II Sowing				
Mean	20.25	8.31	47.84	59.58
SE	0.396	0.764	1.839	0.728
CD	1.442**	2.777**	6.689**	2.648**
III Sowing				
Mean	18.78	4.45	24.96	57.1
SE	0.107	0.092	2.159	1.136
CD	0.390**	0.334**	7.852**	4.133**
Pooled analysis				
CO 5	17.68	4.96	36.67	61.80
CORG 5	19.03	5.88	43.56	64.10
UPAS 120	17.32	3.92	29.01	63.06
Mean	18.01	4.92	36.41	62.98
CORG 11	20.17	16.46	81.34	46.50
PLS 361/1	20.36	17.19	84.98	45.83
SA 1	19.18	18.32	90.51	46.50
Mean	19.40	17.32	85.61	46.27
Grand mean	19.06	12.12	61.00	54.63
Sowing				
SE	0.151	0.496	0.719	0.414
CD	0.456**	1.435**	2.168**	1.247**
Cultivar				
SE	0.241	0.702	1.017	0.585
CD	0.645**	2.114**	3.066**	1.765**
Sowing x Cultivar				
SE	0.371	1.215	1.762	1.014
CD	1.117**	3.663**	5.309**	3.057**

analysis revealed that the uptake of magnesium by different plant components were in the following order, stem (0.734), leaf (0.166), husk (0.124), grain (0.188), root (0.083) and fallen material (0.039). All the nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium recorded higher uptake in long duration cultivars than short duration.

Total nutrient uptake (g.plant^{-1})

The total uptake of nitrogen, phosphorus, potassium, calcium and magnesium were computed on per plant basis from their components and the data are presented (Table 61). Differences were found to be significant at all levels. All the above nutrients decreased progressively from D_1 to D_3. Data on pooled mean revealed that among the nutrients, nitrogen uptake was found to be the maximum (5.147), followed by potassium (3.927), calcium (3.498), magnesium (1.263) and phosphorus (0.879) respectively. Similar to other parameters, long duration cultivars recorded higher nutrient uptake than the short duration cultivars.

Protein Analysis

The protein content on unit weight basis (per cent), per plant basis (g.plant^{-1}) and at community levels (g.m^{-2}) were assessed at harvest stage in the seed and the data were presented (Table 62). Among the sowing dates, second sowing (D_2) recorded the highest percentage (20.25) followed by

D_3 (18.78) and D_1 (18.16). On per plant basis, a progressive reduction was noticed from D_1 to D_3. A similar trend was also noticed on community level also. The differences were found to be a significant at all levels in all the three sowings. In the pooled analysis, long duration cultivars recorded higher protein content on unit weight basis (19.09) as compared to the short duration cultivars (18.01). The gap widened at per plant level and further widened at community level. The pooled value over sowings and varieties were found to be 19.06 per cent, 12.12 ($g.plant^{-1}$) and 61.0 ($g.m^{-2}$) for protein percentage, protein yield on per plant basis and community basis respectively.

Nitrogen Harvest Index (NHI)

Data on nitrogen harvest index are presented (Table 62) The harvest index calculated on the basis of nitrogen content revealed improvement of harvest index over traditional HI values of HI. The nitrogen harvest index followed same trend as that of traditional harvest index. With regard to sowing differences, second sowing (D_2) recorded the highest value (59.58) followed by D_1 (57.10) and D_3 (47.22). The varietal differences were found to be statistically significant in all the three sowings. Even here, short duration cultivars recorded higher NHI than the long duration cultivars.

Stability Analysis

The analysis of variance for phenotypic stability for twelve characters as per Eberhart and Russel model (1966) is presented in the Table 63,64. The variance due to varieties and seasons were significant for all the character at 1% level. The mean squares due to variety x season were significant for all the characters except photosynthesis and number of seed per pod.

Season (linear) mean squares were significant for all the characters except leaf-stem ratio. Variety x season (linear) mean squares were significant at 1% level for LAI, stem weight, total DMA number of branches, harvest index and grain yield and at 5% level for leaf-stem ratio and 1000-seed weight and non significant for individual leaf area, photosynthesis and No. of seeds per pod. Mean squares due to pooled deviations (non linear) were significant at 1% level for harvest index and number of branches and at 5% level for 1000-seed weight and grain yield, and non significant for other characters.

From the analysis of variance table, the percentage of linear and non-linear components of mean squares were worked out and the data were presented in the Table 65. With regard to biomass components like LAI, stem weight and total DMP the linear components had the major share of more than 99%. Photosynthesis and single leaf size accounted for 75.3 and 65.2%

Table 63. Analysis of variance for (mean squares) phenotypic stability-Drymatter components

Source	df	LAI	Individual leaf area	Photosynthesis	Stem weight	Leaf/stem ratio	TDMA
Variety	5	243.66**	36.49**	24.09**	1123423.69**	0.409**	2270059.14**
Season	2	899.94**	181.27**	73.52**	4313393.98**	0.395**	8368775.51**
Variety x season	10	129.69**	8.65**	3.38	805752.16**	0.028**	1493737.17**
Season (Linear)	1	599.96**	120.85**	49.01**	2875595.98**	0.256	5579183.67**
V x S (Linear)	5	86.31**	3.52	1.62	537002.10**	5.18*	995252.97**
Pooled deviation (Non linear)	6	0.124	1.88	0.53	138.34	0.015	476.49
Pooled error	30	0.576	1.83	3.62	658.96	1.55	6210.55

Table 64. Analysis of variance (mean squares) for phenotypic stability-Yield components

Source	df	HI	No. bran-ches per plant	1000-grain weight	No. seed/pod	No. pod/plant	Grain yield
Variety	5	956.36**	158.04**	801.31**	0.245**	407890.35**	10040.69**
Season	2	286.53**	372.47**	109.09**	0.957**	773095.81**	37281.73**
Variety x season	10	117.29**	82.05**	13.72**	0.093	99117.19**	4045.14**
Season (Linear)	1	191.02**	248.31**	72.73**	0.638**	515397.21**	24854.49**
Variety x season (Linear)	5	21.17**	13.18**	3.95*	0.024	65629.57**	2635.58**
Pooled deviation (non linear)	6	47.52**	1.28**	4.34*	0.032	373.79	50.99*
Pooled error	30	3.85	0.324	1.49	0.047	675.57	17.58

Table 65. Percentage contribution of linear and non-linear components.

Dry matter components

Components	LAI	Individual leaf area	Photo-synthesis	Stem weight	Leaf/stem ratio	TDMA
Linear	99.9	65.2	75.3	99.9	99.7	99.95
Non-linear	0.1 NS	34.8	24.7	0.1	0.3	0.05

Yield components

Components	HI	No.branches per plant	1000 grain weight	No.seed/pod	No. pod/plant	Grain yield
Linear	30.8	91.1	47.6	42.9	99.0	98.0
Non-linear	69.2	8.9	52.4	57.1	1.0	2.0

respectively. In the case of yield and yield components, the linear component contribution was more in grain yield (98%), number of pods per plant (99%), number of branches (91) than the other yield components such as 1000-grain weight (47.6%), number of seeds per pod (42.9) and HI (30.8%).

Photosynthesis

There were variations in photosynthesis among varieties and seasons. The mean photosynthetic rates were 24.65, 23.03 and 20.63 for D_1, D_2 and D_3 sowings respectively. The overall mean was found to be 22.76. The cultivar, CORG 5 recorded a higher value than the general mean plus 2 s.e. (Table 66; Fig.2). All the cultivars recorded 'b' values around unity except CORG 11 where the 'b' value deviated significantly from one. The S^-d^2 values for all the varieties were found to be around zero.

Leaf Area Index (LAI)

The mean LAI over seasons were 14.23, 2.74 and 1.35 for D_1, D_2 and D_3 sowings respectively. The overall mean LAI was 6.11. The long duration varieties CORG 11, PLS 361/1 and SA 1 recorded higher LAI than mean plus 2 s.e. (Table 67; Fig.3). All the cultivars recorded 'b' values around unity except PLS 361/1 and SA 1, deviated significantly from one. The S^-d^2 values for all the varieties were around zero.

Stem weight

Here too, the mean performances over the seasons varied widely. The mean stem weight ($g.m^{-2}$) were 902.85,

Table 66. Stability analysis for photosynthetic rate at 50% flowering ($mg\ CO_2.dm^{-2}.hr^{-1}$)

Variety	Seasons				Regression coefficient (b)	Mean square deviation (S^-d^2)
	I	II	III	Mean		
CO 5	26.3	22.8	21.6	23.6	1.12	0.49
CORG 5	28.6	25.4	22.3	25.4	1.54	-0.92
UPAS 120	23.0	22.8	19.8	21.9	0.83	-0.43
CORG 11	25.9	23.7	20.1	23.2	1.45*	-1.19
PLS 361/1	21.8	21.6	19.7	21.0	0.54	-0.93
SA 1	22.3	21.9	20.3	21.5	0.51	-1.09
Mean	24.65	23.03	20.63	22.76	1.00	
SE	1.28	1.37	0.351	0.634	0.254	

Table 67. Stability analysis for LAI at 50% flowering

Variety	Seasons				Regression coefficient (b)	Mean square deviation (S^-d^2)
	I	II	III	Mean		
CO 5	3.52	1.16	0.56	1.75	0.22	-0.15
CORG 5	3.12	1.46	0.46	1.68	0.18	0.089
UPAS 120	1.45	0.53	0.32	0.76	0.084	-0.19
CORG 11	22.60	4.46	2.15	9.74	1.58	-0.19
PLS 361/1	27.50	4.34	2.08	11.31	1.99*	-0.067
SA 1	27.20	4.47	2.53	11.40	1.93*	0.089
Mean	14.23	2.74	1.35	6.11	1.00	
SE	0.755	0.085	0.038	0.254	0.035	

FIG.2 DIFFERENTIAL RESPONSIVENESS OF PIGEONPE CULTIVARS - PHOTOSYNTHETIC RATE

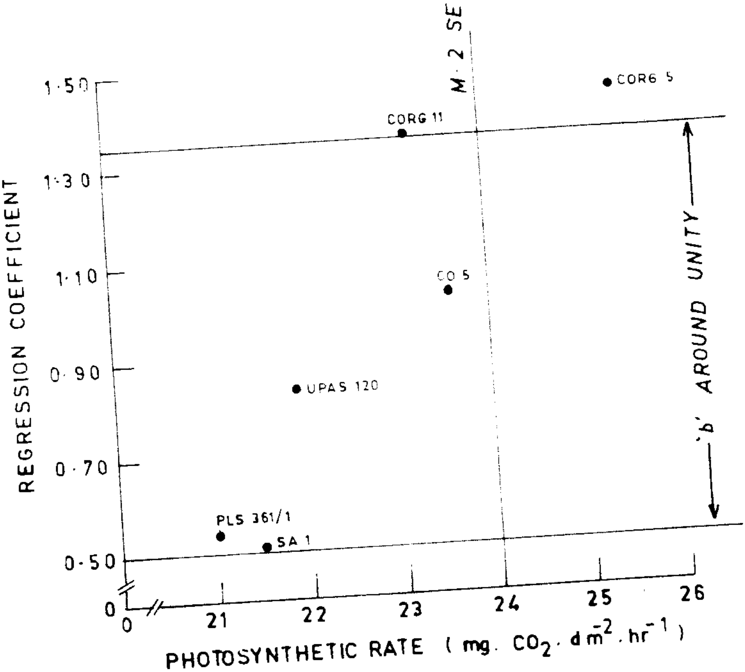
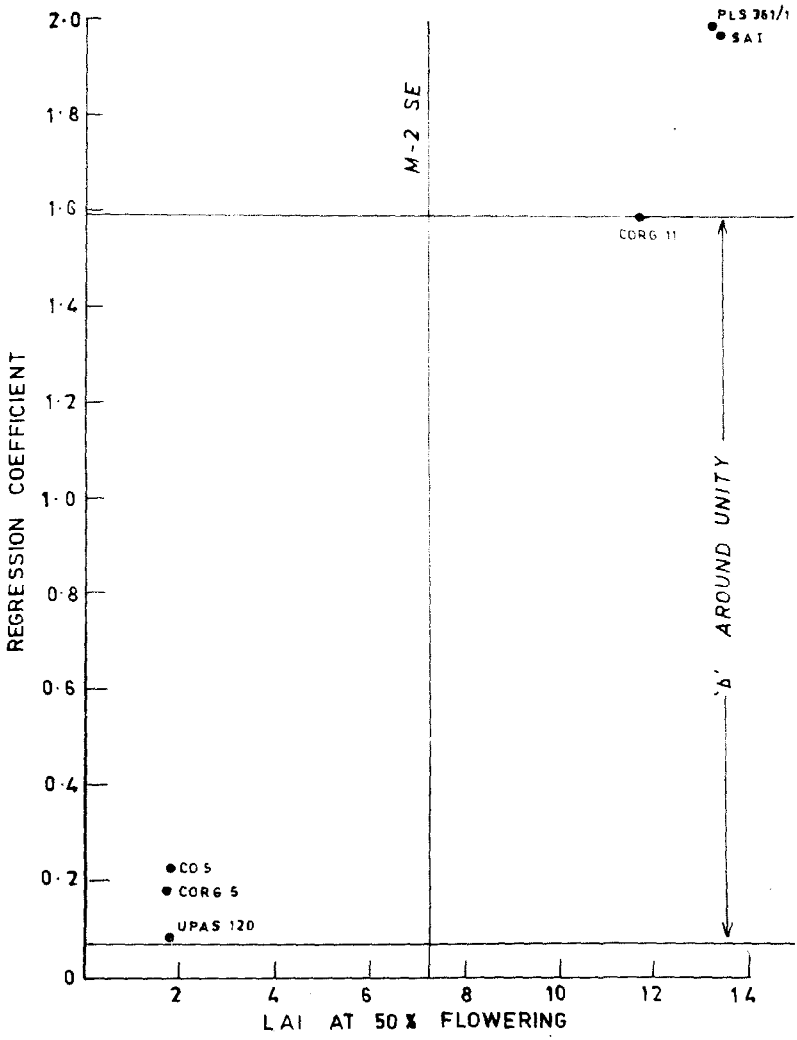


FIG. 3 DIFFERENTIAL RESPONSIVENESS OF PEGEONPEA CULTIVARS :- LEAF AREA INDEX



88.48 and 25.03 for D_1 , D_2 and D_3 sowings respectively. The overall mean was 338.79. The long duration cultivars i.e., CORG 11, PLS 361/1 and SA 1 recorded higher values more than the mean plus 2 s.e. (Table 68; Fig.4). The 'b' values deviated significantly from one except CO 5. The S^-d^2 values were found to be around zero.

Leaf-stem Ratio

The mean leaf-stem ratio over seasons were 0.262, 0.456, and 0.546 for D_1, D_2 and D_3 sowings respectively with the overall mean of 0.420. The leaf-stem ratios of short duration cultivars CO 5, CORG 5 and UPAS 120 exceeded the mean plus 2 s.e. (Table 69, Fig.5). The 'b' values were found to be around unity for all the varieties. The S^-d^2 values found for all the cultivars significantly deviated from zero except UPAS 120.

Individual leaf Area (ILA)

The mean ILA values 15.81, 12.00 and 9.5 for D_1, D_2 and D_3 respectively with the overall mean of 12.45. The cultivar PLS 361/1 recorded higher value more than the general mean plus 2 s.e. (Table 70; Fig.6). The 'b' values were around unity except PLS 361/1. Here also, S^-d^2 values were around zero for all the cultivars except CORG 11 which deviated significantly from zero.

Table 68. Stability analysis for stem weight at harvest stage (g.m^{-2})

Variety	Seasons I	II	III	Mean	Regression coefficient (b)	Mean square deviation (S^2d)
CO 5	38.07	11.0	5.2	18.09	0.036	-213.37
CORG 5	50.81	12.8	6.0	23.20	0.049*	-212.86
UPAS 120	20.95	4.9	2.9	9.58	0.020*	-219.39
CORG 11	1695.00	138.4	41.8	625.07	1.89**	61.28
PLS 361/1	1752.50	190.0	37.4	659.97	1.94**	219.66
SA 1	1859.80	173.8	56.9	696.83	2.06**	-123.19
Mean	902.85	88.48	25.03	338.79	1.00	
SE	25.76	4.30	1.24	8.56	0.017	

Table 69. Stability analysis for leaf/stem ratio at harvest stage

Variety	Seasons I	II	III	Mean	Regression coefficient (b)	Mean square deviation (S^2d)
CO 5	0.45	0.79	0.73	0.66	1.09	0.014**
CORG 5	0.33	0.75	0.57	0.55	1.03	0.043**
UPAS 120	0.46	0.65	0.79	0.64	1.37	1.49
CORG 11	0.11	0.17	0.40	0.23	0.91	0.012**
PLS 361/1	0.11	0.19	0.41	0.24	0.98	9.65
SA 1	0.11	0.18	0.38	0.22	0.85	7.94**
Mean	0.262	0.456	0.546	0.42	1.00	
SE	0.029	0.020	0.17	0.013	0.591	

Table 70. Stability analysis for individual leaf area ($cm^{-2}.leaf^{-1}$)

Variety	Season I	Season II	Season III	Season Mean	Regression coefficient (b)	Mean square deviation ($S^{-}d^{2}$)
CO 5	12.3	10.5	7.7	10.17	0.71	0.030
CORG 5	15.6	10.6	8.7	11.63	1.11	-0.168
UPAS 120	15.0	9.1	6.9	10.33	1.31	0.098
CORG 11	14.4	15.6	11.0	13.67	0.47	6.37
PLS 361/1	20.5	13.9	10.5	14.97	1.59*	-0.42
SA 1	17.1	12.3	12.3	13.90	0.80	1.74
Mean	15.81	12.0	9.52	12.45	1.00	
SE	0.881	0.762	0.685	0.451	0.305	

Table 71. Stability analysis for TDMA (g/m^{-2})

Variety	Season I	Season II	Season III	Season Mean	Regression coefficient (b)	Mean square deviation ($S^{-}d^{2}$)
CO 5	132.6	73.6	46.00	84.07	0.063	-1846.97
CORG 5	149.8	85.9	50.80	95.50	0.071	-1682.45
UPAS 120	88.4	57.2	36.10	60.56	0.036	-1919.27
CORG 11	2400.8	284.0	142.61	942.47	1.85**	- 765.66
PLS 361/1	2548.7	340.0	116.14	1001.61	1.97**	-1880.77
SA 1	2615.1	340.2	167.10	1048.80	2.00**	-1466.97
Mean	1322.5	196.8	93.1	538.84	1.00	
SE	76.69	16.99	6.28	26.29	0.023	

FIG. 4 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- STEM WEIGHT

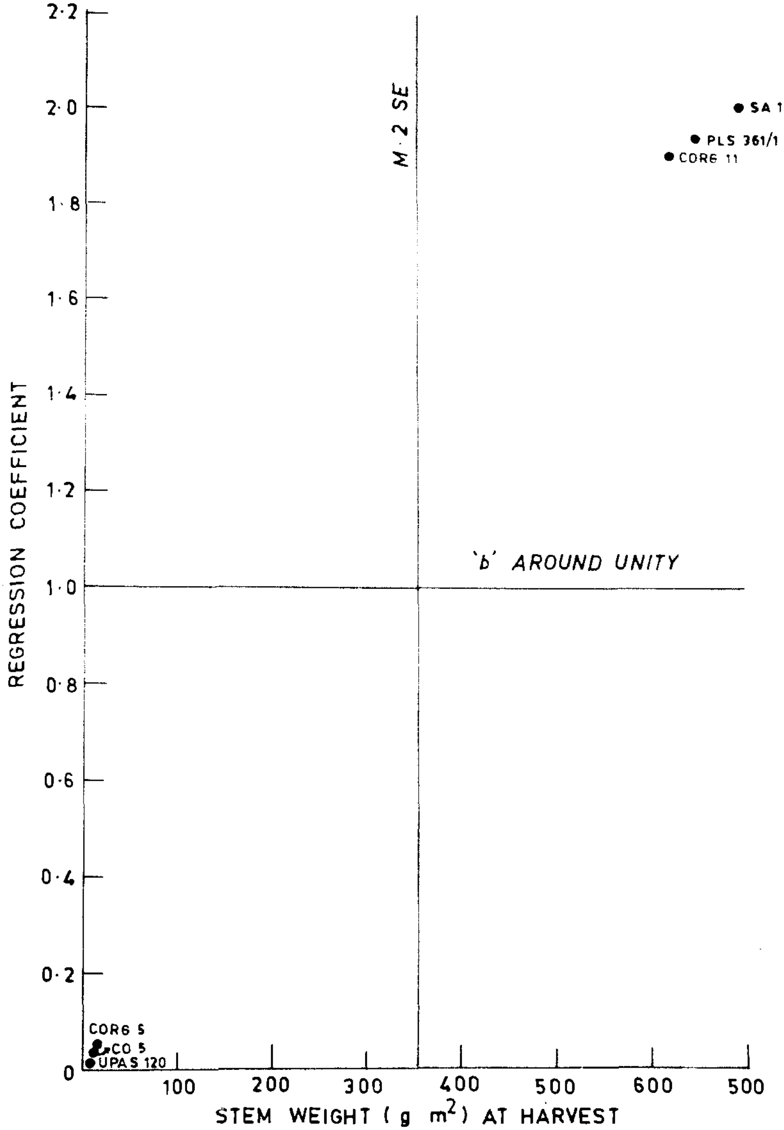


FIG. 5 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- LEAF/STEM RATIO

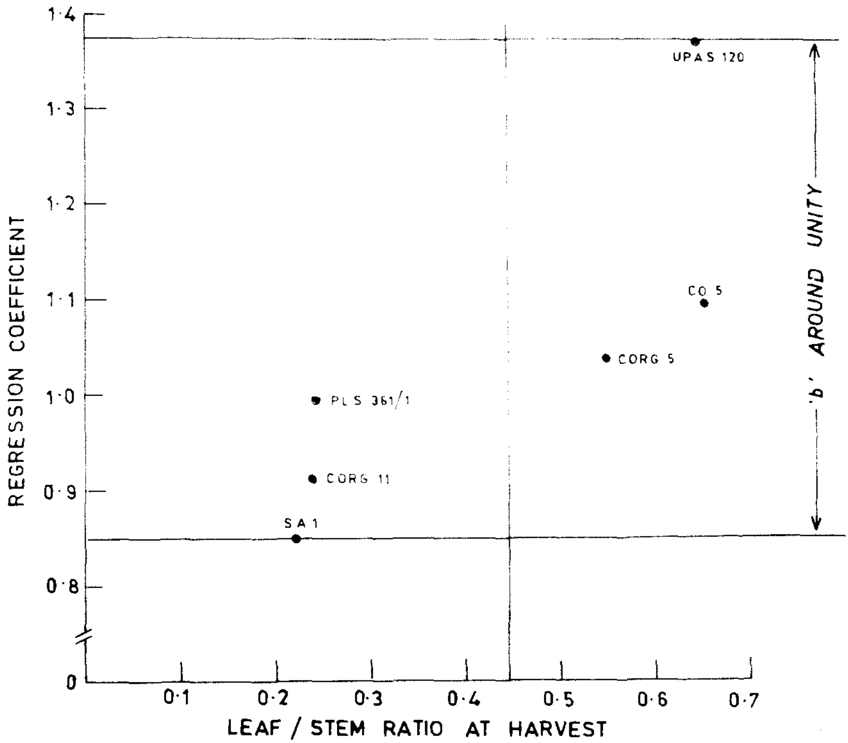


FIG. 6 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS - INDIVIDUAL LEAF AREA

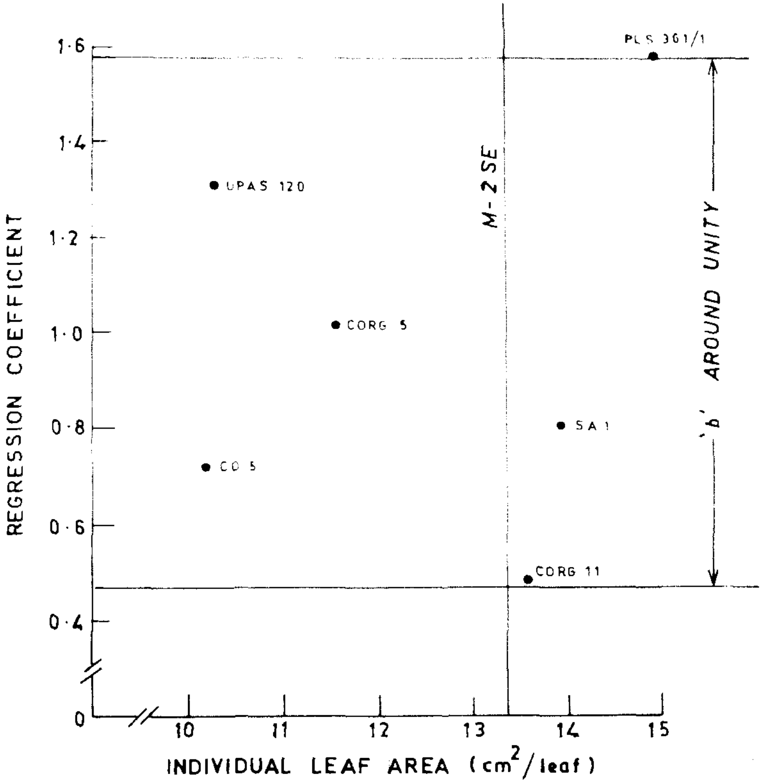
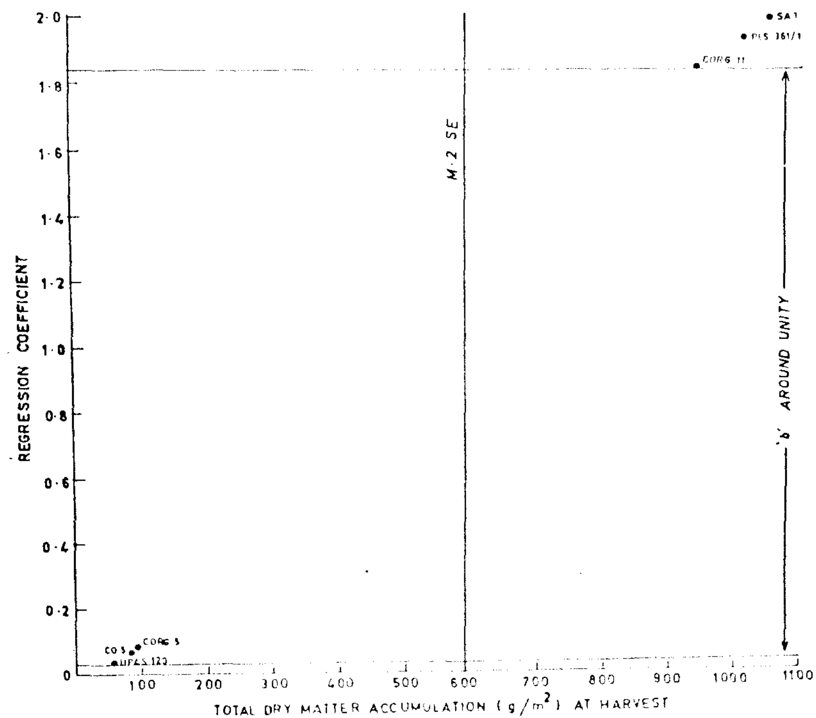


FIG. 7 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- TOTAL DRY MATTER ACCUMULATION



Total DMA

The mean total DMA varied widely among cultivars and seasons. The mean over seasons were 1322.5, 196.8 and 93.1 in D_1, D_2 and D_3 sowings respectively. The overall mean was 538.84. All the long duration cultivars recorded (Table 71, Fig.7) higher value than the general mean plus 2 s.e. The 'b' values for all the short duration cultivars were around unity. Here too, S^-d^2 values were found to be around zero.

Number of branches

The mean number of branches per plant were 16.05, 10.2 and 7.08 for D_1, D_2 and D_3 sowings respectively with the overall mean of 11.12. All the long duration cultivars exceeded the mean plus 2 s.e. (Table 72, Fig.8). The 'b' values were around unity except PLS 361/1. The S^-d^2 values were around zero for all the cultivars except CO 5, CORG 5 and CORG 11.

Number of pods per plant

The number of pods per plant also varied among cultivars and sowings. The mean values were 587.37, 301.48 and 184.51 for D_1, D_2 and D_3 sowings respectively with the overall mean of 357.78. The long duration cultivars CORG 11, PLS 361/1 and SA 1 recorded higher values than the general mean plus 2 s.e. (Table 73, Fig.9). All the cultivars recorded 'b' value significantly deviating from one except CO 5 and CORG 5. The S^-d^2 values was around zero for all the cultivars.

Table 72. Stability analysis for No. of branches/plant

Variety	Seasons				Regression coefficient (b)	Mean square deviation ($S^{-}d^2$)
	I	II	III	Mean		
CO 5	9.6	8.5	5.3	7.8	0.44	1.74**
CORG 5	10.4	8.3	5.2	7.9	0.55	0.94*
UPAS 120	8.9	6.3	4.1	6.4	0.52	0.063
CORG 11	20.9	11.0	9.1	13.7	1.36	3.16**
PLS 361/1	21.2	13.6	9.2	14.7	1.33*	-0.086
SA 1	25.3	13.7	9.6	16.2	1.78	1.19
Mean	16.05	10.23	7.08	11.12	1.00	
SE	0.474	0.184	0.256	0.109	0.176	

Table 73. Stability analysis for No. of pods/plant

Variety	Seasons				Regression coefficient (b)	Mean square deviation ($S^{-}d^2$)
	I	II	III	Mean		
CO 5	220.2	187.2	128.8	178.7	0.21	414.14
CORG 5	241.2	195.6	142.5	193.1	0.23	151.05
UPAS 120	170.8	116.7	95.0	127.5	0.19**	-225.13
CORG 11	902.2	409.2	266.4	525.9	1.68*	875.31
PLS 361/1	944.2	412.8	195.4	517.5	1.86**	-225.19
SA 1	1045.6	487.4	279.0	604.0	1.91*	- 98.56
Mean	587.37	301.48	184.51	357.78	1.00	
SE	12.30	22.50	4.23	8.66	0.066	

FIG. 8 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- NUMBER OF BRANCHES

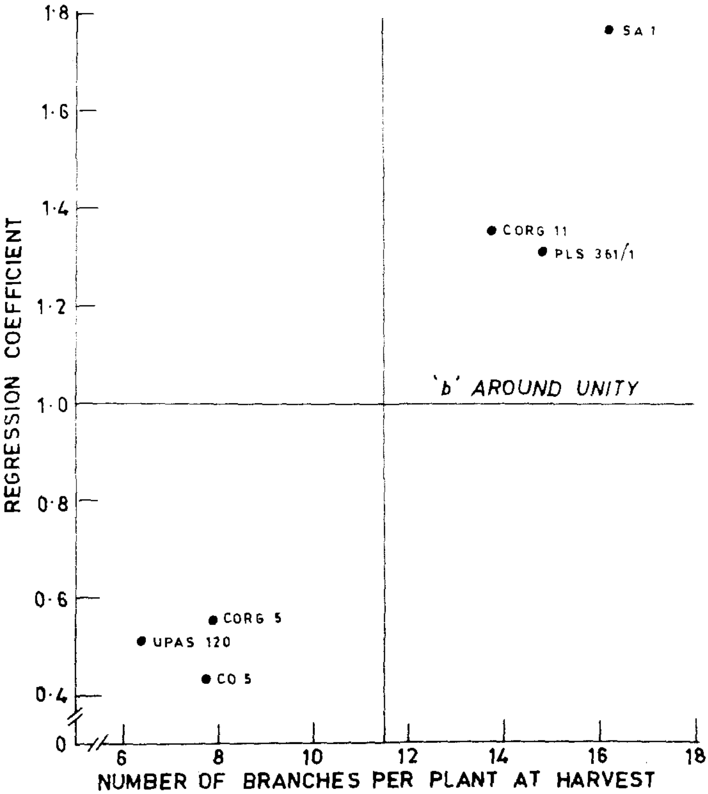
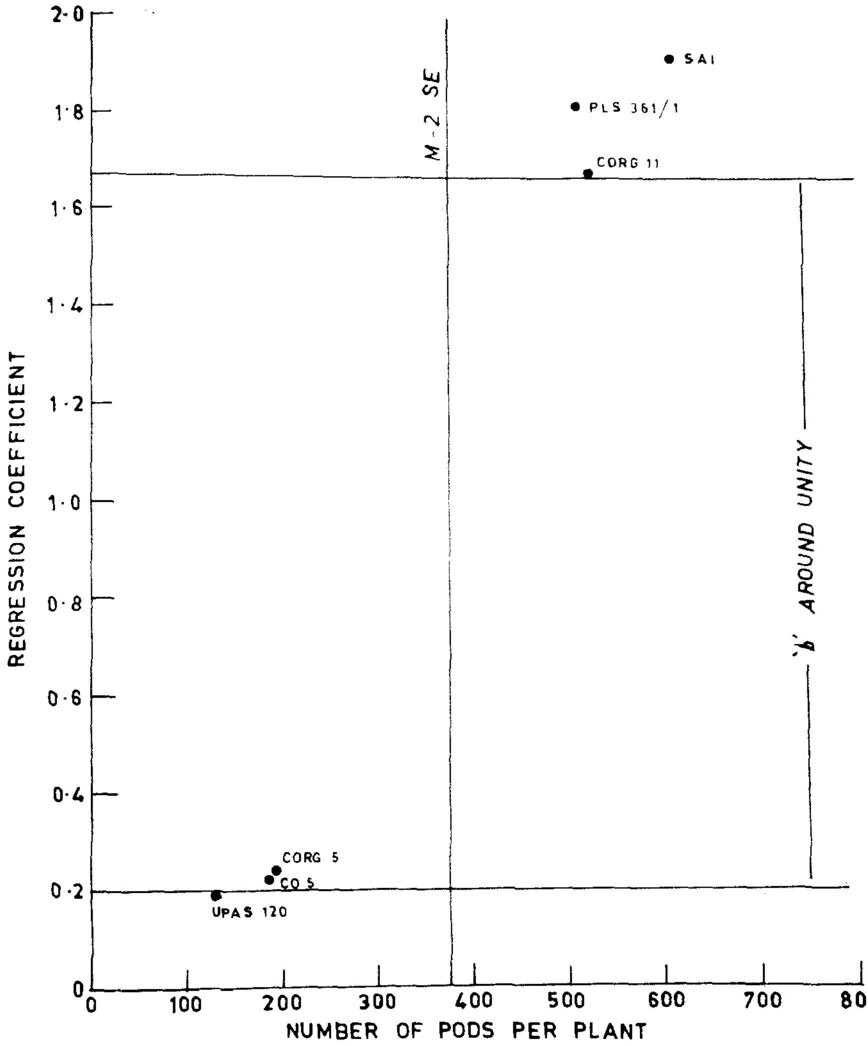


FIG. 9 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- NUMBER OF PODS PER PLANT



Number of seeds per pod

The mean number of seeds per pod over the seasons were 2.77, 3.23 and 2.94 for D_1, D_2 and D_3 respectively with the overall mean of 2.98. The cultivar PLS 361/1 recorded higher value more than the general mean plus 2 s.e. (Table 74; Fig.10). The 'b' values for all the cultivars were found to be around unity. The S^-d^2 values for all the cultivars were around zero except UPAS 120 and PLS 361/1.

1000-seed weight

The mean 1000-seed weight over seasons were 74.11, 78.82 and 74.92 for D_1, D_2 and D_3 sowings respectively. The overall mean was 75.91. The short duration cultivar CORG 5, and long duration cultivars CORG 11 and PLS 361/1 recorded higher value than the general mean plus 2 s.e. (Table 75; Fig.11). Here too, 'b' values were found to be around unity. The S^-d^2 values around zero for all the cultivar except CO 5 and CORG 11 which could deviate significantly from zero.

Harvest Index

The mean harvest index over seasons was 20.3, 27.7 and 26.5 for D_1, D_2 and D_3 sowings respectively with the overall mean of 24.8. The long duration cultivar recorded higher values than the general mean plus 2 s.e. (Table 76; Fig.12). Here also, 'b' values were around unity for all the varieties. The S^-d^2 values were found to be zero for CORG 5 and SA 1 only. The others were deviating significantly from zero.

Table 74. Stability analysis for No. of seed/pod

Variety	Seasons I	II	III	Mean	Regression coefficient (b)	Mean square deviation (S^-d^2)
CO 5	2.69	3.10	2.86	2.88	0.89	-0.016
CORG 5	2.71	2.93	2.91	2.85	0.44	-6.94
UPAS 120	2.31	3.16	3.00	2.82	1.73	0.072*
CORG 11	2.81	3.23	2.90	2.98	0.94	-0.013
PLS 361/1	3.00	3.56	2.85	3.14	1.35	0.070*
SA 1	3.12	3.40	3.16	3.23	0.64	-0.013
Mean	2.77	3.23	2.94	2.98	1.00	
SE	0.134	0.139	0.099	0.073	0.545	

Table 75. Stability analysis for 1000 grain weight (g)

Variety	Seasons I	II	III	Mean	Regression coefficient (b)	Mean square deviation (S^-d^2)
CO 5	78.28	78.20	74.60	77.03	0.28	7.36**
CORG 5	76.95	81.50	77.20	78.58	1.05	-0.31
UPAS 120	54.25	60.60	56.40	57.08	1.29	0.13
CORG 11	73.34	83.20	80.20	78.91	1.71	14.86**
PLS 361/1	80.33	86.30	81.30	82.64	1.30	-0.49
SA 1	81.48	82.40	79.80	81.23	0.35	1.48
Mean	74.11	78.72	74.92	75.91	1.00	
SE	0.529	0.639	0.898	0.407	0.598	

Table 76. Stability analysis for Harvest Index

Variety	Seasons				Regression coefficient (b)	Mean square deviation ($S^{-}d^2$)
	I	II	III	Mean		
CO 5	31.0	39.0	29.0	33.0	0.61	42.86**
CORG 5	31.9	35.0	32.9	33.3	0.33	0.23
UPAS 120	37.8	43.0	27.8	36.2	-0.069	117.92**
CORG 11	6.7	17.0	25.1	16.3	1.91	52.86**
PLS 361/1	7.0	15.0	22.10	14.7	1.53	38.75**
SA 1	7.14	17.0	22.20	15.4	1.69	24.78
Mean	20.3	27.7	26.5	24.8	1.00	
SE	0.923	1.535	0.797	0.654	1.221	

Table 77. Stability analysis for Grain yield

Variety	Seasons				Regression coefficient (b)	Mean square deviation ($S^{-}d^2$)
	I	II	III	Mean		
CO 5	41.2	28.9	13.4	27.8	0.29	52.29*
CORG 5	47.9	30.6	16.7	31.7	0.33	28.17*
UPAS 120	33.6	24.8	10.1	22.8	0.23	53.44*
CORG 11	160.6	49.6	35.9	82.0	1.49	73.06**
PLS 361/1	185.4	50.4	25.8	87.2	1.89*	28.41*
SA 1	186.7	59.1	37.2	94.3	1.77*	35.31*
Mean	109.2	40.57	23.15	57.63	1.00	
SE	4.02	0.265	1.15	1.39	0.110	

FIG.10 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS:- NUMBER OF SEEDS PER POD

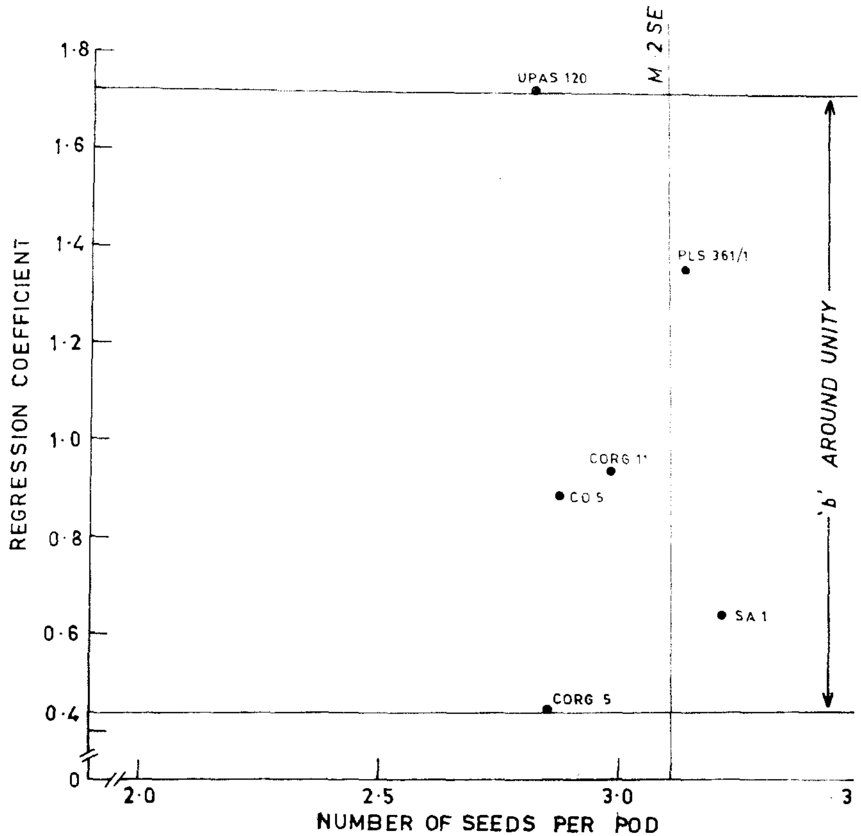


FIG. 11 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA - CULTIVARS :- 1000-GRAIN WEIGHT

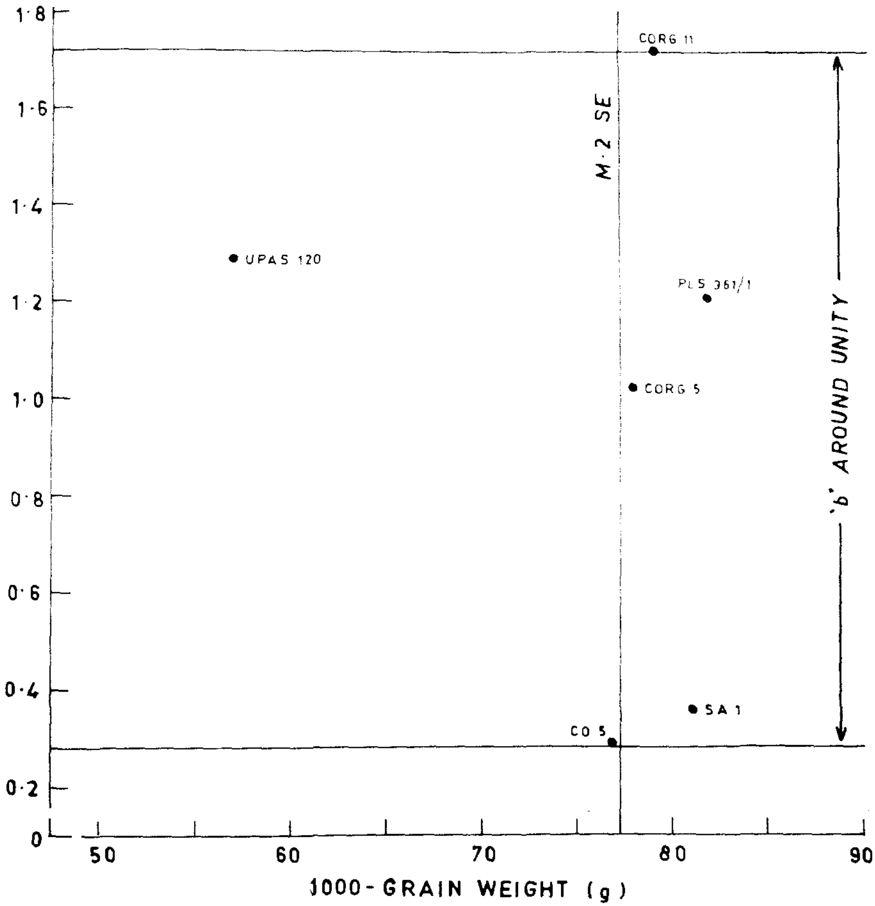


FIG.12 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS:- HARVEST INDEX

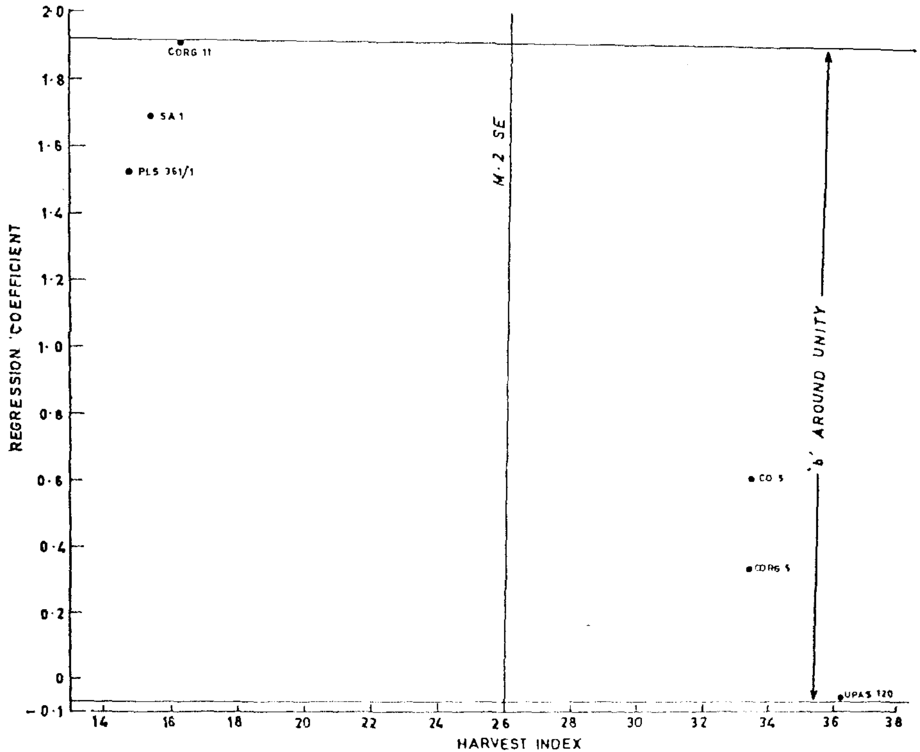
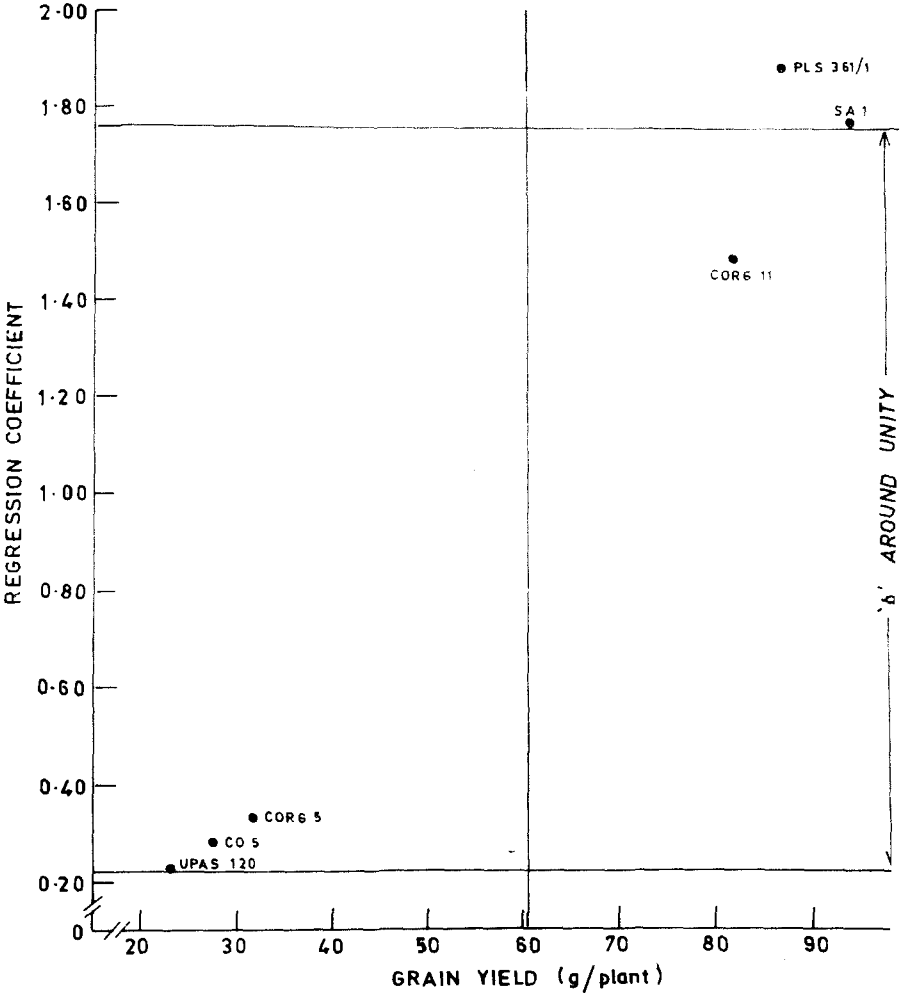


FIG. 13 DIFFERENTIAL RESPONSIVENESS OF PIGEONPEA CULTIVARS :- GRAIN YIELD



Grain yield

The mean grain yield over seasons was 109.2, 40.57 and 23.15 $g.plant^{-1}$ for D_1, D_2 and D_3 respectively with the overall mean value of 57.63. Here also, all the long duration cultivars recorded higher value than the grand mean plus 2 s.e. (Table 77; Fig.13). The 'b' values were found to be around unity except PLS 361/1 and SA 1. The $\bar{s}d^2$ values deviated significantly from zero for all the cultivar.

DISCUSSION

CHAPTER V

DISCUSSION

Pigeonpea is an important pulse crop grown mainly under rainfed conditions in Tamil Nadu as well as other parts of the country. It is one of the mandate crops for ICRISAT, Hyderabad. At present, the interest and the focus on this crop is mainly centre around its productivity. The current productivity trends are 675 $kg.ha^{-1}$ for all India while productivity in Tamil Nadu is 591 $kg.ha^{-1}$ only. The area covered by this crop is about 78,340 ha in Tamil Nadu. The all India production is 1,919,000 tonnes while area is 2,843,500 ha. The production in Tamil Nadu is about 46,290 tonnes which constitute 25 per cent of the total pulse production which is nearly 1.88 lakhs tonnes.

The crop is well known for yield variations when grown under different seasons and agroclimatic situations. It, being a quantitatively photosensitive, can be raised at different cropping seasons. But the yield will be varying depending upon the sowing dates. June sowing gives higher yield whereas September sowings yield less. This yield reduction can be partly made up by increasing the density of the plant population. In February sowings, the yield was known to be comparatively high. It is a fact that variations in the yield in this crop are mainly monitored by changes in the weather parameters. This appears to be the main cause for differences in productivity in different parts of the country. But no information is available about the components of the various weather parameters and their direct and the indirect impact of the phenotypic characters, which were the output expressions of the altered physiological mechanisms.

The need for studying the changed phenotypic characters and the altered physiological mechanisms is felt, because for any crop improvement programme, the production constraints have to be identified before we take up necessary measures to modify them for improved productivity. In addition, the stability of these characters in relation to weather parameters which influence them had not been studied so far. In the current study, an attempt is made to understand this interrelationship, so that, further knowledge can be gained on the physiological constraints relating to yield variations in different seasons. It was considered that this knowledge could be successfully utilised for planning the future strategy to organise our research efforts to unravel the physiological and genetical basis of variations so that improvement in the performance of this crop can be expedited.

Phenological development

The number of days to 50 per cent flowering and harvest were progressively reduced from D_1 to D_3 irrespective of the duration of the cultivars. A predominant inference drawn from this trend was that the grain filling phase remained unaltered by the changes in the weather parameter in both types of cultivars. The reduction in the duration of the crop was mainly due to the reduction in the vegetative phase. Similar observation on the reduction of vegetative phase in pigeonpea was also reported by many authors (Abrams, 1975; Gowda and Kaul, 1982; Wallis et al., 1975; 1980). Such changes in vegetative phase was mainly attributed to shorter photoperiods and temperature effects. The grain filling phase remaining uninfluenced had not been identified by the above authors. Cooler temperature and increased day length prevailing during D_2 and D_3 sowings caused reduction in vegetative phase and thus reduced the crop duration. This is in good agreement with the findings of Wallis et al. (1984) who reported that shorter day length and cooler climate accelerated earlier flowering in pigeonpea.

With regard to the influence of day length on the flowering behaviour, a high, positive and significant correlation ($r = 0.9969^{**}$) was obtained between cumulative day length and days to 50 per cent flowering. Earlier flowering was favoured by lower cumulative day length. This kind of earlier flowering was achieved mainly by cutting down the vegetative growth in D_2 and D_3 sowings. These results are in confirmity with the findings of Hammerton (1976).

Growth and Dry Matter Accumulation

Root growth

Among the three sowings, the root length and root weight appeared to be high during the D_1 sowings. When we compared the long and short duration cultivars, it appeared that short duration cultivars were exhibiting lower length and weight as compared to long duration cultivars. The difference in the accumulation of dry matter appeared to be high between these two types. The short duration cultivars had accumulated nearly 0.874 g. of dry weight per unit length of root (cm), while long duration cultivars mustered 4.92 g. of dry weight per unit length of root. Among the three sowings, D_1 could show 7.54 g per unit length of root while D_2 and D_3 recorded 2.06 and 0.932 g per unit root length respectively. These facts very clearly pointed out that long duration cultivars and the D_1 sowings were able to accumulate more dry matter which indicated a sustained root growth by the cultivars and the sowings. This could be one among the many reason for higher productivity in the long duration cultivars and also in the D_1 sowings, being the high productivity seasons. The higher and longer activity of roots in these two situations may be related to cytokinin activity which mainly decides the sink strength (Michael and Beringer, 1980).

Leaf area development

Comparing the short and long duration types, the leaf area development was phenomenaly high in the long duration cultivars. Nearly 10 fold increase was exhibited by the later types. Similarly between D_1 and D_3, there was 9 fold increase in D_1 over D_3 sowings. The differences were found to be significant at all levels. Experiment conducted at ICRISAT Hyderabad also revealed that late planting beyond June-July significantly reduced the vegetative growth particularly the leaf area development (Anon., 1978). Study of the components of leaf area indicated that the leaf number between these two types was also widely differing. Nearly 6 fold decrease was noticed in the short duration cultivars. Among the sowing dates, the D_1 was leading by 6 fold increase as compared to D_3. Between the two types of cultivars the ILA was larger in long duration cultivars. But the difference was not convincingly wide. Between the sowing dates, there was a difference of 6.3 cm^2 in ILA between D_1 and D_3.

Between D_1 and D_3 sowings, leaf area reduction was only 66 per cent while leaf number reduction was in the order of 525 per cent. Hence the major determinant of leaf area between D_1 and D_3 sowings appeared to be the leaf number. The role of ILA was only secondary. Between two types of cultivars, hereagain, leaf number contributed towards variation in leaf area which was 514 per cent while size contribution was only 18 per cent. It was the leaf number (at the cultivar level) that decided the leaf area per plant. This is in close conformity with the findings of Singh <u>et al</u>. (1977), who also reported that the leaf number was the main determinant of leaf area per plant rather than the individual leaf size. This had been further confirmed by correlation studies at 50 per cent flowering which had shown a high positive and significant relationship of leaf area to the leaf number (r = 0.9878**) rather than to the ILA (r = 0.7918**). The rate of leaf production also followed the similar trend noticed in the leaf number. The leaf weight also followed the trend noticed in the leaf area development. The weight also appeared to be monitored by the leaf number rather than the ILA.

Plant height

The height of the plant was significantly influenced by the sowing dates and it was more in the D_1 sowings as compared to D_3. Similar finding was reported by Roysharma et al. (1980) who recorded 2.85 m of plant height in June sown crop as compared to 1.07 m in September sown crop. In the present study, the short duration cultivars appeared to be shorter as compared to long duration cultivars.

Number of branches and stem weight

Looking to the data relating to the number of branches and stem weight, it could be safely concluded that short duration cultivars were having nearly 50 per cent less of branches as compared to long duration types. The long duration cultivars had 24 folds of stem weight as compared to short duration cultivars. Between sowings, the number of branches showed 2 fold increase in the D_1 in comparison to D_3 whereas the weight of stem showed 35 fold increase in D_1 as against D_3. The differences were found to be significant at all levels. Hammerton (1976) also observed more number of branches per plant in April sowing as compared to September sown crop.

The L/S ratio had indicated that the short duration cultivars were more efficient in the leaf weight increase per unit of stem weight as compared to long duration cultivars. Similarly, the D_3 sowings appeared to be more congenial for efficient leaf production.

Weight of reproductive parts

As expected, the weight of the productive parts was high in the long duration cultivars. Nearly 2 fold increase might be observed in long duration cultivars as compared to short duration cultivars, whereas between D_1 and D_3 sowings, the decrease was more than 3 fold in D_3 which again indirectly influenced the reproductive structures favourably both in D_1 and also in long duration cultivars for higher yield.

Dry matter accumulation

The total dry matter accumulation was significantly affected by date of sowing and it was the major yield determinant along with harvest index, which appeared to be favourably disposed towards the long duration cultivars. This trend was noticeable in the D_1 sowings also. Comparing long and short duration cultivars, the total dry matter accumulation increased nearly 11 fold in the former. Between D_1 and D_3, the increase was nearly 13 fold towards D_1. This is in close conformity with the findings of Chauhan et al. (1982) who recorded higher DMA in April-May plantings than that of November-December plantings. The dry weight of the later plantings were only a tenth of the former. In the present study, the higher yield in the long duration cultivars and in D_1 sowings were mainly monitored by the total dry matter accumulation in this crop.

Growth Analysis

Leaf Area Index

The trend in the LAI indicated that in general, the short duration cultivars were able to maintain lower LAI (0.699) compared to the long duration group which had higher LAI (4.606). The LAI was significantly influenced by sowing dates. Between D_1 and D_3 sowings, latter sowings had shown lower LAI as compared to D_1. Here again, the difference was very wide (0.950 in D_3 as against 8.98 in D_1). Similar findings were reported by Chauhan et al. (1982). They observed that strikingly greater LAI in the April and May sowings than that of

November and December sowings. The time trend in leaf area development (LAI) in this present study had shown that it increased upto 50 per cent flowering and thereafter declined. These observations are in conformity with the findings of Tayo (1983). The fact that higher LAI achieved by the long duration cultivars and in D_1 sowings were able to justify higher productivity in these two situations mainly because the LAI which represented the total photosynthetic surface available for crop productivity. This again determined the total DMA per plant or per unit land area.

Net Assimilation Rate

The trends in NAR could indicate higher values in the short duration cultivars so also in the D_3 sowings. Sheldrake and Narayanan (1979) also obtained a similar findings in pigeonpea that indeterminate cv. T 21 had lower NAR value than the medium duration cultivar cv. ICP 1. It is pertinent to remember in these two situations, whenever, the NAR was low (both in long duration cultivars and also in D_1 sowings), high DMA had occured primarily due to higher LAI noticed both in long duration as well as in D_1 sowings. The higher LAI could have amply compensated the lower NAR thereby leading to higher DMA per unit land area.

Crop Growth Rate

CGR was high in the long duration cultivars and also in D_1 sowings. Experiment conducted at ICRISAT confirmed the above findings. It was observed that June sowings recorded higher CGR than that of December sown crops. The June sowings coincided with high temperature and solar radiation which favoured higher CGR in June sown crops than that of December sown crops (Anon., 1982). These findings indicated that DMA per unit land was mainly monitored by leaf area rather than by NAR. The AGR and RGR also followed the trend similar to that of CGR.

Leaf Area Duration

The LAD was observed to be very high in long duration cultivars (226.05) as compared to short duration types (17.25). Similarly among the sowings D_1 had registered very high LAD (565.84) in comparison to D_3 (31.94). This again goes to prove the fact that long duration cultivars and the D_1 sowings were able to show higher productivity mainly because of higher LAI observed in these two situations. This is in good agreement with the findings of Hegde and Saraf (1982).

Specific leaf weight and Specific leaf Area

The SLW was found to increase continuously during the ontogeny of the plant which was not normally observed in pulse crops. The normal trend of SLW could be an increasing trend up to 50 per cent flowering and thereafter it declined. The trend observed in this parameter also followed. the similar trend in leaf weight. This could only point out that, even when the sink demand was very high, the investment of DM in the leaf was neither reduced nor depleted. The trend of SLA was opposite of SLW since this parameter was the reciprocal of SLW.

Leaf Area Ratio and Leaf Weight Ratio

These ratios generally went down as the age of the plant advanced. The LAR trend indicated that, the leaf area decreased per unit dry weight of plant in all the three sowings. Findings of similar trend were reported by Taye (1982) who observed that decreased LAR towards maturity. The long duration cultivars recorded lower values than those short duration cultivars. The LWR behaved irregularly as regards time trend and also in different sowings. This kind of trend could be surmised since even after flowering continuous production of new leaves was taking place simultaneously with the continued leaf drop throughout the life span.

Fallen leaves

The magnitude of the fallen leaves appeared to follow the major trends noticed in growth analysis. The long duration cultivars and D_1 sowings favoured greater shedding of leaves than that of short duration cultivars and D_3 sowings. A major findings that could be discerned was that the greater weight of leaves was lost at the time of first flowering in all the three sowings. The higher fallen leaf weight observed in D_1 is in conformity with the findings of Roysharma *et al.* (1980) who reported that the quantity of leaf fall was appreciably higher in the June sown crop (6370 $kg.ha^{-1}$) than in the September sown crops (2350 $kg.ha^{-1}$).

Physiological analysis

Chlorophyll content

Between short and long duration cultivars, higher content of total chlorophyll, a, b and total were noticed in the latter type as compared to the former. The time trend had shown that both the a and b and also the total chlorophyll contents were progressively increased upto 50 per cent flowering and decreased thereafter. It was significantly influenced by the sowing dates.

Stomatal Resistance (CO_2) and Photosynthetic Rate

The mean resistance for CO_2 between the two types of cultivars was found to be lower in the case of long duration cultivars as compared to short duration cultivars. The D_1 sowing significantly showed the least resistance among the three different dates of sowing. As regard the time trend, the resistance was on the increasing trend as the crop progressed in its growth. The photosynthetic rate per unit leaf area was high in the short duration cultivars as compared to long duration cultivars. Cultivar differences in the rate of photosynthesis of pigeonpea leaves had also been reported by Pandey et al. (1976). Even though the stomatal resistance for CO_2 was lower in the long duration cultivars, the reason for low photosynthetic rate in these types might be due to higher mesophyll resistance. This is in close conformity with the findings of Natarajaratnam (1985) who also reported that high mesophyll resistance was associated with low photosynthetic rate. One peculiar time trend noticed in all the three sowings was that stomatal resistance for CO_2 increased up to 50 per cent flowering with a simultaneous increase with the photosynthetic rate. This phenomenon could be explained on the basis relative of mesophylls resistance function only. But in the harvest stage, it is not only stomatal resistance which increases, but peculiarly, the photosynthetic rate had come down. Possibly mesophyll resistence suddenly increased resulting in lower photosynthetic rate may be due to normal senescence of leaf cells. The exact reason for such a phenomenon is worth investigating.

Stomatal Resistance (H_2O)

The stomatal resistance for water vapour was significant at all levels. The mean value indicated that the long duration cultivars were possessing lower resistance than that of short duration cultivars. The resistance was found to increase linearly over different stages of crop growth.

Transpiration rate and leaf temperature

The parameters, both transpiration rate and leaf temperature were significantly influenced by the dates of sowings. The difference of stomatal resistance (H_2O) between two type of cultivars on the trend over different growth stages had its reflection on the trend of transpiration rate also. The long duration cultivars favoured higher transpiration rate while the developmental stages indicated lowering of the transpiration rates. The trend between the two types of cultivars was that the higher transpiration rate was accompanied by the lower leaf temperature. This effect was possibly due to the higher evaporative cooling due to higher transpiration rate in the long duration cultivars. Similar opinions were also expressed by Jackson (1981). He expressed that higher transpiration rates were associated with lower leaf temperature. The trend of transpiration rate and leaf temperature over stages was slightly different. The transpiration rate increased upto 50 per cent flowering and declined thereafter. As regards leaf temperature, there was a steady decline upto 50 per cent flowering and a considerable increase was noticed in the harvest stage.

Leaf Relative Humidity

The relationship of leaf relative humidity and transpiration rate between the two types of cultivars had shown that the higher transpiration rate was associated with higher leaf relative humidity. This trend could be readily understood in the light of relative humidity nearer the leaf boundry layer had to be higher in cases wherever the transpiration was higher.

Leaf water potential

The leaf water potential was significantly monitored by the season. The leaf water potential appeared to be less negative (more water content) in the long duration cultivars as compared to short duration cultivars. This could be related to higher transpiration rate recorded in long duration cultivars. In this context, Ramesh Babu et al. (1982) also reported that transpiration rate was closely related to leaf water potential. They also observed the reduced transpiration rate when leaf water potential changed from -13.0 to -18.0 bars, showing thereby that they were more tolerant to water deficit. This might preferably be due to the deeper root system which had already been mentioned. This is in close conformity with the findings of Passioura (1981) who reported that the deeper root system was correlated to the maintenance of low water potential (higher water content). The leaf water potential appeared to decrease progressively from (low water content) D_1 to D_3 (high water content).

Canopy growth and Light interception

The light interception studied at first flowering had shown that the long duration cultivars had higher ground area cover as compared to the short duration cultivars. Similar observations in pigeonpea was also recorded by Hughes *et al.* (1980). The mean of three sowing dates also indicated a similar trend. The D_1 sowing could generate higher leaf area development and higher ground area (95 per cent) as compared to D_3 which showed the least ground coverage (81 per cent). These trends indicated better utilisation of solar light for the crop growth by the long duration cultivars and also in D_1 sowings. The above trend has also been noticed in light extinction coefficient (k). Hughes *et al.* (1981) was also of the same opinion that high light interception was associated with low light extinction coefficient and thus high biomass production.

Path analysis of Yield components

The number of pods per plant was the main yield component which contributed maximum to the yield and pod setting per cent to a lesser extent whereas the 1000-seed weight and number of seeds per pod had only weak positive effect on yield. This is in close conformity with the findings of Rawden *et al.* (1981). Similar findings were reported by many authors (Yadavendra *et al.* 1981; Suresh Kumar, 1983). The high association between grain yield and number of pods per plant was mainly through the maximum direct effect. The indirect effect through other components was negligible. With regard to pod setting, the direct effect was negligible while the indirect effect was through the other components such as, DMP, harvest index and 1000 grain weight.

The negative effect of grain yield with harvest index was mainly through the strong significant negative effect of number of pods per plant. The weak positive association of 1000 grain weight with yield was mainly due to its negative direct effect inspite of all other character which had positive effect. Singh *et al.* (1981) reported that the grain yield had negative association with 1000-grain weight.

Nutrient uptake

Generally, the uptake of all the nutrients such as N, P, K, Ca and Mg were significantly influenced by the sowing dates. In the case of nitrogen uptake, stem accumulated more nitrogen in D_1 and it was influenced by high dry matter accumulation. However, the uptake was decreased progressively from D_1 to D_3. Pooled analysis revealed that the overall N uptake was more in the grain and followed by stem. Similar trend was noticed in the phosphorus uptake too, but the overall P uptake was more in the stem than the grain. Potassium, calcium and magnesium closely followed the phosphorus trend. All these nutrients recorded higher uptake in the long duration cultivars than in the short duration types. The deeper root system, more canopy growth and longer cropping period might have resulted in more nutrient uptake in these cultivars. Similar trends were reported by Singh et al. (1983) who also observed that long duration pigeonpea cultivars removed higher amounts of nutrients from the soil than those of short duration types.

As regards the total uptake of nutrients among crop components, Nitrogen was found to be the major nutrient followed by potassium, calcium, magnesium and phosphorus respectively in the decreasing order of quantity removed.

Protein analysis

The protein content and its turnover were influenced significantly by the sowings. The higher protein content in D_2 coincided with the normal growing season of the crop. The low content in D_1 might be attributed to the higher biomass and yield resulting in the dilution effect. However, Singh et al. (1971) found that protein content of the seed was not at all affected by dates of sowing. The protein turnover both at per plant and at population level decreased progressively from D_1 to D_3. This decrease could be attributed to the reduced grain yield rather than protein content. The second sowing (D_2) recorded the highest NHI among the three sowings. This was achieved by the more efficient nitrogen partition to the sink. This might also be the reason for the higher protein content in D_2 than the other sowings. Similar to the ordinary calculated harvest index, the NHI was more in short duration cultivars. Studies on nitrogen harvest index conducted in wheat by Austin et al. (1980) indicated the trends observed above.

Stability analysis

Genotype x Environment interaction had been widely observed to play an important role in the expression of phenotypes. A phenotype is the result of an interplay of a genotype and its environment. The ability of the individual to show plastic response to varying environments is of special interest in legumes, since no other crop is expected to yield under a diversity of climatic, edaphic and management conditions. This is true in the case of pigeonpea, when yields are subjected to marked contrasts in varying climatic conditions. Importance of studying the Genotype x Environment interaction in terms of physiological traits for crop improvement in pigeonpea had been stressed by Lawn (1980).

In the present study, phenotypic stability performances was measured for 12 parameters in six pigeonpea cultivars comprising of both short duration and long duration cultivars over three different sowings using the model developed by Eberhart and Russell (1966). Similar studies in pigeonpea was conducted by earlier workers (Ramanujam, 1975; Jag Shoran et al., 1981).

A perusal of variance for phenotypic stability in pooled analysis indicated that the season (linear) was significant for all the characters except leaf/stem ratio. Variety x season (linear) was significant for all the characters except number of seeds per pod, individual leaf area and photosynthetic rate. The arithmetic transformation of the mean squares into the percentage of linear and non linear components showed that the presence of high degree of linear component than that of non-linear component for all the yield and dry matter components except HI. Thousand grain weight and number of seeds per pod where these three parameter showed higher non-linear component than the linear component. The linear component was maximum for the LAI, total dry matter, stem weight, L/S ratio, No. of pod per plant followed by No. of branches per plant, photosynthesis and individual leaf area. These findings are in good agreement with the findings of Ramanujam (1975) who reported that the percentage of linear component was higher in number of pods per plant and grain yield than the non linear components.

Eberhart and Russell (1966) defined a stable genotype as one which showed a high mean yield, regression coefficient (b) around unity and deviation from regression near to zero. According to Langer et al. (1979), the regression co-efficient is a measure of response to varying environments. The mean square for deviation from linear regression is a true measure of production stability. Out of six pigeonpea cultivars, only those which showed high mean (overall mean + two SE) were considered for classification and they were classified in to four groups according to the methodology followed by Mehra and Ramanujam (1974) and Singh and Singh (1980).

Group	Mean	'b'	$S^{-}d^{2}$
I	High mean	Around unity (NS)	Around zero (NS)
II	High mean	Significantly deviating from Unity (S)	Around zero (NS)
III	High mean	Significantly deviating from Unity (S)	Significantly deviating from zero (S)
IV	High mean	Around unity (NS)	Significantly deviating from zero (S)

NS = Non significant
S = Significant.

The cultivars falling in group I will have average response and high stability over the seasons. The cultivars in group II will hover around average response (below or above) that will be suitable for stress or favourable environment. Behaviour of the cultivars in group III and IV cannot be predicted. All the three parameters of stability namely, high mean performance, 'b' and $S^{-}d^{2}$ were considered together for the twelve characters studied and were presented in Table 66 to 77, and Figures 2 to 13. From stability analysis, it had been marked out that grain yield in the cultivars tested was the highly unstable trait (Table 78). As stated already, none of the cultivars could show any remarkable stability for this most important trait namely, the grain yield. This instability was also reflected in the HI and

Table 78. Classification of the varieties based on the stability parameters

Parameter	Group I	Group II	Group III	Group IV
1. Photosynthesis	CORG 5	-	-	-
2. LAI	CORG 11	PLS 361/1 SA 1	-	-
3. Stem weight	-	CORG 11 PLS 361/1 SA 1	-	-
4. L/S ratio	UPAS 120	-	-	CO 5 CORG 5
5. Individual leaf area	SA 1	PLS 361/1	-	CORG 11
6. Total dry matter accumulation (TDMA)	-	-	-	CORG 11 PLS 361/1 SA 1
7. Number of branches	SA 1	PLS 361/1	-	CORG 11
8. Number of pods per plant	-	CORG 11 PLS 361/1 SA 1	-	-
9. Number of seeds per pod	SA 1	-	-	PLS 361/1
10. 1000-grain weight	CORG 5 PLS 361/1 SA 1	-	-	CORG 11
11. Harvest index	CORG 5	-	-	CORG 11 UPAS 120
12. Grain yield	-	-	CORG 11 PLS 361/1 SA 1	-

DMA also. These two attributes did not show any stability in any cultivars with one exception i.e., CORG 5 was found to be stable for HI.

GRAIN PRODUCTIVITY-RECAPITULATION AND INTEGRATION OF PHYSIOLOGICAL RESPONSES AND PHENOTYPIC EXPRESSIVITY

In any crop, yield is the final integrated expression of many physiological processes that are involved in the growth and development of the crop. Any manipulation, whether it be genetical, physiological or agronomical, will be useful only if it can lead to higher economic yield. The processes leading to higher economic yield and their patterns in different seasons are the major underlying causes which decide the expression of yield. The variations in yield in different seasons are thus the outcome of the differences in these underlying processes and their patterns.

Pigeonpea shows remarkable variations in yield when grown under different seasons. The experimental results described previously had shown large fluctuations between February, June and September sowings. The grain yield reduction in both group of cultivars in D_2 as compared to D_1 was 60 per cent and when D_3 was again compared to D_1, the reduction was 77 per cent. A reduction of 44 per cent was observed between D_3 and D_2.

In the forthcoming pages, an attempt is being made to understand and discriminate the various physiological parameters and growth attributes which were responsible for yield variations in different sowings. The responses to weather variations and the components of the weather parameters as related to differential responses of physiological attributes/growth characteristics are highlighted in this study. Investigations on the Genotype x Environment interaction which influenced the expression of physiological and morphological attributes pertaining to the various cultivars were also undertaken. The main thrust was to find out either a cultivar known for stability in its yield or those physiological/morphological attributes which were stable over seasons and which could ensure higher stability or performance over various sowings.

The recapitulation and integration of the result is particularly aimed to draw our attention to the various responses of the cultivars as evidenced by the collected data. It is also attempted in the following pages to integrate the various trends so as to justify the objectives defined and also to assess the extent of fulfilment in terms of holistic approach.

Grain productivity

The pooled yield data of both long and short duration cultivars had shown that the productivity decreased progressively from D_1 to D_3. As regards short duration cultivars, the trend was that between D_1 and D_2 the yield went down by 31 per cent, while between D_2 and D_3 the reduction was 52 per cent. The fluctuation between D_1 and D_3 was 67 per cent. The productivity trends in long duration cultivars was also of similar trend- the reduction being 69 per cent between D_1 and D_2, 39 per cent between D_2 and D_3 and 81 per cent between D_1 and D_3. Comparison of yield reduction percentage between the two types had shown that excepting between D_2 and D_3, in other sowings the differences were wider in long duration cultivars. The possible inference could be that substantial reduction did occur in both the types in different sowings. The reason for such variability in yield reduction could be ascribed to various parameters of seasonality. Ganguli and Srivastava (1969) also reported that environmental factors had the greatest influence on seed yield per plant. In this context, Singh et al. (1977) also observed the highest seed yield in crops sown on May 20 while decreased yield was observed in the successive late sowings.

Seasonality and DMA

Sowing dates had significantly influenced the DMA in both types of cultivars. The highest DMA was recorded in D_1 while a decreasing trend was visible in other two sowings. The maximum temperature was higher during the D_1 sowings in comparison to others. During this period, mean photosynthetic rate in all the cultivars was also indicative of higher rates per unit leaf area (Table 39). The LAI (mean of cultivars) also followed a similar trend. The nyctotemperature was the lowest in D_3 and higher nyctotemperature in D_1 could be responsible for higher dark respiration, this did not affect the DMA per unit land area during D_1. This was probably due to higher rate of DMA which compensated the enhanced respiratory usage of DM. The mean day temperature observed during D_1 sowings was 32.94°C. This is found to be nearer the cardinal temperature for maximum growth and photosynthesis of C_3 herbaceous plants (Black, 1973).

Lower nyctotemperatures in D_2 and D_3 sowings were found to be linked with higher HI in these two sowings even though yield and DMA were comparatively lower in these two. Probably partitioning percentage to the sink was more effective in these two sowings. These observations are in good agreement with the inference drawn by Akinola and Whiteman (1974) who were of the opinion that cooler temperature could lead to higher HI. Sheldrake and Narayanan (1977) also obtained higher HI in rabi season as compared to kharif, when the temperature was comparatively higher.

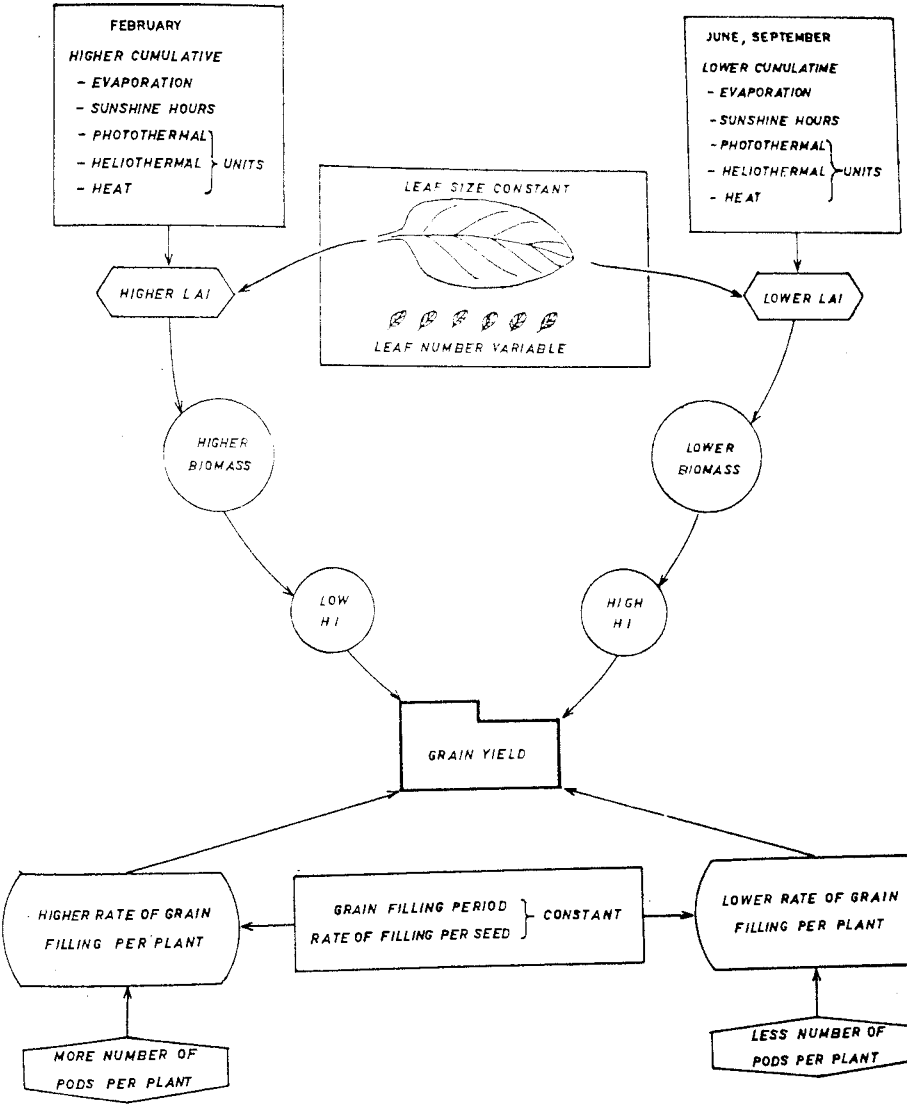
In addition, DMA was highly and positively correlated with cumulative heat units in all the stages of crop growth (Table 55). These findings confirm the observations of Dhingra et al. (1980) who obtained positive and significant correlation between accumulated temperature units and DMA. The cumulative heat units and photothermal units were found to be highest in D_1 sowings and all the weather parameters viz., cumulative evaporation, sunshine hours and solar radiation were positively correlated with DMA.

Seasonality and Sink Characteristics

A distinct outcome from this study of various attributes that were influenced by seasonality was the constancy of grain filling period in all the three sowings irrespective of the cultivars (Fig.14). The weather did not have any impact over this very important trait of the cultivar. The longer grain filling period (GFP) had been recognised as the most important determinant of the high yielding potential of many crops plants (Asana, 1975; Dewit, 1977; Evans, 1982). The fact that this attributes has not been altered by seasonality is a significant understanding for yield manipulations. Hence the reduction in productivity in D_2 and D_3 might be due to the other components relating to the sink strength namely sink size and activity. Sink strength consists of two major components viz., sink size and sink activity (Wareing and Patrick, 1975). The sink activity could be further subdivided into yet another two components and they are the grain filling period (GFP) and the rate of filling (RF) (Pearson and Hall, 1984).

Further analysis of data accumulated in this study pointed out that the sink size in terms of seeds per plant had gone down drastically from D_1 to D_3. The calculated RF was arrived as follows: The DM accumulated by the number of seeds per plant and also per seed was divided by the GFP. The data are given below.

FIG.14 SCHEMATIC REPRESENTATION INFLUENCE OF SOWING DATES ON GRAIN YIELD



Components of sink strength

Date of sowing	Sink size		Sink activity		
	Grain yield per plant	No.of grains per plant	Grain filling period (Days)	Rate of filling (day^{-1})	
				(mg per plant)	(mg per seed)
D_1	102.12	1458.9	43.20	2500	1.71
D_2	40.57	515.4	43.15	940	1.82
D_3	23.15	309.0	42.15	550	1.77

The rate of grain filling calculated on the basis of per plant decreased from D_1 to D_3. When calculations were made on the single seed basis, there was not much difference between D_1 and D_3 and a slightly higher rate was recorded in D_2. This could be related to the significantly higher 1000 grain weight in D_2 as compared to D_1 and D_3. These trends indicated that it was the sink size which determined the yield in different seasons and the size was largely altered by the weather parameters. But RF was not altered by the environment when this was calculated on single seed basis. Of course, when the same parameter was viewed on the basis of a single plant, there was a lot of variation. This was mainly due to higher number of pods per plant in D_1. From this study, it could safely be concluded that the GFP and RF were not altered by the environmental factors. Pearson and Hall (1984) were of the opinion that environmental effects on grain filling could be quite important although it could not be possible to resolve these effects into GFP and RF components from the data published till then.

Analysis of the seasonality components revealed that all the pigeonpea cultivars reduced their vegetative growth period markedly and came to flowering earlier in D_3 sowings. It had been already mentioned that GFP (Period from 50 per cent flowering to harvest) was not changed either in the cultivars or under different seasons. This reduced vegetative growth was probably monitored by its sensitivity to photoperiod and day length since pigeonpea crop happened to be quantitatively a short day plant. But peculiarly number of grains per plant which was indicative of large number of flowers retained, had shown that D_1 and D_2 sowings were better for the intiation and maintenance of larger sink size. This was indirectly achieved through the high LAI and DMA prior to the flowering. These two growth characteristics were largely guided by higher temperature and other favourable environmental conditions. So, it could be concluded that the temperature modulations rather than the shorter day conditions were more responsible for the yield.

Summarising the effect of seasonality on sink characteristics of pigeonpea, it can be concluded that whenever yield variation had been observed under different seasons was attributable mainly due to the reduction in the sink size. In other words, the reduction in the number of seeds per plant was found to be responsible for this phenomenon. The other two sub components contributing for sink strength, namely, GFP and RF were not greatly altered by the environmental changes in different sowings. This indicated that further crop improvement aimed at stabilising yield under different seasons, should be concentrated towards the stabilising the sink size, namely, the number of seeds per plant. This is in good agreement with the inferences drawn by Abrams and Julia (1973) who were of the opinion that seed number per plant was the most important yield determinant in pigeonpea.

Source size

The main contributing factor which reduced the sink size was the variation in the LAI which was very striking in D_2 and D_3. The trend had shown that nearly 80 per cent reduction in LAI had occurred in D_2 as compared to D_1; 50 per cent from D_2 to D_3; 90 per cent from D_1 to D_3. In otherwords, the source strength was the factor that was mainly influencing the sink size (Rahman *et al.*, 1977; Geiger, 1979; Fischer and Stockman, 1980; Yoshida, 1981). The reduced source size (LAI) was responsible for the reduced sink size observed in D_2 and D_3 sowings. When source size was split up into its components, namely, number of leaves and ILA, the following trends were observed. The leaf number was reduced by 75 per cent in D_2 as compared to D_1, 39 per cent in D_3 as compared to D_2. A reduction of 85 per cent was observed in D_3 as compared to D_1

once again. As regards ILA, the reduction was not so much as compared to leaf number. The reductions were 11.5, 22 and 33 per cent as observed between D_1 to D_2, D_2 to D_3 and D_1 to D_3 respectively. From the above trend, it could be inferred that source number (leaf number) rather than the ILA was the determinant of the source size.

Source activity

As regards source activity, the photosynthetic rate per unit leaf area was reduced from D_1 to D_3. A reduction of 3 per cent from D_1 to D_2, 11 per cent from D_2 to D_3 and 14 per cent D_1 to D_3 was noticed. Even though the reduction was progressive, the percentage reduction was comparatively low when viewed simultaneously along with leaf number reduction. Hence it is presumed that any increase in the leaf number (source number) will naturally lead to higher source size which in turn will help to generate higher sink size. This increase must be stable over seasons. The existence of close correlation between grain yield and LAI was recognised in pigeonpea by Singh et al. (1977); Saxena and Sharma (1981) and Sharma and Saxena (1983). They were of the opinion that larger number of smaller leaves or optimum of larger leaves would be necessary to influence sink strength positively.

Observations on the HI, indicated that the partitioning efficiency was not a limiting factor for yield in D_2 and D_3 sowings. The high partitioning efficiency noticed in

D_2 and D_3 did not ensure higher yield because of insufficient source size during these periods. Since sufficient source size was not ensured, the yield could not be maintained in different seasons. The higher yield in D_1 was attributable to the higher source size, which in turn was reflected in the higher canopy development and ground coverage. The ground coverage varied with sowing dates; it was 95 per cent in D_1 92 per cent in D_2 and 81 per cent in D_3. This trend was also reflected in the light extinction coefficient values (k), which increased progressively from D_1 (0.71) to D_2 (2.61) and also from D_2 to D_3 (2.85). The k value trends clearly indicated that the D_1 sowings used the solar energy more efficiently from the DMA than the other sowings. A similar relationship between productivity and radiation interception had been noticed in a number of studies involving grain legumes. In Phaseolus vulgaris, dry matter production increased with increasing irradiance (Magalhaes and Montojos, 1971) which was reflected on the grain yield which showed increase with increasing proportion of intercepted radiation (Enyi, 1975). In soybean crop, there was a linear relationship between maximum dry matter production and amount of radiation intercepted (Shibles and Weber, 1966). In the case of pigeonpea, a non linear relationship was obtained between the dry matter yield and the proportion of radiation intercepted (Hughes et al., 1981). In the present study, eventhough the HI was low in D_1, the yield increase was due to the higher source size represented by higher LAI besides greater DMA. The importance of DMA in improving the grain yield in pigeonpea cannot be minimised and its major role in determining the yield was recognised by Ekahringe (1983).

Patterns in path and stability analyses

The path analysis indicated that the number of pods per plant was the major direct contributing factor to the productivity of pigeonpea. The other parameters also contributed to the yield but indirectly. The partial regression analysis (Table 34) indicated the importance of number of pods per plant to higher yield. The seeds per pod showed negative and weak relationship whereas the HI showed weak positive association with the yield.

A comparison of stability of various parameters as expressed in the cultivars had shown that the grain yield in pigeonpea cultivars was comparatively unstable. This was further confirmed by the analysis of linear and non linear components. It was observed that nearly 98 per cent contribution was by linear component (Environment) and 2 per cent was through non linear component (Genotype). This is in good agreement with the findings of Ramanujam (1975), who also studied the non linear and linear components of genotype x environment interaction in pigeonpea and found 73.61 per cent and 26.39 per cent contribution linear and non linear components respectively. In the present study, the other eleven parameter namely photosynthetic rate per unit leaf area, LAI, ILA, stem dry weight, L/S ratio DMA, number of branches, number of pods per plant, 1000 grain weight and HI seemed to be stable in one or the other cultivars. Having observed that the grain yield was unstable in all the cultivars, it could be noted that the cultivar SAI was performing at a higher plane among all the cultivars as regards its grain productivity. Among the short duration cultivars, CORG 5 seemed to be a high yielder. Even though differences in yield were very high between short and long duration cultivars in D_1 sowings, they were narrowed in D_2 and D_3 sowings (D_1-60 per cent; D_2-23 per cent; D_3-32 per cent).

The variety x Season interaction had already indicated that the number of seeds per pod, ILA and photosynthetic rate were not influenced. All other characters were subjected to seasonality. Strangely enough SA 1 did not show stability for photosynthetic rate per unit leaf area. But it had shown stability for number of seeds per pod, ILA, number of branches and 1000 grain weight under Group 1. These trends indicated that this variety (in Group I) demonstrated average response and high stability over seasons for the attributes which were identified.

Further to this trend, the cultivars in group II were expected to show average response and the performance of the attributes concerned will oscillate around average especially, when these cultivars are subjected to unfavourable and favourable seasonal conditions. Under this grouping, SA 1 had shown stability for LAI and number of pods per plant. Even though these attributes were recognised as highly variable under season x variety interaction, fortunately, number of seeds per pod and ILA which were found to be stable under season x variety interaction, were also found to be fixed by this variety except photosynthetic rate per unit leaf area. This last parameter classified as non significant in season x variety interaction was not fixed by SA 1.

Among the short duration cultivars CORG 5 appeared to be a high yielder in all the three sowings. This cultivar showed stability for photosynthetic rate which indicated non-significance in season x variety interaction. On the other hand, 1000 grain weight and HI which showed stability in this cultivar were significantly differing in the season x variety interactions. Hence, it is presumed that there is an effective integration of various stable physiological parameter in SA 1 and CORG 5 which had contributed cojointly for comparatively higher grain productivity.

As a necessary corollary of this study, the major question that arises is the reason why pigeonpea cultivars do not show stability for grain yield. The answer for the above question is listed below.

1. The two parameters which normally determine the yield are DMA and HI. These are highly influenced by the seasonality.

2. In addition, DMA is not stabilised in any of the cultivars studied

3. Sink strength, particularly the sink size component of it is found to be largely varying under different seasons. Sink size as represented by pods per plant is significantly reacting with differences due to seasonality.

4. As a result of reactions in various attributes due to seasonality, grain yield is found to be highly influenced by the environment. This is further strengthened by the fact that these attributes are not stabilised in any of the cultivars.

5. Seasonality influences the duration of cultivars in a large measure. Changes in the duration affect vegetative growth phase and LAI which largely decides the subsequent grain filling phenomenon.

6. Temperature modulations appeared to be more limiting to growth and reproductive cycles which influence the yield through the vagaries in sink size.

Future perspectives for crop improvement

Stability in DMA can be achieved through increased photosynthetic rate over seasons. This will pay off especially if it can be done in SA 1 which is comparatively good performing long duration cultivar. But this will be a very difficult preposition for the breeder, since photosynthetic rate is monitored by many components. The inheritance pattern and genetic basis of these components have not been fully studied so far. Studies on the inheritance pattern of photosynthetic rate can be taken up through further investigation. The other alternative for stabilising DMA is to increase the photosynthetic output per unit land area. This can be done by increasing the LAI over seasons. This is a comparatively a stable parameter (Group II) in SAI.

* For increasing LAI, increase in leaf number may be fruitfully attempted rather than increasing ILA which is again a stable character (Sharma and Saxena, 1983).

* The number of pods per plant is recognised as a stable parameter in SAI. The stability should further be increased to the level of Group I. If this could be achieved, there are very good possibilities for stabilising the yield in the pigeonpea cultivars. Because, the number of pods per plant is the major yield determinant which had already been identified through path analysis.

* The number of branches is observed as a stable parameter which can be indirectly help the plant to improve the number of pods per plant. Inspite of the fact that the number of branches in SA 1 is under Group I, the number of pods per plant, is under Group II in the same variety. This only indicates that number of pods per branch was probably lower in this cultivar. This should be increased for stabilising the grain yield. Hence the pod number per branch

should be increased and this may not affect the compensation mechanism of yield since pod number and branch number appeared to be stable.

* Programmes may have to be intiated to understand the inheritance pattern of DMA in order to plan effective breeding strategies.

* Over seasons, pod number per unit land area must be stabilised for which varying plant densities involving different genotypes or cultivars must be experimented with. Stability analysis for DMA and HI may throw sufficient light in such experiments.

After this study, our concept and vision regarding the yield performance of pigeonpea are greatly enhanced. We are able to demarcate the deficiencies which were responsible for yield variations in different seasons. Physiological/growth attributes contributing for such an unpredictable behaviour have been recognised. We feel more confident and enthusiastic about the stabilisation of yield which is now a distinct possibility. Provided we work in collaboration with breeders and agronomist who are devoted to the crop productivity, it can never be a distant dream to achieve stability of performance in this crop which is an excellent source of protein and an enviabl genotype that grows unmindful of varying moisture limited situations.

SUMMARY

CHAPTER VI

SUMMARY

Investigations were carried out on the pigeonpeas comprising of both short and long duration cultivars to discriminate their reactions against weather parameters as influenced by the different sowing dates. The physiological attributes, their variations as expressed in phenotypic characters were studied in relation to the productivity. Phenotypic stability analysis relating to the various attributes was utilised as a tool to identify a stable cultivar or parameters which possess higher stability of performance over different sowings. In this study, path analysis was also resorted to bring out the differential contribution of various yield components to the grain productivity.

Phenological changes were largely monitored by dates of sowing. Reduced vegetative growth was recorded in D_3 sowing as compared to D_1. The grain filling phase was not altered by different sowings in any cultivar. But the sink size and rate of filling per plant were affected by variation in dates of sowings.

Growth, in terms of morphological attributes like, plant height, number of branches, number of leaves, leaf area and LMA were significantly affected by different sowings. As a general rule in all the three sowings, leaf number decided the total leaf area rather than ILA which was not altered by sowings. The long duration cultivars dominated the short duration cultivars in all these aspects. The DMA was found to be highly correlated with cumulative heat unit, photothermal, heliothermal units and also with other meteorological parameters. These parameters were found to be higher in D_1 sowings which also accumulated the highest DM among the three sowings.

Growth analysis components such as LAI, AGR, CGR and LAD were more favoured in D_1 sowings and also in long duration cultivars. The NAR, LWR and LAR were recorded more in short duration cultivars and also in D_3 sowings whereas the SLW was significantly low in D_3 sowings as compared to D_2 and D_1. The fallen leaf weight was also found to be more in D_1 sowings and also in long duration cultivars. As regard the physiological attributes, the photosynthetic rate and chlorophyll content were higher in D_1 sowings as compared to D_2 and D_3. The D_1 sowings and long duration cultivars favoured higher transpiration rate than those of other two. The leaf water potential appeared to be low (more water content) in D_3 sowing and also in long duration cultivars. Canopy development was quicker in both in D_1 sowings and also in long duration cultivars.

These trends were reflected in higher ground coverage and low extinction coefficient (k) noticed in these two cases.

The number of pods per plant was the most significant component which decided the yield. This was largely influenced by the sowing dates. The pooled analysis revealed that the HI was negatively associated with yield. Comparing the sowings D_2 recorded the highest HI both in terms of energy basis and also by nitrogen utilisation (NHI). The protein content was low in D_1 and high in D_2 which coincided with normal sowings. The nutrients uptake was found to be more both in D_1 sowing and also in long duration cultivars.

The stability analysis revealed that the L/S ratio was not at all affected by seasons whereas grain yield and DMA were unstable in all the cultivars. The parameters like ILA, photosynthetic rate per unit leaf area and number of seed per pod were not altered by variety and season (Linear) interactions. Among the long duration cultivar groups, SA 1 was able to stabilise ILA, number of branches, LAI, number of pods per plant, number of seeds per pod and 1000 grain weight. Among the short duration types, CORG 5, showed stability for photosynthetic rate, 1000 grain weight and HI. These characters contributed for comparatively higher yield in SA 1 and CORG 5 respectively in long and short duration cultivars over different sowings. The instability of grain yield was due to the fact that the DMA was found to be unstable over sowings.

Comparing the sowings, D_1 sowing showed higher grain productivity than the other two. This was mainly monitored by the higher source strength which was decided by the LAI and photosynthetic rate. This higher source strength influenced the sink strength mainly through sink size in terms of number of pods per plant. Stabilisation of source strength before flowering will lead to stabilised yield in this genotype. The insufficient production of source size and DMA before flowering in D_2 and D_3 were the main reason for comparatively low yield in these two sowings.

This study focuses that future crop improvement in pigeonpea, should be concentrated in the following lines

(1) Stabilisation of DMA by stabilising the LAI over sowings.

(2) LAI could be stabilised by stabilising the leaf number rather than ILA.

(3) The number of seeds per plant should be stable. This can be achieved by the increasing the number of pods per branch over sowings.

(4) Inheritance pattern of photosynthetic components should be studied.

(5) Stability analysis of DMA, HI and grain yield needs further study under different plant densities over different sowing dates.

(6) These studies should be carried out in collaboration with the agronomist and breeders who are interested in increasing the productivity of pigeonpea.

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APPENDICES

Table 1. Duration of day length (Latitude 11°N)

Date of month	January		February		March		April		May		June		July		August		September		October		November		De- ber
	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H
10	11	30	11	43	12	01	12	21	12	37	12	46	12	46	12	30	12	14	12	01	11	41	11
20	11	34	11	48	12	07	12	25	12	41	12	46	12	39	12	22	12	12	11	51	11	38	11
30	11	37	11	54	12	15	12	31	12	45	12	47	12	34	12	19	12	01	11	47	11	34	11

Source: Monthly dew Register and Summaries, C.F. Casella and Co., Ltd., London.

Table 2. Shoot height (cm)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	22.7	44.8	81.9	111.1	121.0	125.5
	CORG 5	23.4	51.7	83.9	122.5	130.3	140.6
	UPAS 120	27.4	47.3	84.6	95.6	97.1	99.3
	CORG 11	24.8	50.9	86.1	279.4	298.6	305.4
	PLS 361/1	28.2	53.4	92.2	297.9	303.1	306.6
	SA 1	25.9	52.8	92.9	317.3	321.3	323.5
21-6-84 (D_2)	CO 5	21.1	38.6	57.5	84.5	94.5	94.8
	CORG 5	21.8	38.1	65.0	91.3	103.3	110.2
	UPAS 120	24.9	40.5	61.2	80.2	85.6	95.6
	CORG 11	27.6	48.1	70.5	191.3	230.8	240.6
	PLS 361/1	28.0	44.8	71.5	197.7	232.8	238.4
	SA 1	26.8	43.7	65.7	220.5	228.5	230.1
21-9-84 (D_3)	CO 5	23.7	32.3	48.8	73.3	81.5	86.4
	CORG 5	23.9	31.9	48.0	68.5	86.6	90.5
	UPAS 120	24.5	31.5	52.3	60.8	71.9	73.6
	CORG 11	23.9	36.9	60.0	120.6	138.8	141.9
	PLS 361/1	25.0	38.3	60.2	124.0	136.8	141.6
	SA 1	26.4	37.3	55.4	127.8	151.0	155.3

Table 3. Root length (cm)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flo-wering	Harvest
21-2-84 (D_1)	CO 5	7.6	18.6	29.9	40.3	44.3	47.4
	CORG 5	9.1	17.8	28.4	44.4	54.8	55.1
	UPAS 120	8.3	19.7	29.7	41.6	47.8	48.0
	CORG 11	8.4	18.8	31.0	118.7	121.5	125.3
	PLS 361/1	8.7	20.8	31.7	125.8	127.5	127.5
	SA 1	9.8	19.4	31.4	120.4	129.4	126.7
21-6-84 (D_2)	CO 5	7.4	18.5	21.9	29.2	29.8	32.6
	CORG 5	7.9	19.2	21.8	30.5	38.5	40.2
	UPAS 120	7.6	19.8	19.6	24.8	26.5	29.7
	CORG 11	7.9	20.1	28.0	53.2	54.0	59.4
	PLS 361/1	7.2	21.1	25.3	51.7	53.0	57.8
	SA 1	7.6	18.5	28.7	54.8	56.2	61.4
21-9-84 (D_3)	CO 5	9.2	13.0	19.9	24.8	30.8	33.4
	CORG 5	8.8	12.5	18.8	29.0	33.3	37.1
	UPAS 120	8.7	12.8	18.6	23.6	26.0	29.0
	CORG 11	8.9	13.9	20.6	30.3	43.8	46.9
	PLS 361/1	9.5	13.3	22.4	36.0	41.6	44.8
	SA 1	9.8	13.7	21.3	34.0	41.9	50.5

Table 4. Number of branches

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	-	4.5	8.8	9.1	9.5	9.6
	CORG 5	-	4.4	7.9	8.7	9.1	10.4
	UPAS 120	-	4.2	6.9	7.9	8.5	8.9
	CORG 11	-	4.9	8.8	16.8	19.7	20.9
	PLS 361/1	-	6.2	9.3	19.9	21.2	21.2
	SA 1	-	5.8	10.0	21.1	25.1	25.3
21-6-84 (D_2)	CO 5	-	3.1	6.2	8.5	8.5	8.5
	CORG 5	-	3.5	5.7	7.2	8.0	8.3
	UPAS 120	-	2.6	5.8	6.0	6.3	6.3
	CORG 11	-	4.0	5.2	9.8	10.2	11.0
	PLS 361/1	-	3.9	6.8	11.0	13.0	13.6
	SA 1	-	4.0	6.0	12.0	13.4	13.7
21-9-84 (D_3)	CO 5	-	2.8	3.5	3.6	4.8	5.3
	CORG 5	-	2.7	3.0	3.5	5.2	5.2
	UPAS 120	-	1.7	2.8	3.0	3.8	4.1
	CORG 11	-	2.6	3.3	7.3	8.0	9.1
	PLS 361/1	-	3.0	4.6	7.4	8.0	9.2
	SA 1	-	2.6	3.6	7.0	9.0	9.6

Table 5. Number of leaves per plant

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	7.0	18.6	102.9	259.3	298.4	230.1
	CORG 5	6.8	20.7	101.5	250.5	300.5	229.0
	UPAS 120	6.9	15.6	83.1	122.8	126.0	72.9
	CORG 11	7.7	17.4	105.0	2286.3	2460.8	1860.9
	PLS 361/1	8.0	27.7	113.4	2158.3	2432.5	1790.0
	SA 1	7.8	22.5	106.9	3027.5	3119.8	2054.5
21-6-84 (D_2)	CO 5	7.0	14.6	32.0	93.4	124.4	98.5
	CORG 5	7.3	13.8	32.8	98.8	135.0	100.8
	UPAS 120	7.1	11.3	21.6	51.0	57.6	42.1
	CORG 11	7.8	15.6	36.5	556.0	636.9	371.7
	PLS 361/1	8.0	16.3	38.5	517.0	567.7	410.4
	SA 1	8.4	16.3	36.0	558.8	604.3	448.7
21-9-84 (D_3)	CO 5	6.5	10.0	22.8	49.2	92.8	57.1
	CORG 5	6.7	9.7	20.7	40.3	62.7	46.9
	UPAS 120	6.2	8.8	19.6	39.0	51.8	38.3
	CORG 11	6.6	13.0	26.3	260.3	364.7	297.3
	PLS 361/1	7.6	12.8	30.4	264.5	380.0	330.1
	SA 1	7.4	11.9	27.2	247.6	392.6	227.7

Table 6. Leaf Production Rate (No.leaves/day)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30–40	40–50	50–First flowering	First flowering to 50 flowering	50% flowering to Harvest
21-2-84 (D_1)	CO 5	1.16	8.40	8.68	2.17	-1.85
	CORG 5	1.39	8.08	7.09	2.38	-1.70
	UPAS 120	0.870	6.75	2.84	0.178	-1.44
	CORG 11	0.970	8.76	27.30	5.45	-12.5
	PLS 361/1	1.94	8.57	23.20	8.45	-13.1
	SA 1	1.47	8.40	32.00	2.49	-23.1
21-6-84 (D_2)	CO 5	0.76	1.74	4.02	2.58	-0.61
	CORG 5	0.65	1.90	4.40	2.58	-0.81
	UPAS 120	0.42	1.03	3.26	0.66	-0.39
	CORG 11	0.78	2.09	7.75	4.75	-5.89
	PLS 361/1	0.83	2.22	6.73	3.38	-3.35
	SA 1	0.79	1.97	7.02	3.23	-3.31
21-9-84 (D_3)	CO 5	0.35	1.28	1.88	4.00	-0.32
	CORG 5	0.30	1.10	1.51	2.04	-0.36
	UPAS 120	0.26	1.08	1.14	1.40	-0.36
	CORG 11	0.64	1.33	6.00	6.96	-1.57
	PLS 361/1	0.52	1.76	5.57	6.41	- 1.06
	SA 1	0.45	1.53	4.79	9.06	-3.51

Table 7. Leaf area (cm^{-2}. $plant^{-1}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	53.2	302.5	1627.5	4258.3	4535.3	2822.8
	CORG 5	49.8	336.4	1650.0	4082.0	4140.5	3574.5
	UPAS 120	51.8	182.1	1098.3	1848.0	1967.5	1095.0
21-2-84 (D_1)	CORG 11	51.9	271.7	1422.0	40454.4	45605.8	26812.4
	PLS 361/1	65.8	373.5	2438.8	49051.5	55637.5	36655.0
	SA 1	61.9	318.9	1547.8	47945.0	55357.5	35267.5
	CO 5	73.4	181.7	403.2	1124.4	1561.7	981.6
	CORG 5	64.9	224.0	460.2	1372.9	1970.7	1065.5
	UPAS 120	59.1	130.8	342.9	583.4	720.3	383.9
21-6-84 (D_2)	CORG 11	89.4	236.5	583.2	8607.3	9042.8	5808.0
	PLS 361/1	76.1	213.6	562.3	7218.6	8781.6	5699.4
	SA 1	100.8	244.3	527.5	7767.4	9061.4	5506.3
	CO 5	28.2	101.8	298.0	633.4	766.2	438.7
	CORG 5	29.8	89.9	260.8	531.2	628.0	408.9
	UPAS 120	31.0	72.2	209.2	311.6	429.6	267.6
21-9-84 (D_3)	CORG 11	32.6	106.9	388.1	3389.7	4355.8	3270.9
	PLS 361/1	46.4	157.3	466.5	3354.7	4147.5	3466.9
	SA 1	38.3	147.8	471.9	3528.9	5127.2	3173.4

Table 8. Leaf weight ($g.m^{-2}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	2.45	10.67	74.84	162.28	171.91	127.45
	CORG 5	2.59	13.26	68.91	157.09	165.25	123.74
	UPAS 120	2.37	8.00	51.13	110.41	124.49	72.62
21-2-84 (D_1)	CORG 11	1.63	7.36	41.49	1189.55	1475.08	942.06
	PLS 361/1	2.37	9.23	48.41	1283.41	1484.47	972.19
	SA 1	2.17	8.00	55.33	1432.11	1603.52	1016.65
	CO 5	1.93	7.63	20.01	47.42	68.17	64.47
	CORG 5	2.22	8.15	24.45	60.02	94.11	71.14
	UPAS 120	2.00	6.22	17.78	25.19	35.57	23.71
21-6-84 (D_2)	CORG 11	1.68	6.13	15.81	219.34	226.75	115.59
	PLS 361/1	1.73	6.07	14.82	206.99	221.81	181.29
	SA 1	2.12	5.88	14.33	187.23	232.67	152.15
	CO 5	1.70	4.08	11.12	23.71	34.08	28.16
	CORG 5	1.48	3.85	9.63	21.49	31.12	25.19
	UPAS 120	1.41	3.33	9.63	12.59	20.75	17.04
21-9-84 (D_3)	CORG 11	1.19	3.11	9.88	105.72	126.46	82.99
	PLS 361/1	1.28	3.75	11.36	99.29	134.86	77.56
	SA 1	1.43	3.41	9.39	108.19	151.16	106.70

Table 9. Stem weight (g.m^{-2})

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	1.07	6.32	43.87	229.56	331.45	282.09
	CORG 5	1.07	5.52	45.20	241.42	407.77	376.51
	UPAS 120	1.09	4.45	40.24	137.46	175.47	155.24
21-2-84 (D_1)	CORG 11	0.332	5.09	28.89	7754.81	8499.76	8374.78
	PLS 361/1	0.383	5.38	39.76	8372.07	8990.30	8657.35
	SA 1	0.939	5.19	37.59	8693.91	9327.19	9187.41
	CO 5	0.815	5.11	15.56	68.17	105.96	81.51
	CORG 5	1.110	4.96	19.27	83.73	145.98	94.35
	UPAS 120	1.030	3.93	14.08	43.72	72.62	36.31
21-6-84 (D_2)	CORG 11	0.988	4.29	13.83	604.16	693.01	683.69
	PLS 361/1	0.939	4.39	15.31	597.74	925.33	[illegible]
	SA 1	1.030	3.83	13.32	625.89	871.91	858.57
	CO 5	0.741	2.67	8.15	22.23	63.73	38.53
	CORG 5	0.889	2.74	7.26	17.78	54.83	44.46
	UPAS 120	0.704	2.37	8.89	14.08	33.34	21.49
21-9-84 (D_3)	CORG 11	0.741	2.27	8.39	127.45	208.96	206.49
	PLS 361/1	0.790	2.67	9.39	138.32	194.64	184.76
	SA 1	0.839	2.37	8.89	133.38	288.99	281.09

Table 10. Root dry weight ($g.m^{-2}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	0.371	2.07	13.41	50.91	75.58	73.36
	CORG 5	0.437	2.29	15.12	53.43	91.88	88.92
	UPAS 120	0.333	2.07	10.89	60.72	84.47	66.69
21-2-84 (D_1)	CORG 11	0.363	1.38	9.09	1150.92	1211.78	1180.17
	PLS 361/1	0.291	1.78	10.57	1407.41	1498.79	1435.56
	SA 1	0.296	1.431	11.16	1229.07	1294.77	1134.22
	CO 5	0.385	0.815	5.32	24.45	28.89	22.97
	CORG 5	0.452	0.889	4.67	20.75	33.35	29.64
	UPAS 120	0.437	0.815	4.29	9.63	12.59	11.12
21-6-84 (D_2)	CORG 11	0.390	0.692	3.51	155.61	164.99	145.24
	PLS 361/1	0.301	0.839	4.00	130.91	174.38	132.88
	SA 1	0.484	0.741	3.71	117.57	153.61	127.45
	CO 5	0.229	1.19	2.52	6.52	11.12	10.37
	CORG 5	0.215	1.04	2.59	4.89	14.08	13.34
	UPAS 120	0.215	1.11	2.67	4.22	11.86	11.12
21-9-84 (D_3)	CORG 11	0.173	0.939	2.42	33.09	49.40	39.03
	PLS 361/1	0.203	0.889	2.82	27.17	48.41	42.48
	SA 1	0.232	1.04	2.37	37.05	48.91	42.98

Table 11. Reproductive parts dry weight (g.m^{2})

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5				30.63	157.09	498.69
	CORG 5				23.16	168.94	539.45
	UPAS 120	-	-	-	25.19	109.67	367.54
	CORG 11				394.21	530.56	1362.95
	PLS 361/1				339.65	538.46	1426.43
	SA 1				448.55	545.89	1579.02
21-6-84 (D_2)	CO 5				21.49	57.06	376.43
	CORG 5				22.97	55.58	440.89
	UPAS 120	-	-	-	26.68	50.39	352.72
	CORG 11				39.03	47.42	458.43
	PLS 361/1				31.62	59.28	426.82
	SA 1				38.04	54 .34	524.41
21-9-84 (D_3)	CO 5				4.67	45.20	275.87
	CORG 5				5.56	59.27	293.44
	UPAS 120	-	-	-	3.65	38.53	220.08
	CORG 11				16.79	48.91	375.98
	PLS 361/1				18.28	50.88	268.93
	SA 1				15.81	63.23	394.71

Table 12. Total Dry Matter Accumulation (g. m^{-2})

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	3.87	19.64	131.89	473.49	736.55	982.57
	CORG 5	4.13	21.04	129.68	486.09	821.77	1110.02
	UPAS 120	3.77	14.52	102.26	334.93	493.51	655.04
	CORG 11	2.71	13.78	79.53	10497.54	11717.19	11859.95
	PLS 361/1	3.54	16.40	98.31	11463.27	12512.53	12590.58
	SA 1	3.40	14.61	103.74	11801.17	12082.53	12918.59
21-6-84 (D_2)	CO 5	3.13	13.56	40.90	161.54	260.09	543.74
	CORG 5	2.79	14.00	48.39	187.47	329.00	636.52
	UPAS 120	4.22	10.97	36.16	105.22	171.17	423.85
	CORG 11	3.06	11.12	33.15	1018.13	1135.71	1402.96
	PLS 361/1	2.97	11.31	34.14	967.25	1407.90	1679.60
	SA 1	3.65	10.47	31.37	968.73	1318.98	1680.59
21-9-84 (D_3)	CO 5	2.68	7.93	21.79	57.13	120.04	340.86
	CORG 5	2.57	7.63	13.71	49.72	139.31	376.43
	UPAS 120	2.35	6.82	21.19	34.53	95.59	267.50
	CORG 11	2.09	6.32	20.69	283.06	433.73	704.49
	PLS 361/1	2.28	7.31	23.56	283.06	428.79	573.73
	SA 1	2.50	6.82	20.65	249.42	552.29	825.47

Table 13. Shoot-Root ratio (length)

Treatments (Date of sowing)	Varieties	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	2.98	2.41	2.74	2.77	2.73	2.64
	CORG 5	2.57	2.90	2.95	2.75	2.52	2.55
21-2-84 (D_1)	UPAS 120	3.30	2.40	2.85	2.29	2.03	2.07
	CORG 11	2.59	2.71	2.77	2.35	2.46	2.43
	PLS 361/1	3.24	2.57	2.91	2.37	2.37	2.40
	SA 1	2.64	2.72	2.98	2.64	2.48	2.46
	CO 5	2.85	2.08	2.63	2.89	3.17	3.02
	CORG 5	2.09	1.98	2.98	2.99	2.68	2.74
21-6-84 (D_2)	UPAS 120	3.27	2.05	3.12	3.23	3.23	3.22
	CORG 11	3.49	2.39	3.52	3.59	4.27	4.05
	PLS 361/1	3.89	2.12	2.85	3.82	4.39	4.12
	SA 1	3.52	2.36	2.79	4.02	4.07	3.74
	CO 5	2.57	2.48	2.45	2.95	2.64	2.58
	CORG 5	2.65	2.55	2.55	2.90	2.60	2.44
21-9-84 (D_3)	UPAS 120	2.64	2.67	2.81	2.57	2.56	2.37
	CORG 11	2.68	2.65	2.91	3.98	3.10	3.02
	PLS 361/1	2.63	2.89	2.68	3.44	3.29	3.16
	SA 1	2.78	2.72	2.60	3.76	3.60	3.07

Table 14. Shoot-Root ratio (Weight)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	9.46	8.46	8.83	8.30	8.74	12.39
	CORG 5	8.46	8.16	7.59	7.18	7.94	11.48
	UPAS 120	10.31	6.00	8.39	4.52	4.84	8.82
	CORG 11	10.19	8.96	7.75	8.08	8.67	10.04
	PLS 361/1	11.15	8.22	8.29	7.18	7.34	7.97
	SA 1	10.48	9.21	8.29	8.60	8.98	10.65
21-6-84 (D_2)	CO 5	7.12	15.6	6.67	5.61	8.00	22.7
	CORG 5	5.16	14.8	9.37	8.04	8.67	20.5
	UPAS 120	8.64	12.5	7.41	9.92	12.60	37.1
	CORG 11	6.84	15.1	8.45	5.54	5.88	8.65
	PLS 361/1	7.83	9.3	7.53	6.39	7.07	11.6
	SA 1	6.53	13.1	7.47	7.21	7.47	12.9
21-9-84 (D_3)	CO 5	10.65	5.69	7.65	7.76	9.80	31.85
	CORG 5	11.03	6.36	4.29	9.17	8.89	27.82
	UPAS 120	10.00	5.13	6.94	7.17	7.06	23.07
	CORG 11	11.14	5.74	7.55	7.55	7.78	17.05
	PLS 361/1	10.24	6.06	7.37	9.42	7.85	12.51
	SA 1	9.79	5.57	7.71	6.95	10.29	18.21

Table 15. Leaf-Stem ratio

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	2.26	1.68	1.71	0.710	0.520	0.450
	CORG 5	2.44	2.40	1.52	0.650	0.410	0.330
	UPAS 120	2.15	1.80	1.27	0.800	0.700	0.460
	CORG 11	1.96	1.45	1.44	0.150	0.170	0.110
	PLS 361/1	2.40	1.53	1.22	0.150	0.180	0.110
	SA 1	2.31	1.54	1.47	0.160	0.170	0.110
21-6-84 (D_2)	CO 5	2.36	1.49	1.28	0.695	0.643	0.791
	CORG 5	2.00	1.64	1.27	0.717	0.645	0.730
	UPAS 120	1.93	1.58	1.26	0.576	0.409	0.653
	CORG 11	1.70	1.43	1.14	0.363	0.324	0.169
	PLS 361/1	1.84	1.38	0.96	0.346	0.233	0.193
	SA 1	2.05	1.53	1.07	0.299	0.267	0.177
21-9-84 (D_3)	CO 5	2.30	1.53	1.36	1.07	0.535	0.730
	CORG 5	1.67	1.41	1.33	1.21	0.568	0.566
	UPAS 120	2.00	1.41	1.08	0.894	0.622	0.793
	CORG 11	1.60	1.37	1.18	0.829	0.605	0.402
	PLS 361/1	1.63	1.41	1.21	0.718	0.693	0.419
	SA 1	1.71	1.44	1.06	0.811	0.521	0.379

Table 16. ILA ($cm^{-2}.leaf^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	7.6	16.3	15.8	16.4	15.2	12.3
	CORG 5	7.3	16.3	16.2	16.3	13.7	15.6
	UPAS 120	7.5	11.7	13.2	15.0	15.6	15.0
	CORG 11	6.7	15.6	13.5	17.7	18.6	14.4
	PLS 361/1	8.2	13.9	21.5	22.7	22.8	20.5
	SA 1	7.9	14.2	14.7	15.9	17.7	17.1
21-6-84 (D_2)	CO 5	10.5	12.4	12.6	12.0	12.6	9.9
	CORG 5	8.9	16.2	14.0	13.9	14.6	10.6
	UPAS 120	8.3	11.5	15.9	11.4	12.5	9.1
	CORG 11	11.5	15.2	15.9	15.5	14.2	15.6
	PLS 361/1	9.5	13.1	14.6	13.9	15.5	13.9
	SA 1	12.0	14.9	14.7	13.9	14.9	12.3
21-9-84 (D_3)	CO 5	4.4	10.2	13.1	12.9	8.3	7.7
	CORG 5	4.5	9.3	12.6	13.2	10.0	8.7
	UPAS 120	5.0	8.2	10.7	7.9	8.3	6.9
	CORG 11	4.9	8.2	14.8	13.0	11.9	11.0
	PLS 361/1	5.1	12.3	15.4	12.7	10.9	10.5
	SA 1	5.0	11.6	15.5	13.3	13.5	12.3

Table 17. ILW (mg. leaf^{-1})

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	46.9	77.4	92.8	84.5	77.7	75.6
	CORG 5	52.1	86.5	91.6	84.6	74.2	72.7
	UPAS 120	45.8	69.2	83.0	107.8	98.9	77.8
	CORG 11	42.9	85.6	80.0	105.4	121.3	102.5
	PLS 361/1	59.8	67.5	86.4	120.3	123.5	109.9
	SA 1	56.1	72.0	104.7	95.7	104.0	100.1
21-6-84 (D_2)	CO 5	37.0	71.0	84.0	68.0	74.0	88.0
	CORG 5	41.0	79.0	100.0	82.0	94.0	95.0
	UPAS 120	30.0	74.0	111.0	66.0	83.0	76.0
	CORG 11	44.0	79.0	83.0	79.0	71.0	63.0
	PLS 361/1	44.0	75.0	78.0	81.0	79.0	89.0
	SA 1	53.0	73.0	81.0	69.0	77.0	68.0
21-9-84 (D_3)	CO 5	35.0	55.0	66.0	65.0	49.0	67.0
	CORG 5	29.0	54.0	63.0	72.0	67.0	72.0
	UPAS 120	31.0	51.0	66.0	43.0	54.0	60.0
	CORG 11	36.0	49.0	76.0	82.0	70.0	56.0
	PLS 361/1	34.0	59.0	76.0	76.0	71.0	48.0
	SA 1	39.0	58.0	69.0	78.0	78.0	94.0

Table 18. LAI

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
	CO 5	0.038	0.22	1.20	3.15	3.52	2.16
	CORG 5	0.037	0.25	1.21	3.02	3.12	2.66
21-2-84 (D_1)	UPAS 120	0.037	0.13	0.81	1.37	1.45	0.80
	CORG 11	0.026	0.13	0.70	19.9	22.6	13.20
	PLS 361/1	0.034	0.18	0.98	24.2	27.5	18.10
	SA 1	0.029	0.16	0.99	23.6	27.30	17.00
	CO 5	0.054	0.14	0.29	0.83	1.16	0.73
	CORG 5	0.048	0.11	0.34	1.01	1.46	0.79
21-6-84 (D_2)	UPAS 120	0.043	0.09	0.25	0.43	0.53	0.29
	CORG 11	0.044	0.12	0.29	4.25	4.46	2.87
	PLS 361/1	0.038	0.11	0.28	3.56	4.34	2.81
	SA 1	0.049	0.12	0.26	3.84	4.47	2.72
	CO 5	0.021	0.075	0.22	0.47	0.56	0.32
	CORG 5	0.022	0.067	0.19	0.39	0.46	0.30
21-9-84 (D_3)	UPAS 120	0.025	0.050	0.15	0.23	0.32	0.19
	CORG 11	0.016	0.052	0.19	1.67	2.15	1.62
	PLS 361/1	0.025	0.078	0.23	1.66	2.05	1.71
	SA 1	0.019	0.073	0.23	1.74	2.53	1.56

Table 19. NAR ($g.g^{-1}.day^{-1}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30-40	40-50	50-First flowering	First flowering to 50% flowering	50% flowering to Harvest
21-2-84 (D_1)	CO 5	0.2835	0.3418	0.1679	0.0875	0.0438
	CORG 5	0.2573	0.3225	0.1585	0.0991	0.0479
	UPAS 120	0.2332	0.3759	0.2155	0.0777	0.0269
	CORG 11	0.2910	0.3320	0.0634	0.0285	0.0025
	PLS 361/1	0.2552	0.3466	0.0342	0.0245	0.0013
	SA 1	0.2516	0.5246	0.0718	0.0193	0.0006
21-6-84 (D_2)	CO 5	0.2517	0.2129	0.2378	0.1428	0.1103
	CORG 5	0.2458	0.2317	0.2338	0.1260	0.0902
	UPAS 120	0.1813	0.2287	0.3587	0.2191	0.2089
	CORG 11	0.2344	0.2157	0.1898	0.0323	0.0359
	PLS 361/1	0.2412	0.2326	0.1800	0.1373	0.0293
	SA 1	0.1851	0.2202	0.1882	0.1134	0.0404
21-9-84 (D_3)	CO 5	0.1930	0.1970	0.1520	0.2380	0.1820
	CORG 5	0.2030	0.0960	0.1910	0.3130	0.1920
	UPAS 120	0.2020	0.2420	0.1720	0.4150	0.2460
	CORG 11	0.2120	0.2450	0.1680	0.0870	0.0590
	PLS 361/1	0.2190	0.2370	0.1520	0.0690	0.0290
	SA 1	0.1890	0.2340	0.1470	0.1250	0.0440

Table 20. CGR ($g. m^{-2}. day^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30–40	40–50	50–First flowering	First flowering to 50% flowering	50% flowering to Harvest
21-2-84 (D_1)	CO 5	1.58	11.22	18.97	14.61	6.65
	CORG 5	1.69	10.85	16.97	15.98	6.86
	UPAS 120	1.08	8.77	16.61	8.34	4.36
	CORG 11	1.11	6.57	130.17	38.10	2.97
	PLS 361/1	1.29	6.19	129.10	33.84	1.59
	SA 1	1.12	8.91	128.63	29.22	0.78
21-6-84 (D_2)	CO 5	1.04	2.73	7.34	10.94	6.79
	CORG 5	1.12	3.44	9.27	14.15	7.32
	UPAS 120	0.675	2.52	7.67	6.59	6.31
	CORG 11	0.805	2.20	14.70	6.68	5.94
	PLS 361/1	0.834	2.29	13.14	29.36	5.90
	SA 1	0.602	2.09	19.42	23.34	7.69
21-9-84 (D_3)	CO 5	0.525	1.39	2.52	6.39	5.66
	CORG 5	0.504	0.907	2.76	8.14	5.38
	UPAS 120	0.449	1.44	1.91	6.78	4.65
	CORG 11	0.422	1.44	6.72	10.04	6.29
	PLS 361/1	0.503	1.63	6.18	8.07	3.32
	SA 1	0.431	1.38	5.95	16.11	5.81

Table 21. RGR ($g.g^{-1}.day^{-1}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30–40	40–50	50–First flowering	First flowering to 50% flowering	50% flowering to Harvest
21-2-84 (D_1)	CO 5	0.1620	0.1900	0.0710	0.0250	0.00770
	CORG 5	0.1620	0.1820	0.0630	0.0250	0.00720
	UPAS 120	0.1350	0.1950	0.0840	0.0200	0.00760
	CORG 11	0.1630	0.1750	0.0610	0.0034	0.00025
	PLS 361/1	0.1530	0.1790	0.0540	0.0028	0.00013
	SA 1	0.1460	0.1950	0.0520	0.0024	0.00006
21-6-84 (D_2)	CO 5	0.1470	0.1100	0.0860	0.0529	0.0176
	CORG 5	0.1620	0.1240	0.0900	0.0401	0.0157
	UPAS 120	0.0960	0.1190	0.1190	0.0486	0.0226
	CORG 11	0.1290	0.1090	0.0510	0.0064	0.0048
	PLS 361/1	0.1330	0.1100	0.0470	0.0250	0.0038
	SA 1	0.1060	0.1090	0.0460	0.0205	0.0052
21-9-84 (D_3)	CO 5	0.1090	0.1010	0.0690	0.0820	0.0270
	CORG 5	0.1080	0.0590	0.0990	0.0940	0.0230
	UPAS 120	0.1070	0.1130	0.0690	0.1030	0.0280
	CORG 11	0.1100	0.1190	0.0670	0.0290	0.0110
	PLS 361/1	0.1170	0.1170	0.0590	0.0230	0.0070
	SA 1	0.1000	0.1110	0.0580	0.0390	0.0080

Table 22. AGR (g. plant^{-1}. day^{-1})

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30-40	40-50	50-First flowering	First flowering to 50% flowering	50% flowering to Harvest
21-2-84 (D_1)	CO 5	0.213	1.52	2.56	1.97	0.897
	CORG 5	0.228	1.47	2.29	2.16	0.926
	UPAS 120	0.145	1.18	2.24	1.23	0.589
	CORG 11	0.224	1.33	26.40	7.72	0.602
	PLS 361/1	0.260	1.66	26.10	6.85	0.322
	SA 1	0.227	1.80	26.00	5.92	0.158
21-6-84 (D_2)	CO 5	0.141	0.369	1.12	1.10	0.987
	CORG 5	0.151	0.464	1.25	1.29	1.000
	UPAS 120	0.091	0.340	1.03	0.89	0.825
	CORG 11	0.163	0.446	2.98	1.40	1.200
	PLS 361/1	0.169	0.462	2.66	5.96	1.190
	SA 1	0.138	0.423	2.56	4.72	1.550
21-9-84 (D_3)	CO 5	0.071	0.187	0.341	0.943	0.764
	CORG 5	0.068	0.082	0.374	1.099	0.727
	UPAS 120	0.061	0.194	0.257	0.916	0.627
	CORG 11	0.086	0.291	1.362	2.033	1.274
	PLS 361/1	0.102	0.329	1.251	1.639	0.623
	SA 1	0.087	0.280	1.205	3.263	1.176

Table 23. LAD (days)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)				
		30–40	40–50	50– First flowering	First flowering to 50% flowering	50% flowering to Harvest
21–2–84 (D_1)	CO 5	1.23	7.10	39.15	60.03	105.08
	CORG 5	1.44	7.30	44.15	64.47	121.17
	UPAS 120	0.84	4.70	15.26	26.79	41.63
	CORG 11	0.80	4.20	824.10	680.00	859.20
	PLS 361/1	1.07	5.80	1107.90	801.35	1117.20
	SA 1	0.94	5.80	1118.80	941.65	1018.90
21–6–84 (D_2)	CO 5	0.94	2.17	9.04	8.95	39.56
	CORG 5	1.07	2.54	10.19	17.33	47.21
	UPAS 120	0.69	1.75	3.09	4.82	16.44
	CORG 11	0.80	2.02	152.02	74.04	164.88
	PLS 361/1	0.71	1.91	136.21	59.25	164.54
	SA 1	0.85	1.91	151.70	62.33	168.94
21–9–84 (D_3)	CO 5	0.48	1.48	4.83	4.64	17.16
	CORG 5	0.44	1.29	3.77	5.23	16.72
	UPAS 120	0.38	1.02	1.33	2.48	9.44
	CORG 11	0.34	1.21	36.27	28.65	81.06
	PLS 361-1	0.50	1.54	39.48	33.03	82.72
	SA 1	0.46	1.52	45.31	34.16	96.12

Table 24 SLA ($cm^{-2}.g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	161.7	210.4	161.6	194.2	195.7	164.0
	CORG 5	140.7	187.8	177.2	193.3	190.6	217.3
	UPAS 120	161.1	170.7	162.6	126.0	117.6	112.8
	CORG 11	155.3	183.8	170.9	168.0	153.0	140.6
	PLS 361/1	155.1	200.4	194.9	188.8	185.2	190.2
	SA 1	140.2	193.1	182.9	165.4	170.6	167.9
21-6-84 (D_2)	CO 5	282.3	176.4	149.3	175.6	195.7	112.8
	CORG 5	216.3	203.6	139.5	163.9	155.2	110.9
	UPAS 120	218.8	154.7	142.8	171.6	150.0	119.9
	CORG 11	262.9	190.7	182.3	193.8	196.0	248.2
	PLS 371/1	217.4	173.7	187.4	172.3	195.6	155.3
	SA 1	234.4	205.3	181.0	204.9	192.3	178.7
21-9-84 (D_3)	CO 5	122.6	185.1	198.7	197.9	166.1	115.4
	CORG 5	149.0	172.9	200.6	183.2	149.6	120.3
	UPAS 120	163.2	160.4	160.9	183.3	153.4	116.3
	CORG 11	135.8	169.7	194.1	158.4	170.2	194.7
	PLS 361/1	178.5	206.9	202.8	166.9	151.9	220.8
	SA 1	132.0	214.2	249.4	161.1	167.6	146.9

Table 25. SLW ($g.cm^{-2}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	0.0064	0.0048	0.0062	0.0052	0.0051	0.0061
	CORG 5	0.0072	0.0053	0.0057	0.0052	0.0053	0.0047
	UPAS 120	0.0062	0.0057	0.0063	0.0081	0.0085	0.0089
	CORG 11	0.0065	0.0056	0.0059	0.0059	0.0065	0.0071
	PLS 361/1	0.0065	0.0050	0.0049	0.0053	0.0054	0.0054
	SA 1	0.0072	0.0051	0.0056	0.0061	0.0059	0.0059
21-6-84 (D_2)	CO 5	0.0035	0.0056	0.0067	0.0057	0.0058	0.0088
	CORG 5	0.0046	0.0049	0.0072	0.0059	0.0064	0.0090
	UPAS 120	0.0045	0.0065	0.0069	0.0058	0.0067	0.0083
	CORG 11	0.0038	0.0052	0.0055	0.0052	0.0050	0.0040
	PLS 361/1	0.0039	0.0057	0.0053	0.0058	0.0051	0.0064
	SA 1	0.0043	0.0048	0.0055	0.0042	0.0052	0.0055
21-9-84 (D_3)	CO 5	0.0085	0.0054	0.0050	0.0051	0.0060	0.0087
	CORG 5	0.0067	0.0058	0.0049	0.0055	0.0067	0.0083
	UPAS 120	0.0061	0.0062	0.0062	0.0054	0.0065	0.0086
	CORG 11	0.0074	0.0059	0.0052	0.0063	0.0059	0.0051
	PLS 361/1	0.0056	0.0048	0.0049	0.0059	0.0066	0.0043
	SA 1	0.0076	0.0047	0.0040	0.0062	0.0059	0.0068

Table 26. LWR ($g.\ g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	0.627	0.543	0.567	0.343	0.233	0.129
	CORG 5	0.634	0.630	0.531	0.323	0.201	0.110
	UPAS 120	0.621	0.551	0.500	0.329	0.252	0.111
	CORG 11	0.604	0.534	0.522	0.129	0.125	0.079
	PLS 361/1	0.667	0.563	0.492	0.112	0.118	0.077
	SA 1	0.636	0.547	0.533	0.121	0.124	0.078
21-6-84 (D_2)	CO 5	0.616	0.562	0.489	0.294	0.262	0.118
	CORG 5	0.798	0.582	0.505	0.320	0.286	0.112
	UPAS 120	0.474	0.568	0.492	0.239	0.208	0.056
	CORG 11	0.549	0.551	0.477	0.215	0.199	0.082
	PLS 361/1	0.582	0.537	0.434	0.214	0.158	0.108
	SA 1	0.582	0.561	0.457	0.193	0.176	0.091
21-9-84 (D_3)	CO 5	0.637	0.514	0.510	0.415	0.285	0.083
	CORG 5	0.573	0.505	0.703	0.432	0.223	0.067
	UPAS 120	0.605	0.489	0.454	0.365	0.132	0.064
	CORG 11	0.565	0.492	0.477	0.374	0.292	0.118
	PLS 361/1	0.565	0.514	0.482	0.351	0.315	0.135
	SA 1	0.572	0.500	0.454	0.367	0.274	0.129

Table 27. LAR ($cm^{-2} . g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)					
		30	40	50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	101.8	114.2	91.4	66.4	45.6	21.3
	CORG 5	89.3	112.4	92.5	62.2	62.1	23.9
	UPAS 120	101.8	92.9	79.6	40.9	29.5	12.4
	CORG 11	94.7	97.4	88.3	23.8	19.2	11.2
	PLS 361/1	91.8	112.5	122.6	21.1	21.9	14.3
	SA 1	86.3	107. 7	73.7	20.5	21.2	13.4
21-6-84 (D_2)	CO 5	173.9	99.3	73.0	51.6	44.5	13.3
	CORG 5	172.6	118.5	70.5	54.3	44.4	12.4
	UPAS 120	103.9	87.8	70.2	41.1	31.2	6.7
	CORG 11	144.4	105.1	86.9	41.7	39.3	20.4
	PLS 361/1	126.6	93.3	81.4	36.8	30.8	16.8
	SA 1	136.6	115.2	83.1	39.6	33.9	16.2
21-9-84 (D_3)	CO 5	78.1	95.1	101.4	82.2	47.3	9.5
	CORG 5	85.4	87.3	140.9	79.8	33.4	8.1
	UPAS 120	98.7	78.5	73.2	66.9	33.3	7.4
	CORG 11	76.7	83.5	92.6	59.2	49.6	22.9
	PLS 361/1	100.9	106.3	97.8	58.6	47.9	29.8
	SA 1	75.5	107.1	112.9	59.2	45.9	18.9

Table 28. Fallen leaves (g.plant^{-1})

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)				
		40-50	50- First flowering	First flowering - 50% flowering	50% flowering to Harvest	Total
21-2-84 (D_1)	CO 5	1.03	2.20	3.10	5.25	11.58
	CORG 5	0.99	2.15	3.05	4.65	10.84
	UPAS 120	1.93	3.07	3.55	4.10	12.65
	CORG 11	1.50	21.67	9.87	8.45	41.49
	PLS 361/1	1.39	23.15	10.67	10.00	45.21
	SA 1	1.34	25.60	12.20	9.50	48.64
21-6-84 (D_2)	CO 5	0.64	1.76	2.40	3.70	8.50
	CORG 5	0.59	1.84	2.71	2.90	8.04
	UPAS 120	0.60	2.00	2.81	3.10	8.51
	CORG 11	0.95	9.84	4.80	7.90	23.49
	PLS 361/1	1.05	10.00	6.20	6.50	23.75
	SA 1	1.00	11.65	5.30	7.00	24.95
21-9-84 (D_3)	CO 5	0.26	1.36	1.45	1.62	4.69
	CORG 5	0.31	1.05	1.72	2.01	5.09
	UPAS 120	0.25	1.65	1.82	1.05	4.77
	CORG 11	0.69	4.85	2.91	3.15	9.60
	PLS 361/1	0.49	5.61	3.26	2.98	12.34
	SA 1	0.75	6.36	3.66	3.16	12.96

Table 29. Yield and yield components

Treatment (Date of sowing)	Cultivars	Grain yield (g/ plant)	Husk yield (g/ plant)	1000-seed weight (g)	No. seed per pod	No. pod per plant	Pod sett (%)	HI	HIP	NHI
21-2-84 (D_1)	CO 5	41.20	26.05	78.28	2.69	220.2	12.21	31.0	28.0	60.2
	CORG 5	47.90	28.58	76.95	2.71	241.2	11.85	31.9	29.0	62.7
	UPAS 120	33.58	16.00	54.25	2.31	170.8	12.00	37.8	33.0	63.1
	CORG 11	160.60	115.30	73.34	2.81	902.2	10.81	6.68	6.50	32.7
	PLS 361/1	178.75	110.0	80.33	3.00	944.2	12.61	7.00	6.80	35.2
	SA 1	186.68	132.96	81.48	3.12	1045.6	11.59	7.14	7.00	29.4
21-6-84 (D_2)	CO 5	28.90	21.9	72.20	3.10	187.2	16.00	39.0	35.0	68.1
	CORG 5	30.60	28.9	81.60	2.93	195.6	15.60	35.0	33.0	66.4
	UPAS 120	24.80	22.8	60.60	3.16	116.7	14.50	43.0	37.0	70.1
	CORG 11	49.60	42.6	83.20	3.23	409.2	13.10	17.0	16.0	49.2
	PLS 361/1	50.40	36.0	86.30	3.56	412.8	12.30	15.0	14.0	49.1
	SA 1	59.10	50.7	82.40	3.40	487.4	13.60	17.0	16.0	54.6
21-9-84 (D_3)	CO 5	13.40	21.40	74.60	2.86	128.8	18.00	28.50	26.0	57.1
	CORG 5	16.74	22.85	77.20	2.91	142.5	16.10	32.90	29.0	63.2
	UPAS 120	10.07	19.65	56.40	3.00	95.0	16.60	27.80	24.0	56.0
	CORG 11	35.87	40.24	80.20	2.90	266.4	15.30	25.10	23.0	57.6
	PLS 361/1	25.67	28.74	81.30	2.85	195.4	17.30	22.10	19.0	53.2
	SA 1	37.16	42.74	79.80	3.16	279.0	16.60	22.20	20.0	55.5

Table 30. Chlorophyll a ($mg.g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
1-2-84 (D_1)	CO 5	0.68	1.21	1.50	0.42
	CORG 5	0.70	1.30	1.60	0.33
	UPAS 120	0.53	1.28	1.40	0.40
	CORG 11	0.56	1.12	1.22	0.39
	PLS 361/1	0.72	1.41	1.81	0.42
	SA 1	0.79	1.39	1.64	0.38
1-6-84 (D_2)	CO 5	0.58	1.01	1.35	0.28
	CORG 5	0.62	1.20	1.29	0.32
	UPAS 120	0.49	1.09	1.05	0.31
	CORG 11	0.60	1.20	1.09	0.29
	PLS 361/1	0.69	1.31	1.31	0.32
	SA 1	0.72	1.19	1.41	0.32
1-9-84 (D_3)	CO 5	0.61	0.98	1.18	0.56
	CORG 5	0.59	1.10	1.20	0.42
	UPAS 120	0.47	1.00	1.15	0.39
	CORG 11	0.69	1.19	1.25	0.57
	PLS 361/1	0.71	1.20	1.18	0.54
	SA 1	0.69	1.26	1.29	0.58

Table 31. Chlorophyll b ($mg.g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	0.46	0.72	1.26	0.12
	CORG 5	0.47	0.68	1.28	0.22
	UPAS 120	0.35	0.76	1.02	0.27
	CORG 11	0.33	0.87	1.15	0.20
	PLS 361/1	0.41	0.81	1.21	0.28
	SA 1	0.45	0.90	1.05	0.27
21-6-84 (D_2)	CO 5	0.36	0.62	1.05	0.17
	CORG 5	0.40	0.59	0.90	0.19
	UPAS 120	0.38	0.50	0.87	0.21
	CORG 11	0.30	0.78	0.98	0.19
	PLS 361/1	0.42	0.76	1.10	0.20
	SA 1	0.39	0.67	1.21	0.19
21-9-84 (D_3)	CO 5	0.39	0.57	0.64	0.31
	CORG 5	0.41	0.61	0.79	0.29
	UPAS 120	0.31	0.65	0.81	0.26
	CORG 11	0.42	0.70	0.71	0.35
	PLS 361/1	0.45	0.76	0.64	0.36
	SA 1	0.42	0.82	0.95	0.35

Table 32. Total chlorophyll ($mg.g^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	1.14	1.93	2.76	0.54
	CORG 5	1.17	1.98	2.81	0.55
	UPAS 120	0.88	2.04	2.42	0.67
	CORG 11	0.89	1.99	2.87	0.59
	PLS 361/1	1.13	2.22	3.02	0.70
	SA 1	1.24	2.29	2.69	0.65
21-6-84 (D_2)	CO 5	0.94	1.62	2.40	0.45
	CORG 5	1.02	1.79	2.27	0.51
	UPAS 120	0.87	1.59	1.92	0.58
	CORG 11	0.90	1.98	2.07	0.48
	PLS 361/1	1.11	2.07	2.41	0.52
	SA 1	1.11	1.86	2.62	0.51
21-9-84 (D_3)	CO 5	1.00	1.55	1.82	0.87
	CORG 5	1.00	1.71	1.99	0.71
	UPAS 120	0.78	1.65	1.96	0.66
	CORG 11	1.11	1.89	2.16	0.92
	PLS 361/1	1.16	1.96	1.82	0.90
	SA 1	1.11	2.08	2.24	0.93

Table 33. Stomatal resistance for CO_2 (S. cm^{-1})

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	0.629	0.714	0.850	1.241
	CORG 5	0.646	0.867	0.986	1.207
	UPAS 120	0.680	0.918	1.054	1.360
	CORG 11	0.612	0.765	0.807	1.394
	PLS 361/1	0.612	0.646	1.071	1.411
	SA 1	0.578	0.697	1.360	1.445
21-6-84 (D_2)	CO 5	0.782	0.816	1.037	1.394
	CORG 5	0.629	0.850	0.935	1.462
	UPAS 120	0.459	0.986	1.088	1.445
	CORG 11	0.510	0.833	1.156	1.241
	PLS 361/1	0.697	0.918	1.173	1.513
	SA 1	0.595	0.952	1.292	1.394
21-9-84 (D_3)	CO 5	0.799	0.901	1.207	1.581
	CORG 5	0.816	1.037	1.394	1.513
	UPAS 120	0.663	0.833	1.292	1.428
	CORG 11	0.425	0.765	1.360	1.445
	PLS 361/1	0.612	0.663	1.343	1.462
	SA 1	0.663	0.663	1.411	1.649

Table 34. Photosynthesis (mg. CO_2.dm^{-2}.hr^{-1})

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	16.2	21.9	26.3	9.8
	CORG 5	17.4	22.9	28.6	11.6
	UPAS 120	13.9	19.9	23.0	10.3
	CORG 11	14.9	23.2	25.9	7.9
	PLS 361/1	13.0	20.9	21.8	11.2
	SA 1	13.4	21.6	22.3	10.6
21-6-84 (D_2)	CO 5	13.2	19.6	22.8	11.7
	CORG 5	14.1	21.6	25.4	13.9
	UPAS 120	12.6	18.4	22.0	12.8
	CORG 11	14.0	21.7	23.7	10.2
	PLS 361/1	14.0	20.4	21.6	11.8
	SA 1	15.3	19.5	21.9	12.3
21-9-84 (D_3)	CO 5	9.2	17.5	21.6	12.0
	CORG 5	8.6	18.3	22.3	13.3
	UPAS 120	10.1	15.6	19.8	14.6
	CORG 11	11.2	17.5	20.1	12.6
	PLS 361/1	13.6	14.9	19.7	12.3
	SA 1	10.7	16.8	20.3	13.3

Table 35. Stomatal resistance (water vapour) ($S.cm^{-1}$)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	0.37	0.42	0.50	0.73
	CORG 5	0.38	0.51	0.58	0.71
	UPAS 120	0.40	0.54	0.61	0.80
	CORG 11	0.36	0.45	0.51	0.82
	PLS 361/1	0.36	0.38	0.63	0.83
	SA 1	0,34	0.41	0.30	0.85
21-6-84 (D_2)	CO 5	0.46	0.48	0.61	0.82
	CORG 5	0.37	0.50	0.55	0.86
	UPAS 120	0.27	0.58	0.64	0.85
	CORG 11	0.30	0.49	0.68	0.73
	PLS 361/1	0.41	0.54	0.69	0.89
	SA 1	0.35	0.56	0.76	0.82
21-9-84 (D_3)	CO 5	0.47	0.53	0.71	0.93
	CORG 5	0.49	0.61	0.82	0.89
	UPAS 120	0.39	0.49	0.76	0.84
	CORG 11	0.25	0.45	0.80	0.85
	PLS 361/1	0.36	0.39	0.79	0.86
	SA 1	0.39	0.39	0.85	0.97

Table 36. Transpiration rate ($\mu g. cm^{-2}.s^{-1}$)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	39.74	40.89	43.26	19.61
	CORG 5	46.42	44.85	45.16	21.45
	UPAS 120	47.21	48.91	47.31	22.60
	CORG 11	46.40	47.96	48.40	31.66
	PLS 361/1	44.10	45.31	47.61	27.60
	SA 1	43.20	44.62	46.91	24.85
21-6-84 (D_2)	CO 5	36.23	37.21	37.50	22.81
	CORG 5	37.17	38.26	39.21	24.85
	UPAS 120	36.87	38.92	38.98	27.43
	CORG 11	39.97	40.24	39.54	28.37
	PLS 361/1	36.30	36.60	37.26	29.14
	SA 1	36.50	37.40	33.32	30.14
21-9-84 (D_3)	CO 5	39.97	32.47	30.80	20.84
	CORG 5	37.63	33.74	30.67	20.85
	UPAS 120	37.47	32.40	30.73	22.45
	CORG 11	37.17	39.00	31.36	18.17
	PLS 361/1	35.10	36.00	30.29	23.19
	SA 1	34.93	30.21	28.80	19.67

Table 37. Leaf water potential (- bars)

Treatments (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	- 9.2	-11.8	-14.5	-16.1
	CORG 5	-11.1	-12.6	-16.5	-18.3
	UPAS 120	-10.5	-12.0	-15.9	-17.6
	CORG 11	- 9.2	- 9.8	-12.6	-14.1
	PLS 361/1	- 8.6	- 9.4	-13.1	-13.6
	SA 1	- 7.1	- 8.6	-11.7	-12.9
21-6-84 (D_2)	CO 5	- 7.8	- 9.6	-10.6	-13.4
	CORG 5	- 8.0	- 9.0	-10.3	-12.6
	UPAS 120	- 7.8	- 8.4	- 9.6	-13.1
	CORG 11	- 6.4	- 7.9	- 9.2	-10.3
	PLS 361/1	- 6.8	- 7.6	- 8.9	-11.2
	SA 1	- 5.6	- 8.0	- 9.1	-10.1
21-9-84 (D_3)	CO 5	- 3.8	- 5.8	- 7.1	-10.6
	CORG 5	- 4.0	- 6.1	- 8.3	-11.2
	UPAS 120	- 3.6	- 5.4	- 9.1	-13.1
	CORG 11	- 2.9	- 4.6	- 7.1	- 9.7
	PLS 361/1	- 3.1	- 5.1	- 6.4	-10.0
	SA 1	- 2.5	- 4.[illegible]	- 5.6	- [illegible].6

Table 38. Leaf temperature (°C)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50% flowering	Harvest
21-2-84 (D_1)	CO 5	31.8	30.5	30.0	33.6
	CORG 5	31.5	31.8	32.0	32.5
	UPAS 120	33.3	31.9	31.6	34.0
	CORG 11	30.1	29.8	29.0	32.1
	PLS 361/1	30.5	30.0	29.4	33.3
	SA 1	29.6	28.7	29.0	31.9
21-6-84 (D_2)	CO 5	33.8	30.8	31.6	34.5
	CORG 5	32.6	29.4	28.6	33.6
	UPAS 120	31.9	29.8	30.1	33.4
	CORG 11	34.0	28.4	27.6	34.3
	PLS 361/1	31.6	26.4	27.1	32.9
	SA 1	31.0	27.6	28.0	31.6
21-9-84 (D_3)	CO 5	28.0	27.6	25.6	30.6
	CORG 5	29.7	27.5	25.3	29.7
	UPAS 120	29.4	27.6	26.7	30.2
	CORG 11	29.8	25.9	25.4	29.0
	PLS 361/1	27.0	24.9	25.6	28.6
	SA 1	26.9	25.8	24.8	29.2

Table 39. Leaf relative humidity (per cent)

Treatment (Date of sowing)	Cultivars	Stages (Days after sowing)			
		50	First flowering	50 % flowering	Harvest
21-2-84 (D_1)	CO 5	28.0	27.6	30.2	32.0
	CORG 5	28.4	27.2	33.4	21.9
	UPAS 120	28.8	27.0	31.6	20.6
	CORG 11	27.6	30.8	31.7	19.9
	PLS 361/1	25.4	31.6	31.9	18.7
	SA 1	29.6	30.6	30.9	24.3
21-6-84 (D_2)	CO 5	28.5	28.9	24.5	22.6
	CORG 5	27.6	28.6	23.7	23.0
	UPAS 120	25.4	27.4	25.6	23.0
	CORG 11	30.0	31.6	28.2	25.4
	PLS 361/1	29.8	30.6	29.0	22.6
	SA 1	31.8	32.3	29.6	27.6
21-9-84 (D_3)	CO 5	30.4	32.6	31.7	27.3
	CORG 5	36.8	38.9	42.4	23.8
	UPAS 120	34.8	37.6	40.6	27.9
	CORG 11	29.6	32.3	37.6	24.9
	PLS 361/1	28.9	34.6	35.3	23.9
	SA 1	31.8	33.3	34.6	29.3

Table 40. Nitrogen uptake (g. plant^{-1})

Treatment (Date of sowing)	Cultivars	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf	Total uptake
	CO 5	1.227	0.185	0.345	0.144	0.0210	0.114	2.036
	CORG 5	1.441	0.154	0.340	0.218	0.0216	0.127	2.297
21-2-84 (D_1)	UPAS 120	0.957	0.108	0.171	0.134	0.0144	0.132	1.516
	CORG 11	5.540	0.576	3.127	6.701	0.477	0.390	16.892
	PLS 361/1	6.256	0.462	3.719	6.133	0.639	0.547	17.756
	SA 1	6.141	0.518	3.251	10.042	0.436	0.462	20.850
	CO 5	0.997	0.151	0.169	0.044	0.0065	0.095	1.463
	CORG 5	1.044	0.202	0.179	0.049	0.0104	0.102	1.616
21-6-84 (D_2)	UPAS 120	0.813	0.155	0.052	0.022	0.0025	0.114	1.1585
	CORG 11	1.765	0.217	0.400	0.816	0.0529	0.340	3.5909
	PLS 361/1	1.829	0.140	0.572	0.798	0.0645	0.330	3.7245
	SA 1	1.192	0.212	0.458	0.799	0.0490	0.299	4.009
	CO 5	0.387	0.124	0.078	0.027	0.0027	0.059	0.6777
	CORG 5	0.528	0.146	0.061	0.037	0.0031	0.061	0.8361
21-9-84 (D_3)	UPAS 120	0.305	0.113	0.077	0.020	0.0024	0.067	0.5444
	CORG 11	1.255	0.197	0.267	0.296	0.0110	0.151	2.177
	PLS 361/1	0.890	0.129	0.229	0.216	0.0111	0.199	1.6741
	SA 1	1.205	0.162	0.300	0.369	0.0174	0.184	2.3174

Table 41. Phosphorus uptake (g. plant^{-1})

Treatment (Date of sowing)	Cultivars	Seed	Pod wall	Leaf	Stem	Root	Fallen leaf	Total uptake
	CO 5	0.148	0.028	0.046	0.061	0.006	0.011	0.300
	CORG 5	0.138	0.034	0.035	0.071	0.008	0.013	0.299
21-2-84 (D_1)	UPAS 120	0.094	0.016	0.018	0.036	0.006	0.014	0.184
	CORG 11	0.594	0.138	0.438	2.54	0.155	0.042	3.307
	PLS 361/1	0.607	0.143	0.472	2.97	0.220	0.041	4.453
	SA 1	0.597	0.146	0.452	2.60	0.135	0.054	3.984
	CO 5	0.085	0.024	0.021	0.017	0.0018	0.010	0.1568
	CORG 5	0.091	0.028	0.019	0.019	0.0026	0.008	0.1676
21-6-84 (D_2)	UPAS 120	0.064	0.027	0.005	0.008	0.00088	0.0094	0.1143
	CORG 11	0.158	0.046	0.044	0.179	0.014	0.026	0.309
	PLS 361/1	0.156	0.036	0.073	0.228	0.014	0.028	0.535
	SA 1	0.159	0.060	0.064	0.208	0.013	0.029	0.535
	CO 5	0.032	0.021	0.007	0.007	0.00067	0.0047	0.0724
	CORG 5	0.045	0.020	0.006	0.008	0.00090	0.0046	0.0845
21-9-84 (D_3)	UPAS 120	0.022	0.021	0.004	0.003	0.00074	0.0048	0.0555
	CORG 11	0.104	0.040	0.024	0.046	0.0051	0.0077	0.2248
	PLS 361/1	0.079	0.028	0.027	0.037	0.0038	0.0110	0.1858
	SA 1	0.104	0.047	0.043	0.063	0.0044	0.0129	0.2743