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Effect of Sowing Times on Growth and Yield of Blackgram (Phaseolus Mungo L.)

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EFFECT OF SOWING TIMES ON GROWTH AND YIELD OF BLACKGRAM (*Phaseolus mungo* L.)

A THESIS SUBMITTED FOR THE DEGREE
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SUBMITTED
BY

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CROP PHYSIOLOGY LABORATORY
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Dedicated
To My
Beloved Mother
and
Departed Father and Father-in-law

DECLARATION

I Md. Obaidullah hereby declare that the whole of the research work now submitted as thesis entitled **"Effect of sowing times on growth and yield of blackgram (*Phaseolus mungo* L.)"** for the degree of Doctor of Philosophy of the University of Rajshahi, is the result of my own investigation.

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CERTIFICATE

This is to certify that Md. Obaidullah, Department of Botany, University of Rajshahi has carried out his original research work under my supervision for the degree of Doctor of Philosophy.

I wish him every success in life.

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Alam.
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The author

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ABSTRACT

An experiment was conducted to study the effect of sowing times on growth and yield of blackgram (*Phaseolus mungo L.*). Four varieties of blackgram viz., BARIMASH-1, BARIMASH-2, BARIMASH-3 and LOCAL VARIETY B-10 were used in the study. Seeds were sown on four different sowing times viz., 01 August (S_1), 11 August (S_2), 21 August (S_3) and 31 August (S_4) over two seasons during the kharif-2 monsoon under field conditions.

The S_3 (21 August) plants had the highest TDM than the other sowing and LOCAL VARIETY B-10 showed the highest TDM at all the sowings. Leaf area index (LAI) and leaf area duration (LAD) at most of the growth stages were found the highest in S_1 (01 August) in both the years. Among the varieties, the highest LAI and LAD were observed in LOCAL VARIETY B-10 in both the years.

CGR, RGR, RLGR, NAR, SLA and LWR at most of the stages were observed higher values in S_3 plants (21 August sowing) whereas higher values in LAR was found in S_1 of all the sowings and varieties in both the years. The highest values of CGR, RGR, RLGR, LAR, SLA and LWR were found in LOCAL VARIETY B-10 whereas NAR showed better performance in BARIMASH-3 variety in both the years. Therefore, most of the growth attributes were higher in S_3 (21 August sowing) and LOCAL VARIETY B-10 in both the years.

Among the growth attributes, TDM, LAI, LAD and CGR increased with increasing plant age and then decreased gradually in both the years. Again, RGR, LAR, RLGR and LWR declined with increasing plant age. With few exceptions, NAR showed increasing tendency towards the later stages of growth. Only SLA showed increasing tendency at the middle stages of growth in both the years.

At the early growing periods, mean air temperature (maximum and minimum) were higher and then declined upto the final harvest. So, S_1 (01, August) had the highest air temperature and the lowest in S_4 (31, August) than that of the middle growth stages in both the years. The lowest sunshine hours were observed during S_1 growing period and the highest in S_4 in both the seasons.

Significant sowing time and varietal effects were found for most of the phenological characters in both the years. Most of the phenological characters were observed higher values in S_4 sowing (31 August) followed by the optimum sowing S_3 (21 August) and showed their highest values in LOCAL VARIETY B-10. Days taken for attainment of most of the phenological stages were higher in S_3 and LOCAL VARIETY B-10 required the highest number of days for attaining the different phenological stages. The requirement of heat units (GDD) at all the stages were significantly higher in S_4 followed by S_3. The LOCAL VARIETY B-10 accumulated the highest heat unit (GDD) at most of the stages for all the sowings. The requirement of helio-thermal unit (HTU) at most of the stages were highest when the crops were sown in S_4 (31 August) followed by S_3. HTU was observed higher values in LOCAL VARIETY B-10 of all the sowings at most of the stages. Pheno-thermal indices (PTI) during the different phenological stages were highest in S_4 followed by S_3 in both the years. At all the stages, PTI values were highest in BARIMASH-3. The plants of S_3 used heat more efficiently than the other sowings and the highest HUE was observed in LOCAL VARIETY B-10 which was followed by BARIMASH-2 in both the years.

Sowing time was always significant for chlorophyll a, b and total chlorophyll and chlorophyll a:b ratio and significant varietal effect was observed for chlorophyll b of matured green leaves. The S_1 plants contained more chlorophyll a, b and total chlorophyll and chlorophyll a: b

ratio was observed for highest in S_4 than the other sowings and BARIMASH-1 produced the highest chlorophyll a, b and total chlorophyll and LOCAL VARIETY B-10 produced be highest chlorophyll a : b ratio in both the years.

The highest RLWC was recorded in S_1 plants at 8.00 a.m. For all the sowings, it was higher at the morning (8.00 a.m.) and got reduced at 12.00 noon and showed some recovery at the afternoon (4.00 p.m.) in both the years. The highest RLWC was observed in BARIMASH-3 followed by LOCAL VARIETY B-10 at 8.00 a.m. and lowest in BARIMASH-2 for most of the cases in both the years.

Among the yield and yield components, significant sowing time and varietal effects were observed at most of the characters in both the years. Most of the yield characters were found higher in S_3 (21 August) sown crops in both the years. Among the varieties, most of the characters showed their higher values in LOCAL VARIETY B-10 followed by BARIMASH-3 in both the years respectively.

Simple correlation co-efficient between yield and yield components indicated that grain yield of all the sowings was positively correlated with total dry matter (TDM) plant^{-1}, pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1} and grain weight plant^{-1} except 3rd sowing whereas it was negatively associated with 100-seed weight and harvest index.

It was suggested that for better growth and yield performances, seeds of blackgram should be sown on 3rd week of August (21 August) in the northern part of Bangladesh. LOCAL VARIETY B-10 may be considered as more widely adapted variety for this region.

CHAPTER 1

INTRODUCTION

Protein malnutrition has been of great concern in the most of the developing countries including Bangladesh for balanced diet. Optimum protein is very much essential in our daily food with other components. Statistically and from the economic point of view this protein requirement is mainly maintained from the 'green world' i.e. from pulses and then from animal source. So, pulses are second in importance next to cereals as a source of human food. Pulses occupy the most important place in the daily diet of the people of Bangladesh. The diet of more than 80% people of our country lacks protein, vitamin, calcium and result in malnutrition. Pulses contain 20 to 25% of proteins, which is double of that found in wheat and three times that found in rice. Cereal grain and legumes are the major sources of energy and protein for a large portion of the world's population (NAS, 1975). In terms of quantity cereals occupy the first place as sources of energy and protein and grain legumes are the next (Salunkhe *et al.* 1982). Grain legumes are cheaper sources of protein compared with animal protein in developing countries (Singh and Jambunathan, 1991).

Pulses are one of the most important crop groups that have been cultivated by human beings since the first ages of history. Pulses are defined by the Food and Agricultural Organization (FAO) of the United Nations as annual leguminous crops yielding from one to twelve grains or seeds of variable size, shape and colour yielding within a pod. From the very ancient time the major pulses in the country are lentil, chickpea, mungbean, blackgram, cowpea and pigeonpea etc. Blakcgram is one of the most important pulse crops which is cultivated successfully in a wider range of climate in Bangladesh. About 10.5% of pulses are obtained from blackgram in our country. Pulse is the cheapest source of protein. It contains adequate quantity of protein such as in blackgram 25-26%, in mungbean 23.6%, in cowpea 28.2%, in lentil 25% in pigeonpea 22.5% and chickpea 17.1% .

Blackgram (*Phaseolus mungo* L. synonyms: *Vigna mungo* L.) is a tropical leguminous plant which belongs to the Asiatic *Vigna* species along with *Vigna radiata, Vigna trilobata, Vigna aconitifolia* and *Vigna glabercence.* It is also known as urdbean, mash, blackmaple etc. It is another important short duration pulse crop grown in many parts of the country. In many countries of the world blackgram is regarded as the national vegetative protein food / crop. It is the world's major source of vegetative protein, carbohydrate, vitamins and minerals. It has been cultivated in many countries all over the world, mainly in South western Asia, Egypt, Europe and adjacent regions (India, Pakistan, Bangladesh, Myanmar, Sri Lanka, Nepal, Afganistan and China). Blackgram is said to be one of the oldest pulses known and cultivated from ancient times both in Asia and Europe. Its probable place of origin lies in south western Aisa. Presently blackgram is successfully cultivated in various districts of Bangladesh. It is grown in various agro-ecological conditions and cropping systems with diverse agricultural practices.

Blackgram is basically a hot season crop exhibiting tolerance to higher temperature and susceptibility to cold and frost. In the northern part of Bangladesh, where the temperatures during winter are quite low, it is cultivated only during the rainy season. Despite of slight variation in temperature, optimum date of sowing during different seasons depending on agroclimatic zone, variety and soil conditions. Recently blakcgram has been cultivated also in summer season in India. Sowing between mid June to mid July is found to be optimum time for Kharif season (Chaudhary *et al.* 1988, Phogat *et al.* 1989, Sharma *et al.* 1990, Venkateswarlu and Rajan 1991). Early planting in the first week of July results in higher yield and any delayed sowing beyond this date causes reduction in yield. The optimum time for sowing the summer crop is March (Gupta and Lal 1989, Chakor and Rana 1992 and Sekhon *et al.* 1993). For Kharif-2 crops sowing during mid August to mid September (post rainy season) results in higher yield (Saharia 1988).

Blackgram (Mashkalai) is the 4th pulse crop among the pulses of Bangladesh and an annual, herbecious and self polinated pulse crop and one of the important grain legumes in the rainfed farming system in dry and intermediate zones of the world on the basis of total grain production. In Bangladesh, it is grown as Kharif crop in medium high land areas, mainly in the north / north-southern part of the country. About 80% of blackgram crop is cultivated during Kharif-2 monsoon as upland crop after the harvest of aus paddy or jute without irrigation. Blackgram is normally sown in the 1st week of August to 2nd week of September and harvested in the beginning of November to early December. So, the short season pulse requires 90-120 days to complete its life cycle. This sowing time depends on the weather condition, topography, soil and the harvesting time of the preceding crops i.e. the cropping pattern of the country. In Bangladesh, blackgram is grown under rainfed, low moisture and fertile conditions in most of the area. The performance of blackgram under this condition is determined by the low soil moisture and high rainfall received during the growing season. So, irrigation is not needed for its successful production especially for the selected varieties of blackgram. Growing of a suitable variety at an appropriate time is essential for ensuring maximum crop productivity and that is why sowing time needs to be adjusted so that the crop germinates well and utilize the soil moisture stored in the soil profile efficiently for initial growth and development. Air temperature, sunshine hour and rainfall during the growing season of blackgram greatly affects it performance. The early sown blackgram plants suffer by excessive soil moisture resulting in seedling damage, fertilizer leaching and long vegetative period. On the contrary, late sown blackgram experiences low temperature at the vegetative phase and as a result various physiological processes decrease. High temperature reduces duration of pod filling period and crop productivity. A comparison of the various agro-climatic indices revealed that accumulated growing degree days (heat units) can be used in the best index to predict different phenological stages of blackgram. For this reason, appropriate sowing time is necessary for ensuring better growth and yield performances of blackgram.

Productivity of blackgram in Bangladesh is low which is not sufficient for the demand and unstable compared to that of wheat or rice. The major constraints of productivity of blackgram in general have genetically low yield potential (particularly the indigenous). It is sensitive to excess water, fertilizer and often show negative response to these factors and have more disease and pest problems than cereals do. Blackgram is tropical crop and tolerates high temperatures (upto 42°C) and can be grown in areas receiving 650 mm rainfall or less. It can be cultivated in most of the soils ranging from light red, red loam, sandy loam, alluvial to heavy clay with pH 7.5 but it performs better in the heavier soils having good water holding capacity.

Seeds are more important than the other dry seeds for its low water content. It is also more sensitive to climate factors such as excess soil moisture, humidity and rainfall, terminal heat stress, and soil factors, when compared with cereals, and receive little attention from farmers with respect to adequate land preparation, fertilization, timely sowing, weeding and plant protection. These constrains on blackgram production result in lack of proper management and unstable production levels.

Environmental factors during the developmental phases might be major constraints of blackgram yield in our country. A high yield of any crop can be achieved only when a proper combination of variety, environment and agronomic practices is obtained. Plant breeders are trying to breed higher yielding varieties, which are better adapted to the local environments. It would be immense help to breeder. In this quest for improved varieties to identify the various morphological and physiological factors governing growth and development such factors are important in affecting the yield of seeds. Detailed information regarding the relationship between the duration of a particular developmental stage and seed yield is currently lacking in blackgram in the context of Bangladesh.

Temperature plays an important role in all aspects of plant growth and development (Went, 1953). The minimum growth temperature of blackgram in Bangladesh is about 25°C and the maximum about 33°C. The accumulated heat unit (AHU) system which is based on the idea that plants have a definite temperature requirement before they attain certain phenological stages have a significant relationship with temperature, plant growth and phenological development of a crop. The heat unit system was adopted for determining the maturity dates of different crops (Bierhuizen, 1973 and Nuttonson, 1955).

However, the phenology and ambient temperature interaction in blackgram under late sown field conditions not yet studied in Bangladesh. In the present study, the effect of ambinet temperature on the phenological development of blackgram grown under field conditions was studied employing two methods for computing AHU. Besides the growing degree days (GDD). another unit, helio-thermal unit (HTU) was also incorporated using the AHU system a phenothermal index (PTI) was suggested (Chakravarty and Sastry, 1983) to relate the crop phenology with ambient temperature condition.

The present investigation was undertaken to study the effect of sowing times on growth and yield of blackgram (*Phaseolus mungo* L.) grown under kharif-2 season. Physiological studies are important in evolving a suitable plant type that can ensure maximum yield in a given environment. The present experiment was undertaken to obtain such information.

- To find out the variability of different growth attributes, grain yield and yield components of blackgram varieties under different sowing times.
- To observe the variability of different phenological traits of blackgram varieties under different sowing times.
- To observe the variability of chlorophyll and relative leaf water content of blackgram varieties.
- To select suitable variety and sowing time for the northern region of Bangladesh.

CHAPTER 2

REVIEW OF LITERATURE

The success of any crop improvement program requires adequate knowledge on most important traits of the crop studied. Such as physiological traits, morphological traits, agronomic traits etc. Crop production is closely related to the adequate supply of soil moisture, optimum temperature and different levels of plant nutrients. So, appropriate sowing time is necessary for optimum growth and productivity.

Sowing time of blackgram crop is not critical in Bangladesh, where the better performance is observed in Kharif monsoon. Sowing of blackgram is generally delayed beyond its optimum time due to late harvest of aus rice or jute. Delayed sowing results in an unusual change in physiological processes brought about by one or a combination of the environmental factors. As a result, it affects vegetative as well as reproductive growth by causing early maturity of the crop and finally reduction of yield and yield components occurs. Some related literatures are reviewed here under the following heads:

Growth and Development

Among the pulse crops blackgram is very sensitive to the environmental condition e.g. temperature, sunshine hour, rainfall and humidity during its growth and developmental period. Temperature, sunshine and rainfall plays an important role in all aspects of plant growth and development. Available literature reveals that an unfavorable environmental condition reduce plant growth activities.

Pandey *et al.* (1978) made a comparative study of growth parameters of 5 genotypes of blackgram (*Vigna mungo* L.) and reported that the differences in leaf area among the genotypes were significant at 42, 49 and 56 days after sowing. The rate of increase in leaf growth was higher early in the season and tended to decrease later. Significant genotypic difference in CGR appeared at 49 and 56 DAS. Genotypic differences in LAR were significant at all the stages of growth. A negative relationship was found between NAR and SLA.

Lawn (1979) conducted agronomic studies on *Vigna* spp. in south-eastern Queensland. He observed that 16 cultivars showed substantial response to sowing date, with highest total dry matter (TDM) and seed yield for December sowing. Delayed sowing reduced growth such that for late February sowings, total DM at maturity and seed yields were generally less than one-tenth of the maximum. Harvest index revealed an optimum type response to sowing date with highest values for late December/early January sowings. He also observed that seed yield and total dry matter (DM) at maturity were highest in blackgram and lowest in the adzuki beans. Within species, vegetative development was generally higher in the late maturing cultivars but the same was not true for seed yield. Harvest index was negatively associated with cultivar maturity both in the grams and adzuki beans.

Kalubarme and Pandey (1979) observed that CGR was very slow in (*Vigna radiata*) during the early vegetative phase thereafter increased with the advancement in the growth period in all the genotypes. The highest RGR was found at the early phase and then declined rapidly in most of the varieties. Maximum NAR was found in the early phase and then fluctuated. SLA was initially low and slowly increased with the advancement of time. Non-significant genotypic differences were observed for NAR and RGR, but significant for CGR.

Abdel-Raouf *et al.* (1983) carried out an experiment to find out the associations between growth attributes of barley and grain yield under different seeding dates. They observed that plant height, dry weight, leaf area and LAI of 7-week old plants decreased with delay in sowing date. Highest CGR and RGR of 7 to 14-week old plants were obtained by sowing on 5 December. After 15-17 week the highest values were obtained by sowing on 15 November. Grain yield was positively correlated with plant height at all the growth stages. DM accumulation, leaf area and LAI at the latest growth stage were negatively correlated with RGR and NAR.

Kirby *et al.* (1985) studied the effect of sowing date and variety on main shoot leaf emergence and number of leaves of barley and wheat. They found that the final number of leaves per plant decreased with advance in sowing date, except for the winter varieties with the last date, when the number rose. Differences in final number of leaves were observed among the varieties and there was a strong variety x sowing date interaction, which was attributed to differences in vernalization response. Leaf emergence rate rose with the delay in sowing date in both crops, and differences in the rate were observed among the varieties, although there was no marked variety x sowing date interaction. In both crops, winter varieties tended to have higher rate. Rate of leaf emergence was correlated with rate of change of daylength at different sowing dates.

Kanani and Jadan (1985) carried out an experiment on the variability for high temperature tolerance in bread wheat and to identify suitable genotypes during early growth period. They sowed 110 genotypes of wheat on 5 October as an early and 15 November as a normal sowing and recorded days to flowering, tillers/plant, grains/spike, grain weight / spike, 1000-grain weight and grain yield/plant. They reported that 18 genotypes from the 110 genotypes had tolerance to high temperatures. They also reported that ‘Hindi 62’ gave twice as much yields in early sowing as in normal sowings. They found that C 306 and ‘K 65’ were old varieties still well grown on rainfed condition. They had high grain weight with good tillering when sown early.

Johansen *et al.* (1985) worked on *Corchorus capsularies* and *C. olitorius* and observed that dry matter accumulation of both genotypes was exponential for 40-50 days from sowing with relative growth rate (RGR) of 0.14-0.20 gg^{-1} day^{-1} for `D-154’ and about 0.20 gg^{-1} day^{-1} for ‘0-4’. RGR declined markedly and continued at a low rate until the final harvest at up to 174 days. The decline in RGR coincided with the onset of the monsoon period.

Saini and Dadhwal (1986) worked on grain growth duration and kernel size in wheat as influenced by sowing dates. They found that when Kalyansona and Sonalika varieties of bread wheat (*Triticum aestivum*) and HD 4502 variety of macaroni wheat (*Triticum aestivum*) were grown in temperature between 13 and 27°C. Grain growth in temperatures between 13 and 27°C the grain growth duration from anthesis to maturity declined by 26 days for every 1°C rise in temperature. The photoperiod effects on the grain growth duration from anthesis to maturity were found to be negligible. For every 1°C rise in temperature, kernel weight declined by 2.5 mg in Sonalika, by 1.58 mg in Kalyansona and by 1.9 mg in HD 4502 which corresponded to a decline of about 3.8% (HD 4502) to 4.5% (Kalyansona and Sonalika) of their maximum predicted kernel weight of 16°C.

Salam *et al.* (1987) studied different parameters for growth analysis such as LAI, CGR, RGR, NAR, LAR, SLW and their interrelations to grain yield of five cultivars of mungbean. Among all the cultivars, LAI was highest in 6601. CGR values had been found to be maximum at the stage of pod maturity in all the cultivars studied. They occupied the 1st and 2nd position in grain yield respectively. A strong positive correlation between the total dry matter and grain yield had been observed following their positive correlation with LAI values.

Khandkar *et al.* (1990) studied the comparative growth analysis of jute varieties. They reported that growth curves on dry matter accumulation and distribution in *Corchorus capsularis* (Var. D-154, CVL-1, CVE-3, CC-45 and Dhabdhabey) and in *C. olitorius* (Var. 0-4, 0-9897 and Chaitali) have been constructed. The dry matter accumulation was exponential upto 60 days in all the varieties which declined thereafter and continued at a lower rate. The bark formation reached about 25% of the total dry weight by 60-75 days in most of the varieties and maintained a slow increase in rate during the remaining growing period. The stick development received the major portion of the metabolite produced during the growing period after 45 days RGR, NAR, LAR and RLGR in all the cultivars were highest at their stages of growth and then declined with the advancement of age. The results showed low physiological variability among varieties except in 0-9897 which showed a higher RGR trend supported by its higher LAR values in the mid growing period.

Lopez-Castaneda and Richards (1994) observed that barley achieved a higher grain yield and biomass in a shorter duration than the other species. It reached physiological maturity about 10 d (180 thermal units) before the other species, and reached double ridge and anthesis earlier. They also observed that barley and triticale developed a greater leaf area and DW faster than the wheat and oats. The difference in leaf area was established from the time the 1st leaf had fully expanded. Barley also developed main stem leaves and tiller faster than the other species. They found that CGR was greatest in barley and triticale up to anthesis, but no differences between species were found in their RGR. The growth rates of individual grains and of total grain per unit ground area were substantially greater in barley than the other species The change in stem weight between anthesis and physiological maturity, which was determined to assess the possible contribution of stem reserves to grain, was also positively associated with grain yield at the 2 sites where it was determined, and more so at the drier site. The change in stem weight averaged 76 g/m^2 at the 2 sites and this represented 25 of total grain yield. However, the range varied from 13 to 39% of grain yield. The loss in leaf sheath weight averaged 68 g/m^2 at both sites; this was not associated with grain yield.

Samanta *et al.* (1997) studied the different growth stages and yield of proso-millet cultivars as influenced by sowing date. The showed four proso-millet cultivars viz., Kumadhan, BPM-24, BPM-40 and Tuher on five dates starting from 15 November at an interval of 15 days at BAU Farm mymensingh. They observed that sowing at 15 November took the highest number of days for attaining various growth stages and thereafter decreased with delayed sowing. Among the cultivars, Kumardhan took the highest number of days for attaining various stages of growth. They reported that LAI was maximum at 50% flowering in all the cultivars and decreased sharply at 15 days after flowering (DAF) and LAD had similar trend as the LAI. The rate of dry matter accumulation gradually increased upto 15 DAF and then declined due to leaf sencscence in all the cultivars and sowings.

Grain yield was significantly higher on 15 November sowing followed by 30 November than the other sowing due to shorter growth period and higher ambient temperature during the grain filling stage. The cultivar Kumardhan produced the highest number of leaves, LAI, LAD, TDM and grain yield (2.06 t ha^{-1}) on 15 November sowing followed by 30 November sowing.

Hussain *et al.* (1997) studied the growth and yield of chickpea crop grown at different sowing dates and plant population. Total dry matter production was strongly correlated both with total and post-flowering leaf area duration. However, seed yield was poorly related with leaf area duration. Early sowing or higher plant population accumulated more TDM because of greater leaf area indices and thus greater LAD than the late sowing and lower plant populations. Thus early sowing enabled with increased populations of enhance CGR, which resulted in higher yields than late sowing or low plant populations.

Yasmin *et al.* (2000) studied the effects of time of sowing and varieties on the yield of cotton seed. The experiment consisted of two factors-1) three sewing dates viz., 27 August, 16 September and 6 October, 1996 and 2) six varieties viz., A/92-B, DPL-20, DPL-50, DPL 51, BC-038T and $S_1/9_1/646$. Plant height, leaf area index, total dry matter production and crop growth rate showed significant variability due to the effect of sowing date, variety and their interactions. The highest cotton seed yield (2099.08 kg ha^{-1}) was recorded when the seeds were sown on 27 August and the variety $S_1/9_1/646$ performed the best (2116 70 kg ha^{-1}). It was also showed that the variety $S_1/9_1/646$ when sown on 27 August produced highest yield of cotton seed.

Dapaah *et al.* (2000) studied the growth and yield of pinto beans (*Phaseolus vulgaris* L.) cv. Othello in response to a total of six sowing dates (from October to December) and irrigation over two seasons. In 1994/95, two irrigation treatments (nil and full) were combined with two sowing dates (27 October and 24 November). In 1995/96 Othello was examined under two irrigation treatments (nil and full) and four sowing dates (1 November, 15 November, 29 November and 13 December). Both irrigation and sowing date had a marked effect on growth and yield. Averaged over both seasons seed yield for fully irrigated crops was 337 $gm^{-2,}$ which was 50% higher than the yield of unirrigated crops. The irrigated crops yielded more than the unirrigated crops because they attained greater canopy closure. They also had on the average 47% higher leaf area duration (LAD), 72% higher maximum leaf area index (LAI) and greater utilization coefficient. The mid to late November sown crops yielded more than the late October to early November and December sown crops because the leaf area of the former increased most rapidly and achieved a higher maximum LAI and LAD consequently increased more photosynthetically active radiation (PAR). The also had faster pod growth rates and 26% of stored assimilates contributed to pod growth compared with 13% in late October to early November and 5% in December sown crops.

Biswas *et al.* (2002) carried out an experiment to evaluate the growth and yield performance of two blackgram varieties i.e., BARI mash 3 and BARI mash 1 under three different population densities. The planting configurations were 40×10 cm^2, 30×10 cm^2 and 40×5 cm^2 representing 25, 33 and 50 plants m^{-2}. Both the blackgram varieties showed identical results in LAI, CGR, NAR, RGR as well as grain yield. But planting density had significant effects on LAI and CGR of the blackgram varieties. The highest planting density showed the highest LAI and CGR but the highest grain yield was recorded from intermediate population density due to the highest number of pods per unit area. The NAR and RGR did not differ due to different population densities.

Begum and Paul (2005) studied the effect of time of planting on the growth of two cassava varieties. Total dry matter and leaf area index at most of the growth stages were found highest for 15 May planting (S_3) and lowest for 1 July (S_6). The highest value of crop growth rate was found for 1 June (S_4) and lowest for 1 July (S_6). Net assimilation rate (NAR) and relative leaf growth rate had higher values for 15 April (S_1) but at the later stages of growth NAR had higher values for 15 June (S_5) in Local-1 and for 1June (S_4) in Local-3. Leaf area ratio was higher for 1 June (S_4) in Local-1 and for 1 July (S_6) in Local-3. Simple correlation co-efficient indicated that tuber yield was positively correlated with LAI, CGR, RGR, LAR and LWR.

Paul and Sarker (2005) studied the growth of two wheat cultivars BL 1183 and Kanchan under 4 dates of sowing viz., 1 November, 19 November, 1 December and 15 December. The highest total dry matter was produced in 1 November and then gradually reduced in the subsequent sowings. LAI attained peak at 58-68 days after sowing and declined thereafter in both the cultivars in all the sowings. LAR declined with increase of time but CGR increased to certain peak and then decreased gradually. NAR increased slowly at the early growth stages but sharply at the later stages except BL 1183 in which a decreasing tendency was noted towards the later stages of growth in 1 December sowing only. Simple correlation co-efficient between growth attributes indicated that CGR was positively correlated with total dry matter, LAI and NAR and negatively with LAR. The grain yield in all the four sowing had no significant association with any of the growth attributes.

Aher *et al.* (2006) studied on physiological variation for growth causing yield differences in sixteen diverse genotypes of blackgram conducted during Kharif 2000. TAU-1 and AKU-7 were the high yielding genotypes along with considerable amount of dry matter accumulation upto 50 DAS. Another high yielding genotype UTC-55 had shown better performance for dry matter accumulation along with high magnitude of AGR, PGR and NAR. The rapid increase in AGR at 30-40 days appears due to rapid increase in dry matter accumulation. The high magnitude of PGR was recorded at 40-50 Days after sowing may be due to higher rate of dry matter accumulation towards pod development. The NAR decreased towards pod filling stage and again increased towards maturity may be due to increased efficiencies of leaves owing to higher demand for growing seeds. The LAI increased with the advancing age of the crop upto 60 days after sowing and declined towards maturity due to leaf senescence and heavy demand for reproductive stage.

Khatun and Kundu (2007) carried out an experiment with three cultivars of mungbean (*vigna radiata* L. Wilczek) viz., BARI Mung-5, BARI mung-2 and BINA mung-5 to study the influence of watering on some eco-physiological characters. Watering had no significant effect on chlorophyll content and leaf stomatal characters but had significant effect on relative turgidity and transpirational characteristics. Relative turgidity and rates of transpiration were always higher in the well watered plants. But relative leaf water content (RLWC) at stomatal closure was lower and time taken to stomatal closure was higher in the well-watered plants. The reverse condition was found in the water stressed plants. Cultivar transpiration was significantly lower in the water stressed plants suggesting increased cultivar resistasnce for avoiding drought during the time of stomatal closure.

Islam *et al.* (2010) carried out an experiment at the Horticultural Farm of the Bangladesh Agricultural Research Institute, Joydebpur, Gazupur, during September 2006 to April 2007 to investigate growth and yield of sweet pepper as influenced by sowing date. There were seven levels of sowing date viz., September 1, September 15, October 1, October 15, October 30, November 15 and November 30. The results of the experiment indicated that the majority of growth parameters and yield components were significantly increased at the earlier sowing (October 1). The highest yield (19.36 t ha^{-1}) of fruit was recorded from the earlier sowing (October 1) with the spacing (50 × 30 cm) which also gave the highest benefit cost ratio (4.58). Considering the yield of fruits per hectare and cost of production and net return, the treatment combinations of October 1 sowing appeared to be recommendable for the cultivation of sweet pepper.

Phenology and Degree-days

Lawn (1979) conducted an experiment on *Vigna* spp. in south-eastern Queensland. He observed that vegetative and reproductive growth of 16 cultivars from four *Vigna* spp. (*V. radiata*, green gram; *V. mungo* blackgram; *V. angularis*, adzuki bean ; and *V. umbellata,* rice been) were studied over a range of sowing dates at Lawes in south-eastern Queensland. Phenological response *per se* was not a useful predictor of the effect of sowing date on yield or total DM for any of the 16 cultivars, since in all cases growth rates varied substantially with sowing date, apparently in response to temperature. The linear form of the Arrhenius equation relating mean growth rate and mean prevailing temperature provided an excellent description of the response of both yield and total

DM accumulation rates over sowing dates for all cultivars. Among the cultivars there was a significant correlation between the slope of the Arrhenius plots (*K* values) for seed yield and total DM accumulation implying similar relative temperature sensitivity for both growth processes. For the 16 cultivars tested, the absolute magnitude of the *K* values for both seed yield and total DM accumulation was significantly negatively correlated with the latitude from which the cultivars were introduced, which implied greater temperature sensitivity for cultivars from the tropics.

Lyall (1980) observed that barley yields in East Midlands in 1971-78 were negatively correlated with mean air temperature, soil temperature and total rainfall during the establishment stage, positively correlated with total rainfall in the vegetative stage and negatively correlated with mean air and soil temperature, sunshine hour, evaporation and humidity after anthesis. Average yields in Scotland in 1971-77 were not significantly correlated with climate, except for a positive correlation with sunshine hour during the vegetative stage.

Wiegand and Cuellar (1981) observed the effect of temperature on grain filling and kernel weight of wheat from the beginning flowering to mealy ripeness of the kernels and predicted grain yield by regression analysis. They stated that grain yields were proportional to kernel weight, which was affected by temperature. They observed the phenology especially anthesis to grain filling duration for two years. The regression of temperature and grain filling duration indicate that 3.1 days of grain filling duration was shortened by every 1°C rise in temperature of daily mean air temperature in the first year and similarly 2.8 days in the 2nd year. They also reported that 2.8 and 1.5 mg kernel weight were decreased by every 1°C rise in temperature of daily mean temperature during grain filling duration for the first year and second year respectively. They concluded that temperatures during grain filling had a detrimental effect on kernel weight when temperatures were in excess of about 15°C. They suggested longer grain filling duration for better kernel weight of wheat.

Stegemann and Kuhn (1981) observed that there were no significant yield differences between sowing dates. In 1977, 1979 and 1980, sowing after 17 September reduced yield. Over the 5 years high yields were obtained when the sum of average daily temperature >5°C between sowing and the end of the year was C. 300. Yields were significantly lower when the temperature sum was 260-280 degree. Yield variability was also influenced by precipitation during the sowing period.

Korovin and Mamaev (1983) studied the effect of lowered temperature on yield and vegetative growth period of oats and barley. They observed that keeping plants at 4, 6 or 8 degree for 5 or 10 days did not affect the grain yield or duration of growth period, but when plants were held at 4 or 6 degree for 15 or 20 days the yield was decreased and the growth period increased. The lower temperature causes a greater yield decrease. The growth and yield period were not affected when plants were subjected to 8 degree for 20 days.

Inagaki and Masuda (1984) observed that 10 representative Japanese varieties grown under a 24 h day, flag leaf emergence advanced with rise in temperature from 5 to 20°C regardless of variety, while varietal differences in number of days to flag-leaf emergence were also observed under short day condition at 20°C. In a combined field and frame experiment, when night temperatures in the frame were 5 and 10°C higher than natural daytime field temperatures, flag-leaf emergence in earlier varieties was more advanced than in the later varieties. In studies of 110 entries under short (11 h) and long (24 h) days at 10 and 20°C after treatment of germinated grains at 1°C for 8 weeks, there were only slight differences in flag-leaf emergence under long days at both temperatures but there were considerable differences under short days. A temperature of 10°C was established as more suitable for detecting differences in daylength sensitivity than one of 20°C.

Chakravarty *et al.* (1984) studied the phenology, biomass accumulation and ambient temperature relationship in eight genotypes of barley. They expressed these relationship through phenothermal index and heat use efficiency. In four barley genotypes, heat use efficiency was computed and found to be in phase with crop growth rate.

Russelle *et al.* (1984) studied growth analysis based on degree-days. They suggested the use of a temperature index such as modified growing degree days as the divisor in growth functions to faciliate treatment comparisons within certain experiments and to reduce effects of differing temperature regimes among experiments on these comparisons. Three experiments were identified to provide data to analyze this new approach. Mean absolute growth rate (CGR) and mean relative growth rate (RGR) were compared in two experiments with maize (*Zea mays* L.). Previously published values of RGR and NAR of barley (*Hordeum vulgare* L.) grown under controlled in a soil temperature study were also evaluated. Use of modified growing degree days rather than days as the divisor in these growth functions led to the recognition of physiological differences due to or associated with treatment.

Metzger *et al.* (1984) studied some genotypes of mid western type barleys in respect of grain filling duration and yield. They showed significant differences among the genotypes for grain filling duration but they failed to direct a yield advantage due to similar maturity. They suggested that grain filling duration was not only yield limiting factor in barley on their circumstances because other factors were concerned on yield potential e.g. temperature, synchronous flowering, height and lodging etc.

Chaturvedi *et al.* (1985) studied the effects of sowing date on the spike characters of mother shoot and various tillers of wheat (*Triticum aestivum* L.). They sowed the seeds of C 306, Kalyansona and Sonalika on 7 dates at an interval of 15 days starting from 01 October. They also studied the phenology and yield components of the main shoot. The duration of phenological phases and the ear differentiation were affected more in Kalyansona than C 306 by a change in photoperiod and temperature. In the early sown plants the difference between main shoot and tillers were negligible for the number of spikelets, grains/spike and grain weight/spike except in Sonalika where grain weight/spike was more in the main shoots. They found that all the attributes of ear of each variety were affected with delayed sowing. The grain weight/spike, grain number/spike and grain yield decreased significantly with the increase of temperature. They reported that Sonalika should be always higher seed rate irrespective of the date of sowings whereas Kalyansona and C 306 had the higher seed rate only in the late sowings.

Ghadekar *et al.* (1985) studied the growth and heat unit accumulation in sorghum hybrids in wet season on the vertisols of Nagpur. They sowed sorghum hybrids of CSH9, CSH5 and CSH1 on 5 different dates viz., 28 June, 5, 12, 19 and 26 July. They observed that the highest TDM, plant height, grain yield, grain number/ear, fodder yield and husk yield were produced when sown on 28 June followed by 5 July and these characters were decreased with further delay in sowing. Among the hybrids, CSH9 was the best as the weather was helpful on that dates. It was observed that the highest heat unit were accumulated by the crop sown on 28 June followed by 5 July for all the phenological stages and further delay in sowing caused a decline in heat unit accumulation.

Puri *et al.* (1985) studied grain yield of barley, wheat and triticale in relation to solar radiation and heat units for 3 years. They used four planting dates (17 April - 7 May) and 4 seeding densities (100-400 seeds m^{-2}) of seven cultivars of barley, wheat and triticale. They computed solar radiation and heat units for each of three growth periods: early vegetative (EVP), early reproductive (ERP) and late reproductive (LRP). They observed that grain yields declined with later sowing dates. They also stated that wheat and triticale were more affected than barley. There was little effect of sowing densities on grain yields. They reported that barley requires less solar radiation and heat units than wheat and triticale to produce maximum grain yield. Higher temperature and lower solar radiation during the EVP appeared to be beneficial for all 3 crops.

Muchow (1985) was examined the comparative responses of phenology, and seed yield and its components to prolonged water deficits in soybean (*Glycine max* cvs. Buchanan and Durack), green gram (*Vigna radiata* cvs. black gram (*V. mungo*), cowpea (*V. unguiculata* cv.) labaab bean (*Lablab purpureus* cv.) and pigeon pea (*Cajanus cajan* cvs. Royes and insensitive) during the dry season in semi-arid tropical Australia. In general water deficits had little effect on the date of flowering but the duration of flowering and pod-filling was reduced and the time to maturity was markedly shortened. Under well-watered conditions seed yields were similar in green gram, cowpea, soybean and pigeon pea, with slightly higher yields being obtained in black gram and lablab bean. In contrast green gram, cowpea and lablab bean produced the highest yield under conditions of water deficit. Early-maturing cultivars yielded better than late-maturing cultivars but inter-species variation in seed yield was not necessary related to phenology. Most of the reduction in yield arose from a decrease in pod numbers although there was some variation in seed size and seeds per pod. In contrast to absolute yield levels the reduction in yield due to water deficits relative to the well-watered situation was with the exception of black gram, greater the later the maturity of the grain legume. Thus the relative reduction in yield was least in green gram followed by cowpea, soybean cv. Buchanan, insensitive pigeonpea and lablab bean with black gram, soybean cv. Durack and pigeon pea cv. Royes having the greatest yield reduction due to water deficits.

Saeed *et al.* (1986) conducted a field experiment to determine the relative contribution of yield components and the effects of environmental factors in two growth period e.g. planting to bloom and bloom to physiological maturity on yield and its components in 46 sorghum hybrids tested in contrasting field environments. They found that the relative importance of seed weight as well as the number of seeds increased from low night temperature was dependent on the length of the grain filling period and the rate of grain filling that affected by growing degree unit (GDU). They reported that GDU in the range of 1250-1350 favoured development of high yields. They stated that low night temperature at the first growth period (planting to bloom) and subsequently high night temperature at the second growth period (bloom to physiological maturity) favoured high yields.

Zhao *et al.* (1986) worked on the influence of sowing dates on growth and development of barley. They observed that, cv.Zhepi 1 sown on 28 October or 7, 17 or 27 November on a silt loam in 1982-83 and 1983-84 had 10-12 leaves on the main stem irrespective of the sowing dates. With delay in sowing, tiller and ear number/10 plants decreased from 64 to 41 and from 49 to 18, respectively and the period from differentiation of outer and inner glumes to heading decreased from 88 to 30 days. The duration from heading to maximum grain weight was 35 days. The increase of grain weight and filling rate were highest at 21-28 days after heading for most of the sowing dates. The full growth period was shortened with delay in sowing.

Saini *et al.* (1986a) studied the influence of sowing dates on pre-anthesis phenology in wheat. They observed the dates of first spikelet initiation, terminal spikelet initiation and anthesis on HD 4502 a semi-dwarf medium duration variety of *Triticum durum* and 3 varieties of *T. aestivum* viz., Hindi 62, at all late flowering variety. Kalyansona a semi-dwarf medium duration variety and Sonalika a semi-dwarf early flowering variety. They found that when sown early or late the initiation of the first and terminal spikelet was hastened and anthesis occurred earlier. HD 4502 was less responsive to sowing earlier. When Hindi 62 was delaying in sowing the duration from sowing to first and terminal spiklet initiation decreased but the period between the first and terminal spikelet initiation did not change much and 8 day delay in sowing reduced the duration from sowing to first spikelet initiation by 1 day.

Saini *et al.* (1986b) studied the thermal and photoperiod effects on phase duration of four wheat varieties (three bread and one macaroni wheat) grown on different dates of sowing. They found that sowing to first spikelet initiation was relatively tolerant but first spikelet to terminal spikelet and terminal spikelet to anthesis phases of growth were most sensitive to changing photoiperiod. They observed that margin differences during the first spikelet to terminal spikelet and a large differences during terminal spikelet to anthesis. When photoperiod and temperature were changed, the duration from terminal spikelet initiation to anthesis declined more on increasing photoperiod but less on increasing temperature in HD 4502 whereas it was declined more on increasing photoperiod in Kalyansona. This later duration declined equally to increasing photoperiod as well as temperature in Sonalika. They found that when sown early or late the initiation of first and terminal spikelet was hastened and anthesis occurred earlier.

Stewart and Dwyer (1987) studied phenological observations on barley using the Feekes scale. They took several approaches to quantify phenological development rates of barley under different growth conditions. First, all stages were expressed as a function of growing degree-days (GDD) with a base temperature of 5°C. Missing phenological observations were then interpreted using a linear technique and an iterative procedure that included information from development rates of replicate plants to calculate the GDD associated with missing stages. Finally a non-linear least squares algorithm was used to fit phenological observation to a function of GDD modified by photoperiod. Statistical analysis of function coefficient provided a quantitative basis for comparison of phenological development rates among the different environments. In addition the non-linear function could be used to predict phenological stage according to the Feekes scale as a function of GDD and photoperiod.

Ye and Weng (1987) studied growth characteristics of barley during grain filling. They observed that the increases in weight of the vegetative and reproductive organs were divided into 4 stages. Even during seed formation at 10 days after heading the vegetative organs still dominated the accumulation of photosynthesis with 22.9% of the total compared with 5.8% in grain. Accumulation decreased in the order leaf blade >stem >leaf sheath. Accumulation and export/unit length of stem were highest in the top internode and decreased in successive internodes down the stem. The development of the grain was divided into 3 stages. Equations were derived to describe the growth of the leaf and stem and seed development.

Gu *et al.* (1987) studied the effect of filling rate and duration on increasing grain weight of barley. They used 6 barley cultivars with or without application of 12.5 kg ammonium sulphate/mu and investigated the relationship between grain weight and rate and duration of grain filling. They expressed the relationship by a curvilinear regression equation. They observed that the effect of filling rate was greater than that of duration and during rapid growth the effect of duration could become negligible. Fertilizer application decreased the limiting effect of rate of filling and the negative interaction between filling rate and filling duration. The relative effect of filling rate was greater in weak than in strong grains. [1mu=0.067 ha].

Rajput *et al.* (1987) studied the influence of planting dates on phenology and heat unit relationships in wheat under late sown conditions. They observed that the requirement of accumulated heat units (AHU) decreased with delayed planting. They computed helio-thermal unit (HTU) as the product of growing degree days with the bright sunshine hours. They also computed phenothermal index (PTI) as the AHU per growth day. They also observed that the HUE was also decreased with delayed planting. The phenothermal index was nearly constant irrespective of planting dates and sites. A regression for predicting the maturity date for wheat crop using heat units accumulated up to flowering initiation was developed.

Bhuiya *et al.* (1987) conducted an experiment to study the growth and development in wheat. They reported that six growth phases and twelve growth stages have been recognized in the life cycle of wheat plant. The significance of these phases and stages of growth has been discussed. The calendar of morphological development of the wheat cultivar Sonalika has been presented. The cultivar Sonalika which was sown on December 4, 1985 required 0-8 days after sowing to complete its germination and emergence, 9 to 30 days for tillering, 31 to 65 days for stem elongation, 66 to 72 days for heading, 73 to 79 days for flowering and 80 to 107 days for the completion of grain formation and ripening phases respectively.

Saini and Nanda (1987) studied the temperature and photoperiodic response in flowering of wheat. They found that marginal changes in temperature as an orthogonal function of photoperiod during each sowing to first spikelet initiation, first spikelet to terminal spikelet formation and terminal spikelet to anthesis did not contribute appreciably in alternating flowering duration of Kalyansona, Sonalika and Hindi 62 bread wheat (*Triticum aestivum* L.) and HD 4502 macaroni wheat (*T. durum* L.). The extent as well as phenological phase of photoperiodic response varried in all the four varieties.

Cao and Moss (1989a) designed an experiment to determine the interaction of temperature and daylength on the leaf phyllochron in winter wheat and spring barley. They worked in growth chamber with all combinations of three temperatures (10, 15, 20°C) and four daylengths (6, 10, 14, 18h) on four wheat and barley genotypes. They stated that wheat and barley had a constant phyllochron at a given temperature and daylength combination. Phyllochron increased as temperature measured or as daylength decreased. They quantified the phyllochron as the thermo/photo ratio (the ratio of daily degree-days to day length). The phyllochron for all the genotypes was linearly related to thermo/photo ratio in all the temperature and daylength combinations. They suggested that cultivar specific coefficients would be necessary to predict cultivar response of phyllochron to the thermo/photo ratio in wheat and barley.

In another experiment, Cao and Moss (1989b) determined the effect of temperature on leaf emergence and phyllochron in wheat and barley. They conducted nine experiments in growth chambers at constant temperatures between 7.5-25°C in four winter wheat and four spring barley genotypes. They recorded the number of leaves per culm from seedling emergence until the fourth leaf was matured. They found that emergence of new leaves was a linear function of time for all the genotypes at a given temperature. They reported that the slope at the linear regression of the leaf emergence rates differed among the genotypes. For all the genotypes, the leaf emergence rates increased parabolically with increasing temperature until an optimum temperature was reached and then declined. They stated that as temperature increased, the phyllochron (degree-days/leaf) increased exponentially. They suggested that the temperature effect must be considered in modelling phyllochron in wheat and barley.

Yang *et al.* (1989) studied the effect of various photosynthetic parts on grain filling and yield of barley. They observed that more than 90% of DM in grains originated from the photosynthetic parts above the least 2 leaves and the rest (10%) from awns. Grain filling rate decreased with the number of photosynthetic parts and reached its peak earlier than in controls. Photosynthates stored in stem was a major source of grain DM during the early filling stage (0-8 d after flowering) that in the parts above the least 2 leaves was a major source during the middle filling stage (9-20 d) and that in the flag-leaf and spike parts was a major source during late filling stage (21-32 d). The photosynthate in functional leaves moved predominantly into grains and decrease of photosynthetic parts was mainly responsible for the loss of yield. They also suggested that it was very important to prevent the senescence of photosynthetic parts and to develop cultivars whose photosynthetic parts above the flag-leaf have high photosynthetic efficiency and a longer functional period.

Dahiya and Narwal (1989) conducted an experiment to study the phenological behaivour and thermal requirement of maize varieties sown on various dates. They worked with 4 varieties viz., Partapi, Ageti 76, Gange 5 and DHM 103 at four different sowing dates starting from 19 December at an interval of 10 days. Growing degree days were calculated using a growth threshold temperature of maize (7°C). They found that the seedlings emerged 11, 12, 13 and 14 days after sowing in maize sown on 19, 29 December and 8, 18 January respectively. They also found that the days to tassel emergence and silking decreased progressively with delay in sowing. The crops sown on 19 and 29 December required less growing degree days for all the phenological phases than those sown on 8 and 18 January. The growing degree days requirement for tassel emergence, silking and maturity was identical in the crop sown on 19 and 29 December, whereas the requirement for tassel emergence, silking and maturity was more in the crop sown on 8 and 15 January.

Nam *et al.* (1991) studied the relationship between leaf senescence and photosynthetic translocation during grain filling in barley. They observed that rate of grain filling was highest in cultivars with rapid leaf senescence. Photosynthetic rate was highest in cultivars with rapid leaf senescence during early grain filling and in cultivars with slow leaf senescence during late grain filling. They found close correlation between rate of grain filling and 14C translocation into grains.

Dofing (1992) studied the comparative growth, phenology and yield components of three early maturing barley and wheat during 1989-91 growing season at Palmer, Alaska. He found that barley cultivars produced an average of 1.1 more leaves than wheat, and had a smaller (4.5 growing degree-days/leaf) phyllochron interval. They also stated that the early maturity of barley relative to wheat was due mainly to its ability to fill and ripen grain under cool conditions.

Randhawa *et al.* (1992) studied the rate and duration of grain filling in wheat. They reported that the varieties did not differ in the rate of grain filling. The rate of grain filling in early sowing was the lowest (0.62 mg grain day) which progressively increased in timely and late sowings. Wheat varieties differed widely in the duration of grain filling. They also found that the average duration of grain filling in early sowing was 65.3

day which progressively declined to 56 and 38.3 days in timely and late sowings respectively.

Martin *et al.* (1993) conducted an experiment to predict reproductive growth stages in barley. They observed that development time decreased with delayed sowing up to "spike at 1cm" but not thereafter. However, thermal development time with base temperature of 4°C and photothermal development time with a base temperature of 0°C and a base photoperiod of 8h were unaffected by sowing date. In both years thermal time from ear emergence to hard dough stage averaged 460 day-degrees above 4 degree and photothermal time 314 day-degrees above 0 degree adjusted for photoperiod. Cultivar Magnum took up to 88 day-degrees above 4 degree longer, and up to 55 day-degrees above 0 degree adjusted for photoperiod longer to reach a particular growth stage than cv. Triumph with cv. Illia generally being intermediate. Double ridge occurred when there were 3 or 4 fully expanded leaves, spike at 1 cm occurred between 5 and 6 leaves, apical primordium stage occurred between 6 and 7 leaves and first node occurred at about the same time that 7 leaves had fully expanded.

Kirby (1995) observed that rate of leaf emergence of wheat and barley changed with sowing date and temperature and appears to be set early in the plants life cycle. Four models that advanced different hypotheses to explain this variation were examined. None was completely satisfactory, partly because of a nonlinear response to thermal or photothermal time. Soil strength, N nutrition and depth of sowing affected rate of leaf emergence as may sub-zero temperature or ontogeny. An alternative hypothesis proposes that leaf emergence rate depends on daylength and acclimatization to temperature. Potential rate of leaf emergence may be determined by factors acting on leaf primordia which are initiated early in the life cycle.

Bishnoi *et al.* (1995) conducted an experiment to develop the relationship of phenological development with thermal units under different sowing dates and moisture levels in wheat. The crop was sown on 5 dates viz., 29 October, 13 November, 29 November, 13 December and 29 December and three moisture levels (lo, l_1, and l_2). They observed different phenological stages such as germination, crown root initiation, last tiller, flagleaf, last node, ear emergence, anthesis, grain filling, milking, hard dough and maturity. They found that the number of leaves emerged maximum in early sowing (29 October followed by 13 November). Its number was higher in main stem and decreased with later tillers. The emergence of leaves showed a linear response with cumulative heat units. They also found that the total number of leaves on the main stem and tillers were strongly related with the accumulated heat units and emergence of leaves. The requirement of heat units decreased with delay in sowing.

Kernich *et al.* (1995) studied the relative effects of photoperiod and irradiance on pre-anthesis development in spring barley. They used three barley cultivars and imposed them two photoperiods (10 and 18 h) with similar levels of daily radiation and under 18h photoperiod with differing irradiance levels. They observed that the duration of this photoperiod in two photoperiod-sensitive barley cultivars, Clipper and Galleon, was reduced by a factor of ca. 2.6 and 2.7 respectively, by the 18h photoperiod in comparison with the 10 h photoperiod. They found that the maximum number of spikelet primordia at the apex of the main culm was higher by a factor of 1.7 under 10 h photoperiod compared with the

18 h photoperiod in Clipper and Galleon. Similarly, the final number of leaves on the main culm and the length of the main culm were greater under 10 h photoperiod compared with the 18 h photoperiod at the same level of irradiance for Clipper and Galleon. The photoperiod-insensitive cultivar. Finlay exhibited little response to photoperiod for both the above-mentioned characters. Under a 10 h photoperiod, anthesis was delayed in all three cultivars.

Shaykewich (1995) reviewed the response of phenological development of cereal crops, primarily maize, wheat and barley to environmental conditions. He concluded that the development rate of most species is a sigmoidal rather than a linear function of temperature. Consequently, phenological models assuming a liner relationship (e.g.; degree-days) are inappropriate. Another consequences of the way plant respond to temperature is that the most precise phenological models will require use of temperature data over relatively short period (e.g.; 3 hour) rather than just a daily mean temperature. He suggested the way of standard climatological data used in phenological modelling. He also reviewed phenological response to photoperiod.

Kernich and Halloran (1996) studied the effect of temperature on the duration of the spikelet growth phase and spikelet abortion in barley. They assessed the effects of high temperatures on the length of the spikelet growth phase, the number of spikelet nodes per spike and level of spikelet abortion in spring barley cvs. Bandulla, Schooner and Weeah. The spikelet growth phase was subjected to two temperature regimes. In the first two sowings, the mean daily maximum temperature for one regime was 24°C (maintained for 6 h daily) and the mean daily minimum was 8 ^{0}C (24/8 ^{0}C). The second temperature regime was 27/17 ^{0}C.

Corresponding temperatures for the second sowing, which were subjected to slightly longer photoperiods were 26/8 and 26/17 respectively. They observed that the duration of the spikelet growth phase was longer for 27/17 than for 24/8 in the first sowing when measured in calendar time (day). In the second sowing, the duration of the spikelet growth phase was slightly shorter under the higher temperature regime (day). They also found that the duration of the spikelet growth phase (in degree Cd) was greatly increased by the higher temperature treatment in both sowings. In the first sowing, the percentage of aborted spikelet was greater at high temperature than at low temperature for Bandulla and Weeah at both sowing times and the duration of spikelet growth phase increased with higher night temperatures suggesting that length of the spikelet growth phase was not the sole factor responsible for the proportion of aborted spikelets.

Bishnoi *et al.* (1996) studied the micro-climatic conditions under different environments in wheat crop. They measured the profiles of temperature, relative humidity, leaf temperature, leaf wetness and wind speed in the crop canopies of different sowing treatments. Higher air temperature and lower soil moisture were observed during the reproductive phase under delayed sowings. Statistically higher grain yield was obtained from 31 October to 14 November under favourable microclimate conditions at the different phenological phases. Because maximum leaf area index and total dry matter accumulations were found under the above sowing times.

Samanta *et al.* (1997) studied the different growth stages and yield of proso-millet cultivars as influenced by sowing date. They sownd four proso-millet cultivars viz., Kumardhan, BPM-24, BPM-40 and Tupher on five dates starting from 15 November at an interval of 15 days at BAU

Farm Mymensingh. They observed that late sowing caused late germination and reduced the period (days) of panicle initiation, flowering and maturity due to low temperature at the seedling stage and high temperature at the grain filling stage.

Sandhu *et al.* (1999) studied the yield performance and heat unit requirement of wheat (*Triticum aestivum* L.) varieties as affected by sowing dates under rainfed conditions. They sowed the wheat varieties (PBW 175, PBW 299, PBW 320 and PBW 359) on four dates (from 25 October to 24 November at an interval of 10 days). The crops sown on 25 October produced better grain yield which decreased with delay in sowing. PBW 175 wheat variety gave the highest yield followed by PBW 299. They observed the occurrence of different growth stages as well as the heat units to relation to different sowing dates. They reported that crop growth duration and the heat units decreased with delay in sowing. The number of days taken for seedling emergence and jointing increased with a concomitant decrease in the duration of reproductive phase, particularly flowering to maturity. Heat units did not differ so much during seedling emergence but increased during emergence to jointing and decreased during jointing to flowering when crops were sown on 4 November. The heat units decreased during flowering to maturity with delay in sowing due to shortening of the ripening period.

Sharratt (1999) conducted an experiment to assess the thermal requirements of barley maturation and leaf development. He monitored the air temperature and spring barley development over the six growing seasons (1987-1992) at Fairbanks and Alaska. Sowing dates ranged from 30 April to 31 May. He used the meteorological data to assess the base temperature (Tb) in the linear, thermal-unit x-intercept, and regression coefficient methods. These methods indicated a range in Tb from 0°C to 1.5°C. They observed that at Tb of 0°C, barley required nearly 1100 degree Cd to mature. They also found that the phyllochron differed between early and late sowing and averaged 75 degree C d leaf^{-1}. Sowing date appeared to influence the phyllochron during early vegetative growth due to differences in daylength as well as temperature.

Savin and Nicolas (1999) carried out an experiment to determine the importance of timing of short period of high temperature and drought on grain weight and grain quality of barley cv. Schooner. Cultivar Schooner was exposed to short period of heat stress (40°C for 6 h/day for 5 consecutive days) or drought at early grain filling (10-15 days after anthesis), mid grain filling (20-25 DAA) and late grain filling (30-35 DAA). They observed that individual grain weight was most sensitive to heat stress and drought treatments imposed early in grain filling and was less sensitive to later treatments. They also found that the reduction in grain weight was greater under heat stress (13%) than under drought (6%). Starch was reduced in amount and quality, especially with early stresses during grain filling but grain nitrogen percentage was similar between treatments.

Miralles *et al.* (2000) conducted an experiment to investigate whether altering the duration of stem elongation period in wheat and barley increased floret fertility and grain number. They observed that an increased duration of the late reproductive phase from terminal spikelet to heading in wheat resulted in more fertile florets per spike. A similar relationship was observed in barley but only for a limited range of duration of the stem elongation period. Shorter photoperiods reduced the rate of floret development and extended the time to reach the fertile floret stage. They stated that the duration of the late reproductive phase during which the spike and stem competing for assimilates was associated with the number of fertile florets per spike. This suggested that extending the stem elongation period in cereals could be a way to reduce assimilates competition and thereby increases the number of fertile florets and grain yield.

Flood *et al.* (2000) studied the influence of photoperiod on barley development. They recorded time to awn emergence and leaf number on the main culm for 10 barley cultivars grown under a short and long photoperiod after 4 weeks cold treatment at 4°C. The appearance of leaves on the main stem was also recorded at regular interval. There were differences among the cultivars for photoperiod response and the duration of the basic vegetative phase. Photoperiod response tended to be complementary with basic vegetative phase, as one increased the other decreased and vice versa. Leaf appearance generally did not differ significantly between photoperiod treatments. In the short day, leaf appearance continued for a longer period with more leaves produced in the main stem. Leaf appearance as a function of time was best described by a cubic or a quadratic exponential polynomial function. The absolute rate of leaf appearance under short day showed an increase to a maximum followed by a decrease to a minimum and then a further increase. Under long day, three patterns of absolute rate of leaf appearance were evident. There was a rapid increase to a maximum followed by either a rapid or more gradual decline; in several cultivars the pattern was similar to the one seen for the cultivars in the short day treatment, although it was somewhat truncated.

Juskiw *et al.* (2001) carried out an experiment to understanding the phenological development of barley grown under field conditions in the major growing area (Botha, Lacombe and Olds) in the northern Great Plains, the Canadian province of Alberta. They used 5 cultivars and measured 12 growth stages, the final leaf number of the main culm, phyllochrons and leaf area indices. They observed that the average phyllochron was 69.1 growing degree-days (GDD), and the final leaf number was 9.0. While location year differences in GDD requirements to each successive stage could be related to environmental conditions. The genotypic effects and genotype x environment interactions would require that specific genotypic coefficients be introduced into the model. For instance, cv. Manley required only 129 GDD to emerge, 493 GDD to reach apex-1 but required 1495 GDD to reach physiological maturity while cv. Tukwa required 133 GDD to emerged, 514 GDD to reach apex-1 and only 1431 GDD to reach physiological maturity.

Paynter *et al.* (2001) examined phenological development in eight cultivars of two-row spring barley with two sowing dates in two diverse environments at Northam (Australia) and Lacombe (Canada). The Australian and Canadian barley cultivars used had different combinations of basic vegetative phase and daylength sensitivity. They observed that barley grown at Lacombe reached each stage of phenological development in less time than at Northam. Most noticable was a shorter duration of the photoperiod between seedling emergence to double ridge and between double ridge and awn emergence. They found that at Northam, nearly 20% of the barley's life cycle was spent on vegetative growth, just over 40% on ear/stem growth and close to 40% on grain filling. At Lacombe, barley spent nearly 55% of its life cycle filling grain and only 10% on vegetative growth and 35% on ear/stem growth. Later seeding accelerated all stages of development at Northern but only those stages until awn emergence at Lacombe. Late sown barley at Lacombe took longer to reach physiological maturity. The relative contribution to each phase of crop growth was unaffected by date of seeding.

In another experiment, Flood *et al.* (2001) suggest that the duration of the photoperiod insensitive phase was associated with the length of the basic vegetative phase and ended sometime before the start of flower initiation.

Tamaki *et al.* (2002) studied the effect of temperature on leaf emergence and leaf growth on the main stem in winter barley plants. They counted the leaf number on the main stem every day from the emergence of the third leaf until the emergence of the seventh leaf. The area was measured from the second to the sixth leaves on the main stems. The emergence of new leaves was a linear function of time at all temperature regimes. The leaf emergence rate increased with increasing temperature until an optimum temperature of 22.5°C was reached and then decreased with further increases in temperature, but not significantly, compared with peak. The leaf emergence rate per degree-day was slower with increasing temperature. The leaf growth rate increased with increasing temperature until an optimum temperature of 20°C was reached and then declined with further increase in temperature. The leaf growth rate per day-degree had its maximum at 17.5°C. The leaf emergence and leaf growth under different temperatures but at same day-degree were different. The response to temperatures for emergence and growth of barley leaves were different.

Yield and yield component

Scott *et al.* (1973) studied the effect of sowing date and season on growth and yield of oil-seed rape (*Brassica napus*). They found that there was a major effect of sowing date. Late autumn sowing (after mid September) gave lower yields than early spring sowings. The best autumn sowings (early September) gave about 3 t ha^{-1} of seed but late sowings less than half of this, oil content also decreased with delay in sowing from 45% to as low as 38%. Delayed sowing restricted growth, leaf area and pod production and also had a slight effect on seed weight. Frost damage on flower buds appeared to be the cause of reduced yield from early sowing (August) in one experiment. In Spring, the earliest sowing (late march) gave the best yields. Vigorous but late vegetative growth from the later sowing (ends of April) did not lead to high yields possibly due to pest and disease effects.

Ahmed *et al.* (1975) studied the optimum date of sowing of the high yielding varieties of wheat in the northern part of Bangladesh. Five varieties of wheat were included in the experiment and effect of different dates of sowing on their maturity, height, yield etc. were studied. On an average the treatment T_3 i.e. wheat sown on 9.11.70 and the variety Mexipak-65 gave the highest yield among all the treatments.

Rao *et al.* (1980) conducted a field experiment to find out the optimum date of sowing in wheat (*Triticum aestivum* L.) and the relationship between the date of sowing and the yield production. The dates of sowing were from 05 November to 19 January at 15 days interval. They found that sowing on 20 November was the optimum time of sowing for the highest grain yield. They also found that sowing on 20 December did not occur much reduction in yield and further sowing in late (4 and 19 January caused more reduction in yield due to high temperature at the grain filling stage.

Mendham *et al.* (1981) studied the effects of delayed sowing and weather on growth, development and yield of winter oil seed rape (*Brassica napus*). They reported that late sowing produced 3000-6000 pods m^{-2} and the number of seeds retained per pod varied widely. Early sowings however produced apparently excessive numbers of pods (6000-12000 m^{-2}) and few seeds per pod (6-10), so that yield varied little regardless of crop size. A high yielding crop type may therefore need to incorporate the restricted pod production and good seed retension of some well-grown late sown crops with the reliability and desirable agronomic features of early sown crops.

Lawn (1983) conducted an experiment on agronomic studies on *Vigna* spp. in south-estern Queensland. He observed the response of two each of blackgram (*Vigna mungo*), adzuki bean (*V. angularis*) and green gram (*V. radiata*) to sowing arrangement was evaluated in November, December and January sowings in south-eastern Queensland. He showed that dry matter production was generally maximized at the highest population density. However significant species × sowing arrangement and sowing date × sowing arrangement interaction occurred for seed yield. Yields of blackgrams were least responsive to population density/ sowing date combinations apparently because of their indeterminate growth habit. The green grams (determinate habit) and adzuki beans (weakly indeterminate) responded to progressively higher population density as sowing was delayed from November to January reflecting progressively shorter duration with later sowing.

Photiades and Hadjichristodoulou (1984) conducted a series of trials under dryland conditions in a Mediterranean type climate to study the main effect and interaction of sowing date, depth and rate and row spacing on wheat and barley. They observed that there was an optimum period of sowing date which depended on rainfall pattern. For Cyprus this period was mid November to mid December. Yields were reduced by up to 70% with late sowing while tiller number and plant height also tended to decline.

Ahmed and Haque (1985) studied the effect of dates of sowing with different varieties of coriander both local and exotic on their growth and seed yield. Sowing of coriander seeds was done at one month's interval on November 15, December 15 and January 15. Among the three sowing dates earlier sowing on November 15 gave higher number of leaves as well as higher quantity of coriander seeds. On the other hand, the local variety of coriander produced highest quantity of seed plot (168.11 g plot^{-1}), while both the exotic varieties namely cilantro and chinese parsley produced higher number of leaves per plant (394.26 and 383.48 respectively).

Green and Ivins (1985) conducted an experiment to observe the effect of sowing times on yield of winter wheat. They sowed three winter wheat cultivars on optimum and late seeding condition under two growing seasons. They found that advancing the date of sowing for winter wheat cultivars increased the duration of the growing period and it increased the opportunity for the absorption of photons. As sowing being delayed, total dry matter accumulation decreased which ultimately influenced the yield of wheat. They approached mid-September as an optimum sowing. They reported that yield potential declined at a rate of 0.35% for everyday when sowing was delayed after 22 September.

Green *et al.* (1985a) studied the influence of sowing date on the yield of winter barley (*Hordeum distichon* L. cv. Igri) under three growing seasons. They sowed the seeds from early September to mid November. They found that delayed sowing resulted in a linear decrease in maximum grain yield. They also found that advancing the date of sowing increased the duration of pre-anthesis development, increased the level of tillering and enhance ear density at the final harvest. They reported that yield was linearly related to higher number of grains.

Green *et al.* (1985b) observed the influence of planting date on development of winter wheat crops grown during the season of 1981-82. They sowed normal cultivars at the rate of 450 seeds m^{-2} at four sowing dates. They found that earlier sowing induced a faster production of tillers of consequently higher maximum number of tillers because of higher mean temperature over the period of early vegetative growth. Delayed sowing reduced the tillering efficiency and not compensate by increasing higher seed rate and resulted lower number of ears. Earlier sown crops had faster tendency to accumulate dry matter in grains than the late sown crops, which was not significantly affected by sowing time. As sowing was delayed, yield was reduced because of a decrease in number of grains caused by fewer tillers being produced. However while mean individual grain yield was increased as sowing was delayed for barley. No similar effects could by detected for wheat.

Islam and Paul (1985) conducted a comparative study on the production and partition of dry matter and yield of six rape seed (*Brassica campestris* L.) cultivars. They observed that the range of variation was pronounced in dry matter production in all the plant parts and total plant weight throughout the whole growing period. Dry matter of all the cultivars increased with the advancement of plant age. A wide range of variation was pronounced in all the yield characters considered except the number of secondary branches and the number of fruits per main branch. Days taken to first flowering was positively correlated with the numbers of primary branches, number of seeds per fruit and plant weight at harvest. Seed yield was positively correlated with the number of primary fruits per plant. Harvest index was negatively correlated with days taken to first flowering, number of primary branches and plant weight at harvest.

Mannan and Rashid (1986) studied the influence of growing season on the yield and yield contributing characters of Mukhikachu (*Colocasia esculenta*). The time of planting (10th February, March and April) and time of harvesting (75, 115, 155, 195 and 235 days after each planting). It was observed that the average height decreased with each successive delay in planting without affecting the yields. The harvest of the March planting after 195 days gave the highest fresh as well as dry yield plant^{-1} and ha^{-1}.

Uddin *et al.* (1986) studied the effect of sowing dates on the yield and some of its components of mustard and rapeseed. They reported that sowing dates significantly affected primary branch/plant, seed number/pod and seed yield/plant and varieties significantly interacted with the sowing periods for all the traits except primary branch/plant. All the varieties showed significant differences among the four sowing periods for all the characters except primary branch/plant and secondary branch/plant. Seeding in October 25 and November 04 gave better performances compared to others but there were no significant differences between these two sowings.

Islam and Soth (1987) studied growth and yield performance of four cultivars of chickpea grown during spring and winter seasons. There was no significant difference in grain and biological yield. However, harvest index was significantly different both among the cultivars and between the growing seasons. Spring crop yield did not respond favourable even after adequate irrigation.

Rahman *et al.* (1987) studied the effect of sowing time on the performance of mustard (SS-75) and they reported that seed yield was highest when the crop was sown on November 13 but was not significantly different from November 23 sowing. No significant variation in aphid infestation was found in between November 13 and November 23 sowings. Yield was mainly influenced by number of siliquae per plant and 100-seed weight. Delayed sowing (December 3 to December 13) encountered adverse climate conditions and aphid infestation, which reduced the seed yield drastically.

Hossian and Farid (1988) studied the influence of sowing date and seed rate on two wheat varieties (Akbar and Barkat). They were sown on four dates starting from 5 November at an interval of 15 days under irrigated condition. The higher yield was obtained on November 20 followed by December 5 due to higher number of spikes/m^2, number of grains/spike and 100-grain weight for favourable atmospheric temperature prevailing from sowing to grain filling period. The early sowing (November 5) caused reduction (8.8%) in grain yield due to high temperature prevailing from sowing to seedling emergence and tiller initiation resulting in lower number of tillers per unit area. The late sowing (December 20) produced low yield due to shorter growing period at the vegetative phase and steep rise in atmospheric temperature at the grain filling period. It was observed that the early sowing produced the taller plants than the late sowing. It was also observed that Akbar gave significantly higher grain yield than that of Barkat irrespective of date of sowing.

Rashid *et al.* (1990) studied the effect of time of planting on the performance of some cauliflower varieties. They reported that planting time significantly influenced the growth and yield of cauliflower varieties. Curd yield was higher in the earlier (September 1) planting. Early planting required longer period for curd maturation. In September 1 planting, the variety Agrahayani produced the highest curd yield. In October 1 planting, the varieties F_1 Win, Supreme and Rukhushi late topped the list and produced yields in the range of 20.7-21.0 t ha^{-1}; and in November 1 planting, the variety F_1 Win produced the highest yield (22.5 t ha^{-1}). The varieties Agrahayani, Pousrali Main Crop, F_1 Win, Supreme and Line 78-882 produced reasonable yields in all the three plantings. However, most varieties were characterized by quick buttoning in October 1 and November 1 plantings.

Islam *et al.* (1991) studied the effect of different dates of planting and number of plants per hill on plant growth and yield of tomato. The experiment consisted of four dates of planting (October 26, November 11, November 27 and December 13) and three treatments regarding the number of plants per hill (one, two and three plants per hill). The results revealed that plant height, number of leaf, flower and fruits and yield were the maximum in October 26 planting with one plant per hill. Total yield of tomato was highest (70.22 t ha^{-1}) in three plants per hill which was statistically similar to two plants per hill.

Torofder and Altab (1991) observed the effect of sowing dates on the yield of four varieties of barley for two years. They sowed the varieties namely Contineka AP 19, AP 20 and Jamalpur local in 30 October to 30 December at an interval of 15 days at Jamalpur. The higher grain yields were obtained from 15 November to 30 November than those of the other sowing dates due to higher number of spikes/m^2, grain spike and 1000-grain weight in both the years. Sowing after 15 December, the grain yield decreased due to shorter growing period and higher temperature at the grain filling stages that caused early maturity. Compared to the other varieties, Jamalpur local produced the highest yield.

Zaman *et al.* (1991) studied the effect of dates of sowing on the performance of mustard under zero tillage condition. They reported that the dates of sowing had significant effect on the number of seeds/pod and seed yield/ha of mustard. All the yield components under study significantly different among varieties except plant populations/m^2 and 100-seed weight. The interaction of sowing and variety had significant influence on number of pods/plant, number of seeds/pod and seed yield. The late sowing of November 7 was unfavourable for production. The variety 'Sambal' produced highest yield in the first sowing date. There had been a negative linear response of all the varieties to dates of sowing starting from October 18.

Jain *et al.* (1992) studied the effect of sowing time on wheat varieties. They worked on 6 varieties of bread wheat (*Triticum aestivum* L.) and 1 of macaroni wheat (*T. durum*) under five dates of sowing starting from 20 December at an interval of 10 days. They found that late sowing significantly reduced the grain yield in all the varieties i.e. by 4.17, 22.30, 30.71 and 56.62% with delay in sowing by 10, 20, 30 and 40 days compared with crop sown on 20 December.

Mondal *et al.* (1992) studied the effect of variety and planting date on the yield performance of rape seed. They reported that planting dates significantly influenced plant height, number of siliquae/plant, seed yield/plant and seed yield/ha. They planted four varieties viz., Tori-7, SS-75, TS-72 and J-5004 on October 1, October 16, November 1 and November 16. The highest seed yield (1.45 t ha^{-1}) was obtained from the plants of second planting date (October 16). The performance of the variety J-5004 (Daulat) was the best among the four varieties over all dates of planting.

Ramzan *et al.* (1992) studied two mungbean cultivars (M28 and V 6601) which were planted on 4, 14 and 24 th of July and 3, 13 and 23 August on a sandy loam soil during 1986 and 1987. Both the varieties planted between 4 and 14 July only gave significantly greater seed yield and yield components. Sowing thereafter seed yield reduced massively. Maximum seed yield 430 kg ha^{-1} was obtained from both varieties planted on 4 July. This sowing also produced taller with better yield components. The data concluded that 4-14 July is the optimum planting time for mungbean in the rainfed condition of Chakwal.

In a field experiment Nelson (1993) observed that seedling emergence and survival were 10 to 15% higher with the high sowing rate but grain yield was only increased when the crop was sown late. Seedling survival was decreased by 15% from sowing late (30 September) compared with 15 September sowing.

Dixit *et al.* (1993a) conducted an experiment at Madhya Pradesh, India to observe the response of chickpea to planting date. They found that planting of gram on 26 October and 16 November is the best for obtaining maximum number of branches/plant and yield attributes like number of pods/plant, double seeded pods/plant, grain/plant and 100-seed weight.

Dixit *et al.* (1993b) carried out another experiment to observe the moisture use pattern and yield of chickpea in relation to planting date, variety and irrigation. They observed that due to optimum climatic factors 26 October and 16 November planting chickpea varieties gave maximum straw and grain yield. Earlier or late sowing caused drastic reduction in yield and net profit compared with timely sowing from 26 October to 16 November.

Islam *et al.* (1994) worked on the effects of sowing date on plant development, growth and yield of mustard and rape. They reported that for cultivation of mustard and rape, sowing date had been found to be an important factor in influencing the seed yield. A through knowledge on the physiological processes of the crop in relation to sowing date effects may be helpful in bringing about its yield improvement.

Quayyum *et al.* (1994) carried out an experiment to determine the optimum sowing dates of four maize cultivars at Joydebpur. In this study there were five sowing dates starting from 15 October to 15 February at an interval of 1 month and four maize cultivars namely Pirsabak 8146, La-Maquina 7827, Khoibhutta and Shuvra. They reported that yield attributes were significantly affected by seedling dates and cultivars. Significant highest grain yield (4.40 t ha^{-1}) was obtained from 15 November sowing by producing the higher number of grains/cob and individual grain weight in both the years. The lowest yield obtained from 15 January sowing was probably due to low temperature during early vegetative phase and high temperature during grainfilling period. They also observed that late sown crop took longer time to germinate that reduced the effective growth period of the crop. Among the cultivars, Pirsabak 8146 gave the highest grain yield (5.13 t ha^{-1}) followed by La-Maquina 7827, Khoibhutta and Shuvra.

Shatilov *et al.* (1995) observed the effect of sowing date on rate of emergence, plant population, coefficient of productive tillering, plant height aboveground plant dry weight, spike weight, number of grains/spike, seed germination and 1000-grain weight. Sowing before the end of April gave grain yields of 6.78-7.02 t ha^{-1}.

Moula *et al.* (1996) studied the effect of sowing date and row direction on the yield of wheat (*Triticum aestivum* L.). They reported that the plant height, spike length, 100-grain weight and grain yield were significantly influenced by sowing dates. The experiment involved four sowing dates viz., November 20, November 30, December 10 and December 20 and the raw direction viz., north-south and east west. Sowing in November 20 and 30, December 10 and 20 were found obtained in grain yield. Higher grain yield obtained from November 30 sowing was due to the cumulative influence of higher number of spikes/m^2, number of grains/spike and 100-grain weright. The lowest yield produced from December 20 sowing was attributed to lowest number of spikes/m^2, number of grains/spike and 100-grain weight. The row direction showed non significant effect on grain yield. The highest gross benefit, net return and benefit cost ratio were obtained from November 30 to December 10 sowing.

Podder *et al.* (1996) investigated stability analysis for seed yield and yield components in mustard under different dates of sowing. They reported that sowing date influenced significantly seed yield and yield components in mustard. Ten promising varieties/lines were evaluated under five dates of sowing to estimate the crop response to days to 50% flowering, days to maturity, plant height, pods/plant, seeds/pod and seed yield. All the varieties significantly interacted for the characters under study and the interactions were accounted for the linear and non-linear components of joint regression over sowing date. Overall sowing on 1 November provided the most favorable environment followed by 16 November and 16 December was the most adverse environment for all the varieties. The simultaneous consideration of the stability parameters (band S^2d) and their correlations with mean performances of seed yield showed that high yielding varieties Daulat and Rai 5 and average yielding lines Nap-3142 and Nap 8509 were very responsive and found to be stable only under the most favourable sowing time. Another high yielding variety Sampad was highly sensitive but was average above stable over the date of sowing. Low yielding varieties like Tori-7, SS-75, Bina-3 and Dhali had least degree of response and were stable under a wide range of sowing time.

Khan *et al.* (1996) conducted an experiment at BAU, Mymensingh to observe the effect of boron and sowing date on different wheat varieties. They sowed the three varieties viz., Sonalika, Kanchan and Aghrani and applied boron at the rate of 10 and 3 kg B ha^{-1} on four dates beginning from 20 November at an interval of 10 days. It was observed that the highest grain yield was obtained when seed was sown on 30 November and followed this order November 30> November 20> December 10> December 30. Kanchan produced higher grain yield followed by Aghrani and Sonalika. It was observed that boron had positive significant effect on the number of grains/spike and grain yield. Boron treatment and sowing time had influenced the wheat yield independently so that the yield loss due to late sowing was not compensated by added B and similarly the yield gap due to B deficiency was not removed by timely sowing.

Sarkar *et al.* (1996) conducted an experiment to investigate the effect of dates of planting on the growth and yield of some modern cultivars of wheat. They sowed four modern wheat e.g. Kanchan, Ananda, Akbar and Barkat on six different dates starting from 15 November at an interval of 10 days. They found no significant difference between cultivars in respect to yield. But they reported that Barkat produced significantly the highest straw yield in comparison to the other cultivars. They also reported that 25 November and 5 December sown plants produced significantly higher grain yield in respect to other dates of planting. They observed that the grain yield was severely reduced when planting was delayed beyond 25 December and 4 January.

Aziz *et al.* (1998) conducted an experiment with three varieties of sesame and six dates of planting at Ishurdi. Yield and yield attributes were significantly affected by sowing dates and cultivars. Significant highest seed yield was obtained from 15 March. Sowing due to higher number of pods plant^{-1}, seeds pod^{-1} and individual seed weight which was identical to 01 March sowing (1095 kg ha^{-1}). Among the cultivars, T-6 produced highest yield (1140 kg ha^{-1}) but it did not differ significantly from that of Jamalpur, compared to the sowing date of 15 March other dates of sowing reduced yield by 0.03 to 85.86%. The first fortnight of March was found to be the optimum time of sowing. The cultivar T-6 performed best followed by Jamalpur.

Dhar *et al.* (1998) conducted an experiment to find out the suitable planting date for year round production of pineapple in the Chittagong hill tracts. August to October planting was found better for obtaining year round pineapple production with higher yield, although October planting took the longest crop duration (615.6 days) followed by September planting (598.1 days). Vegetative growth, fruit size and weight and yield of fruit in this planting were higher and significantly superior to other plantings. The highest percentage of off-season fruits (65.83% was obtained from July planting but the yield was low (69.83). The heaviest fruit (3.17 kg) and the highest yield (99.08 t ha^{-1}) were obtained from September planting and the lowest (1.93 kg /fruit and 60.63 t ha^{-1}) from May planting.

Samanta *et al.* (1999) carried out an experiment with five mungbean cultivars (Kanti, NM-92, BINA Mung-1, BINA Mung-2 and Patuakhali local) under five dates of sowing at an interval of 15 days starting from 15 December to 15 February during 1995-96. Mungbean performed better when sown on 15 December, 30 January and 15 February. The cultivar Kanti produced significantly highest seed yield followed by NM-92, BINA Mung-2, Patuakhali local and BINA Mung-1. The interaction effect showed that all the cultivars except BINA Mung-1 gave better performance under 15 December, 30 January and 15 February sowings. BINA Mung-1 showed higher yield in early sowing.

Nag *et al*. (2000a) planted two mungbean cultivars viz., Kanti and Barisal local on nine sowing dates (15 December to 5 March) at an interval of 10 days during the rabi season. Both the varieties planted between 15 January and 15 February gave significantly higher seed yield and yield components. Sowing thereafter reduced seed yield drastically. The maximum seed yields (919.88 and 1033.25kg ha^{-1}) were obtained when both the varieties were planted on 25 January. This sowing date also produced taller plants, higher number of branches/plant, pods/plant, pod length, seeds/pod and 1000-grain weight. Of the two cultivars, Kanti gave higher grain yield (1207.00 and 1298.75 kg ha^{-1}) when seeds were sown on 25 January. Both the varieties also gave higher seed yields when seeds were sown on 15 January to 15 February.

Nag *et al.* (2000b) studied the effect of sowing date on yield and yield components of selected mustard and rapeseed genotypes. The treatments included four sowing date viz., 1 November, 15 November, 1 December and 15 December with five rape seed and mustard genotypes, e.g. Tori-7, Daulat, M-27, M-21-E_2-6-1 and M-37-E_2-7. All the plant characters and seed yield showed positive and significant response to early sowing date at 01 November followed by 15 November. The highest seed yield (1.18 t ha^{-1}) was obtained from 1 November sowing followed by 15 November (1.13 t ha^{-1}) and the lowest one (0.56 t ha^{-1}) received from 15 December. Seed yield declined gradually by 4.24%, 38.14% and 52.54% respectively for 15 days delay after 1 November sowing. Among the genotypes highest seed yield (0.99 t ha^{-1}) was obtained from M-21-E_2-6-1which was statistically identical (0.96 t ha^{-1}) with M-37-E_2-7. Interaction effect of sowing date and genotype showed that maximum seed yield (1.29 t ha^{-1} was obtained from M-27 with the sowing time of 1 November.

Ali and Rahim (2000) conducted an experiment to study the effects of different time of plantings on growth and yield of three varieties of carrot. Seeds of three varieties of carrot i.e., New Kuroda, KS Kuroda and Nantes were planted at five different dates viz., November 1, November 16, December 1, December 16 and December 31. Planting time showed significant effects on growth and yield of carrots. Maximum yields were obtained from December 1 planting. All these parameters showed decreasing tendency except foliage dry matter. December 1 planting gave the highest yield of 34.63 g ha^{-1} while the lowest yield of 18.14 t ha^{-1} by November 1 planting. There was no significant variation among the varieties in respect of yield.

Islam *et al* (2000) studied five varieties of mustard and rape viz, Tori-7, TS 72, Daulat, Rai-5 and Sonali Sarisha and compared yield and yield components with respect to sowing on 20 October, 04 November, 18 November and 2 December, 1994. Results showed that yields were greater when seeds were sown on 04 November compared to both the early and late sowings. Yield reductions were much higher beyond 18 November sowing. Varieties differed significantly for seed yields as Sonali Sarisha>Daulat>Rai-5>TS-72>Tori-7. The yield reductions due to delayed sowing up to 18 November were much lower in Tori-7 and TS-72 compared to other varieties. Sowing on 20 October appeared to be early for Daulat, Rai-5 and Sonali Sarisha since these varieties gave higher yields when sown on 04 November. Correlation studies between plant size at different developmental stages and seed yield/plant evidenced that sowing on 04 November produced suitable sized plants, which efficiently yielded more and each of early and late sowings produced either oversized or under sized plants for producing lower seed yields.

Haque *et al.* (2001) conducted an experiment from February to August, 1997 to evaluate the effect of planting dates on yield and quality of two summer mungbean cultivars. Treatments comprised two varieties viz.. Kanti and BINA Mung- 1 and five planting dates viz., 16 March, 31 March, 16 April, 1 May and 16 May. Plant height and straw yield increased progressively due to delayed planting in both the varieties but

Kariti had more pronounced effect on these parameters. Pods m^{-2} and harvest index were highest on 16 March planting and thereafter it declined in both the varieties. Between the two varieties, BINA Mung-1 out yielded Kanti. Planting on 16 March produced the highest seed yield and the yields were gradually decreased due to delayed planting. Yield reduction due to delayed planting was lower in BINA Mung-1 than in Kanti. Seeds of BINA Mung-1gave significantly higher germination percentage (60.7%) than that of Kanti (58.8%). Two varieties differed significantly in their vigour index. Seeds of BINA Mung-1 showed higher vigour index. The nitrogen as well as protein contents of the seeds were found to be statistically similar in both the varieties.

Biswas *et al.* (2002) conducted an experiment to determine optimum sowing time for different varieties of blackgram in Jamalpur region (AEZ-9) of Bangladesh. Pooled analysis exhibited a significant variation among the varieties in respect of seed yield. Barimash-3 produced the highest seed yield (977 kg ha^{-1}) which was statistically similar to that of Binamash-1 (960 kg ha^{-1}). Barimash-2 produced the lowest seed yield (866 kg ha^{-1}). Sowing dates exerted significant effect on seed yield. First sowing (31 August) produced significantly highest seed yield (1168 kg ha^{-1}) while the lowest seed yield (541 kg ha^{-1}) was found in the latest (28 September) sowing. Interaction also produced significant effect on seed yield. The highest seed yield (1225 kg ha^{-1}) was recorded from Barimash-3 with August sowing while the lowest (404 kg ha^{-1}) was found in Barimash-2 with September 28 sowing. All the varieties produced maximum seed yield with August sowing. Barimash-3 and Birarnash-1 performed better than others with delayed sowing up to September 14 in both the years.

Islam *et al.* (2002) conducted an experiment on three okra varieties viz., IPSA Okra, BARI Dherosh-1 and Parboni Kanti which were planted on 15 July, 15 August, 15 September and 15 October at the Research Farm of Agricultural University, Gazipur in order to find out the effect of dates of sowing on the seed yield. The higher seed yield of 1.38 t ha^{-1} was obtained from IPSA Okra planted in July, BARI Dherosh-1 also had similar yield. Seed yield decreased gradually with delayed planting. Seed yield from October planting was very low. The performance of Parboni Kanti was not satisfactory in respect of both vegetative growth and seed yield.

Yousaf *et al.* (2002) conducted an experiment to determine the response of different sowing dates on growth and yield parameters of canola. The treatments included two canola varieties (Dunkled and Rainbow) and three sowing dates (11, 21 and 31 October, 1999-2000). Dunkled variety planted on early sowing date (October, 11) produced higher grain yield of 2111.05 kg ha-1 as compared to Rainbow and late sowings. Comparatively low seed yield of 1806 kg ha-1 was produced of October 31 sowing. The different sowing dates significantly affected the number of primary branches/plant, number of secondary branches/plant, number of pods/plant and seed yield.

Zaman and Choudhuri (2002) studied the effect of different crop sequences on water use, growth and yield of green gram [*Vigna radiata* (L.) Wilczek] during 1992-93 and 1993-94 under rainfed upland condition in Indo-Gangetic plains of West Bengal. Greengram sown in the month of March as pre rainy (summer) season crop and when the winter crops vacated the land produced highest dry matter of 372 gm^{-2} which was significantly highest in blackgram yellow sarson sequence.

The results of the field experimentation revealed that green gram gave highest grain yield to the extent of 10.80 q ha^{-1} when sown after blakgram (rainy season) followed by yellow sarson (winter season) while the crop produced 10.63 q ha^{-1} under sesame yellow sarson sequence. Highest water use of 267 mm was achieved in greengram under blackgram-yellow sarson sequence and the crop gave water use efficiency of 4.07 kg ha^{-1} mm^{-1} under blakcgram-yellow sarson sequences.

Rahman *et al.* (2003) carried out an experiment to find out a suitable sowing time of barley. BARI Barley-2 was tested against a traditional (local) variety. Four sowing dates were included in the study viz., 16 November: 26 November, 6 December and 16 December. The results revealed that sowing time significantly influenced grain yield and other yield contributing characters. The higher grain yield (3.45 t ha^{-1}) was obtained for BARI Barley-2 sown on 26 November but it was statistically identical with 6 December sowing and the later was followed by the 16 December sowing. The result showed that BARI Barley-2 gave 35% higher grain yield than local variety, which was sown on 26 November. The lowest grain yield (1 .88 t ha^{-1}) was obtained from the local variety when sown on 16 November. The yield was reduced gradually after 16 December sowing. The optimum sowing time of barley should range from 26 November to 6 December for cultivation at charland of Nagarpur in Tangail.

Turk *et al.* (2003) studied the effects of sowing date (1 January, 15 January and 2 February) of lentil to plant density (80, 100 and 120 plants m^{-2}) phosphorus level (0, 17.5, 35.0 and 52.5 kg P ha^{-1}) and ethephon application [1500 ppm. ethephon (2-chloroethel phosphonic acid) applied 30 days after sowing were investigated in the semi-arid region in the north of Jordan. High yields were obtained for early sowing (1 January), high plant density (120 plants m^{-2}) and high phosphorus application rate (52.5 kg P ha^{-1}). Yield and yield components were not effected by ethephon application 30 days after sowing.

Mondal (2004) studied the performance of three modem varieties of mungbean viz,, BINA Mung 1, BINA Mung 4 and BARI Mung 2 under six dates of sowing from 15 September to 30 November during 1998-99 at the Agricultural Training Institute Farm, Rangpur, All the cultivars planted between 15 September and 15 October showed significantly higher seed yield and yield components and sowing thereafter reduced seed yield drastically. The maximum seed yield (1236 kg ha^{-1}) was obtained when all the cultivars were planted on 30 September due to higher number of pods/plant, pod length and seeds/pod. Of the three cultivars, both BINA Mung 1 and BINA Mung 4 gave higher grain yield when seeds were sown between 15 September to 15 October and considering pooled seed yield. B1NA Mung 4 produced the highest seed yield among three cultivars studied.

Oweis *et al.* (2004) studied three sowing dates (early: mid November, normal: late December to mid January and late: late January to mid February) and four levels of supplemental irrigation (SI) (Full SI, 1/3 SI, 2/3 SI and no SI). The results indicated that lentil grain and biomass yield increased with increased SI. Mean grain yield of 1.04 t ha^{-1} under rainfed conditions increased to 1.42 at 1/3 SI, and 1.81 t ha^{-1} at full SI, while mean water productively was 0.44 kg grain m^{-3} water when rainfed 0.54 at 1/3, SI, 0.6 at 2/3 SI, 0.58 kg m^{-3} at full SI. Early sowing increased lentil biomass production by 0.47 and 1.56 t ha^{-1} over normal and late sowing dates. However, the highest grain yield of 1.60 t ha^{-1} was obtained at the normal sowing date. Sowing date had the greatest impact on crop response under rainfed conditions.

Thanki *et al.* (2004) conducted experiment on sesame which were sown on 10, 17 or 24 February and supplied with 0, 15, 30 or 45 kg P_2O_5 ha^{-1} with or without biofertilizer in a field experiment during the summer of 1999- 2000. Sowing in 17 February gave the highest plant height (104 cm) and pooled yield (1290 kg t ha^{-1}). The number of capsules and branches per plant and test weight were highest with 17 February sowing although differences among sowing dates were not significant. Plant height, test weight, oil content and pooled yield increased with increasing of P_2O_5. Differences in the values of the parameters measured due to the application or non-application of biofertilizers were not significant.

Khan *et al.* (2005) studied the effect of sowing date (15 April, 1 May, 1 June, 15 June, 1 July, 15 July and 1 August) on the performance of mungbean (Cultivar BINA MUNG 98). Sowing on 1 May resulted in the highest number of branches (4.75) and pods (83.38) per plant, 1000-grain weight (40.47g) and grain yield (1429 kg ha^{-1}). The interaction between day length and grain yield was studied at 3 stages of crop growth, i.e. vegetative stages (up to 30 days after sowing), reproductive stage (31-60 days after sowing) and maturity stage (from 61 days after sowing until physiological maturity). Shorter day length at the vegetative stage resulted in a lower dry matter production. Longer day length at the productive stage resulted in the highest grain formation and yield. The decline in day length at maturity resulted in lower yields. The results suggested that the optimum sowing time for mungbean was from 15 April to 15 May.

Sudhakar *et al.* (2006) evaluated on ten genotypes each of blackgram and greengram for traits contributing to water use efficiency in a field experiment during Rabi, 2004-05. Under terminal moisture stress conditions there was a significant reduction of SCMR (SPAD chlorophyll meter reading) and SLA (Specific leaf area) both in blackgram and greengram genotypes. Blackgram genotypes PBG 107, LBG 20 and MBG 207, and greengram genotypes MGG 336 and MGG 351 showed higher SCMR and lower SLA under stress. Significant inverse relationship ($r = 0.73$, $P<0.05$) was observed between SLA and SCMR in blackgram genotypes while no correlation was observed in greengram genotypes. Significant positive relationships were observed between under moisture stress indicating that SCMR could be used as a screening tool for grain yield under drought conditions.

Ahmed *et al.* (2006) conducted an experiment to find out the suitable variety (BARI Barley-1, BARI Barley-2 and local and sowing time of barley (30 November, 15 December and 30 December). Grain and straw yields increased significantly with early sowing (30 November) in all the varieties in both the years. The results showed that early sowing (30 November) combined with BARI Barley-1 gave the highest grain yield (2.55 t ha^{-1}) and straw yield (4.28 t ha^{-1}), whereas the lowest grain yield (1.33 t ha^{-1}) and straw yield (3.21 t ha^{-1}) were obtained from local variety with delayed sowing. Besides, local variety of barley could be replaced by BARI Barley varieties for higher yield. If transplanting aman rice harvest is delay then BARI Barley-I could be grown up to 15 December for getting optimum grain yield in High Barind Rajshahi area of AEZ 26.

Bozhek *et al.* (2006) conducted an experiment to determine the interaction of sowing date and plant density in Nazilla 84 cotton cultivar in Aegean Region. It was found that delaying sowing date significantly decreased seed cotton yield but the differences among plant densities were non-significant in both the cultivars. The correlation coefficients and path analysis results among yield components, fiber technological characteristics and dry matter accumulation at first true leaf-boll retention showed that the ginning turnout had the highest positive direct effect on seed yield. It was concluded that when the plant has less boll retention, dry matter accumulations between flowering-boll retention had adverse effect on seed yield.

Malik *et at.* (2006) conducted an experiment to determine the effect of sowing dates and planting patterns on growth and yield of mungbean (cv. M-6). Treatments comprised two sowing dates (main plot) i.e, third week of June and third week of July and three sowing methods (sub plot) i.e 30 cm apart flat sowing and 30 cm apart ridge and 20 apart 40 cm wide bed sowing. The seed yield was significantly affected by both sowing time and planting pattern. The maximum seed yield (1259.26 kg ha^{-1}) was recorded in third week of July sowing. Among the sowing methods, bed sowing (40/20 cm) resulted in maximum seed yield (1117.28 kg ha^{-1}). However, interaction between these two factors was found to be non-significant.

Kawsar *et al.* (2009) studied the influence of sowing date on growth and yield of four summer mungbean [*Vigna radiata* (L.) Wilczek] varieties viz., BINA moog 2, BINA moog 5, BINA moog 6 and BINA moog 7 were sown at 10 days intervals starting from 20 February to 11 April to identify the suitable variety and optimum sowing date for getting maximum yield of summer mungbean. Among the varieties, BINA moog 7 was ranked first in terms of seed yield (938.40 kg ha^{-1}) followed by of

BINA moog 6 (711.72 kg ha^{-1}), BINA moog 5 (684.00 kg ha^{-1}) and BINA moog 2 (547.80 kg ha^{-1}). BINA moog 6 matured earlier than the other three varieties. The highest seed yield (969.62 kg ha^{-1}) was obtained from 2 March sowing followed by 20 February (917.54 kg ha^{-1}) and 12 March sowing (869.52 kg ha^{-1}). Sowing after 2 March gradually decreased the seed yield producing the lowest value (388.87 kg ha^{-1}) at 11 April sowing. In general delayed sowing enhanced the maturity. BINA moog 7 yielded the highest (1201.32 kg ha^{-1}) when sown on 2 March which was statistically similar to 20 February and 12 March sowing. They concluded that summer mungbean variety BINA moog 7 may be sown during the period from 20 February to 12 March for higher seed yield and for late sowing, BINA moog 6 may be considered as it matures earlier than the others.

CHAPTER 3

MATERIALS AND METHODS

Materials

Materials used in the present investigation consisted of four varieties of blackgram (*Phaseolus mungo L.*) which were as follows:

(i) BARIMASH-1
(ii) BARIMASH-2
(iii) BARIMASH-3
(iv) LOCAL VARIETY B-10

Seeds of BARIMASH varieties were obtained from Regional Agricultural Research Station, Ishurdhi, Pabna and Local variety B-10 was obtained from Rajshahi local market.

Methods

The experiment was conducted in the experimental field of Rajshahi University campus during the period from August to November (Kharif-2 season) of 2005-2006 and 2006-2007. The soil of the experimental field was well drained sandy to loam with pH 7.5. The different sowing dates of the two consecutive years were:

i) 01 August (S_1)
ii) 11 August (S_2)
iii) 21 August (S_3)
iv) 31 August (S_4)

The experiment was laid out in a split plot design with three replications. Dates of sowing were assigned to the main plot and varieties in the sub plot. The size of the experimental plot was 28m×23m which was prepared for sowing after repeated ploughing and harrowing by removing weeds of the previous corps. After preparation of the field, it was divided into four main plots which was again subdivided into three replications. Each main plot (sowing) was 7m long and 6m in breadth consisted of 20 rows. There were 5 rows for each variety. Row to row distance was 20 cm, plant to plant 20 cm, plot (sowing) to plot spacing was 1m and depth of seeding was 1-1.5cm. The footpath was 1m and the distance between the replication was 50cm. For the experimental purpose 3 rows were selected for each variety and the two border rows were used as non experimental to eliminate the border effects. After three days of sowing, emerged seedlings were thinned to uniform and desirable number of plants.

Crop management

Although blackgram doesn't require fine tilth, better land preparation results in good germination and uniform stand of the crop. It also helps the crop to achieve higher seedling vigour and early growth. A basal dose of nitrogen (18 kg ha^{-1}), triple super phosphate (T.S.P) (40 kg ha^{-1}) and murate of potash M. P (24 kg ha^{-1}) was applied to the soil before sowing. 30 kg ha^{-1} nitrogen was also applied after 30 days of sowing. Necessary weeding was done to keep the crop free of weeds in first 6 weeks from seedling emergence until the canopy was established. Proper soil moisture is important for good and uniform germination (first 3 weeks). As blackgram is grown under kharif-2 monsoon, so irrigation was not used in this investigation.

Tilt-250 E.C (0.05%) and pythrin (10 E.C) fungicides were sprayed 3 times at 10-12 days interval from seedling emergence to maturity for control powdery mildew. Besides this, systemic insecticide 1m.l Nogos

(100 E.C)/litre water was sprayed to control of vectors like sucking insects, pests and diseases.

Measurement of plant dry weight and leaf area

Collection of data

There were 07 harvests per sowing with equal intervals of 10 days and the first harvest was taken at 15 days after sowing (DAS). Three plants were randomly selected per replication, per variety, per sowing were harvested on each occasion. At each harvest the plants were cut off at the ground level of stem and the tops were separated into different plant parts as leaflet, stem, petiole, flower and green immature pods (if present). Plant height, leaflet number and petiole number were recorded at each harvest as morphological data. The different plant parts were dried separately in an electric oven at about 85°C for 48 hours and the weights of these plant parts were taken by an electronic balance until a constant weight was attained. For leaf area determination, 10 leaf discs were cut off with the help of a cork borer and its area was measured through length and breadth and then dried in an oven. The oven dried discs were weighted. Then the leaf area was determined by using the following formula:

$$\text{Leaf Area} = \frac{\text{Area of discs} \times \text{weight of leaves}}{\text{Weight of discs}}\ \text{cm}^2$$

Total Dry Matter = Leaf dry weight +stem dry weight + petiole dry weight.........+ x (where, x = Flower dry and pod dry weights). Leaf area was determined by the disc method (Islam and Paul, 1986).

Growth attributes

Both the harvest interval method (classical technique) and curve-fitting method (functional technique) of growth analysis were followed to determine the various growth attributes in the present investigation like crop growth rate, relative growth rate, relative leaf growth rate, net assimilation rate, leaf area ratio from the dry weight of different plant parts between two sequential harvests. Leaf area index, specific leaf area and leaf weight ratio were also calculated separately for each harvest according to the classical technique of growth analysis (Radford, 1967).

1. Crop growth rate (CGR) $= \dfrac{W_2 - W_1}{t_2 - t_1}$

2. Leaf area duration $(\text{LAD}) = \dfrac{(LA_2 + LA_1)(t_2 - t_1)}{2}$

3. Relative growth rate (RGR) $= \dfrac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$

4. Net assimilation rate (NAR) $= \dfrac{(W_2 - W_1)(\log_e LA_2 - \log_e LA_1)}{(LA_2 - LA_1)(t_2 - t_1)}$

5. Leaf area ratio (LAR) $= \dfrac{(LA_2 - LA_1)(\log_e W_2 - \log_e W_1)}{(\log_e LA_2 - \log_e LA_1)(W_2 - W_1)}$

6. Relative leaf growth rate (RLGR) $= \dfrac{\log_e LA_2 - \log_e LA_1}{t_2 - t_1}$

The following growth attributes were calculated separately for each harvest.

7. Specific leaf area (SLA) $= \dfrac{\text{Leaf area}}{\text{Leaf dry weight}}$

8. Leaf weight ratio (LWR) $= \dfrac{\text{Leaf dry weight}}{\text{Total plant dry weight}}$

9. Leaf area index (LAI) $= \dfrac{\text{Leaf area}}{\text{Ground area}}$

Where, W_2 and W_1 are the total dry weights, LA_2 and LA_1 are the leaf area per plant and t_2 and t_1 are time at the later and former harvest respectively.

In the curve-fitting method, polynomial functions were fitted to natural logarithmic values of total dry weight, leaf dry weight and total leaf area (Hunt, 1978). The $\log_e$ transformation was made in order to render the homogeneousity with time (Hughes and Freeman, 1967). The selection of appropriate polynominal regression model was done by "lack of fit" method of Nicholls and Calder (1973). The second degree polynomial curves have been used in all cases. The second degree formulae for growth attributes in the functional techniques were used as follows:

1. $RGR = b+2ct$
2. $LAR = \text{Anti} \log_e (\log_e LA - \log_e W)$
3. $NAR = RGR / LAR$
4. $RLGR = b' + 2c't$

Where, b and c are constants of dry weight and b′ and c′ are constants of leaf area per plant obtained from polynomial equations and 't' is the instantaneous time of harvest. The $\log_e$ total dry weights, $\log_e$ leaf dry weights and $\log_e$ leaf area were taken from similar curve fitted value and it was possible to derive values for specific leaf area (SLA) and leaf weight ratio (LWR).

Phenological stages

The following stages were recorded in days when 50% plants of a variety of each replication reached a definite as the representative of that stage.

1. Seed emergence
2. Leaflet initiation
3. Flower initiation
4. Pod initiation
5. Pod filling
6. Physiological maturity

Day degree

The accumulated heat unit system which is based on the idea that plants have a definite temperature requirements before they attain certain phenological stages, have a significant relationship with temperature, plant growth and phenological development of a crop. The daily maximum and minimum air temperatures and sunshine hours were recorded. It was done from the date of sowing upto maturity.

The following measurements were calculated according to the formulae of Rajput (1980).

1. Growing degree days (GDD) = $\sum_{i=1}^{n} [T_{max} + T_{min})/2 - T_b]$

Where i = 1------ n denotes each day from sowing to physiological maturity.

T_{max} = Daily maximum temperature

T_{min} = Daily minimum temperature

and T_b = Base temperature = 10°C

2. Helio-thermal unit (HTU) = GDD × duration of sunshine hours
3. Heat use efficiency (HUE) =Grain yield kg ha^{-1} ÷ GDD
4. Phenothermal index (PTI) = GDD ÷ Growth days

Chlorophyll content

Chlorophyll content of matured green leaves were estimated. For the determination of chlorophyll, five leaf discs were taken from the different positions of matured green laves and the extraction of chlorophyll was carried out with 80% aqueous acetone using a morter and pestle to grind the tissues. The suspension was poured into centrifuge tubes and centrifuged for three minutes. After centrifugation, the upper clear green solution was decanted from the colourless residue and then made up to 10 ml with 80% acetone. Against 80% acetone, the optical density (OD) of this solution was determined using a spectrophotometer at wave lengths of 645 nm and 663 nm. Chlorophyll contain was measured according to the formulae given by Mackinney (1941) and later used by Arnon (1949). Chlorophyll a and b were determined as follows:

$OD = 2 - \log t$, Here, t = transmitance

Quantity of chlorophyll a = $12.717\ A_2 - 2.584\ A_1$ = mg chlorophyll a litre^{-1}

Quantity of chlorophyll b = $22.896\ A_1 - 4.670 A_2$ = mg chlorophyll b litre^{-1}

Where A_1 and A_2 are OD at wave lengths of 645 nm and 663 nm respectively.

Amount of chlorophyll per unit leaf area was calculated by the following way:

$$\frac{\text{mg chlorophyll 'a' or 'b' litre}^{-1}}{1000 \times \text{leaf area}} \times 10\ \text{mgl}^{-1}/\text{dm}^2$$

Relative leaf water content

Relative leaf water content was (RLWC) was determined from five matured green leaves. The leaves were collected at 8.00 a.m., 12.00 noon and 4.00 p.m. Five matured green leaves were taken from each replication of each variety of each treatment randomly and immediately taken in sealed polythene bags. Their fresh weights (FW) were taken separately and then sunk into water kept in test tubes for 4 hours. After 4 hours when the cells of the leaves became fully turgid the leaves were taken out from water and drying with blotting paper and their turgid weights (TW) were determined. Then the leaves were dried in an electric oven at 85°C for 24 hours and weighted. These gave the dry weights (DW). Relative leaf water content (RLWC) was meseared according to the following formulae given by Barrs and Weatherley (1962).

$$\text{RLWC} = \frac{\text{FW-DW}}{\text{TW-DW}} \times 100$$

Where, FW = Fresh weight

TW = Turgid weight

DW = Dry weight

Yield and yield components

Six plants/variety/replication/treatment were harvested (naturally dry) after maturity for the determination of the grain yield and its components. In this case root was not considered. At the time of final harvest following characters were recorded:

1. Plant height (cm)
2. Total dry matter plant^{-1} (g)
3. Pod number plant $^{-1}$
4. Pod dry weight plant^{-1} (g)
5. Grain number plant^{-1}
6. Grain weight plant^{-1} (g)
7. 100-seed weight (g)
8. Grain yield (kg ha^{-1})
9. Harvest index (%)

Harvest index was calculated by using the following formula:

$$\textbf{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100 = \frac{\text{Grain yield}}{\text{Total plant dry weight}} \times 100$$

Meteorological data

Meteorological data were collected from Regional Meteorological Station, Shyampur, Rajshahi which is about two km from the experimental field. Various meteorological information like maximum and minimum air temperature (^oC), relative humidity (%), sunshine hours (h) and total rainfall (mm) were collected during the growth period. Data were collected from 01 August, 2005 to 30 November, 2005 and 01 August, 2006 to 30 November, 2006 (Shown in Figure 1).

Statistical analysis of data

Statistical analysis was performed by Microsoft Excel and Irritate 3.1 software. Statistical analysis was done according to Gomez and Gomez (1984). Throughout the thesis, different notations have been used to specify statistical significance.

NS = Non– significant
* = Significant at 5% level (i.e., $p = 0.05$)
** = Significant at 1% level (i.e., $p = 0.01$)
LSD = Least significant differences

CHAPTER 4

RESULTS

Meteorological Data

Monthly mean air temperature (maximum and minimum) and sunshine hours (h) from sowing to final harvest are presented in Figure 1 for the 2005-2006 and 2006-2007 growing seasons respectively. It was observed that at the early growth periods (August and September) both the maximum and minimum air temperatures (°C) were higher and then declined upto the final harvest in both the seasons. So, at the early growing period, S_1 had the highest air temperature (°C) and the lowest in S_4 than that of the middle growth stages (October) in both seasons. On the other hand the lowest mean sunshine hours (h) were observed during the early growing periods till August and then increased gradually upto the final harvest (November) in both the seasons. The lowest sunshine hours were observed during S_1 growing period and the highest in S_4 plants for both the seasons.

Choice of Growth Analysis Technique

For the study of plant growth and productivity, growth analysis has long been established as a standard technique. There are two different approaches of plant growth analysis classical and functional techniques. Out of the two approaches followed, the classical one lies strictly on the harvest data sets where parameters like mean relative growth rate (RGR) between a pair of harvests are taken into consideration while the second one (functional technique) uses regression procedures. In the later, a suitable mathematical function represented by a smooth curve is fitted to

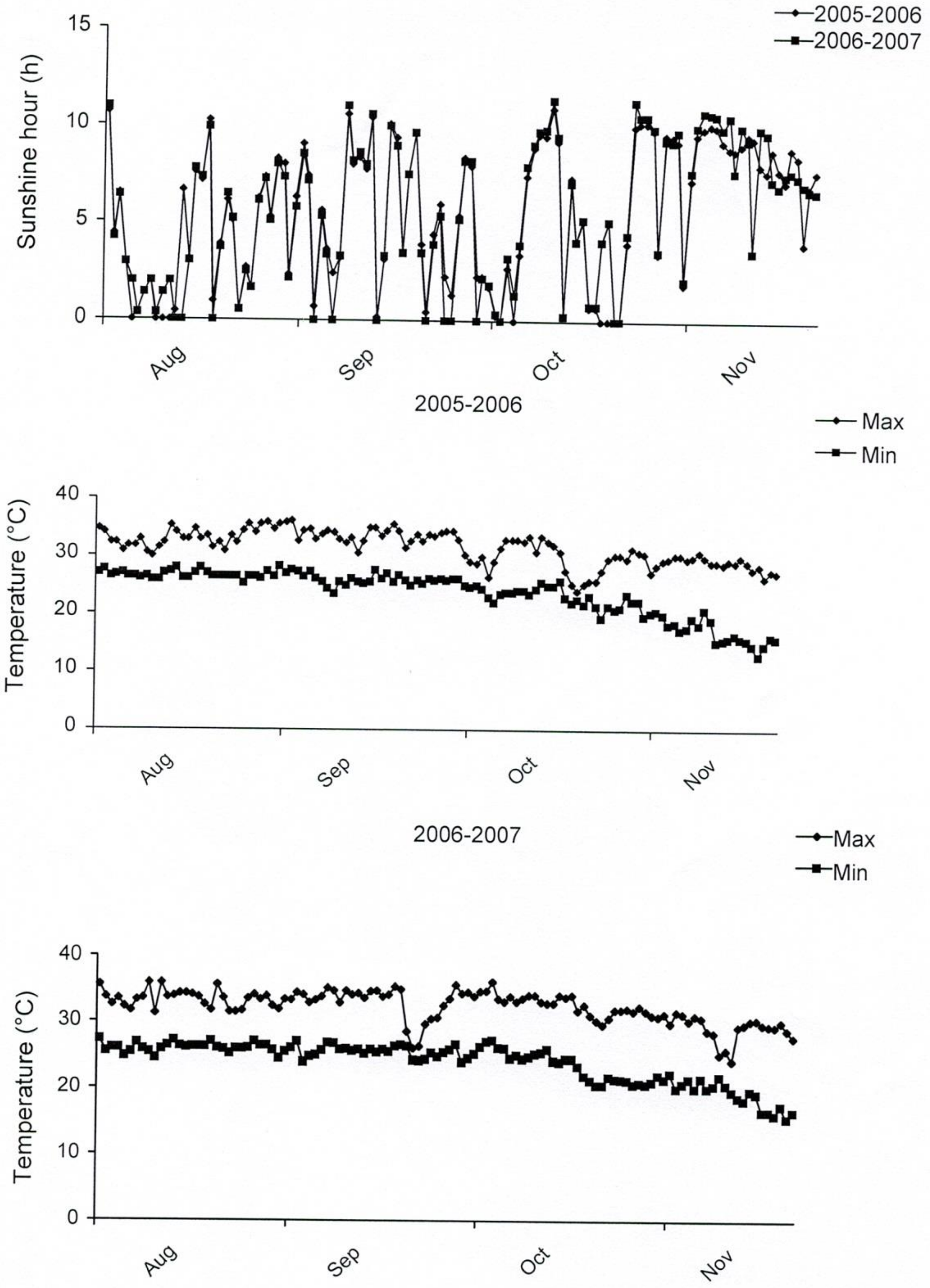


Figure 1: Two meteorological parameters during two crop growing seasons.

the recorded values of plant dry weight (W) or leaf area (LA) so that it approximates the real growth curve. However, the major difficulty encountered in the classical approach is of the sampling error of the primary data which seriously obliterates the derived functions in the regression analysis. On the other hand looser confidence limits are acceptable. However, the major problem lies in the choice of a suitable function that represents the best approximation of the observed growth. Among the various statistical models proposed, polynomial exponential model has been the most popular one because the simple mathematical and statistical properties of the model enable it to be fitted to data by an exact and relatively straight-forward models of linear regression. After reviewing different methods it is concluded that use of polynomials is preferable in growth analysis. A polynomial exponential model has great potential in a purely empirical approach to the study of plant growth, where objective is to assess and compare either genetic or environmental influences. In the present experiment both the classical and the functional techniques (polynomial exponential technique) were followed.

The residual sum of squares were calculated for linear, quadratic and cubic equations fitted to $\log_e$ total dry matter per unit ground area, $\log_e$ total dry matter plant^{-1}, $\log_e$ leaf area plant^{-1}, $\log_e$ leaf area index, and $\log_e$ leaf dry weight plant^{-1} as a function of time (Tables 1a and 1b – 5a and 5b). The changes in LAI, leaf area and leaf dry weight were adequately described by second degree polynomial in the four blackgram varieties ($p = 0.05$ and $p = 0.01$) but in case of total dry matter per unit ground area and total dry matter plant^{-1} a third degree polynomial was adequate. However, the second degree polynomial curves have been used in all the cases for comparison.

Coefficients obtained from quadratic fitted curves of $\log_e$ total dry matter (gm^{-2}) and $\log_e$ leaf area plant^{-1} (cm^2) of four blackgram varieties as influenced by sowing times are presented in (Tables 6 and 8). It was observed that the equations a, a′, b and b′ coefficients were always positive and c and c′ coefficients were always negative for $\log_e$ total dry matter (gm^{-2}) and $\log_e$ leaf area plant^{-1} (cm^2) in both the years. On the other hand coefficient obtained from quadratic fitted curves of $\log_e$ total dry matter plant^{-1}(g), $\log_e$ leaf area index (LAI) and $\log_e$ leaf dry weight plant^{-1} (g) of four blackgram varieties as affected by sowing times are given in (Tables 7, 9 and 10). For these cases the equations b and b′ coefficients were always positive in both the years. The equations a, a′, c and c′ coefficients were always negative for $\log_e$ total dry matter plant^{-1} (g), $\log_e$ leaf area index and $\log_e$ leaf dry weight plant^{-1} (g) in both the years except for leaf dry weight plant^{-1}(g) (Table 10) only a′ coefficient was positive for 2nd year in BARIMASH-2 and BARIMASH-3 of all the varieties and sowings.

Table 1a. Reduction in mean squares due to successive terms of $\log_e$ total dry matter ($g\ m^{-2}$) of four blackgram varieties as affected by sowing times for (2005-2006).

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.794*	8.211*	11.345*	9.032*
Deviation from linear	5	0.367	0.242	0.260	0.259
Reduction due to quadratic	1	1.717	1.182	1.077	1.199
Deviation from quadratic	4	2.228	2.059	2.892	2.282
Reduction due to cubic	1	0.074	0.0003	0.045	0.022
Deviation from cubic	3	3.519	3.139	4.200	3.435

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.244*	9439*	11.206*	9.299*
Deviation from linear	5	0.409	0.221	0.426	0.308
Reduction due to quadratic	1	2.028	1.056	1.724	1.255
Deviation from quadratic	4	2.3 15	2.372	2.903	2.396
Reduction due to cubic	1	0.0001	0.0002	0.265	0.126
Deviation from cubic	3	3.763	3.515	4.358	3.571

(Table 1a. continued)

BARIMASH-3

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.647*	9.238*	10.513*	9.233*
Deviation from linear	5	0.331	0.293	0.459	0.253
Reduction due to quadratic	1	1.605	1.310	1.769	1.170
Deviation from quadratic	4	2.175	2.349	2.760	2.332
Reduction due to cubic	1	0.007	0.015	0.420	0.038
Deviation from cubic	3	3.432	3.563	4.130	3.486

LOCAL VARIETY B-10

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.001*	12.679*	14.511*	11.749*
Deviation from linear	5	0.307	0.141	0.427	0.149
Reduction due to quadratic	1	1.401	0.652	1.917	0.574
Deviation from quadratic	4	2.284	3.183	3.683	2.979
Reduction due to cubic	1	0.005	0.023	0.039	0.004
Deviation from cubic	3	3.511	4.454	5.536	4.163

Table 1b. Reduction in mean squares due to successive terms of $\log_e$ total dry matter plant^{-1} ($g\ m^{-2}$) of four blackgram varieties as affected by sowing times for (2006-2007)

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.798*	8.213*	11.332 *	9.020*
Deviation from linear	5	0.367	0.242	0.262	0.259
Reduction due to quadratic	1	1.715	1.183	1.082	1.198
Deviation from quadratic	4	2.229	2.059	2.889	2.279
Reduction due to cubic	1	0.074	0.0003	0.046	0.021
Deviation from cubic	3	3.519	3.140	4.198	3.430

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.239*	9439*	11.219*	9.304*
Deviation from linear	5	0.409	0.22 1	0.428	0.308
Reduction due to quadratic	1	2.029	1.055	1.728	1.252
Deviation from quadratic	4	2.3 14	2.372	2.907	2.398
Reduction due to cubic	1	0.0001	0.0002	0.268	0.128
Deviation from cubic	3	3.762	3.5 15	4.363	3.572

(Table 1b. continued)

BARIMASH-3

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.646*	9.238*	10.505*	9.236*
Deviation from linear	5	0.331	0.293	0.459	0.253
Reduction due to quadratic	1	1.606	1.310	1.762	1.169
Deviation from quadratic	4	2.174	2.349	2.759	2.332
Reduction due to cubic	1	0.007	0.015	0.418	0.038
Deviation from cubic	3	3.432	3.563	4.127	3.487

LOCAL VARIETY B-10

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.992*	12.679*	14.511*	11.751*
Deviation from linear	5	0.307	0.141	0.427	0.149
Reduction due to quadratic	1	1.401	0.652	1.917	0.574
Deviation from quadratic	4	2.282	3.183	3.683	2.980
Reduction due to cubic	1	0.005	0.023	0.039	0.004
Deviation from cubic	3	3.508	4.454	5.536	4.164

Table 2a. Reduction in mean squares due to successive terms of $\log_e$ total dry matter plant^{-1}(g) of four blackgram varieties as affected by sowing times for (2005-2006).

BARI MASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.794*	8.211*	11.345*	9.032*
Deviation from linear	5	0.367	0.242	0.260	0.259
Reduction due to quadratic	1	1.717	1.182	1.077	1.199
Deviation from quadratic	4	2.228	2.059	2.892	2.282
Reduction due to cubic	1	0.074	0.0003	0.045	0.022
Deviation from cubic	3	3.519	3.139	4.200	3.435

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.244*	9.439*	11.206*	9.299*
Deviation from linear	5	0.409	0.221	0.426	0.308
Reduction due to quadratic	1	2.028	1.056	1.724	1.255
Deviation from quadratic	4	2.315	2.372	2.903	2.396
Reduction due to cubic	1	0.001	0.0002	0.264	0.126
Deviation from cubic	3	3.763	3.515	4.358	3.571

(Table 2a. Continued)

BARIMASH-3

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.647*	9.238*	10.513*	9.233*
Deviation from linear	5	0.331	0.293	0.459	0.253
Reduction due to quadratic	1	1.605	1.310	1.769	1.170
Deviation from quadratic	4	2.174	2.349	2.760	2.332
Reduction due to cubic	1	0.007	0.015	0.420	0.038
Deviation from cubic	3	3.432	3.563	4.130	3.486

LOCAL VARIETY B-10

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.001*	12.679*	14.511*	11.749*
Deviation from linear	5	0.307	0.141	0.427	0.149
Reduction due to quadratic	1	1.401	0.652	1.917	0.574
Deviation from quadratic	4	2.284	3.183	3.683	2.979
Reduction due to cubic	1	0.005	0.023	0.039	0.004
Deviation from cubic	3	3.511	4.454	5.536	4.163

Table 2b. Reduction in mean squares due to successive terms of $\log_e$ total dry matter plant^{-1} (g) of four blackgram varieties as affected by sowing times for (2006-2007).

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.798*	8.213*	11.332*	9.020*
Deviation from linear	5	0.367	0.242	0.262	0.259
Reduction due to quadratic	1	1.715	1.183	1.082	1.198
Deviation from quadratic	4	2.229	2.059	2.889	2.279
Reduction due to cubic	1	0.074	0.0003	0.046	0.021
Deviation from cubic	3	3.519	3.140	4.198	3.430

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	9.239*	9.439*	11.2 19*	9.304*
Deviation from linear	5	0.409	0.221	0.428	0.308
Reduction due to quadratic	1	2.029	1.055	1.728	1.252
Deviation from quadratic	4	2.314	2.372	2.907	2.398
Reduction due to cubic	1	0.0001	0.0002	0.268	0.128
Deviation from cubic	3	3.762	3.515	4.363	3.572

(Table 2b. continued)

BARIMASH-3

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.646*	9.238*	10.505*	9.236*
Deviation from linear	5	0331	0.293	0.459	0.252
Reduction due to quadratic	1	1.606	1.310	1.762	1.169
Deviation from quadratic	4	2.174	2.349	2.759	2.332
Reduction due to cubic	1	0.007	0.015	0.418	0.038
Deviation from cubic	3	3.432	3.563	4.127	3.487

LOCAL VARIETY B-10

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	8.992*	12.679*	14.511*	11.751*
Deviation from linear	5	0.307	0.141	0.427	0.149
Reduction due to quadratic	1	1.400	0.652	1.917	0.575
Deviation from quadratic	4	2.282	3.183	3.683	2.980
Reduction due to cubic	1	0.005	0.023	0.039	0.004
Deviation from cubic	3	3.507	4.454	5.536	4.164

Table 3a. Reduction in mean squares due to successive terms of Log$_e$ leaf area plant^{-1} (cm^2) of four black gram varieties as affected by sowing times for (2005-2006).

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	3.008	1.366	2.819	1.487
Deviation from linear	5	0.498	0.462	0.501	0.318
Reduction due to quadratic	1	2.249	2.285	2.052	1.428
Deviation from quadratic	4	0.812	0.348	0.818	0.412
Reduction due to cubic	1	0.043	0.002	0.342	0.131
Deviation from cubic	3	1.818	1.225	1.660	0.982

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.559	2.153	2.155	2.089
Deviation from linear	5	0.549	0.396	0.669	0.419
Reduction due to quadratic	1	2.675	1.850	2.977	1.963
Deviation from quadratic	4	0.657	0.571	0.631	0.556
Reduction due to cubic	1	0.057	0.002	0.306	0.019
Deviation from cubic	3	1.749	1.377	1.732	1.389

(Table 3a. continued)

BARIMASH-3

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.390	2.536	1.408	2.172
Deviation from linear	5	0.498	0.499	0.623	0.350
Reduction due to quadratic	1	2.393	2.281	2.569	1.580
Deviation from quadratic	4	0.622	0.687	0.489	0.586
Reduction due to cubic	1	0.002	0.014	0.479	0.117
Deviation from cubic	3	1.626	1.672	1.348	1.269

LOCAL VARIETY B-10

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	5.325	7.310*	6.716*	4.009
Deviation from linear	5	0.303	0.224	0.384	0.392
Reduction due to quadratic	1	1.397	0.880	1.847	1.763
Deviation from quadratic	4	1.361	1.887	1.697	1.052
Reduction due to cubic	1	0.111	0.229	0.041	0.066
Deviation from cubic	3	2.243	2.733	2.865	1.968

Table 3b. Reduction in mean squares due to successive terms of Log_e leaf area plant^{-1} (cm^2) of four blackgram varieties as affected by sowing times for (2006-2007).

BARIMASH-1

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	3.006	1.368	2.813	1.484
Deviation from linear	5	0.497	0.462	0.503	0.319
Reduction due to quadratic	1	2.247	2.284	2.059	1.430
Deviation from quadratic	4	0.811	0.349	0.817	0.412
Reduction due to cubic	1	0.043	0.002	0.342	0.133
Deviation from cubic	3	1.816	1.225	1.661	0.982

BARIMASH-2

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.558	2.154	2.155	2.088
Deviation from linear	5	0.549	0.396	0.669	0.418
Reduction due to quadratic	1	2.676	1.849	2.974	1.959
Deviation from quadratic	4	0.657	0.571	0.633	0.555
Reduction due to cubic	1	0.058	0.002	0.309	0.019
Deviation from cubic	3	1.748	1.377	1.732	1.387

(Table 3b. continued)

BARIMASH-3

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.395	2.536	1.408	2.172
Deviation from linear	5	0.497	0.499	0.620	0.350
Reduction due to quadratic	1	2.389	2.281	2.559	1.581
Deviation from quadratic	4	0.623	0.687	0.488	0.585
Reduction due to cubic	1	0.002	0.014	0.478	0.117
Deviation from cubic	3	1.626	1.672	1.345	1.269

LOCAL VARIETY B-10

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	5.329	7.310*	6.716*	4.013
Deviation from linear	5	0.303	0.224	0.384	0.392
Reduction due to quadratic	1	1.397	0.880	1.847	1.761
Deviation from quadratic	4	1.362	1.887	1.697	1.053
Reduction due to cubic	1	0.109	0.229	0.041	0.067
Deviation from cubic	3	2.245	2.733	2.865	1.969

Table 4a. Reduction in mean squares due to successive terms of Log$_e$ leaf area index of four blackgram varieties as affected by sowing times for (2005-2006).

BARIMASH-1

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	3.008	1.366	2.819	1.487
Deviation from linear	5	0.498	0.462	0.501	0.318
Reduction due to quadratic	1	2.249	2.285	2.052	1.428
Deviation from quadratic	4	0.812	0.348	0.818	0.412
Reduction due to cubic	1	0.043	0.002	0.342	0.131
Deviation from cubic	3	1.818	1.225	1.660	0.982

BARIMASH-2

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.559	2.153	2.155	2.089
Deviation from linear	5	0.549	0.396	0.669	0.419
Reduction due to quadratic	1	2.676	1.850	2.977	1.963
Deviation from quadratic	4	0.657	0.571	0.631	0.556
Reduction due to cubic	1	0.057	0.002	0.306	0.019
Deviation from cubic	3	1.749	1.377	1.732	1.389

(Table 4a. continued)

BARIMASH-3

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.390	2.536	1.408	2.172
Deviation from linear	5	0.497	0.499	0.623	0.350
Reduction due to quadratic	1	2.393	2.281	2.569	1.580
Deviation from quadratic	4	0.622	0.687	0.489	0.586
Reduction due to cubic	1	0.002	0.014	0.479	0.117
Deviation from cubic	3	1.626	1.672	1.348	1.269

LOCAL VARIETY B-10

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	5.325	7.310*	6.716*	4.009
Deviation from linear	5	0.303	0.224	0.384	0.392
Reduction due to quadratic	1	1.397	0.880	1.847	1.763
Deviation from quadratic	4	1.361	1.887	1.697	1.052
Reduction due to cubic	1	0.111	0.229	0.041	0.066
Deviation from cubic	3	2.243	2.733	2.865	1.968

Table 4b. Reduction in mean squares due to successive terms of Log_e leaf area index of four blackgram varieties as affected by sowing times for (2006-2007).

BARIMASH-1

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	3.006	1.368	2.813	1.484
Deviation from linear	5	0.497	0.462	0.503	0.319
Reduction due to quadratic	1	2.247	2.284	2.059	1.430
Deviation from quadratic	4	0.811	0.349	0.817	0.412
Reduction due to cubic	1	0.043	0.002	0.342	0.133
Deviation from cubic	3	1.816	1.225	1.661	0.982

BARIMASH-2

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.558	2.154	2.155	2.088
Deviation from linear	5	0.549	0.396	0.669	0.418
Reduction due to quadratic	1	2.676	1.849	2.974	1.959
Deviation from quadratic	4	0.657	0.571	0.633	0.555
Reduction due to cubic	1	0.058	0.002	0.309	0.019
Deviation from cubic	3	1.748	1.377	1.732	1.387

(Table 4b. continued)

BARIMASH-3

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.395	2.536	1.408	2.172
Deviation from linear	5	0.497	0.499	0.620	0.350
Reduction due to quadratic	1	2.389	2.281	2.559	1.581
Deviation from quadratic	4	0.623	0.687	0.488	0.585
Reduction due to cubic	1	0.002	0.014	0.478	0.117
Deviation from cubic	3	1.626	1.672	1.345	1.269

LOCAL VARIETY B-10

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	5.329	7.310*	6.716*	4.013
Deviation from linear	5	0.303	0.224	0.384	0.392
Reduction due to quadratic	1	1.398	0.880	1.847	1.761
Deviation from quadratic	4	1.362	1.887	1.697	1.053
Reduction due to cubic	1	0.109	0.229	0.041	0.067
Deviation from cubic	3	2.245	2.733	2.865	1.969

Table 5a. Reduction in mean squares due to successive terms of Log$_e$ leaf dry weight plant^{-1} (g) of four blackgram varieties as affected by sowing times for (2005-2006).

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	4.249	2.369	4.279	3.486
Deviation from linear	5	0.410	0.422	0.374	0.299
Reduction due to quadratic	1	1.989	2.106	1.620	1.358
Deviation from quadratic	4	1.078	0.593	1.132	0.906
Reduction due to cubic	1	0.003	0.002	0.045	0.022
Deviation from cubic	3	2.099	1.492	2.035	1.653

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	4.036	3.388	3.862	3.966
Deviation from linear	5	0.531	0.356	0.494	0.398
Reduction due to quadratic	1	2.608	1.632	2.286	1.738
Deviation from quadratic	4	1.032	0.884	1.012	1.055
Reduction due to cubic	1	0.076	0.029	0.004	0.033
Deviation from cubic	3	2.211	1.713	2.110	1.974

(Table 5a. continued)

BARIMASH-3

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	3.485	3.837	3.516	4.209
Deviation from linear	5	0.460	0.414	0.480	0.367
Reduction due to quadratic	1	2.221	1.787	1.956	1.747
Deviation from quadratic	4	0.892	1.029	0.990	1.074
Reduction due to cubic	1	0.056	0.118	0.134	0.004
Deviation from cubic	3	1.910	1.929	1.928	2.013

LOCAL VARIETY B-10

Sources of variation	df	Mean squares			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	7.050*	9.003*	9.207*	6.369
Deviation from linear	5	0.349	0.241	0.266	0.268
Reduction due to quadratic	1	1.679	1.110	1.246	1.097
Deviation from quadratic	4	1.779	2.274	2.323	1.653
Reduction due to cubic	1	0.001	0.063	0.019	0.017
Deviation from cubic	3	2.932	3.3 82	3.507	2.565

Table 5b. Reduction in mean squares due to successive terms of Log$_e$ leaf dry weight plant^{-1} (g) of four blackgram varieties as affected by sowing times for (2006-2007).

BARIMASH-1

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.498	1.024	2.587	1.997
Deviation from linear	5	0.337	0.283	0.295	0.252
Reduction due to quadratic	1	1.628	1.382	1.274	1.159
Deviation from quadratic	4	0.639	0.264	0.697	0.525
Reduction due to cubic	1	0.001	0.010	0.111	0.087
Deviation from cubic	3	1.395	0.809	1.317	1.058

BARIMASH-2

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	2.067	1.775	1.923	2.335
Deviation from linear	5	0.363	0.281	0.397	0.348
Reduction due to quadratic	1	1.710	1.308	1.922	1.698
Deviation from quadratic	4	0.543	0.468	0.497	0.594
Reduction due to cubic	1	0.087	0.069	0.054	0.022
Deviation from cubic	3	1.266	1.038	1.285	1.350

(Table 5b. continued)

BARIMASH-3

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	1.653	1.971	2.027	2.450
Deviation from linear	5	0.282	0.307	0.355	0.343
Reduction due to quadratic	1	1.365	1.254	1.432	1.656
Deviation from quadratic	4	0.425	0.563	0.593	0.627
Reduction due to cubic	1	0.032	0.235	0.205	0.020
Deviation from cubic	3	1.011	1.090	1.199	1.382

LOCAL VARIETY B-10

Sources of variation	**df**	**Mean squares**			
		S_1	S_2	S_3	S_4
Reduction due to linear	1	4.323	6.728*	6.677*	4.089
Deviation from linear	5	0.202	0.270	0.276	0.199
Reduction due to quadratic	1	0.943	1.340	1.342	0.913
Deviation from quadratic	4	1.098	1.685	1.679	1.043
Reduction due to cubic	1	0.0001	0.002	0.006	0.051
Deviation from cubic	3	1.778	2.693	2.684	1.678

Table 6. Constant obtained from quadratic fitted curves of $\log_e$ total dry matter ($g\ m^{-2}$) of four blackgram varieties as affected by sowing times for 2005-2006 and 2006-2007.

BARI MASH-1	**2005-2006**			**2006-2007**		
	Constants					
Sowing time (S)	a	b	c	a′	b′	c′
S_1	3.1860	0.1418	-0.0014	3.2142	0.1418	-0.0014
S_2	3.1143	0.1253	-0.0012	3.1359	0.1254.	-0.0012
S_3	3.1034	0.1316	-0.0011	3.0885	0.1317	-0.0011
S_4	3.0010	0.1285	-0.0012	3.0131	0.1284	-0.0012
BARI MASH-2	**2005-2006**			**2006-2007**		
S_1	3.1962	0.1507	-0.0016	3.1988	0.1507	-0.0016
S_2	3.0736	0.1253	-0.0011	3.0822	0.1253	-0.0011
S_3	2.9692	0.1492	-0.0014	2.9781	0.1494	-0.0014
S_4	3.0943	0.1310	-0.0012	3.0849	0.1309	-0.0012
BARI MASH-3	**2005-2006**			**2006-2007**		
S_1	3.2835	0.1385	-0.0014	3.2944	0.1385	-0.0014
S_2	3.1361	0.1324	-0.0012	3.1228	0.1324	-0.0012
S_3	3.0106	0.1483	-0.0015	3.0151	0.1482	-0.0014
S_4	3.1961	0.1282	-0.0012	3.1994	0.1282	-0.0012
LOCAL VARIETY B-10	**2005-2006**			**2006-2007**		
S_1	3.2578	0.1342	-0.0013	3.2869	0.1341	-0.0013
S_2	2.8366	0.1202	-0.0009	2.8804	0.1202	-0.0009
S_3	2.8198	0.1626	-0.0015	2.8265	0.1626	-0.0015
S_4	2.9235	0.1 144	-0.0008	2.9589	0.1144	-0.0008

Table 7. Constant obtained from quadratic fitted curves of $\log_e$ total dry matter p1ant^{-1}(g) of four blackgram varieties as affected by sowing times for 2005-2006 and 2006-2007.

BARI MASH-1	**2005-2006**			**2006-2007**		
	Constants					
Sowing time (S)	a	b	c	a′	b′	c′
S_1	-0.0329	0.1418	-0.0014	-0.0046	0.1418	-0.0014
S_2	-0.1045	0.1253	-0.0012	-0.0830	0.1254	-0.0012
S_3	-0.1155	0.1316	-0.0011	-0.1303	0.1317	-0.0011
S_4	-0.2179	0.1285	-0.0012	-0.2058	0.1284	-0.0012
BARI MASH-2	**2005-2006**			**2006-2007**		
S_1	-0.0227	0.1507	-0.0016	-0.0201	0.1507	-0.0016
S_2	-0.1452	0.1253	-0.0011	-0.1367	0.1253	-0.0011
S_3	-0.2497	0.1492	-0.0014	-0.2407	0.1494	-0.0014
S_4	-0.1246	0.1310	-0.0012	-0.1339	0.1309	-0.0012
BARI MASH-3	**2005-2006**			**2006-2007**		
S_1	0.0646	0.1385	-0.0014	0.0755	0.1385	-0.0014
S_2	-0.0827	0.1324	-0.0012	-0.0960	0.1324	-0.0012
S_3	-0.2082	0.1483	-0.0015	-0.2038	0.1482	-0.0014
S_4	-0.0228	0.1282	-0.0012	-0.0195	0.1282	-0.0012
LOCAL VARIETY B-10	**2005-2006**			**2006-2007**		
S_1	0.0389	0.1342	-0.0013	0.0681	0.1341	-0.0013
S_2	-0.3823	0.1202	-0.0009	-0.3385	0.1202	-0.0009
S_3	-0.3991	0.1626	-0.0015	-0.3924	0.1626	-0.0015
S_4	-0.2954	0.1144	-0.0008	-0.2600	0.1144	-0.0008

Table 8. Constant obtained from quadratic fitted curves of $\log_e$ leaf area plant^{-1} (cm^2) of four blackgram varieties as affected by sowing times for 2005-2006 and 2006-2007

BARI MASH-1	**2005-2006**			**2006-2007**		
	Constants					
Sowing time	a	b	c	a′	b′	c′
S_1	4.1740	0.1310	-0.0016	4.1892	0.1309	-0.0016
S_2	4.1220	0.1210	-0.0016	4.1365	0.1210	-0.0016
S_3	4.1398	0.1255	-0.0016	4.1345	0.1256	-0.0016
S_4	4.1021	0.1013	-0.0013	4.1075	0.1013	-0.0013
BARI MASH-2	**2005-2006**			**2006-2007**		
S_1	4.2168	0.1373	-0.0018	4.2326	0.1378	-0.0018
S_2	4.1182	0.1168	-0.0015	4.1333	0.1168	-0.0015
S_3	4.1669	0.1407	-0.0019	4.1672	0.1406	-0.0019
S_4	4.1012	0.1190	-0.0015	4.1025	0.1189	-0.0015
BARI MASH-3	**2005-2006**			**2006-2007**		
S_1	4.2937	0.1305	-0.0017	4.2967	0.1304	-0.0017
S_2	4.1302	0.1290	-0.0016	4.1202	0.1290	-0.0016
S_3	4.3499	0.1274	-0.0017	4.3504	0.1272	-0.0017
S_4	4.2503	0.1101	-0.0014	4.2502	0.1102	-0.0014
LOCAL VARIETY B-10	**2005-2006**			**2006-2007**		
S_1	4.1508	0.1210	-0.0013	4.1762	0.1210	-0.0013
S_2	3.8214	0.1125	-0.0010	3.8518	0.1125	-0.0010
S_3	4.0059	0.1379	-0.0015	4.0 159	0.1379	-0.0015
S_4	4.0520	0.1248	-0.0014	4.0770	0.1247	-0.0014

Table 9. Constant obtained from quadratic fitted curves of $\log_e$ leaf area index of four blackgram varieties as affected by sowing times for 2005-2006 and 2006-2007.

BARI MASH-1	**2005-2006**			**2006-2007**		
	Constants					
Sowing time (S)	a	b	c	a′	b′	c′
S_1	-1.8175	0.1310	-0.0016	-1.8023	0.1309	-0.0016
S_2	-1.8695	0.1210	-0.0016	-1.8550	0.1210	-0.0016
S_3	-1.8517	0.1255	-0.0016	-1.8570	0.1256	-0.0016
S_4	-1.8894	0.1013	-0.0013	-1.8840	0.1013	-0.0013
BARI MASH-2	**2005-2006**			**2006-2007**		
S_1	-1.7747	0.1373	-0.0018	-1.7588	0.1373	-0.0018
S_2	-1.8733	0.1168	-0.0015	-1.8582	0.1168	-0.0015
S_3	-1.8246	0.1407	-0.0019	-1.8242	0.1406	-0.0019
S_4	-1.8902	0.1190	-0.0015	-1.8890	0.1189	-0.0015
BARI MASH-3	**2005-2006**			**2006-2007**		
S_1	-1.6977	0.1305	-0.0017	-1.6948	0.1304	-0.0017
S_2	-1.8613	0.1290	-0.0016	-1.8713	0.1290	-0.0016
S_3	-1.6416	0.1274	-0.0017	-1.6410	0.1272	-0.0017
S_4	-1.7412	0.1101	-0.0014	-1.7412	0.1102	-0.0014
LOCAL VARIETY B-10	**2005-2006**			**2006-2007**		
S_1	-1.8407	0.1210	-0.0013	-1.8153	0.1210	-0.0013
S_2	-2.1701	0.1125	-0.0010	-2.1396	0.1125	-0.0010
S_3	-1.9856	0.1379	-0.0015	-1.9755	0.1379.	-0.0015
S_4	-1.9395	0.1248	-0.0014	-1.9145	0.1247	-0.0014

Table 10. Constant obtained from quadratic fitted curves of log$_e$ leaf dry weight plant^{-1} (g) of four blackgram varieties as affected by sowing times for 2005-2006 and 2006-2007.

BARI MASH-1	**2005-2006**			**2006-2007**		
	Constants					
Sowing time (S)	a	b	c	a′	b′	c′
S_1	-0.2673	0.1313	-0.0015	0.1595	0.1134	-0.0014
S_2	-0.2651	0.1241	-0.0016	0.1779	0.0961	-0.0013
S_3	-0.3622	0.1224	-0.0014	0.0533	0.1043	-0.0012
S_4	-0.4381	0.1116	-0.0013	-0.0420	0.0972	-0.0012
BARI MASH-2	**2005-2006**			**2006-2007**		
S_1	-0.2261	0.1437	-0.0018	0.2730	0.1128	-0.0014
S_2	-0.2963	0.1184	-0.0014	0.1498	0.1001	-0.0012
S_3	-0.3395	0.1361	-0.0016	0.1546	0.1170	-0.0015
S_4	-0.3413	0.1239	-0.0014	0.0631	0.1142	-0.0014
BARI MASH-3	**2005-2006**			**2006-2007**		
S_1	-0.1184	0.1328	-0.0016	0.3681	0.1008	-0.0013
S_2	-0.2925	0.1245	-0.0015	0.1825	0.0998’	-0.0012
S_3	-0.3321	0.1270	-0.0015	0.0791	0.1052	-0.0013
S_4	-0.2291	0.1253	-0.0014	0.1874	0.1138	-0.0014
LOCAL VARIETY B-10	**2005-2006**			**2006-2007**		
S_1	-0.2475	0.1350	-0.0014	0.3040	0.1029	-0.0011
S_2	-0.6333	0.1257	-0.0011	-0.1834	0.1248	-0.0013
S_3	-0.5274	0.1304	-0.0012	-0.0712	0.1247	-0.0013
S_4	-0.4913	0.1163	-0.0011	0.0177	0.1008	-0.0010

Total dry matter (TDM)

Effect of sowing times on total dry matter (TDM) of four blackgram varieties at different stages of growth are shown in Figures 2.1a- 2.2a for 2005-2006 and 2.1b-2.2b for 2006-2007 growing season. It was observed that TDM increased up to at 75 DAS. TDM production increased slowly at the early vegetative phases (15, 25 and 35 DAS) and then increased rapidly with the advancement of the growth period in all the varieties and sowings in both the years. The S_3 plants had the highest TDM than other sowings irrespective of varieties and the lowest in S_2 in both the years. Among the varieties, LOCAL VARITY B-10 produced highest TDM followed by BARIMASH-3 and the lowest TDM was observed in BARIMASH-1 for S_4 in both the years.

Mean squares from the analysis of variance of TDM indicated that sowing time effect was significant at 15, 25, 45, 65 and 75 DAS in the 2nd year and non significant at all the stages of growth in the 1st year. Varietal effect was always non significant at all the stages of growth in the 1st year and significant at 25, 35, 65 and 75 DAS in the 2nd year. Significant sowing time and varietal interaction (S×V) was observed at 15, 55, 65 and 75 DAS in the 2nd year and non Significant in the 1st year at all the stages of growth. The curve-fitted values of TDM (Figures 2.2a and 2.2b) indicated that they were moderately fitted among the varieties in both the years.

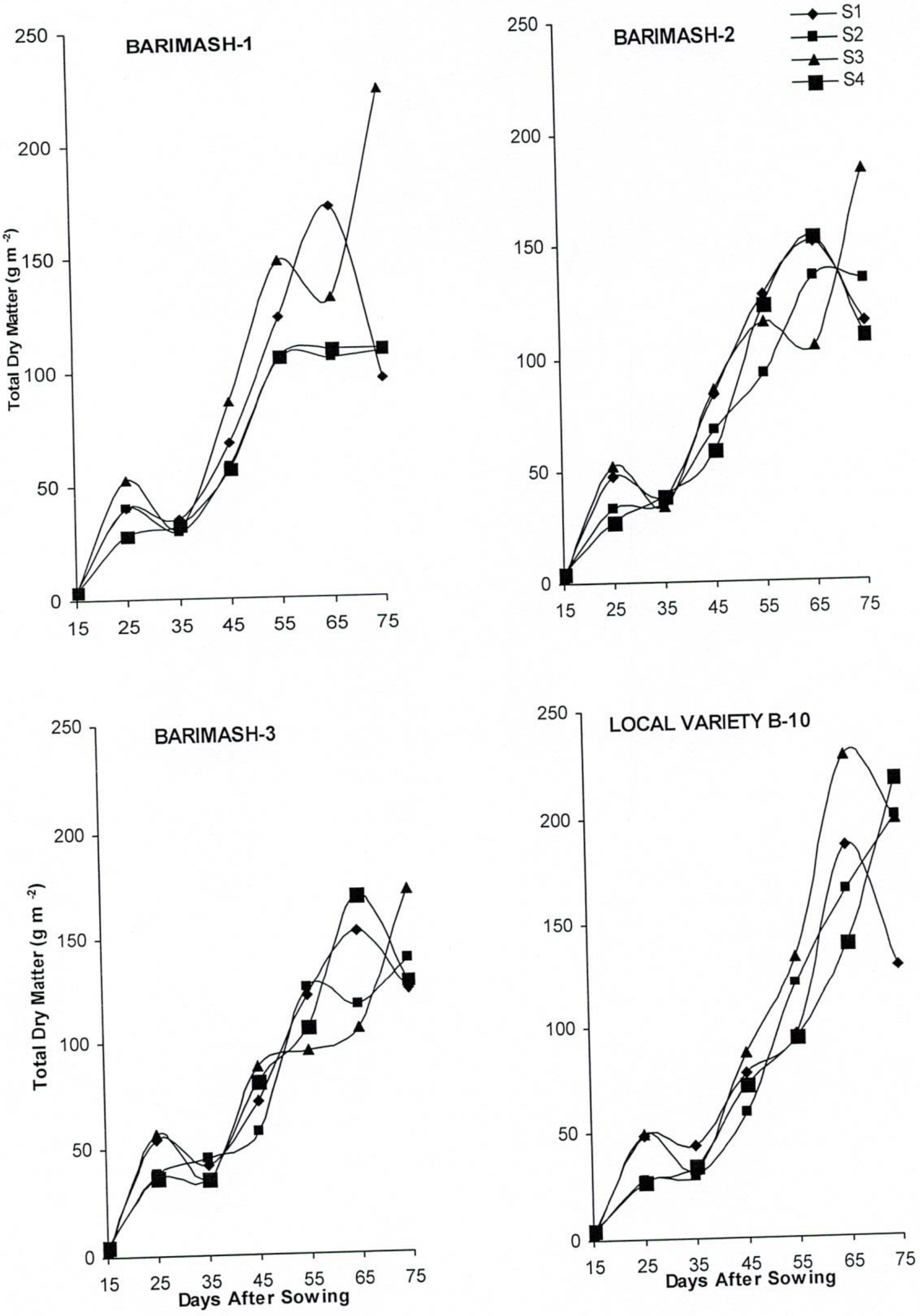


Figure 2.1a. Effect of sowing times on total dry matter (TDM) of four blackgram varieties at different stages of growth from original values (2005-2006).

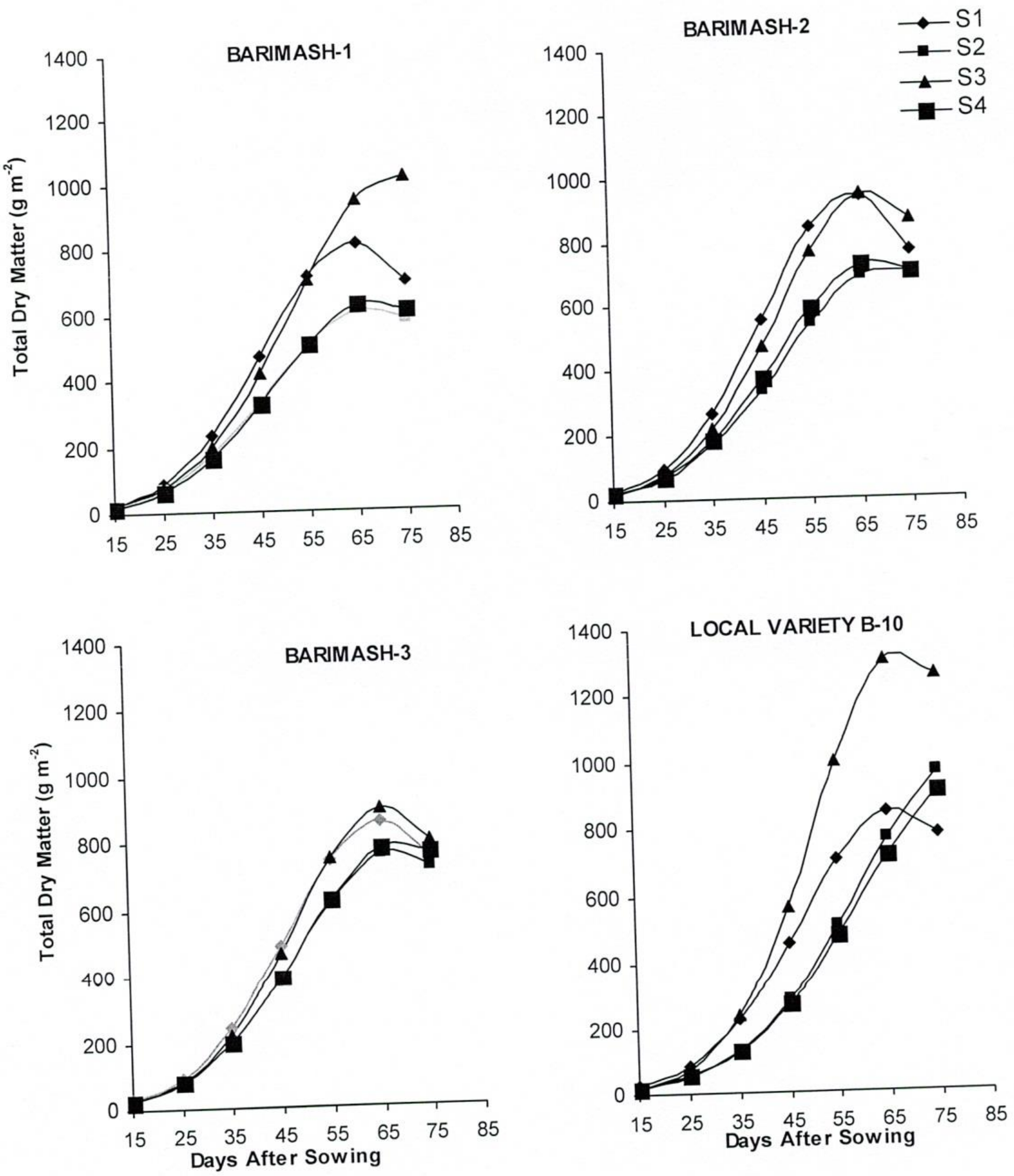


Figure 2.2a. Effect of sowing times on total dry matter (TDM) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

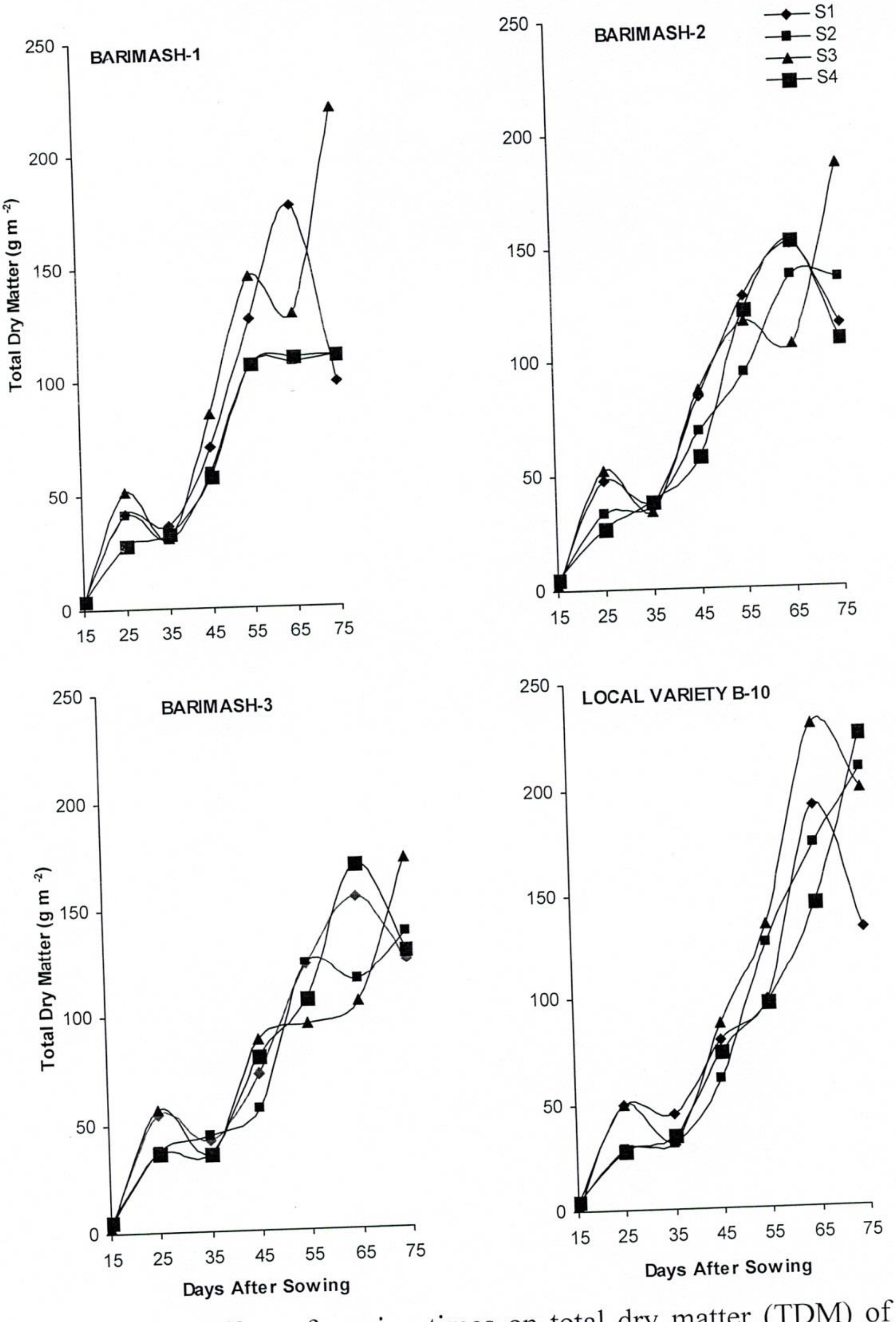


Figure 2.1b. Effect of sowing times on total dry matter (TDM) of four blackgram varieties at different stages of growth from original values (2006-2007).

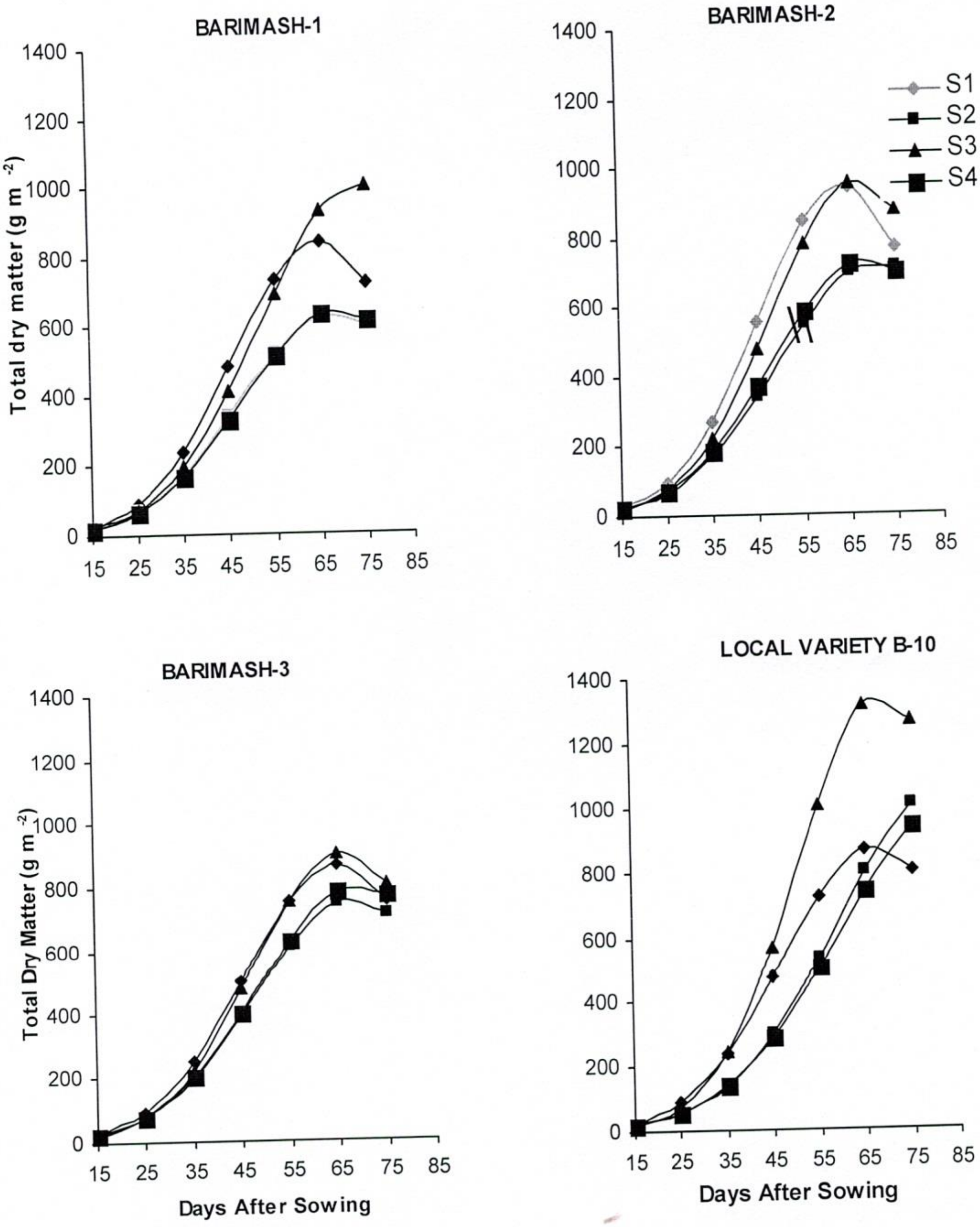


Figure 2.2b. Effect of sowing times on total dry matter (TDM) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Leaf Area Index (LAI)

Effect of sowing times on leaf area index (LAI) showed that the pattern of its development was more or less similar in four blackgram varieties at successive stages of growth are presented in Figures 3·1a-3.2a and 3·1b-3.2b for 2005-2006 and 3.2a-3.2b for 2006-2007 growing season. LAI of all the varieties for all the sowings started from a lower value and reached higher peak at 35 DAS with few exceptions in both the years. S_1 plants had the highest and S_4 had the lowest LAI than other sowing in both the years. LOCAL VARIETY B-10 showed the highest LAI in S_3 followed by S_1 and the lowest LAI was observed in BARIMASH-1 for S_4 plants in both years.

Mean squares from the analysis of variance of LAI indicated that sowing time, Variety and the interaction of sowing time and variety (S×V) were non significant in the 1st year at all the stages of growth, whereas significant sowing time effect was observed at all the stages of growth except 75 DAS and varietal effect was significant at all the stages of growth except 35 DAS in the 2nd year. LAI calculated by the harvest interval method showed a close correspondence with the instantaneous values of LAI obtained from the curve fitting method (Figures 3.2a and 3.2b).

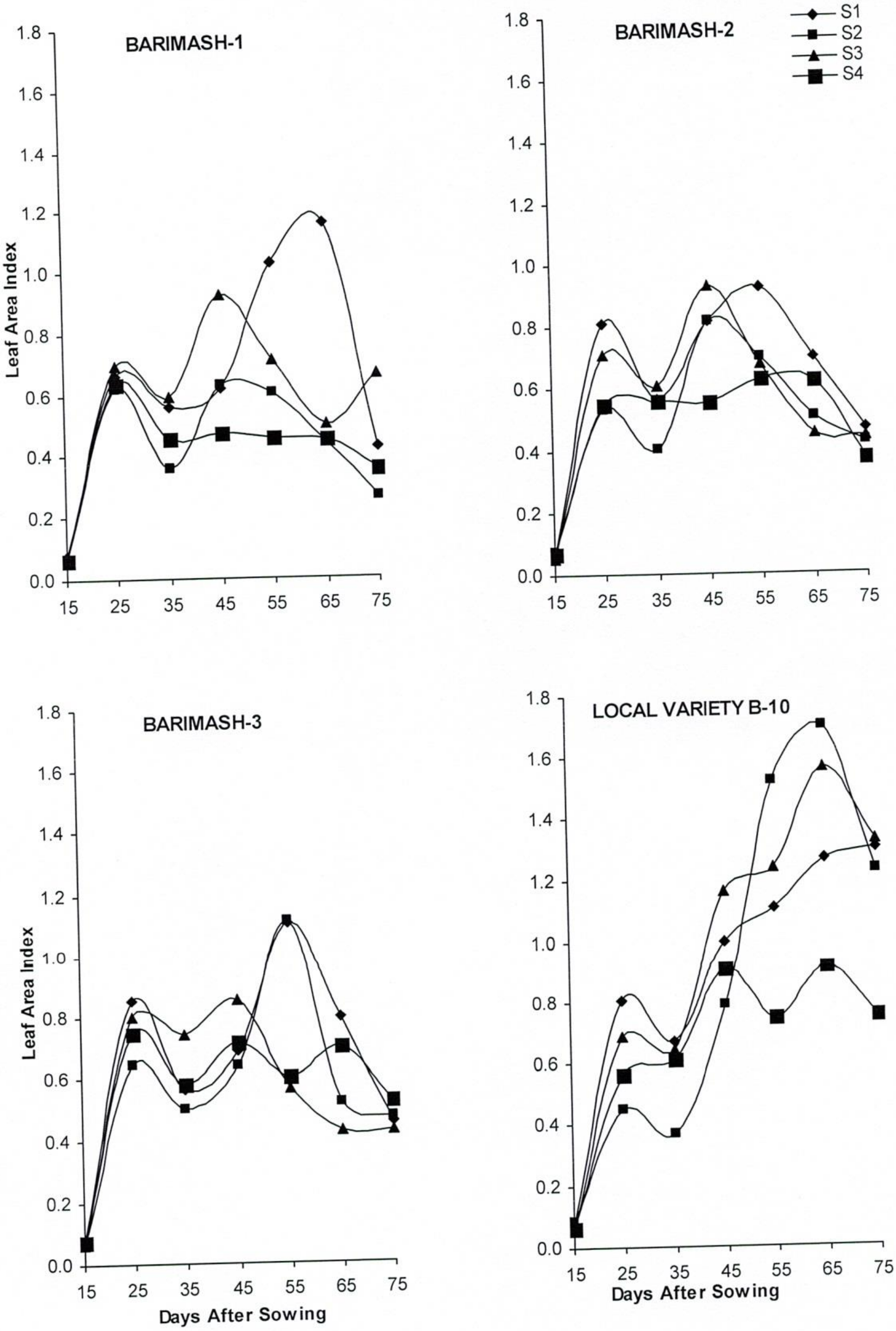


Figure 3.1a. Effect of sowing times on leaf area index (LAI) of four blackgram varieties at different stages of growth from original values (2005-2006).

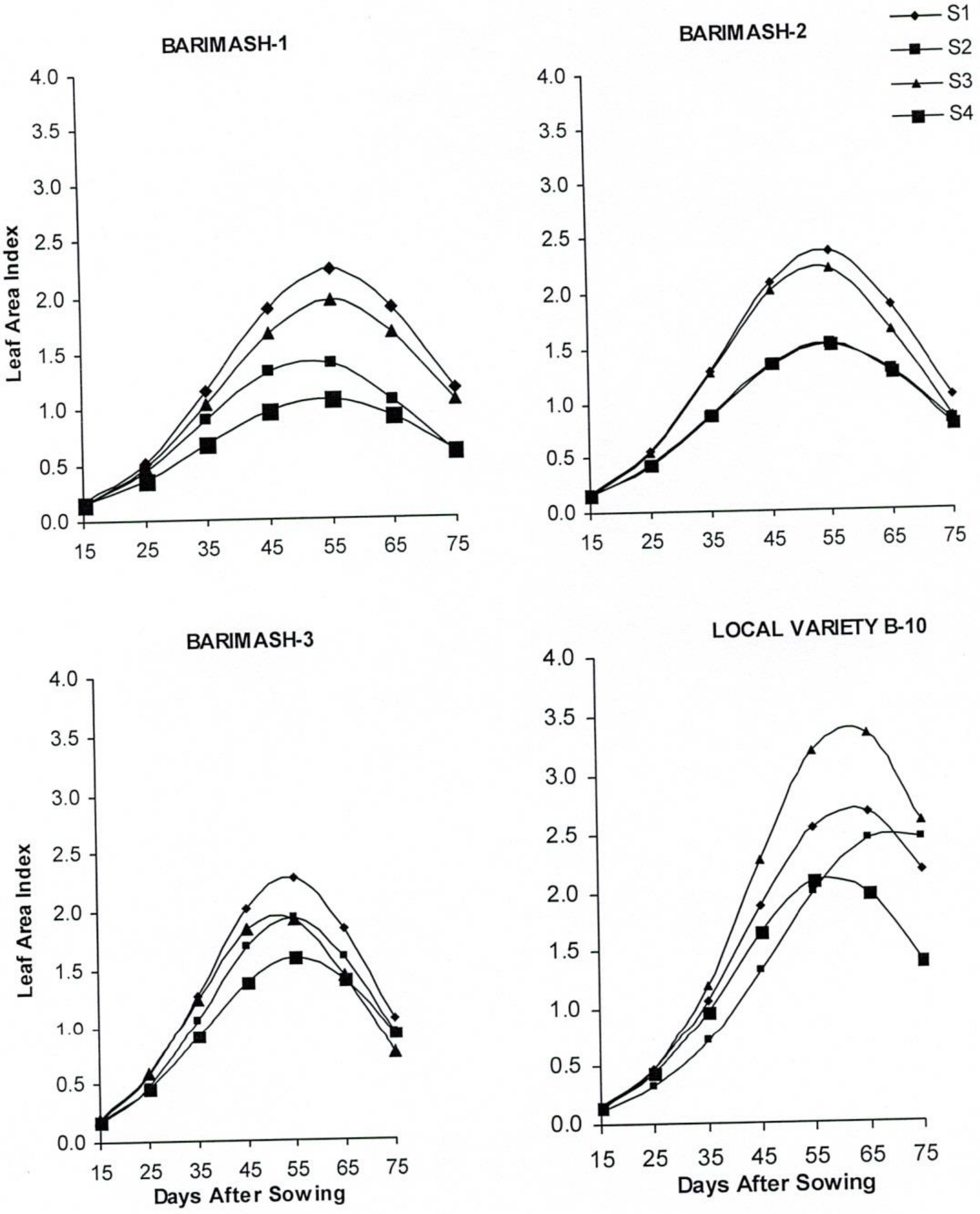


Figure 3.2a. Effect of sowing times on leaf area index (LAI) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

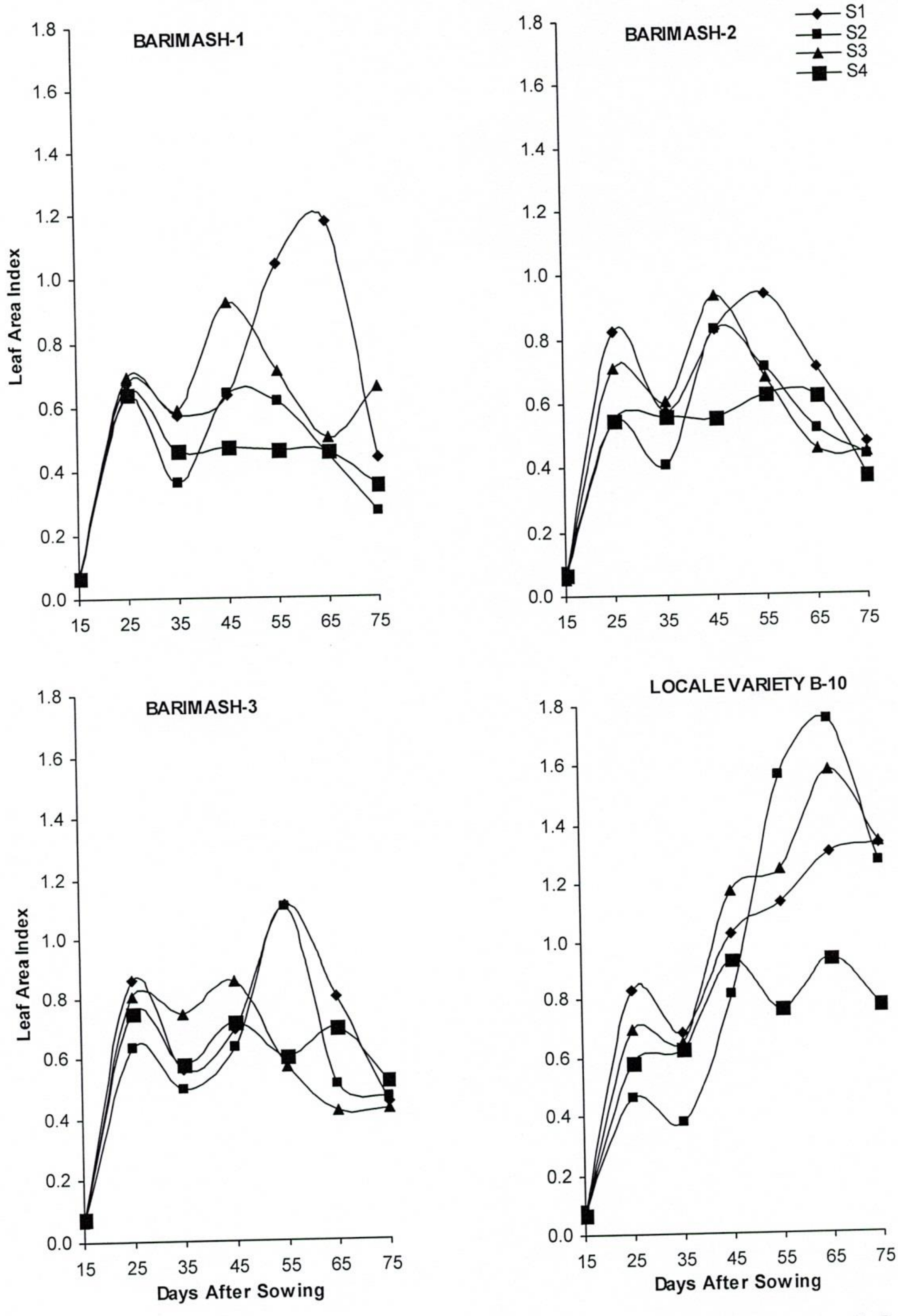


Figure 3.1b. Effect of sowing times on leaf area index (LAI) of four blackgram varieties at different stages of growth from original values (2006-2007).

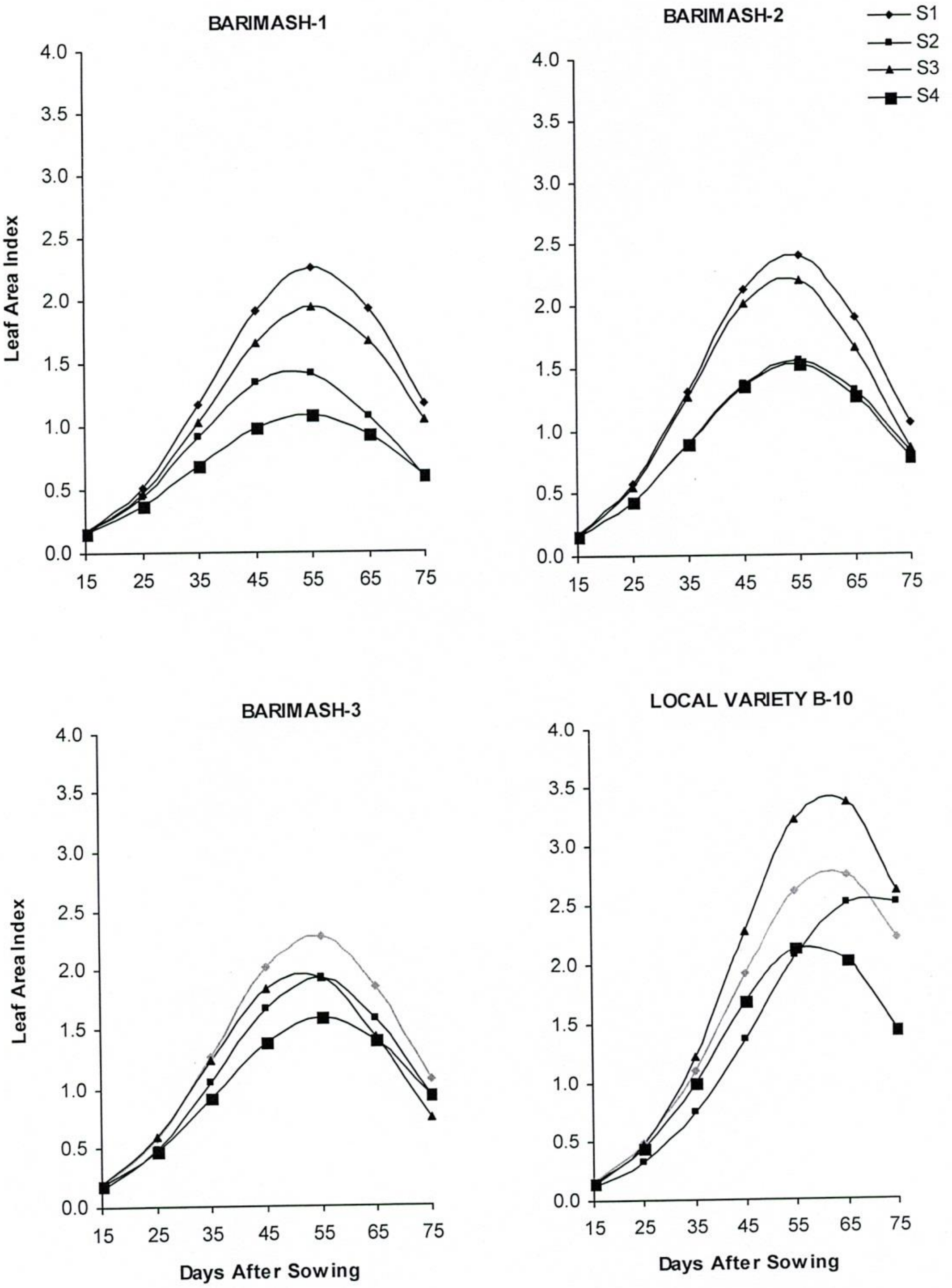


Figure 3.2b. Influence of sowing times on leaf area index (LAI) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Leaf area duration (LAD)

The pattern of leaf area duration (LAD) was essentially similar as in LAI that described previously (Figures 4.1a-4.2a for 2005-2006 and 4.1b-4.2b for 2006-2007). LAD reached a certain peak at 40 DAS and then declined in both the years. Higher LAD values were observed in S_1 plants and the lowest values in S_4 of all the varieties than other sowings except LOCAL VARIETY B-10 that produced the highest LAD for S_3 plants in both the years and BARIMASh-1 had the lowest LAD for S_4 of all the sowings in both the years.

Mean squares from the analysis of variance of LAD indicated that significant sowing time effect was observed at all the stages of growth in both the years. Varietal effect was non significant at all the stages of growth in both the years. It was also found that sowing time and varietal interaction (S×V) was non-significant at all the stages of growth in both the years except at 40 DAS in the 2nd year.

LAD calculated from original values exhibited a close resemblance with fitted values (Figures 4.2a and 4.2b) in both the years respectively.

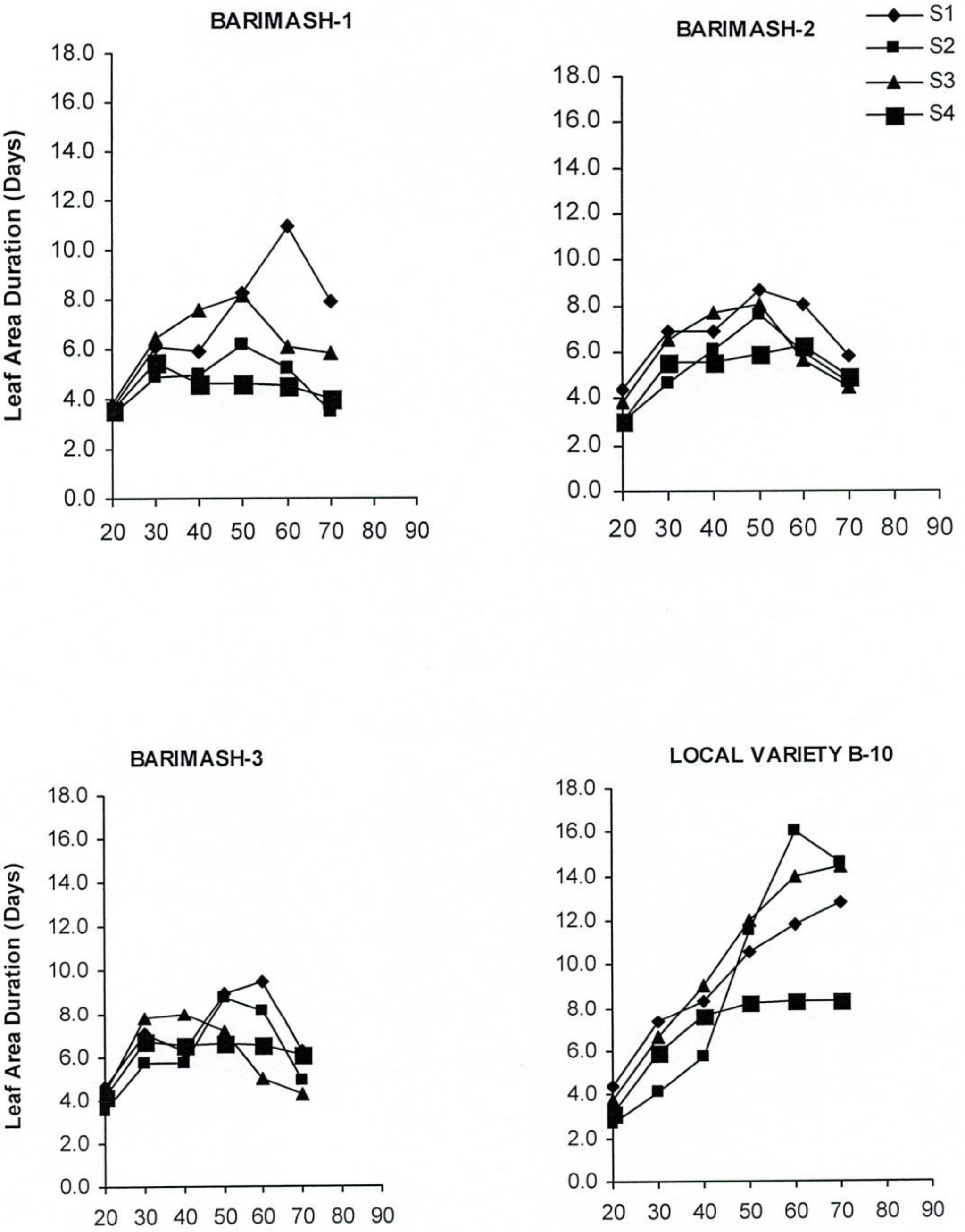


Figure 4.1a. Effect of sowing times on leaf area duration (LAD) of four blackgram varieties at different stages of growth from original values (2005-2006).

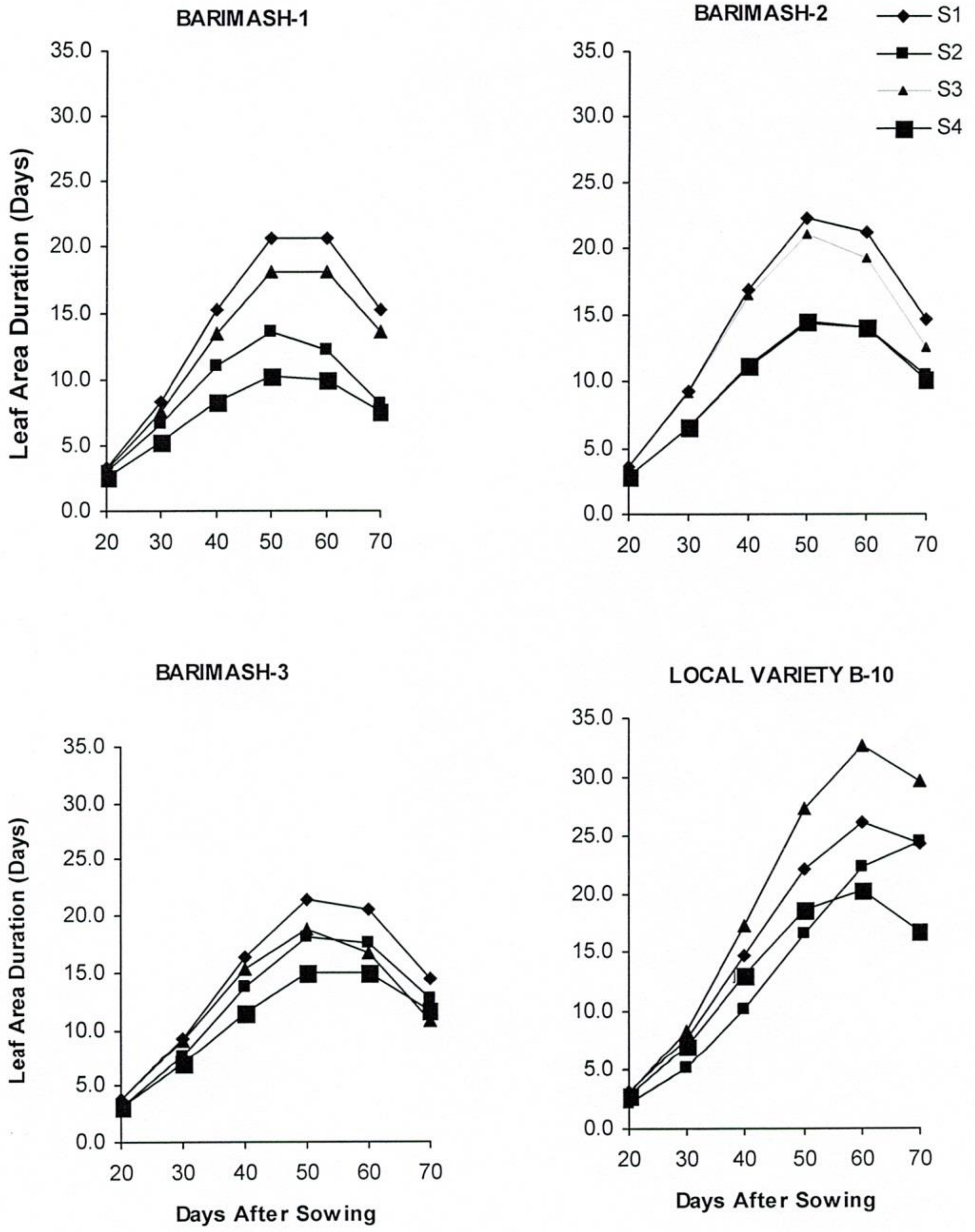


Figure 4.2a. Effect of sowing times on leaf area duration (LAD) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

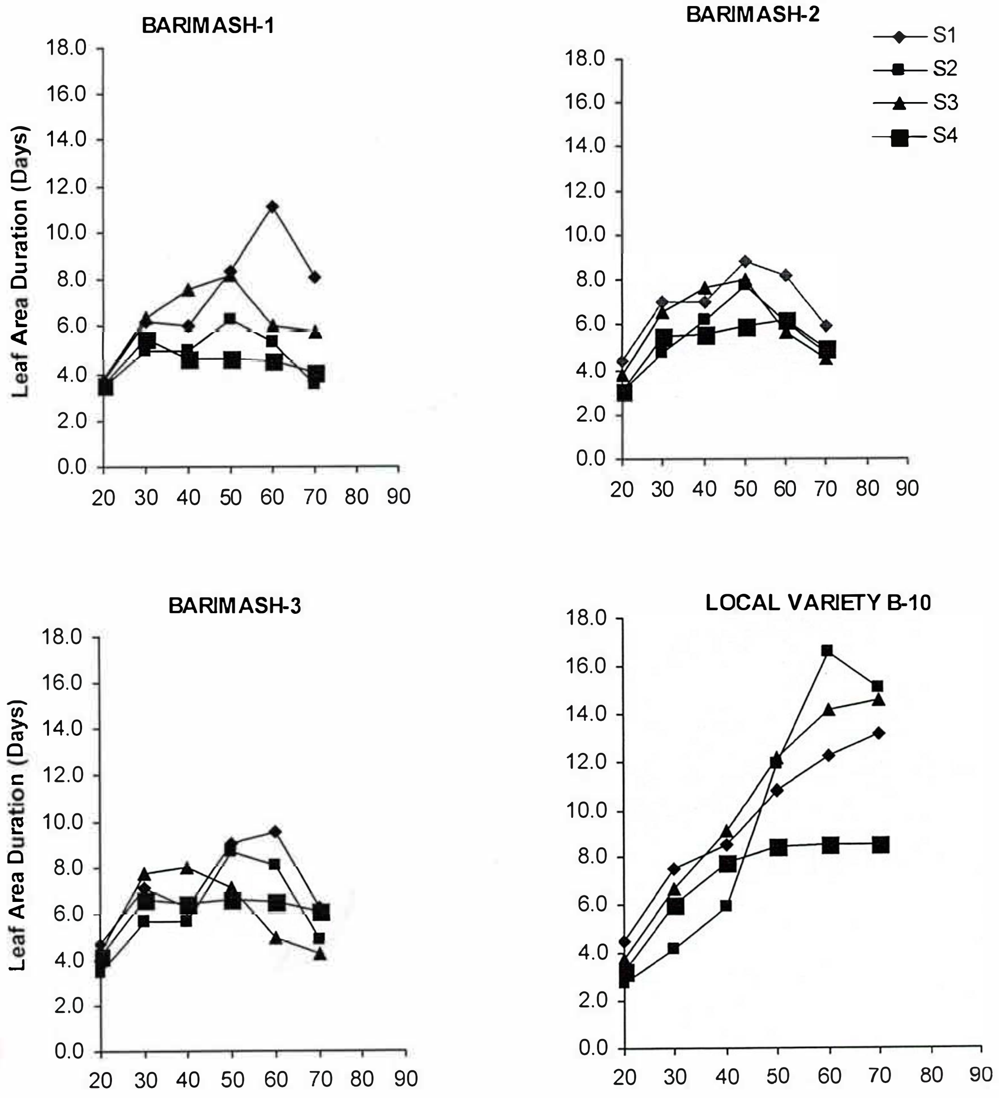


Figure 4.1b. Effect of sowing times on leaf area duration (LAD) of four blackgram varieties at different stages of growth from original values (2006-2007).

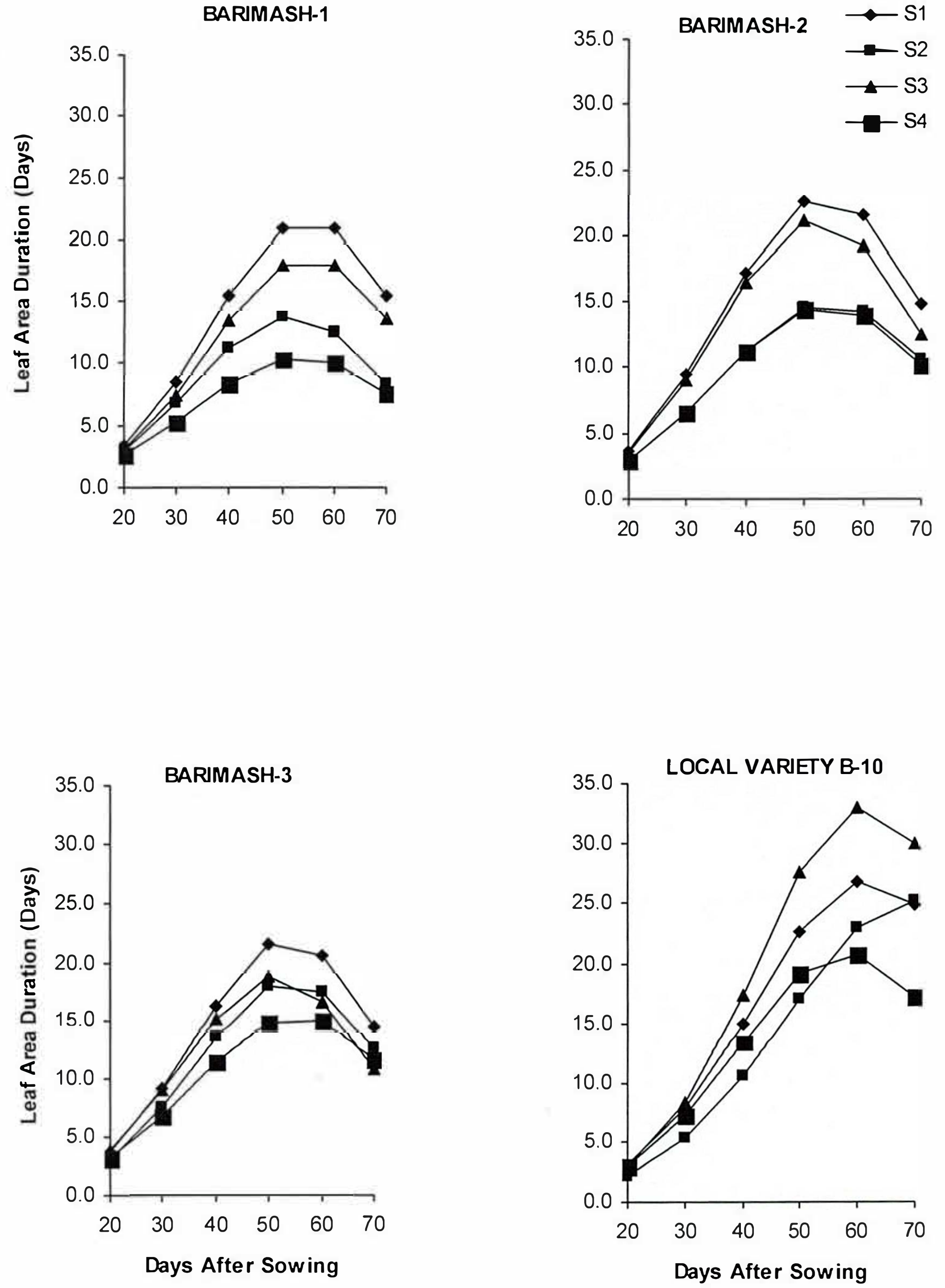
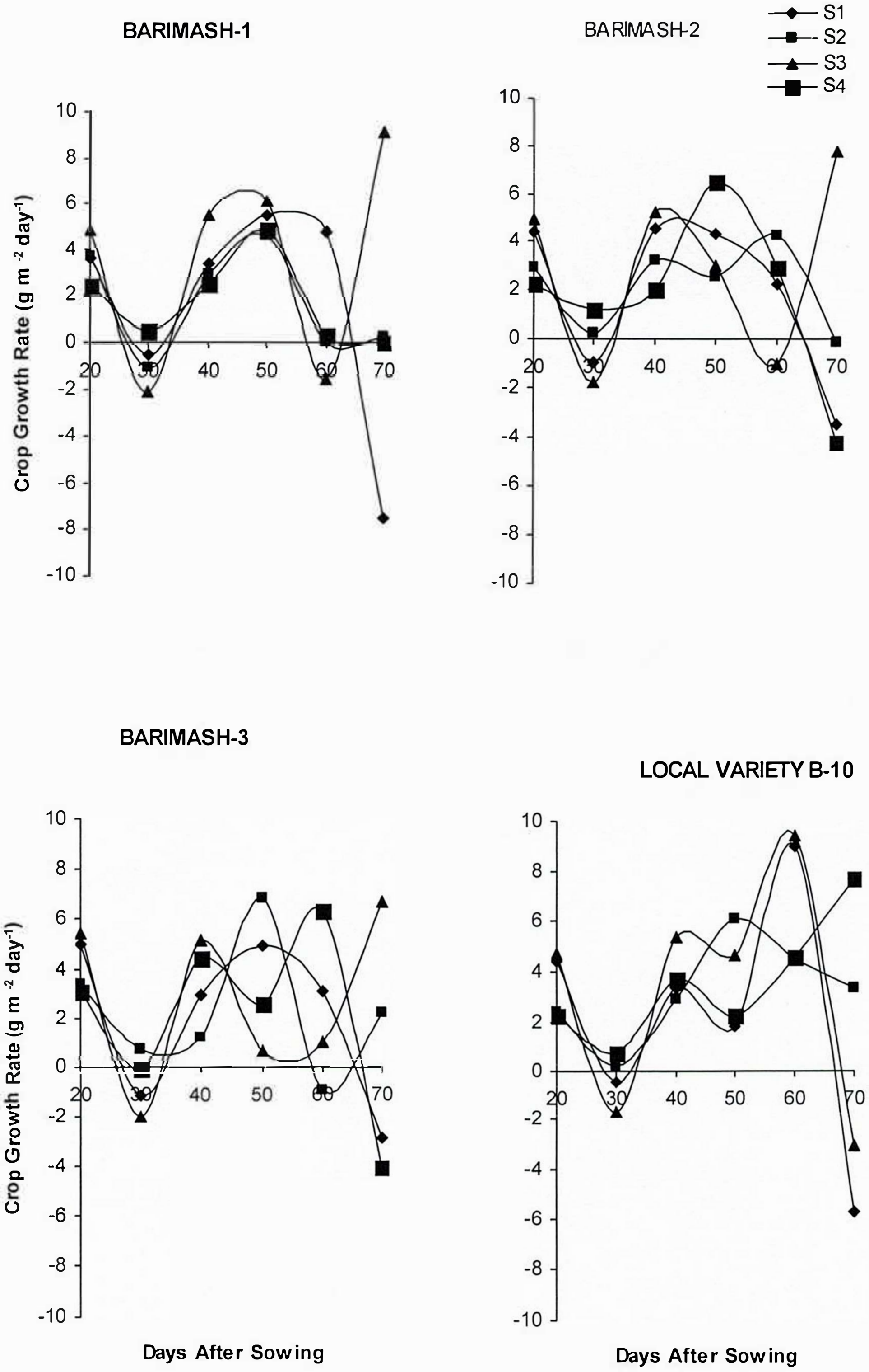


Figure 4.2b. Effect of sowing times on leaf area duration (LAD) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Crop Growth Rate (CGR)

Effect of sowing times on crop growth rate (CGR) of four blackgram varieties are presented in Figures 5·1a- 5·2a for 2005-2006 and 5.1b-5.2b for 2006-2007 growing season. Starting from lower values CGR of all the varieties reached a certain peak and thereafter declined with lower negative values at 30 DAS and then increased gradually and sharply reached their highest value at 50 DAS and then declined to negative values at the later stages of growth. All the varieties had generally higher CGR for S_3 than other sowings except LOCAL VARIETY B-10 where better performance was observed in S_4 and lower in S_1 plants in both the years. The highest CGR was observed in LOCAL VARIETY B-10 for S_4 and the lowest in BARIMASH-1 for S_1 plants in both the years.

Mean squares from the analysis of variance of CGR indicated that sowing time was non significant at all the stages of growth in the 1st year and significant at 20, 40 and 70 DAS in the 2nd year. Varietal item was significant at 50 and 70 DAS in the 1st year and 20 and 60 DAS in the 2nd year. Significant sowing time and varietal interaction (S×V) was observed at 50 DAS in the 1st year and all the stages of growth in the 2nd year except at 30 DAS only. CGR calculated from the quadratic fitted values increased upto a certain peak and decreased thereafter uncharacteristically negative values at the later stages of growth (Figures 5.2a and 5.2b).



BARIMASH-1

BARIMASH-2

BARIMASH-3

LOCAL VARIETY B-10

Figure 5.1a. Effect of sowing times on crop growth rate (CGR) of four blackgram varieties at different stages of growth from original values (2005-2006).

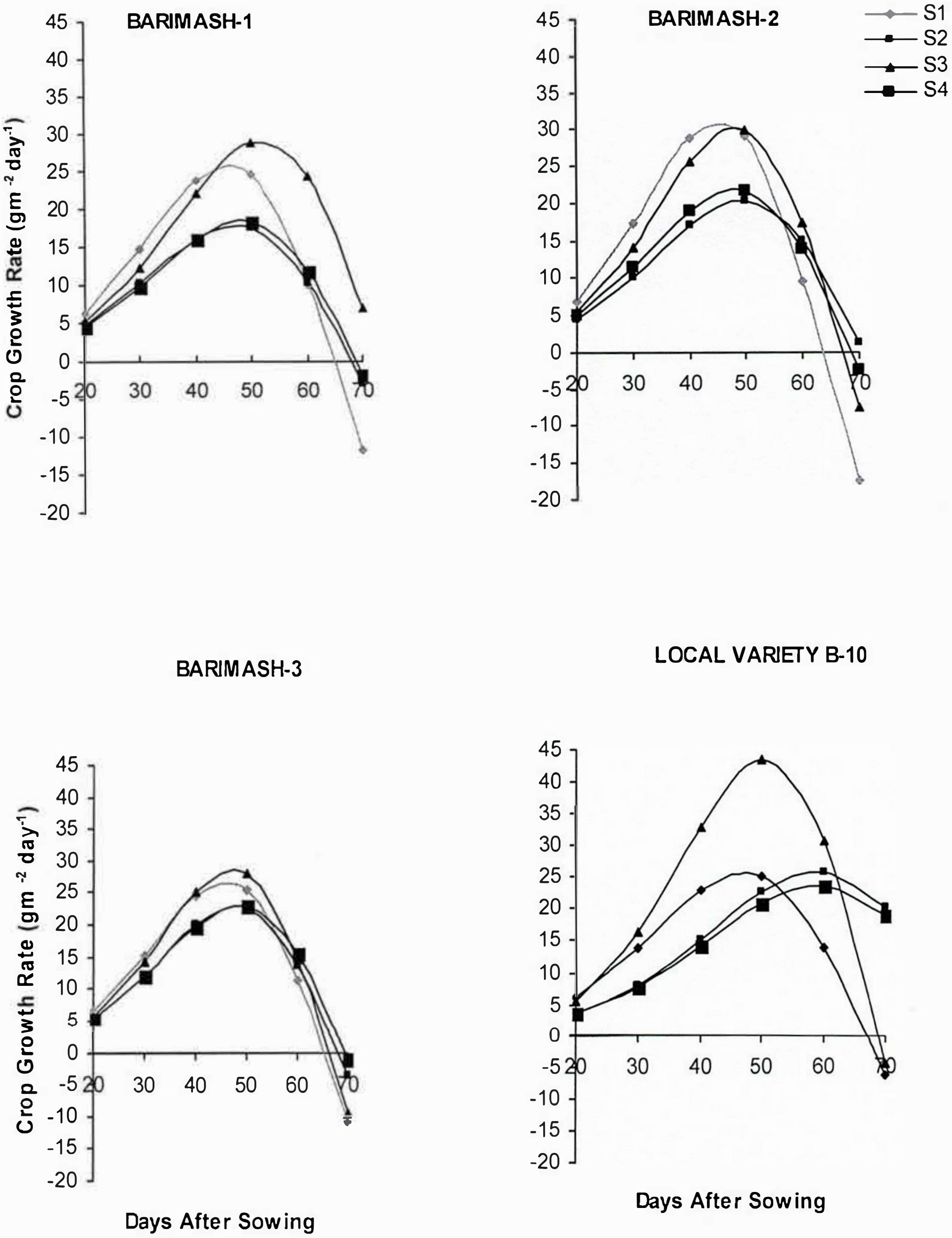


Figure 5.2a. Effect of sowing times on crop growth rate (CGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

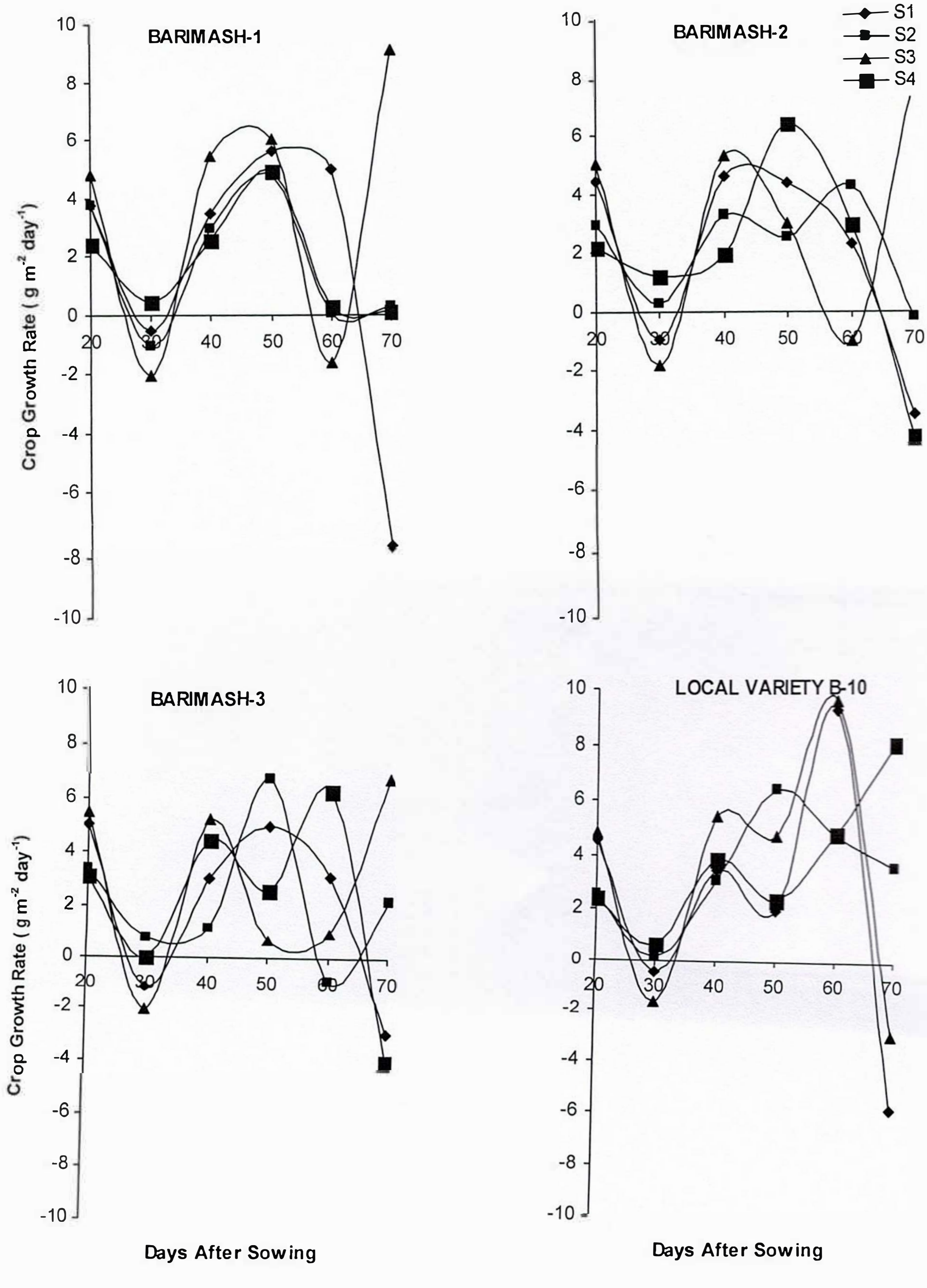


Figure 5.1b. Effect of sowing times on crop growth rate (CGR) of four blackgram varieties at different stages of growth from original values (2006-2007).

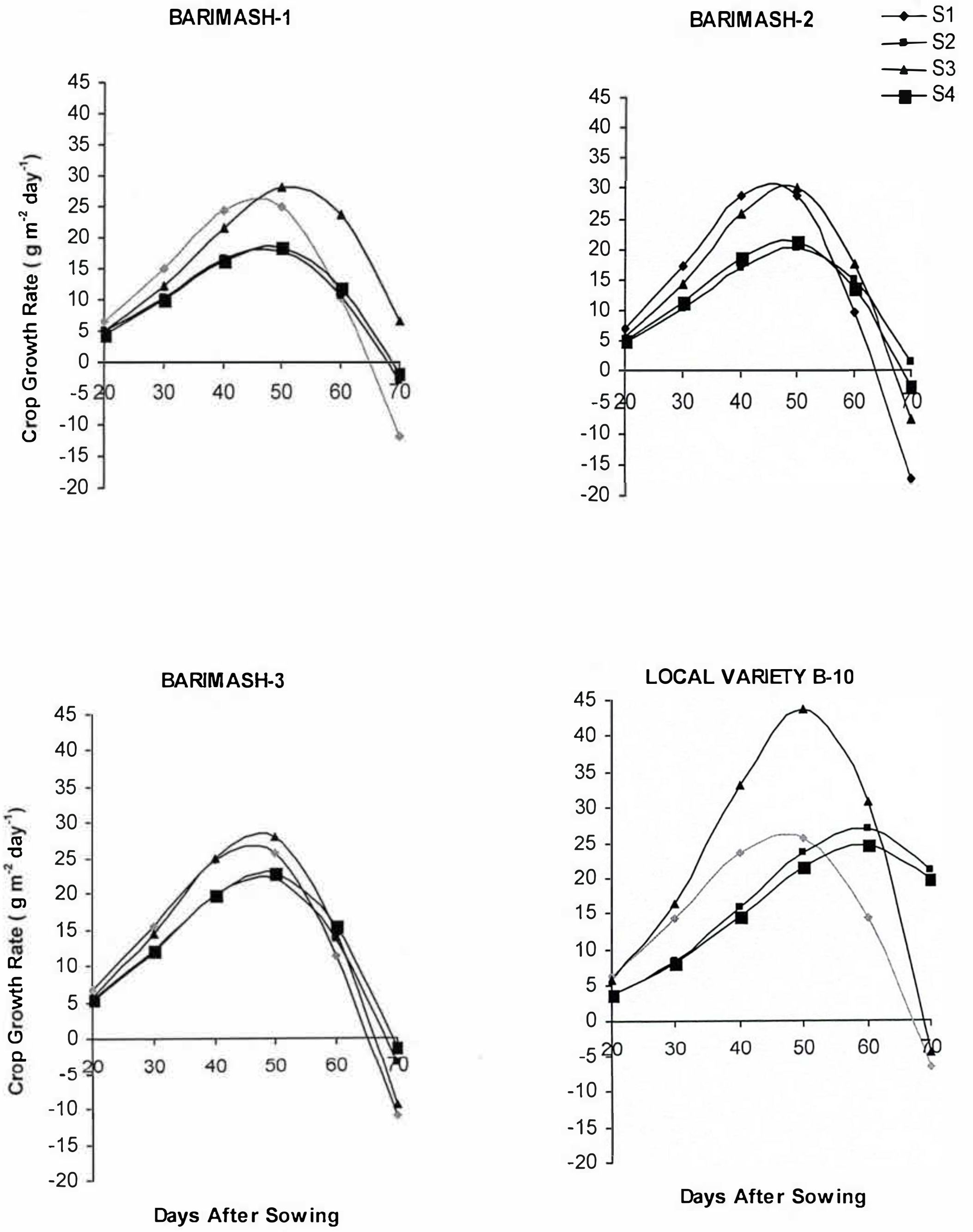


Figure 5.2b. Effect of sowing times on crop growth rate (CGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Relative growth rate (RGR)

Effect of sowing times on relative growth rate (RGR) of four blackgram varieties at successive stages of growth are shown in Figures 6.1a - 6.2a for 2005-2006 and 6.1b -6.2b for 2006-2007 growing season. RGR of all the varieties irrespective of sowing time declined with increasing plant age and plant dry weight having uncharacteristically negative values at 30 DAS in both the years. The highest RGR was observed in the S_3 plants than other sowings and the lowest in S_4 plants in both the years. Among the varieties, LOCAL VARIETY B-10 produced higher RGR in S_3 than other sowings at most of the growth stages. The lowest RGR was observed in BARIMASH-1 than other varieties in both the years. RGR values of all the sowings were higher at the early growth stages, while lower at the later stages of growth.

Mean squares from the analysis of variance of RGR indicated that sowing time was always non significant at all the stages of growth in the 1st year and significant at all the stages of growth in the 2nd year. Varietal item was significant at 50 and 70 DAS in the 1st year and at 20, 50 and 60 DAS in the 2nd year. It was also observed that sowing time and varietal interaction (S×V) was non significant at all the stages in the 1st year and significant at all the stages of growth except at 30 and 40 DAS in the 2nd year. RGR calculated from the quadratic fitted values indicated that S_4 plants of all the varieties gradually decreased with time sharply with negative values at the later stages of growth (Figures 6.2a and 2.2b).

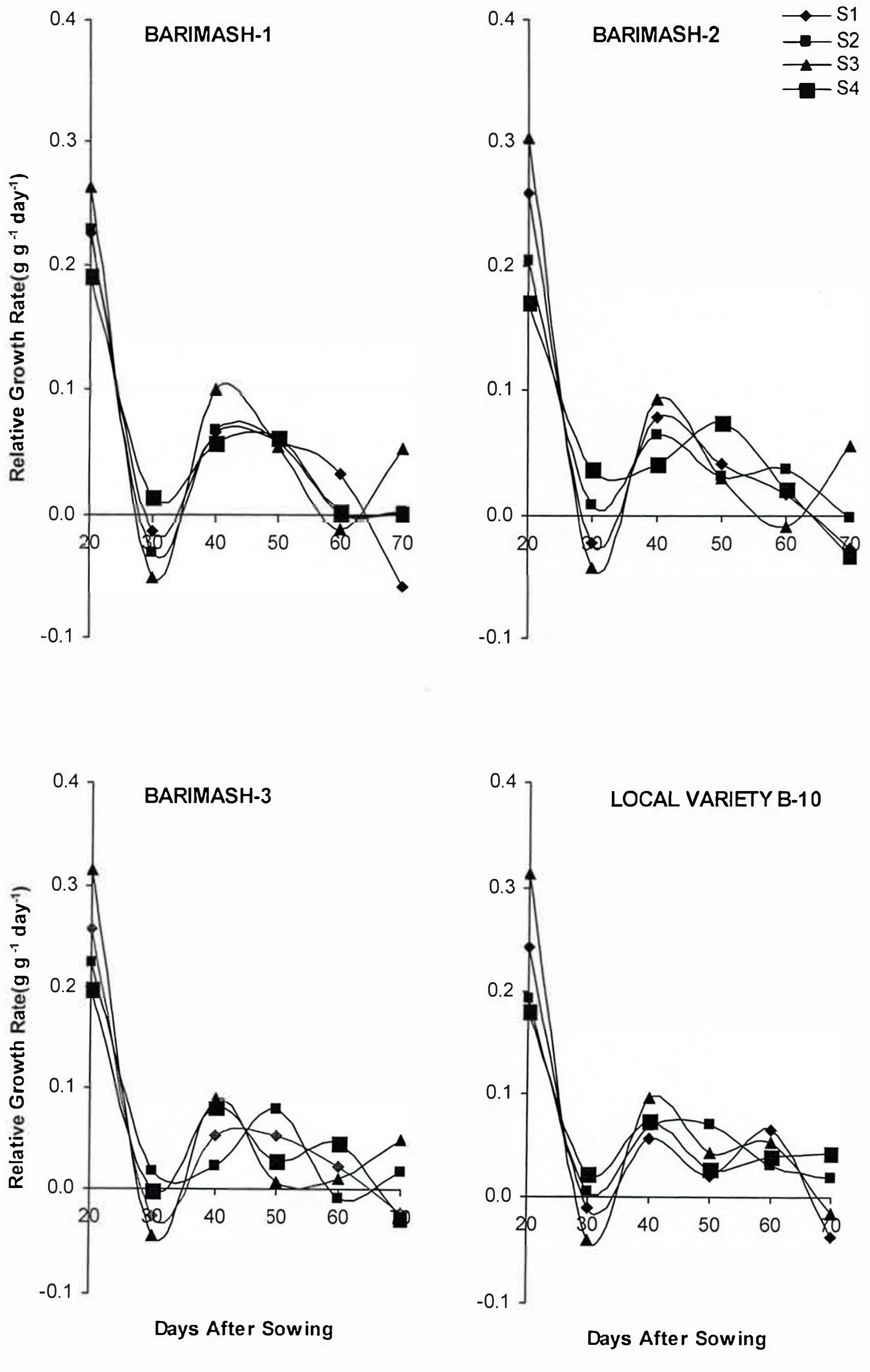


Figure 6.1a. Effect of sowing times on relative growth rate (RGR) of four blackgram varieties at different stages of growth from original values (2005-2006).

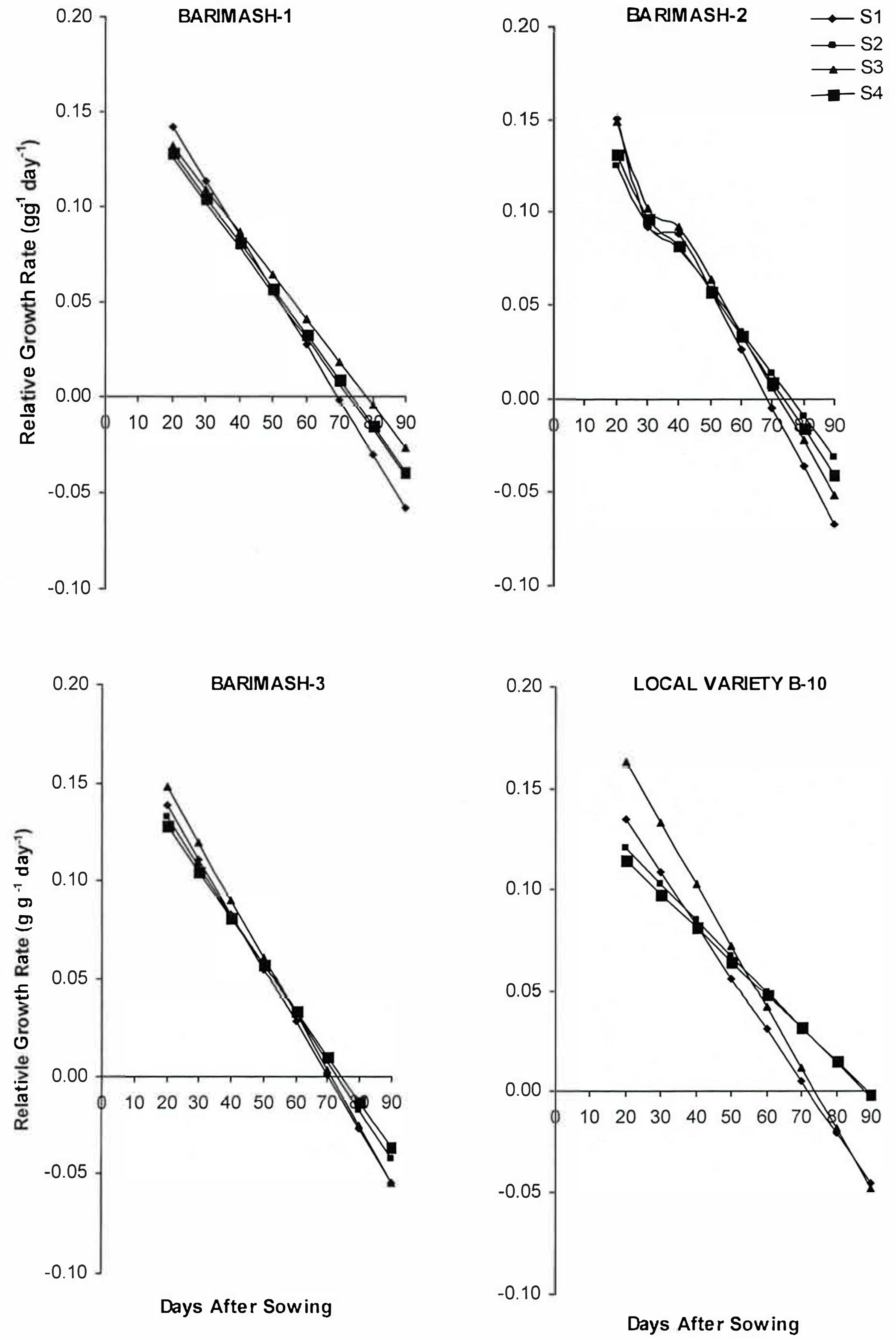


Figure 6.2a. Effect of sowing times on relative growth rate (RGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

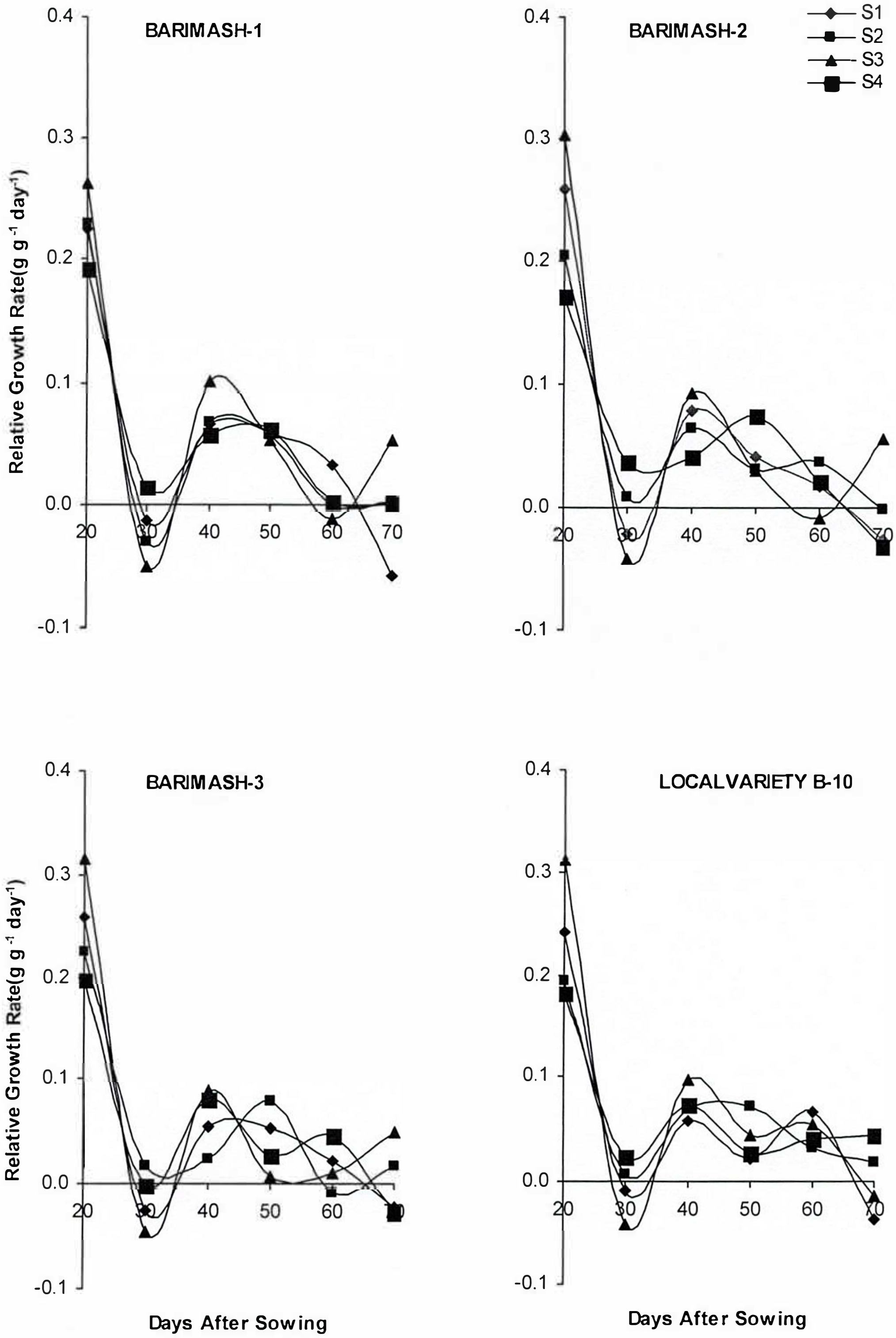


Figure 6.1b. Effect of sowing times on relative growth rate (RGR) of four blackgram varieties at different stages of growth from original values (2006-2007).

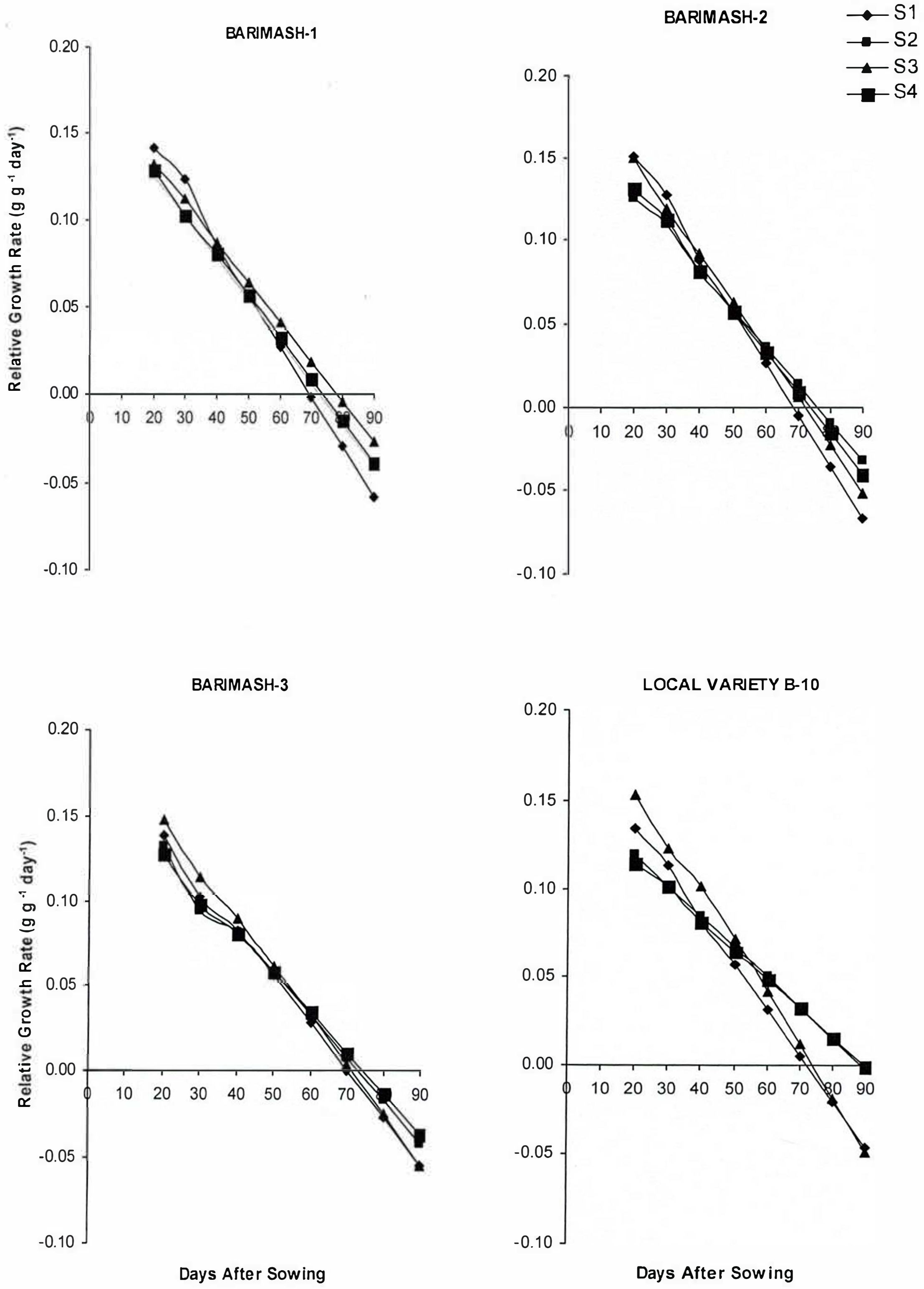


Figure 6.2b. Effect of sowing times on relative growth rate (RGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Net Assimilation Rate (NAR)

The pattern of sowing times effect on net assimilation rate (NAR) of four blackgram varieties at different stages of growth are presented in Figures 7.1a – 7.2a for 2005-2006 and 7.1b-7.2b for 2006-2007 growing season. All the varieties for all the sowings, with few exceptions NAR increased slowly at the early vegetative stages and reached its peak at 30 DAS and thereafter declined in both the years irrespective of sowing times and variety. In the present investigations, NAR of four varieties and sowings, then reached negative values at the later stages of growth with fluctuations. The S_3 plants had the highest NAR than other sowing except S_4 while it showed the better performance in LOCAL VARIETY B-10 for both the years and the lowest in S_1 plants of all the sowings. The highest NAR values was observed in BARIMASH-3 for S_3 and the lowest in LOACAL VARIETY B-10 among the varieties in both the years.

Mean squares from the analysis of variance of NAR revealed that sowing time was always non significant at all the stages of growth in the 1st year and significant sowing time effect was found at all the stages of growth except 40 DAS in the 2nd year. Varietal effect was significant at 20 DAS only in the 1st year and at 20 and 50 DAS in the 2nd year. Sowing time and varietal interaction (S×V) was always non significant at all the stages of growth except 40 DAS in the 2nd year. The curves of NAR in both the years showed that they were fitted adequately (Figures 7.2a and 7.2b).

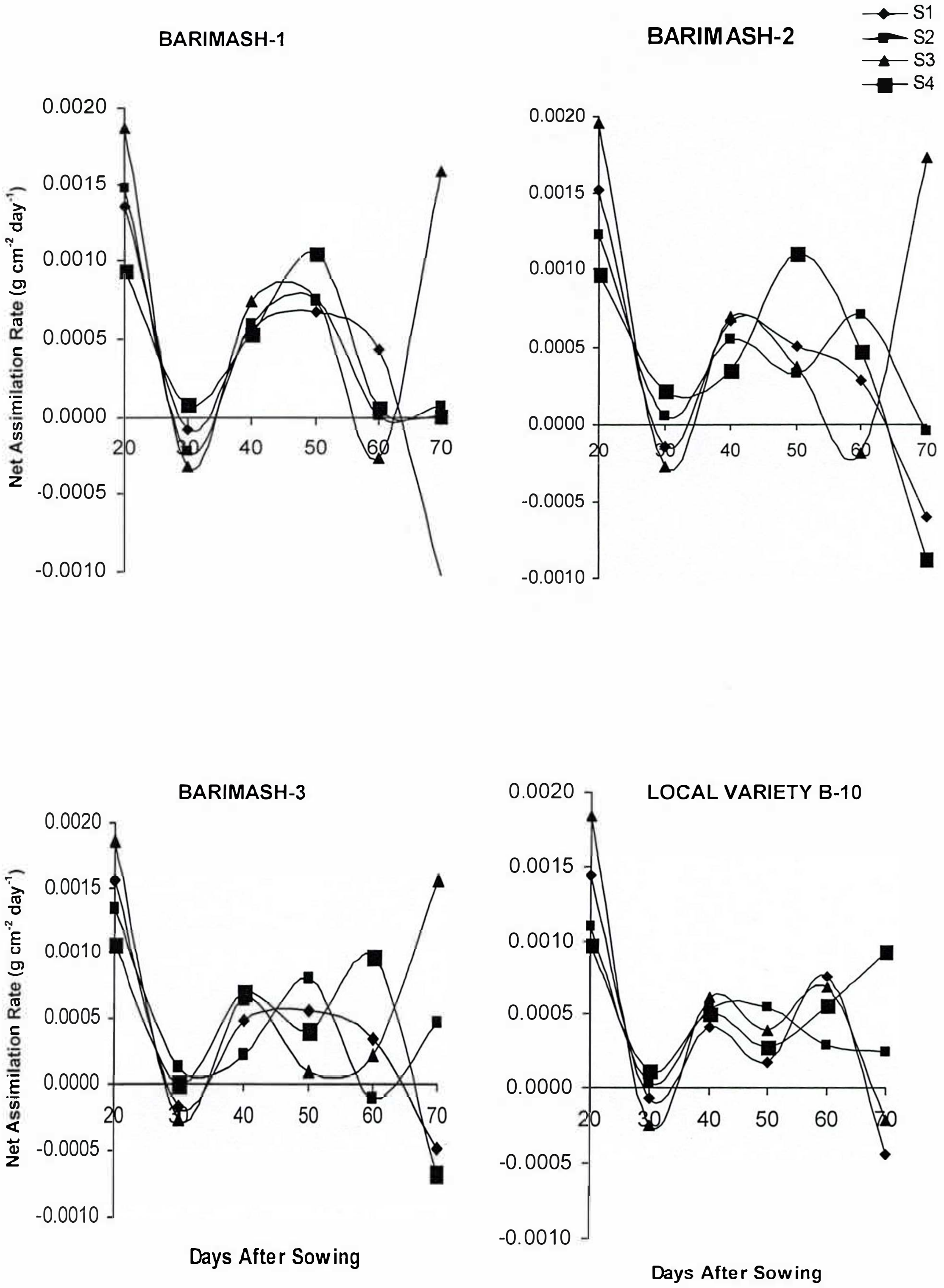


Figure 7.1a. Effect of sowing times on net assimilation rate (NAR) of four blackgram varieties at different stages of growth from original values (2005-2006).

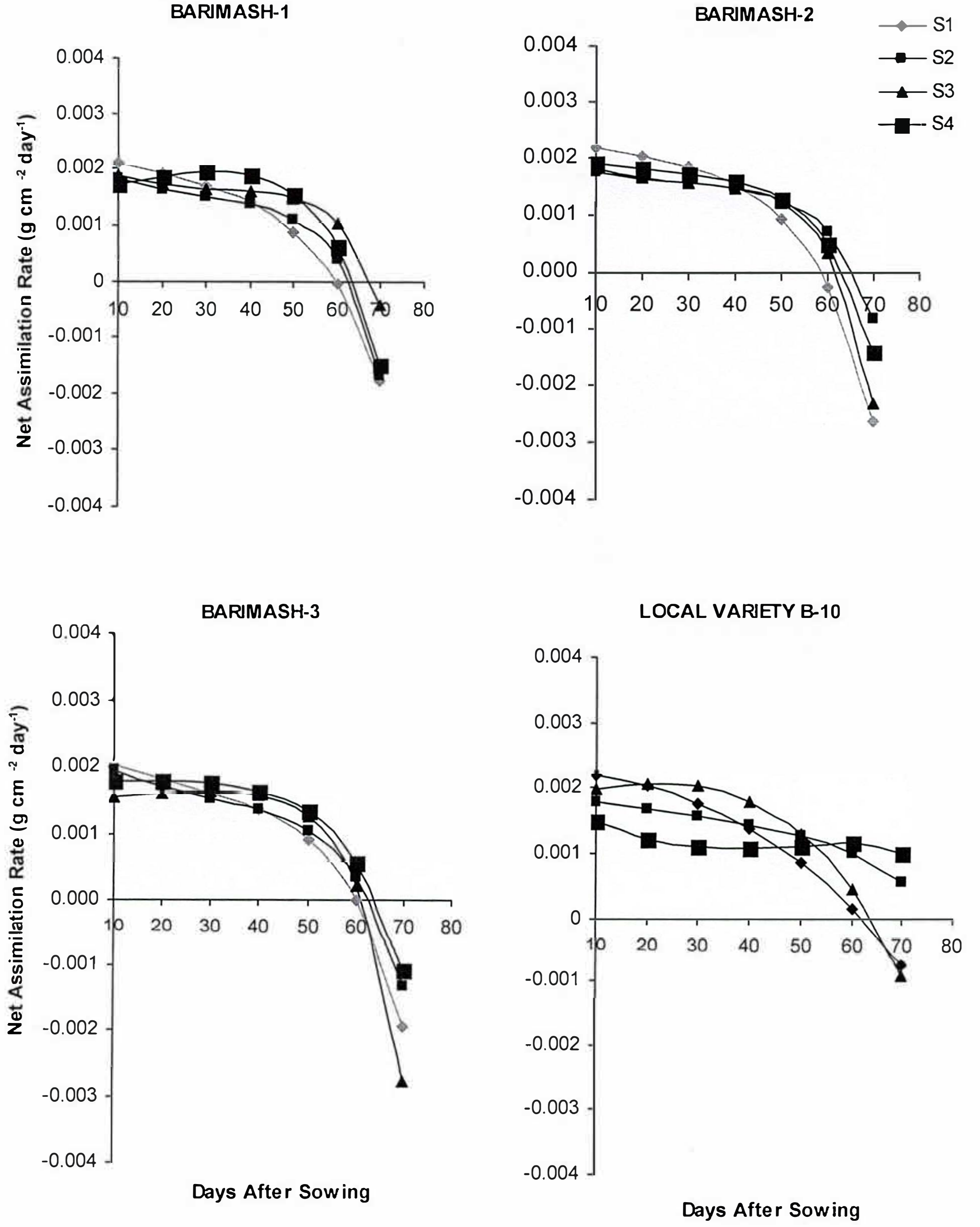


Figure 7.2a. Effect of sowing times on net assimilation rate (NAR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

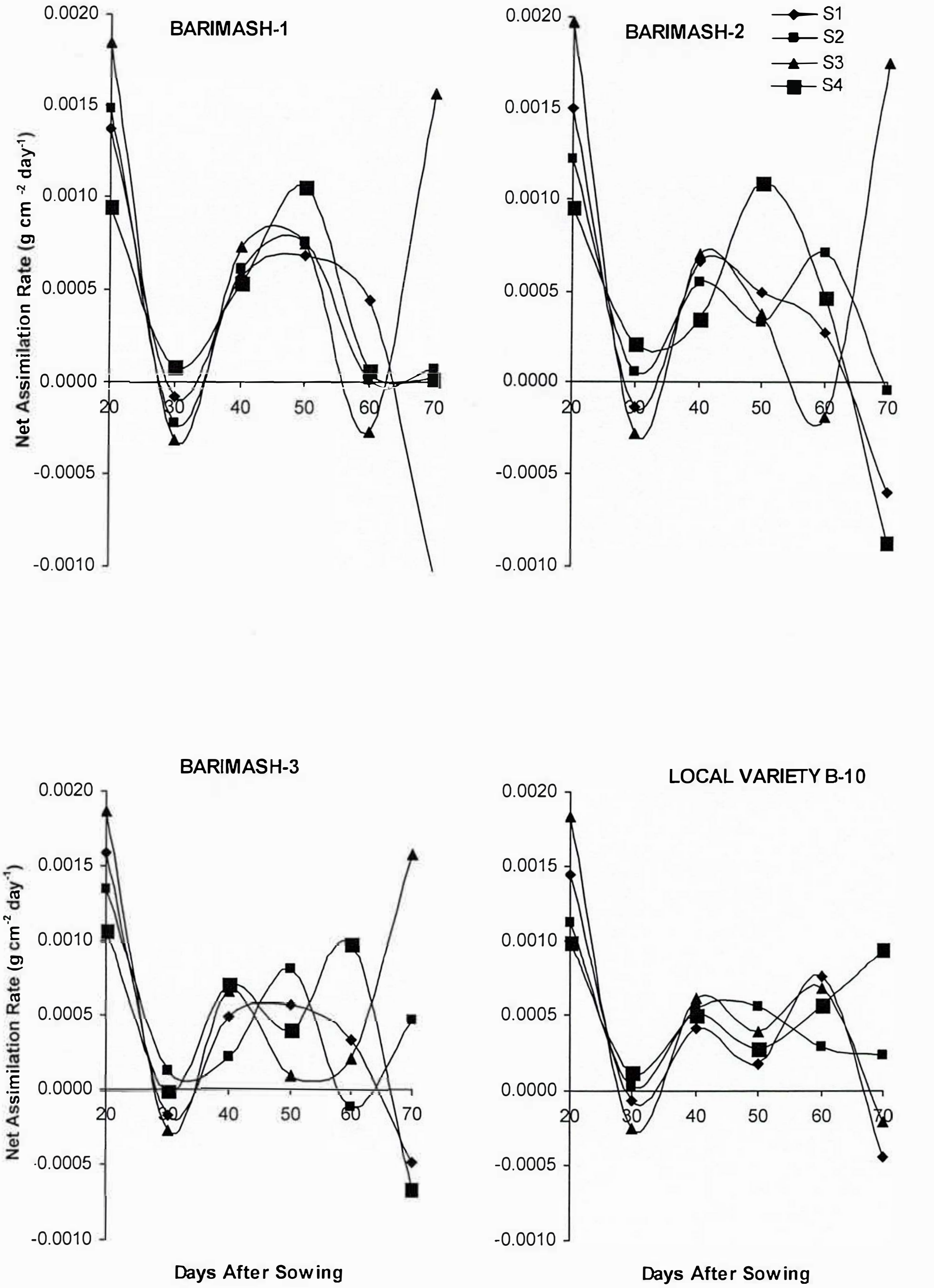


Figure 7.1b. Effect of sowing times on net assimilation rate (NAR) of four blackgram varieties at different stages of growth from original values (2006-2007).

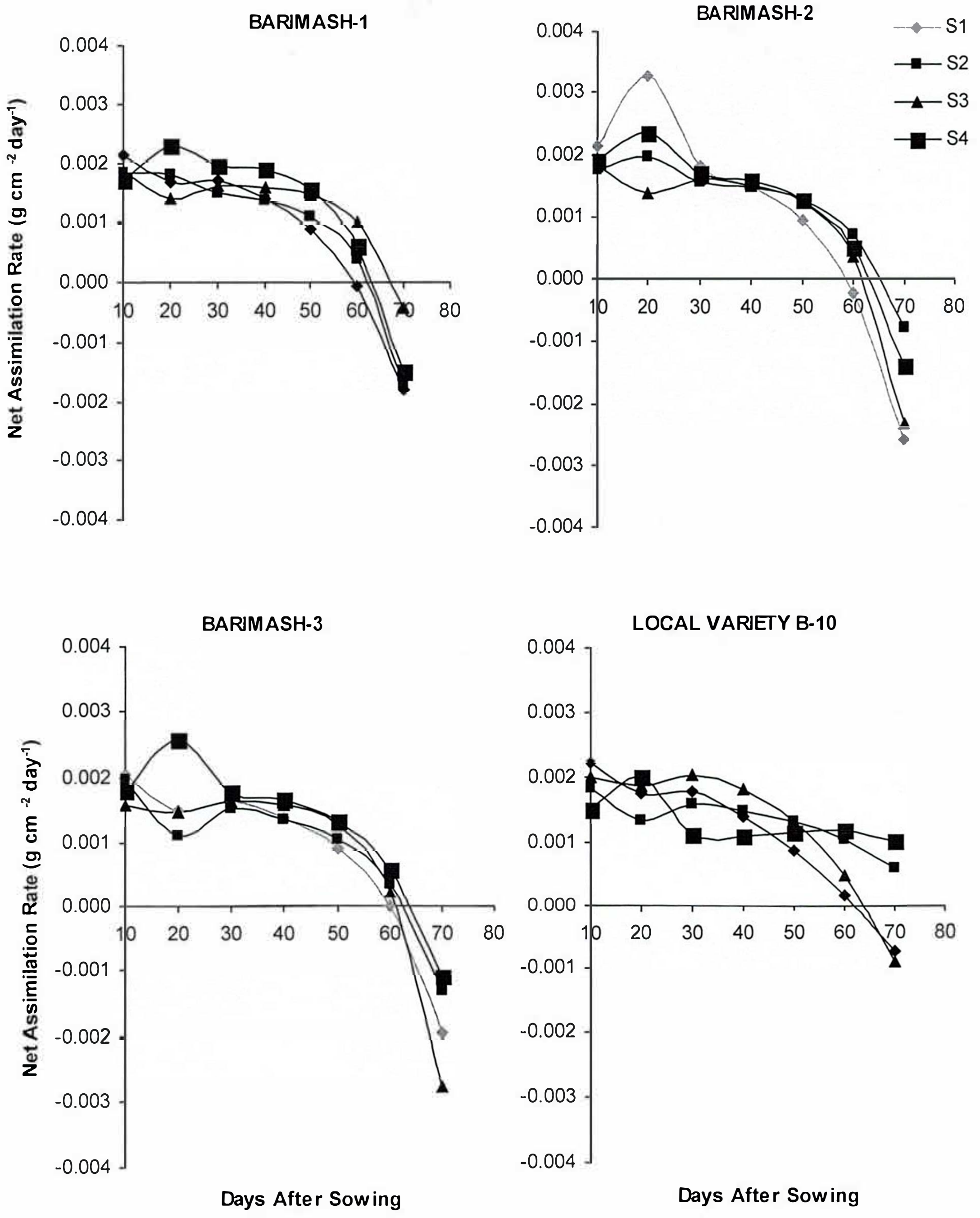


Figure 7.2b.Effect of sowing times on net assimilation rate (NAR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Leaf area ratio (LAR)

Effect of sowing times on leaf area ratio (LAR) of four blackgram varieties at different stages of growth are presented in Figures 8.1a -8.2a for 2005-2006 and 8.1b -8.2b for 2006-2007 growing season. In the present investigation, LAR of all the varieties started from higher values at the early stages of growth and then declined steadily throughout the whole growth period in both the years. Most of the cases higher values observed in S_1 plants than other sowings except LOCAL VARIETY B-10 that showed higher LAR for S_2 plants in both the years. The highest LAR value was found in LOCAL VARIETY B-10 than other sowings and the lowest LAR in BARIMASH-1 in both the years. Comparatively higher LAR was observed in LOCAL VARIETY B-10 irrespective of sowing times.

Mean squares from the analysis of variance of LAR revealed that sowing time was significant at 50, 60 and 70 DAS in the 1st year and was always significant at all the stages of growth in the 2nd year. Varietal item was significant at 20 DAS in the 1st year and always significant at all the stages of growth in the 2nd year. The interaction between sowing time and variety (S×V) was found to be always non significant at all the stages of growth in the 1st year and significant at 20, 30, 60 and 70 DAS in the 2nd year.

The pattern of LAR calculated from the curve fitted values (Figures 8.2a and 8.2b) was closer to that calculated from the original values (Figures 8.1a and 8.1b) Again, the curve of LAR showed that they were also closely fitted in both the years.

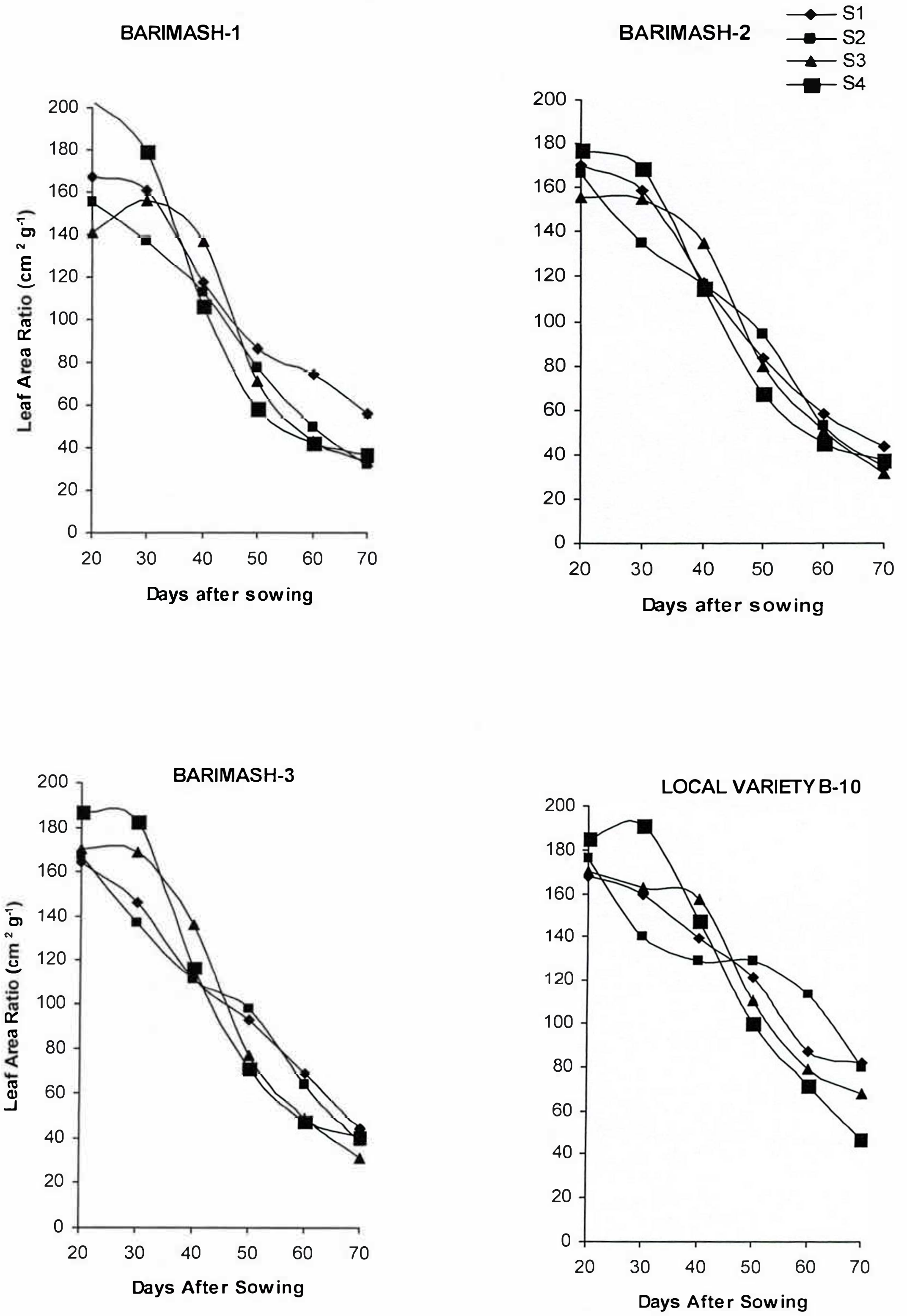


Figure 8.1a. Effect of sowing times on leaf area ratio (LAR) of four blackgram varieties at different stages of growth from original values (2005-2006).

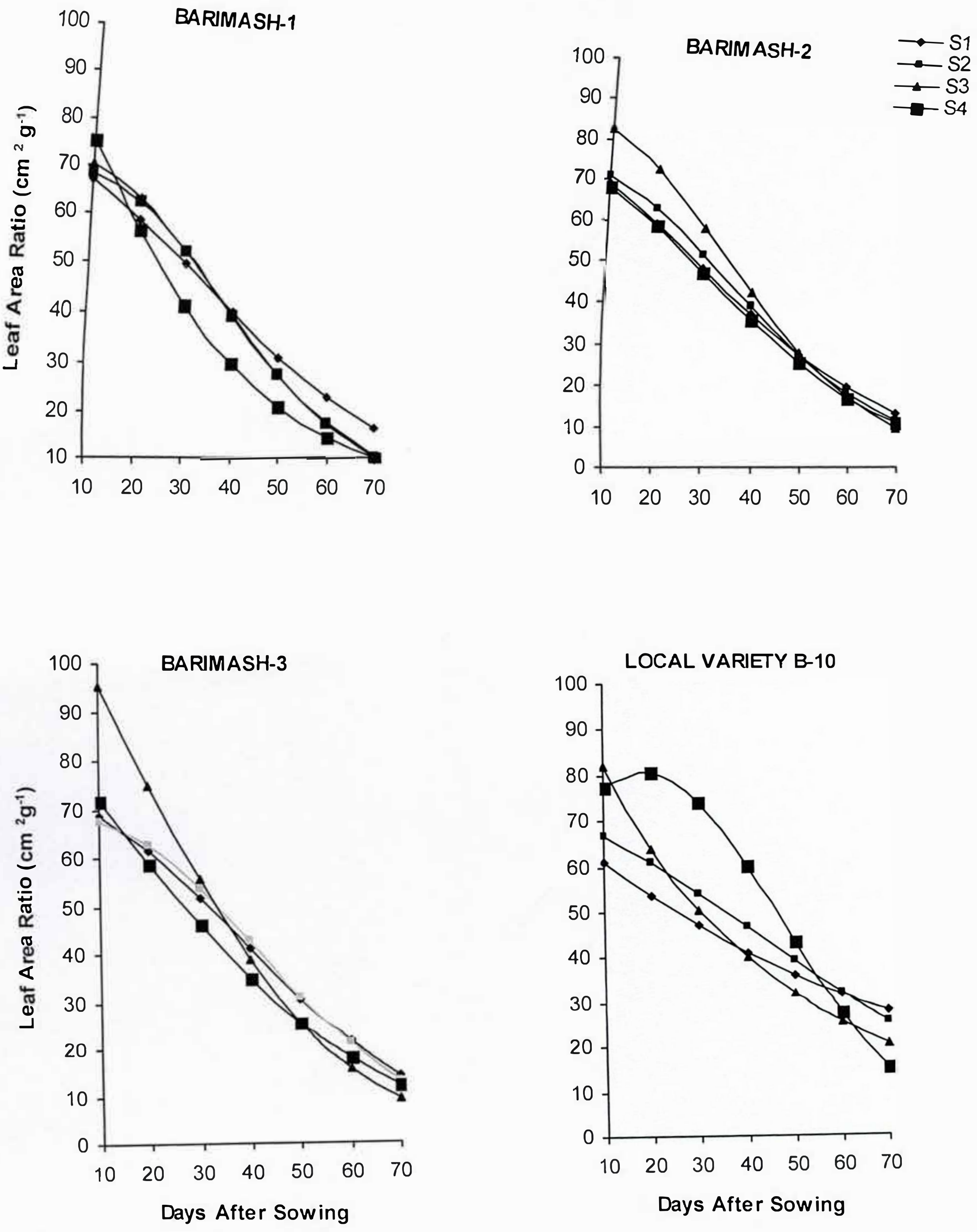


Figure 8.2a. Effect of sowing times on leaf area ratio (LAR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

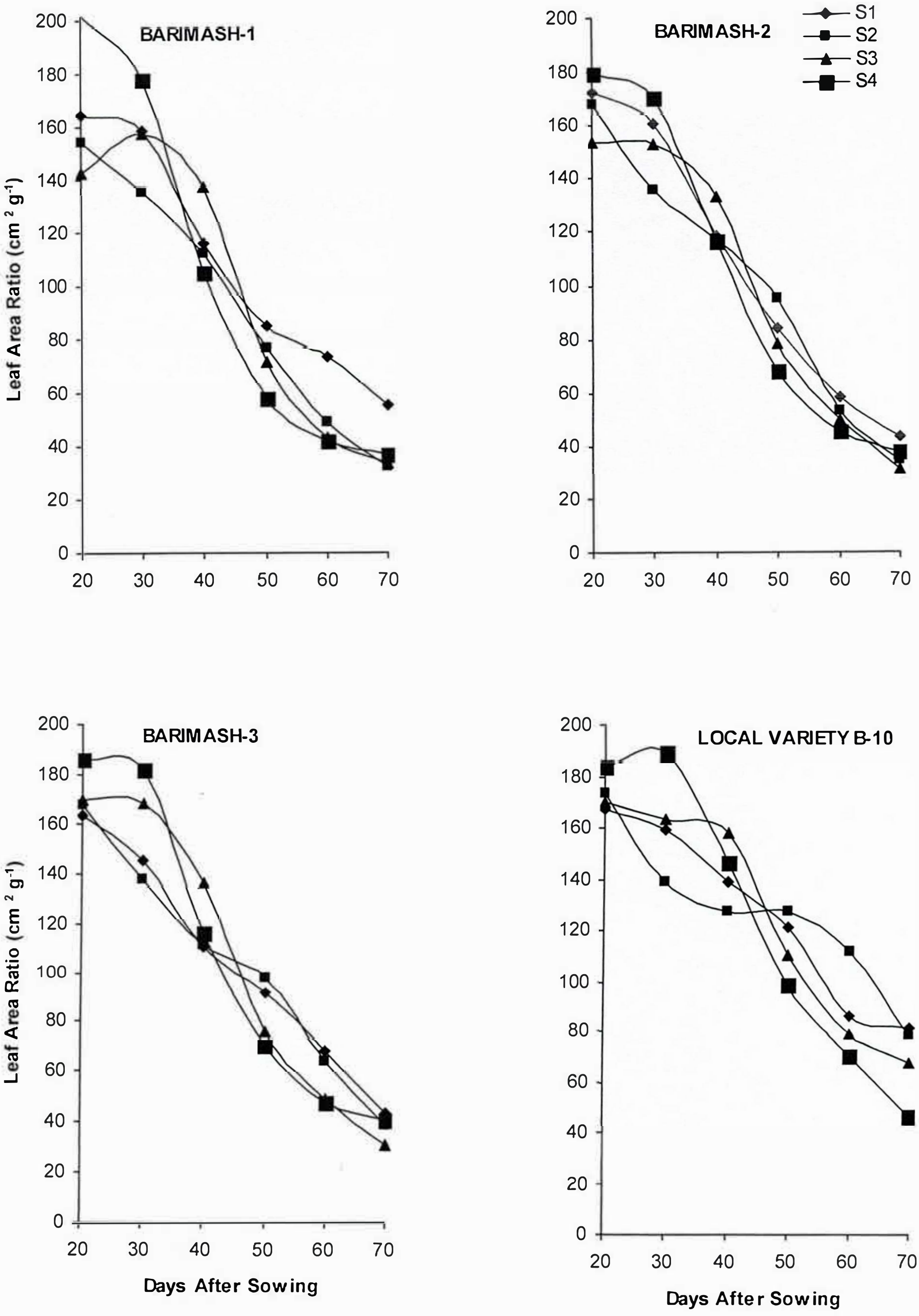


Figure 8.1b. Effect of sowing times on leaf area ratio (LAR) of four blackgram varieties at different stages of growth from original values (2006-2007).

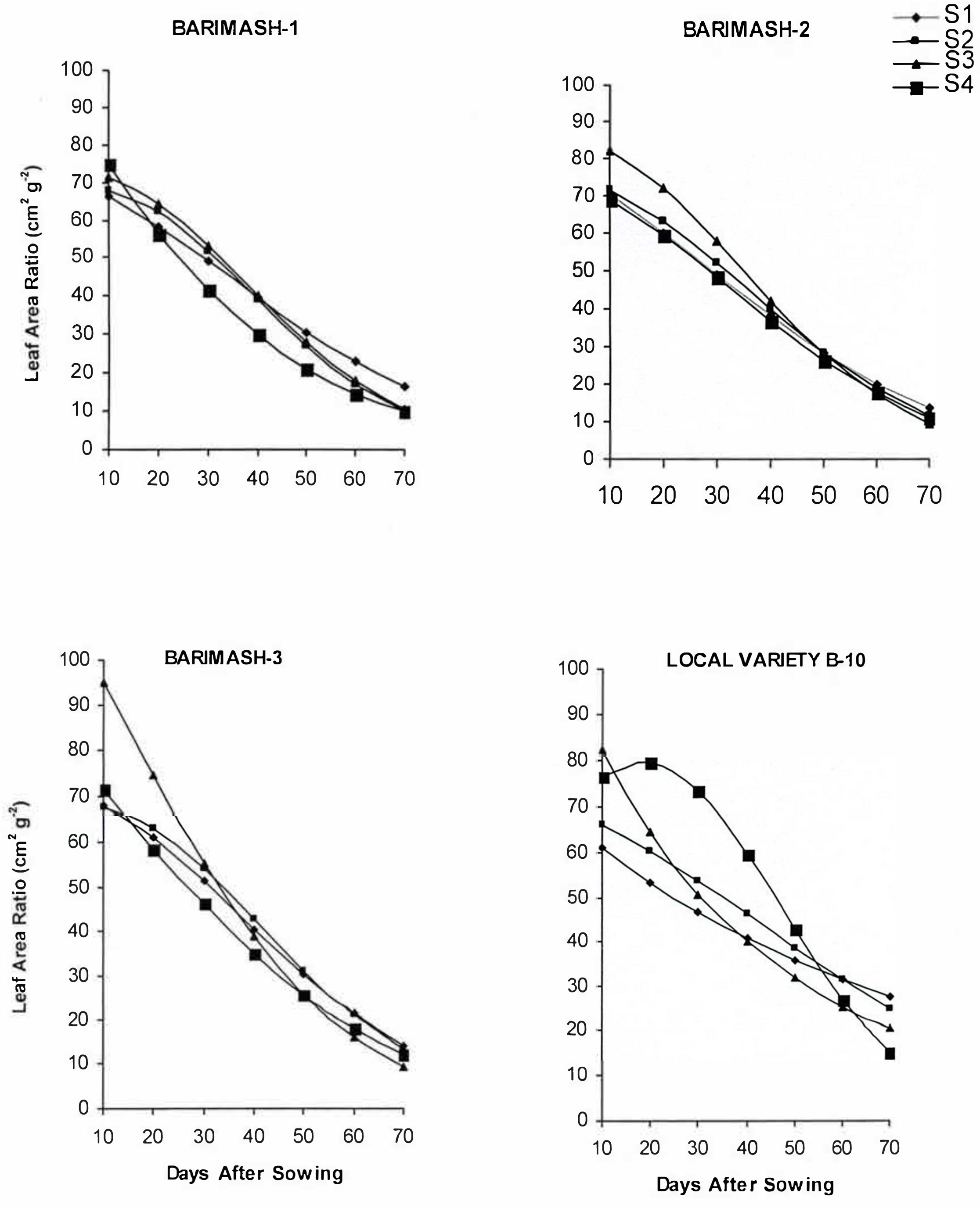


Figure 8.2b. Effect of sowing times on leaf area ratio (LAR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Relative leaf growth rate (RLGR)

Effect of sowing times on relative leaf growth rate (RLGR) of four blackgram varieties at different growth stages are shown in Figures 9.1a-9.2a for 2005-2006 and 9.1b- 9.2b for 2006-2007 growing season. RLGR of all the varieties and sowings, started from higher positive values at the early stages of growth and the declined with heavy fluctuations and became negative values at the later stages of growth. The S_3 plants had the highest RLGR followed by S_1 than other sowings and the lowest in S_2 plants for both the years. Among the varieties, LOCAL VARIETY B-10 had the highest RLGR for S_3 and the lowest in BARIMASH-1 for S_2 in both the years.

Mean squares from the analysis of variance of RLGR indicated that sowing time was always non significant at all the stages of growth in the 1st year and significant at all the stages of growth except 30 DAS only in the 2nd year. Varietal effect was significant at 50 DAS only in the 1st year and at all the stages of growth except 30 and 70 DAS in the 2nd year. Significant sowing time and varietal interaction (S×V) was observed at 30 DAS in the 1st year and at 20, 50, 60 and 70 DAS of all the stages of growth in the 2nd year. RLGR calculated from the curve-fitted values showed linear drift with increasing plant age for all the sowings and varieties in both the years (Figures 9.2a and 9.2b).

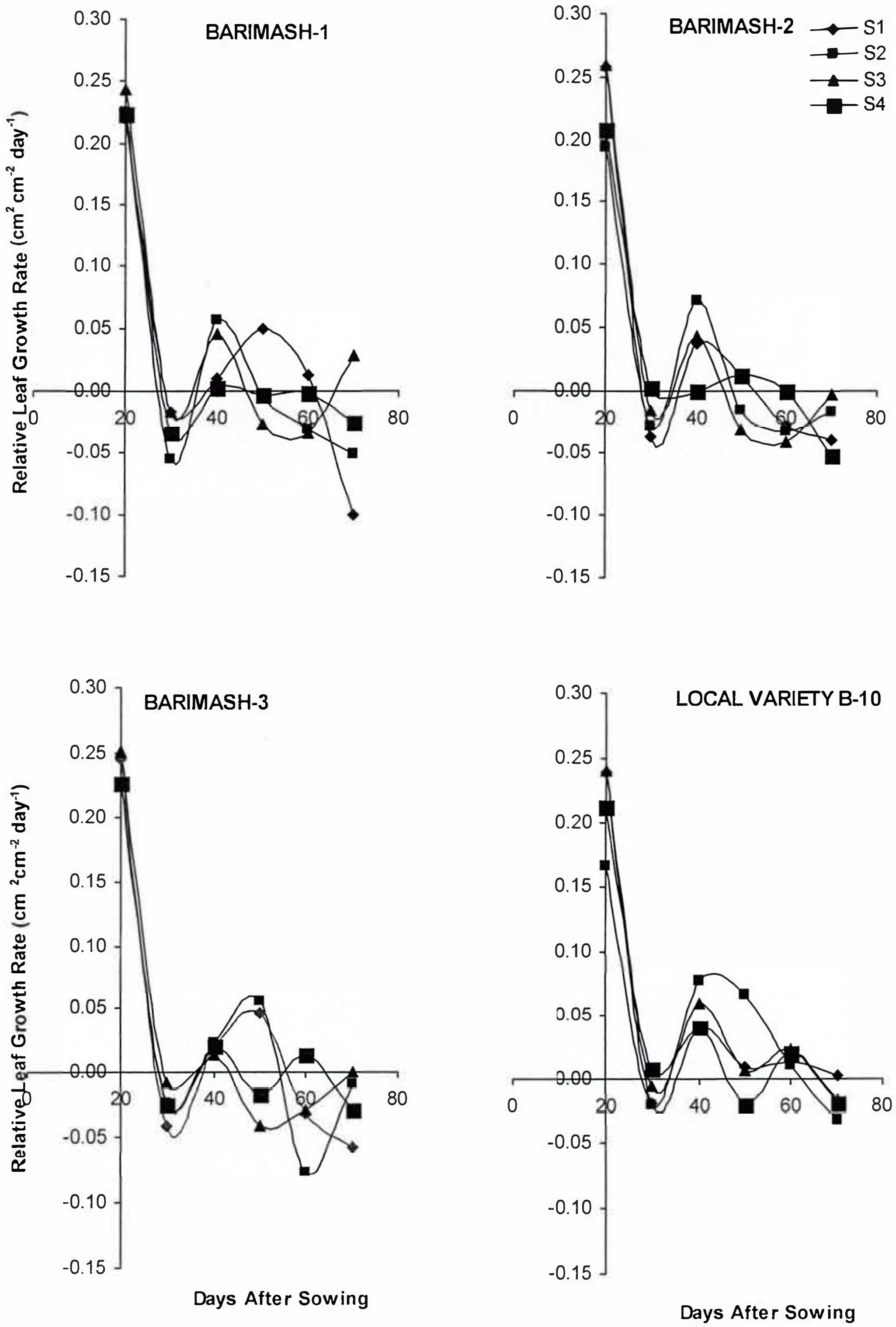


Figure 9.1a. Effect of sowing time on relative leaf growth rate (RLGR) of four blackgram varieties at different stages of growth from original values (2005-2006).

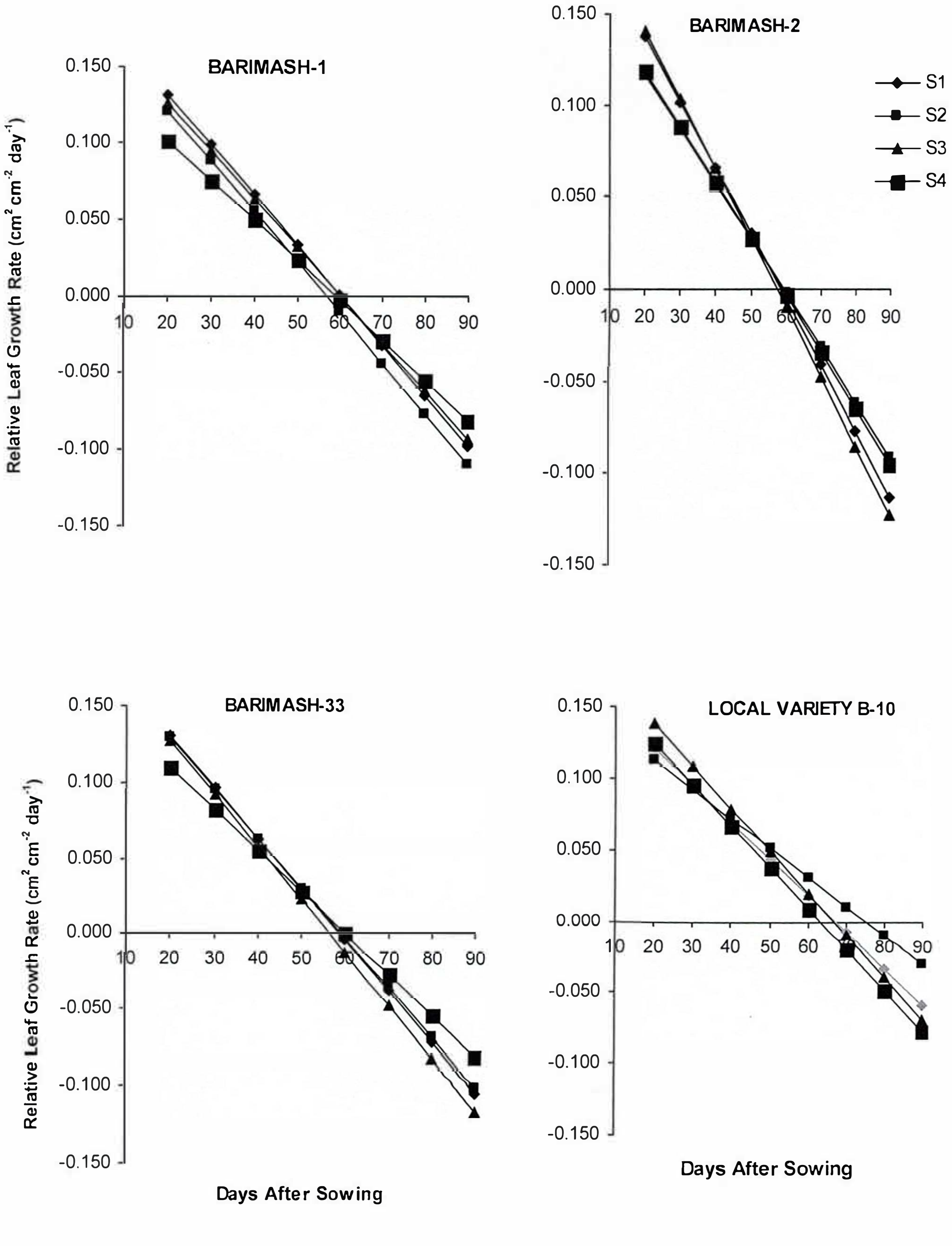


Figure 9.2a. Effect of sowing times on relative leaf growth rate (RLGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

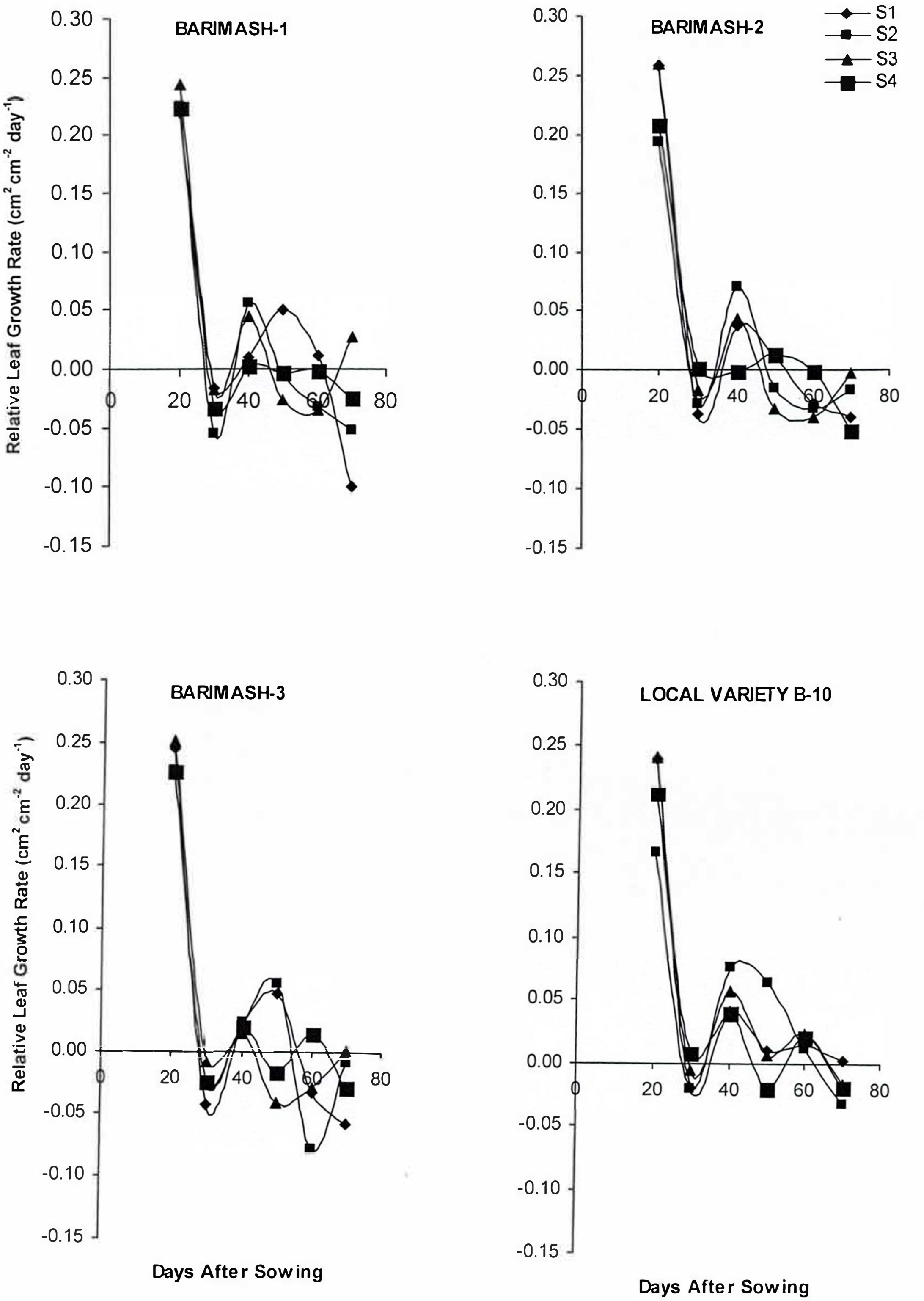


Figure 9.1b. Effect of sowing times on relative leaf growth rate (RLGR) of four blackgram varieties at different stages of growth from original values (2006-2007).

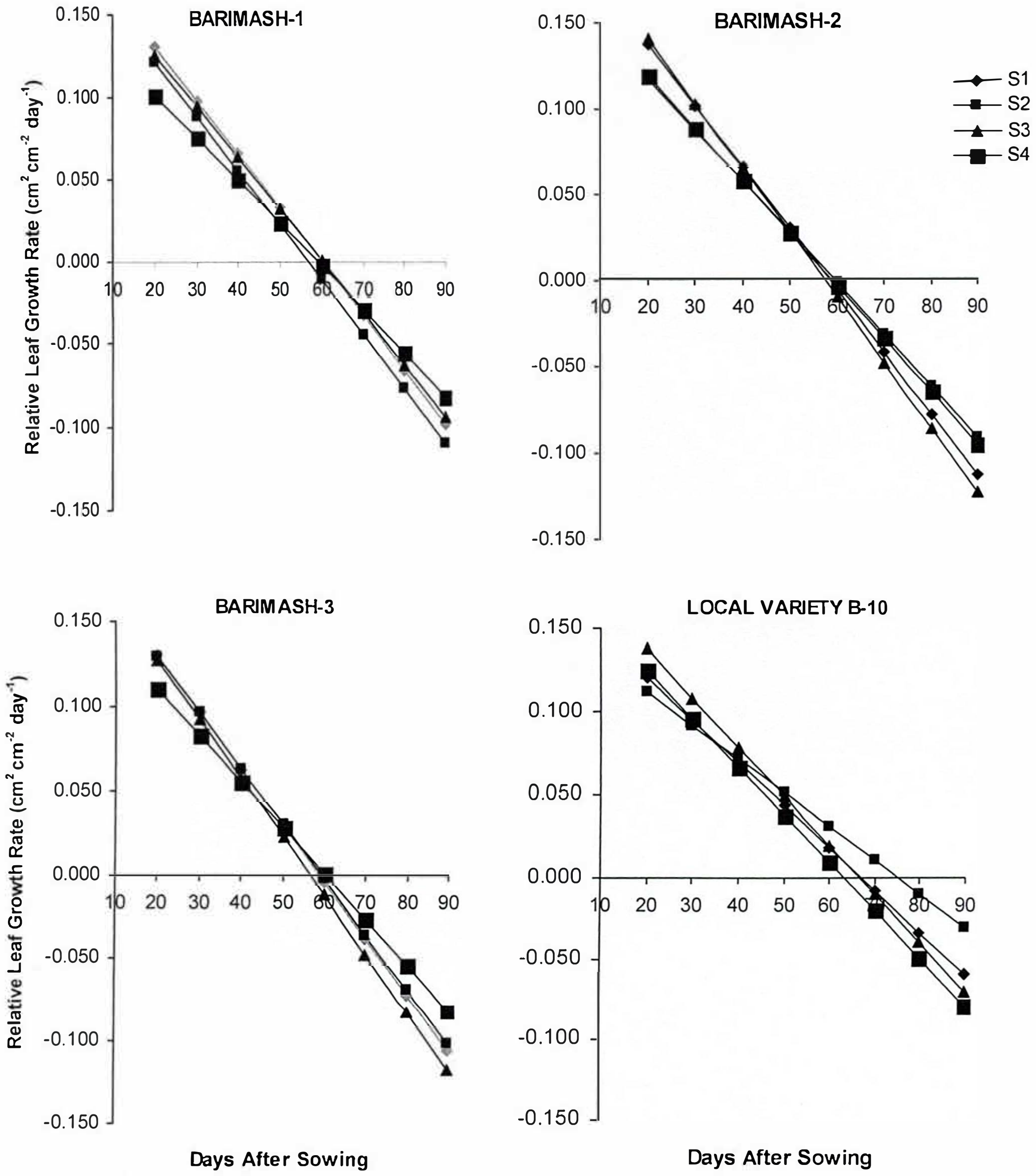


Figure 9.2b. Effect of sowing times on relative leaf growth rate (RLGR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Specific leaf area (SLA)

Effect of sowing times on specific leaf area (SLA) of four blackgram varieties at different stages of growth are shown in Figures 10.1a-10.2a for 2005-2006 and 10.1b- 10.2b for 2006-2007 growing season. SLA calculated from the quadratic fitted values indicated that all the varieties had generally higher SLA at the early stages of growth but it was lower at the middle stages and there was an increasing tendency at the later stages (Figures 10.2a and 10.2b). Most the varieties in all the sowings declined gradually with fluctuation in both the years, although some varieties had increasing tendency with very short time at the early stages of growth and thereafter declined (Figures 10.1a and 10.1b). The S_3 plants had the highest SLA than other sowings and the lowest in S_4 plants in both the years. Among the varieties, LOCAL VARIETY B-10 had the highest SLA followed by BARIMASH-3 and the lowest in BARIMASH-2 than other varieties in both the years.

Mean squares from the analysis of variance of SLA revealed that sowing time effect was always non significant at all the stages of growth in the 1st year wheares significant at all the stages of growth except at 65 and 75 DAS in the 2nd year. Varietal effect was significant at 15 and 55 DAS in the 1st year and at 15, 45 and 65 DAS in the 2nd year. Non significant sowing time and varietal interaction (S×V) was observed at all the stages of growth in the 1st year, whereas significant sowing time and varietal interaction (S×V) was found at all the stages of growth except at 25 and 75 DAS in the 2nd year.

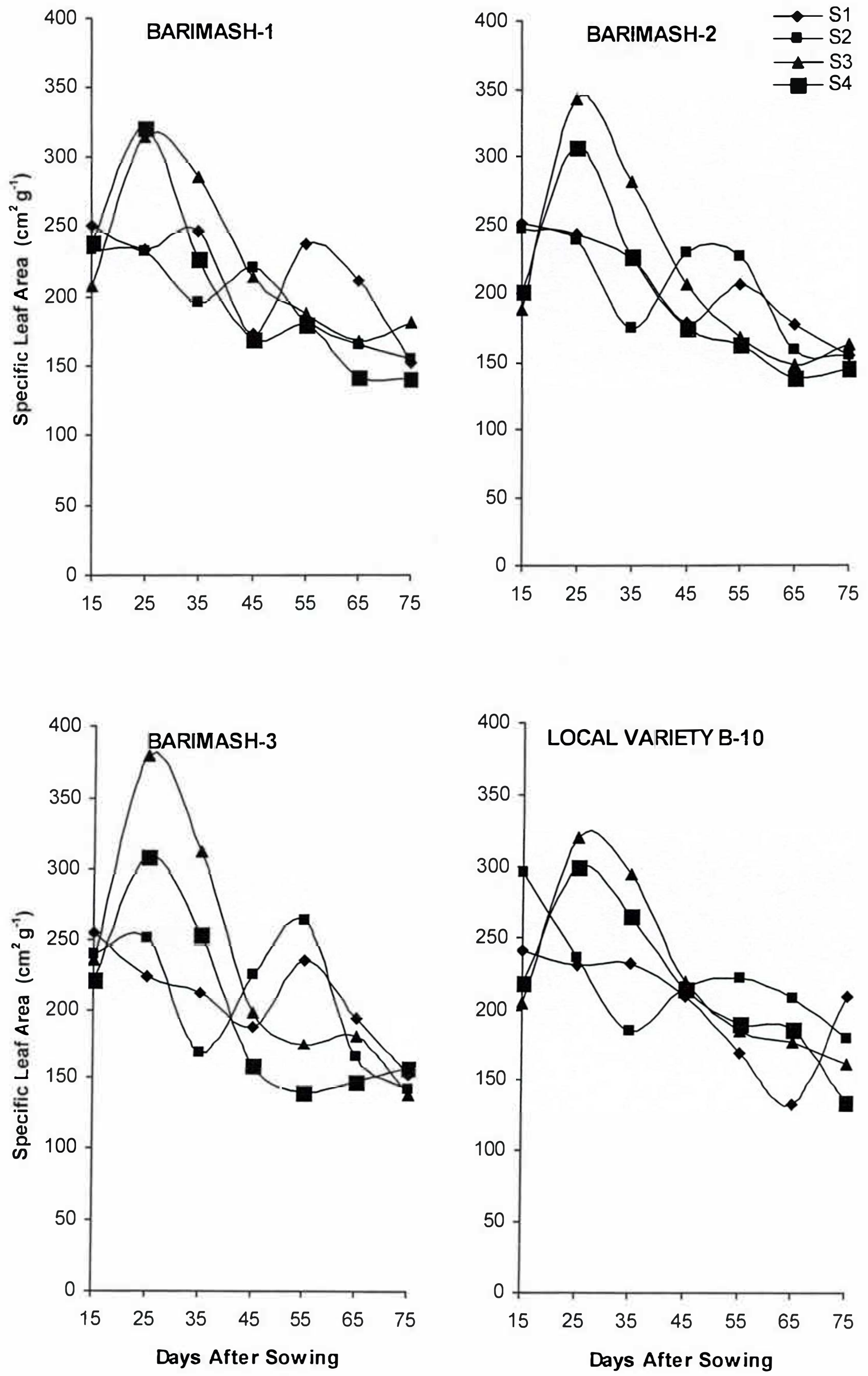


Figure 10.1a. Effect of sowing times on specific leaf area (SLA) of four blackgram varieties at different stages of growth from original values (2005-2006).

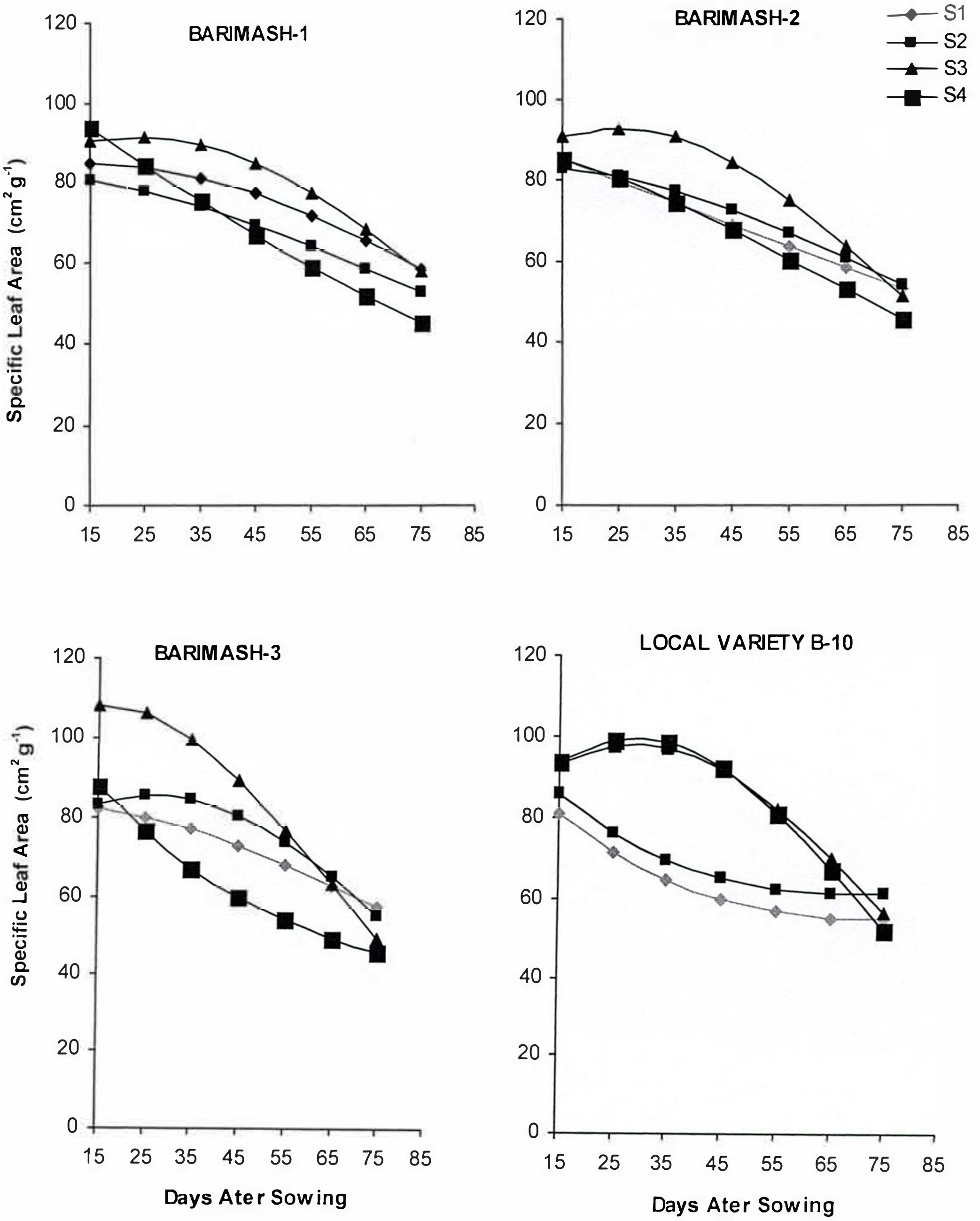


Figure 10.2a. Effect of sowing times on specific leaf area (SLA) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

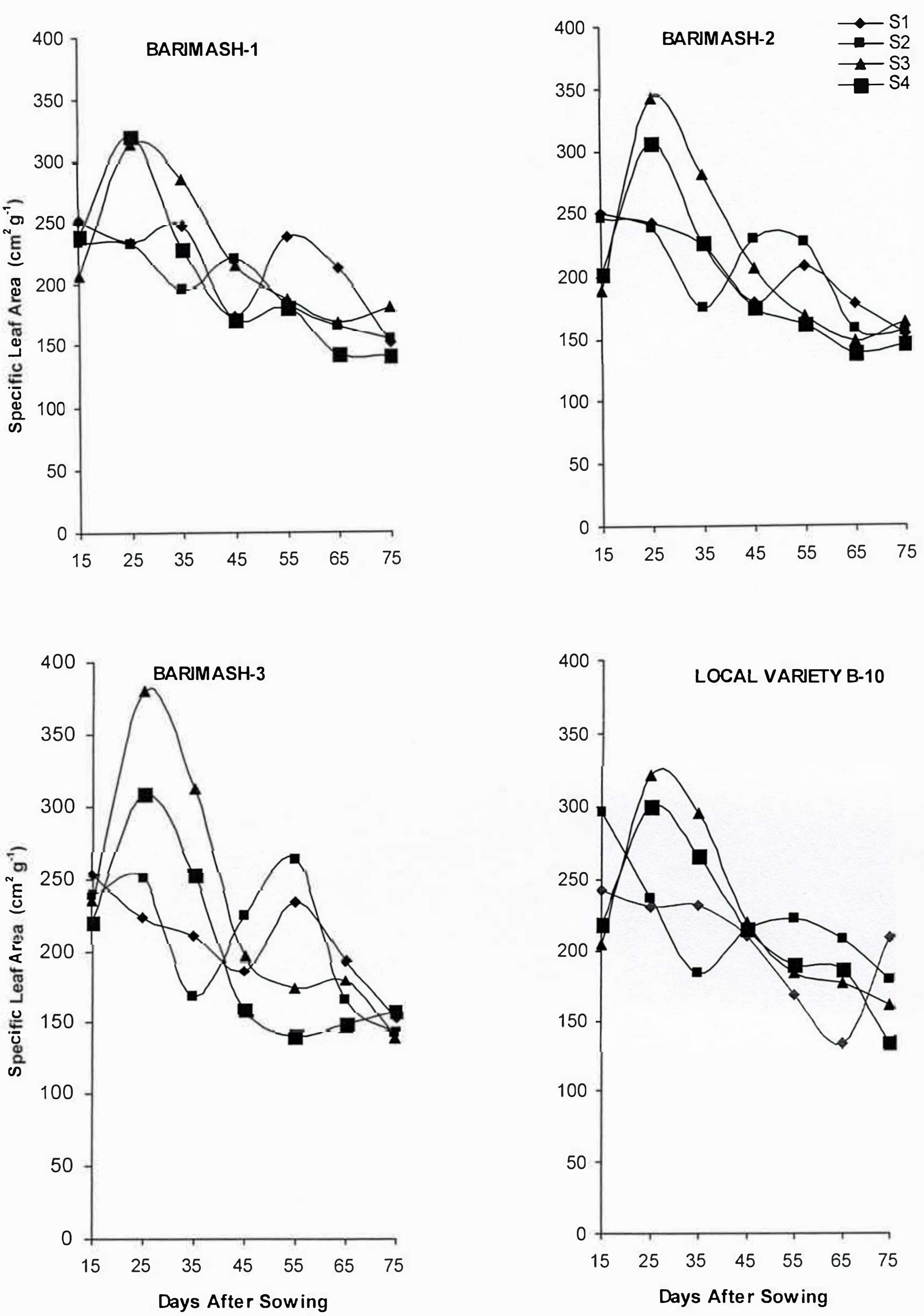


Figure 10.1b. Effect of sowing times on specific leaf area (SLA) of four blackgram varieties at different stages of growth from original values (2006-2007).

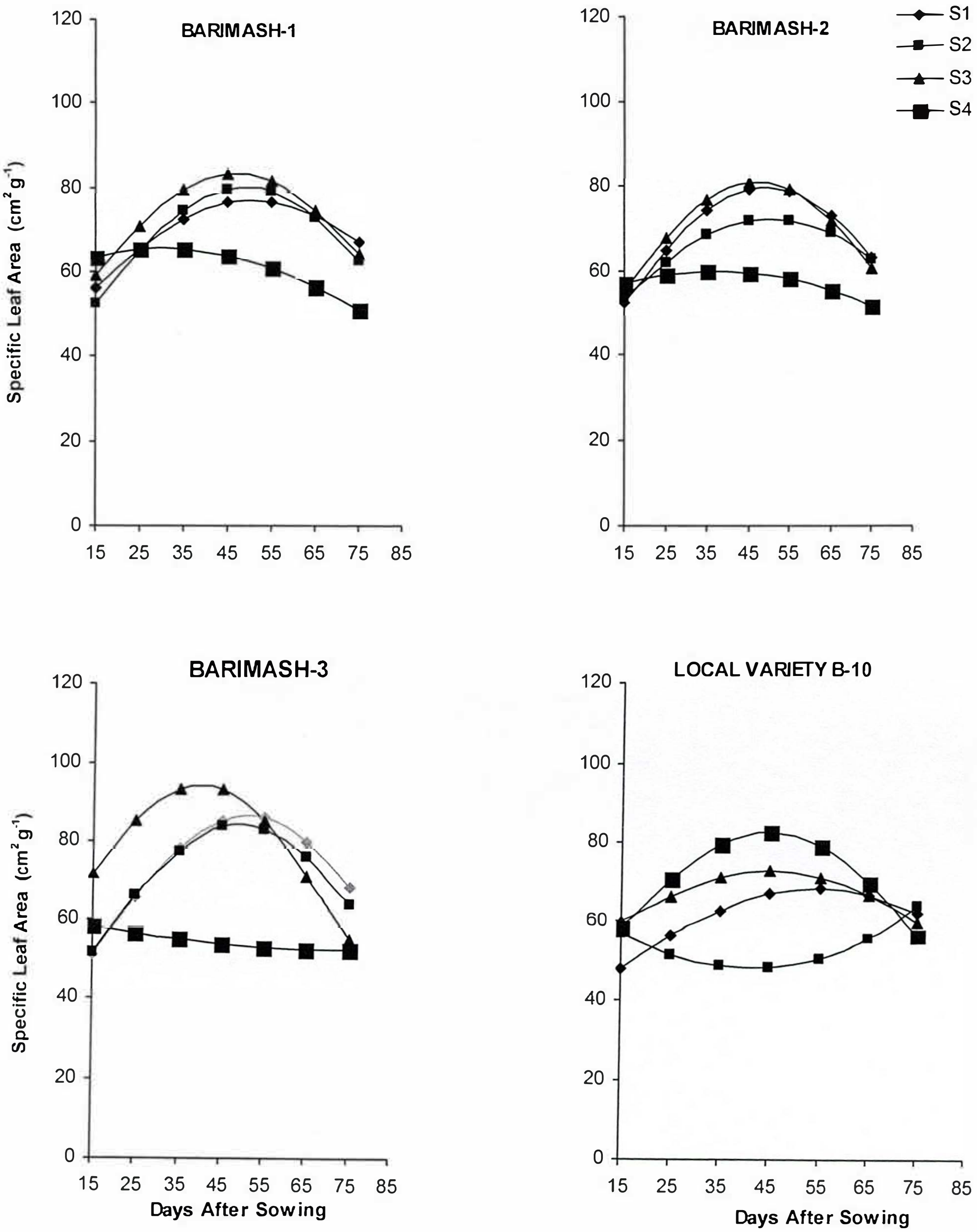


Figure10.2b. Effect of sowing times on specific leaf area (SLA) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Leaf weight ratio (LWR)

LWR calculated from the curve-fitted values and the original values both showed downward drifts with age in all the varieties and sowing (Figures 11.1a - 11.2a for 2005-2006 and 11.1b- 11.2b for 2006-2007 growing season. In the present investigation it was observed that LWR were increasing tendency at the early stages of growth within very short time and thereafter declined gradually irrespective of sowing and variety in both the years. At the early stages of growth (15 DAS) all the varieties had higher LWR for S_3 plants and lower in S_2 in both the years. The highest LWR was found in LOCAL VARIETY B-10 for S_3 and the lowest in BARIMASH-1 for S_3 plants in both years.

Mean squares from the analysis of variance of LWR indicated that sowing time was significant at 35, 55 and 65 DAS in the 1st year and at 15, 25, 55 and 65 DAS in the 2nd year. Varietal effect was always non significant at all the stages of growth except 25 DAS in the 2nd year. It was also observed that sowing time and varietal interaction (S×V) was non-significant at all the stages of growth in the 1st year, whereas significant at all the stages of growth except at 35 and 75 DAS in the 2nd year.

The pattern of LWR calculated from the curve-fitted values (Figures 11.2a and 11.2b) was closer to that calculated from the original values (Figures 11.1a and 11.2b). It was also observed that the curves of LWR were closely fitted in both the years.

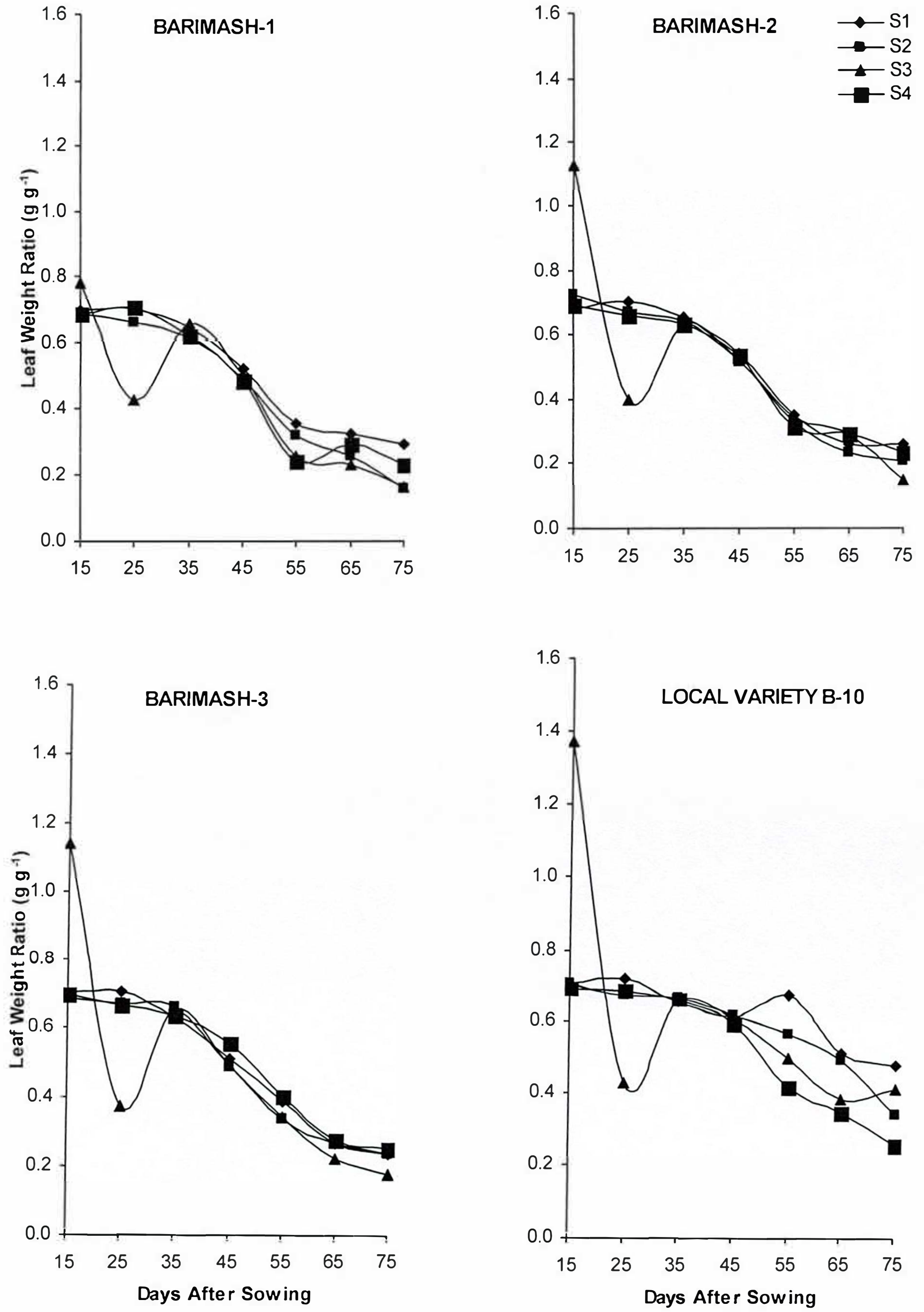


Figure 11.1a. Effect of sowing times on leaf weight ratio (LWR) of four blackgram varieties at different stages of growth from original values (2005-2006).

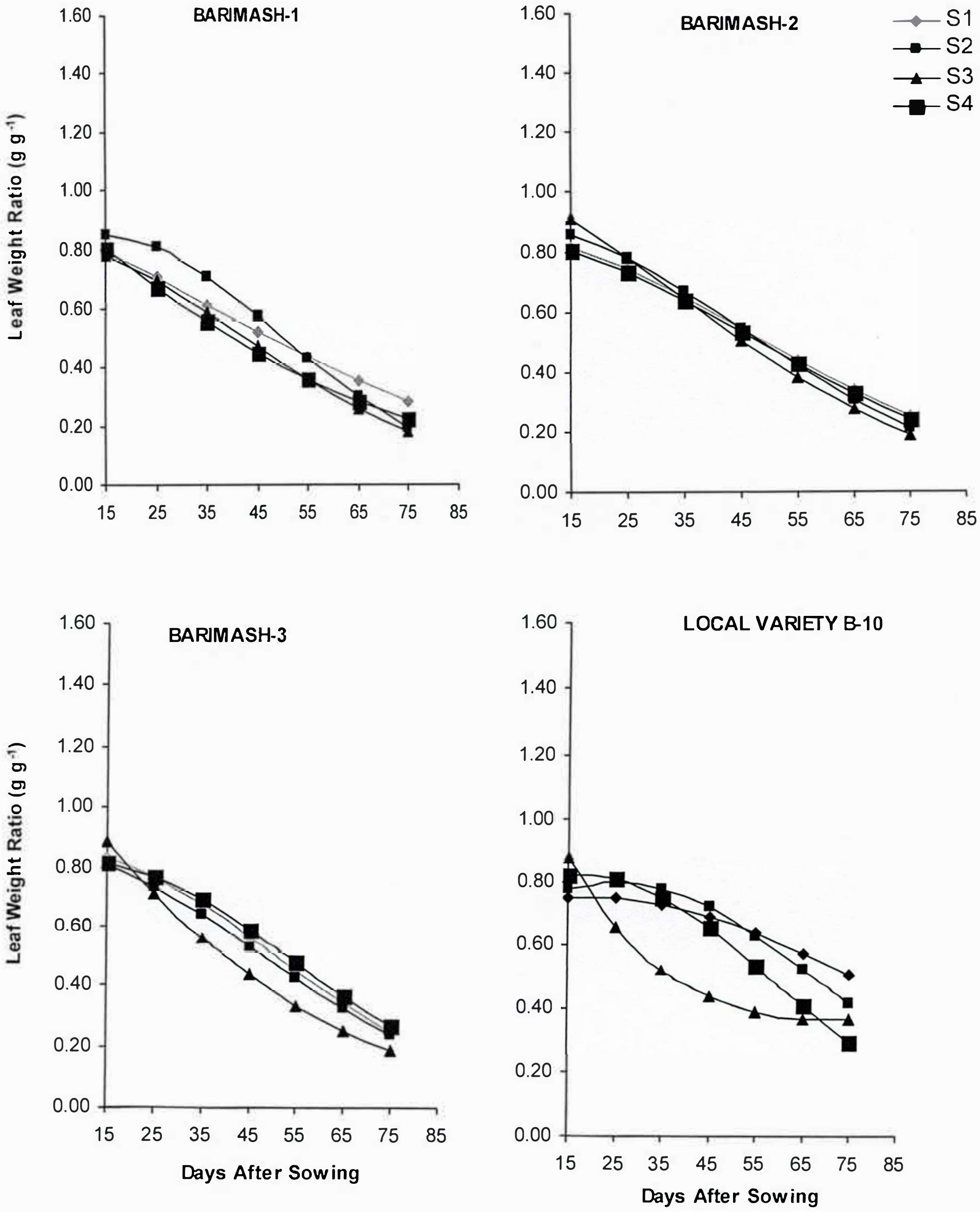


Figure 11.2a. Effect of sowing times on leaf weight ratio (LWR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2005-2006).

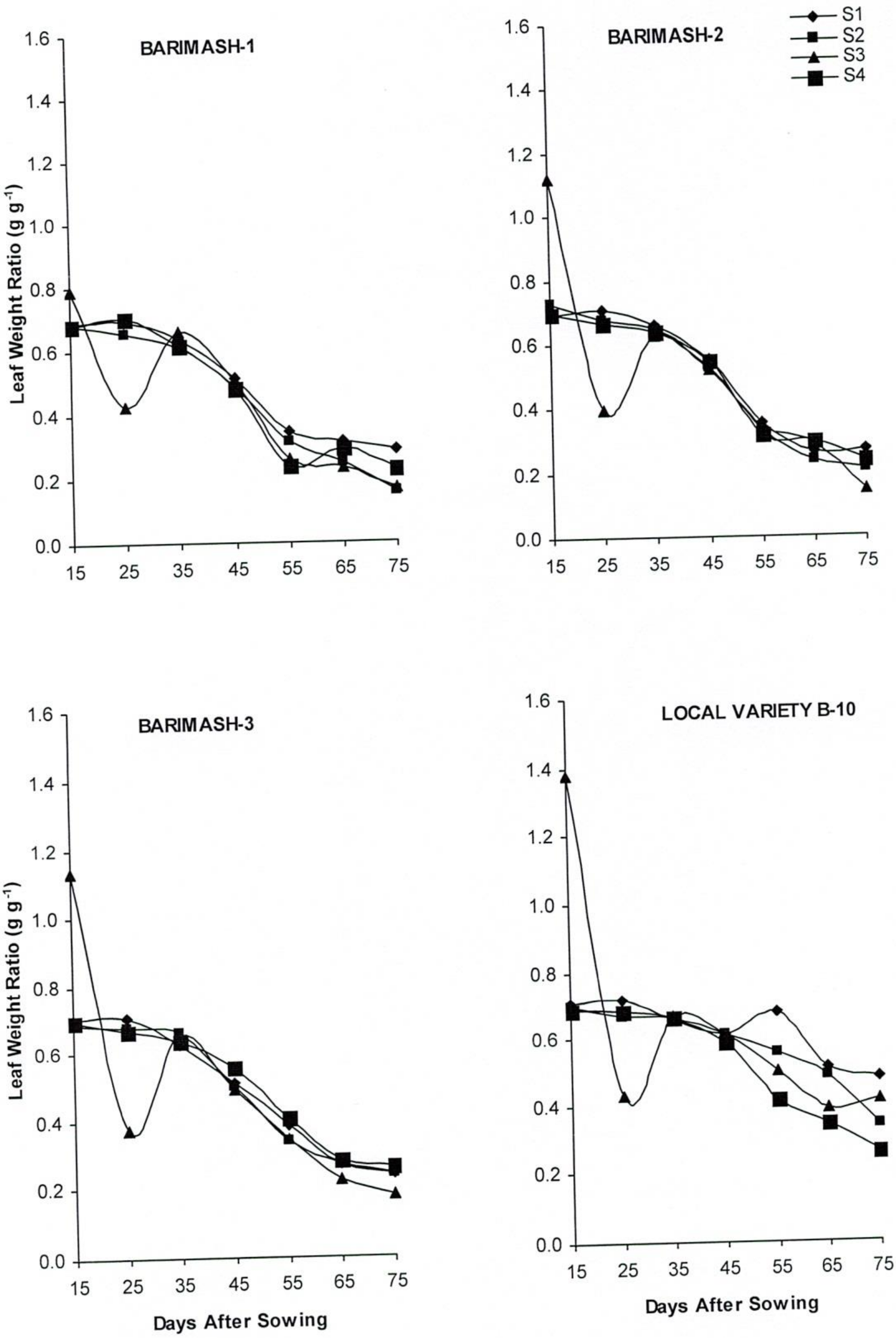


Figure 11.1b. Effect of sowing times on leaf weight ratio (LWR) of four black gram varieties at different stages of growth from original values (2006-2007).

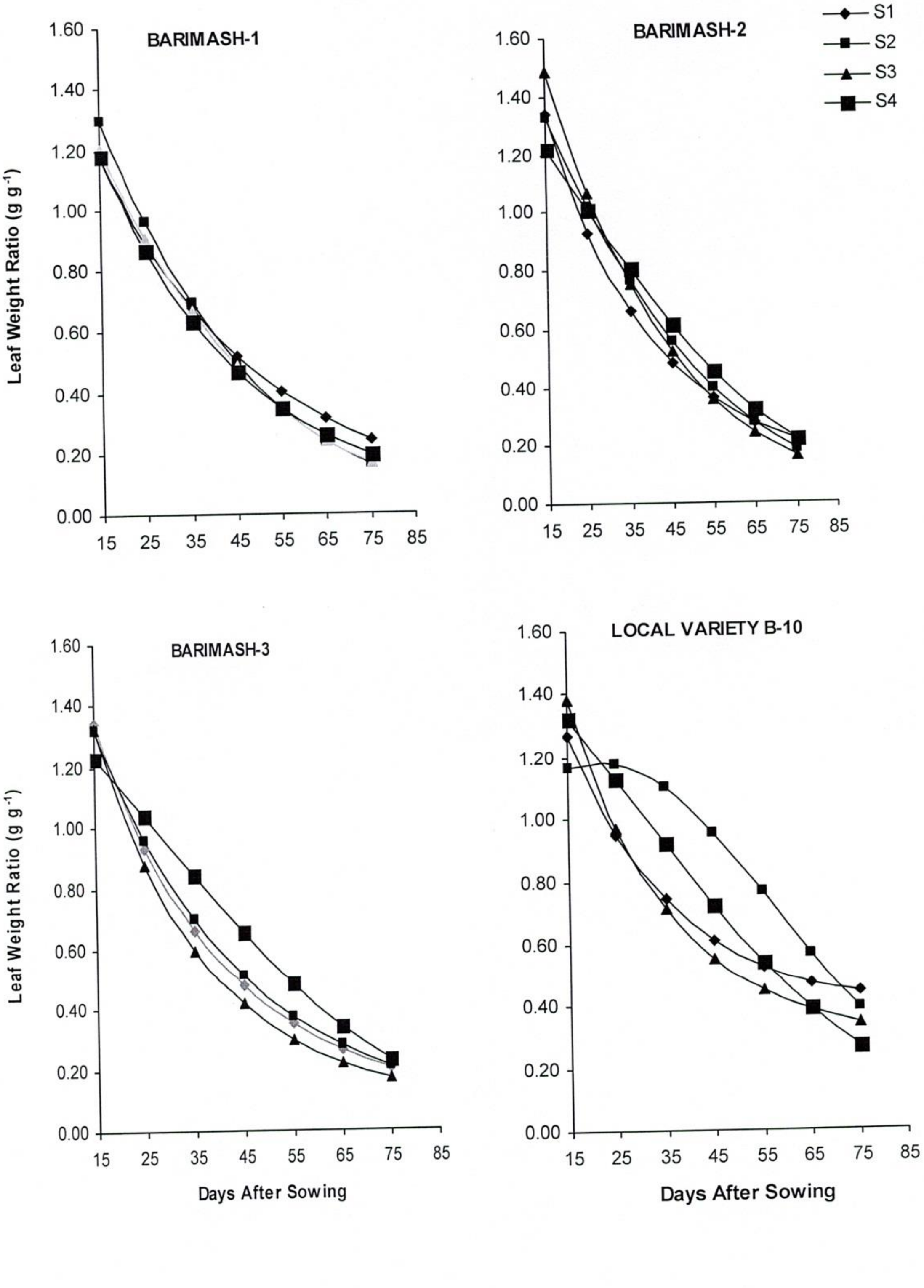


Figure 11.2b. Effect of sowing times on leaf weight ratio (LWR) of four blackgram varieties at different stages of growth from quadratic curve fitted values (2006-2007).

Phenology (days)

Phenology (days) at different stages of four blackgram varieties as affected by sowing times are presented in Tables 11a and 11b for 2005-2006 and 2006-2007 respectively. For each variety, a definite days was required to attain certain phenological stage of growth. Number of days for attainment of different phenological stages differed from variety to variety and the required days were decreased for every late sowings at most of the phenological stages. The number of days taken for attainment at most of the phenological stages were in the order of $S_3>S_2>S_1>S_4$ except physiological maturity where the order was $S_1>S_2>S_3>S_4$ in both the years. Among the varieties, LOCAL VARIETY B-10 required the highest number of days for attaining the flower initiation, pod initiation, pod filling and physiological maturity, whereas BARIMASH-3 showed the better performance for seed emergence and BARIMASH-1 for leaflet initiation in both the years. The lowest number of days required in BARIMASH-3 for most of the phenological characters except seed emergence while it was observed in BARIMASH-1 in both the years.

Sowing time was significant for most of the phenological stages except seed emergence and flower initiation stages in both the years. Varietal effect was significant of all the phenological stages except leaflet initiation in the 1st year and seed emergence in the 2nd year. It was also found that sowing time and variety interaction (S×V) was significant for all the phenological stages except seed emergence in the 2nd year and flower initiation in both the years.

Table 11a. Phenology (days) at different phenological stages of four blackgram varieties as affected by sowing times in 2005-2006.

Seed emergence

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	3.0 b	3.0 b	3.0 b	3.0 b	3.0
BARIMASH 2	3.7 a	3.0 b	4.0 a	3.7 a	3.6
BARIMASH 3	4.0 a	3.7 a	3.3 b	3.7 a	**3.7**
LOCAL VARIETY B-10	3.0 b	4.0 a	4.0 a	3.0 b	3.5
S-MEAN	3.4	3.4	**3.6**	3.3	3.4
LSD at 5%	S=NS				V=0.3

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	24.3 b	24.7 b	25.7 a	24.3 a	**24.8**
BARIMASH 2	25.3 a	24.3 b	26.0 a	23.3 b	24.8
BARIMASH 3	23.7 b	25.0 b	25.0 a	23.0 b	24.2
LOCAL VARIETY B-10	24.0 b	26.7 a	25.0 a	23.0 b	24.7
S-MEAN	24.3	25.2	**25.4**	23.4	24.6
LSD at 5%	S=0.9				V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Flower initiation

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	32.3a	34.7 a	35.0a	33.3a	33.8
BARIMASH 2	33.3a	35.0a	36.3a	33.7a	34.6
BARIMASH 3	33.0a	34.3a	34.3a	34.7a	34.1
LOCAL VARIETY B-10	55.3a	52.3a	57.0a	46.0b	**52.7**
V-MEAN	38.5ab	39.1ab	**40.7a**	36.9b	38.8
LSD at 5%	S=NS				V=2.7

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

(Table 11a. continued)

Pod initiation

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	55.3 b	55.3 b	53.3 c	52.7 b	54.2
BARIMASH 2	54.7 b	54.0 b	54.7 b	52.7 b	54.0
BARIMASH 3	54.7 b	54.7 b	53.3 c	51.7 b	53.6
LOCAL VARIETY B-10	68.3 a	72.3 a	75.0 a	66.7 a	**70.6**
S-MEAN	58.3	59.1	**59.1**	55.9	58.1
LSD at 5%	S=1.0				V=0.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Pod filling

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	44.0 b	44.3 b	45.0 c	43.3 b	44.2
BARIMASH 2	44.7 b	44.3 b	46.3 b	44.3 b	44.9
BARIMASH 3	44.7 b	45.0 b	45.0 c	44.0 b	44.7
LOCAL VARIETY B-10	64.0 a	67.0 a	68.0 a	59.3 a	**64.6**
S-MEAN	49.3	50.2	**51.1**	47.8	49.6
LSD at 5%	S=0.8				V=0.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Physiological maturity

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	80.3 b	76.7 b	72.0 b	69.0 b	74.5
BARIMASH 2	79.3 b	76.0 b	70.7 bc	70.0 b	74.0
BARIMASH 3	77.7 c	77.3 b	69.7 c	67.0 c	72.9
LOCAL VARIETY B-10	89.0 a	88.3 a	85.0 a	81.0 a	**85.8**
S-MEAN	**81.6**	79.6	74.3	71.8	76.8
LSD at 5%	S=1.0				V=0.8

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 11b. Phenology (days) at different phenological stages of four blakgram varieties as affected by sowing times in 2006-2007.

Seed emergence

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3.3a	3.3a	3.3a	3.3a	3.3
BARIMASH 2	3.3a	3.7a	3.7a	3.3a	3.5
BARIMASH 3	3.7a	3.7a	3.3a	3.3a	**3.5**
LOCAL VARIETY B-10	3.3a	3.3a	3.7a	3.7a	3.5
S-MEAN	3.4a	3.5a	**3.5a**	3.4a	3.5

LSD at 5% S=NS V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	26.0 ab	26.7 ab	27.7 a	26.3 a	**26.7**
BARIMASH 2	26.7 a	25.3 c	27.0 ab	24.7 b	25.9
BARIMASH 3	25.0 b	26.0 bc	26.0 b	24.3 b	25.3
LOCAL VARIETY B-10	25.3 b	27.7 a	26.0 b	24.3 b	25.8
S-MEAN	25.8	26.4	**26.7**	24.9	25.9

LSD at 5% S= 1.0 V=0.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Flower initiation

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	36.7a	34.0a	37.0a	35.0a	35.7
BARIMASH 2	36.0a	34.7a	37.3a	35.0a	35.8
BARIMASH 3	35.3a	34.3a	35.3a	36.0a	35.3
LOCAL VARIETY B-10	53.3a	56.7a	58.0a	47.3b	**53.8**
S-MEAN	40.3ab	39.9ab	**41.9a**	38.3b	40.1

LSD at 5% S= NS V=2.7

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

(Table 11b. continued)

Pod initiation

Sowing time(S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	45.3 b	46.0 b	47.0 b	45.7 b	46.0
BARIMASH 2	45.7 b	45.7 b	47.3 b	16.0 c	45.9
BARIMASH 3	45.3 b	46.3 b	46.0 b	46.0 b	38.7
LOCAL VARIETY B-10	60.7 a	68.3 a	69.0 a	65.3 a	**65.8**
S-MEAN	49.3	51.6	**52.3**	43.3	49.1

LSD at 5% S=1.0 V=0.7

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Pod filling

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	57.0 b	55.3 b	57.0 b	54.3 b	55.9
BARIMASH 2	56.0 b	55.7 b	55.3 b	54.0 b	55.3
BARIMASH 3	56.0 b	54.3 b	56.0 b	53.0 b	54.8
LOCAL VARIETY B-10	69.7 a	76.0 a	73.7 a	68.0 a	**71.8**
S-MEAN	59.7	60.3	**60.5**	57.3	59.5

LSD at 5% S= 0.8 V=0.8

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Physiological maturity

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	82.0 b	78.3 b	73.7 b	70.7 b	76.2
BARIMASH 2	80.7 b	77.3 b	72.0 c	71.0 b	75.3
BARIMASH 3	79.0 c	78.7 b	71.0 c	67.0 c	73.9
LOCAL VARIETY B-10	90.3 a	89.7 a	86.3 a	82.3 a	**87.2**
S-MEAN	**83.0**	81.0	75.8	72.8	78.1

LSD at 5% S= 1.3 V=0.8

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Growing degree days (GDD)

Growing degree days (GDD) from sowing to different phenological stages of growth of four blackgram varieties are shown in Tables 12a and 12b for 2005-2006 and 2006-2007 respectively. Growing degree days taken for attainment at most of the phenological stages were in the order $S_4>S_3>S_2>S_1$ in both the years except pod filling and physiological maturity stages. It was observed that the highest heat unit (GDD) was required in S_4 followed by S_3, S_2 and S_1 at most of the phenological stages for all the varieties in both the years except pod filling and physiological maturity stages, whereas they showed the better performance in S_3 plants for both the years. On average, the S_4 plants required the heat units 668.67 for seed emergence, 1082.66 for leaflet initiation, 1318.41 for flower initiation, 1527.30 for pod intiation, 1581.15 for pod filling and 2212.48a for physiological maturity in the 1st year and the corresponding values were 657.90, 1082.56, 1330.94, 1555.63, 1466.91a and 1681.07 in the 2nd year. It was also observed that the requirement of heat units for most of the phenological stages decreased with early in sowing in both the years. So, the lowest heat unit requirement for all the phenological stages in all the varieties was observed in S_1. Among the varieties, LOCAL VARIETY B-10 accumulated the highest heat unit (GDD) for all the sowings at most of the phenological stages except BARIMASH-3 while showed the better performance for seed emergence in the 1st year and BARIMASH-1 for leaflet initiation in both the years.

The highest heat unit (GDD) in LOCAL VARIETY B-10 was 1331.96a for flower initiation, 1531.38 for pod initiation, 1571.36 for pod filling and 1974.80 for physiological maturity in the 1st year and 364.13a for seed emergence, 1339.79a for flower initiation, 1555.38 for pod initiation, 1480.77 for pod filling and 1615.54 for physilogical maturity in the 2nd year.

Sowing time was significant at most of the phenological stages in both the years except physiological maturity in the 1st year and pod filling in the 2nd year. Varietal effect was significant of all the stages except leaflet initiation and physiological maturity in the 1st year, whereas seed emergence and pod filling stages in the 2nd year. It was also observed that sowing time and varietal interaction (S×V) was significant at most of the phenological stages except flower initiation and physiological maturity in the 1st year and seed emergence, flower initiation and pod filling stages in the 2nd year.

Table 12a. Growing degree days at different phonological stages of four blackgram varieties as influenced by sowing times in 2005-2006.

Seed emergence

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	61.20 b	254.00 b	452.80 b	662.00 b	357.50
BARIMASH 2	74.27 a	254.00 b	472.30 a	675.33 a	368.98
BARIMASH 3	80.80 a	268.00 a	459.30 b	675.33 a	**370.86**
LOCAL VARIETY B-10	61.20 b	275.00 a	472.30 a	662.00 b	367.63
S-MEAN	69.37	262.75	464.18	**668.67**	366.24

LSD at 5%, S=3.34 V=5.62

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	478.93 a	695.60 b	909.23 a	1082.63 ab	**791.60**
BARIMASH 2	459.30 ab	688.80 b	916.00 a	1101.97 a	791.52
BARIMASH 3	452.80 b	702.60 b	896.13 a	1069.73 b	780.32
LOCAL VARIETY B-10	452.63 b	736.50 a	895.70 a	1076.30 b	790.28
S-MEAN	460.92	705.88	904.27	**1082.66**	788.43

LSD at 5%, S=18.09 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Flower initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	695.60 b	845.47 b	1095.30 b	1255.33 b	976.96 b
BARIMASH 2	702.60 b	864.63 b	1121.87 b	1260.97 b	987.52 b
BARIMASH 3	689.13 b	858.07 b	1082.63 b	1278.00 b	972.93 b
LOCAL VARIETY B-10	1044.57 a	1288.57a	1515.37 a	1479.33 a	**1331.96 a**
S-MEAN	782.98	964.18	1203.79	**1318.41**	1067.34

LSD at5%, S=61.56 V=52.70

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

(Table 12a. continued)

Pod initiation

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	883.03 b	1095.63 c	1260.97 b	1441.70 b	1178.05
BARIMASH 2	883.03 b	1121.87 b	1272.30 b	1454.10 b	1182.83
BARIMASH 3	896.13 b	1095.30 c	1266.67 b	1454.10 b	1170.33
LOCAL VARIETY B-10	1314.57 a	1515.37 a	1536.27 a	1759.30 a	**1531.38**
S-MEAN	994.19	1207.04	1334.05	**1527.30**	1265.65

LSD at 5% S=16.01 V=11.54

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Pod filling

Sowing time (S)					
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	1101.97 b	1255.33 b	1581.70 a	1466.87 b	1351.47
BARIMASH 2	1076.07 b	1278.00 b	1581.90 a	1453.87 b	1347.46
BARIMASH 3	1089.30 b	1255.33 b	1567.80 a	1454.10 b	1341.63
LOCAL VARIETY B-10	1410.90 a	1614.73 a	1593.20 a	1666.60 a	**1571.36**
S-MEAN	1169.56	1350.85	**1581.15**	1510.36	1402.98

LSD at 5% S=97.23 V=73.71

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Physiological maturity

Sowing time (S)					
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	1549.87a	1640.10a	1757.63a	1206.97a	1538.64
BARIMASH 2	1536.27a	1629.70a	1736.00a	1220.00a	1530.49
BARIMASH 3	1510.27a	1650.57a	1688.97a	1944.13a	1698.48
LOCAL VARIETY B-10	1677.77b	1197.87b	3667.30a	1356.27b	**1974.80**
S-MEAN	1566.54a	1529.56a	**2212.48a**	1431.84a	1685.60

LSD at 5% S=NS V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 12b. Growing degree days at different phenological stages of four blackgram varieties as influenced by sowing times in 2006-2007

Seed emergence

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	66.77 a	263.03 a	458.97 a	654.73 a	360.88 a
BARIMASH 2	66.77 a	263.03 a	465.23 a	661.07 a	364.02 a
BARIMASH 3	73.33 a	263.03 a	458.97 a	661.07 a	364.10 a
LOCAL VARIETY B-10	66.77 a	269.77 a	465.23 a	654.73 a	**364.13 a**
S-MEAN	68.41	264.72	462.10	**657.90**	363.28

LSD at 5% S= 8.15 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	518.30 a	718.43 ab	938.33 a	1087.10 ab	**815.54**
BARIMASH 2	484.63 b	692.57 c	925.20 ab	1099.30 a	800.43
BARIMASH 3	478.07 b	705.50 bc	905.33 b	1068.93 b	789.46
LOCAL VARIETY B-10	478.37 b	738.87 a	905.40 b	1074.90 b	799.38
S-MEAN	489.84	713.84	918.57	**1082.56**	801.20

LSD at 5% S= 19.97 V=11.47

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Flower initiation

Sowing time (S)					
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	718.43 b	865.53 b	1105.60 b	1266.47 b	989.01 b
BARIMASH 2	705.50 b	878.70 b	1112.13 b	1266.47 b	990.70 b
BARIMASH 3	692.87 b	872.23 b	1074.90 b	1286.73 b	981.68 b
LOCAL VARIETY B-10	1038.90 a	1299.80 a	1516.37 a	1504.10 a	**1339.79 a**
S-MEAN	788.93	979.07	1202.25	**1330.94**	1075.30

LSD at 5% S= 61.00 V=51.59

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

(Table 12b. continued)

Pod initiation

Sowing time (S)

Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	905.33 b	1105.83 b	1273.67 b	1472.30 b	1189.28
BARIMASH 2	898.73 b	1112.13 b	1280.23 b	1478.63 b	1192.43
BARIMASH 3	911.93 b	1086.70 b	1273.03 b	1478.63 b	1187.58
LOCAL VARIETY B-10	1331.77 a	1534.37 a	1562.43 a	1792.93 a	**1555.38**
S-MEAN	1011.94	1209.76	1347.34	**1555.63**	1281.17

LSD at 5% S= 19.23 V=14.16

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Pod filling

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	1296.67a	1368.40a	1342.97a	1355.53a	1428.88
BARIMASH 2	1314.70a	1455.03a	1444.90a	1438.23a	1413.22
BARIMASH 3	1405.97a	1529.40a	1488.07a	1499.63a	1340.89
LOCAL VARIETY B-10	1466.27a	1331.20a	1591.70a	1326.33a	**1480.77**
S-MEAN	1370.90a	1421.01a	**1466.91a**	1404.93a	1415.95

LSD at 5% S= NS V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Physiological maturity

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASH 1	1583.03 a	1685.70 a	1834.60 a	1272.73 b	1594.02
BARIMASH 2	1562.43 a	1669.47 a	1809.43 a	1277.47 b	1438.98
BARIMASH3	1534.37 a	1691.20 a	1728.20 a	1508.40 a	1579.70
LOCAL VARIETY B-10	1718.10 a	1257.97 b	1352.03 b	1427.83 ab	**1615.54**
S-MEAN	1599.48	1576.08	**1681.07**	1371.61	1557.06

LSD at 5% S= 119.28 V=102.76

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Helio-thermal unit (HTU)

The helio-thermal unit from sowing to physiological maturity of four blackgram varieties are given in Tables 13a and 13b for the 1st and 2nd year respetively. Helio-thermal unit (HTU) at most of the phenological stages were highest when the crops were sown on S_4 (31 August) followed by the order of $S_4>S_3> S_2>S_1$ in both the years but at physiological maturity stage it was in the order of $S_3>S_4>S_2>S_1$ in both the years. In S_4, the highest HTU was 2968.63 for seed emergence, 5331.22 for leaflet initiation, 6294.23 for flower initiation, 7516.07 for pod initiation, 7560.67 for pod filling stage in the 1st year and the corresponding values were 2769.60, 5033.85, 5977.72, 7481.58 and 7619.0 in the 2nd year, whereas in 8286.3 and 8681.4 for physiological maturity stage for S_3 in both the years respectively. Among the varieties, LOCAL VARIETY B-10 had the highest HTU for all the sowings at all the phenological stages execpt BARIMASH-1 showed the better Performance at leaflet initiation and BARIMASH-3 at physiological maturity stages in both the years.

The lowest HTU was observed in BARIMASH-3 for leaflet initiation, flower initiation and pod filling in both the years whereas BARIMASH-1 was found in seed emergence and BARIMASH-2 had the lowest in physiological maturity in both the years .

Significant sowing time effect was observed in all the phenological stages in both the years. Varietal effect was significant at all the phenological stages in both the years except leaflet initiation in the 1st year and seed emergence and physilogical maturity in the 2nd year. It was also found that sowing time and variety interaction (S×V) was significant at most of the phenological stages except flower initiation, pod initiation and pod filling stages in the 1st year and seed emergence, flower initiation, pod initiation and pod filling stages in the 2nd year.

Table 13a. Helio-thermal unit at different phenological stages of four blackgram varieties as influenced by sowing times in 2005-2006.

Seed emergence

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	440.10 b	716.60 b	1659.60 b	2964.30 a	1445.15
BARIMASH 2	477.77 a	716.60 b	1691.80 a	2972.97 a	1464.78
BARIMASH 3	496.60 a	759.73 a	1670.33 ab	2972.97 a	1469.38
LOCAL VARIETY B-10	440.10 b	781.30 a	1691.80 a	2964.30 a	**1474.91**
S-MEAN	463.64	743.56	1678.38	**2968.63**	1463.55

LSD at 5% S=9.17 V=11.42

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	1732.93 a	3054.03 b	4346.20 ab	5338.87 a	**3619.03**
BARIMASH 2	1670.33 a	3015.67 b	4414.30 a	5375.83 a	3618.01
BARIMASH 3	1659.60 a	3079.23 b	4258.27 bc	5285.57 a	3570.67
LOCAL VARIETY B-10	1652.80 a	3204.73 a	4210.00 c	5324.60 a	3598.03
S-MEAN	1678.92	3088.42	4307.19	**5331.22**	3601.44

LSD at 5% S=97.73 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Flower initiation

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3054.03 b	4009.23 b	5367.40 b	5950.60 b	4609.06 b
BARIMASH 2	3079.23 b	4147.97 b	5427.77 b	5950.60 b	4651.39 b
BARIMASH 3	3036.53 b	4079.23 b	5338.87 b	5981.60 b	4595.32 b
LOCAL VARIETY B-10	4991.97 a	5997.10 a	7394.77 a	7294.13 a	**6419.49 a**
S-MEAN	3540.44	4558.38	5882.20	**6294.23**	5068.81

LSD at 5% S=376.26 V=316.10

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

(Table 13a. continued)

Pod initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	4170.33 b	5361.57 b	5950.60 b	7115.23 b	5649.43
BARIMASH 2	4170.33 b	5427.77 b	5966.10 b	7164.40 b	5682.15
BARIMASH 3	4258.27 b	5367.40 b	5966.10 b	7164.40 b	5689.04
LOCAL VARIETY B-10	6075.70 a	7394.77 a	7406.60 a	8620.23 a	**7374.33**
S-MEAN	4668.66	5887.88	6322.35	**7516.07**	6098.74

LSD at 5% S=44.92 V=54.53

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Pod filling

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	5375.83 b	5950.60 b	7237.47 b	7424.90 b	6497.20 b
BARIMASH 2	5299.83 b	5981.60 b	7142.07 b	7406.60 b	6467.23 b
BARIMASH 3	5347.30 b	5950.60 b	7164.40 b	7406.60 b	6457.53 b
LOCAL VARIETY B-10	6885.33 a	7604.93 a	8089.90 a	8004.57 a	**7646.18 a**
S-MEAN	5727.08	6371.93	7408.46	**7560.67**	6767.03

LSD at 5% S=324.58 V=251.51

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Physiological maturity

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	7406.6 a	7862.0 a	8763.5 a	6808.0 b	7710.0
BARIMASH 2	7406.6 a	1629.7 b	8651.6 a	6933.2 b	6155.3
BARIMASH 3	7391.1 a	7966.8 a	8270.1 a	9686.8 a	**8328.7**
LOCAL VARIETY B-10	8163.3 a	6722.5 a	7460.0 a	8035.5 b	7595.3
S-MEAN	7591.9	6045.2	**8286.3**	7865.9	7447.3

LSD at 5% S=978.96 V=771.50

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 13b. Helio-thermal unit at different phenological stages of four blakgram varieties as influenced by sowing times in 2006-2007.

Seed emergence

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	457.77 a	696.70 a	1611.67 a	2769.60 a	1383.93 a
BARIMASH 2	457.77 a	696.70 a	1621.73 a	2769.60 a	1386.45 a
BARIMASH 3	476.83 a	696.70 a	1611.67 a	2769.60 a	1388.70 a
LOCAL VARIETY B-10	457.77 a	717.00 a	1621.73 a	2769.60 a	**1391.53 a**
S-MEAN	462.53	701.78	1616.70	**2769.60**	1387.65

LSD at 5% S= 21.67 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	1935.63 a	2934.60 ab	4420.60 a	5042.03 a	**3583.22**
BARIMASH 2	1712.67 b	2891.60 b	4375.40 a	5074.77 a	3513.61
BARIMASH 3	1672.23 b	2913.10 ab	4191.33 b	5009.30 a	3446.49
LOCAL VARIETY B-10	1702.60 b	3033.63 a	4198.90 b	5009.30 a	3486.11
S-MEAN	1755.78	2943.23	4296.56	**5033.85**	3507.36

LSD at 5% S= 98.72 V=62.92

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Flower initiation

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	2934.60 b	3955.77 b	5107.50 b	5579.37 b	4394.31 b
BARIMASH 2	2913.10 b	3977.73 b	5160.83 b	5579.37 b	4407.76 b
BARIMASH 3	2858.10 b	3977.73 b	5009.30 b	5635.83 b	4370.24 b
LOCAL VARIETY B-10	4718.10 a	5669.60 a	7125.73 a	7116.33 a	**6157.44 a**
S-MEAN	3355.98	4395.21	5600.84	**5977.72**	4832.44

LSD at 5% S= 319.09 V=275.92

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

(Table 13b. continued)

Pod initiation

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	4191.33 b	5128.10 a	5602.07 b	6994.43 b	5466.87 b
BARIMASH 2	4132.50 b	5160.83 a	5610.43 b	7020.27 b	5481.01 b
BARIMASH 3	4250.17 b	5009.30 a	5587.73 b	7020.27 b	5478.98 b
LOCAL VARIETY B-10	5911.27 a	5272.47 a	7263.60 a	8891.33 a	**6834.67 a**
S-MEAN	4621.32	5142.67	6015.96	**7481.58**	5815.38

LSD at 5% S= 835.28 V=675.94

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Pod filling

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	5128.1 b	5602.1 b	7083.6 b	7458.6 a	6318.1 b
BARIMASH 2	5009.3 b	5610.4 b	7020.3 b	7400.5 a	6260.1 b
BARIMASH 3	5042.0 b	5548.3 b	7020.3 b	7314.4 a	6231.2 b
LOCAL VARIETY B-10	6786.4 a	7723.8 a	8216.3 a	8302.4 a	**7757.2 a**
S-MEAN	5491.5	6121.2	7335.1	**7619.0**	6641.7

LSD at 5% S=557.70 V=487.96

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Physiological maturity

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH I	7290.7 a	8078.0 a	9276.1 a	7325.9 a	7992.7
BARIMASH 2	7263.6 a	7952.1 a	9083.0 ab	7373.5 a	7918.0
BARIMASH 3	7158.4 a	8097.3 a	8376.7 ab	8353.1 a	**8010.4**
LOCAL VARIETY B-10	8314.9 a	7198.3 a	7989.7 b	8538.6 a	7996.4
S-MEAN	7506.9	7831.4	**8681.4**	7897.8	7979.4

LSD at 5% S= 605.38 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Phenothermal index (PTI)

Phrnothermal index (PTI) of four blackgram varieties at different phenological stages as affected by sowing times are presented in Tables 14a and 14b for the 1st and 2nd year respectively. The phenothermal indices at different phenological stages were in the order of $S_4>S_3>S_2>S_1$ in both the years except physiological maturity where the order was $S_3>S_4>S_2>S_1$ in both the years. The highest PTI for S_4 was 203.97 for seed emergence, 44.88 for leaflet initiation, 36.08 for flower inition, 31.38 for pod initiation,28.58 for pod filling in the 1st year and the corresponding values were 191.50, 42.08, 34.97, 46.10, 28.03 in the 2nd year whereas 29.10a and 22.53 for physiological maturity of S_3 in both the years respectively.

It was observed that phenothermal indices was slightly higher at the initial stages of growth (seed emergence) and then decreased with the advancement of plant age because at the initial stage, growth duration was lower and then increased with plant age although GDD increased with plant age. As a result, the value of PTI for diffferent phenological stages were nearly constant irrespective of sowing dates. It was also observed that PTI values of all the sowings were very close to one developmental phase to another developmental phase i.e., the results of PTI did not so differ between the developmental phases during the whole growth period. Among the varieties, BARIMASH-3 attained the highest PTI at leaflet initiation, pod filling and physiological maturity stages and the lowest PTI was observed in LOCAL VARIETY B-10 at most of the phenological stages in both the years. The highest PTI, were also found in BARIMASH-1 at seed emergence, flower initiation and pod initiation stages in both the years.

Significant sowing time and varietal effects were observed in all the phenological stages in both the years except pod filling and physiological maturity in the 1st year. Sowing time and varietal interaction (S×V) was significant at all the phenological stages except pod filling and physiological maturity in the 1st year and seed emergence in the 2nd year.

Heat use efficiency (HUE)

Heat use efficiency (HUE) of four blackgram varieties as influenced by different sowing times are presented in Tables 15a and 15b for 2005-2006 and 2006-2007 respectively. The S_3 plants of all the varieties used heat more efficiently than other sowings and the order was $S_3>S_2>S_4>S_1$ in both the years. The highest HUE was observed in LOCAL VARIETY B-10 which was followed by BARIMASH-2 in both the years. The lowest HUE was found in BARIMASH-3 in both the years. There were significant effects for sowing time and variety in both the years. Sowing time and varietal interaction (S×V) was always significant in both the years.

Table 14a. Phenothermal index of four blackgram varieties at different phenological stages as affected by sowing times in 2005-2006.

Seed emergence

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	20.40 a	84.70 a	150.90 a	220.70 a	**119.18**
BARIMASH 2	20.27 a	84.70 a	118.10 b	187.23 b	102.58
BARIMASH 3	20.20 a	74.03 a	139.97 a	187.23 b	105.36
LOCAL VARIETY B-10	20.40 a	68.70 a	118.10 b	220.70 a	106.98
S-MEAN	20.32	78.03	131.77	**203.97**	108.52

LSD at 5% S=6.92 V=10.34

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	19.70 a	28.20 a	35.40 ab	44.47 b	31.94
BARIMASH 2	19.70 a	28.30 a	35.20 b	43.50 c	31.68
BARIMASH 3	19.70 a	28.10 ab	35.83 a	45.17 a	**32.20**
LOCAL VARIETY B-10	19.70 a	27.60 b	35.80 a	44.80 ab	31.97
S-MEAN	19.70	28.05	35.56	**44.48**	31.95

LSD at 5% S=0.40 V=0.28

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Flower initiation

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	20.10 a	26.13 a	31.30 ab	37.70 a	**28.81**
BARIMASH 2	20.10 a	25.93 a	30.90 b	37.50 a	28.61
BARIMASH 3	20.10 a	26.00 a	31.57 a	36.90 b	28.64
LOCAL VARIETY B-10	19.97 a	23.27 b	26.60 c	32.20 c	25.51
S-MEAN	20.07	25.33	30.09	**36.08**	27.89

LSD at 5% S= 0.26 V=0.21

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

(Table 14a. continued)

Pod initiation

	Sowing time (S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	19.90 a	24.33 a	29.13 a	32.80 a	**26.54**
BARIMASH 2	19.90 a	24.17 a	28.70 b	32.60 a	26.34
BARIMASH 3	19.90 a	24.30 a	28.80 b	32.60 a	26.40
LOCAL VARIETY B-10	19.63 a	22.30 b	25.93 c	27.50 b	23.84
S-MEAN	19.83	23.78	28.14	**31.38**	25.78

LSD at 5% S= 0.32 V=0.15

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Pod filling

Sowing time (S)

	Sowing time (S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	19.90 a	23.57 a	26.53 a	30.00 a	25.00 a
BARIMASH 2	19.90 a	23.37 a	26.60 a	30.00 a	24.97 a
BARIMASH 3	19.90 a	23.57 a	26.63 a	30.33 a	**25.11 a**
LOCAL VARIETY B-10	19.50 a	21.50 a	24.37 a	23.97 b	22.33 b
S-MEAN	19.80	23.00	26.03	**28.58**	24.35

LSD at 5% S=1.36 V=1.19

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Physiological maturity

	Sowing time (S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	19.27a	21.40a	24.43a	17.47a	22.99
BARIMASH 2	19.37a	21.40a	24.57a	17.43a	20.69
BARIMASH 3	19.43a	21.37a	24.23a	29.07a	**23.53**
LOCAL VARIETY B-10	18.83b	13.60b	42.80a	16.73b	20.64
S-MEAN	19.23a	19.44a	**29.01a**	20.18a	21.96

LSD at 5% S=13.25 V=10.43

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Table 14b. Phenothermal index of four blackgram varieties at different phenological stages as affected by sowing times in 2006-2007.

Seed emergence

	Sowing time (S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	20.07 a	79.97 a	139.90 a	199.70 a	**109.91 a**
BARIMASH 2	20.07 a	79.97 a	128.90 a	183.30 a	103.06 a
BARIMASH 3	20.03 a	79.97 a	139.90 a	183.30 a	105.80 a
LOCAL VARIETY B-10	20.07 a	74.53 a	128.90 a	199.70 a	105.80 a
S-MEAN	20.06	78.61	134.40	**191.50**	106.14

LSD at 5% S=13.59 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Leaflet initiation

	Sowing time(S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	19.70 a	26.97 a	33.90 b	41.83 bc	30.60
BARIMASH 2	19.60 a	27.30 a	34.30 ab	41.20 c	30.60
BARIMASH 3	19.60 a	27.13 a	34.83 a	42.80 a	**31.09**
LOCAL VARIETY B-10	19.63 a	26.73 a	34.80 a	42.47 ab	30.91
S-MEAN	19.63	27.03	34.46	**42.08**	30.80

LSD at 5% S= 0.42 V=0.39

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Flower initiation

	Sowing time(S)				
Variety (V)	S$_1$	S$_2$	S$_3$	S$_4$	V-MEAN
BARIMASH 1	19.60 a	25.43 a	29.90 b	36.17 a	**27.78**
BARIMASH 2	19.60 a	25.33 a	29.80 b	36.17 a	27.73
BARIMASH 3	19.60 a	25.40 a	30.40 a	35.73 b	27.78
LOCAL VARIETY B-10	19.50 a	22.93 b	26.17 c	31.80 c	25.10
S-MEAN	19.58	24.78	29.07	**34.97**	27.10

LSD at 5% S=0.20 V=0.19

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

(Table 14b. continued)

Pod initiation

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	19.70 a	23.50 a	28.13 a	32.23 b	**40.96**
BARIMASH 2	19.70 a	23.47 a	28.07 a	92.60 a	25.89
BARIMASH 3	19.70 a	23.60 a	28.10 a	32.13 b	25.88
LOCAL VARIETY B-10	19.50 a	22.23 a	25.77 b	27.43 c	23.73
S-MEAN	19.65	23.20	27.52	**46.10**	29.12

LSD at 5% S= 1.19 V=0.97

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Pod filling

	Sowing time (S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	19.40 a	23.00 a	26.30 a	29.83 a	24.63
BARIMASH 2	19.43 a	23.00 a	26.40 a	29.93 a	24.69
BARIMASH 3	19.40 a	23.07 a	26.40 a	30.17 a	**24.76**
LOCAL VARIETY B-10	19.50 a	21.67 a	24.53 a	22.17 b	21.97
S-MEAN	19.43	22.68	25.91	**28.03**	24.01

LSD at 5% S= 1.76 V=1.48

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Physiological maturity

	Sowing time(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	19.33 a	21.50 a	24.93 a	18.00 b	20.94
BARIMASH 2	19.40 a	21.57 a	25.17 a	17.97 b	21.03
BARIMASH 3	19.40 a	21.50 a	24.33 a	22.53 a	**21.94**
LOCAL VARIETY B-10	19.03 a	14.00 b	15.67 b	17.33 b	16.51
S-MEAN	19.29	19.64	**22.53**	18.96	20.10

LSD at 5% S= 1.65 V=1.51

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT

Table 15a. Heat use efficiency of four blackgram varieties as influenced by different sowing times in 2005-2006.

Heat use efficiency

	Sowing time (s)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	0.56 a	0.67 b	0.56 b	0.60 b	0.60
BARIMASH 2	0.53 a	0.69 b	0.63 b	0.63 b	0.62
BARIMASH 3	0.48 a	0.58 b	0.56 b	0.60 b	0.56
LOCAL VARIETY B-10	0.51 a	1.02 a	1.40 a	0.96 a	**0.97**
S-MEAN	0.52	0.74	**0.79**	0.70	0.69

LSD at 5% S=0.09 V=0.08

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 15b. Heat use efficiency of four blackgram varieties as influenced by different sowing times in 2006-2007

Heat use efficiency

	Sowing time (s)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	0.58 a	0.69 b	0.58 b	0.63 b	0.62
BARIMASH 2	0.56 a	0.72 b	0.67 b	0.67 b	0.65
BARIMASH 3	0.51 a	0.61 b	0.60 b	0.63 b	0.59
LOCAL VARIETY B-10	0.55 a	1.09 a	1.49 a	**1.03 a**	1.04
S-MEAN	0.55	0.78	**0.83**	0.74	0.72

LSD at 5% S=0.09 V=0.08

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Chlorophyll contents

Mean values of chlorophyll a, b, total chlorophyll and chlorophyll a:b ratio of matured green leaf as influenced by sowing times are presented in Tables 16a and 16b for 2005-2006 and 2006-2007. It was observed that the S_1 plants contained more chlorophyll a, chlorophyll b, and total chlorophyll of matured green leaves than the other sowings in all the varieties in both the years. On the other hand chlorophyll a:b ratio was observed highest for S_4 and lowest in S_1 than other sowings in all the varieties in both the years. Among the varieties BARI MASH-1 produced the highest chlorophyll a, chlorophyll b and total chlorophyll in both the years. But LOCAL VARIETY B-10 produced the highest and BARIMASH-1 produced the lowest chlorophyll a:b ratio in both the years in all the varieties.

Mean squares from the analysis of variance of chlorophyll contents indicated that sowing time was always significant for chlorophyll a chlorophyll b, total chlorophyll and chlorophyll a:b ratio in both the years except chlrophyll a where the sowing time was non significance in the 1st year. Varietal effect was non significant for chlorophyll a, total chlorophyll and chlorophyll a:b ratio in both the years. But significant varietal effect was observed for chlorophyll b in both the years. It was also observed that sowing time and variety interaction (S×V) was always non significant for chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a:b ratio in both the years.

Table 16a. Chlorophyll contents of four blackgram varieties as influenced by different sowing times in 2005-2006.

Chlorophyll a (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	3.34 a	2.57 a	3.03 a	1.90 a	2.71 a
BARIMASM-2	2.70 a	2.83 a	2.43 a	2.37 a	2.58 a
BARIMASM-3	2.20 a	2.60 a	1.93 a	1.73 a	2.12 a
LOCAL VARIETY B-10	2.80 a	2.00 a	2.37 a	1.50 a	2.16 a
S-MEAN	**2.76**	2.50	2.44	1.89	2.39

LSD at 5% S = NS V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Chlorophyll b (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	1.67 a	1.17 a	1.37 a	0.80 a	**1.25 a**
BARIMASM-2	1.40 a	1.17a	0.77 a	0.73 a	1.02 ab
BARIMASM-3	1.17 a	1.00 a	0.87 a	0.60 a	0.90 b
LOCAL VARIETY B-10	1.20 a	0.60 a	0.90 a	0.37 a	0.77 b
S-MEAN	**1.36**	0.98	0.97	0.62	0.98

LSD at 5% S = 0.30 V = 0.31

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Total Chlorophyll (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	5.03 a	3.73 a	4.40 a	2.73 a	**3.97 a**
BARIMASM-2	4.13 a	3.97 a	3.17 a	3.10 a	3.59 ab
BARIMASM-3	3.37 a	3.63 a	2.80 a	2.37 a	3.04 b
LOCAL VARIETY B-10	4.03 a	2.57 a	3.27 a	1.87 a	2.93 b
S-MEAN	**4.14**	3.47	3.40	2.52	3.38

LSD at 5% S = 0.82 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Chlorophyll a:b ratio

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	2.20 a	2.29 a	2.17 a	2.43 b	2.27 b
BARIMASM-2	1.93 a	2.60 a	3.40 a	3.40 ab	2.83 ab
BARIMASM-3	1.90 a	2.87 a	2.40 a	2.97 ab	2.53 ab
LOCAL VARIETY B-10	2.33 a	3.50 a	2.73 a	4.17 a	**3.18 a**
S-MEAN	2.09	2.80	2.67	**3.24**	2.70

LSD at 5% S = 0.68 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 16b. Chlorophyll contents of four blackgram varieties as influenced by different sowing times in 2006-2007.

Chlorophyll a (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	3.30 a	2.67 a	3.10 a	2.00 a	**2.77 a**
BARIMASM-2	2.80 a	2.87 a	2.47 a	2.40 a	2.63 a
BARIMASM-3	2.03 a	2.67 a	1.97 a	1.77 a	2.10 a
LOCAL VARIETY B-10	2.87 a	2.01	2.43 a	1.53	2.20 a
S-MEAN	**2.75**	2.55	2.49	1.92	2.43

LSD at 5% S = 0.51 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Chlorophyll b (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	1.77 a	1.10 a	1.37 a	0.77 a	**1.25 a**
BARIMASM-2	1.47 a	1.17 a	0.77 a	0.73 a	1.03 ab
BARIMASM-3	1.20 a	1.03 a	0.77 a	0.60 a	0.90 ab
LOCAL VARIETY B-10	1.20 a	0.63 a	0.90 a	0.37 a	0.77 b
S-MEAN	**1.40**	0.98	0.95	0.62	0.99

LSD at 5% S = 0.32 V = 0.34

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Total Chlorophyll (mg dm^{-2})

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	5.03a	3.77a	4.43a	2.79a	**4.00a**
BARIMASM-2	4.23a	4.03a	3.27a	3.13a	3.67ab
BARIMASM-3	3.27a	3.70a	2.60a	2.39a	2.98b
LOCAL VARIETY B-10	4.10a	2.60	3.34a	1.87a	2.97b
S-MEAN	**4.16**	3.52	3.40	2.53	3.41

LSD at 5% S = 0.81 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Chlorophyll a:b ratio

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	2.03a	2.41a	2.33a	2.61a	2.34a
BARIMASM-2	2.01a	2.63a	3.17a	3.37a	2.79a
BARIMASM-3	1.7a	2.97a	3.67a	3.07a	2.87a
LOCAL VARIETY B-10	2.41a	3.27a	2.73a	4.23a	**3.16a**
S-MEAN	2.06	2.82	2.97	**3.32**	2.79

LSD at 5% S = 0.69 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Relative Leaf Water Content (RLWC)

Effect of sowing time on relative leaf water content (RLWC) of matured green leaf of four blackgram varieties at different times of a day are presented in Tables 17a and 17b. The S_1 plants had always higher RLWC than other sowings of all the varieties at 8.00 a.m. while it showed higher in S_3 plants at 12.00 noon and 4.00 p.m. in both the years. It was observed that all the varieties of every sowing, the higher RLWC was at the morning (8.00 a.m.) and got reduced at 12.00 noon whereas it increased gradually at the later part of the day (4.00 p.m.) in both the years. The highest RLWC was observed in BARIMASH-3 followed by LOCAL VARIETY B-10 at the morning (8.00 a.m.) and lowest in BARIMASH-2 for most of the cases (8.00 a.m. and 4.00 p.m) in both the years, whereas LOCAL VARIETY B-10 showed the higher performance at 12.00 noon in both the years.

Mean squares from the analysis of variance of RLWC indicated that sowing time effect was always significant at all the times in both the years. Varietal effect was significant at 4.00 p.m. in both the years, whereas it was non significant at 8.00 a.m. and 12.00 noon in both the years. It was also observed that sowing time and variety (S×V) interaction was significant at 4.00 p.m. in the 1st year and non significant at other times in both the years.

Table 17a. Relative leaf water content of four blackgram varieties as influenced by different sowing times of the day in 2005-2006.

Relative leaf water content (RLWC) at 8.00 a.m.

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	91.3 a	88.7 a	86.7 a	91.4 a	89.5 b
BARIMASM-2	90.2 a	87.6 a	88.4 a	87.6 a	88.4 a
BARIMASM-3	93.9 a	89.8 a	89.4 a	87.4 a	**90.1 a**
LOCAL VARIETY B- 10	92.8 a	89.6 a	90.9 a	86.7 a	90.0 a
S-mean	**92.0**	88.9	88.8	88.3	89.5

LSD at 5% S = 2.0 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Relative leaf water content (RLWC) at 12.00 noon

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	79.2 a	74.9 a	81.1 a	79.8 a	78.8 b
BARIMASM-2	82.7 a	76.4 a	80.7 a	79.7 a	79.9 ab
BARIMASM-3	83.7 a	75.0 a	80.7 a	81.9 a	80.3 ab
LOCAL VARIETY B-10	82.0 a	76.5 a	85.7 a	86.5 a	**82.7 a**
S-mean	81.9	75.7	**82.0**	81.9	80.4

LSD at 5% S = 3.4 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Relative leaf water content (RLWC) at 4.00 p.m.

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	85.7 a	88.9 a	90.6 a	87.9 ab	**88.3**
BARIMASM-2	79.7 a	81.5 b	90.9 a	85.7b	84.4
BARIMASM-3	82.2 a	68.2 c	95.7 a	92.3 a	84.6
LOCAL VARIETY B-10	79.5 a	90.7 a	92.2 a	82.2 b	86.2
S-mean	81.8	82.3	**92.3**	87.0	85.9

LSD at 5% S = 5.4 V = 3.0

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 17b. Relative leaf water content of four blackgram varieties as influenced by different sowing times of the day in 2006-2007.

Relative leaf water content (RLWC) at 8.00a.m.

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	91.4 a	88.7 a	86.9 a	91.5 a	89.6 a
BARIMASM-2	90.1 a	87.6 a	88.3 a	87.5 a	88.4 a
BARIMASM-3	93.6 a	89.8 a	89.0 a	87.0 a	**89.9 a**
LOCAL VARIETY B-10	92.6 a	89.6 a	90.7 a	86.5 a	89.8 a
S-mean	**91.9**	88.9	88.7	88.1	89.4

LSD at 5% S = 2.0 V = NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Relative leaf water content (RLWC) at 12.00 Noon

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	79.3 a	75.1 a	81.3 a	79.9 a	78.9 b
BARIMASM-2	82.6 a	76.2 a	80.6 a	79.6 a	79.8 ab
BARIMASM-3	83.3 a	74.7 a	80.4 a	81.6 a	80.0 ab
LOCAL VARIETY B-10	81.8 a	76.2 a	85.4 a	86.2 a	**82.4 a**
S-mean	81.8	75.6	**81.9**	81.8	80.3

LSD at 5% S = 3.4 V =NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Relative leaf water content (RLWC) at 4.00 p.m.

	Sowing time (S)				
Variety (V)	**S_1**	**S_2**	**S_3**	**S_4**	**V-MEAN**
BARIMASM-1	85.9 a	86.7 a	90.8 a	88.1 ab	87.9 ab
BARIMASM-2	79.7 a	85.6 a	90.8 a	85.6 ab	85.4 b
BARIMASM-3	81.9 a	91.5 a	95.4 a	91.9 a	**90.1 a**
LOCAL VARIETY B-10	79.3 a	90.5 a	91.9 a	82.0 b	85.9 b
S-mean	81.7	88.6	**92.2**	86.9	87.4

LSD at 5% S =1.6 V = 3.2

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Yield and yield components

Mean values of yield and yield components of four blackgram varieties at maturity as influenced by different sowing times are presented in (Tables 18a and 18b) for the 1st and 2nd year respectively. Among the yield and yield components, significant sowing time was observed in plant height(cm), total dry matter (g plant^{-1}), pod number plant^{-1}, pod dry weight (g plant^{-1}), grain number plant^{-1}, grain weight (g plant^{-1}), grain yield (kg ha^{-1}) and harvest index (%) in both the years except 100-seed weight (g) in the 1st year. Significant varietal effect was observed in total dry matter (g plant^{-1}), pod number plant^{-1}, pod dry weight (g plant^{-1}), grain number plant^{-1}, grain weight (g plant^{-1}), grain yield (kg ha^{-1}) and harvest index (%) in both the years. But plant height (cm) and 100-seed weight (g) were observed non significant for both the years. It was also observed that sowing time and varietal interaction (S×V) was significant for total dry matter (g plant^{-1}), pod number plant^{-1}, grain weight (g plant^{-1}), grain yield (kg ha^{-1}) and harvest index (%) in both the years whereas significant grain number plant^{-1} in the 1st year and pod dry weight (g plant^{-1}) in the 2nd year. On the other hand, plant height (cm), pod dry weight plant^{-1} and100-seed weight (g) were non-significant in the 1st year and plant height (cm), grain number plant^{-1} and 100-seed weight (g) were non-significant in the 2nd year among the yield and yield components.

Plant height (cm)

The S_4 plants of all the varieties produced taller plants than the other sowings for both the years whereas the lowest value for plant height was recorded under S_1 sowing. Among the varieties, BARIMASH-3 had the tallest plant followed by BARIMASH-2 and the shortest in BARIMASH-1 for both the years (Tables 18.1a and 18.1b).

Total dry matter (g plant^{-1})

Total dry matter (g plant^{-1}) was highest for S_2 plants than other sowings for both the years whereas the lowest value was recorded under S_1 sowing. The highest total dry matter was found in LOCAL VARIETY B-10 in both the years and the lowest in BARIMASH-1 both the years (Tables 18.2a and 18.2b).

Pod number plant^{-1}

Pod number plant^{-1} was highest for S_3 plants than other sowings and the lowest in S_4 in both the years. Among the varieties, maximum pod number was observed in LOCAL VARIETY B-10 in both the years. The minimum pod numbers was found in BARIMASH-1 in the 1st year and BARIMASH-3 in the 2nd year (Tables 18.3a and 18.3b).

Pod dry weight (g plant^{-1})

Pod dry weight (g plant^{-1}) was highest for S_3 than other sowings and the lowest in S_1 in both the years for all the varieties. LOCAL VARIETY B-10 had the highest pod dry weight (g plant^{-1}) for both the years and the lowest in BARIMASH-1 in the 1st year and BARIMASH-3 in the 2nd year (Tables 18.4a and 18.4b).

Grain number plant^{-1}

Grain number plant^{-1} was highest for S_3 than other sowings in both the years and the lowest in S_4 in the 1st year and S_1 in the 2nd year of all the varieties. LOCAL VARIETY B-10 had the highest grain number in both the years than the other varieties. The lowest grain number plant^{-1} was found in BARIMASH-3 for both the years (Tables 18.5a and 18.5b).

Grain weight (g plant^{-1})

Grain weight (g plant^{-1}) was highest for S_3 than other sowings and the lowest in S_1 in both the years. Among the varieties, highest grain weight was observed in LOCAL VARIETY B-10 in both the years and the lowest in BARIMASH-3 in both the years (Tables 18.6a and 18.6b).

Table 18a. Mean values of yield and yield components of four blackgram varieties as influenced by different sowing times in 2005-2006

Table 18.1a. Effect of sowing times on plant height (cm) of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	33.8a	42.3a	42.3a	43.8a	40.5a
BARIMASH 2	36.5a	47.0a	47.7a	48.0a	44.8a
BARIMASH 3	36.6a	54.4a	58.4a	56.7a	**51.5a**
LOCAL VARIETY B-10	37.4a	43.7a	43.8a	45.1a	42.5a
S-MEAN	36.1	46.9	48.1	**48.4**	44.8

LSD at 5% level S=3.4 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.2a. Effect of sowing times on total dry matter (g plant^{-1}) of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	8.33 b	7.65 b	8.88 b	6.040 c	7.73
BARIMASH 2	7.41 bc	8.76 b	9.42 b	6.78 c	8.10
BARIMASH 3	6.15 c	7.72 b	7.83 b	9.40 b	7.78
LOCAL VARIETY B-10	11.83 a	17.05 a	13.98 a	12.69 a	**13.89**
S-MEAN	8.43	**10.30**	10.03	8.73	9.37

LSD at 5% level, S= 1.35 V= 0.93

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.3a. Effect of sowing times on pod number (g plant^{-1}) of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	24.0 ab	17.9b	24.0 b	14.0 c	19.9
BARIMASH 2	21.7 bc	19.0 b	25.0 b	14.5 c	20.1
BARIMASH 3	18.6 c	18.5 b	22.0 b	21.1 b	20.1
LOCAL VARIETY B-10	27.3 a	38.4 a	33.8 a	29.6 a	**32.3**
S-MEAN	22.0	23.4	**26.2**	19.8	23.1

LSD at 5% level, S= 3.0 V= 2.5

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18b. Mean values of yield and yield components of four blackgram varieties as influenced by different sowing time in 2006-2007

Table 18.1b: Effect of sowing times on plant height (cm) of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	39.2 a	52.0 a	52.6 a	52.8 a	47.2 a
BARIMASH 2	38.9 a	57.2 a	54.1 a	56.7 a	51.7 a
BARIMASH 3	38.8 a	51.6 a	61.7 a	58.6 **a**	**52.7 a**
LOCAL VARIETY B-10	40.6 a	51.2 a	46.2 a	50.6 a	49.1 a
S-MEAN	39.4	53.0	53.6	**54.6**	50.2

LSD at 5% S=4.6 V= NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.2b. Effect of sowing times on total dry matter (g plant^{-1}) of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	8.64 b	7.94b	9.25 b	6.29 c	8.03
BARIMASH 2	7.84 bc	9.27 b	9.92 b	7.16 c	8.55
BARIMASH 3	6.44 c	8.11 b	8.23 b	9.87 b	8.16
LOCAL VARIETY B-10	12.59 a	18.16 a	14.88 a	13.50 a	**14.78**
S-MEAN	8.88	**10.87**	10.57	9.20	9.88

LSD at 5% S=1.44 V=0.98

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.3b. Effect of sowing times on pod number plant^{-1} of four blackgram varieties in 2006-2007

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	23.8 a	26.8 a	27.5 a	25.1 a	25.1 a
BARIMASH 2	19.2 a	27.6 a	24.1 a	24.9 a	23.9 a
BARIMASH 3	21.5 a	23.6 a	25.3 a	23.6 a	23.5 a
LOCAL VARIETY B-10	25.2 a	24.9 a	26.8 a	23.3 a	**25.8 a**
S-MEAN	24.8	25.7	**25.9**	24.2	24.6

LSD at 5% S=4.1 V=2.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.4a. Effect of sowing times on pod dry weight (g plant^{-1}) of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3.4a	3.9a	4.2a	3.6a	3.8b
BARIMASH 2	3.7a	4.0a	4.0a	3.9a	3.9ab
BARIMASH 3	4.3a	4.5a	4.9a	4.9a	4.7ab
LOCAL VARIETY B-10	4.9a	4.7a	5.4a	4.3a	**4.8a**
S-MEAN	4.1	4.3	**4.6**	4.2	4.3

LSD at 5% level, S= 0.8 V= 0.9

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.5a. Effect of sowing times on grain number plant^{-1} of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	111.2 b	98.2 b	133.2 b	80.1 b	105.7
BARIMASH 2	102.8 b	107.9 b	127.8 b	73.0 b	102.9
BARIMASH 3	96.3b	97.0 b	116.9 b	93.2b	100.9
LOCAL VARIETY B-10	140.5 a	253.5 a	193.4 a	176.2 a	**190.9**
S-MEAN	112.7	139.1	**142.9**	105.6	125.1

LSD at 5% level, S=18.8 V=14.3

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.6a. Effect of sowing times on grain weight (g plant^{-1}) of four blackgram varieties in 2005-2006

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3.5 a	3.8 b	4.8 a	3.0 b	3.8
BARIMASH 2	3.2 a	4.2 b	4.9 a	3.2 b	3.9
BARIMASH 3	3.0 a	3.8 b	4.0 b	3.5 b	3.6
LOCAL VARIETY B-10	3.5 a	7.0 a	5.5 a	5.4 a	**5.3**
S-MEAN	3.3	4.7	**4.8**	3.8	4.1

LSD at 5% level, S=0.6 V=0.4

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.4b. Effect of sowing times on pod dry weight (g plant^{-1}) of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	5.4 a	5.4 b	7.1 ab	4.3 b	5.6
BARIMASH 2	5.0 a	6.0 b	7.2 ab	4.8 b	5.8
BARIMASH 3	4.4 a	5.5 b	6.0 b	5.5 b	5.4
LOCAL VARIETY B-10	5.6 a	10.3a	8.3 a	8.4 a	**8.2**
S-MEAN	5.1	6.8	**7.2**	5.8	6.2

LSD at 5% S= 0.9 V=0.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.5b. Effect of sowing times on grain number plant^{-1} of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	125.5 a	150.2 a	145.8 a	132.1 a	138.4 a
BARIMASH 2	94.5 a	147.7 a	170.0 a	143.1 a	136.3 a
BARIMASH 3	110.8 a	125.9 a	129.5 a	114.6 a	120.2 a
LOCAL VARIETY B-10	127.0 a	147.3 a	140.2 a	130.6 a	**138.8 a**
S-MEAN	114.4	142.8	**146.4**	130.1	133.4

LSD at 5% S=25.3 V=17.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.6b. Effect of sowing times on grain weight (g plant^{-1}) of four blackgram varieties in 2006-2007

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	4.4 a	4.4 a	4.8 a	4.3 a	4.5a
BARIMASH 2	3.4 a	5.1 a	4.7 a	4.2 a	4.4 a
BARIMASH 3	4.0 a	4.3 a	4.2 a	3.7 a	4.0 a
LOCAL VARIETY B-10	4.7 a	4.8 a	5.0 a	4.4 a	**4.7 a**
S-MEAN	4.1	4.7	**4.6**	4.2	4.4

LSD at 5% S=0.8 V=1.2

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

100-seed weight (g)

S_1 plants had the highest 100-seed weight (g) than other sowings for both the years and the lowest in S_2 in the 1st year and S_3 in the 2nd year. BARIMASH-3 had the highest value of 100-seed weight (g) in the 1st year and for LOCAL VARIETY B-10 in the 2nd year. The lowest 100-seed weight (g) was observed in BARIMASH-1 in both the years (Tables 18.7a and 18.7b).

Grain yield (kg ha^{-1})

The highest grain yield (kg ha^{-1}) was recorded under S_3 plants than other sowings and the lowest value of grain yield was recorded under S_1 sowing in both the years. LOCAL VARIETY B-10 had the highest grain yield (kg ha^{-1}) among the varieties and sowings followed by BARIMASH-2 and the lowest in BARIMASH-3in both the years. In the present investigation, average grain yield were found in 1044.58 kg ha^{-1} in the 1st year and 1100.92 kg ha^{-1} in the 2nd year. Among the varieties, LOCAL VARIETY B-10 had the highest grain yield 1350.70 (kg ha^{-1}) in the 1st year and 1438.56 (kg ha^{-1}) in the 2nd year (Tables 18.8a and 18.8b).

Harvest index (%)

Harvest index (%) was significantly highest in S_3 than other sowings and the lowest in S_1 in both the years. BARIMASH-1 had the highest harvest index (%) among the varieties and sowings and the lowest harvest index (%) was observed in LOCAL VARIETY B-10 in both the years (Tables 18.9a and 18.9b).

Table 18.7a. Effect of sowing times on 100 seed weight (g) of four blackgram varieties in 2005-2006.

Sowing (S)					
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3.6a	3.5a	3.7a	3.6a	3.5a
BARIMASH 2	3.7a	3.4a	3.3a	3.6a	3.6a
BARIMASH 3	3.9a	3.7a	3.8a	3.7a	**3.8a**
LOCAL VARIETY B-10	4.0a	3.5a	3.4a	3.7a	3.7a
S-MEAN	**3.8**	3.5	3.6	3.7	3.6

LSD at 5% level, S=NS V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.8a. Effect of sowing times on grain yield (kg ha^{-1}) of four blackgram varieties in 2005-2006.

Sowing (S)					
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	888.1 a	945.2 b	1220.2 ab	763.2b	954.2
BARIMASH 2	822.5 a	1053.4 b	1224.5 ab	808.6b	977.2
BARIMASH 3	748.6 a	960.2 b	1007.9 b	868.2 b	896.2
LOCAL VARIETY B-10	881.9 a	1760.7 a	1381.2a	1379. 0a	**1350.7**
S-MEAN	835.3	1179.9	**1208.4**	954.7	1044.6

LSD at 5% level, S=156.5 V=105.8

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.9a. Effect of sowing times on harvest index (%) of four blackgram varieties in 2005-2006.

	Sowing (S)				
Variety(V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	40.8 b	47.8 a	52.5a	48.3 a	**47.4**
BARIMASH 2	42.1 b	45.8 a	49.4 a	45.3 a	45.6
BARIMASH 3	46.3a	47.0 a	48.7 a	35.0 c	44.3
LOCAL VARIETY B-10	27.7 c	38.8 b	37.0 b	40.7 b	36.1
S-MEAN	39.2	44.9	**46.9**	42.3	43.3

LSD at 5% level, S= 2.6 V=1.9

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.7b. Effect of sowing times on 100 seed weight (g) of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	3.6 a	3.4 a	3.6 a	3.7 a	3.6 a
BARIMASH 2	3.8 a	3.6 a	3.4 a	3.8 a	3.7 a
BARIMASH 3	3.9a	3.6 a	3.6 a	3.8 a	3.8 a
LOCAL VARIETY B-10	4.1 a	3.9 a	3.8 a	3.8 a	**3.9 a**
S-MEAN	**3.9**	3.6	3.6	3.8	3.70

LSD at 5% S=0.1 V=NS

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.8b. Effect of sowing times on grain yield (kg ha^{-1}) of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	921.8 a	981.8 b	1270.1 ab	794.9 b	992.1
BARIMASH 2	870.8 a	1112.9 b	1289.8 a	854.1 b	1031.9
BARIMASH 3	784.7 a	1008.7 b	1058.7 b	912.4 b	941.1
LOCAL VARIETY B-10	940.1 a	1875.7 a	1470.5 a	1468.0 a	**1438.6**
S-MEAN	879.3	1244.8	**1272.3**	1007.4	1100.9

LSD at 5% S=164.0 V=109.8

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 18.9b. Effect of sowing times on harvest index of four blackgram varieties in 2006-2007.

	Sowing(S)				
Variety (V)	S_1	S_2	S_3	S_4	V-MEAN
BARIMASH 1	42.7 b	50.0 a	54.9 a	50.5 a	**49.5**
BARIMASH 2	44.3 b	48.2 a	52.0 ab	47.7 a	48.0
BARIMASH 3	48.9 a	49.7 a	51.5 b	37.0 c	46.8
LOCAL VARIETY B-10	29.6 c	41.4 b	39.7c	43.5 b	38.5
S-MEAN	41.4	47.3	**49.5**	44.7	45.7

LSD at 5% S=2.7 V=1.6

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Simple correlation Co-efficients between yield and yield components

Simple correlation co-efficients between yield and yield components in four sowings are presented in Tables 19, 20, 21 and 22.

Association between yield and yield components of the 1st sowing

Plant height was positively correlated with total dry matter (TDM) plant^{-1}, pod number plant^{-1}, pod dry weight plant^{-1}, grain number plant^{-1}, grain weight plant^{-1} and grain yield in the 1st year and with TDM plant^{-1} in the 2nd year. It had negative significant correlation with 100-seed weight and harvest index in both the years. TDM had positive significant correlation with pod number plant^{-1}, pod dry weight plant^{-1}, grain number plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It was also negatively correlated with 100-seed weight and harvest index in both the years. Pod number was found to positively correlated with pod dry weight plant^{-1}, grain number plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It had negative significant correlation with 100-seed weight and harvest index in the 1st year and with harvest index in the 2nd year. Pod dry weight was positive significant correlation with grain number plant^{-1}, grain weight plant^{-1} and grain yield in both the years but negatively correlated with 100-seed weight and harvest index in the 1st year. Grain number was positively associated with grain weight plant^{-1} and grain yield in both the years but negatively with 100-seed weight and harvest index in the 1st year. Grain weight had positive significant correlation with grain yield in both the years. But it was negatively correlated with harvest index in the 1st year. 100-seed weight had positive significant correlation with harvest index in both the years. There was a negative association between harvest index and grain yield in the 1st year (Table 19).

Table 19. Simple correlation co-efficient between yield and yield components of four blackgram varieties in the 1st sowing of 2005-2006 (upper diagonal) and 2006-2007 (lower diagonal).

Characters	Plant height (cm)	Total dry matter plant^{-1}(g)	Pod no. plant^{-1}	Pod dry weight plant^{-1}(g)	Grain no. plant^{-1}	Grain weight plant^{-1}(g)	100-seed weight(g)	Grain yield (kg ha^{-1})	Harvest index (%)
Plant height(cm)	–	0.94**	0.94**	0.85**	0.96**	0.79**	-0.87**	0.79**	-0.90**
Total dry matter plant^{-1}(g)	0.81**	–	0.99**	0.97**	0.99**	0.94**	-0.71**	0.94**	-0.98**
Pod no. plant^{-1}	0.53	0.92**	–	0.97**	1.00**	0.94**	-0.74**	0.94**	-0.94**
Pod dry weight plant-^{1}(g)	0.24	0.77**	0.91**	–	0.96**	0.99**	-0.58*	0.99**	-0.95**
Grain no. plant^{-1}	0.54	0.89**	0.94**	0.87**	–	0.93**	-0.78**	0.93**	-0.94**
Grain weight plant^{-1}(g)	0.10	0.66*	0.84**	0.98**	0.84**	–	-0.51	1.00**	-0.91**
100-seed weight(g)	-0.86**	-0.73**	-0.56	-0.22	-0.55	-0.11	–	-0.51	0.61*
Grain yield (kg ha^{-1})	0.10	0.66*	0.84**	0.98**	0.84**	1.00**	-0.11	–	-0.91**
Harvest index (%)	-0.95**	-0.81**	-0.59*	-0.28	-0.51	-0.11	0.85**	-0.11	–

Association between yield and yield components of 2nd sowing

Plant height was positively correlated with total dry matter (TDM) plant^{-1}, pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It had negative significant correlation with 100-seed weight and harvest index in both the years. TDM had positive significant correlation with pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It was also negatively correlated with 100-seed weight and harvest index in both the years. Pod number was found to associated positively with pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It had negative significant correlation with 100-seed weight and harvest index in both the years. Pod dry weight was positive significant correlation with grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years but negatively correlated with 100-seed weight and harvest index in the 2nd year. Grain number was positively associated with grain weight plant^{-1} and grain yield in both the years but negatively significant correlated with 100-seed weight and harvest index in both the years. Grain weight had positive significant correlation with grain yield in both the years. But it had negative significant correlation with 100-seed weight and harvest index in the 2nd year. 100-seed weight had positive significant correlation with harvest index in both the years but negative significant correlation was observed with grain yield in the 2nd year. There was a negative association between harvest index and grain yield in the 2nd year (Table 20).

Table 20. Simple correlation co-efficient between yield and yield components of four blackgram varieties in the 2nd sowing of 2005-2006 (upper diagonal) and 2006-2007 (lower diagonal).

Characters	Plant height (cm)	Total dry matter plant^{-1}(g)	Pod no. plant^{-1}	Pod dry weight plant^{-1}(g)	Grain no. plant^{-1}	Grain weight plant^{-1}(g)	100-seed weight(g)	Grain yield (kg ha^{-1})	Harvest index (%)
Plant height(cm)	–	0.92**	0.95**	0.75**	0.95**	0.75**	-0.89**	0.75**	-0.86**
Total dry matter plant^{-1}(g)	0.93**	–	0.96**	0.92**	0.96**	0.93**	-0.70*	0.93**	-0.79**
Pod no. plant^{-1}	0.97**	0.99**	–	0.86**	0.94**	0.84**	-0.76**	0.84**	-0.84**
Pod dry weight plant-^{1}(g)	0.90**	1.00**	0.97**	–	0.90**	0.98**	-0.51	0.98**	-0.52
Grain no. plant^{-1}	0.97**	0.99**	0.99**	0.98**	–	0.91**	-0.79**	0.91**	-0.71**
Grain weight plant^{-1}(g)	0.91**	1.00**	0.98**	1.00**	0.99**	–	-0.48	1.00**	-0.52
100-seed weight(g)	-0.93**	-0.81**	-0.87**	-0.78**	-0.87**	-0.80**	–	-0.48	0.72**
Grain yield (kg ha^{-1})	0.91**	1.00**	0.98**	1.00**	0.99**	1.00**	-0.80**	–	-0.52
Harvest index (%)	-0.86**	-0.91**	-0.92**	-0.88**	-0.89**	-0.89**	0.73**	-0.89**	–

Association between yield and yield components of 3rd sowing

A positive significant co-relation was observed in plant height with total dry matter (TDM) plant^{-1}, grain no. plant^{-1} in the 1st year and TDM plant^{-1}, pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in the 2nd year. But it had negative significant correlation with harvest index in the 1st year and 100-seed weight and harvest index in the 2nd year. TDM was positively correlated with pod no. plant^{-1}, grain no. plant^{-1} in the 1st year and pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in the 2nd year. It was also negatively correlated with harvest index in the 1st year and 100-seed weight and harvest index in the 2nd year. Pod number was observed to associated positively with pod dry weight plant^{1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years, while it showed negative significant correlation with 100-seed weight and harvest index in the 2nd year. Pod dry weight was positively correlated with grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years but it was negatively correlated with harvest index in the 2nd year. Grain number was positively correlated with grain weight plant^{-1} and grain yield in the 2nd year but it had negative significant correlation with harvest index in the 1st year and 100-seed weight and harvest index in the 2nd year. Grain weight was positively correlated with grain yield in both the years and negatively correlated with harvest index in the 2nd year. 100-seed weight was positively correlated with harvest index in the 2nd year. Harvest index was negatively correlated with grain yield in the 2nd year (Table 21).

Table 21. Simple correlation co-efficient between yield and yield components of four blackgram varieties in the 3rd sowing of 2005-2006 (upper diagonal) and 2006-2007 (lower diagonal).

Characters	Plant height (cm)	Total dry matter plant^{-1}(g)	Pod no. plant^{-1}	Pod dry weight plant^{-1}(g)	Grain no. plant^{-1}	Grain weight plant^{-1}(g)	100-seed weight(g)	Grain yield (kg ha^{-1})	Harvest index (%)
Plant height(cm)	–	0.88**	0.44	0.08	0.77**	-0.02	-0.47	-0.02	-0.97**
Total dry matter plant^{-1}(g)	0.94**	–	0.73**	0.51	0.94**	0.42	-0.30	0.42	-0.86**
Pod no. plant^{-1}	0.84**	0.96**	–	0.84**	0.89**	0.76**	-0.21	0.76**	-0.37
Pod dry weight plant-^{1}(g)	0.72**	0.90**	0.93**	–	0.62*	0.98**	0.28	0.98**	-0.01
Grain no. plant^{-1}	0.89**	0.98**	0.99**	0.91**	–	0.54	-0.35	0.54	-0.71**
Grain weight plant^{-1}(g)	0.71**	0.88**	0.92**	1.00**	0.89**	–	0.39	1.00**	0.10
100-seed weight(g)	-0.80**	-0.73**	-0.72**	-0.49	-0.78**	-0.46	–	0.39	0.53
Grain yield (kg ha^{-1})	0.71**	0.88**	0.92**	1.00**	0.89**	1.00**	-0.46	–	0.10
Harvest index (%)	-0.95**	-0.89**	-0.79**	-0.60*	-0.83**	-0.58*	0.81**	-0.58*	–

Association between yield and yield components of 4th sowing

Plant height was positively correlated with total dry matter (TDM) plant^{-1}, pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years. It had negative significant correlation with 100-seed weight and harvest index in the 1st year and 100-seed weight in the 2nd year. TDM had positive significant correlation with pod no. plant^{-1}, pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years but it was negatively correlated with harvest index in the 1st year and 100-seed weight in the 2nd year. Pod number was positively correlated with pod dry weight plant^{-1}, grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years but it had significant negative correlation with harvest index in the 1st year and 100-seed weight in the 2nd year. Pod dry weight was positively correlated with grain no. plant^{-1}, grain weight plant^{-1} and grain yield in both the years but it was negatively correlated with harvest index in the 1st year and 100-seed weight in the 2nd year. Grain number was positively correlated with grain weight plant^{-1} and grain yield in both the years, while it showed negative significant correlation with 100-seed weight and harvest index in the 1st year and 100-seed weight in the 2nd year. Grain weight was positively correlated with grain yield in both the years but it was negatively correlated with harvest index in the 1st year and 100-seed weight in the 2nd year. 100-seed weight had significant negative correlation with grain yield in the 2nd year. There was a negative association between harvest index and grain yield in the 1st year (Table 22).

Table 22. Simple correlation co-efficient between yield and yield components of four blackgram varieties in the 4th sowing of 2005-2006 (upper diagonal) and 2006-2007 (lower diagonal).

Characters	Plant height (cm)	Total dry matter plant^{-1}(g)	Pod no. plant^{-1}	Pod dry weight plant^{-1}(g)	Grain no. plant^{-1}	Grain weight plant^{-1}(g)	100-seed weight(g)	Grain yield (kg ha^{-1})	Harvest index (%)
Plant height(cm)	–	0.77**	0.88**	0.77**	0.97**	0.73**	-0.71**	0.73**	-0.69*
Total dry matter plant^{-1}(g)	0.92**	–	0.94**	0.99**	0.90**	0.97**	-0.21	0.97**	-0.92**
Pod no. plant^{-1}	0.93**	0.99**	–	0.91**	0.96**	0.87**	-0.48	0.87**	-0.91**
Pod dry weight plant-^{1}(g)	0.97**	0.97**	0.98**	–	0.89**	0.99**	-0.16	0.99**	-0.86**
Grain no. plant^{-1}	0.99**	0.94**	0.95**	0.98**	–	0.86**	-0.58*	0.86**	-0.80**
Grain weight plant^{-1}(g)	0.97**	0.94**	0.95**	0.99**	0.99**	–	-0.10	1.00**	-0.81**
100-seed weight(g)	-0.84**	-0.67*	-0.72**	-0.75**	-0.84**	-0.78**	–	-0.10	0.28
Grain yield (kg ha^{-1})	0.97**	0.94**	0.95**	0.99**	0.99**	1.00**	-0.78**	–	-0.81**
Harvest index (%)	-0.23	-0.56	-0.51	-0.36	-0.25	-0.24	0.00	-0.24	–

CHAPTER 5

DISCUSSION

Crop production is a complex process. It includes the functions of soil, climatic variables, particularly temperature, relative humidity, rainfall and sunshine hours with management of all of them together. A proper management of these factors may give higher yield. Appropriate manipulation of yield contributing factors helps in attaining potential yield. For these purposes, identification of appropriate stages that are to be manipulated and time for the manipulation are important characters. An investigation on the effect of time of sowing conducted under uncontrolled condition does not permit the partitioning of the influence of individual environmental factors on the process of growth, development and seed yield. In the present investigation, an effort was made to relate the observed pattern of growth, development and seed yield of blackgram with the changes in the climatic variables. Variation in dry matter accumulation and pod production in different varieties may be related to factors such as CGR, RGR etc.

Although the use of exponential polynomial equation in growth analysis is advocated (Hurd, 1977, Hunt 1978) due to the difficulty of selecting the degree of polynomial to be fitted, Nicholls and Calder (1973) suggested a statistically objective method. However, a serious problem arises when unequal degree of polynomials decrease the relationship between $\log_e$ dry weight and $\log_e$ leaf area with time in different sets of data under comparison. The main reason is that this result is the strongly dissimilar patterns of derived growth parameters such as CGR, NAR etc. For which no physiological explanation can be offered. Therefore Hurd

(1977) and Hunt (1978) suggested the use of simplest, quadratic relationship for all varieties or sowings under comparison and the same was followed in the present work. A close agreement between the harvest interval and curve fitting method in the present work also suggests that the selected polynominal adequately described the data except the dry weight.

Growth analysis represents the first step in the analysis of primary production being a link between nearly recording plant production and analyzing it by means of physiological methods. In growth analysis, growth is defined as increase in dry weight of plants. Growth analysis is based on the primary values. Total accumulated plant weight, dry weights of different plant organs are obtained at the beginning time period of plant growth. These are used to calculate CGR, RGR, NAR, LAR, RLGR, LWR, and distribution of dry matter into the stem, petiole, leaflets, primary and secondary branches, pods plant^{-1}, grain pod^{-1} and grain yield plant^{-1}. The growth functions, growth rate (GR), relative growth rate (RGR) and net assimilation rate (NAR) increase with temperature and light flux within a range specific for a given crop (Voldeng and Blackman, 1973 a, b).

In the present investigation, significant varietal difference was observed for total dry weight at some of the growth phases in the 2nd year. Total dry matter (TDM) production was significantly greater for the S_3 plants (21 August sowing) in the 2nd year the other sowings irrespective of varieties and the lower values in S_2 plants (Figures 2.1a 2.2b). Total dry weight per ground area was higher in the early sowing that was reported by Sarker and Paul (1993) in rape seed. Similar result was reported by Khan and Agarwal (1985) in mustard. The results of the present study showed that total dry matter (TDM) production is the integral of plant growth over the entire growth period. The total dry weight of plants in all the varieties was practically the same at the first harvest at 15 DAS. Total dry matter increased slowly at the early vegetative phases (15, 25, and 35 DAS) and then increased rapidly with the advancement of the growth periods in all the varieties and sowings in both the years. The early or appropriate sowing plants produced higher TDM due to longer duration of the vegetative phase. This confirms the findings of Chauhan and Singh (1977) and Vergera *et al.* (1964). Pandey *et al.* (1981), Roy and Paul (1991) and Biswas *et al.* (1992). reported that dry matter production of all the varieties of rape seed increased with the advancement of plant age. Among the varieties, LOCAL VARIETY B-10 produced the highest TDM obtaining the highest number of petioles and leaves with the tallest plant influenced by optimum temperature throughout its growth period in S_3 (21 August) sowing. Begum and Paul (2005) reported that total dry matter at most of the growth stages was found highest for S_3 planting of cassava varieties. Khandkar *et al.* (1990) also reported that growth curves on dry matter accumulation was exponential up to 60 days in all the varieties which declined thereafter and continued at a lower rate of jute varieties. The quadratic polynomials predicted dry weights to drop just prior to maturity while the actual dry weights continued to increase (Figures 2.2a and 2.2b). It may be attributed that polynomial was the most appropriate expression for fitting dry weight data. At the early growth stages, LOCAL VARIETY B-10 had lower TDM but it was higher with the advancement of plant age (S_3 plants). This result is in agreement with the findings of Lawn (1979), Prodhan and Ghose (1986) and Samanta *et al.* (1997).

The results of the study showed that leaf area index (LAI) of all the varieties in all the sowings started from a lower value and reached higher peak al 35 DAS with few exceptions in both the years. Higher LAI was observed for S_1 and lower in S_4 than the other sowings in both years. Except LOCAL VARIETY B-10, which showed the highest LAI in S_3 followed by S_1 and the lowest LAI was observed in BARIMASH-1 S_4 plants in both the years (Figures 3.1a-3.2b). Similar result was reported by Samanta *et al.* (1997). Sarker and Paul (1993) also reported that LAI was higher in mustard for the 1st sowing at all the stages of growth. This confirms the finding of Hussain *et al.* (1997) in chickpea. Significantly higher LAI was found in the 1st sowing. Similar result was reported n several plants like barley (Kirby, 1969), sorghum (Sivakumar *et al.,* 1979 and Rabindranath and Shivraj 1983), mustard (Mondal and Paul, 1992), mungbean (Salam *et al.* 1987), rape (Clarke and Simpson, 1978; Paul and Kundu 1991) and sweet pepper (Islam *et al.,* 2010). In the present investigation, starting from a lower value LAI reached a certain peak and then declined with age. Paul and Sarker (2005) also reported that LAI attained peak at 58-68 days after sowing and declined thereafter in both the cultivars of wheat in all the sowings. Pandey *et al.* (1978) stated that senescence and abscission of the older leaves caused the depletion of LAI at the later stages of growth in wheat. Similar result was reported by Abdel-Raouf *et al.* (1983). Aher *et al.* (2006) reported that LAI increased with the advancing age of the crop up to 60 days after sowing and declined towards maturity due to leaf senescence and heavy demand for reproductive stage in blackgram. Roy and Paul (1991) also reported that LAI attained its peak value at certain days after sowing and thereafter declined. The lower LAI in the later sowing (S_4 sowing) might be due to the influence of low temperature at the seedling stage resulting in short growth period (Zauralov and Zhidkin, 1983). The decline of LAI at the later growth stages might be due to the senescence and death of the leaves in succession from the base of the stem upward. Similar results were also reported by Prodhan and Ghose (1986) and Samanta *et al.* (1997). The pattern of LAI obtained from the curve fitted method (Figures 3.2a and 3.2b) was more or less similar with that of the original values (Figures 3.1a and 3.1b).

The pattern of leaf area duration (LAD) was essentially similar with LAI. It the present investigation, LAD reached a certain peak at 40 DAS and then declined in both the years. LAD was significantly higher in S_1 (01 August) and lower in S_4 of all the varieties than the other sowings in both the years (Figures 4.1a-4.2b). Similar result was reported by Samanta *et al.* (1997) in proso-millet cultivars. Islam *et al.* (2010) reported that the majority of growth parameters i.e. LAD was significantly increased at the earlier sowing (October1) in sweet pepper. Among the varieties, LOCAL VARIETY B-10 the highest LAD in S_3 plants of all the sowings in both the years followed by BARIMASH-3 variety. However, the pattern of LAD calculated from the curve fitted method (Figures 4.2a and 4.2b) was closer to the original values (Figures 4.1a and 4.1b). The cause of the similar pattern is due to best fitness of LAI in the quadratic polynomial.

CGR is regarded as the most meaningful growth function, since it represents the net results of photosynthesis, respiration and canopy area interactions. As noted by Williams *et al.* (1965), CGR is also representative of the most common agronomic measurement, i.e., yield of dry matter per unit ground area. Starting from a lower values, CGR increased up to a certain peak and thereafter declined with lower negative values at 30 DAS and then increased gradually and shaply reached their highest value at 50 DAS and again declined negative values at the later stages of growth (Figures 5.1a-5.2b). Irrespective of varieties and sowings, CGR increased slowly at the early stages of growth at 20 DAS and increased rapidly at 40-50 DAS and then rapidly decreased at 60-70 DAS in both the years. Islam and Soth (1987) also observed that CGR showed slow trend during early vegetative phase of chickpea. Rapid increase in CGR in the peak period of growth was reported by Kollar *et al.* (1970) in soybean. In the present study, all the varieties had generally higher CGR for S_3 plants than other sowings except LOCAL VARIETY B-10, where better performance was observed in S_4 and lower in S_1 plants in both the years. CGR increased to certain peak and then decreased gradually was reported by Paul and Sarker (2005) in wheat. Among the varieties, the highest CGR was observed in LOCAL VARIETY B-10 and the lower in BARIMASH-1 in S_1 plants in both the years. Significant varietal difference was observed at 50 and 70 DAS in the 1st year and 20 and 60 DAS in the 2nd year. This conforms the findings of Ghai *et al.* (1977), Pandey *et al.* (1978) and Kalubarme and Pandey (1979). Kalubarme and Pandey (1979) also reported that CGR was very slow during the early vegetative phase thereafter increased with the advancement in the growth period in all the genotypes in *Vigna radiata.* Similar result was reported by Abdel-Raouf *et al.* (1983) in barley. Salam *et al* (1987) reported that CGR values had been found to be maximum at the stage of pod maturity in all the cultivars of mungbean. Lopez-Castaneda and Richards (1994) found that CGR was greatest in barley and triticle up to anthesis. Yasmin *et al.* (2000) reported that CGR showed significant variability due to the effect of sowing date, variety and their interaction in cotton. Similar result was obtained by Biswas *et al.* (2002) in blackgram varieties.

RGR of all the varieties irrespective of sowing time declined with increasing plant age and plant dry weight having uncharacteristically negative values in both the years (Figures 6.1a– 6.2b). Similar results were reported for RGR in *Crotalaria sp.* (Pandey and Sinha, 1979), in *Pennisetum americanum* (Chanda *et al.*, 1987) and in rape (Clarke and Simpson, 1979). It had been suggested that the decrease in RGR could be attributed to self shading of lower leaves by upper leaves (Thorne, 1961). In the present study, all the verieties showed higher RGR at the early stages of growth (15-25 DAS). Tan *et al.* (1978) found higher RGR values at the earlier stages of growth. Islam and Paul (1986) found the highest RGR at 25-29 DAS in all the cultivars and then declined gradually in rape seed. Similar result was obtained by Kalubarme and Pandey (1979) in *Vigna radiata* and in jute (Khandkar *et al.*, 1990 and Johansen *et al.*, 1985). Haloi and Baldev (1986) reported higher RGR at the initial stage of growth. In the present work higher RGR was found in S_3 than the other sowings and lowest in S_4. BARIMASH-1 had the lower and LOCAL VARIETY B-10 had higher RGR in both the years Sarker and Paul (1993) found higher RGR in the S_3 sowing in rape seed. RGR calculated from the quadratic fitted values indictated that S_4 plants of all the varieties decreased with time sharply with negative values at the later stages of growth (Figures 6.2a and 6.2b). The pattern of RGR in both the curve fitting and classical methods are agreed with findings of Sarker and Paul (1998) in wheat and disagreed with Mondal and Paul (1992) in mustard and Saha and Paul (1995) in wheat. So the curves were not fitted adequately.

In the present investigation, net assimilation rate (NAR) calculated from the quadratic fitted values showed that it increased slowly at the early vegetative stages and reached its peak at 30 and 70-80 DAS and thereafter declined sharply at the later stages of growth in both the years irrespective of sowing times and variety with few exceptions (Figures 7.2a and 7.2b). NAR values were higher in all the sowings of all the varieties at the early stages. Dissimilar result was observed by Sharma and Kumar (1989) in mustard, they observed significantly increased NAR. In many cases it reached negative values at the later stages of growth. Similar result was reported by Yang *et al.* (1990) in barley. In the present study, the highest NAR was observed in S_3 plants than the other sowings in all the varieties while it showed the better performance in LOCAL VARIETY B-10 in both the years because the S_4 growth periods passed through comparatively lower temperature at the early vegetative stages and subsequently higher temperature at the later stages of growth. Among the varieties, BARIMASH-3 attained the highest NAR for the optimum sowing S_3 in both the years. Sarker and Paul (1993) observed NAR in rape seed and reported the highest NAR in S_3 sowing. Kalubarme and Pandey (1979) reported that maximum NAR was found in the early phase and then fluctuated in V*igna radiata.* Similar result was reported by Khandkar *et al.* (1990) in jute varieties and Paul and Sarker (2005) in wheat cultivars. Aher *et al.* (2006) also reported that NAR decreased towards pod filling stage and then increased towards maturity may be due to increased efficiences of leaves owing to higher demand for growing seeds. However, the pattern of NAR calculated from the curve fitted method (Figure 7.2a and 7.2b) showed a close correspondence with that calculated from the original values (Figures 7.1a and 7.1b). It was also evident that all the varieties in both the years showed increasing tendency of NAR towards the later stages of growth.

Leaf area ratio (LAR) of all the varieties of all the sowings started from higher values at the early stages of growth and then declined steadily throughout the whole growth period in both the years (Figures 8.1a-8.2b). Similar result was reported by Mondal and Paul (1994), Begum and Paul (1993) in mustard. Khandkar *et al.* (1990) reported that LAR of all the cultivars were highest at the early stages of growth and then declined with the advancement of age in jute varieies. Similar result was reported by Wallace and Munger (1965) in dry bean. Dissimilar result was reported by Begum and Paul (2005) for late sowing in local cassava varieies. LAR might be due to abscission of older leaves at the later growing stages. Similar result was also reported by Pandey *et al.* (1978) in blackgram, Shamsuddin and Paul (1988) in sweet potato, Islam and Paul (1986) in rape, Mondal and Paul (1992) and Khan and Paul (1993) in mustard. In the present study, LAR was found higher in S_1 plants than the other sowing except LOCAL VARIETY B-10 that showed higher LAR in S_2 plants in both the years. Among the varieties LAR was found higher in LOCAL VARIETY B-10 irrespective of sowing times in both the years. The pattern of LAR calculated from the curve fitted method (Figures 8.2a and 8.2b) showed a close correspondence with that calculated from the original values (Figures 8.1a and 8.1b).

Relative leaf growth rate (RLGR) of all the varieties and sowings started from higher positive values at the early stages of growth and then declined with heavy fluctuations and became negative values at the later stages of growth (Figures 9.1a – 9.2b). Similar result was reported by Sarker and Paul (1993) in rape seed, Roy and Paul (1991) and Kundu (1992) in rape, Chanda *et al.* (1987) in pearl millet, Paul (1980) in rape, kale, swede and turnip, Pandey *et al.* (1978) in blackgram and Khandkar *et al.* (1990) in jute. The cause of decline of RLGR at the later stages was due to abscission of older leaves. It was also observed that high temperature at the later stages of growth accelerated the abscission of older leaves. In the present study, RLGR was higher in S_3 (21 August sown) in both the years. However, the highest RLGR was found in LOCAL VARIETY B-10 in S_3 and the lowest in BARMASH-1 in S_2 in both the years. RLGR values obtained form the curve fitted values showed linear drift with increasing plant age and also with increasing plant weight in both the years (Figures 9.2a and 9.2b) is agreed with findings of Saha and Paul (1995) in wheat.

There were no clear pattern of sowing time effects on SLA and declined throughout the advancement of growth stages with fluctuations for all the sowings in both the years (Figures 10.1a and 10.1b). The S_3 plants shad the highest SLA than the other sowings in both the years. The highest SLA was found in LOCAL VARIETY B-10 followed by BARIMASH-3 and the lowest in BARIMASH-2 than the other varieties in both the years. The decline of SLA with age was reported by Paul (1980) in rape, swede, kale and turnip, Hossain and Paul (1984) in Jute, Islam and Paul (1986) and Sarker and Paul (1993) in rape seed, Shamsuddin and Paul (1988) in sweet potato. SLA values decreased with increasing plant dry weight was observed by Chanda *et al.* (1987) in pearl millet. It might be attributed to low demand of photosynthate during that period. Again, SLA of most of the varieties showed slightly increasing tendency towards the later stages of growth (Figures 10.2a and 10.2b). Kalubarme and Pandey (1979) also reported that SLA was initially low and slowly increased with the advancement of time.

In the present study, LWR showed the increasing tendency at the early stages of growth within very short time and thereafter declined gradually irrespective of sowing and variety in both the years (Figures 11.1a and 11.1b) i,e., the declining pattern was downward drift throughout the whole growth period. Strong drift of LWR with increasing plant dry weight was reported by Chanda *et al*. (1987) in pear millet. The curve-fitted values of LWR indicated that it gradually decreased irrespective of varieties and sowings in both the years (Figures 11.2a and 11.2b). LWR values declined very sharply with increasing plant age. Saha and Paul (1995) reported that the sharp decrease in LWR at the later stages might be due to the sharp increase of TDM. Similar result was also supported by Sarker and Paul (1998), Nahar and Paul (1998) in wheat, Sarker and Paul (1993) in rape, Khan and Paul (1993) and Mondal and Paul (1992) in mustard, Shamsuddin and Paul (1988) in sweet potato and Islam and Paul (1986) in rape seed. In the present investigation, the S_3 plants had higher LWR than the other sowings in both the years. The high temperature prevailing in the S_3 growing period of the later stages of growth produced lower TDM. Elias and Causton (1975) found that high temperature depressed the mean overall LWR mainly during the later part of the growth period. Among the varieties, the highest LWR was found in LOCAL VARIETY B-10 for S_3 and lowest in BARIMASH-1 in both the years because of higher incensement of leaf weight in that sowing. The pattern of LWR calculated from the curve fitting method (Figures 11.2a and 11.2b) showed a close correspondence with that calculated from the original values (Figures 11.1a and 11.1b).

In both the years, significant sowing time and varietal differences were found for most of the phenological characters. The number of days taken for attainment of different phenological stages (Tables 11a and 11b) were higher at most of the phenological stages in S_3 except physiological maturity, where the highest value was observed for S_1 in both the years. Number of days for attaining the different phenological stages differed variety to variety and the required days were decreased for every late sowings. Similar results were reported by Rajput *et al.* (1987), Paul and Sarker (2000), Chakravarty and Sastry (1983) in wheat and Dahiya and Narwal (1989) in maize. Among the varieties, LOCAL VARIETY B-10 required the highest number of days for attaining the different phenological stages than the other varieties. Longer duration of the phenological stages for S_3 may be due to more pod number, highest pod dry weight, higher grain number, maximum grain weight, higher grain yield and harvest index. These occured due to favourable environmental conditions, particularly temperature throughout the whole growth period. There was optimum temperature (25-32°C) for S_3 at the vegetative stage. On the other hand, the late sown plants beyond August experinced the higher temperature at the early stages (25-33°C) and lower temperature (24-31°C) at the reproductive stages. This fluctuated temperature reduced the number of days for most of the phenological characters by supplying the lower amount of assimilates which reflected to the different growth stages resulting in quick maturity of plants. Inagaki and Masuda (1984) observed significant varietal differences in number of days to flag-leaf emergence under short day condition at 20°C. Weigand and Cuellar (1981) reported that 2.8 and 1.5 mg kernel weight were decreased by every 1°C rise in temperature of daily mean temperature during grain filling duration of wheat. Saini *et al.* (1986 a, b) also found that when wheat crop sown early or late the initiation of the 1st and terminal spikelet was hastened and anthesis occurred earlier. Samanta *et al.* (1997) reported that late sowing caused late germination and reduced the period (days) of different phenological stages due to low temperature at the seedling stage and high temperature at the grain filling stage in proso-millet. As LOCAL VARIETY B-10 is the late and BARIMASH-3 is the early maturing varieties, so, it might be possible that all the phenological characters showed comparatively higher and lower values in LOCAL VARIETY B-10 and BARIMASH-3, respectively.

Significant sowing time and variety differences were found for the phenological characters in both the years. The requirement of heat units (GDD) was higher for S_4 at most of the phenological stages for all the varieties in both the years except pod filling and physiological maturity stages whereas they showed better performance in the optimum sowing (S_3) and lower heat unit (GDD) was observed in S_1 (Figures 12a and 12b). Among the varieties, LOCAL VARIETY B-10 accumulated the highest heat unit (GDD) for all the sowings at most of the phenological stages except BARIMASH-3 which showed the better performance for seed emergence in the 1st year and BARIMASH-1 for leaflet initiation in both the years. It was observed that delayed sowing increased the duration of phenology as compared to optimum sowing due to fluctuated temperature during the growth period. So the required accumulated heat units decreased for most of the phenological stages with early in sowing in the present study. Dissimilar results were reported by Sandhu *et al.* (1999), Rajput and Sastry (1985), Rajput *et al.* (1987), Masoni *et al.* (1990), Bishnoi *et al.* (1995), Paul and Sarker (2000), Saini and Dadhwal (1986) in wheat and Ghadekar *et al.* (1985) in sorghum. Stegemann and

Kuhn (1981) reported that yields were significantly lower when the temperature sum was 260-280 degree. Korovin and Mamaev (1983) reported that when plants were held at 4 or 6 degree for 15 or 20 days the yield was decreased and growth period increased. Puri *et al.* (1985) was reported that barley required less solar radiation and heat units than wheat and triticale to produce maximum grain yield. Saeed *et al.* (1986) reported that growing degree unit (GDU) in the range of 1250-1350 favoured development of high yields in sorghum. Kernich and Halloran (1996) found that the duration of the spikelet growth phase was greatly increased by the higher temperature treatment in barley.

Helio-thermal unit (HTU) of definite phenology is the product of the length of sunshine hour of a day and the required days of the phenology accumulated heat units by plants. In the present invesitigation the requirement of HTU at most of the phenological stages were highest when the crops were sown on S_4 (31 August) followed by the order of S_4>S_3>S_2 >S_1 in both the years except physiological maturity stage and it was higher in S_3 plants in both the years (Tables 13a and 13b). Significant sowing and varietal effects were found for all the phenological stages in both the years. The S_4 plants (31 August sowing) passed their growth period under bright sunlight that influenced the photosynthesis effectively. On the other hand, the early sown plants passed their most growth period with foggy (moist) condition that hampered the photosynthetic efficiency. So, HTU of the early sowing plant was lower than the late sown plants that produced lower grain yield in the present study. Among the varieties, LOCAL VARIETY B-10 had the highest HTU for all the sowings at all the phenological stages except BARIMASH-1 which showed better performance at the leaflet initiation and BARIMASH-3 at the physiological maturity stages in both the years. Dissimilar results were reported by Masoni *et al.* (1990), Rajput and Sastry (1985), Rajput *et al.* (1987), Paul and Sarker (2000), Sastry and Chakravarty (1982) and Bishnoi *et al.* (1995) in wheat.

In the present study, the phenothermal indices (PTI) during the different phenological stages were in the order of $S_4>S_3>S_2>S_1$ in both the years except physiological maturity, where the order was $S_3>S_4>S_2>S_1$ in both the years. PTI was slightly higher at the initial stages of growth (seed emergence) and then decreased with the advancement of plant age. Because at the initial stage, growth duration was lower and then increased with plant age although GDD increased with plant age. As a result, the values of PTI for different phenological stages were nearly constant irrespective of sowing time in both the years. Rajput *et al.* (1987) supported this. It was also observed that PTI values of all the sowings were very close to one developmental phase to another developmental phase i.e., the results of PTI did not differ much between the developmental phases during the whole growth period. Among the varieties, LOCAL VARIETY B-10 obtained the lowest PTI at most of the phenological stages in both the years because of its longer growth periods and subsequently BARIMASH-3 attained the highest PTI because of its shorter growth periods. In both the years significant sowing time and varietal differences were found for all the phenological stages except pod filling and physiological maturity stages in the 1st year.

In the present study, the S_3 plants of all the varieties used heat more efficiently than the other sowings and the order was $S_3>S_2>S_4>S_1$ in both the years (Tables 15a and 15b). Similar result was reported by Rajput *at el.* (1987). Chakravarty *et al.* (1984) determined the relationship between accumulated heat units and biomass production in barley and expressed the ratio of biomass production per unit degree days. Similar result was reported by Chakravarty and Sastry (1983). Paul and Sarker (2000) reported that HUE of wheat decreased with delayed planting. Among the varieties, the highest HUE was observed in LOCAL VARIETYB-10 which was followed by BARIMASH-2 in both the years and the lowest HUE was found in BARIMASH-3. The S_3 plants (21 August) produced higher grain yield by using accumulated heat units efficiently. Temperature was optimum throughout in S_3 (21 August sown) followed by S_2 (11 August sown) growing periods. It accumulated heats more efficiently and increased biological activities that confirmed higher grain yield of plants of those two sowings. From the results of HUE it can be concluded that blackgram should be sown within 21 August, especially in the northern part of Bangladesh.

Chlorophyll a and b are the most important pigments active in the photosynthetic process. In the present experiment, chlorophyll a, cholorphyll b and total chlorophyll of matured green leaves were comparatively higher for S_1 plants in both the years. But chlorophyll a:b ratio was observed higher for S_4 and lower in S_1 than the other sowings in all the varieties in both the years (Figures 16a and 16b). BARIMASH-1 produced the highest chlorophyll a, b and total chlorophyll in both the years. LOCAL VARIETY B-10 produced the highest and BARIMASH-1 the lowest chlorophyll a:b ratio in both the years in all the varieties. Chlorophyll formation decreased with delayed sowing in the present study as because of low temperature at the early vegetative stages. Several workers have reported that the rate of photosynthesis in leaves is positively associated with chlorophyll (Kariya and Tsunoda, 1971). In the present study, chlorophyll a, chlorophyll b, total chlorophyll and chlorophyll a:b ratio were found to be affected by sowing time. Paul (1993) found higher chlorophyll a, b and total chlorophyll per unit area in leaves at 20°C and in the present study, temperature of 25-33°C at the vegetative stages was noticed in S_1 (01 August). Kundu and Paul (1997) reported that chlorophyll content decreased at the later stages of growth due to older leaves of the plants.

In the present investigation, relative leaf water content (RLWC) of matured green leaves were significantly higher for S_1 (01 August sowing) plants of all the varieties and always had higher RLWC than the other sowing at 8.00 a.m., while it showed higher in S_3 plants at 12.00 noon and 4.00 p.m. in both the years (Figures 17a and 17b). During the S_1 growing periods, temperature increased the relative turgidity of cells which enhanced RLWC of the leaves for S_1. Besides this, higher RLWC was associated with higher dry matter production rates of the early sowing plants that were determined or controlled by cell turgidity through stomatal opening and closing properly where water movement and nutrients uptake were increased and made more food by efficient photosynthetic pathway. However, RLWC of the matured green leaves decreased with delay in sowing causing heat stress in the leaves.

In the present study, varietal effect was found significant for RLWC at 4.00 p.m. in both the years. It was observed that all the varieties of every sowing, higher RLWC was in the morning (8.00 a.m.) and got reduced at 12.00 noon whereas it increased gradually at the later part of day (4.00 p.m.) in both the years. S_1 plants had the highest RLWC in BARIMASH-3 at 8.00 a.m. and S_3 plants had the highest RLWC in LOCAL VARIETY B-10 at 12.00 noon in both the years. Begum and Paul (1993) also reported that RLWC of mustard was highest at 8.00 a.m. and gradually decreased and thereafter showing some recovery at the afternoon. Similar result was reported by Raja and Bishnoi (1990) in rape and Joshi *et. al.* (1988) in groundnut. Schonfeld *et. al.* (1988) also reported that RLWC declined with increasing drought stress. The decrease of RLWC at the midday might be due to higher evapotranspiration resulting from increased temperature and light intensity.

The yield of a crop is a complex process. It is function of the interactions among factors responsible for crop growth and depend on the environmental factors for expression of yield potential. Although pulse Research Center of Bangladesh Agricultural Research Institute (Ishurdi, Pabna) has released some varieties of blackgram with high yield potential, these varieties cannot sustain for longer period due to their high sensitivity to fluctuation in changing environment and none has taken it into account of all the growth variables. Therefore, to overcome this acute problem further information is needed for developing appropriate blackgram production technologies.

The yield being a complex character depending upon a large number of morphological and physiological characters. In the present study, most of the yield and yield components were significantly affected by sowing time. Plant height was higher for S_4 (31 August sowing) in the late sowing and lower in the early sowing S_1 (01 August) in both the years. Total dry matter was higher for S_2 (11 August sowing) and lower in the early sowing S_1 whereas 100-seed weight was higher for S_1 in both the years and lower in S_2 in the 1st year and S_3 in the 2nd year respectively. Pod number plant^{-1}, pod dry weight grain yield and harvest index were higher in S_3 (21 August sowing) and lower values for S_1 in both the years

(Tables 18a and 18b). Among the cultivars, LOCAL VARIETY B-10 had the highest values of the above characters in both the years. In case of plant height and 100-seed weight) higher values were found in BARIMASH-3 than LOCAL VARIETYB-10. On the other hand, BARIMASH-1 had the highest harvest index and the lowest was observed in LOCAL VARIETYB-10 of all the varieties and sowings in both the years. Again, the lowest values of plant height total dry matter pod number plant^{-1}, pod dry weight and 100-seed weight were observed in BARIMASH-1 whereas the lowest values of grain number plant^{-1}, grain weight plant^{-1} and grain yield were found in BARIMASH-3 of all the varieties and sowing in both the years.

In the present study, yield and yield components were more or less reduced by late sowings (S_4 sowing) as compared to S_3 sowing (21 August) that was the optimum sowing time for highest grain yield. Similar result was reported by Ali and Rahim (2000) in carrot, Sandhu *et al.* (1999) in wheat. Oweis *et al.* (2004) reported that the highest grain yield of 1.60 t ha^{-1}was obtained at the normal sowing date (late December to mid January) in lentil. Ahemd *et al.* (1975) reported that seeding in the 3rd week of December reduced the grain yield by 50%. Scott *et al.* (1973) stated that late autumn sowing (after mid September) gave lower yields than early spring sowings. The best autumn sowings (early September) gave about 3 t ha^{-1} of yield in oil-seed rape. Mendham *et al.* (1981) reported that late sowings produced 3000-6000 pods /m^2 and early sowings produced 6000-12000 pods/m^2 oil-seed rape. Similar result was reported by Samanta *et al.* (1999) in mungbean.

Ramzan *et al.* (1992) also observed that maximum seed yield (430 kg ha^{-1}) was obtained from both mungbean varieties planted on 4 July.

Mondal *et al.* (1992) reported that the highest seed yield (1.45 t ha^{-1}) was obtained from the plants of 2nd planting date (October 16). They also reported that planting dates significantly influenced plant height, no. of siliquae/plant, seed yield/plant and seed yield/ha. Nelson (1993) observed that grain yield was only increased when the crop was sown late.

Aziz and Rahman (1994) found that the seed yield difference is too high in late-sown in chickpea. They found yield of 4.37 and 0.67 t ha^{-1} at 1 December and 1 January, respectively. Biswas *et al.* (2002) reported that sowing dates exerted significant effect on seed yield of blackgram. First sowing (31 August) produced significantly highest seed yield (11 68 kg ha^{-1}). The highest seed yield (1225 kg ha^{-1}) was recorded from Barimash-3 with August sowing.

Thanki *et al.* (2004) found that sowing in 17 February gave the highest plant height (104 cm) and pooled yield (1290 kg ha^{-1}) in sesame. Khan *et al.* (2005) reported that sowing on 1 May resulted in the highest number of branches (4.75) and pods/plant (83.38), 1000-grain weight (40.47g) and grain yield (1429 kg ha^{-1}) in mungbean. Uddin *et al.* (1986) reported that sowing dates significantly affected primary branch/plant, seed no. /pod and seed yield in mustard and rapeseed.

Rahman *et al.* (1987) reported that seed yield was highest when the crop was sown on November 13 but was non-significantly different from November 23 in mustard (SS-75). Rashid *et al.* (1990) reported that planting time significantly influenced the growth and yield of cauliflower. Curd yield was higher in the early panting (September 1).

Zaman *et al.* (1991) reported that the dates of sowing had significant effect on the number of seed/pod and seed yield/ha of mustard under zero tillage condition. They also reported that the variety produced highest yield in the 1st sowing date than the late sowing. Similar result was reported by Dixit *et al.* (1993a, b).

Podder *et al.* (1996) reported that sowing date influenced significantly seed yield and yield components in mustard. Khan *et al.* (1996) observed that the highest grain yield was obtained when seed was sown on 30 November (S_2 sowing) in wheat. Similar result was reported by Samanta *et al.* (1999) and Mondal (2004) in mungbean. Nag *et al.* (2000 a) reported that both the varieties planted between 15 January and 15 February gave significantly higher seed yield and yield components in mungbean. Sowing thereafter reduced seed yield drastically. The maximum seed yields (919.88 kg ha^{-1} and 1033.25 kg ha^{-1}) were obtained when both the varieties were planted on 25 January. Nag *et al.* (2000b) also reported that the highest seed yield was obtained from early sowing and lowest in late sowing. Islam *et al.* (2000) showed that yields were greater when seeds were sown on 04 November (S_2 sowing) compared to both the early and late sowings of mustard and rape.

Haque *et al.* (2001) reported that BINA mung-1 produced the highest seed yield in the early sowing (S_1 sowing) than in Kanti and the yields were gradually decreased due to delayed planting. Yield reduction due to delayed planting was lower in BINA mung-1 than in Kanti. The highest yield was obtained from 15 November (S_1 Sowing) and a decreasing trend was observed with delay in planting. Similar result was reported by Islam *et al.* (2002) in okra and Yousaf *et al.* (2002) in canola. Malik *et al.* (2006) reported that the maximum seed yield (1259.26 kg ha^{-1}) was recorded in 3rd week of July sowing (S_2 sowing) in mungbean (Cultivar M-6). Kawsar *et al.* (2009) also reported that the highest seed yield (969.62 kg ha^{-1}) of summner mungbean was obtained from 2 March (S_2

sowing) followed by 20 February (S_1 sowing) and BINA moog 7 had the highest seed yield (938.40 kg ha^{-1}) followed by BINA moog-6. Delayed sowing gradually decreased the seed yield and BINA moog 6 matured earlier than the others for late sowing.

In the present study, higher grain yield was obtained from 21 August sowing due to cumulative influence of optimum temperature (25-32^{0}C) at the reproductive stage. On the other hand, the lowest yield obtained from 01 August sown crops was due to higher temperature (25-33^{0}C) at the early stages of growth.

In the present study, simple correlation co-efficient between yield and yield components are presented (Tables 19, 20, 21 and 22). Grain yield of all the sowings was positively correlated with total dry matter (TDM) plant^{-1}, pod number plant^{-1} pod dry weight plant^{-1} except 3rd sowing, whereas it was negatively associated with 100-seed weight and harvest index.

The overall results of the present investigation indicated that LAI, LAD and LAR were higher in S_1 (1 August) in both the years and some growth attributes like TDM, CGR, RGR, RLGR, NAR, SLA and LWR at most of the stages were observed higher values in S_3 (21 August sowing) of all the sowings and varieties in both the years. Among the growth attributes, TDM, LAI, LAD, and CGR were increased with increasing plant age then decreased gradually in both the years. Again, RGR, LAR, RLGR, SLA and LWR declined with increasing plant age. With few exceptions, NAR showed increasing tendency towards the later stages of growth. Only SLA showed increasing tendency at the middle stages of growth in both the years. LAI, dry matter production, crop growth rate and harvest index seemed to be important in improving seed yield of blackgram. Most of the phenologcial characters were observed higher values in S_4 (31 August) followed by the optimum sowing S_3 (21 August). The number of days taken for attainment at most of the phenological stages were higher in S_3 followed by S_2 (11 August sowing). The requirement of heat units (GDD), helio-thermal unit (HTU) and pheno-thermal indices (PTI) at all the stages were significantly higher in S_4 followed by S_3 . The plants of S_3 used heat more efficiently than the other sowings. Among the phenological characters, growing degree days (GDD), helio thermal unit (HTU), phenothermal index (PTI) and heat use efficiency (HUE) were observed higher values in LOCAL VARIETY B-10 at most of the phenological stages which was followed by BARIMASH varieties. Among the yield and yield components most of the characters like pod number plant^{-1}, pod dry weight (g plant^{-1}), grain number plant^{-1}, grain weight (g plant^{-1}) and grain yield (kg ha^{-1}) were found higher in S_3 sown crops and showed their higher values in LOCAL VARIETY B-10 than BARIMASH-3 in both the years. So, LOCAL VARIETY B-10 may be considered as more widely adapted variety in all the sowings.

Therefore, to get higher yield, LOCAL VARIETY B-10 may be recommended for the optimum time of sowing at the 3rd week of August (21 August sowing) of the blackgram growing season (Kharif-2) in the northern part of Bangladesh.

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