# PHYSIOLOGICAL EVALUATION OF SOURCE-SINK RELATIONSHIPS IN SOYBEAN (*Glycine max* L. Merrill) GENOTYPES UNDER VARIABLE PHOTOPERIODS

**Dissertation**

**Submitted to the Punjab Agricultural University**
**in partial fulfilment of the requirements**
**for the degree of**

**DOCTOR OF PHILOSOPHY**
**in**
**BOTANY**
**(Minor subject: Plant Breeding and Genetics)**

**By**

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# CERTIFICATE I

This is to certify that the dissertation entitled**, "PHYSIOLOGICAL EVALUATION OF SOURCE-SINK RELATIONSHIPS IN SOYBEAN (*Glycine max* L. Merrill) GENOTYPES UNDER VARIABLE PHOTOPERIODS"** submitted for the degree of **Ph.D**, in the subject of **Botany (Minor subject: Plant Breeding and Genetics)** of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Anil Kumar Dogra (L-2010-BS-55-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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# CERTIFICATE II

This is to certify that the dissertation entitled, **"PHYSIOLOGICAL EVALUATION OF SOURCE-SINK RELATIONSHIPS IN SOYBEAN (*Glycine max* L. Merrill) GENOTYPES UNDER VARIABLE PHOTOPERIODS”** submitted by **Anil Kumar Dogra (L-2010-BS-55-D)** to the Punjab Agricultural University, Ludhiana, in partial fulfilment of the requirements for the degree of **Ph.D**, in the subject of **Botany (Minor subject: Plant Breeding and Genetics)** has been approved by the Student’s Advisory Committee after an oral examination on the same.

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## ABSTRACT

Soybean is a short day plant. Both photoperiod and temperature control the duration of pre and post flowering phase and are expected to affect source-sink relationships. The present investigations were aimed at evaluating the relative performance of different maturing group of soybean genotypes with respect to different physiological and biochemical indices for higher productivity under variable photoperiods. To achieve the objectives, field experiments were conducted during *kharif* seasons of 2012 and 2013 at Punjab Agricultural University, Ludhiana. The experiment were laid out in randomised block design with three replications consisting of 15 genotypes to screen for various morpho – physiological traits, yield and yielding attributes in first year. On the basis of results obtained from the first year experimentation, two genotypes from early maturing genotypes and each of three from medium and late maturing genotypes were selected for biochemical analysis. Morpho-physiological parameters viz., leaf area, leaf area index, leaf and stem fresh and dry weight, net photosynthesis, growth efficiency, chlorophyll content, photochemical efficiency and transpiration rate were affected by photoperiods. Under both the photo-periodic conditions, the late maturing group genotypes maintained higher leaf area, biomass accumulation, leaf area index, photosynthetic rate and transpiration rate as compared to medium and early maturing genotypes leading to higher yield. Under longer photoperiod i.e. June sowing showed more metabolic status as compared to shorter photoperiod (July sowing). Nitrogen metabolizing enzymes viz., GOGAT, GS, GDH and NR activity showed varied response in leaf and stem. Highest activity of these enzymes was found in longer photoperiod as compared to shorter photoperiod. Carbon metabolizing enzyme- invertase also showed varied response in podwall and developing seeds. The activity of this enzyme increased in developing seeds and the highest activity was observed in late maturing genotypes. Finally, it can be concluded that for selection of better genotypes under variable photoperiods, the physiological parameters total dry matter, CGR, RGR, photosynthetic rate, chlorophyll content, LAI, SPLW, 100 seed weight, numbers of pods per plant and harvest index should be considered. These parameters were found to have significant positive correlation with seed yield. Of the evaluated 15 diverse maturing genotypes, the early maturing genotypes EC 457161, medium SL 983 and late SL 958 are superior in terms of yield as well as in other morpho-physiological traits. Of all genotype SL 958 performed the best.

**Keywords:** Soybean, Maturity group, Source –sink, Photoperiod

**Signature of Major Advisor** **Signature of the Student**

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**ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ**

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***Place:***

***Date:*** ***Anil Kumar Dogra***

## CONTENTS

## CHAPTER I

# INTRODUCTION

Soybean (*Glycine max* L. Merrill) is one of the important legume crop and major source of high quality protein for human daily diet and livestock feed in the world (Lie *et al* 2006). Botanically, soybean belongs to the family *Fabaceae.* In addition to its rich protein (35-45%) and oil content (15-25%), soybean seed also contains about 33% carbohydrates, upto 16.6% of which are soluble sugars (Hou *et al* 2009). Besides being an important source of protein for human diet and animal feed, soybean has been considered to be one of the most promising crops for producing bioenergy (biodiesel) in the near future (Soy Stats 2010).

India ranks fifth in the world after USA, Brazil, Argentina and China in soybean production and accounts for 11.5 million metric tons (3%) of total world production in the year 2012-13 (Soy Stats 2013). However, average yield of soybean in India is less than that of world average which needs to be improved through genetic manipulations. Cultivation of soybean in India is restricted mainly to Madhya Pradesh, Uttar Pradesh, Maharashtra and Gujarat. It is also grown on a small acreage in Himachal Pradesh and Punjab.

Crop growth and development is ultimately controlled by the environmental factors such as photoperiods and temperature. Soybean is a short day plant. Both photoperiods and temperature control the duration of pre and post flowering phases and are expected to affect source- sink relationships. Economic yield of a crop is a function of better assimilation of photosynthates and growth rate of crop. The availability of assimilates is determined by a rate of photosynthetic capacity and by the photoperiods (the periods when conditions are suitable for plant growth and development). To prolong and improve yield of soybean in the future, physiological understanding of yield traits is essential.

Photoperiod has been account to play an important role in flowering induction, floral organ differentiation (Zhang *et al* 2001) and flowering development (Han and Wang 1995, Kantolic and Slafer 2001). The previous studies mainly focused on post-flowering features, instead of other growth stages under variable photoperiods. As response to photoperiods, the best appropriate plants for high seed yield should possess characters such as vertical leaf orientation, larger leaf area, high photosynthetic and assimilatory capacity, more canopy reflectance, a short and stout stem that allow maximum supply of assimilates due to shorter distance and result in additional seed production (Cooper 1981, Board and Tan 1995, Ma *et al* 2001 and Ustun *et al* 2001).

A soybean crop is usually source restricted during the reproductive period of seed formation (Egli 1998). During this period canopy photosynthetic rate is increased by carbon or light enrichment, more seeds are produced (Hardman and Brun 1971 and Schou *et al* 1978). Crop growth limitations imposed by shading and defoliation reduce pod and seed number as reported by Egli and Zhen-Wen 1991, Jiang and Egli 1995. If the crop is exposed to favourable environmental conditions during the critical period, high photosynthetic and crop growth rate had attained under these conditions and source restrictions are attenuated (Egli 1998).

Relationship between source-sink may be modified by manipulating plant responses to the environmental dynamics controlling development, mainly photoperiod and temperature. Photoperiod seems to have no major direct effect on crop growth but functioning in regulation of duration of most phase of soybean development (Raper and Kramer 1987, Kantolic and Slafer 2001). Temperature control both growth and development of crop by regulating plant architecture and duration of crop. Longer photoperiods may result in delay floral initiation (Caffaro and Nakayama 1988), promote node differentiation and appearance and delay flowering (Hadley *et al* 1984).

Longer photoperiods may also result in greater production of photosynthates and to increase biomass, growth efficiency, duration of crop and yield per plant and thus mitigating source limitations (Summerfield *et al* 1998, Ellis *et al* 2000). Results from the previous studies reported that the changes in seed number due to photoperiodic manipulations during post-flowering stages are scare and contradictory. But exposure to longer photoperiods has been found to increase seed per pod by means of higher node per plant and fertility (Guiamet and Nakayama 1984). Soybean yield is determined by the number of pods (seeds) produced per unit area and individual seed weight (Desclaux *et al* 2000, Ohashi and Nakayama 2009). The seed number depends upon the number of floral buds that initiate pods and attain maturity. Generally, soybean plants produce an abundance of floral buds, but a large proportion of them abort during development. Indeed, rates of flower and pod abscission or abortion were estimated to reach 80% (Shibles *et al* 1975). During the grain-filling period limited resource availability mainly results in source restrictions by reducing current photosynthesis and less by sink limitations (Madani *et al* 2010, Eghareuba *et al* 2006).

Photosynthetic activity by crop canopy declines gradually during the effective grain filling period and current photosynthesis is considered to be main source for seed growth in soybean (Liu *et al* 2006). Partitioning of photosynthetic metabolites between leaf and stem is an important factor in yield determination (Misra *et al* 2009). The response of the sink (seed) to source-sink alterations during seed filling depends upon the assimilate level in the seed and the ability of the seed to respond to a change in assimilate supply (Jenner *et al* 1991). So, a change in the photosynthetic source-sink balance is an important factor that can regulate photosynthesis (Paul and Foyer 2001).

In addition, these results accounts in highly controlled environments with plant sown in plots, so that the direct extrapolation of the results under natural field growing crop does not seem warranted. In a field experiment, conducted with four indeterminate soybean genotypes exposing the plants after R3 (beginning pod stage) to photoperiods 2h longer than the natural daylenth resulted in a longer period of pod and seed formation (Kantolic and Slafer 2001). These increments were obvious under longer photoperiods (early sowing) but were not noticeable when the sowing was delayed.

Moreover, photoperiod has shown to affect the growth and development of soybean (Adam *et al* 2001). Most of the soybean genotypes are sensitive to photoperiod and different maturity groups are expected to have differential response to photoperiod. Under Punjab conditions soybean genotypes sown in June- July are likely to flower at the same time due to sensitivity to day length leading to variation in duration of vegetative and reproductive development which is controlled by both genetics and photoperiod (Kumudini *et al* 2007) and expected to have affect on source-sink relationships.

Considering the constraints in the production potential of soybean, it is worth to study the influence of different photoperiod conditions on the production potential of soybean. It is also utmost important to understand the physiological basis of yield variation due to changes in photoperiods conditions, since a simple description of growth and yield without the context of growing condition is inadequate. The present knowledge of the physiology of yield and inter relationship of source-sink and physiological characters with the environment is meager.

Considering the present Punjab scenario as depleting natural resources and unabated soil degradation as a consequence of intensive agriculture calls for crop diversification. Soybean is the most viable option, which requires less number of irrigations and inputs as compared to paddy. The overall aim of this study is:

- To investigate physiological factors involved in regulating source-sink relationships under variable photoperiods.
- To study the mobilization of reserves within the soybean canopy throughout growth and development.

## REFERENCES

Adam S R, Pearson S and Hadley P (2001) Improving quantitative flowering models through a better understanding of the phases of photoperiod sensitivity. *J Exp Bot* **52**: 655-62.

Board J E and Tan Q (1995) Assimilatory capacity effects on soybean yield components and pod number. *Crop Sci* **35:** 846-851.

Caffaro S V and Nakayama F (1988) Vegetative activity of the main stem terminal bud under photoperiod and flower removal treatments in soybean. *Aust J Plant Physiol* **15:** 475-480.

Cooper R L (1981) Development of short-statured soybean cultivars. *Crop Sci* **21:** 127-131.

Desclaux D, Huynh T T and Roumet P (2000) Identification of soybean plant characteristics that indicate the timing of drought stress. *Crop Sci* **40:** 716-22.

Eghareuba P N, Horocks R D and Zuber M S (2006) Dry matter accumulation in maize (*Zea mays* L.) in response to defoliation. *J Agron* **93:** 40-43.

Egli D B (1998) *Seed Biology and the Yield of Grain Crops*. CAB International, UK.

Egli D B and Zhen-wen Y (1991) Crop growth rate and seeds per unit area in soybeans. *Crop Sci* **31:** 439-442.

Ellis R H, Asumadu H, Qi A and Summerfield R J (2000) Effects of photoperiod and maturity genes on plant growth, partitioning, radiation use efficiency and yield in soybean [*Glycine max* (L.) Merrill] 'Clark'. *Ann Bot* **85:** 335-343.

Guiamet J J and Nakayama F (1984) The effects of long days upon reproductive growth in soybeans (*Glycine max* (L.) Merr.) cv. Williams. Jpn. *J Crop Sci* **53:** 35-40.

Hadley P, Roberts E H, Summerfield R J and Minchin F R (1984) Effects of temperature and photoperiod on flowering in soybean (*Glycine max* (L.) Merrill) varieties. *Agron J* **63:** 227-230.

Han T and Wang J (1995) Studies on the post-flowering photoperiodic responses in soybean. *Acta Botan Sinica* **37:** 863-869.

Hardman L L and Brun W A (1971) Effects of atmospheric carbon dioxide enrichment at different development stages on growth and yield components of soybeans. *Crop Sci* **11:** 886-888.

Hou A, Chen P, Alloatti J, Li D, Zhang B and Shi A (2009) Genetic variability of seed sugar content in worldwide soybean germplasm collections. *J Crops Sci* **49:** 903-12.

Jenner C F, Ugalde T D and Aspinall D (1991) The physiology of starch and protein deposition in the endosperm of wheat. *Aust J Pl Physiol* **18:** 211-26.

Jiang H and Egli D B (1995) Soybean seed number and crop growth rate during flowering. *Agron J* **87:** 264-267.

Kantolic A G and Slafer G A (2001) Photoperiod sensitivity after flowering and seed number determination in indeterminate soybean cultivars. *Field Crops Res* **72:** 109-118.

Kumudini S, Pallikonda P and Steele C (2007) Photoperiod and *E*-genes directly influence the duration of soybean reproductive development. *Crop Sci* **47:** 1510-17.

Lei W, Tong Z and Shengyan D (2006) Effect of drought and rewatering on photosynthetic physioecological characteristics of soybean. *Acta Ecologica Sin* **26:** 2073-78.

Liu X B, Herbert S J, Hashemi A M, Litchfield G V, Zhang Q Y and Barzegar A R (2006) Responses of soybean yield and yield component distribution across the main axis under source-sink manipulation. *J Agron Crop Sci* **192:**140-46.

Ma B L, Dwyer L M, Costa C, Cober E R and Morrison M J (2001) Early prediction of soybean yield from canopy reflectance measurements. *Agron J* **93:** 1227-1234.

Madani A, Shirani-Rad A H, Pazoki A, Nourmohammadi Gh and Zarghami R (2010) Grain filling and dry matter partitioning responses to source: sink modifications under post-anthesis water and nitrogen deficiencies in winter wheat (*Triticum aestivum* L.). *Acta Scientarum Agron* **32:** 145-51.

Misra A, Srivastava N K, Srivastava A K and Khan A (2009) Influence of etherel and gibberellic acid on carbon metabolism, growth, and alkaloids accumulation in *Catharanthus roseus* L. *Afr J Pharm Pharmacol* **3:** 515-20

Ohashi Y and Nakayama N (2009) Differences in the responses of stem diameter and pod thickness to drought stress during the grain filling stage in soybean plants. *Acta Physiol Pl* **31:** 271-7.

Paul M J and Foyer C H (2001) Sink regulation of photosynthesis. *J Exp Bot* **52**: 1383-400.

Raper C D and Kramer P J (1987) Stress physiology, in Wilcox J R (ed.) *Soybeans: Improvement, Production and Uses.* Madison, WI, agronomy monograph no. 16, pp. 589-641.

Schou J B, Jeffers D L and Streeter JG (1978) Effects of reflectors, black boards, or shades applied at different stages of plant development on yield of soybeans. *Crop Sci* **18:** 29-34.

Shibles R M, Anderson I C and Gibson A H (1975) Soybean, in Evans L T (ed.) *Crop physiology*, Cambridge University Press, London. pp. 151-89.

Soy Stats (2010) *A reference guide to important soybean facts and figures*. American Soybean Association.

Soy Stats (2013) http:/ / www.soystats.com/2013/Default-frames.htm.

Summerfield R J, Asumadu H, Ellis R H and Qi A (1998) Characterization of the photoperiodic response of post-flowering development in maturity isolines of soyabean [*Glycine max* (L.) Merrill] ‘Clark’. *Ann Bot* **82:** 765-71.

Ustun A, Allen F L and English B C (2001).Genetic progress in soybean of the US mid-south. *Crop Sci* **41:** 993-998.

Zhang L, Wang R and Hesketh J D (2001) Effects of photoperiod on growth and development of soybean floral bud in different maturity. *Agron J* **63:** 944-948.

## CHAPTER II

## REVIEW OF LITERATURE

Soybean is a member of the family *Fabaceace*, subfamily *Papilionoideae*, and tribe *Phaseoleae*. The crop originated in Manchuria, a province of China and domestication probably took place between 1700 and 1100 BC (Hymowitz and Singh 1987). Soybean has been repeatedly mentioned in later records as an important cultivated legume crop throughout Asia and particularly in China.

Soybeans growth and development is influenced by temperature. Soybean, however, is very sensitive to photoperiod (daylength) and does not change from vegetative to reproductive growth until a critical daylength is met. Soybean has been recognized as a quantitative short-day plant, in which flowering is promoted within a certain time range but is retarded and/or diminished outside this time frame (Loomis and Connor 1992). The soybean plant flowers earlier and more profusely in response to day lengths that are shorter than a certain value (usually 14 hours) within a 24-hour cycle (maturity group V and up). This requirement restricts a cultivar's adaptability to a band of about 150 miles north and south of its adapted area. Photoperiod and temperature are the two main environmental factors controlling classification of soybean cultivars into maturity groups (as discussed in introduction).Therefore, an attempt has been made in the present investigation to understand the growth, development and physiology of different maturity date genotypes of soybean as influence by planting dates under variable photoperiods. Keeping in view the above facts, the literature reviewed has been divided into following sub-sections:

2.1 Developmental Stages
2.2 Photoperiod
2.3 Temperature
2.4 Vegetative Growth
2.5 Reproductive Growth
2.6 Growth Parameters
2.7 Dry Matter Accumulation and Its Partitioning
2.8 Biophysical Parameters
2.9 Yield and Yield Attributes
2.10 Biochemical Parameters

### 2.1 Developmental stages of Soybean

An understanding of the developmental stages of a soybean plant is important in evaluating its yield potential. The use of indeterminate versus determinate as well as plants of various maturity groups allows growers to maximize the yield potential within their growing season. The developmental stages in soybeans are characterized by the standards established by Fehr and Caviness (1977) (Figure 1). The life cycle of soybean is split into vegetative (V stage) and reproductive (R stage) stages. The stages begin with VE, defined as seedling emergence, the appearance of the seedling above the soil surface. The next stage is the VC stage, which is when the cotyledonary leaf open and the node above it has a leaf that has just unrolled. In an unrolled leaf, the edges of the leaf blade must not be touching one another. Following the VC stage, all other vegetative (V stages) stages are numbered according to the number of nodes on the main axis (Vn) with a fully developed leaf (Bean and Miller 1998). A fully developed leaf is defined as one that has a leaf above it (at the next node) that has just unrolled. The V1 stage is defined as when the primary unifoliate leaf (at the next node above the cotyledons) is fully developed and the leaf at the node above them has just unrolled. Subsequent vegetative stages are defined in a similar manner. For example, the V5 stage is when the sixth node above the cotyledon has a fully developed leaves and the leaf above it has just unrolled.

The reproductive (R stage) stages are split into two flower stages (R1 and R2), two pod stages (R3 and R4), two seed stages (R5 and R6), and two maturity stages (R7 and R8). The R1 stage is defined as the stage at which one open flower appears at any node on the main stem. The R2 stage refers to an open flower at one of the two upper most nodes on the main axis with a fully developed leaf. The R3 stage is when atleast one pod 5 mm long is apparent on one of the four uppermost nodes of the main stem axis with a fully developed leaf. The R4 stage occurs when at least one pod reaches 2 cm at one of the four uppermost nodes of the main stem axis with a fully developed leaf. The R5 stage occurs when at least one seed within a pod is 3 mm (1/8 inch) long at one of the four uppermost nodes of the main stem axis with a fully developed leaf. At the R6 stage at least one seed extends to the length and width of the pod cavity at one of the four uppermost nodes of the main stem axis with a fully developed leaf. The R7 stage is considered to be the point at which one normal pod on the main stem reaches its mature pod color. The R7 stage is when seed filling ends and is called physiological maturity. At this stage, the seed has about 60% moisture and contains all necessary plant parts to germinate. The normal color of a mature pod can range from tan to brown depending on the genotype. The R8 stage is when 95% of the pods have reached their mature pod color and is called harvest maturity. By this time, the soybean seed would have a moisture level of 15%, which is considered the harvestable level.

## Developmental Stages

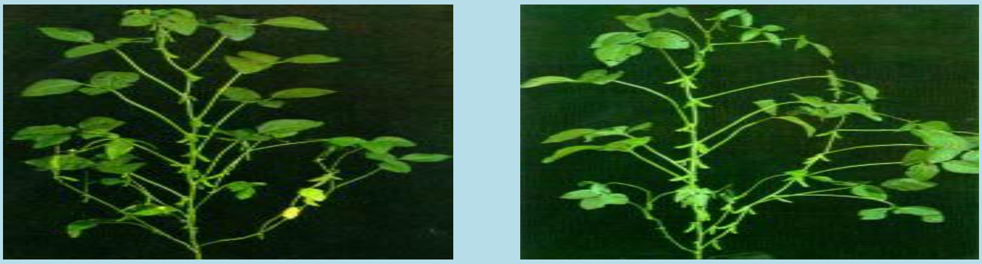
| Vegetative Stages | Reproductive Stages |
|---|---|
| VE (emergence) | R1 (beginning bloom, first flower) |
| VC (cotyledon stage) | R2 (full bloom, flower in top 2 nodes) |
| V1 (first trifoliolate) | R3 (beginning pod, 3/16” pod in top 4 nodes) |
| V2 (second trifoliolate) | R4 (full pod, 3/4” pod in top 4 nodes) |
| V3 (third trifoliolate) | R5 (1/8” seed in top 4 nodes) |
| V(n) (nth trifoliolate) | R6 (full size seed in top 4 nodes) |
| V6 (flowering will soon start) | R7 (beginning maturity, one mature pod) |
|  | R8 (full maturity, 95% of pods on the plant are mature) |

**Figure1. Developmental stages of soybean.**

**Beginning Bloom (R1)** **Full Bloom (R2)**

**Beginning Pod (R3)** **Full Pod (R4)**

**Figure 2: Reproductive stages (R1 to R4).**



**Beginning Seed (R5)** **Full Seed (R6)**

**Beginning Maturity (R7)** **Full Maturity (R8)**

**Figure 3: Reproductive stages (R5 to R8).**

## 2.2 Photoperiod

Both photoperiod and temperature control the duration of pre- and post-flowering phases. Long photoperiods delay floral initiation and slow down the rate of development of flower primordial (Thomas and Raper 1977, Caffaro and Nakayama 1988, Thomas and Kanchanapoom 1991, Fleming *et al* 1997) and consequently, delay flowering (Hadley *et al* 1984, Upadhyay *et al* 1994, Zhang *et al* 2001). Although it is also known that long photoperiods extend the duration of post-flowering phases as well (Thomas and Raper 1976, Guiamet and Nakayama 1984, Summerfield *et al* 1998, Kantolic and Slafer 2001, Han *et al* 2006), our understanding of photoperiodic control of development in soybean has been mostly restricted to pre-flowering responses, which are in fact the bases for the characterization of soybean cultivars into different maturity groups (Summerfield and Roberts 1985). In spite of the high importance of post-flowering phases on yield definition, the knowledge of photoperiodic responses after flowering is fragmentary and far less comprehensive.

In consequence, the link between post flowering response to photoperiod and yield has not been established. A quantitative or continuous response to photoperiod is a pre-requisite for a plant which is permanently sensing a changing photoperiod environment and has a continuous capacity to respond to this perception. Although it has been found that indeterminate soybeans quantitatively responded to the length of photoperiod when the treatments were imposed continuously (Kantolic and Slafer 2005), it is not clear if post-flowering development is quantitatively responsive to the length of the exposure to long photoperiod or whether the response saturates in just one or few cycles of long photoperiod. In wheat (*Triticum aestivum*), a long-day plant, there is some evidence of the existence of a so-called ‘memorized’ or ‘historic’ effect of photoperiod on development.

Changes in sensitivity to photoperiod during the post flowering phases and the possibility of memorized effects of photoperiod on later development have to be assessed before it is possible to design breeding or management strategies which apply our understanding of soybean post-flowering response to photoperiod. Moreover, the evaluation of these responses under highly controlled environments as proposed by Adam *et al* (2001) is possibly limited if their consequences on seed production and yield are to be drawn.

The soybean has ability to continuously perceive the photoperiod under which they are grown during their reproductive development, as found in other crop species e.g. wheat and barley (Miralles *et al* 2003). During most of post-flowering phases plants were sensitive to changes in photoperiod. In soybean, it has been found previously that photoperiod effects persist throughout flowering, podding, seed filling and maturation phases of maturity group, when evaluating highly contrasting and constant photoperiod regimes (12 h against 18 h; Han *et al* 2006).

Soybean seed weight is generally source-limited (Egli 1999, Borra´s *et al* 2004) and an increase in seed number without changes in crop photosynthesis should result in smaller seeds, as source and sink are usually in balance (Egli and Bruening 2001). It has been proposed that the less inductive photoperiod during reproductive phases increases assimilate availability, as a longer duration results in greater radiation interception and greater production of assimilates (Kantolic and Slafer 2005) and there is some evidence in wheat to support this hypothesis (Gonza´lez *et al* 2005). If the photoperiod responses are mediating a mechanism such that seed weight maintains high while seed number is nearly doubled, manipulating sensitivity to photoperiod during the critical pod formation phase may be a means of improving the source : sink ratio during the critical period, a very potent trait to further increase soybean yields (Kumudini 2002).

However, the adaptation is not only controlled by photoperiod but also by the temperature which influences the time required to reach floral differentiation, floral expression and subsequent reproductive stage under inductive photoperiods. Norman (1978) reported that longer day length delay flowering in soybean and results in large number of flowers, but the percentage of flower and pod shedding also increases. Settimi (1987) reported that a long reproductive photoperiod was positively correlated with branch development. Verma and Sawaji (1994) screened 3000 soybean genotypes for photoperiodic insensitivity and reported that most rainy season soybean varieties do not do well in the winter seasons characterized by prolonged flowering and maturity periods. The genotypes which fit under short day conditions of 9 – 10 hours were considered as photoperiod insensitive.

Han and Wang (1995) indicated that flowering of early soybean varieties was insensitive to photoperiod. However, post flowering development was affected by both pre and post flowering photoperiods. To determine the response of some soybean genotypes to photoperiod and temperature in different environments (different dates during *kharif* and spring) Deka and Talukdar (2000) observed majority of the genotypes took less than 70 days to flower during *kharif* sowing environments while 70 – 80 days in spring environments.

## 2.3 Temperature

Calves *et al* (1988) found that low night temperature reduced the assimilate translocation within soybean plants, particularly that of newly synthesized assimilates, thereby decreased seed yield. Nigam *et al* (1990) and Tiwari *et al* (1994) studied the performance of different soybean cultivars under different environmental conditions and reported significant genotype and environment interaction. Exposing the different reproductive phases to different levels of high temperatures, Gibbson and Mollen (1996) observed 27 percent reduction in the seed yield when exposed to $35^0$C for 10 hrs per day from flowering to maturity. The reduction in seed yield was due to reduced photosynthetic rates. They also concluded that the reduction in yield from high temperatures are primarily a response to day temperatures and moderate to high night temperatures have only a small effect on seed yield components.

## 2.4 Vegetative growth

The amount of mobile reserves in the vegetative parts will determine the yield gap (Madani *et al* 2010). Limitations to crop yields are often sought in either source or sink restrictions. The rate of assimilate transportation from source to sink depends upon the rate of assimilates production in the source on one hand and the rate of up-loading the products at sink. Mature leaves produces more assimilates than their need and therefore export the extra carbohydrates to other organs. They are called source and the destination of photosynthetic products are called sink (Emam *et al* 1994).

The source activity, which determines the availability of assimilates and the sink capacity, which determines the potential of assimilate utilisation are the two major processes involved in determining the yield potential of a crop (Egli and Bruening 2001). Modification of source activity of soybean during flowering and early pod expansion usually results in a corresponding change in pod number and this has been well described under optimal soil moisture conditions (Egli and Yu 1991, Board and Tan 1995, Andrade and Ferreiro 1996, Board and Harville 1998). Yield production begins with vegetative growth when the formation of organs for nutrient absorption and photosynthesis provides the machinery to produce yield.

The rate of canopy photosynthesis is determined by the inherent photosynthetic capacity of the leaves, environmental conditions (temperature, solar radiation, $CO_2$

concentration, nutrient and water availability) and the proportion of the incident solar radiation absorbed by the plant canopy. Leaf area is the ratio of the leaf area to the ground area (Watson 1947), and is described by the leaf area index (Wells 1991, Board and Harville 1996). There is a linear relationship between LAI and radiation interception until radiation interception is maximized (Heilman *et al* 1977, Taylor *et al* 1982). The length of the vegetative growth phase, maximum vegetative mass and LAI is directly related to cultivar maturity (Egli 1993, 1994, Edwards and Purcell 2005).

Canopy photosynthesis ($CO_2$ fixation expressed on a ground area basis) (Wells 1991) and crop growth rate (an indirect estimate of canopy photosynthesis) (Board and Harville 1994) are directly related to LAI and radiation interception during the initial stages of vegetative growth. Canopy photosynthesis increases rapidly during early vegetative growth and reaches its maximum level when radiation interception is complete. Canopy photosynthesis, crop growth rate and ultimately yield will be reduced if the canopy does not reach maximum interception by the beginning of reproductive growth. The potential size of the yield container is determined by the number of seeds that are set (a function of fruit number and seeds per fruit) and the potential size of the seed (Egli 1998).

Plant height and number of branches are influenced by the interaction between the environmental variables and genetic makeup of the plant. Among the environmental variables, temperature strongly influences branching, plant height and length of the vegetative period. Raut *et al* (1991) reported a wide genotypic variation for plant height and number of branches among the ten soybean genotypes with a range from 18.0 cm (Monetta) to 50.0 cm (MACS-II) and 2.6 (DS – 11 – 2) to 5.8 (MACS-111) respectively during *kharif* season indicating variability for these traits. The traits contributing to seed yield in determinate, indeterminate and semi determinate soybean types, has significant influence on seed yield, irrespective of growth habit (Bhattacharyya and Ram 1992). Naidu *et al* (1993) observed a whole genotype variability for plant height among 20 diverse genotypes of greengram and the range was from 34.5 to 54.4 cm, but variation for branches per plant was low (1.23 to 1.92), showing that growing environment had a profound influence on these parameters.

Sharma and Sharma (1993) observed a wide variation in plant height (57.2 to 83.9 cm) and number of branches (3 to 4.2) among soybean genotypes. Similarly, (Verma and Sawaji 1994) also indicated that in soybean, the plant height varied from 20.5 to 120.0 cm among 3000 lines of soybean. Ouattara and Weaver (1995) found that determinate plants have more main stem branches and more two seeded pods than indeterminate plants and further reported that growth habit did not affect total pods per plant or branch per plant.

## 2.5 Reproductive growth

The rate of photosynthesis may be affected by the size of the reproductive sink and reducing sink size often reduces photosynthesis (Mondal *et al* 1978, Goldschmidt and Huber 1992). Relating the rate of photosynthesis to reproductive sink size is completely untenable with the argument that fruit number and sink size are determined by the assimilate supply (Egli 1998). The competition for assimilate between vegetative and reproductive sinks could reduce fruit and seed numbers (Egli 1998). The soybean plant has two mechanisms by which fruit and seed number are adjusted to match the assimilate supply. First the flower production responds to environmental conditions and varies among cultivars and second is not all flowers produce fruits and not all fruits survive until maturity (Jiang and Egli 1993).

The number of flowers is directly related to the number of nodes (Egli 2005), although the environmental conditions can influence the number of flowers per node. Late-maturing cultivars generally have more nodes (Jiang and Egli 1993), while delayed planting shortens the vegetative growth period and reduces node number (Egli and Bruening 2000). Flowering time is important because, environmental condition during the reproductive phase have a major impact on final yield (Kobraee *et al* 2010).

Abortion is influenced by manipulation of the assimilate supply (Mann and Jaworski 1970, Heitholt *et al* 1986, Jiang and Egli 1993, Miceli *et al* 1995). Abortion and abscission occur at several stages of reproductive development with flowers (Kato *et al* 1955, Huff and Dybing 1980, Heitholt *et al* 1986), immature pods (Hansen and Shibles 1978, Heitholt *et al* 1986) and seeds (Duthion and Pigeaire 1991, Westgate and Peterson 1993) all participating in the process. A fruit development suggests that abortion may result from competition for assimilate between rapidly growing fruits from early flowers and small fruits from later developing flowers (Bruening and Egli 1999, Egli and Bruening 2002). The capacity to adjust flower number and to abort flowers and developing fruits allows soybean to match the size of the yield container to the productive capacity of the plant in most environments.

The export rate of sucrose from source (leaves) to sink (fruits/seeds) organs is dependent on the current photosynthetic rate and the concentration of sucrose in the leaves (Grodzinski *et al* 1998, Komor 2000). The export rate of sucrose could be expressed as a positive linear function to the photosynthetic rate and the concentration of sucrose in the leaves (Fader and Koller 1983, Huber *et al* 1984). Both a low rate of photosynthesis and a low sucrose concentration in the leaves may cause a decreased rate of sucrose export to the sink organs, and thereby affect the reproductive development.

Intensity and quality of solar radiation intercepted by a soybean canopy during the reproductive period is an important environmental factor determining soybean yield and yield components (Board and Harvill 1992, Evans 1996, Biabani *et al* 2008). Increased seed yield of soybean through narrow rows, can be attributed to increased light interception during reproductive period (Board *et al* 1992, Board and Harville 1996, Liu *et al* 2004). Light enrichment initiated at early flowering stages increased productive pod number, resulting in a 144 to 252% increase in seed yield (Mathew *et al* 2000).

### 2.6 Growth Parameters

The technique of growth analysis has been extensively used in recent years for better understanding of the physiological basis of yield variation in crop in chronological sequence elucidate and account the causes for differences in yield through the events that have occurred at different stages of growth (Krishnamurthy *et al* 1973). Leaf area duration is an important factor for growth and development of a crop. Sinclair and Dewit (1976) reported that the leaf area plays an important role in determining productivity in soybean. Significant genotypic variability in CGR among blackgram genotypes at 49 and 56 days after sowing. NAR and RGR decreased with the advancement of crop growth in all the genotypes (Pandey *et al* 1978).

The dry matter accumulation and leaf area in diverse soybean cultivars showed significant difference for various growth analysis parameters like crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR), leaf weight ratio (LWR) and specific leaf area (SLA). The CGR was maximum at late vegetative and early reproductive stages (18.6 $m^{-2}$ $days^{-1}$). Whereas, the RGR, NAR and LAR were highest during early vegetative growth and decreased as season progressed (Scott and Batchelor 1979).

Soybean leaves adapt to their growth regime primarily by adjusting leaf dimensions (leaf thickness) and the high irradiance during growth resulting in thicker leaves with more photosynthetic apparatus per unit leaf area (Gourdon and Planchon 1982). Reddy and Saxena (1983) studied the leaf area index in six diverse soybean genotypes and showed significant differences for this trait. Singh *et al* (1985) observed that LAI was higher in all the greengram genotypes grown during summer as compared to *kharif*. Specific leaf weight continued to increase from 33 to 44 days after sowing in all the varieties of greengram during both *kharif* and summer seasons and decreased thereafter until maturity.

Nijhawan (1986) found that leaf area differed significantly among twenty five promising varieties of greengram. An increasing trend of leaf area upto 15 days after the initiation of buds and thereafter there was a study decline in all the cultivars. The high yielding cultivars also possessed higher leaf area. Significant differences among twenty five diverse greengram genotypes with respect to both SLW and LAR. Seed yield is associated with high LAI and number of seeds / $m^2$ and moderate seed weight and dry matter production in soybean. Panwar *et al (*1986 ) noticed both LA and LAI attained maximum values around 49th day from sowing, remained stable upto 70 days after sowing and started declining thereafter in all the greengram genotypes studied. The cultivars which possessed larger leaf area as well as leaf area index were high yielders.

Temperature and solar radiation affects growth parameters of soybean. Early soybean cultivars had higher RGR and CGR but lower leaf area duration and partitioned more assimilates to reproductive parts than the late cultivars (Shah 1989). They further reported a high degree of variability for CGR, RGR and NAR. Egli and Yu (1991) reported that the number of seeds per unit area is an important yield component in soybean and linear relationship between CGR and a seed per $m^2$ was established. They computed that a seed per $m^2$ is a direct function of canopy photosynthesis and partitioning co-efficient.

Sharma and Sharma (1993) reported that the CGR, RGR and NAR differed significantly among the soybean genotypes. The CGR and NAR values ranged from 11.6 to 21.6 g $m^{-2}$ $day^{-1}$ and 0.17 to 2.21 mg $cm^{-2}$ $day^{-1}$, respectively. However, significant differences for dry matter accumulation were not observed. Zhang *et al* (1993) observed that the LAI of 3.98 at flowering, 5.80 at podding and 4.91 at seed filling, are most ideal for high yield in some of soybean genotypes. Similarly, Bhatia *et al* (1996) observed differences in SLW (at beginning seed fill stage) for various soybean cultivars and the range was from 4.73 (PK-472) to 4.81 (MACS 101).

The important morpho-physiological traits associated with higher productivity in greengram are higher number of leaves, higher TDM, LAI, CGR, LAD, photosynthetic rate, nitrate reductase activity, higher number of fruiting clusters, higher seeds per plant and higher harvest index. These traits may be considered important for developing an ideotype concept in greengram (Goswami 2000). Forty one genotypes of cluster bean and forty seven genotypes of mothbean were evaluated for crop physiological and yield traits during *kharif* There exists a significant relationship between SLA and seed yield, further suggested that low SLA could be an important character for selecting for higher yield (Talwar *et al* 2004).

### 2.7 Dry Matter Production and Its Partitioning

Shibles and Weber (1966) showed that during vegetative stage, the dry matter production increased linearly as leaf area increased until LAI of 4.0 was reached. Seasonal dry matter accumulation exhibits essentially a linear trend between about mid – bloom and late seed filling stage with a maximum vegetative dry weight occurring at about mid – bean filling stage. Vegetative and pod dry weight decline during the later stages of bean filling as tissues lose dry matter because of respiration and mobilization to the bean fraction (Evans 1975). Reddy and Saxena (1983) in soybean reported that the total dry matter production increased with an increase in the age of plant upto 100 DAS and then remained constant in Bragg, Clark – 63 and Lee upto harvest whereas, it decreased towards harvest in Hardee and improved pelican.

Dry matter production increased with an advancement of the crop and the genotypes with better accumulation of dry matter at reproductive stage were more productive in green gram genotypes (Goswami 2000). While investigating the varietal differences in the dry matter production in both winter and summer grown soybean genotypes. Liaw and Chen (1988) found that the summer crop had a higher LAI coupled with higher photosynthetic rate and resulted in higher productivity as compared to winter crop. They also reported significant correlation among dry matter production, CGR and photosynthetic rate during pod development to maturity in summer, but not in the winter crop. Bhattacharya (1996) concluded that the yield potential in mungbean is related to physiological traits during pre and post flowering periods. During pre-flowering period, dry matter and its rate of accumulation in leaf as well as whole plant had a significant influence on yield. During post flowering period, stem and total plant dry weight had definite role in influencing the yield in mungbean genotypes. It was concluded that in normal seeding of chickpea genotypes, yield is greatly affected by dry matter partitioning in stem and leaf and their respective rates of accumulation. While during late seeding (45 days late to normal) yield had substantial positive effects for total dry matter during pre and post flowering periods (Ganguly and Bhattacharya 2001).

### 2.8 Biophysical Parameters

The relationship between crop growth rate and the rate of photosynthesis is well known. The rate of photosynthesis depends on carbon diffusion into the site of carbon assimilation and the diffusion process in turn depends mainly on stomatal and mesophyll conductances. In legumes, the photosynthetic rate during vegetative phase had more pronounced effect on total dry matter production. However, photosynthetic rate declined sharply as pods began to develop, which was further associated with a fall in total nitrogen content, loss of ribulose 1, 5 – bisphosphate carboxylase activity and disintegration of nodules in legumes. Christy and Porter (1982) reported that diurnal changes in canopy photosynthesis is one of the important determinants of total photosynthates available for plant use and the peak canopy photosynthesis occurs at 60 per cent of full sunsight. Lugg and Sinclair (1981) found no greater apparent photosynthesis for soybean leaves developed during reproduction; they and Gordon *et al* (1982) observed that such leaves retained their maximum activity for longer periods than lower leaves. They further explained the lower leaves generally will have slower AP during their most active period than do middle or upper leaves.

For indeterminate types, leaves reproduced during vegetative growth have AP ranging from 19 to 25 u mol $m^{-2}$ $s^{-1}$, but leaves produced during flowering and pod growth have rates ranging from 30 to 40 u mol $m^{-2}$ $s^{-1}$. Wells *et al* (1982) in soybean reported that during seed filling stage, the canopy photosynthesis progressively decreases and it will be zero near physiological maturity. High CER has always been considered desirable characteristics and several attempts have been made to select for a specific photosynthetic component that would results in a higher CER.

. Hence, CER is an alternative tool, which gives broad view of photosynthetic apparatus (Jaleh 1985, Rao and Ghildiyal 1985) observed that the rate of photosynthesis in greengram attained its peak at 28 days after sowing and decreased subsequently. Wells *et al* (1986) reported that the cultivars with high canopy photosynthesis during reproductive development also had highest SLW and these genotypes possessed higher leaf soluble proteins and RUBP carboxylase levels per unit leaf area. Shibles *et al* (1987) reported moderate temperatures of 20 – $30^0$C is desirable for photosynthesis in soybean. Similarly, Zou *et al* (1991) while studying the photosynthesis for two soybean cultivars under different range of temperatures reported that the most optimum temperature is $28^0$C for higher photosynthetic rate in soybean.

The greater sink demand by higher yielding cultivars was responsible for higher apparent photosynthesis and not vice versa and they further stated that seed yield is positively correlated with apparent photosynthesis only at seed development stage in late maturing genotypes. Canopy apparent photosynthesis (CAP) of soybean plants during reproductive development differs among genotypes, which is a heritable trait and is positively associated with seed yield ($r = 0.66$). This strongly holds good for determinate types also (Ashley and Boerma 1989) they further showed that canopy photosynthesis decreases during reproductive development and showed genotypic variation for this trait.

On the other hand, Panwar *et al* (1990) found that the rate of photosynthesis in greengram was higher at 50 days after sowing as compared to 60 days after sowing. Sung *et al* (1990) reported that in soybean, the rate of photosynthesis is highest during vegetative stage and observed no correlation between photosynthetic rate per unit leaf area and seed yield but there was a positive correlation between photosynthetic rate per plant and seed yield. Zou *et al* (1991) reported significant differences in rate of photosynthesis and diffusive resistance among soybean cultivars and further opined that the optimum temperature for photosynthesis is $28^0$C. Fu and Zhang (1993) studied the photosynthetic rate, RUBP carboxylase activity, chlorophyll content, SLW and stomatal resistance and further reported that photosynthetic rate of wild soybean was higher than that of cultivated soybean at vegetative stage, but lower at the reproductive stages.

Mingan *et al* (1995) reported that the apparent photosynthesis, stomatal conductance, mesophyll conductance, intercellular $CO_2$ concentration and respiration rates were greater at the late seed filling stage than at flowering stage in 12 soybean cultivars studied. Venkateshwarlu and Balasubramanian (1993) studied various biophysical parameters, i.e., rate of photosynthesis, transpiration and stomatal conductance among eight greengram cultivars (both traditional and high yielding) at different growth stages under rainfed condition and concluded that all the above biophysical processes showed a relatively higher rate during early pod growth stage and declined subsequently with the advancement in crop growth.

### 2.9 Yield and yield attributes

The yield of soybean is determined by two components: the number of seeds per unit area and individual seed weight (Kokubun *et al* 2001). Because seed per pod is genetically influenced (Shibles *et al* 1975), the number of seeds is determined predominately by the number of pods, which is largely dependent on the number of floral buds that initiate pods and attain maturity (Desclaux *et al* 2000). Soybean plants produce an abundance of floral buds, but a large proportion of the ovaries are aborted prior to developing into mature pods (Wiebold *et al* 1981, Dybing *et al* 1986). It has been reported that 40–80% of the flowers and pods initiated eventually abort under conventional cultivation (Wiebold *et al* 1981).

Pod number is primarily determined during early stage of pod development (within 5 days after anthesis) (Dybing *et al* 1986). The individual seed weight is a product of the rate and the duration of seed filling (Munier *et al* 1998), it is generally determined during seed filling after the pod number had been fixed (Westgate and Grant 1989, Desclaux *et al* 2000, Brevedan and Egli 2003).

Both yield components (pod number and individual seed weight) are genetically determined (Tischner *et al* 2003) and are subjected to environmental conditions that prevail during reproductive development (Fageria *et al* 1997) The seed-filling period starts when the seeds begin to accumulate dry matter and ends at physiological maturity ( Tekrony *et al* 1979). The total seed growth rate is directly affected by the assimilate supply (Egli 1999) through effects on seed number and individual seed growth rate (Egli and Bruening 2001). There are two sources of assimilate: current photosynthesis and remobilization of stored carbohydrates. The capabilities of the vegetative plant, the characteristics and capabilities of the seeds (the sink), and the environment, all play a role in determining the total seed growth rate (Egli 1998, 2006).

The productivity of the soybean canopy begins to decline shortly after the beginning of seed filling (Larson *et al* 1981, Acock *et al* 1985, Boerma and Ashley 1988) as senescence destroys the photosynthetic machinery and nitrogen is exported from the leaf (Crafts-Brandner and Egli 1987). The nitrogen exported from the senescing leaf is translocated to the developing seed (Morris and Weaver 1983) where it can account for up to 100% of the seed nitrogen at maturity (McBlain and Hume 1981, Zeiher *et al* 1982, Egli *et al* 1983).

The duration of seed fill is under genetic control, but it is also influenced by environmental conditions. Seed-fill duration increases as temperature drops below 30°C in many crops (Egli 2004), but Egli and Wardlaw (1980) found little difference between 20°C and 30°C in soybean. Boote *et al* (1996) found that they could improve the predictability of the CROPGRO soybean simulation model in cool environments by making the seed-fill duration less sensitive to temperature than earlier stages of reproductive growth. Seed-fill duration is regulated by the plant through the supply of assimilate to the developing seed and by the characteristics of the seed (Egli 1998).

Flowering occurs for over four to six weeks period depending upon seasonal adaptation, but the sequence of flowering differs with growth habit and depends on photoperiods and temperature. The seed yield is determined basically by the number of flowers and the percentage of those which can develop into mature seed and seed size. The number of flower per plant is a varietal trait but is also affected by photoperiods and agronomic practices in soybean. Tall late varieties tend to produce more flowers than early short varieties. The high yield potential of some varieties tend to be levelled out by flower and fruit drop which varied from 27 to 87 per cent according to the variety and meteorological conditions (Janicka and Szymer 1989). Increasing the length of seed filling period in soybean has suggested as a means of increasing yield as in other crop species.

The number of seeds per pod ranged from 5 to 15 with an average of 10.7 high yielding strains had higher seed number per pod. Test weight (1000-seed weight) ranged from 10 to 85 g with a mean of 30 g. They further indicated that moderate to heavy seed weight was associated with higher yield. Jepson *et al* (1978) established a positive correlation between harvest index and seed yield after studying 32 soybean genotypes and HI ranged from 0.14 to 0.60. Gay *et al* (1980) reported that yield improvement is possible by lengthening the grain filling period rather than increasing the partitioning of photosynthates to the seed.

Schapaugh and Wilcox (1980) studied the relationship between HI and seed yield in indeterminate, semi-determinate and determinate soybean strains and reported that the HI is inversely correlated with biological yield and plant height. The HI and seed yield were not consistently related from one season to the next and no relationship existed between the growth and the HI of a genotype. Reicosky *et al* (1982) observed a wide range of filling period among the soybean genotypes of 18 to 54 days with a mean of 40 days.

The strains with longer seed filling periods maintained seed growth at the end of seed filling for a longer time than strains with a shorter seed filling period. They further concluded that reproductive period and seed filling period were highly correlated across years, which indicated genetic control of the characters. The characters were highly correlated with each other indicating that any of these methods could be used to evaluate the length of the seed filling period.

The genotypes showed differences for seed yield and the environments also appeared to be affects their performance was shown by (Henry and Daulay 1983) in mothbean genotypes. Genotypic variations were observed between the pod weight and grain yield per plant in greengram (Pramila Kumari and Verma 1983). Meckel *et al* (1984) found that the seed filling period (R5-R7) varied from 22-30 days in some soybean cultivars under different environmental conditions. There is considerable evidence that seed yield is principally a function of number of fruits and seed determined during flowering and fruit set (Shibles *et al* 1987). Hanson (1988) concluded that high yielding genotypes had lower dry weight per seed volume than low yielding genotypes of soybean.

Raghuwanshi *et al* (1988) reported a wide seasonal variation of seed yield in soybean genotypes during *kharif* season mainly due to variation in rainfall. They further concluded based on different dates of sowing that sowing of soybean in the first week of July produced higher grain yield as compared to that sown in the last week of July and also noticed significant differences in seed yield among the four varieties tested. Bhati (1989) recorded a significantly high seed yield when crop was sown on last week of July when compared to early, mid July and early August in moth bean.

Holkar *et al* (1991) also reported a significant interaction effect between genotypes and environment in ten soybean genotypes tested in three *kharif* seasons. The results indicated significant variation for seed yield, days to flowering, pods per plant, days to maturity, 100 - seed weight and harvest index. While, Egli and Yu (1991) reported that yield is the function of the number of seeds per unit area and the average weight per seed which vary with the environment. The primary yield components in greengram are the number of pods per plant, number of seeds per pod and seed weight and all these are quantitative characters and are genetically controlled (Poehlman 1991).

The number of pods per plant, number of seed per plant and 100 seed weight differed significantly in *kharif* season and the number of pods ranged from 41.5 to 93.9, the number of seed per plant varied from 61.6 to 152.9 and 100 seed weight from 9.50 to 13.3 g in ten soybean cultivars (Raut *et al* 1991). Bhattacharyya and Ram (1992) reported that in indeterminate soybean, the plant height, number of pods per branch and pods per plant differed significantly among the cultivars.

Hiremath *et al* (1992) recorded significantly higher yield of 869 kg per ha in the cultivar KHSb-2 as compared to Hardee (745 kg/ha) and Monetta (293 kg/ha) in *rabi* season. The higher yield in these cultivars was attributed to the duration, prolonged vegetative phase with more plant height, higher total dry matter production per plant, more number of pods / plant, higher seed weight per plant and test weight. Pushpakumari *et al* (1993) found significant differences in harvest index and its correlation with seed yield in soybean. In a study to find out the yielding attributing characters in six soybean genotypes in rainfed situation (Sharma and Sharma 1993) obtained seed yield ranging from 21.1 to 26.0 q per ha with a harvest index of 41.9 to 43.8 and oil content of 18.4 to 19.0 per cent and 100 seed weight ranging from 12.6 to 15.4 g. Similarly, the seed yield range of 4.7 to 11.1 g per plant with 19.4 to 40.5 pods per plant, 27.1 to 74.0 numbers of seeds and 100 seed weight of 13.5 to 21.5 were reported in 25 diverse soybean genotypes by (Knoieczny *et al* 1994).

Kumar (2002) observed that there is a significant genotypic difference for majority of the traits in mothbean at different environments and explained linear and non- linear components of genotype and environment interactions were involved in the expression of important traits including grain yield. A yield reduction of 15.8, 29.0 and 45.7 per cent was recorded with successive delay in sowing at every 15 days interval beyond 20th November of winter seasons was observed by (Munir *et al* 2002) in fababean.

### 2.10 Biochemical Parameters

Sucrose is the major solute in the phloem translocates (Patrick 1997) and the concentration of this material determines the turgor induced mass flow in the sieve tube. Photo-assimilate is the major substrate for plant metabolism and most biomass yield is derived from photosynthetically-fixed carbon (Jackson 2003). Assimilate distribution under different fixed source activities might differ from one time to the next. Sala *et al* (2007) stated that late planting shortens the growing season and the chance to better complete pod formation and thus reduces the number of seeds per pod and the final seed yield. The plant couples the nutrient source (the maternal tissue) to the nutrient sink (the seed propaqule) on the assumption there is a proportional linkage of the strength of the seed sink to input of the nutrient source perhaps regulated at the transport level.

Exposure to continuous light, which is a manipulation giving a surplus source rather than a direct sink-limitation, was shown to decrease leaf photosynthetic rate and activation ratio of Rubisco in leaf (Sawada *et al* 1989). Manipulations giving surplus source rather than sink-limitation, exposure to continuous light and high $CO_2$ treatment were shown to decrease leaf photosynthetic rate and activation ratio of Rubisco in leaf (Sage *et al* 1989, Sawada *et al* 1989). These manipulations rise to accumulation of carbohydrate (e.g., sucrose, starch) in leaf (Sawada *et al* 1986, Sage *et al* 1989, Xu *et al* 1994). Existing evidence suggests inhibition of photosynthesis by accumulation of carbohydrate in leaf (Paul and Pellney 2003). Therefore, it is likely that leaf photosynthetic rate is regulated under surplus source and sink-limitation through changes in the activation state of Rubisco by the same regulatory mechanism of photosynthesis that involves the leaf carbohydrate status, although the precise mechanism is still un-known.

The genotypic variation in chlorophyll content has been reported in various crops (Singh *et al* 1985 and Chandrababu 1990). Singh *et al* (1994) found an increasing trend of both chlorophyll ‘a’ and chlorophyll ‘b’ in greengram upto 45 days after sowing and declined significantly at 60 days after sowing. Genotypic differences in chlorophyll a, chlorophyll b and total chlorophyll contents among twenty four cultivars of soybean (different yield groups) have also been reported (Koti 1997). He also observed an increasing trend of these parameters from 30 to 60 days after showing and decreased thereafter irrespective of the cultivars. Higher chlorophyll content was associated with higher yield in some promising hybrids of greengram and blackgram (Jayapragasam *et al* 1998). Goswami *et al* (2000) observed significant differences in chlorophyll a: b ratio and total chlorophyll among the different yield potential greengram genotypes sown during *kharif.*

The nitrate reductase activity, which is the key enzyme in nitrogen metabolism is known to be regulated by various environmental factors apart form its own substrate, nitrate. It is also believed that the reduction of nitrate to nitrite by NRA is the rate limiting process for the utilization of nitrogen in the form of nitrate. The peak activity of NRA coincided with the maximum chlorophyll content thereby complementing the carbon - nitrogen balance in the plant. It was further observed that NRA had positive significant relationship with LAI, chlorophyll content, total dry matter and stem nitrogen content.

Hanway and Weber (1971) studied the accumulation of ‘N’ by soybean plants and reported that the total ‘N’ accumulation in plants followed patterns similar to that of dry matter accumulation. More than 50 per cent of N in the mature seeds was translocated from other plant parts and the remaining from soil and nodules. They reported significant differences in N content of leaves, stem, petioles, seeds and pod walls at different stages.

Harper and Hageman (1972) studied the nitrate reductase profiles within the soybean plant canopy and observed that the mean activity per gram fresh weight per hour of the entire plant was highest in the seedling stage while the total activity (activity per gram fresh weight per hour times the total leaf weight) reached a maximum when the plants were in full bloom to mid pod fill stages.

In soybean, the loss of N from the vegetative tissue coincides with the accumulation of N in the seed (Derman *et al* 1978). Thus, seed contained maximum concentration (6.55%) of nitrogen at maturity followed by leaves (1.46), stems (0.64), roots (1.66) and pods (0.62). The nitrogen content in the leaf reached a maximum level during growth stage R5 and began to decline at approximately growth stage R6. Abrol *et al* (1984) reported that activity of NR is expected to be correlated to growth and yield. But Antony (1995) reported that NR activity was correlated with TDM at early stage, but did not have positive correlation with any of the yield and yield components.

Sung *et al* (1990) noticed the seasonal pattern of variation in NR ‘ase in soybean and reported that leaf NRA declined rapidly after flowering. Li *et al* (1993) found a wide variation in nitrate reductase activity among soybean cultivars and further reported that the young leaves possessed higher activity of the enzyme than the older leaves.

Khan (1994) showed that the NRA was more in shoots than roots under both normal as well as under salt stress conditions in leguminous crops like lentil, chickpea and peas. Hayati *et al* (1995) studied the N redistribution along with photosynthesis during seed filing period and concluded that increasing photosynthesis during seed filling period increased seed dry matter.

Yohe and Poehlman (1972) found an inverse relationship between seed yield and protein content among 321 diverse greengram genotypes. The protein concentration of mungbean seed ranged from 24 to 26 per cent on dry weight basis and the nitrogen requirement for seed development was more (Mitra *et al* 1987). The seed protein content decreased with increased number of seeds $m^{-2}$ and number of pods per plant but increased with increasing average seed weight, whereas seed oil content increased with increasing number of seeds per $m^2$ and number of seed per pod (Benati *et al* 1988). The high protein soybean cultivars exhibited shorter seed filling interval as compared with low protein soybean (Leffel *et al* 1992). Naidu *et al* (1993) reported a wide genotypic variation in shoot nitrogen and seed protein contents among twenty diverse genotypes of greengram.

The shoot nitrogen concentration ranged from 1.98 to 2.66 per cent; while the seed protein content varied from 23.59 to 27.47 per cent. Among sixty diverse genotypes of soybean, the protein content ranged from 34.5 to 41.4 per cent, whereas, the oil content ranged from 19.1 to 22.4 per cent. Jain (1975) and Koti (1997) also reported significant variability of seed protein content among soybean genotypes. The pod walls store and redistribute starch, reducing sugars and nitrogenous materials.

Based on pH optimum, acid invertase and neutral invertase were present. Invertase activities generally peak later than sucrose synthase activity during fruit growth, which is related to enlargement of sink cells, and usually have a sharp rise during the ripening process (Yelle *et al* 1988), which seems related more to ripening or after-ripening of tomato fruits.

Yelle *et al* (1988) found a single peak curve with highest acid invertase activity at mid fruit development. It seems that the sharp rise in invertase activity at maturity may be related to the ripening process in tomato fruits.

PEPC [PEP (phosphoenolpyruvate) carboxylase] (EC 4.1.1.31) is an important enzyme situated at a crucial branch point in plant carbohydrate metabolism. It catalyses the irreversible $\beta$-carboxylation of PEP in the presence of $HCO^{3-}$ to yield OAA (oxaloacetate) and $P_i$ using $Mg^{2+}$ as a cofactor. The enzyme is present in all plants, green algae and cyanobacteria, most archaea and non-photosynthetic bacteria, but is absent from animals and fungi (O'Leary *et al* 2011).

Ammonia is then assimilated into glutamine, glutamate and sometimes in asparagine or even in other amino acids, which serve to translocate organic nitrogen from sources to sinks in legumes and non-legumes (Lea and Miflin 1980, Lam *et al* 1995). Prior to 1970, major route of entry of ammonium into organic form had been considered via glutamate dehydrogenase (GDH) and ubiquitously available reversible enzyme catalyzing reductive amination of 2-oxoglutarate and vice-versa. Glutamate acts as both the acceptor and product of ammonia assimilation by the joint action of glutamine synthetase (GS) (GS: E.C.6.3.1.2) and glutamate synthase ferredoxin dependent (GOGAT: E.C.1.4.7.1) which is often designated as GS-GOGAT cycle (Rhodes *et al* 1980) or the GOGAT cycle (Rhodes *et al* 1980, Robinson *et al* 1992).

Several evidences suggest that GS-GOGAT pathway is the major route for ammonia assimilation in the plants under normal growth conditions (Kumar and Abrol 1990, Lea *et al* 1990). Glutamate dehydrogenase has been found to be of near universal occurrence in living organisms. In a number of species representing the three types of plants utilizing the $C_4$ photosynthetic pathway, 69-87% of NAD-linked GDH activity was equally distributed between mesophyll and bundle sheath cells. GDH activity levels in various plant tissues have been shown to be affected by age, nutritional and environmental conditions (Binbin *et al* 2005).

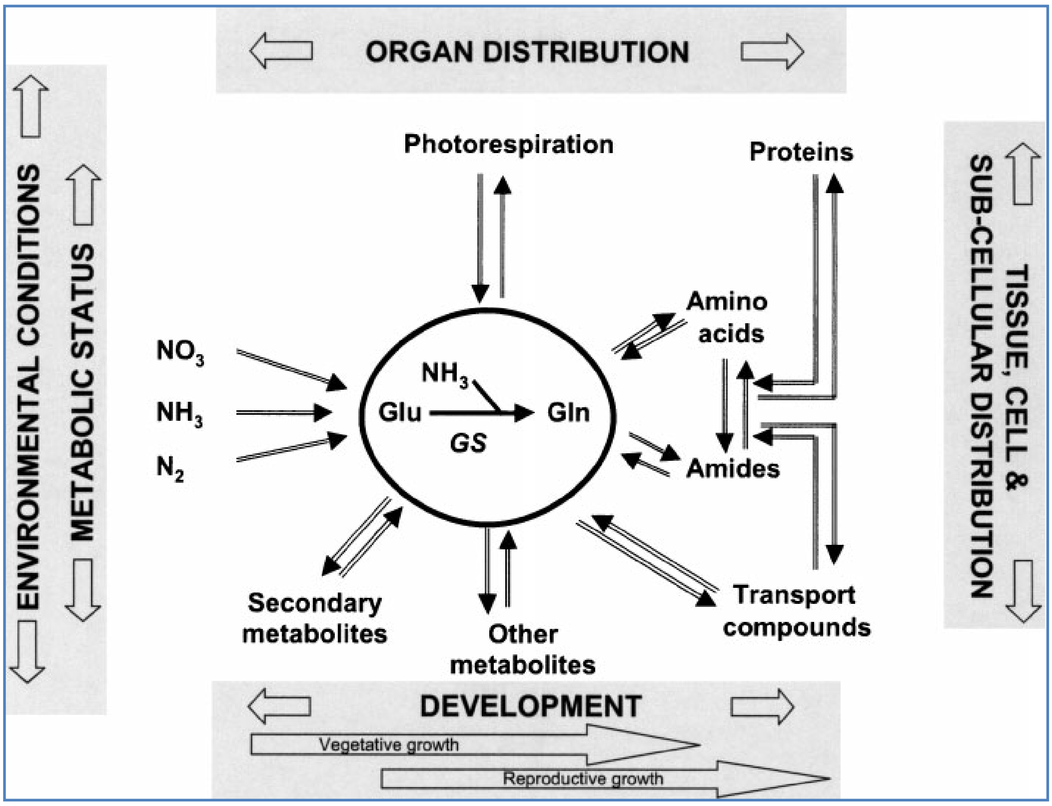


**Figure 4. The central role of GS in the complex matrix of plant N metabolism. The central scheme encompasses the total role of GS. The boxes around the outside indicate the matrix of various locations and environments in which GS may be operating. The direction of the flow of N (and thus the arrows) will depend on which part of the matrix is under consideration. Thus in the developing seed the flux will be from incoming transport compounds towards proteins whilst in the germinating seed the flow will be in the reverse direction**

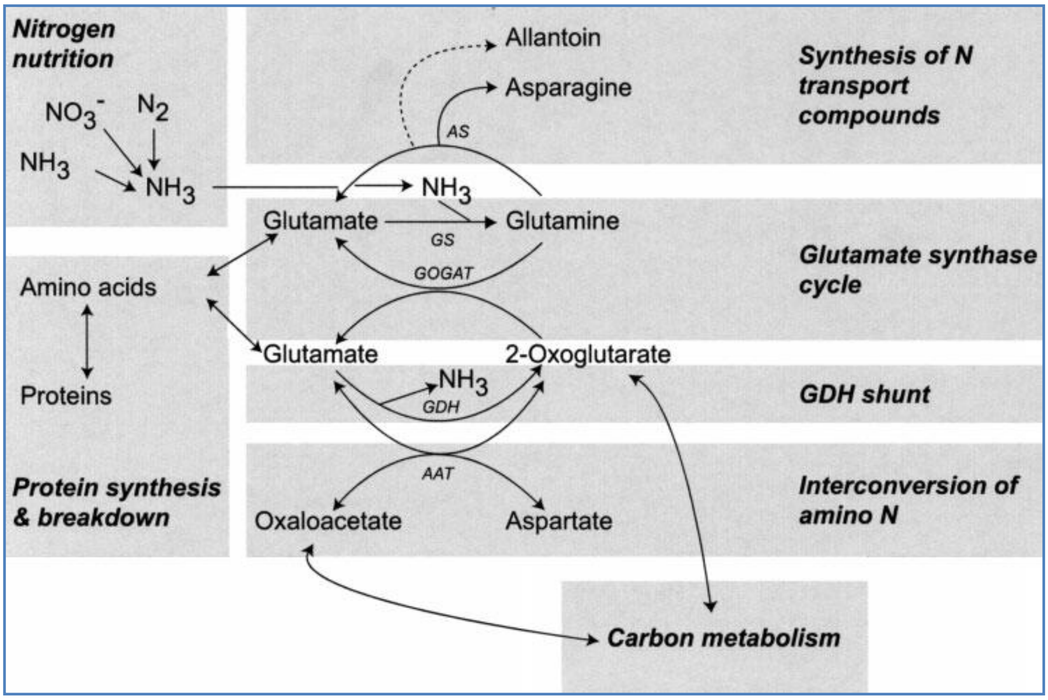


**Figure 5: Enzyme pathways important in the balance of C and N metabolism. AAT, aspartate amino transferase; AS, asparagine synthetase; GS, glutamine synthetase; GOGAT, glutamate synthase.**

## REFERENCES

Abrol Y P, Kumar P A and Nair T V R (1984) Nitrate uptake assimilation and grain nitrogen accumulation. *Adv Cereals Sci and Technol* **6**: 1- 48.

Acock B, Reddy V R, Hodges H F, Baker D N and McKinion J M (1985) Photosynthetic response of soybean canopies to full-season carbon dioxide enrichment. *J Agron* **77:** 942-47.

Adam S R, Pearson S and Hadley P (2001) Improving quantitative flowering models through a better understanding of the phases of photoperiod sensitivity. *J Exp Bot* **52**: 655-62.

Andrade F H and Ferreiro M A (1996) Reproductive growth of maize, sunflower and soybean at different source levels during grain filling. *Field Crop Res* **48:** 155-65.

Antony E (1995) *Nitrogen utilization studies in groundnut (Arachis hypogaea L.,) genotypes*. M.Sc. (Agri.) thesis, University of Agricultural Sciences, Dharwad, India.

Ashley D A and Boerma H R (1989) Canopy photosynthesis and its association with seed yield in advanced generations of soybean. *Crop Sci* **29:** 1042 - 45.

Benati R, Danasd F, Amaducci M T and Venturi G (1988) The effects of sowing date on seed oil and protein content in soybeans (*Glycine max* (L.) Merr). *Rivista di Agronomia* **22:** 279 -81.

Bean B and Miller T (1998) Soybean growth staging. Texas Agricultural Extension Service SCS-1998-23. Website: http://soilcrop.tamu.edu/publications/pubs/scs1998-23.pdf

Bhati D S (1989) Effect of sowing date on mothbean farming systems. *Farming Systems* **5:** 52- 54.

Bhatia V S, Tiwari S P and Joshi O P (1996) Inter relationship of leaf photosynthesis, specific leaf weight and leaf anatomical characters in soybean. *Indian J Plant Physiol* **1:** 6-9.

Bhattacharya A (1996) Influence of dry matter allocation and their rates during pre and post flowering phases in various plant parts on mungbean seed yield. *Leg Res* **19:** 179-84.

Bhattacharyya P K and Ram H H (1992) Yield components in determinate vs indeterminate soybean. *Soy Genetics Newsletter* **19:** 52-54.

Biabani A, Hashemi M and Herbert S J (2008) Agronomic performance of two intercropped soybean cultivars. *Int J Plant Prod* **2:** 215-22.

Binbin L, Yuan Y, Zhang C, Qu J, Zhou W and Lin O (2005) Modulation of key enzymes involved in ammonium assimilation and carbon metabolism by low temperature in rice (*Oryza sativa* L.) roots. *Plant Sci* **169:** 295-302.

Board J E and Harville B G (1992) Explanations for greater light interception in narrow vs. wide -row soybean. *Crop Sci* **32:** 198-202

Board J E and Harville B G (1994) A criteria for acceptance of narrow-row culture in soybean. *J Agron* **86:** 1103-06.

Board J E and Harville B G (1996) Growth dynamics during the vegetative period affects yield of narrow-row and late-planted soybean. *J Agron* **88:** 567-72.

Board J E and Harville B G (1998) Late-planted soybean yield response to reproductive source/sink stress. *Crop Sci* **38:** 763-71.

Board J E and Tan Q (1995) Assimilatory capacity effects on soybean yield components and pod number. *Crop Sci* **35:** 846-85.

Boerma H R and Ashley D A (1988) Canopy photosynthesis and seed-fill duration in recently developed soybean cultivars and selected plant introductions. *Crop Sci* **28:** 137-40.

Boote K J, Jones J W and Pickering N B (1996) Potential uses and limitations of crop models. *J Agron* **88:** 704–16.

Borra´s L, Slafer G A and Otegui M (2004) Seed dry weight response to source-sink manipulations in wheat, maize and soybean: a quantitative reappraisal. *Field Crops Res* **89:** 131-46.

Brevedan R E and Egli D B (2003) Short periods of water stress during seed filling, leaf senescence and yield of soybean. *Crop Sci* **43:** 2083-88.

Bruening W P and Egli D B (1999) Relationship between photosynthesis and seed number at phloem isolated nodes in soybean. *Crop Sci* **39:** 1769-75.

Caffaro S V and Nakayama F (1988) Vegetative activity of the main stem terminal bud under photoperiod and flower removal treatments in soybean. *Aust J Plant Physiol* **15:** 475-80.

Calves J, Naddy De S M, Viala G and Blanchet R (1988) The influence of low night temperature on leaf assimilate transfers to the seeds of soybeans. *Information Tech* **104:** 23-28.

Chandrababu R (1990) *Physiological basis for yield improvement in greengram (Vigna radiata (L.) Wilezek) cultivars.* Ph.D. dissertation. Tamil Nadu Agricultural University, Coimbatore, India

Christy A L and Porter C A (1982) Canopy photosynthesis and yield in soybean. In: Govindjee (ed) *Photosynthesis, Development, Carbon Metabolism and Plant Productivity*. Pp 499–11 Vol. II. Academic Press, New York, USA.

Crafts-Brandner S J and D B Egli (1987) Sink Removal and leaf senescence in soybean. *Plant Physiol* **85:** 662-66.

Deka S D and Talukadar (2000) Response of some soyabean (*Glycine max* (L.) Merill) Genotypes to photoperiod and Temperature in different environment. *Leg Res* **23:** 186 – 88.

Derman B D, Rupp D C and Nooden L D (1978) Mineral distribution in relation to fruit development and monocarpic senescence in anoka soybeans. *American J Bot* **65:** 205-13.

Desclaux D, Huynh T-T and Roumet P (2000) Identification of soybean plant characteristics that indicate the timing of drought stress. *Crop Sci* **40:** 716-22.

Duthion C and Pigeaire A (1991) Seed lengths corresponding to the final stage in seed abortion in three grain legumes. *Crop Sci* **31:** 1597-83.

Dybing C D, Ghiasi H and Paech C (1986) Biochemical characterization of soybean ovary growth from anthesis to abscission of aborting ovaries. *Plant Physiol* **81:** 1069-74.

Edwards J T and Purcell L C (2005) Soybean yield and biomass responses to increasing plant population among diverse maturity groups. I. Agronomic characteristics. *Crop Sci* **45:** 1770-77.

Egli D B and Yu Z W (1991) Crop growth rate and seeds per unit area in soybean. *Crop Sci* **31:** 439-42.

Egli D B (1993) Cultivar maturity and potential yield of soybean. *Field Crops Res* **32:** 147-58.

Egli D B (1994) Cultivar maturity and reproductive growth duration in soybean. *J Agron and Crop Sci* **173:** 249-54.

Egli D B (1998) *Seed Biology and the Yield of Grain Crops*. CAB International, Wallingford, UK.

Egli D B (1999) Variation in leaf starch and sink limitations during seed filling in soybean. *Crop Sci* **39:** 1361-68.

Egli D B (2004) Seed-fill duration and yield of grain crops. *Adv in Agron* **83:** 243-79.

Egli D B (2005) Flowering, pod set and reproductive success in soya bean. *J Agron and Crop Sci* **191**: 283-91.

Egli D B (2006) The role of the seed in the determination of yield of grain crops. *Aust J Agric Res* **57:** 1237-47.

Egli D B and Bruening W P (2000) Potential of early-maturing soybean cultivars in late plantings. *J Agron* **92:** 532-37.

Egli D B and Bruening W P (2001) Source-sink relationships, seed sucrose levels and seed growth rates in soybean. *Ann Bot* **88:** 235-42.

Egli D B and Bruening W P (2002) Flowering and fruit set dynamics during synchronous flowering at phloem-isolated nodes in soybean. *Field Crops Res* **79:** 9-19.

Egli D B and Wardlaw I F (1980) Temperature response of seed growth characteristics of soybean. *J Agron* **72:** 560-64.

Egli D B, Meckel L, Phillips R E, Radcliffe D and Leggett J E (1983) Moisture stress and N redistribution in soybean. *J Agron* **75:** 1027-31.

Emam Y and M Niknejad (1994) An introduction to crop plant physiology. *Shiraz Exp Bot* **53:** 979-87.

Evans L T (1975) The physiological basis of crop yield. In: Evans L T (ed) *Crop Physiology: Some case history* Pp 227-48. Cambridge University Press, London.

Evans L T (1996) *Crop evolution, adaptation and yield*. Cambridge Univ. Press, Cambridge, UK.

Fader G M and Koller H R (1983) Relationships between carbon assimilation, partitioning, and export in leaves of two soybean cultivars. *Plant Physiol* **73:** 297-303.

Fageria N K, Baligar, V C and Charles Allen Jones (1997) *Growth and mineral nutrition of field crops*. 2nd ed. New York, Marcel Dekker, Inc.

Fehr W R and Caviness C E (1977) *Stages of soybean development*. Iowa Agric. Exp.Stan. Spec. Rep., 80.

Fleming J E, Ellis R H, John P, Summerfield R J and Roberts H (1997) Developmental implications of photoperiod sensitivity in soybean (*Glycine max* [L.] Merr.*). Int J Plant Sci* **158:** 142-51.

Fu Y C and Zhang X Z (1993) Study on the photosynthetic characteristics of wild, semi- wild, and cultivated soybean. *Soy Sci* **12:** 255-58.

Ganguly S B and Bhattacharya (2001) Effect of physiological traits on chickpea yield under normal and late seeding. *Leg Res* **24:** 6-10.

Gay S, Egli D B and Reicosky D A (1980) Physiological aspects of yield improvement. *J Agron* **72**: 387-91.

Gibson L R and Mollen R E (1996) Influence of day and night temperature on soybean yield. *Crop Sci* **36:** 98-104.

Goldschmidt E E and Huber S C (1992) Regulation of photosynthesis by end-product accumulation in leaves of plants storing starch, sucrose, and hexose sugars. *Plant Physiol* **99:** 1443-48.

Gonza´lez F G, Slafer G A and Miralles D J (2005) Photoperiod during stem elongation in wheat: its impact on fertile floret and grain number determination similar to that of radiation? *Funct Pl Biol* **32:** 181-85.

Gordon A J, Hesketh J D and Peters D B (1982) Soybean leaf photosynthesis in relation to maturity classification and stage of growth. *Photosynth Res* **3:** 81-93.

Goswami R K (2000) *Physiological indices for higher productivity in greengram [Vigna radiate (L.) Wilczek]*. Ph. D. dissertation. University of Agricultural Sciences, Dharwad, India.

Gourdon F and Planchon C (1982) Response of photosynthesis to irradiance and temperature in soybean. (*Glycine max* (L) Merr.). *Photosynth Res* **3:** 31-43.

Grodzinski B, Jiao J R and Leonardos E D (1998) Estimating photosynthesis and concurrent export rates in $C_3$ and $C_4$ species at ambient and elevated $CO_2$. *Plant Physiol* **117:** 207-15.

Guiamet J J and Nakayama F (1984) The effects of long days upon reproductive growth in soybeans (*Glycine max* (L.) Merr.) cv. Williams. *Japanese J Crop Sci* **53:** 35-40.

Hadley P, Roberts E H, Summerfield R J and Minchin F R (1984) Effects of temperature and photoperiod on flowering in soya bean [*Glycine max* (L.) Merrill]: a quantitative model. *Ann Bot* **53:** 669-81.

Han T F, Wu C, Tong Z, Mentreddy R S, Tan K and Gai J (2006) Post flowering photoperiod regulates vegetative growth and reproductive development of soybean. *Environ and Exp Bot* **55:** 120-29.

Han T F and Wang J L (1995) Pre and post flowering photoperiod responses in early soybean varieties. *Soy Genetics Newsletter* **22**: 89-92.

Hansen W R and Shibles R (1978) Seasonal log of the flowering and podding activity of field-grown soybeans. *J Agron* **70:** 47-50.

Hanson W D (1988) Analysis of differences in sink activity among soybean genotypes based on dry matter accumulation rates per unit seed coat area. *Crop Sci* **28**: 830-34.

Hanway J J and Weber C R (1971) Dry matter accumulation in eight soybean varieties. *J Agron* **63**: 227-230.

Hymowitz T and Singh R J (1987) Taxonomy and speciation. In: *Soybeans: improvement, production and uses*, 2nd ed., Agronomy Monograph 16, pp. 23-48, Wilcox, J.R., ed. ASACSSA-SSSA, Madison, Wisc.

Harper J E and Hageman R H (1972) Canopy and seasonal profiles of nitrate reductase in soybeans (*Glycine max* L. Merr). *Plant Physiol* **49**: 146-54.

Heilman J L, Kanemasu E T and Paulsen G M (1977) Estimating dry-matter accumulation in soybean. *Can J Bot* **55:** 2196-2201.

Heitholt J J, Egli D B and Leggett J E (1986) Characteristics of reproductive abortion in soybean. *Crop Sci* **26:** 589-95.

Henry A and Daulay H S (1983) Genotype x environment interactions for seed yield in mothbean. *Indian J Agric Sci* **53:** 469-70.

Hiremath S M, Chittapur B M and Hosamani M M (1992) Response of soybean cultivars to row spacing during *rabi* season. *J oilseeds Res* **9:** 154-56.

Holkar S, Mishra V K and Nigam P K (1991) Phenotypic stability of yield and its components in rainfed soybean. *J Maharashtra Agric Univ* **16**: 435-36.

Huber S C, Rogers H H and Mowry F L (1984) Effects of water stress on photosynthesis and carbon partitioning in soybean (*Glycine max* L. Merr.) plants grown in the field at different $CO_2$ levels. *Plant Physiol* **76:** 244-49.

Huff A and Dybing C D (1980) Factors affecting shedding of flowers in soybean (*Glycine max* (L.) Merrill). *J Exp Bot* **31:** 751-62.

Jackson J E (2003) Photosynthesis, respiration and carbohydrate transport, partitioning and storage. In: Jackson J E (ed) *Biology of apples and pears.* Pp 237- 67. Cambridge University Press, Cambridge.

Jaleh D (1985) Carbohydrate partitioning and metabolism in crops. *Horti Rev* **7**: 69-97.

Janicka M and Szyrmer J (1989) Problems of flowering and pod set in soybean plants. *Soy Abstracts* **12**: 141.

Jayapragasam M, Sreerangasamy S R and Thangaraj M (1998) Biochemical studies in the progenies of the interspecific cross between greengram (*Vigna radiate* L. Wilczek) and blackgram (*Vigna mungo* L. Hepper). *Indian J Plant Physiol* **3**: 121-124.

Jepson R G, Johnson R R and Hadley H H (1978) Variation in mobilization of plant nitrogen to the grain in nodulating and non - nodulating soybean genotypes. *Crop Sci* **18**: 1055-62.

Jiang H and Egli D B (1993) Shade induced changes in flower and pod number and fruit abscission in soybean. *J Agron* **85:** 221-25.

Kantolic A G and Slafer G A (2001) Photoperiod sensitivity after flowering and seed number determination in indeterminate soybean cultivars. *Field Crops Res* **72:** 109-18.

Kantolic A G and Slafer G A (2005) Reproductive development and yield components in indeterminate soybean as affected by post-flowering photoperiod. *Field Crops Res* **93:** 212-22.

Kato I, Sakaguchi S and Naito Y (1955) Anatomical observations of fallen buds, flowers, and pods of soya-bean, *Glycine max* M. *Tokai-Kinki National Agri Exp Station Bulletin* **2:** 159-68.

Khan M G (1994) Effect of salt stress on nitrate reductase activity in some leguminous crops. *Indian J Plant Physiol* **37**: 185 – 187.

Knoieczny G, Muszynski A and Nawaracala J (1994) Variation of seed yield components of soybean genotypes. *Soy Genetics Newsletter* **21**: 146-48.

Kobraee S, Shamsi K, Rasekhi B and Kobraee S (2010) Investigation of correlation analysis and relationships between grain yield and other quantitative traits in chickpea (*Cicer arientnum* L.) *Afri J Biotech* **9:** 2342-48.

Kokubun M, Shimada S and Takahashi M (2001) Flower abortion caused by pre anthesis water deficit is not attributed to impairment of pollen in soybean. *Crop Sci* **41:** 1517-21.

Komor E (2000) Source physiology and assimilate transport: the interaction of sucrose metabolism, starch storage and phloem export in source leaves and the effects on sugar status in phloem. *Aust J Plant Physiol* **27:** 497-505.

Koti R V (1997) *Influence of seasons on phenology, reproductive efficiency and physiological indices in soybean genotypes*. Ph.D. dissertation. University of Agricultural Sciences, Dharwad, India

Krishnamurty K, Bommegouda A, Venugopal N, Jagannath M K, Ragunath C and Rajashekhar B G (1973) Investigations of the varietal difference in the growth components of sorghum. *Mysore J Agric Sci* **8**: 52-59.

Kumar D (2002) New plant type with unbranded growth habit in mothbean. *Indian J Pulses Res* **15**: 179-80.

Kumar P A and Abrol Y P (1990) *Ammonia assimilation in higher plants*. In Abrol Y P (ed) *Nitrogen in higher plants*. Pp 159-80. John Wiley and Sons, New York.

Kumudini S (2002) Trials and tribulations: a review of the role of assimilate supply in soybean genetic yield improvement. *Field Crops Res* **75:** 211-22.

Lam H M, Coschigano K, Schultz C, Melo-Oliveira R and Tjaden G (1995) Use of Arabidopsis mutants and genes to study amide amino acid biosynthesis. *Plant Cell* **7:** 887-98.

Lawlor D W (2002) Carbon and nitrogen assimilation in relation to yield: mechanisms are key to understanding production systems. *J Exp Bot* **53:** 773-87.

Lea P J and Miflin B J (1980) Transport and metabolism of asparagine and other nitrogen compounds within the plant. In: Miflin B J (ed) *The Biochemistry of plants; amino acids and derivatives.* Pp 329-57.New York Academic, New York.

Lea P J, Robinson S A and Stewart G R (1990) The embryology and metabolism of glutamine, glutamate and asparagines. In: Miflin B J and Lea P J (eds) *The biochemistry of Plants*. Vol. 16. Pp121-59. New York Academic.

Leffel R C, Cregan P B and Bolgiano A P (1991) Nitrogen metabolism of soybean genotypes selected for seed composition, fasciated stem or harvest index. *Crop Sci* **32**: 1428-32.

Li X M, Zhu C G, Miao V N and Zhang L H (1993) Changes of nitrate – nitrogen and activity of nitrate reductase in different parts of soybean during plant development. *Plant Physiol* **29**: 263-65.

Liaw S I and Chen C Y (1988) The characteristics of dry matter production and seed yield of winter and summer crop soybean. *J College sci and Engin* **25**: 27-48.

Liu X B, Jin J, Wang G H, Herbert S J and Hashemi M (2004) Influences of row spacing on competing limited resources in soybean. *Soy Sci* **23:** 215-21.

Loomis R S and Connor D J (eds) (1992). In: *Crop Ecology :Productivity and management in agricultural systems.* pp 104-28. Cambridge Univ. Press, Cambridge, England.

Lugg D G and Sinclair T R (1981) Seasonal changes in photosynthesis of field grown soybean leaflets. 1. Relation to leaflet dimensions. *Photosynthetica* **15**: 129- 37.

Madani A, Shirani-Rad A H, Pazoki A, Nourmohammadi Gh and Zarghami R (2010) Grain filling and dry matter partitioning responses to source: sink modifications under post-anthesis water and nitrogen deficiencies in winter wheat (*Triticum aestivum* L.). *Acta Scientarum Agron* **32:** 145-51.

Mann J D and Jaworski E G (1970) Comparison of stress which may limit soybean yields. *Crop Sci* **10:** 620-24.

Mathew J P, Herbert S J, Zhang S H, Rautenkranz A A F and Litchfield G V (2000) Differential response of soybean yield components to the timing of light enrichment. *J Agron* **92:** 1156-61.

McBlain B A and Hume D J (1981) Reproductive abortion, yield components, and nitrogen content in three early soybean cultivars. *Can J Plant Sci* **61:** 499-505.

Meckel L, Egli D B, Phillips R E, Radchiffe D and Leggett J E (1984) Effect of moisture stress on seed growth in soybeans. *J Agron* **76**: 647-50.

Miceli F, Crafts-Brandner S J, and Egli D B (1995) Physical restriction of pod growth alters development of soybean plants. *Crop Sci* **35:** 1080-85.

Mingan Y, Junyi G, Yuhda M A, and Jodo S (1995) The relationship of leaf photosynthetic rate to stomatal and mesophyll conductance in soybeans. *Acta Agronomica sinica* **21**: 145-49.

Miralles D J, Slafer G A, Richards R A and Rawson H M (2003) Quantitative developmental response to the length of exposure to long photoperiod in wheat and barley. *J Agric Sci* **141:** 159-67.

Mitra R, Pawar S E and Bhatia C R (1987) Nitrogen : the major limiting factor for mungbean yield. *Proceedings of the second International Symposium on mungbean* Pp. 244-251 Bangkok (Thailand), 16-20 November, 1987.

Mondal M H, Brun W A and Brenner M L (1978) Affects of sink removal on photosynthesis and senescence in leaves of soybean (*Glycine max* L.) plants. *Plant Physiol* **61:** 394-97.

Morris D R and Weaver R W (1983) Mobilization of 15N from soybean leaves as influenced by Rhizobial strains. *Crop Sci* **23:** 1111-14.

Munier-Jolain N G, Munier-Jolain N M, Roche R, Ney B and Duthion, C (1998) Seed growth rate in grain legumes-I. Effect of photoassimilate availability on seed growth rate. *J Exp Bot* **49:** 1963-69.

Munir A, Turk and Abdel Rahman M (2002), Effects of dates of sowing and seed size on yield and yield components of local fababean under semi-arid condition. *Leg Res* **25**: 301-302.

Naidu N V, Rosaiah G, Satyanarayana A and Rajarajeswari V (1993) Variation in developmental and morpho – physiological traits under different environments and their relation to grain yield of greengram (*Phaseolus radiatus*). *Indian J Agric Sci* **63:** 473-78.

Nigam P K, Sharma R A, Mishra V K, Holkar S and Billore S D (1990) Phenotypic stability of seed yield, dry matter and water use efficiency of soybean (*Glycine max*) under rainfed condition. *Indian J Agric Sci* **60:** 185-88.

Nijhawan D C (1986) A quantitative analysis of growth attributes in mungbean (*Vigna radiata* (Roxb.) Wilezek). *Leg Res* **11:** 53-58.

Norman A G (1978) *Soybean physiology, Agronomy and utilization*.Pp 78-89.Academic Press. New York.

O'Leary B, Park J and Plaxton W C (2011) The remarkable diversity of plant PEPC (Phosphoenolpyruvate carboxylase): recent insights into the physiological functions and post-translational controls of non-photosynthetic PEPCs. *J Biochem* **436:** 15-34.

Ouattara S and Weaver D B (1995) Effect of growth habit on yield components of late planted soybean. *Crop Sci* **35**: 411-15.

Pandey R K, Saxena M C and Singh V B (1978) Growth analysis of blackgram genotypes. *Indian J Agric Sci* **48**: 466-73.

Panwar J D S, Abbas S and Sita Ram (1990) Effect of benzyl amino purine and girdling site on photosynthesis, translocation and nitrogen fixation in Y- shaped mungbean. *Indian J Plant Physiol* **33**: 16-20.

Panwar J D S, Shukla D S and Sirohi G S (1986) Growth and developmental aspects in relation to yield of mungbean (*Vigna radiata* L. Wilczek). *Indian J Plant Physiol* **29**: 312-16.

Patrick J W (1997) Phloem unloading: Sieve element unloading and post-sieve element transport. *Ann Rev Plant Physiol* **48:** 191-222.

Paul M J and Pellney T K (2003) Carbon metabolite feedback regulation of leaf photosynthesis and development. *J Exp Bot* **54:** 539-47.

Poehlman J M (1991) *The mungbean.* Pp 375-80. Oxford and IBH publishing Co. Pvt. Ltd., New Delhi, India.

Pramila Kumari and Verma S K (1983) Genotypic differences in flower production, shedding and yield in mungbean (*Vigna radiata* L. Wilczek). *Indian J Plant Physiol* **27**: 402-05.

Pushpakumari R, Nair R V and Kumari V L G (1993) Varietal variation in the growth pattern of soybean. *Leg Res* **16**: 63-66.

Raghuwanshi R K S, New M L, Umat R and Thakur H S (1988) Effect of sowing dates and fertility levels on the grain yield of soybean. *J Oilseeds Res* **5**: 168-69.

Rao T R K and Ghildiyal M C (1985) Analysis of photosynthetic source and sink relationship in mungbean (*Vigna radiata* L. Wilczek). *Indian J Plant Physiol* **28**: 135-44.

Raut V M, Halvankar G B, Taware S P and Patil V P (1991) Heterosis studies in soybean. *J Maharashtra Agric Univ* **16**: 346-48.

Reddy A S and Saxena M C (1983) Studies on growth analysis of soybean. *The Andhra Agric J* **30**: 213-15.

Reicosky D A, Orf J H and Poneleit C (1982) Soybean germplasm evaluation for relation to plant architecture in soybean. *Soy Genetics Newsletter* **23**: 92- 97.

Rhodes D, Render G A and Flokes B F (1980) Pathway of ammonia assimilation in illuminated Lemna minor. *Phytochem* **19**: 357-65.

Robinson S A, Slade A P, Fox G G, Phillips R, Ratcliffe R G and Stewart G R (1991) The role of glutamate dehydrogenase in plant nitrogen metabolism. *Plant Physiol* **95**: 509-16.

Sage R F, Sharkey T D and Seemann J R (1989) Acclimation of photosynthesis to elevated $CO_2$ in five $C_3$ species. *Plant Physiol* **89:** 590-600.

Sala R G Westgate M E and Andrade F H (2007) Source/sink ratio and the relationship between maximum water content, maximum volume, and final dry weight of maize kernels. *Field Crops Res* **101:** 19-25.

Sawada S T, Hayakawa K, Fukushi and Kasai M (1986) Influence of carbohydrates on photosynthesis in single rooted soybean leaves used as a source-sink model. *Plant Cell Physiol* **27:** 591-600.

Sawada S, Hasegawa Y, Kasai M and Sasaki M (1989) Photosynthetic electron transport and carbon metabolism during altered source/sink balance in single-rooted soybean leaves. *Plant Cell Physiol* **30:** 691-98.

Schapaugh W T and Wilcox J R (1980) Relationships between harvest indices and other plant characters in soybean. *Crop Sci* **20**: 529-33.

Scott H D and Batchelor A (1979) Dry weight and leaf area production rate of irrigated determinate soybeans. *J Agron* **71**: 776-82.

Settimi J R (1987) Effects of photoperiod at non-optimal planting dates on branch developments and yield of soybeans (*Glycine max* L. Merr.) *Dissertation Abstracts International* **47**: 3590B.

Shah P (1989) Growth curve analysis of soybean cultivars. *Dissertation Abstracts International,* **50**: 380.

Sharma J P and Sharma S P (1993) Influence of genotypes and plant densities on physiological parameters, grain yield and quality of soybean (*Glycine max* L.), *Indian J Agron* **38**: 311-13.

Shibles R M and Weber C R (1966) Interception of solar radiation and dry matter production by various soybean planting patterns, *Crop Sci* **6**: 55-59.

Shibles R M, Anderson I C and Gibson A H (1975) Soybean. In: Evans L T (ed) *Crop physiology*. Pp 151-89 Cambridge University Press, London.

Shibles R M, Secor J and Ford D M (1987) Carbon assimilation and metabolism. In: Wilcox J R(ed) *soybean improvement, production and Uses*. Pp 535-88 Agronomy, Monographs Madison, WI.

Sinclair T R and Dewit C T (1976) Analysis of the carbon and nitrogen limitations to soybean yield. *J Agron* **68**: 319-24.

Singh A P, Sharma S, Bargale M, Sharma H K and Sharma S (1994) Association analysis for yield and its components in soybean. *Crop Res* **7**: 247-51.

Singh B B, Srivastava M K and Lalchand (1985) Relationships among leaf chlorophyll, yield and other characters in field grown soybean cultivars. *Photosynthetica* **19**: 240-43.

Singh G B, Jagan Mohan Rao V, Suguna C A and Madhusudhana Rao L (1985) Varietal differences in growth and yield of mungbean (*Vigna radiate* (L.) Wilczek) during summer and *kharif* seasons. *Indian J Plant Physiol* **28**: 207-14.

Summerfield R J and Roberts E H (1985) *Glycine max*. In: Halevy A H (ed) *Handbook of flowering* Vol. 1. Pp 100-17 Boca Raton, FL: CRC Press.

Summerfield R J, Asumadu H, Ellis R H and Qi A (1998) Characterization of the photoperiodic response of post-flowering development in maturity isolines of soybean [*Glycine max* (L.) Merrill] 'Clark'. *Ann Bot* **82:** 765-71.

Sung D K, Shin D C, Son Y and Kim Y C (1990) Photosynthesis and some characteristics in different stages of soybean cultivars (*Glycine max.* L.). Research Reports of the Rural Development Administration, Upland Industrial Crops **32**: 32 -37.

Talwar H S, Soni M L and Beniwal B K (2004) Evaluation of crop physiological traits in cluster bean (*Cyamopsis tetragomoloba* L.) and Mothbean (*Vigna aconitifolia* Ja(q.). *Proceedings of National Seminar of Plant Physiology held on Dec. 27–29.* Pp.121 Pune 2004.

TeKrony D M, Egli D B, Balles J, Pfieffer T and Fellows R J (1979) Physiological maturity in soybean. *J Agron* **71:** 771-75.

Thomas J F and Kanchanapoom M L (1991) Shoot meristem activity during floral transition in (*Glycine max* (L.) Merr.*). Botanical Gazette* **152:** 139-47.

Thomas J F and Raper C D Jr (1976) Photoperiodic control of seed filling for soybeans. *Crop Sci* **16:** 667-72.

Thomas J F and Raper C D Jr (1977) Morphological response of soybeans as governed by photoperiod, temperature and age at treatment. *Botanical Gazette* **138:** 321-28.

Tischner T, Allphin L, Chase K, Orf J H and Lark K G (2003) Genetics of seed abortion and reproductive traits in soybean. *Crop Sci* **43:** 464-73.

Tiwari S P, Bhatnagar P S and Prabhakar (1994) Identification of suitable soybean (*Glycine max.* L.) varieties for non - traditional regions of India. *Indian J Agric Sci* **64**: 872-74.

Upadhyay A P, Summerfield R J, Ellis R H, Roberts E H and Qi A (1994) Variation in the duration of the photoperiod-sensitive and photoperiod insensitive phases of development to flowering among eight maturity isolines of soybean [*Glycine max* (L.) Merrill]. *Ann Bot* **74:** 97-101.

Venkateshwarlu S and Balasubramanian V (1993) Photosynthesis during reproductive phase of rainfed greengram. *Indian J Plant physiol* **36**: 174-77.

Verma V D and Sawaji B V (1994) Screening of soybean germplasm for photoperiodic insensitivity under natural conditions in Vidarbha region of Maharashtra, *Soy Genetics newsletter* **21**: 137-41.

Watson D J (1947) Comparative studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties, and within and among years. *Ann Bot* **11:** 41–76.

Wells R (1991) Soybean growth response to plant density:-Relationship among canopy photosynthesis, leaf area and light interception. *Crop Sci* **31:** 755-61.

Wells R, Ashley D A and Boerma H R (1986) Physiological comparisons of two soybean cultivars differing in canopy photosynthesis. I. Variation in varietal $CO_2$ labelling and dry weight partitioning. *Photosynthesis Res* **9**: 285-94.

Wells R, Schulz, L L, Ashley D A, Boerma H R and Brown R H (1982) Cultivar differences in canopy apparent photosynthesis and their relation to seed yield in soybeans, *Crop Sci* **22**: 886-90.

Westgate M E and Grant T G L (1989) Water deficits and reproduction in maize. Responses of the reproductive tissue to water deficits at anthesis and mid-grain fill. *Plant Physiol* **91:** 862-67.

Westgate M E and Peterson C M (1993) Flower and pod development in water-deficient soybeans (Glycine max L. Merr.). *J Exp Bot* **258:** 109-17.

Wiebold W J, Ashley D A and Boerma H R (1981) Reproductive abscission levels and pattern for eleven determinate soybean cultivars. *J Agron* **73:** 43-46.

Xu D Q, Gifford R M and Chow W S (1994) Photosynthetic acclimation in pea and soybean to high atmospheric $CO_2$ partial pressure. *Plant Physiol* **106:** 661-71.

Yelle S, Hewitt J D, Robinson N L, Damon S and Bennett A B (1988) Sink metabolism in tomato fruits. III. Analysis of carbohydrate assimilation in a wild species. *Plant Physiol* **87:** 737-40.

Yohe J M and Poehlman J M (1972) Genetic variability in the mungbean, *Vigna radiata* (L.) Wilezek. *Crop Sci* **12**: 461-64.

Zeiher C, Egli D B, Leggett J E and Reicosky D A (1982) Cultivar differences in N redistribution in soybeans. *J Agron* **74:** 375-79.

Zhang L, Wang R and Hesketh J D (2001) Effects of photoperiod on growth and development of soybean floral bud in different maturity. *J Agron* **63:** 944-48.

Zhang H S, Fu Y H, Sun T S, Liang Z F, Zhao A L and Peng B (1993) A study of the rates of the accumulation of oil and protein in soybean seed. *Soybean Sci* **12**: 296-301.

Zou Q, Sun G Y and Cheng B S (1991) Comparative study on response characteristics of photosynthesis to light temperature and $CO^2$ concentration in common and small grain soybean cultivars. *J Shandong Agric Univ* **22**: 311-317.

## CHAPTER III

## PUBLISHED/ACCEPTED/SUBMITTED RESEARCH ARTICLES

| SR. NO. | PUBLICATION | JOURNAL | IMPACT FACTOR | NAAS RATING | STATUS |
|---|---|---|---|---|---|
| 1. | Photoperiodic Dynamics alters biomass accumulation and its Partitioning in Soybean (*Glycine max*. L. Merrill) Genotypes Under Sub-Tropical Punjab Conditions | International Journal Of Advanced Research | 1.69 | - | Published |
| 2. | Comparative Performance of Different Maturity Groups of Soybean (*Glycine max* L. Merrill) Genotypes Under Sub-Tropical Conditions of Punjab | Hortflora Research Spectrum | - | - | Published |
| 3. | Impact of Planting Time on the Performance of Soybean (G*lycine max* L. Merrill) Genotypes Under Punjab Conditions | Soybean Research | - | 3.4 | Accepted |
| 4. | Correlation and path analysis of morpho-physiological traits with yield of soybean (*Glycine max* L. Merrill) genotypes under variable photoperiods | Journal of Environmental Biology | 0.88 | 7.1 | Submitted |

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RESEARCH ARTICLE

# Photoperiodic Dynamics alters biomass accumulation and its Partitioning in Soybean (*Glycine max.* L. Merrill) Genotypes Under Sub-Tropical Punjab Conditions

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## *Abstract*

Soybean is a quantitative short-day plant and is very sensitive to photoperiod that is the reason it does not change from vegetative to reproductive growth until a critical day length is met. Our objective was investigation of photoperiodic changes effect on important physiological traits such as dry matter production and harvest index that affected grain yield. A field experiment was carried out in randomized block design with three replications. Fifteen divergent genotypes of soybean (*Glycine max.* L. Merrill) were grouped into three categories on the basis of maturity dates; early, medium and late were planted on two planting dates (normal and late). Grain yield increased with increasing biomass and its proper utilization under optimal planting date and decreased with delaying in planting date due to improper accumulation of photosynthate between vegetative to reproductive phase. Compared with the normal sowing, the delayed sowing genotypes had the lower dry matter which indicated that the photoperiodic changes would affect the duration of growth under different sowing dates. Finally, the results depicted that in early (EC 457161), medium, (SL 983) and late (SL 958) maturity date genotypes produce maximum dry matter accumulation and gave higher yield in normal sowing due to better environmental conditions as compared to late sown conditions.

## Introduction

Soybean (*Glycine max.* L. Merrill) has a prominent position among the legumes that supplement nearly one-third of the world population and popularly known as "Miracle Bean" because of its versatility. Soybean is a highly nutritive and energy rich monocarpic legume crop with proteins (40 %) and edible oil (20 %). Soybean genotypes respond much differently to sowing date than other crops because flowering is closely related to photoperiod. Raising soybean production is possible through a more effective use of resources by appropriate sowing time adjustments. Dry matter accumulation during the reproductive period strongly influences the yield and yield components (Liu *et al.*, 2004). Variations in biomass and harvest index were strongly associated with the amount of intercepted radiation during grain filling stage. Change in both biomass accumulation and harvest index were crucial in determining yield reductions associated with late planting dates in a subtropical environment. In response to shorter day lengths the soybean plant flowers earlier and is shorter, thus reducing biomass production and yield. The two main environmental factors controlling classification of soybean genotypes into maturity groups are the photoperiod and temperature. Premature flowering induced by short days was a major seed yield-reduction factor at late planting dates (Board and Harville, 1996, Anderson and Vasilas, 1985; Trostle and Bean, 2001). Yield of soybean crop is a function of light interception, dry matter production, and partition of dry matter into the plant's seed. The total dry matter level required for optimum seed number and yield per area is a useful growth criterion to predict optimal yield. Soybean growth is measured by the amount of total dry matter accumulating in the plant. The soybean plant produces 95% of its total dry matter through photosynthesis (Taiz and Zeiger, 2002). It has been reported that timely sowing of soybean under Indian conditions (second fortnight of June) showed superiority over the late planting with respect to all the parameters along with grain yield (Billore *et al.,* 2009). Early sowing (end May to early June) provides long vegetative and reproductive growth periods thereby, facilitating the crop to produce more biomass, enhancing the number of pods per plant, grains per pod and 100-grain weight (Kumar *et al.,* 2005). Late sowings may produce lower grain yields due to shortening of growth period and less accumulation of photosynthetically active radiation (Purcell *et al.,* 2002). The importance of maximum utilization of environmental parameters during the growth of crop is important to choose an appropriate sowing date for any crop anywhere.

## Materials and Methods

The field experiment was conducted at the research area of the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, between June and November 2012. Ludhiana is situated in the sub-tropical zone of Punjab at about 247m above sea level on latitude 30° 54'N and longitude 75° 48'E. The experimental design was a randomized block design with three replications and the soil at the experimental site is sandy loam. Each block consisted of 15 plots, each of which measured 5m x 4m, giving a total of 45 plots, and the spacing between plants and rows were 5cm and 45cm with one meter alleys between the blocks. Fifteen divergent genotypes of soybean grouped into three categories on the basis of maturity dates; five early (SL 688, SL 778, SL 795, EC 457161and EC457286), five medium (SL 525, SL 744, SL 955, SL 983 and SL 1123) and five late (SL 900, SL 958, DS 12-5, DS 26-13 and DS 26-14) maturing genotypes were planted on two planting dates are 12 June (normal) and 12 July (late). Germination and emergence of seedlings took place five to 8 days after sowing. The dry matter was taken at the vegetative, flower initiation, pod initiation and harvest stage. Five sampled plants from each plot were put in labelled envelopes and oven dried at 90°C for 48 hours, and then weighed, and the average weight calculated.

## Data Analysis

All data was analyzed using the Analysis of Variance (ANOVA) and genotypes differences among early, medium and late maturity date were compared using the Least Significant Difference (LSD) procedure at 5% level of probability.

## Results and Discussion

Analysis of variance pooled over planting dates under variable photoperiods revealed significant differences among genotypes, environments and genotype x environment interaction for leaf dry matter, stem dry matter, dry matter at harvest, harvest index and seed yield (Table 2). The data regarding the leaf and stem dry matter under both the sowing of different maturity date genotypes in response to variable photoperiods is presented in Table 1. Leaf and stem dry matter decreased with delay in sowing. Significantly maximum leaf and stem dry matter were recorded by early (EC 457161), medium (SL 983) and Late (SL 958) genotypes under both the sowing. The genotype SL 958 (late) had significantly higher dry matter accumulation at harvest stage than medium (SL 958) and early (EC 457161) in normal sown conditions because of more accumulation of photosynthates under relatively longer photoperiods. Soybean genotypes differed significantly in respect of harvest index (Table 1). There was also a significant interaction between genotypes and planting dates for harvest index. Harvest index showed opposite trend as found in dry matter production and seed yield producing lower value of HI at normal sowing and higher in late sown conditions due to lower vegetative growth and results in less accumulation of dry matter. Genotypes under different maturity dates showed significant differences in their harvest index during both the sowing. The genotype early (EC 4571 61), medium (SL 983) and late (SL 958) had maximum harvest index value in normal sowing. Higher seed yield under normal sowing is due to more dry matter production and its proper utilization by the crop in response to photoperiods. Genotype SL 958 (late) produced the highest seed yield (2,370 kg/ha) followed by medium maturity date genotype SL 983 (2,345 kg/ha) and EC 457161 early maturity genotype (2,054 kg/ha). Results of correlation analysis showed that seed yield had significant and positive correlation with majority of traits in both the conditions (normal and late). The highest significant and positive correlations were observed between stem dry matter at vegetative, flower initiation and pod initiation stages and seed yield at 0.01 and 0.05% level of probability (Table 3). Results showed that all other parameters were statistically at par but no significantly positive correlations were observed with yield. Significantly positive correlations were also observed for dry matter at harvest stage, harvest index and yield in medium and late genotypes in normal sowing. However, negative correlation was found among certain characters in medium and late maturity date genotypes with yield because of shorter photoperiod during late sown crop season. These findings were also reported by (Algan, 2011, Patil *et al*, 2003). Soybean genotypes differed significantly among themselves in respect to leaf and stem dry matter upto harvest at all the stages. Dry matter in response to photoperiods also showed significant interaction between genotypes and planting date (Table 2). Similar results were noticed by (Samant *et al*, 1999 and Miah *et al,* 2009). The crop sown under late planting conditions could not accumulate sufficient dry matter because of lesser vegetative growth and reproductive period due to shorter day length. The proper mobilization of dry matter production towards the sink (seed yield) is an important factor for economic yield. The capacity of plant to produce more dry matter depends upon the leaf size and duration of day length (photoperiod), but some genotypes have more potential to translate assimilates towards economic yield due to differential response of genotypes. Similar results were reported by (Patil *et al*, 2003, Reddy, 2009). The higher dry matter production under normal sowing conditions indicates the role of longer photoperiods in terms of more vegetative growth and development and their positive association with seed yield of soybean (Sadeghipour, 2008). The lower harvest index under normal sown conditions was due to higher temperature and longer photoperiods that enhanced the vegetative growth of crop and also increase canopy (Reddy, 2009 and Singh *et al*, 2010). Genotypes of soybean do differ in grain yields (Veni *et al.,* 2003; Billore *et al.,* 2009; De Bruin and Pedersen 2009). The results were in agreement with (Isler and Caliskan, 1998; Arshad, 2006).

## Conclusion

From the present investigation it is concluded that to improve the soybean production and productivity under Punjab conditions, timely sowing in the first fortnight of June would be beneficial. Selection of suitable genotypes also plays an important role in soybean production. However from the present day genotypes, only SL 958 (late), SL 983 (medium) and EC 457161(early) showed improved yield under normal and late planted conditions.

**Table 1: Biomass production and its partitioning in diverse soybean genotypes as influenced by planting dates under variable photoperiods.**

| Maturity group | Genotypes | LDMV (g) | | LDMF (g) | | LDMP (g) | | SDMV (g) | | SDMF (g) | | SDMP (g) | | DMH (g) | | HI (%) | | Seed Yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Normal | Late | Normal | Late | Normal | Late | Normal | Late | Normal | Late | Normal | Late | Normal | Late | Normal | Late | Normal | Late |
| EARLY | SL 688 | 2.66 | 2.65 | 4.06 | 2.48 | 8.57 | 5.34 | 2.28 | 1.07 | 3.58 | 2.41 | 8.21 | 5.45 | 29.17 | 25.01 | 30.87 | 38.66 | 1111 | 852 |
| | SL778 | 3.43 | 2.53 | 3.74 | 2.32 | 8.46 | 4.52 | 2.68 | 2.48 | 5.74 | 2.78 | 10.74 | 7.29 | 44.17 | 30.84 | 37.37 | 42.36 | 1648 | 1398 |
| | SL 795 | 2.48 | 2.36 | 4.65 | 3.53 | 9.55 | 7.36 | 2.74 | 2.85 | 5.95 | 2.29 | 12.84 | 10.31 | 46.86 | 31.67 | 30.04 | 35.91 | 1704 | 1611 |
| | EC 457161 | 4.05 | 3.42 | 6.68 | 2.78 | 11.58 | 9.42 | 3.99 | 3.95 | 7.86 | 3.11 | 13.54 | 11.19 | 49.16 | 37.51 | 38.67 | 52.51 | 2054 | 1778 |
| | EC457286 | 3.85 | 3.53 | 6.54 | 2.63 | 11.28 | 7.63 | 3.82 | 2.33 | 7.83 | 3.01 | 12.91 | 11.09 | 32.51 | 30.84 | 37.37 | 43.07 | 1981 | 1639 |
| | MEAN | 3.29 | 2.90 | 5.13 | 2.75 | 9.89 | 6.85 | 3.11 | 2.54 | 6.19 | 2.72 | 11.65 | 9.07 | 40.37 | 31.17 | 34.86 | 42.50 | 1700 | 1456 |
| MEDIUM | SL 525 | 2.75 | 2.68 | 6.41 | 3.54 | 11.48 | 5.68 | 3.22 | 2.75 | 7.97 | 3.79 | 13.21 | 7.73 | 35.01 | 27.51 | 33.11 | 40.95 | 1528 | 1425 |
| | SL 744 | 3.51 | 3.21 | 7.62 | 3.76 | 11.74 | 6.14 | 3.24 | 2.76 | 8.03 | 4.06 | 15.39 | 9.63 | 44.66 | 33.67 | 38.77 | 41.22 | 2169 | 1685 |
| | SL 955 | 2.28 | 2.01 | 5.48 | 2.94 | 10.12 | 4.86 | 2.85 | 2.48 | 5.29 | 2.54 | 13.43 | 6.32 | 39.17 | 26.66 | 35.11 | 32.26 | 1935 | 1294 |
| | SL 983 | 3.96 | 3.93 | 7.96 | 4.05 | 13.93 | 7.28 | 4.52 | 3.56 | 9.11 | 5.11 | 19.55 | 12.12 | 45.17 | 36.17 | 39.04 | 42.61 | 2345 | 2157 |
| | SL1123 | 2.51 | 2.29 | 5.71 | 2.08 | 11.41 | 4.35 | 2.72 | 2.56 | 7.09 | 3.06 | 16.71 | 6.42 | 34.34 | 29.34 | 35.44 | 29.43 | 1370 | 972 |
| | MEAN | 2.98 | 2.82 | 6.64 | 3.27 | 11.74 | 5.66 | 3.31 | 2.82 | 7.50 | 3.71 | 15.66 | 8.44 | 39.67 | 30.67 | 36.29 | 37.29 | 1869 | 1507 |
| LATE | SL900 | 2.84 | 2.69 | 3.76 | 2.11 | 9.51 | 5.89 | 3.04 | 2.23 | 4.67 | 2.66 | 12.11 | 9.99 | 30.17 | 30.84 | 27.11 | 34.39 | 1768 | 1667 |
| | SL 958 | 4.49 | 4.16 | 6.64 | 5.09 | 12.79 | 9.53 | 5.07 | 2.94 | 7.98 | 4.82 | 23.73 | 11.74 | 51.66 | 41.01 | 42.34 | 38.12 | 2370 | 2208 |
| | DS 12-5 | 3.86 | 3.52 | 4.77 | 5.06 | 10.05 | 8.52 | 3.74 | 3.13 | 5.64 | 2.31 | 13.56 | 9.31 | 40.84 | 40.01 | 35.44 | 36.35 | 1935 | 1657 |
| | DS 12-13 | 3.45 | 2.85 | 5.52 | 4.29 | 11.78 | 7.02 | 4.84 | 2.65 | 6.99 | 4.70 | 15.48 | 11.46 | 32.51 | 31.67 | 32.53 | 37.43 | 1843 | 1667 |
| | DS 26-14 | 3.68 | 3.56 | 6.29 | 3.23 | 11.63 | 7.48 | 3.72 | 2.47 | 7.34 | 3.59 | 15.41 | 10.43 | 43.51 | 30.67 | 36.84 | 32.22 | 1954 | 1863 |
| | MEAN | 3.65 | 3.36 | 5.40 | 3.96 | 11.15 | 7.69 | 4.08 | 2.68 | 6.52 | 3.62 | 16.06 | 10.59 | 39.74 | 34.84 | 34.85 | 35.70 | 1974 | 1812 |
| | LSD (0.05%) | 0.56 | 0.61 | 1.09 | 0.76 | 1.52 | 1.61 | 0.52 | 0.84 | 1.81 | 1.06 | 1.39 | 2.03 | 15.39 | 9.53 | 3.18 | 3.83 | 302.82 | 287.45 |
| | CV (%) | 17.28 | 11.89 | 11.46 | 13.57 | 8.29 | 14.25 | 9.01 | 18.03 | 16.11 | 19.10 | 5.76 | 12.98 | 20.87 | 17.76 | 5.37 | 5.96 | 10.05 | 10.31 |

LDMV=Leaf dry matter at vegetative LDMP=Leaf dry matter at flower initiation, LDMP=Leaf dry matter at pod initiation, SDMV= Stem dry matter at vegetative, SDMF= Stem dry matter at flower initiation, SDMP= Stem dry matter at pod initiation stage, DMH= Dry matter at harvest, HI=Harvest index.

**Table 2: Mean squares for analysis of variance pooled over planting dates for dry matter accumulation and yield.**

| Source of Variance | d.f. | LDMV | LDMF | LDMP | SDMV | SDMF | SDMP | DMH | Harvest index (%) | Plot Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Rep (within Env) | 4 | 0.53 | 0.55 | 0.848 | 0.18 | 0.11 | 0.2 | 284.44 | 2.475 | 401664.1 |
| Planting date | 1 | 0.04* | 127.68* | 393.72* | 10.09* | 258.43* | 582.73* | 1946.95* | 224.73* | 707237.4* |
| Genotypes | 14 | 2.79* | 4.16* | 6.71* | 1.90* | 6.01* | 98.28* | 192.95* | 35.55* | 232522.6* |
| Interaction | 14 | 0.38* | 4.07* | 7.20* | 0.93* | 3.61* | 46.99* | 91.05* | 17.97* | 31128.5* |
| Error | 56 | 0.43 | 0.31 | 0.86 | 0.17 | 0.78 | 4.42 | 61.25 | 1.08 | 20124.14 |

Note: * indicates significant at 0.05 level of significance

**Table 3: Correlation coefficients of different parameters with grain yield.**

| Parameter Studied | Normal Sowing | | | Late Sowing | | |
|---|---|---|---|---|---|---|
| | Early Maturity Genotypes | Medium Maturity Genotypes | Late Maturity Genotypes | Early Maturity Genotypes | Medium Maturity Genotypes | Late Maturity Genotypes |
| LDMV | 0.63 | 0.75 | 0.84 | 0.47 | 0.92 | 0.83 |
| LDMF | 0.79 | 0.72 | 0.75 | 0.43 | 0.91 | -0.18 |
| LDMP | 0.83 | 0.52 | 0.74 | 0.74 | 0.98** | 0.71 |
| SDMV | 0.98** | 0.79 | 0.66 | 0.82 | 0.89* | -0.20 |
| SDMF | 0.99** | 0.34 | 0.72* | 0.56 | 0.89* | 0.60 |
| SDMP | 0.95* | 0.44 | 0.95* | 0.94* | 0.96** | 0.63 |
| DMH | 0.55* | 0.97** | 0.92* | 0.89* | -0.03 | -0.25 |
| HI | 0.72 | 0.82* | 0.91* | 0.50 | 0.85 | 0.27 |

Note: ** indicates significant at 0.01 and * at 0.05 level of significance

## References:

Algan, N. and Celen, A.E. (2011). Evaluation of mungbean (Vigna radiata L.) as green manure in Aegean conditions in terms of soil nutrition under different sowing dates. Afri. J. Agril. Res., 6: 1744-1749.

Anderson, L.R. and Vasilas, B.L. (1985). Effects of planting date on two soybean cultivars: seasonal dry matter and seed yield. Crop Sci., 25: 999-1004.

Arashad, M., Ali, N. and Ghafoor, A. (2006). Character correlation and path coefficient in soybean Glycine max (L.) Merrill. Pak. J. Bot., 38(1): 121-130.

Billore, S. D., Ramesh, A., Vyas, A. K. and Joshi, O. P. (2009). Potassium-use efficiencies and economic optimization as influenced by levels of potassium and soybean (Glycine max) genotypes under staggered planting. Indian J agric Sci., 79: 510-14.

Board, J. E. and Harville, B. G. (1996). Growth dynamics during the vegetative period affects yield of narrow-row, late-planted soybean. Agron. J., 88: 567-572.

De Bruin, J.L. and Pedersen, P. (2009). New and old soybean cultivar responses to plant density and intercepted light. Crop Sci., 49: 2225-32.

Isler, N. and Caliskan, M.E. (1998). Correlation and path coefficient analysis for yield and some yield components of soybean (Glycine max L. Merr.) grown in south eastern Anatolia. Turkish J. Agri. and Forestry., 22:1-15.

Kumar, M. S., Singh, D. and Rao, V. U. M. (2005). Effect of planting dates on yield and yield components of soybean genotypes. Haryana J Agron., 21: 202-05.

Liu, F., Andersen, M.N. and Jensen, C.R. (2004). Root signal controls pod growth in drought-stressed soybean during the critical, abortion-sensitive phase of pod development. Field Crops Res., 85: 159–166.

Miah, M.A.K., Anwar, M.P., Begum, M., Juraimi, A.S. and Ialam, M.A. (2009). Influence of sowing date on growth and yield of summer mungbean varieties. J. Agric. Soc. Sci., 5: 73-76.

Patil, B.L., Hedge, V.S. and Saliath, P.M. (2003). Studies on genetic divergence over stress and non stress environment in mungbean. Indian J. Gent. Plant Breed., 63: 77-76.

Purcell, L.C., Ball, R. A., Reaper, J. D. and Vories, E.D. (2002). Radiation use efficiency and biomass production in soybean at different plant population densities. Crop Sci., 42: 172-77.

Reddy, A. A. (2009). Pulses production technology: Status and way forward. Eco.Polt. Weekly, 44: 73-80.

Sadeghipour, O. (2008). Response of mungbean varieties to different sowing dates. Pak. J. Biol.Sci., 11: 2048-50.

Samant, S.C., Rashid, M. H., Biswas, P. and Hasan, M.A. (1999). Performance of five cultivars of mungbean under different dates of sowing. Bangladesh J. Agric. Res., 24: 521-527.

Singh, Guriqbal., Sekhan, H.S., Ram, Hari., Gill, K.K. and Sharma, P. (2010). Effect of date of sowing on nodulation, growth, thermal requirement and grain yield of Kharif mungbean genotypes. J. Food Legumes., 23: 132-134.

Taiz, L. and Zeiger, E. (2002). Plant physiology.3rd edition. Sinauer Associates Publisher, 690 pages.

Trostle, C. and Bean, B. (2001). Effect of planting date and maturity group on soybean yield in the Texas south plains in 2001. [Online]. Texas Cooperative Extension. Available at http://lubbock.tamu.edu/othercrops/soybeandat.htm (verified 6 Nov 2006).

Veni, B. L., Murthy, V. R. K., Shaik, M. and Ramesh, G. I. (2003). Performance of soybean varieties to different sowing dates under rainfed conditions of southern Telangana Region of Andhra Pradesh. Res Crops., 4: 52-55.

## 3.2

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# COMPARATIVE PERFORMANCE OF DIFFERENT MATURITY GROUPS OF SOYBEAN (*Glycine max* L. Merrill) GENOTYPES UNDER PUNJAB CONDITIONS

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**ABSTRACT :** Soybean (*Glycine max* L. Merrill) is an important leguminous pulse and vegetable oil seed crops growing in tropical and sub-tropical regions of India. It is a thermo-sensitive crop and its response to yield is governed by genotype which differing maturity. Fifteen genotypes differing in maturity dates-early, medium and late were selected and sown on first fortnight of June. The genotypes with late maturing date produced higher yield as compared to the early and medium maturing genotypes. The results revealed that the genotypes early (EC 457161), medium (SL 983) and late (SL 958 ) produced higher numbers of pods per plant, plant height, more 100-seed weight, harvest index and maximum seed yield (2053.67, 2441.91 and 2370.86 kg/ha) than other because of their better genotypic records. Finally, the genotype SL-958 at late maturing date seemed to be more effective in getting higher grain yields.

**Keywords :** *Maturity groups, soybean genotypes, seed yield.*

Considering the present Punjab scenario as depleting natural resources and unabated soil degradation as a consequence of intensive agriculture calls for crop diversification. Soybean is most viable option, which requires less number of irrigations and inputs as compared to paddy. Soybean (*Glycine max* L. Merrill), belonging Fabaceae family, is one of the important-vegetable legume crops and major source of high quality protein for human daily diet and livestock feed in the world (Lie *et al.,* 12). It is one of the most important oil seed crops in the world (Aduloju *et al.,* 1). In addition to its rich protein (35-45%) and oil content (15-25%), soybean seed also contains about 33% carbohydrates, upto 16.6% of which are soluble sugars (Hou *et al.,* 7). Besides being an important source of protein for human diet and animal feed, soybean has been considered to be one of the most promising crops for producing bioenergy (biodiesel) in the near future (Soy Stats, 19). India ranks fifth in the world after USA, Brazil, Argentina and China in soybean production. Soybean production in India accounts for only 3% of total production in the global market. As per latest USDA report 8,800 thousand metric tonnes is the estimated domestic output in 2010-2011. Cultivation of soybean in India is restricted mainly to Madhya Pradesh, Uttar Pradesh, Maharashtra and Gujarat. It is also grown on a small acreage in Himachal Pradesh and Punjab.

Several studies have been made to understand their performances which mainly include the contribution of various yield components towards yield (Chettri, 5; Jian *et. al.,* 9; and Mehta *et al.,* 15). To understand the physiological basis of yield difference among the genotypes of soybean, it is essential to quantify the components of growth, and the relevant variables, which is useful in crop improvement. Variation in dry matter accumulation and pod production in different maturity group genotypes may be related to some factors such as leaf area (LA), Leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR). A better understanding of crop growth and yield parameters and the partitioning of assimilates into seed would help to expedite yield improvement of field crops. Very little work has been done in this regard in soybean in sub-tropic areas. A detailed analysis of growth and yield parameters of fifteen soybean genotypes which were differing in maturity groups was therefore undertaken.

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## MATERIALS AND METHODS

The experiment was carried out at the experimental field of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana Punjab in Kharif (June - October) season of 2012. With fifteen soybean genotypes, five early (SL 688, SL 778,SL 795,EC 457161and EC457286), five medium (SL 525, SL 744,SL 955, SL 983 and SL 1123) and five late (SL 900, SL 958,DS 12-5, DS 26-13 and DS 26-14) maturing dates genotypes were used as planting materials. Experiment was laid out in randomized block design with three replicates. The soil of the experimental field was sandy loam. The plot size was 4 m × 5 m and row to row and plant to plant distances were 45 and 5 cm, respectively. Normal cultural practices for raising a successful crop were followed uniformly throughout the experiment. Irrigation was applied at weekly intervals or as when needed. Data were collected on some morpho-physiological parameters viz leaf area (LA), leaf area index (LAI), harvest index (HI) and yield attributes such as number of pods per plant, 100-seed weight and seed yield per plant and seed yield per plot. Sampling were taken at vegetative, flowering and pod stages. From each sampling, five plants were selected randomly and uprooted from each plot for collecting necessary parameters. Leaf area of each sample was measured by automatic leaf area meter and leaf area index was measured by Sun scan canopy analyser. Yield components were recorded at harvest from ten randomly selected plants of each plot. The seed yield was measured as mature seed harvested and seed weight was recorded as weight of 100 randomly selected seeds from a bulk at each plot. All data were analyzed statistically using Least Significant Difference (LSD) test at 0.05% probability level to compare the differences among the genotypes.

## RESULTS AND DISCUSSION

### Leaf area

The data given in Fig.1 revealed that leaf area per plant indicated significant differences between early, medium and late maturing genotypes at all the stages. It differed significantly with all the genotypes, In early maturing group, the genotype EC 457161 recorded significantly higher leaf area per plant and lower leaf area was recorded in SL 688 at all the growth stages.

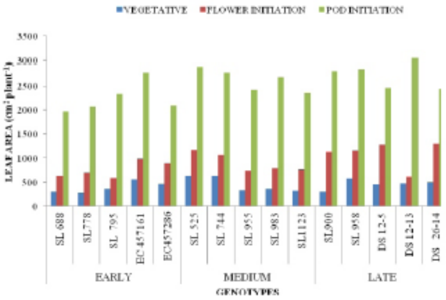

Figure 1 : Leaf area (cm$^2$ plant$^{-1}$) of diverse soybean genotypes at different growth stages.

In medium maturing group genotypes, the maximum leaf area was recorded in genotype SL 983 and minimum in SL 955 at all the growth and development stages. Whereas, in late maturing group, the genotype SL 958 attained maximum leaf area and minimum in SL 900 at all the stages. The mean proportion of leaf area of late maturing genotypes was higher from vegetative to pod initiation stage followed by medium and least in early maturing group genotypes. The data indicated a wide genotypic variability with respect to leaf area. This is in agreement with the reports of Nijhawan and Chandra (17). It is evident from the data that the genotypes which yielded high maintained significantly higher leaf area over other genotypes thereby indicating the importance of leaf area in yield determination. Greater leaf area improved seed yield due to increased interception of solar radiation and enhanced carbon exchange rate (Kumudini *et al.,* 11).

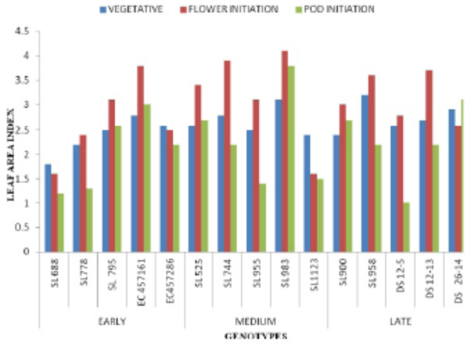

Figure 2 : Leaf area index of diverse soybean genotypes at different growth stages.

### Leaf area index

The data on leaf area index per plant (Fig.2) indicated significant differences between the early, medium and late maturing genotypes at all the stages. There was a linear increase in leaf area index upto flowering stage and declined thereafter in all the genotypes during later stages.

Among the early maturing group, the genotype EC 457161 recorded significantly higher leaf area index upto flowering stage and decreased during pod initiation stage. Significantly lower leaf area index at all stages was recorded in genotype SL 688. At pod initiation stage all the genotypes showed decrease in leaf area index due to remobilization of assimilates towards sink and the plant parts entering senescence phase. Among medium maturing group genotypes, the genotype SL 983 recorded higher leaf area index upto flowering stage and it was at par with genotype SL 744. Upto flower initiation stage, leaf area index showed increment in all the genotypes and lowest leaf area index recorded in genotype SL 1123. In late maturing group genotypes, mean leaf area index values were higher at flower and pod initiation stages then early-and medium- maturing group genotypes thereby showing more photosynthate production, partitioning and accumulation towards sink. However, the genotype SL

958 showed highest leaf area index upto flowering stage and thereafter decreased towards pod initiation stage, while, lower leaf area index recorded in genotype DS 12-13. Panwar *et al.* (18) reported that in greengram, both leaf area and leaf area index attained the maximum values at 45 DAS and started declining thereafter till harvest. Basuchaudhari (2) found that the seed yield is associated with high leaf area index in soybean.

### Plant height (cm)

The data on plant height (Table1) indicated significant differences among the genotypes of early, medium and late maturing groups. In early maturity group, the genotype EC 457161 recorded significantly higher plant height followed by genotype EC 457286 and lower was recorded in genotype SL 688. Among medium group, the genotype SL 744 had reached maximum plant height followed by genotype SL 983 and minimum plant height was recorded in genotype SL 955. While, in late maturing group, the genotype SL 958 recorded highest plant height followed by genotype DS 12-5 and lowest was recorded by genotype DS 12-13. Kumar (10) has also reported that plant height is influenced by the interaction between the environmental variables and genetic make up of the plant.

### Number of pods per plant

The number of pod is an important factor to be considered during selection of desirable genotypes. The variations in number of pods in present investigations were found to be highly significant due to divergent genotypes. The number of pods ranged from 57.02 to 107.30 per plant (Table 1). Among early maturing group genotypes, the genotype EC 457161 recorded significantly higher number of pods per plant. Significantly lower number of pods per plant was recorded by genotype SL 688. While among medium maturing group genotypes, SL 983 recorded higher number of pods per plant followed by SL 744 and lower number of pods per plant was recorded in SL 525. However, in late maturing group genotypes, the genotype SL 958 recorded higher number of pods per plant and lower was recorded in genotype SL 900. These results get sufficient validation from the findings of Malik *et al.*, (13) Molhotra (16), Jagtap and Mehetre (8), and Mehmet *et al.* (14).

### Seed weight (g)

Seed weight is an important yield parameter and vary from genotype to genotype. In the present study 100-seed weight (g) ranged from 10.0 to 12.60 g (Table 1). Among early maturing group genotypes, the genotype EC 457161 recorded higher seed weight and lower was recorded in genotype SL 688. While among medium maturing group genotypes, the genotype SL 983 recorded significantly higher 100 seed weight and genotype SL1123 recorded significantly lower seed weight. In late maturing group genotypes, the genotype SL 958 recorded higher seed weight and it was found to be statistically at par with genotype DS 26-14 and lowest was recorded in genotype DS 12-13.Chand *et al.* (4) and Taware *et al.* (20) also reported the similar results.

### Harvest index

Harvest index reveals the efficiency of translocation of assimilates towards economic parts and therefore, harvest index and seed yield are closely related. Among early maturing genotypes, the genotype EC 457161 recorded significantly higher harvest index and lower harvest index was recorded in SL 795 (Table 1). Among medium maturing group genotypes, the genotype SL 983 recorded higher harvest index which was at par with genotype SL 744. Significantly lower harvest index was recorded in genotype SL 955. In late maturing group genotypes, the genotype SL 958 recorded significantly higher harvest index and lower was recorded in genotype SL 900.

### Seed yield (g/plant)

The data on seed yield per plant (Table 1) differed significantly between the early, medium and late maturing genotypes. In early maturing genotypes, the genotype EC457161 recorded significantly higher seed yield per plant which was at par with genotype EC 457286. A lower seed yield per plant recorded in genotype SL 688. Among medium maturity group genotypes, the genotype SL 983 recorded higher seed yield per plant followed by genotype SL 744 and minimum seed yield was recorded in genotype SL 1123. However, in late maturity genotypes, the genotype SL 958 produced higher seed yield followed by genotype DS 26-14 and lower seed yield was recorded in genotype DS 12-13. The differences could be caused by high day and night temperature differences in the region, different impacts of very high summer temperatures on growth periods of plants and may be due to the fact that the genotypes of different maturity groups. The findings seem to support of Beyyava *et al.* (3) and Gizlenci *et al.* (6).

### Seed yield (Kg ha$^{-1}$)

Seed yield, being complex trait, is highly influenced by various environmental factors including

**Table 1 : Comparative performance of different maturity date genotypes of soybean for yield and yield attributes.**

| Groups | Genotypes | Plant height (cm) | No. of pods/plant | 100-seed weight (g) | Harvest index (%) | Yield/plant (g) |
|---|---|---|---|---|---|---|
| **Early** | SL 688 | 51.83 | 79.34 | 10.97 | 30.87 | 11.06 |
| | SL 778 | 61.91 | 99.41 | 11.53 | 37.37 | 13.78 |
| | SL 795 | 55.37 | 79.81 | 11.67 | 30.04 | 10.63 |
| | EC 457161 | 71.36 | 108.51 | 12.07 | 37.67 | 15.91 |
| | EC457286 | 65.86 | 100.71 | 11.38 | 42.37 | 15.11 |
| | **MEAN** | **61.27** | **93.56** | **11.52** | **35.66** | **13.30** |
| **Medium** | SL 525 | 70.31 | 74.24 | 11.89 | 33.11 | 15.44 |
| | SL 744 | 78.73 | 92.67 | 11.56 | 38.77 | 16.03 |
| | SL 955 | 66.71 | 92.67 | 10.67 | 35.11 | 13.38 |
| | SL 983 | 70.17 | 105.64 | 12.59 | 38.04 | 16.22 |
| | SL1123 | 73.57 | 81.54 | 9.98 | 35.44 | 10.94 |
| | **MEAN** | **71.90** | **89.35** | **11.34** | **36.09** | **14.40** |
| **Late** | SL900 | 80.87 | 57.01 | 12.39 | 27.11 | 11.03 |
| | SL 958 | 82.84 | 101.77 | 12.32 | 35.34 | 17.24 |
| | DS 12-5 | 82.13 | 96.17 | 11.48 | 39.44 | 15.34 |
| | DS 12-13 | 64.31 | 82.37 | 11.04 | 32.53 | 14.31 |
| | DS 26-14 | 67.12 | 88.41 | 11.21 | 36.84 | 15.34 |
| | **MEAN** | **75.46** | **85.15** | **11.69** | **34.25** | **14.65** |
| | **LSD (0.05%)** | **7.23** | **3.95** | **1.09** | **3.18** | **2.89** |
| | **CV** | **6.21** | **2.64** | **4.90** | **5.37** | **12.25** |

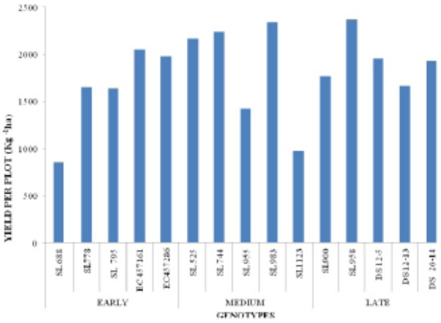

Figure. 3 : Comparative study of diverse genotypes for yield attribute.

biotic and abiotic factors. It is also interplay of various morphological characters which either favour or worsen the final yield. In present investigation seed yield per plot in kg per hectare was measured. Seed yield (Fig 3) was found to be highly significantly different due to different maturing group soybean genotypes. Among early maturing group genotypes, the genotype EC 457161 recorded significantly higher seed yield and significantly lowest was recorded in genotype SL 688. While among in medium maturing group genotypes, the genotype SL 983 recorded higher seed yield and it was found to be at par with genotype SL 744. Significantly lower seed was recorded in genotype SL 1123 followed by SL 955. However, in late maturing genotypes, the genotype SL 958 recorded significantly higher seed yield and lower was recorded in genotype DS 12-13. It was further observed that the genotypes with highest seed weight and more pod numbers had produced higher yield. The findings of Molhotra (16), Malik *et al.* (13), and Mehmet *et al.* (14) also are in accordance with these results.

From the foregoing discussion, it is clear that among various yield components, leaf area, leaf area index, 100- seed weight and harvest index are the most important traits for yield determination in soybean as all these parameters exhibited a significant positive association with seed yield, irrespective of the nature of genotypes and the growing conditions.

## Conclusion

After evaluation of 15 different maturity groups of soybean genotypes, it is concluded that in early maturing genotypes EC 457161, medium SL983 and late SL 958 are superior in term of yield production as well as in other important morphological traits and yield components. Finally, genotype SL 958 at late maturity date seems to be more effective in getting higher grain yields. It is, therefore suggested that this genotype must be brought forward for testing across the various zones of the Punjab.

## REFERENCES

1. Aduloju, M. O., Mahamood, J. and Abayomi, Y A. (2009). Evaluation of soybean [*Glycine max(L)*

Merrill] genotypes for adaptability to a southern Guinea savanna environment with and without P fertilizer application in north central Nigeria. *African J. Agric. Res.*, **4** (6): 556-563.

2. Basuchaudhari, P. (1987). Above ground characteristics of soybean crop. *Anna Agric. Res.*,**8** (1) : 135 – 140.
3. Beyyava, V., Haliloglu, H. and Yýlmaz, A. (2007). The effect of different sowing dates of second crop soybean yield and yield components. J. Agri. Faculty, University of *Harran,***11** (3/4): 23-32
4. Chand, P. (1999). Association analysis of yield and its components in soybean *(Glycine max L.)* Merrill. Madras Agric. J., **86**: 378-381.
5. Chettri, S. S. (2003). Study of variation for yield and yield contributing characters in soybean. *Soybean Sci.*, **23**: 6-9.
6. Gizlenci, S., Ustun, A,. Acar, M,. Dok, M and Aygun, Y. (2005). Determination of the most suitable sowing dates of early and middle early soyabean in middle Black Sea Region. *Turkish 4th Field Crops Cong.*, 5-9 September, Antalya/Turkey, 1:381-386.
7. Hou, A., Chen, P., Alloatti, J., Li, D., Zhang, B. and Shi, A. (2009). Genetic variability of seed sugar content in worldwide soybean germplasm collections. *J. Crops Sci.*, **49**: 903-12.
8. Jagtap, D.R. and Mehetre, S.S. (1994). Genetic variability in some quantitative characters of soybean. *Ann. Agric. Res.*, **15**: 45-49.
9. Jian, J., Guanghua, W., XiaoBing, L., YanXia, X., Liang, M. and Herbert, S. J. (2007). Yield and quality changes from 50 years of genetic improvement of soybean cultivars in Heilongjiang Province. *Res. Agric. Modern.*, **28**(6): 757-761.
10. Kumar, D. (2001). Phenotypic stability of quantitative traits in moth bean. *Indian J. Pulses* Res., 14(2): 116-118.
11. Kumudini, S., Hume, D. J. and Chu, G. (2001). Genetic improvements in short season soybeans I. Dry matter accumulation, partitioning and leaf area duration. *Crop Sci.*, **41**:391–398.
12. Lei, W., Tong, Z. and Shengyan D. (2006). Effect of drought and rewatering on photosynthetic physioecological characteristics of soybean. *Acta Ecol. Sinica,* **26**(7) pp: 2073-2078.
13. Malik, M. F. A., Qureshi, A. S., Ashraf, M. and Ghafoor, A. (2006). Genetic variability of the main yield related characters in soybean. *Int. J. Agric. Biol.*, **8**: 815-819.
14. Mehmet, O., K. Abdullah, Goksoy, A.T. and Turan, Z. M. (2009). Interrelationships of agronomical characteristics in soybean *(Glycine max L.)* grown in different environments. *Int. J. Agric. Biol.*, **11**(1): 85-88.
15. Mehta, N., Bohar, A. B. L., Raneat, G. S. and Mishra Y. (2000). Variability and character association in soybean. *Bangladesh J. Agric. Res.*, **25**: 1-7.
16. Molhotra, R. S. (1973). Genetic variability and discriminate function in soybean (*Glycine max* L. Merrill.). *Madras. Agric. J.*, **60**(4): 225-228.
17. Nijhawan, D. C. and Chandra, S. (1980). The physiology of plant growth with particular reference to the concept of photosynthetic efficiency in mungbean (*Vigna radiata* (Roxb.) Wilezek). *Indian J. Plant Physiol.*, **23** : 40 – 46.
18. Panwar, J. D. S., Shukla, D. S. and Sirohi, G. S. (1986). Growth and developmental aspects in relation to yield of mungbean (*Vigna radiata* L. Wilczek). *Indian J.Plant Physiol.*, **29**(4) : 312 – 316.
19. Soy Stats, (2001). A reference guide to important soybean facts and figures. American Soybean Assoc..
20. Taware, S.P., Halvankar, G.B. and. Raut, V.M. (1997). Variability, correlation and path analysis in some germplasm lines of soybean *(Glycine max.)* with high oil content. *Indian J. Agric. Sci.*, **67**: 476-477.

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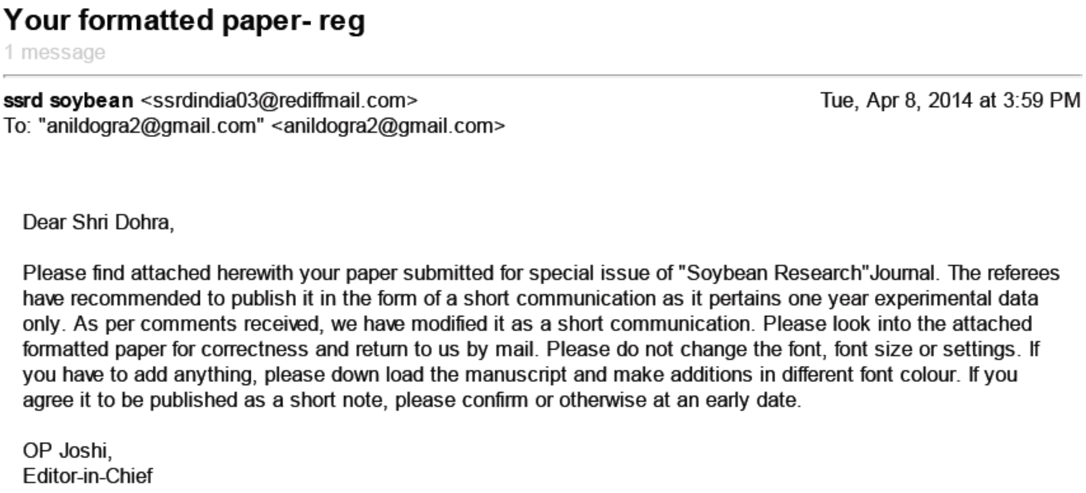

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# 3.3 Impact of Planting Time on the Performance of Soybean (G*lycine max* L. Merrill) Genotypes Under Punjab Conditions

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## ABSTRACT

Soybean (*Glycine max* L. Merrill) yields often decline when plantings are done outward a relatively restricted period of time. The objective was to evaluate the impact of sowing time and genotypes on yield and yield attributes of soybean. For the purpose, an experiment was conducted during *kharif* 2012 at Punjab Agricultural University, Ludhiana, India on the sandy loam soil. Fifteen genotypes with diverse phenology were selected and sown on first fortnight of June and July. Design of the experiment was a randomized block design with three replications and data on different yield attributes were collected. Mean comparison was done by using analysis of variance and significant differences were observed among means of traits at different sowing dates. Further, early sown genotypes gave higher yield as compared to late sown because of more favourable agro-climatic conditions. The genotypes EC 457161, SL 983 and SL 958 produced higher numbers of pods per plant, more 100-seed weight and maximum seed yield than others. The highest seed yield (1,848 kg/ha) recorded was significantly higher in June sown crop than July sowing (1,591 kg/ha). Finally, genotype SL 958 and early planting seems to be more effective in getting higher seed yields.

**Key words: Soybean, planting time, Punjab, yield**

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## INTRODUCTION:

Despite the positive benefits created from the rice-wheat system, the state of Punjab presently faces a number of problems threatening its sustainability. The most important is the over-exploitation of its ground water resources due to excess of paddy cultivation. Soybean is most viable option, which requires less number of irrigations and inputs as compared to paddy. Soybean is an important legume crop contains 20 per cent edible oil and 40 per cent of protein. It has medicinal value and provides protection against heart disease, cancer and other diseases. Soybean is short day plant and is most sensitive to photoperiod. The soybean growth and development can be affected on account of environmental factors, temperature, photoperiod and planting date. Planting at appropriate time of a crop leads to optimum yield. Reduced yields consequent upon late plantings during vegetative and reproductive periods mainly result from shorter day lengths (Board and Settimi, 1986) and decreases the growth period from emergence to R5 (Fehr and Caviness, 1977) resulting in too little vegetative growth for optimum yield (Egli *et al*., 1987). On the other hand, genotype adaptability to a region influences soybean physiology which can be affected by growth habit and planting date (Pedersen and Lauer, 2004). Early planting of soybean genotypes result in more nodes and a greater numbers of pods, higher seeds weight (Woong and Takeo, 2006; Boquet and Clawson, 2007). These yield component changes are linked to extended growth periods during R1 (Bastidas *et al*., 2008) through R8 soybean stages in early as compared to late planted soybean. A shorter day length can also decrease the length of growth stage (Calvin and Brent, 2001) and increase seed mass. The decreases in life cycle of soybean plant due late planting between 13-25 days in comparison with early planting date and it may leads to decrease the biomass of plant. Reduction in seed yield at non-optimal sowing dates resulted from reduced pod set and smaller seed size. The objective of this study was to examine the effect of sowing dates on yield and yield attributes of fifteen diverse genotypes of soybean under Punjab conditions.

## MATERIAL AND METHODS

The experiment was based on randomized block design with three replications in Punjab Agricultural Ludhiana, Punjab, ($30^{o}$ 54’ N $75^{o}$ 48´ E), India in 2012 on the sandy loam soil to investigate the impact of planting date on yield traits of fifteen soybean genotypes. Experiment consisted of two planting dates (first fortnight of June and July) and fifteen genotypes (SL 688, SL 778, SL 795, EC 457161, EC457286, SL 525, SL 744, SL 955, SL 983, SL 1123, SL 900, SL 958, DS 12-5, DS 26-13 and DS 26-14). Each plot consisted of 4 rows, 45 cm apart and 5 m long. Randomly ten plants were taken from each plot to measure plant height (cm), number of pods per plant, 100-seed weight (g), seed weight per plant (g) and seed yield per plot. All the data collected were subjected to statistical analysis to obtain the mean effects of sowing dates and their interaction with genotypes according to analysis of variance (ANOVA) and mean values were compared with least square difference.

## RESULTS AND DISCUSSION

***Plant height (cm):*** Analysis of variance in (Table 1) showed that there was a significant effect of planting time on plant height (Fig. 1). Of the soybean genotypes sown in first fortnight of June, SL 958 had attained maximum plant height followed by genotype DS 12-5 and minimum plant height was recorded by genotype SL 688. While in early July sowing, the same genotype SL 958 recorded maximum plant height, but was less as compared to early June sowing and significantly lowest plant height recorded in genotype SL 688. It appears that genotypes planted in early June better utilises the water and nutrients, which might have led to higher plant height than those planted in early July. Therefore, we expect that the results of this experiment corresponded to lower yields in late planting. Also, the results of analysis of variance showed that there was significantly affect regarding to interaction effect between planting time and genotypes on plant height at 5% probability level (Table 2).

***Number of pods per plant*:** Highly significant variation among the number of pods per plant between genotypes at both the sowing was noted (Table 1). Variance due to interaction between genotypes and sowing dates was also significant. The mean pod number per plant, in case of early June sowing was 89.35 which varied from range 57.01 to 108.71 pods (Table 2). The genotype SL 958 had the highest number of pods per plant, which was statistically at par with genotype EC 457161 followed by genotype SL 744 and SL 983. Significantly lower number of pods per plant recorded in genotypes SL 900. In early July sowing, highest number of pods per plant was produced by EC 457161 followed by genotype EC 457286 and SL 983. Bello (2000) stated that experiment in the Southern Guinea earlier sowings increase the number of pods per plant, number of branches and ultimately increase yield. Also, significantly minimum number of pods per plant was produced by genotype SL 525. These results are in accordance with the finding of Batwal *et al.* (2004) and Kantolic and Slafer (2007).

***100-seed weight (g):*** Plating date, genotypes and their interactions significantly affected 100-seed weight (Table 1). In general, the planting in early July decreased the 100-seed weight as compared to early June planting. This can be accounted for better partitioning of photosynthate to seeds, and shortening of seed fill period and environmental temperature inclement and attitude of plant. In early June planted genotypes, SL 983 produced highest 100-seed weight followed by genotype SL 958, which was at par with genotype EC 457161. Significantly lower value of 100-seed weight was recorded in genotype SL 688. While in early July planted genotypes, SL 958 produced highest value of 100-seed weight followed by genotype DS 26-14 and lower value was recorded in genotype SL 955 (Table 2). So, planting date of June was with suitable conditions for vegetative and reproductive growth of plants and 100-seed weight was greater than late sown. The results of these accords with findings of Moosavi *et al*. (2011).

***Harvest index* :** Large variations for harvest index were observed within and between the environments (Table 1).The mean harvest index value increased from early June to early July planting (Table 2).Among genotypes sown in early June SL 958 had maximum value of harvest index followed by SL 983 and minimum value was recorded by genotype SL 900. However, in early July sowing, the genotypes EC 457161 had obtained maximum value of harvest index followed by genotype EC 457286 and minimum was recorded by genotype SL 1123. Most of the genotypes had high harvest index in late sowing as compare to normal sowing in June. The genotypes in normal sowing produced high biomass that could not be converted into high grain yield thus resulting in low value of harvest index. The genotypes with high harvest index were different in different sowing dates indicating G X E interaction for harvest index (Table 1). Similar results were obtained by Oad *et al.* (2002), Pederson and Lauer (2004).

***Seed yield (g/plant):*** The effect of sowing time on seed yield was found to be highly significant (Table 1). Interaction between genotypes and sowing time was also significant. In case of early June sowing, highest mean (Table 2) seed yield per plant was recorded by genotype SL 958 and followed by SL 983. The lowest seed yield per plant was recorded by genotype DS 12-13. However in early July sowing , the genotype SL 958 had maximum seed yield followed by genotype SL 983 and significantly minimum seed yield per plant recorded by genotype SL 688. The trends recorded in seed yield per plant was similar as was in case of  pods per plant. Thus, grain yield was highest in the optimal sowing date which confirms to the results of Parvez *et al.* (1989), Shishodia and Singh (1995) and Oad *et al.* (2002). Kumar *et al* (2008), Bastidas *et al.* (2008) and Ngalamu *et al.* (2012) also reported decrease in yield with late sowing. In the late planting date crop growing with shorter days and earlier onset of flowering and reproductive competition with the growing consumption of photosynthesis, amount of yield affected.

**Seed yield per plot (kg/ha):** Significant differences in seed yield on account of sowing time were observed (Table 1). In early June sowing, the genotype SL 958 produced more seed yield (Fig. 2) followed by genotype SL 983 and lowest seed yield was recorded by genotype SL 1123. While among in early July sowing, the genotype SL 958 had attained maximum seed yield followed by genotypes SL 983 and EC 457161. Significantly lower seed yield was recorded by genotype SL 688. Such behaviour can be accounted for reduced vegetative phase limiting accumulations of photosynthetes and their translocation to seed due to late planting. As a result, the total amount of assimilates produced in comparison with the number of leaves per plant, will be reduced. In other hand because of the reduction in plant height and number of branches, leading to the lower production number of pods per plant. Also, due to the short duration of grain effecting period, seed reserve amount is also reduced, which will result in reduced 100-seed weight. Other studies of researchers stated yield loss due to delay in planting date. Also, Johnson *et al*., (1995) showed that delayed in planting date leading to decrease seed yield. Reduced size of the canopy and shorten the vegetative growth period stated as one of the main reasons for reduced seed yield history of late sowing (Hocking and Stapper, 2001). Egli and Bruening, (2000) in their study reported a decrease in yield with delayed sowing.

The results of this study showed that significant effect on seed yield and its attributes due to planting dates. The increase in these traits at early planting date may be due to the prevailing of favourable temperature and day length leading to greater of these attributes of soybean plants. The genotypes EC 457161, SL 983 and SL 958 produced higher numbers of pods per plant, more 100-seed weight and maximum seed yield than other because of their better genotypic records. Finally, genotype SL-958 and early planting seem to be more effective in getting higher seed yields.

## *REFERENCES*

Bastidas A M, Setiyono T D, Dobermann A, Cassman K G, Elmore R W, Graef G L and Specht J E. 2008. Soybean sowing date: The vegetative, reproductive, and agronomic impacts. *Crop Science* **48**: 727-40.

Batwal G D, Sebale R N and Varshneya M N. 2004. Effect of sowing time on growth, yield and quality of soybean. *Journal of Maharashtra Agricultural Universities* **29**: 84-5.

Bello L L. 2000. *Effect of Early and Late Planting on Three Soybean Cultivars in Southern Guinea Savanna of Nigeria Department of Crop Production*, University of agriculture P.M.B.2373. makurdi, Nigeria.

Board J E and Settimi J R. 1986. Photoperiod effect before and after flowering on branch development in determinate soybean. *Agronomy Journal* **78**: 995–1102.

Boquet D J and Clawson E L. 2007. Planting dates for soybean varieties in North Louisiana. *Louisiana Agriculture Magazine*, LSUA, center. Com.

Calvin T and Brent B. 2001. Effect of planting date and maturity group on soybean yield. Texas South Extension. *Agronomy Journal* **806**: 35.

Egli D B and Bruening W P. 2000. Potential of early-maturing soybean cultivars in late planting. *Agronomy Journal* **92**: 532-7.

Egli D B, Guffy R D and Heitholt J J. 1987. Factors associated with reduced yields of delayed plantings of soybean. *Crop Science* **159**: 176–85.

Fehr W R and Caviness C E. 1977. *Stages of Soybean Development*. Special Report 80, Iowa Agricultural Experimental Station., Ames, IA.

Hocking P J and Stapper M. 2001. Effects of sowing time and nitrogen fertilizer on canola and wheat, and nitrogen fertilizer on Indian mustard. I. Dry matter production, grain yield and yield components. *Australian Journal of Agricultural Research* **52**: 623-34.

Johnson B L, Mckay K R, Schneiter A A, Hanson B K and Schatz B G. 1995. Influence of planting date on canola and crambe production. *Journal of Production Agriculture* **8**: 594-9.

Kantolic A G and Slafer G A. 2007. Development and seed number in indeterminate soybean as affected by timing and duration of exposure to long photoperiods after flowering. *Field Crops Research* **93**: 212-22.

Kumar A, Pandey V, Shekh A M and Kumar M. 2008. Growth and yield response of soybean (*Glycine max* L.) in relation to temperature, photoperiod and sunshine duration at Anand, Gujarat, India. *American Eurasian Journal of Agronomy* **1**: 45-50.

Moosavi S S, Seyed M J M, Ali A I, Ali M K and Babak S M. 2011. Study of effect of planting date on vegetative traits, reproductive traits and grain yield of soybean cultivars in cold region of Ardabil (Iran). *African Journal of Agricultural Research* **6**(21): 4879-83.

Ngalamu T, Meseka S and Ashraf M. 2012. Performance of soybean (*Glycine max* L. Merrill) genotypes under different planting dates in Sennar State of the Sudan.Journal of Applied Bioscience **49**: 3363-70 .

Oad F C, Gandahi A W, Soomro N M, Samo M A and Oad N L. 2002. Response of soybean *Glycine max* (L) Merrill to planting time. *Journal of Applied Science* **2**: 107-8.

Parvez A Q, Gardner F P and Boote K J. 1989. Determinate and indeterminate type soybean cultivars response to patterns, density and planting date. *Crop Science* **29**: 1557.

Pedersen P and Lauer J G. 2004. Soybean growth and development response to rotation sequence and tillage system. *Agronomy Journal* **96**: 1005-12.

Shishodia S K and Singh S S. 1995. Effect of different planting dates on growth parameters, yield and quality components of three soybean cultivars. *Indian Journal of Environment and Toxicology* **5**: 77-9.

Woong C J and Takeo Y. 2006. *Laboratory of Plant Nutrition*, Division of Soil Science and Plant Production, Kyushu University, 6-10-1 Hakozaki, Fukuoka 812-8581, Japan.

**Table 1. Results of analysis of variance of mean squares for different traits in soybean genotypes pooled over planting dates**

| **Source of variation** | **df** | **Plant height** | **pods/ plant** | **100-seed weight** | **Harvest index** | **Yield/plant** |
|---|---|---|---|---|---|---|
| Replication (in env.) | 4 | $92.61^{ns}$ | $8.661^{ns}$ | $0.042^{ns}$ | $2.46^{ns}$ | $10.19^{ns}$ |
| Sowing time (D) | 1 | 520.75* | 8128.18* | 85.88* | 224.72* | 78.12* |
| Genotypes (G) | 14 | 436.67* | 602.55* | 3.17* | 98.28* | 25.66* |
| Interaction (G x D) | 14 | 49.70* | 154.57* | 1.12* | 46.99* | 8.28* |
| Error | 56 | 20.60 | 6.50 | 0.32 | 4.42 | 2.48 |

*Ns=Non-significant,*Significant at 5%*

**Table 2. Comparison of mean performance of diverse soybean genotypes sown at two planting dates for number of pods, 100-seed weight, harvest index and grain yield**

| **Genotypes** | **Pods (No/plant)** | | **100-Seed weight (g)** | | **Harvest index (%)** | | **Seed yield (g/plant)** | |
|---|---|---|---|---|---|---|---|---|
| | **Early June planting** | **Early July planting** | **Early June planting** | **Early July planting** | **Early June planting** | **Early July planting** | **Early June planting** | **Early July planting** |
| SL 688 | 79.34 | 63.97 | 9.98 | 8.09 | 30.87 | 38.66 | 11.06 | 8.09 |
| SL778 | 99.41 | 79.07 | 11.53 | 9.26 | 37.37 | 42.36 | 13.78 | 13.51 |
| SL 795 | 79.81 | 68.97 | 11.67 | 9.20 | 30.04 | 35.91 | 14.31 | 10.91 |
| EC457161 | 105.71 | 81.84 | 12.07 | 9.74 | 37.67 | 52.51 | 15.91 | 14.21 |
| EC457286 | 92.51 | 81.27 | 11.38 | 9.41 | 38.37 | 43.07 | 15.11 | 13.20 |
| SL 525 | 74.24 | 52.17 | 11.89 | 8.56 | 33.11 | 40.95 | 15.44 | 11.04 |
| SL 744 | 101.64 | 71.07 | 11.56 | 9.95 | 38.77 | 41.22 | 16.03 | 12.13 |
| SL 955 | 92.67 | 69.04 | 10.67 | 7.99 | 35.11 | 32.26 | 15.34 | 11.03 |
| SL 983 | 100.67 | 79.07 | 12.59 | 10.30 | 39.04 | 42.61 | 16.22 | 14.83 |
| SL1123 | 81.54 | 70.07 | 10.97 | 8.83 | 35.44 | 29.43 | 11.03 | 9.71 |
| SL900 | 63.97 | 57.01 | 11.39 | 9.82 | 27.11 | 34.39 | 10.94 | 9.31 |
| SL 958 | 108.17 | 72.91 | 12.32 | 11.36 | 42.34 | 38.12 | 17.24 | 15.04 |
| DS 12-5 | 96.77 | 67.27 | 11.48 | 10.24 | 35.44 | 36.35 | 15.34 | 14.46 |
| DS 12-13 | 82.37 | 64.34 | 11.04 | 9.83 | 32.53 | 37.43 | 10.63 | 10.71 |
| DS 26-14 | 88.41 | 70.11 | 11.21 | 11.08 | 36.84 | 32.22 | 13.38 | 11.76 |
| Mean | 89.35 | 70.34 | 11.52 | 9.58 | 35.34 | 38.50 | 14.12 | 12.28 |
| **LSD (P = 5%)** | **3.95** | **4.57** | **1.09** | **0.78** | **3.18** | **3.84** | **2.89** | **2.34** |
| CV (%) | 2.64 | 3.88 | 4.90 | 4.91 | 5.37 | 5.96 | 12.25 | 11.45 |

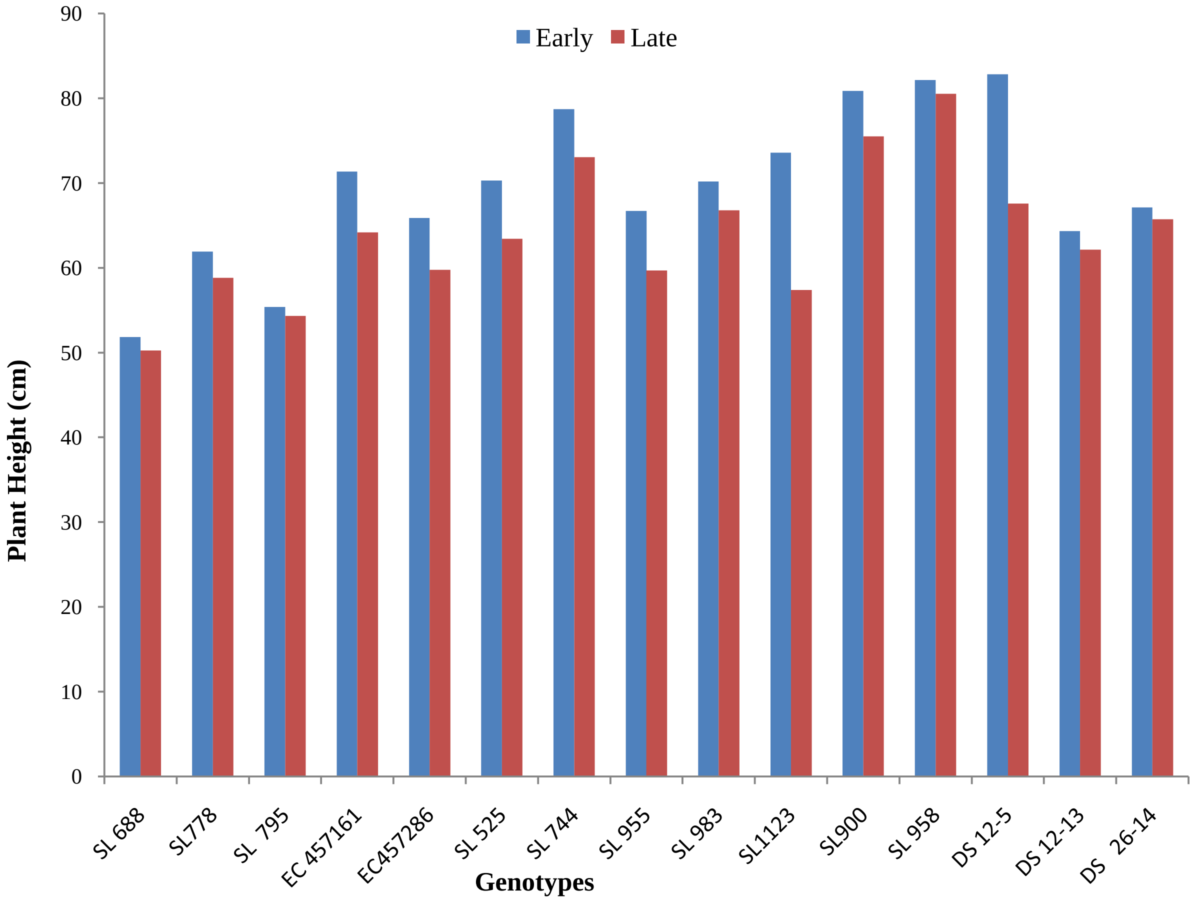

**Fig 1.** **Interactive effect of planting date and genotypes on plant height (cm) of diverse soybean genotypes**

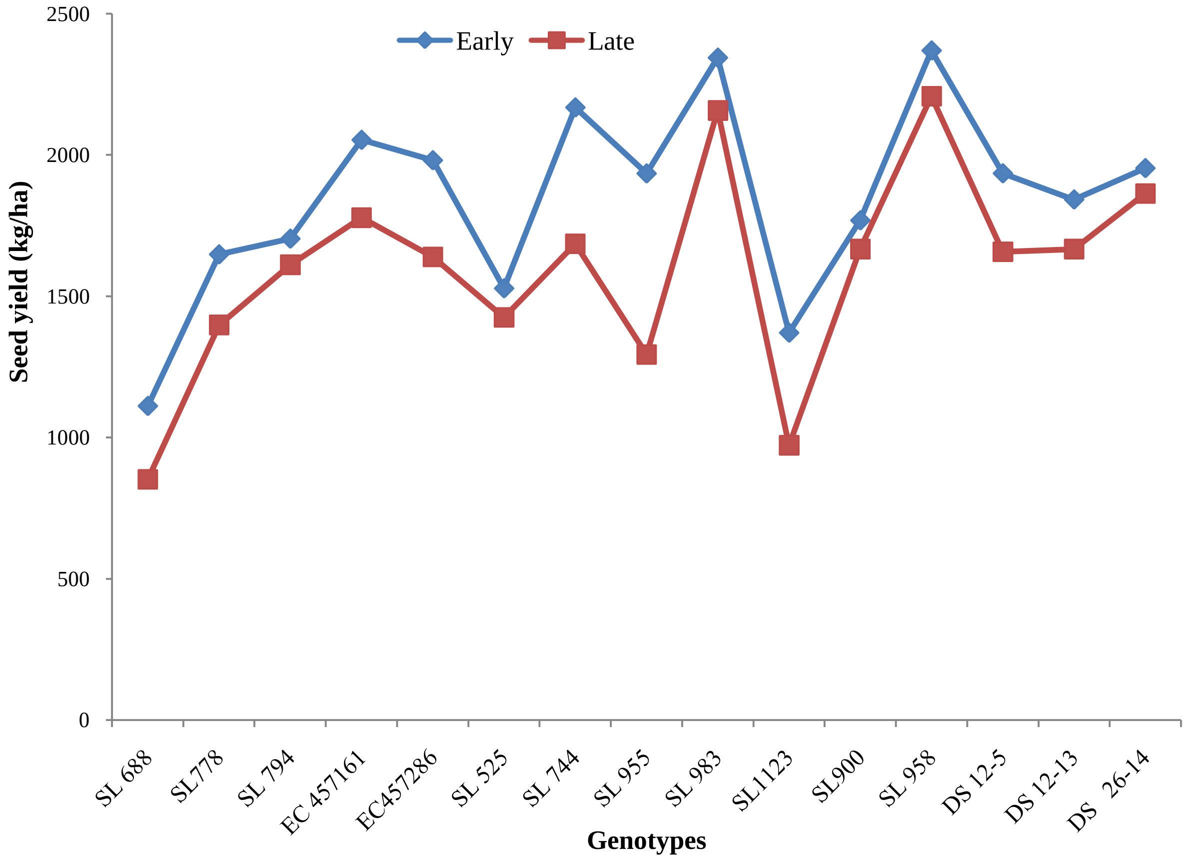

**Fig 2. Interactive effect of planting date and genotypes on seed yield (kg/ha) of diverse soybean genotypes**

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## Acknowledgement Letter

Dear Sir/ Madam,

We acknowledge with thanks the receipt of your paper entitled:

**Correlation and path analysis of morpho-physiological traits with yield of soybean (*Glycine max* L. Merrill) genotypes under variable photoperiods**

*Anil Kumar Dogra, Jagmeet Kaur, B S Gill and Tilak Raj*

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## 3.4 Correlation and path analysis of morpho-physiological traits with yield of soybean (*Glycine max* L. Merrill) genotypes under variable photoperiods

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### Abstract

Grain yield is the most important quantitative character inbreeding of soybean, depending on both the genotypic potential and environmental conditions. Soybean yield reduces under shorter photoperiod due to decrease in duration of crop growth period and ultimately resulted in declines of yield attributes. A experiment was conducted at Punjab agricultural University, Ludhiana during *kharif* season 2012, where fifteen soybean genotypes were grown under longer (early June) and shorter (early July) photoperiods. Various morpho-physiological characters viz., leaf area index, specific leaf weight, net photosynthetic rate and transpiration rate all at vegetative, flowering and pod initiation stages, crop growth rate and relative growth rate both at 30-45 DAS and 45-60 DAS and seed yield were evaluated by applying correlation and path analysis in order to determine the relationships between these characters under variable photoperiodic conditions. The correlation analysis showed significant positive relationships between most of the traits with seed yield. Path coefficient analysis revealed that under longer photoperiod the maximum direct effect was observed in crop growth rate at 45-60 days after sowing with seed yield (1.649). Similarly, maximum value of direct relationship was observed between transpiration rate at flowering and seed yield (1.884) under shorter photoperiod. The present study explored the importance of morpho-physiological traits viz., leaf area index at vegetative, leaf area index at flowering, specific leaf weight at vegetative, crop growth rate at 30-45 DAS, relative growth rate at 30-45 DAS and 45-60 DAS, net photosynthetic rate at vegetative and flowering stage, for the selection of superior genotypes in soybean.

**Key words**: Soybean, Correlation coefficient, Path analysis, Photoperiod, Seed yield.

## INTRODUCTION:

Soybean (*Glycine max.* L. Merrill) is one of the most important leguminous crops in the world. Its importance can be understood by its outstanding properties. Soybean contains 35-40 % of good quality protein (Hou *et al.,* 2009) and 18-20 % oil comprising 85 % of unsaturated fatty acids and is free from cholesterol along with adequate amount of mineral elements which are highly desirable in human diet. Besides, it can also be utilized as animal feed. Being a leguminous crop, soybean enhances soil fertility by supplying nitrogen and organic matter to the soil. India ranks fifth in the world after USA, Brazil, Argentina and China in soybean production and accounts for 11.5 million metric tons (3%) of total world production in the year 2012-13 (Soy Stats, 2013). However, average yield of soybean in India is less than that of world average which needs to be improved through genetic manipulations.

Grain yield of soybean is a complex character which is dependent on a number of components. In breeding programme to improve yield of crops, the breeder has the choice to select yield directly or indirectly through yield related traits. Morpho-physiological traits, if correlated with grain yield in soybean, can be used as indirect selection for yield. The path coefficient analysis helps to partition correlation coefficient in to direct and indirect effects (Dewey and lu, 1959; Saleem *et al.,* 1999) can be used to supplement information on correlation coefficients. The correlations of yield with yield components and morphological traits has been studied extensively and used as a tool to improve seed yield of soybean (Board *et al.,* 1997; Arshad *et al.,* 2006; Malik *et al.,* 2006). But correlations among different character can vary under different environments. Keeping these points in view, the present study has been planned with the following objectives. First, to establish the correlation between yield and morpho-physiological traits under variable photoperiods and second, to determine the direct and indirect effect of morphological traits on grain yield in soybean genotypes grown under variable photoperiods in order to find out a suitable trait that could be used for the yield improvement.

## Materials and Methods

The field experiment was conducted at the research area of the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, between June and November 2012. Ludhiana is situated in the sub-tropical zone of Punjab at about 247m above sea level on latitude 30° 54’N and longitude 75° 48’E. The soil at the experimental site is sandy loam and experimental material consisting of 15 soybean genotypes were sown in randomized block design with three replications. Each block consisted of 15 plots, each of which measured 5m x 4m, giving a total of 45 plots, and the spacing between plants and rows were 5cm and 45cm respectively, with one meter alleys between the blocks. Data were recorded on 5 plants of each plot for morpho-physiological traits viz., Leaf area index, specific leaf weight, crop growth rate, relative growth rate, photosynthetic rate, transpiration rate and seed yield (g/plant) and average was calculated. The data were statistically analyzed using ANOVA. Correlation and path coefficient analysis were carried out using SPSS 16.

## Results and Discussion

### Correlation coefficient analysis:

The correlation matrix of yield and morpho-physiological traits of soybean genotypes under variable photoperiods (longer and shorter) are illustrated on Table 1. A close look at the Table 1 (top diagonal) elucidates all parameters were positively and significantly correlated with seed yield under longer photoperiodic conditions. Leaf area index at vegetative stage was highly correlated with seed yield per plot i.e. r =

0.890 followed by leaf Area Index at flowering (r = 0.825), net photosynthetic rate (r = 0.785) and transpiration rate at vegetative (r = 0.768). Likewise, specific leaf weight at flowering was positively and significantly linked with crop growth rate at 30-45 DAS (r=0.518). Specific leaf weight at flowering was positively and significantly correlated with net photosynthetic rate at flowering and pod stage. Further, net photosynthetic rate at vegetative was positively and significantly associated with transpiration rate at vegetative, flowering and pod stage with the value of correlation coefficient of 0.835, 0.693 and 0.526, respectively. Similarly, leaf area index at vegetative, flowering and pod stage were positively and significantly linked with net photosynthetic rate at vegetative, flowering and pod stage. The highest correlation was obtained between relative growth rate at 30-45 DAS and relative growth rate at 45-60 with correlation coefficient of 0.963 and was significant. Plant breeders are interested to know the extent of relationship between yield and its various morpho-physiological traits, which will enhance their selection processes. Our Correlation results showed significantly positive relationships between most of the traits and seed yield. Since the leaves are better exposed to solar radiation owing to the broader leaf area, photosynthesis processes thus increase on the leaf surface with the resultant increase in productivity. Our results depicted that leaf area index at harvest was found to have positive significant correlation with seed yield during both the photoperiodic condition. This suggests that the maintenance of high leaf area index, particularly at the time of flowering stage is necessary for higher productivity in soybean. Gill *et al.* (1992) also observed a positive correlation of seed yield with leaf area index in greengram. Similar reports have been made by Renganayaki and Sreerangasamy (1992) in blackgram. Singh and Singh (1982) reported that specific leaf weight made a substantial contribution to seed yield and was found to be strongly associated with seed yield in greengram. Similar to our findings, Dornhoff and Shibles (1970) suggested that specific leaf weight may be considered as an important character for higher productivity in soybean. The results of correlation studies indicated a significant positive association of crop growth rate (30 – 45 DAS and 45 -60 DAS) with seed yield during both the photoperiods. These results are in agreement with the reports of Gill *et al.* (1992), who found a significant positive correlation between seed yield and crop growth rate in greengram. Similar pattern of association has also been reported by Prasad *et al.* (1979) in chickpea and by Kenneth and Hell (1980) in soybean.

Likewise, a glance at Table 1 (bottom diagonal) showed that all parameters were positively correlated with seed yield under shorter photoperiodic condition. Leaf area index at vegetative stage showed the highest correlation with seed yield (r=0.909) than other parameters. Specific leaf weight at vegetative stage associated positively and significantly with net photosynthetic rate at vegetative, pod and flowering stages. Specific leaf weight at vegetative stage had correlation coefficient of 0.805 with seed yield which was significant. Similarly, Leaf area index at vegetative stage was positively and significantly related with net photosynthetic rate at vegetative and flowering stage. Likewise, leaf area index at flowering stage linked with net photosynthetic rate at vegetative, flowering and pod stage with correlation coefficient of 0.821, 0.846 and 0.636, respectively and net photosynthetic rate at vegetative, flowering and pod stage along with transpiration rate at vegetative, flowering and pod stages were positively and significantly correlated with seed yield under shorter photoperiodic condition. Besides, net photosynthetic rate was also positively and significantly correlated with transpiration rate at vegetative, flowering and pod stage. Photosynthetic rate was found to have significant positive correlation with seed yield, thereby clearly indicating the importance of this parameter in improving the yield potential of genotypes. Kuo *et al.* (1977) also reported a significant positive association between the seed yield and the photosynthetic rate in greengram. Similarly, Rao and Ghildiyal (1985) established a positive relationship between photosynthetic rate and seed yield in greengram. It is obvious that higher photosynthetic rate and transpiration rate leads to higher production of dry matter and yield and this has also been proved from the results of the present investigation.

### Path Coefficient Analysis:

The results presented in Table 2 revealed that under longer photoperiodic conditions, leaf area index at pod initiation stage, specific leaf weight at flowering, specific leaf weight at pod, crop growth rate at 45-60 DAS, net photosynthetic rate at flowering and pod, transpiration rate at vegetative and pod stage had negative direct effect on seed yield. This suggested that selection on the basis of these traits might lead to loss in term of soybean yield. However, leaf area index at vegetative, leaf area index at flowering, specific leaf weight at vegetative, crop growth rate at 30-45 DAS, relative growth rate at 30-45 DAS and 45-60 DAS, net photosynthetic rate at vegetative and flowering showed the positive direct effect with seed yield. Maximum direct effect was observed in crop growth rate at 45-60 days after sowing on grain yield with a value of (1.649). In the same way, under shorter photoperiod leaf area index at flowering and pod, specific leaf weight at pod, crop growth rate at 30-45 DAS and 45-60 DAS, net photosynthetic rate at flowering and transpiration rate at vegetative exerted negative direct effect on seed yield (Table 3). In contrary, leaf area index at vegetative, specific leaf weight at vegetative and flowering, relative growth rate at 30-45 DAS, net photosynthetic rate at vegetative and pod stage, transpiration rate at flowering and pod stage demonstrated positive direct effect on seed yield. Maximum value of direct relationship was observed between transpiration rate at flowering and seed yield (1.884). The results of this experiment are also supported by other researchers (Ball *et al.,* 2001; Arshad *et al.,* 2006).

## Conclusion

Our results suggest that the leaf area index at vegetative and flowering stage, crop growth rate at 30 - 45 DAS, net photosynthetic rate at vegetative and transpiration rate at vegetative and flowering stage should be considered while selecting for high yielding soybean genotypes under variable photoperiods. Additionally, path coefficient results explicitly indicate that the leaf area index at vegetative, leaf area index at flowering, specific leaf weight at vegetative, crop growth rate at 30-45 DAS, relative growth rate at 30-45 DAS and 45-60 DAS, net photosynthetic rate at vegetative and flowering which directly contributed substantially towards seed yield, should be indices for selection in soybean. Interestingly, the correlation and path coefficients results are in agreement confirming the importance of these traits during selection.

## References:

Arshad, M., N. Ali and A. Ghafoor: Character correlation and Path coefficient in Soybean *Glycine max* (L.) Merrill. *Pakistan J. Bot.,* **38,** 121-130 (2006).

Ball, R. A., R. W. McNew, E. D. Vories, J. C. Keisling and L. C. Purcell: Path analysis of population density effects on short-season soybean yield. *Agron. J.*, **93,** 187-195 (2001).

Board, J.E., M.S. Kang and B.G. Harville: Path analyses identify indirect selection criteria for yield of late planted soybean. *Crop Sci.,* **37,** 879-884 (1997).

Dewey, D. R. and K. H. Lu: Correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agron. J.*,**51,** 515–518 (1959).

Dornhoff, R. G. M. and R. M. Shibles: Varietal differences in net photosynthesis of soybean leaves. *Crop Sci*., **10**, 42-45 (1970).

Gill, D. S., M. M. Verma and G. S. Brar: Physiological parameters determining yield in mungbean. *Crop improvement.,* **19**, 29 – 33 (1992).

Hou, A., P. Chen, J. Alloatti, D. Li, B. Zhang and A. Shi: Genetic variability of seed sugar content in worldwide soybean germplasm collections. *J Crops Sci* **49,** 903-12 (2009).

Kenneth, J. J. and A. E. Hell: Drought adoption of cowpea. Influence of drought on plant growth and relation with seed yield. *Agron. J.,* **72**, 428 -433(1980).

Kuo, C. G., L. J. Wang, A. C. Cheng and M. H. Chou: Physiological basis for mungbean yield improvement. In : *Proceedings of the first International Symposium on Mungbean,* University of Philippines, Los Banos, 16 – 19 August, 1977, pp. 205 – 213. (1977).

Malik, M F A., A S. Qureshi, M. Ashraf and A. Ghafoor: Genetic variability of the main yield related characters in soybean. *Intl. J.Agric. and Biol.,* **8**, 815-819 (2006).

Prasad, V. V. S., R. K. Pandey, and M. C. Saxena: Physiological analysis of yield variation in gram (*Cicer arietinum* C.) genotypes. *Indian J of Pl Physiol.,* **21**: 228 – 234 (1979).

Rao, T. R. K. and M. C. Ghildiyal: Analysis of photosynthetic source and sink relationship in mungbean (*Vigna radiata* L. Wilczek). *Indian J of Pl Physiol.,* **28**, 135 – 144 (1985).

Renganayaki, K. and S. R. Sreerangasamy: Path coefficient analysis in blackgram. *Madras Agricultural Journal.,* **79**, 634– 639 (1992).

Saleem, M. S., M. Ali, W. Yousuf, A. A. Haris: Path coefficient analysis of seed yield and quantities traits in chickpea (Cicer arietinum L.). *Int. J. Agric. Biol*. **1,** 106–107 (1999).

Singh, G.B. and J. N. Singh: Effect of seasonal changes on growth parameters of greengram (*Vigna radiate* (L.) Wilezek). *Indian J of Pl Physiol.,* **25**, 382 – 389 (1982).

Stats, S: http:/ / www.soystats.com/2013/Default-frames.htm. (2013).

**Table 1: Correlation matrix of yield and Morpho-physiological traits of soybean genotypes under longer photoperiod ( top of diagonal ) and shorter photoperiod ( bottom of diagonal).**

| | LAIV | LAIF | LAIP | SLWV | SLWF | SLWP | CGR1 | CGR2 | RGR1 | RGR2 | NPRV | NPRF | NPRP | TRV | TRF | TRP | SY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LAIV | 1 | 0.787** | 0.757** | 0.735** | 0.716** | 0.657** | 0.755** | 0.760** | 0.759** | 0.764** | 0.784** | 0.767** | 0.791** | 0.724** | 0.753** | 0.620* | 0.890** |
| LAIF | 0.684** | 1 | 0.740** | 0.557* | 0.784** | 0.524* | 0.596* | 0.523* | 0.637* | 0.639* | 0.611* | 0.697** | 0.661** | 0.669** | 0.590* | 0.377 | 0.825** |
| LAIP | 0.611* | 0.528* | 1 | 0.543* | 0.721** | 0.682** | 0.688** | 0.643** | 0.858** | 0.857** | 0.658** | 0.534* | 0.671** | 0.596* | 0.557* | 0.580* | 0.713** |
| SLWV | 0.707** | 0.751* | 0.613* | 1 | 0.664** | 0.645** | 0.293 | 0.294 | 0.472 | 0.495 | 0.732** | 0.688** | 0.708** | 0.523* | 0.788** | 0.525* | 0.741** |
| SLWF | 0.531* | 0.398 | 0.203 | 0.391 | 1 | 0.677** | 0.518* | 0.377 | 0.580* | 0.530* | 0.524* | 0.641* | 0.673** | 0.564* | 0.635* | 0.518* | 0.701** |
| SLWP | 0.407 | 0.247 | 0.142 | 0.27 | 0.182 | 1 | 0.462 | 0.461 | 0.610* | 0.630* | 0.584* | 0.710** | 0.540* | 0.295 | 0.608* | 0.675** | 0.553* |
| CGR1 | 0.603* | 0.298 | 0.144 | 0.486 | 0.384 | 0.326 | 1 | 0.961** | 0.833** | 0.821** | 0.606* | 0.475 | 0.649* | 0.672** | 0.51 | 0.630* | 0.668** |
| CGR2 | 0.644** | 0.503 | 0.229 | 0.552* | 0.588* | 0.401 | 0.879** | 1 | 0.803** | 0.822** | 0.605* | 0.515* | 0.601* | 0.603* | 0.503 | 0.572* | 0.607* |
| RGR1 | 0.773** | 0.759** | 0.505 | 0.852** | 0.402 | 0.373 | 0.641* | 0.732** | 1 | 0.963** | 0.772** | 0.487 | 0.651** | 0.723** | 0.48 | 0.729** | 0.737** |
| RGR2 | 0.718* | 0.589* | 0.412 | 0.772** | 0.585* | 0.353 | 0.776** | 0.882** | 0.799** | 1 | 0.767** | 0.528* | 0.623* | 0.619* | 0.473 | 0.712** | 0.752** |
| NPRV | 0.604* | 0.821** | 0.549* | 0.792** | 0.156 | 0.204 | 0.504 | 0.601* | 0.868** | 0.652** | 1 | 0.638* | 0.744** | 0.835** | 0.693** | 0.526* | 0.785** |
| NPRF | 0.665** | 0.846** | 0.548* | 0.779** | 0.452 | 0.524* | 0.268 | 0.501 | 0.766** | 0.694** | 0.719** | 1 | 0.747** | 0.45 | 0.830** | 0.436 | 0.636* |
| NPRP | 0.419 | 0.636* | 0.141 | 0.530* | 0.051 | 0.473 | 0.271 | 0.336 | 0.574* | 0.482 | 0.48 | 0.666** | 1 | 0.738** | 0.942** | 0.505 | 0.768** |
| TRV | 0.646** | 0.615* | 0.579* | 0.703** | 0.262 | 0.048 | 0.409 | 0.51 | 0.821** | 0.524* | 0.825** | 0.505 | 0.213 | 1 | 0.611* | 0.371 | 0.717** |
| TRF | 0.642** | 0.703** | 0.455 | 0.649** | 0.351 | 0.524* | 0.661** | 0.868** | 0.775** | 0.789** | 0.783** | 0.683** | 0.49 | 0.602* | 1 | 0.434 | 0.672** |
| TRP | 0.611* | 0.747** | 0.214 | 0.697** | 0.351 | 0.252 | 0.673** | 0.691** | 0.723** | 0.667** | 0.815** | 0.599* | 0.478 | 0.613* | 0.706** | 1 | 0.660** |
| SY | 0.909** | 0.772** | 0.576* | 0.805** | 0.386 | 0.202 | 0.544* | 0.568* | 0.775 | 0.673** | 0.705** | 0.662* | 0.516* | 0.725** | 0.629* | 0.731** | 1 |

Note: *, ** indicates the correlation significant at the 0.05 and 0.01 probability level.

LAIV= Leaf Area Index at Vegetative, LAIF=Leaf Area Index at Flowering, LAIP=Leaf Area Index at Pod , SLWV= Specific Leaf Weight at Vegetative, SLWF=Specific Leaf Weight at Flowering, SLWP = Specific Leaf Weight at Pod, CGR1= Crop Growth Rate at 30-45 days after sowing, CGR2= Crop Growth Rate at 45-60 days after sowing , RGR1= Relative Growth Rate at 30-45 days after sowing, RGR2= Relative Growth Rate at 45-60 days after sowing, NPRV= Net Photosynthetic Rate at vegetative, NPRF= Net Photosynthetic Rate at Flowering, NPRV= Net Photosynthetic Rate at Pod, TRV= Transpiration Rate at vegetative, TRF= Transpiration Rate at Flowering, TRP= Transpiration Rate at Pod, SY= Seed Yield.

**Table 2. Direct (diagonal) and indirect (off diagonal) effects of 16 characters on seed yield of soybean genotypes under longer photoperiod.**

| | LA1V | LAIF | LAIP | SLWV | SLWF | SLWP | CGR1 | CGR2 | RGR1 | RGR2 | NPRV | NPRF | NPRP | TRV | TRF | TRP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LA1V** | **1.082** | 0.570 | -0.412 | 0.043 | -0.331 | -0.151 | 1.244 | -1.514 | 0.639 | 0.097 | 0.294 | -0.373 | -0.318 | -0.603 | 0.658 | -0.037 |
| **LAIF** | 0.852 | **0.725** | -0.403 | -0.033 | -0.362 | -0.120 | 0.983 | -1.060 | 0.536 | 0.081 | 0.229 | -0.338 | -0.266 | -0.557 | 0.516 | -0.022 |
| **LAIP** | 0.819 | 0.537 | **-0.544** | 0.032 | -0.333 | -0.157 | 1.135 | -1.280 | 0.722 | 0.109 | 0.247 | -0.260 | -0.270 | -0.496 | 0.486 | -0.035 |
| **SLWV** | 0.795 | 0.404 | -0.296 | **0.059** | -0.307 | -0.148 | 0.483 | -0.586 | 0.397 | 0.063 | 0.275 | -0.334 | -0.285 | -0.436 | 0.688 | -0.031 |
| **SLWF** | 0.775 | 0.568 | -0.392 | 0.039 | **-0.462** | -0.155 | 0.855 | -0.751 | 0.489 | 0.067 | 0.196 | -0.311 | -0.271 | -0.470 | 0.554 | -0.031 |
| **SLWP** | 0.711 | 0.379 | -0.371 | 0.038 | -0.313 | **-0.230** | 0.761 | -0.919 | 0.514 | 0.080 | 0.219 | -0.345 | -0.217 | -0.246 | 0.531 | -0.040 |
| **CGR1** | 0.817 | 0.432 | -0.375 | 0.017 | -0.240 | -0.106 | **1.649** | -1.916 | 0.701 | 0.104 | 0.227 | -0.231 | -0.261 | -0.559 | 0.445 | -0.037 |
| **CGR2** | 0.822 | 0.386 | -0.350 | 0.017 | -0.174 | -0.106 | 1.586 | **-1.992** | 0.676 | 0.104 | 0.227 | -0.250 | -0.242 | -0.502 | 0.439 | -0.034 |
| **RGR1** | 0.821 | 0.462 | -0.467 | 0.028 | -0.268 | -0.140 | 1.373 | -1.600 | **0.842** | 0.122 | 0.289 | -0.237 | -0.262 | -0.602 | 0.419 | -0.043 |
| **RGR2** | 0.827 | 0.463 | -0.466 | 0.029 | -0.245 | -0.145 | 1.353 | -1.637 | 0.810 | **0.127** | 0.288 | -0.256 | -0.251 | -0.515 | 0.413 | -0.042 |
| **NPRV** | 0.849 | 0.443 | -0.358 | 0.043 | -0.242 | -0.134 | 0.999 | -1.206 | 0.649 | 0.098 | **0.375** | -0.310 | -0.299 | -0.695 | 0.605 | -0.031 |
| **NPRF** | 0.830 | 0.505 | -0.291 | 0.040 | -0.296 | -0.163 | 0.783 | -1.027 | 0.410 | 0.067 | 0.239 | **-0.486** | -0.301 | -0.375 | 0.725 | -0.026 |
| **NPRP** | 0.856 | 0.479 | -0.365 | 0.041 | -0.311 | -0.124 | 1.070 | -1.197 | 0.548 | 0.079 | 0.279 | -0.363 | **-0.402** | -0.615 | 0.823 | -0.030 |
| **TRV** | 0.784 | 0.485 | -0.324 | 0.031 | -0.261 | -0.068 | 1.108 | -1.201 | 0.609 | 0.079 | 0.313 | -0.219 | -0.297 | **-0.833** | 0.533 | -0.022 |
| **TRF** | 0.815 | 0.428 | -0.303 | 0.046 | -0.293 | -0.140 | 0.841 | -1.002 | 0.404 | 0.060 | 0.260 | -0.403 | -0.379 | -0.508 | **0.873** | -0.026 |
| **TRP** | 0.671 | 0.274 | -0.316 | 0.031 | -0.239 | -0.155 | 1.038 | -1.141 | 0.613 | 0.091 | 0.197 | -0.212 | -0.155 | 1.038 | 0.379 | **-0.060** |

LAIV= Leaf Area Index at Vegetative, LAIF=Leaf Area Index at Flowering, LAIP=Leaf Area Index at Pod , SLWV= Specific Leaf Weight at Vegetative, SLWF=Specific Leaf Weight at Flowering, SLWP = Specific Leaf Weight at Pod, CGR1= Crop Growth Rate at 30-45 days after sowing, CGR2= Crop Growth Rate at 45-60 days after sowing , RGR1= Relative Growth Rate at 30-45 days after sowing, RGR2= Relative Growth Rate at 45-60 days after sowing, NPRV= Net Photosynthetic Rate at vegetative, NPRF= Net Photosynthetic Rate at Flowering, NPRV= Net Photosynthetic Rate at Pod, TRV= Transpiration Rate at vegetative, TRF=Transpiration Rate at Flowering, TRP= Transpiration Rate at Pod, SY= Seed Yield.

**Table 3. Direct (diagonal) and indirect (off diagonal) effects of 16 characters on seed yield of soybean genotypes under shorter photoperiod.**

| | **LAIV** | **LAIF** | **LAIP** | **SLWV** | **SLWF** | **SLWP** | **CGR1** | **CGR2** | **RGR1** | **RGR2** | **NPRV** | **NPRF** | **NPRP** | **TRV** | **TRF** | **TRP** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LAIV** | **1.157** | -0.636 | -0.096 | -0.073 | 0.342 | -0.247 | -0.013 | -1.296 | 0.463 | -0.004 | 0.051 | -0.325 | 0.016 | -0.251 | 1.201 | 0.333 |
| **LAIF** | 0.791 | **-0.929** | -0.084 | 0.077 | 0.256 | -0.15 | -0.007 | -1.016 | 0.455 | -0.004 | 0.07 | -0.414 | 0.241 | -0.238 | 1.317 | 0.406 |
| **LAIP** | 0.706 | -0.49 | **-0.158** | 0.063 | 0.131 | -0.086 | -0.003 | -0.46 | 0.302 | -0.002 | 0.047 | -0.268 | 0.053 | -0.224 | 0.852 | 0.116 |
| **SLWV** | 0.818 | -0.697 | -0.097 | **0.102** | 0.251 | -0.164 | -0.011 | -1.12 | 0.51 | -0.005 | 0.067 | -0.381 | 0.210 | -0.272 | 1.213 | 0.379 |
| **SLWF** | 0.614 | -0.369 | -0.032 | 0.04 | **0.643** | -0.110 | -0.008 | -1.193 | 0.24 | -0.004 | 0.013 | -0.221 | 0.019 | -0.101 | 0.657 | 0.191 |
| **SLWP** | 0.47 | -0.229 | -0.023 | 0.028 | 0.116 | **-0.609** | -0.007 | -0.807 | 0.224 | -0.002 | 0.017 | -0.257 | 0.179 | -0.019 | 0.982 | 0.137 |
| **CGR1** | 0.697 | -0.277 | -0.023 | 0.05 | 0.247 | -0.198 | **-0.022** | -1.781 | 0.384 | -0.005 | 0.043 | -0.131 | 0.103 | -0.159 | 1.249 | 0.367 |
| **CGR2** | 0.745 | -0.468 | -0.037 | 0.057 | 0.379 | -0.244 | -0.02 | **-2.020** | 0.439 | -0.005 | 0.051 | -0.245 | 0.127 | -0.197 | 1.636 | 0.376 |
| **RGR1** | 0.894 | -0.706 | -0.08 | 0.088 | 0.259 | -0.228 | -0.014 | -1.470 | **0.599** | -0.005 | 0.074 | -0.376 | 0.217 | -0.319 | 1.467 | 0.394 |
| **RGR2** | 0.831 | -0.547 | -0.065 | 0.079 | 0.376 | -0.214 | -0.017 | -1.783 | 0.479 | **-0.005** | 0.056 | -0.34 | 0.187 | -0.204 | 1.651 | 0.362 |
| **NPRV** | 0.699 | -0.764 | -0.087 | 0.081 | 0.101 | -0.125 | -0.012 | -1.221 | 0.521 | -0.004 | **0.085** | -0.352 | 0.182 | -0.321 | 1.477 | 0.443 |
| **NPRF** | 0.769 | -0.787 | -0.087 | 0.08 | 0.291 | -0.319 | -0.006 | -1.009 | 0.459 | -0.004 | 0.061 | **-0.489** | 0.252 | -0.197 | 1.289 | 0.327 |
| **NPRP** | 0.485 | -0.592 | -0.022 | 0.055 | 0.032 | -0.288 | -0.006 | -0.677 | 0.345 | -0.003 | 0.041 | -0.327 | **0.379** | -0.083 | 0.918 | 0.259 |
| **TRV** | 0.748 | -0.572 | -0.092 | 0.072 | 0.169 | -0.293 | -0.009 | -1.037 | 0.493 | -0.003 | 0.07 | -0.248 | 0.081 | **-0.388** | 1.128 | 0.334 |
| **TRF** | 0.743 | -0.654 | -0.072 | 0.067 | 0.226 | -0.318 | -0.013 | -1.748 | 0.467 | -0.005 | 0.067 | -0.335 | 0.186 | -0.233 | **1.884** | 0.385 |
| **TRP** | 0.708 | -0.694 | -0.034 | 0.072 | 0.227 | -0.154 | -0.015 | -1.393 | 0.434 | -0.004 | 0.069 | -0.294 | 0.181 | -0.238 | 1.133 | **0.544** |

LAIV= Leaf Area Index at Vegetative, LAIF=Leaf Area Index at Flowering, LAIP=Leaf Area Index at Pod , SLWV= Specific Leaf Weight at Vegetative, SLWF=Specific Leaf Weight at Flowering, SLWP = Specific Leaf Weight at Pod, CGR1= Crop Growth Rate at 30-45 days after sowing, CGR2= Crop Growth Rate at 45-60 days after sowing , RGR1= Relative Growth Rate at 30-45 days after sowing, RGR2= Relative Growth Rate at 45-60 days after sowing, NPRV= Net Photosynthetic Rate at vegetative, NPRF= Net Photosynthetic Rate at Flowering, NPRV= Net Photosynthetic Rate at Pod, TRV= Transpiration Rate at vegetative, TRF=Transpiration Rate at Flowering, TRP= Transpiration Rate at Pod, SY= Seed Yield.

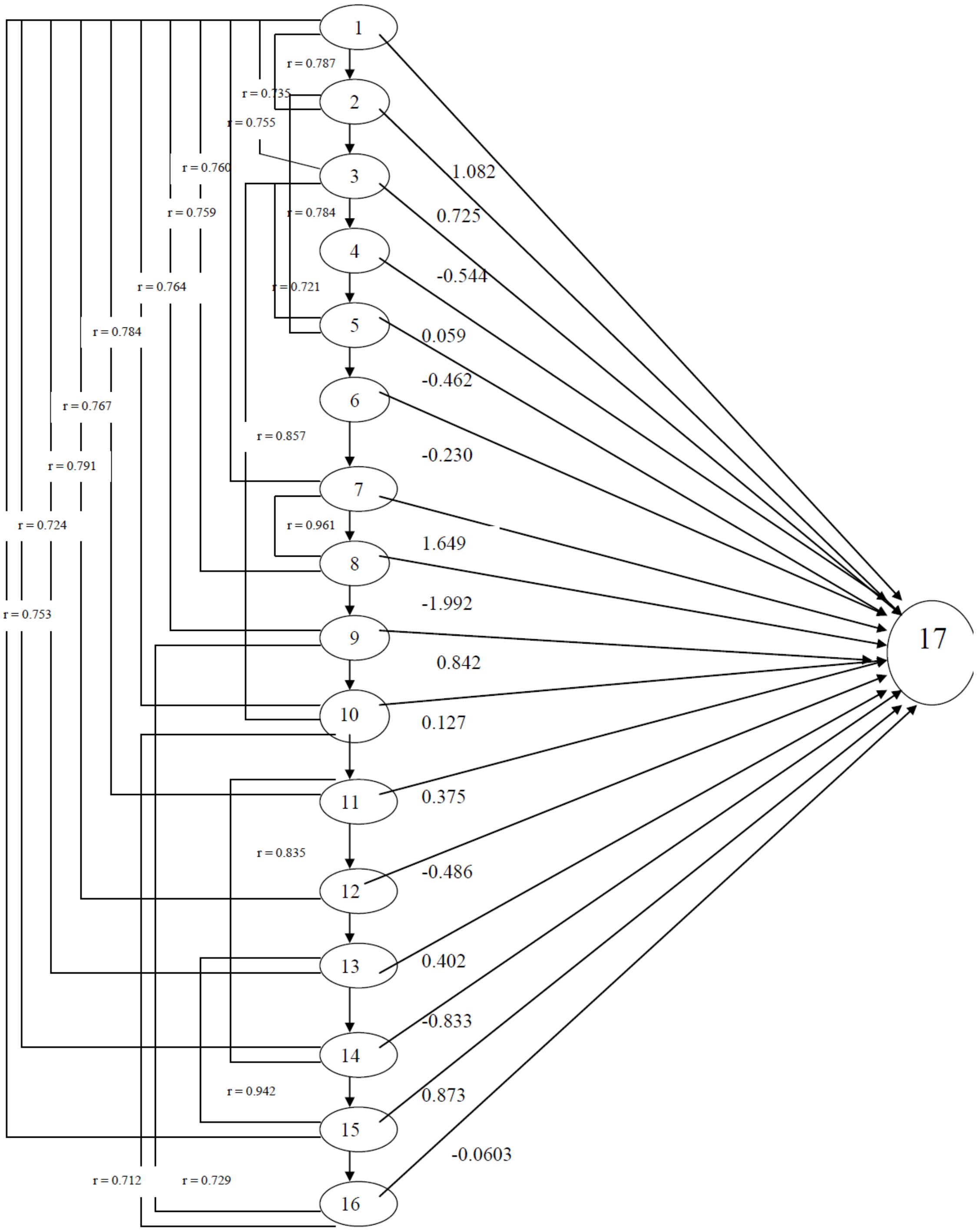

**Figure 1. Path diagram showing the path coefficients and correlation coefficients of seed yield and morpho-physiological traits in soybean genotypes under longer photoperiod.**

1= Leaf Area Index at Vegetative, 2=Leaf Area Index at Flowering, 3=Leaf Area Index at Pod , 4= Specific Leaf Weight at Vegetative, 5=Specific Leaf Weight at Flowering, 6= Specific Leaf Weight at Pod, 7= Crop Growth Rate at 30-45 days after sowing, 8= Crop Growth Rate at 45-60 days after sowing , 9= Relative Growth Rate at 30-45 days after sowing, 10= Relative Growth Rate at 45-60 days after sowing, 11= Net Photosynthetic Rate at vegetative, 12= Net Photosynthetic Rate at Flowering, 13= Net Photosynthetic Rate at Pod, 14= Transpiration Rate at vegetative, 15= Transpiration Rate at Flowering, 16= Transpiration Rate at Pod, 17= Seed Yield.

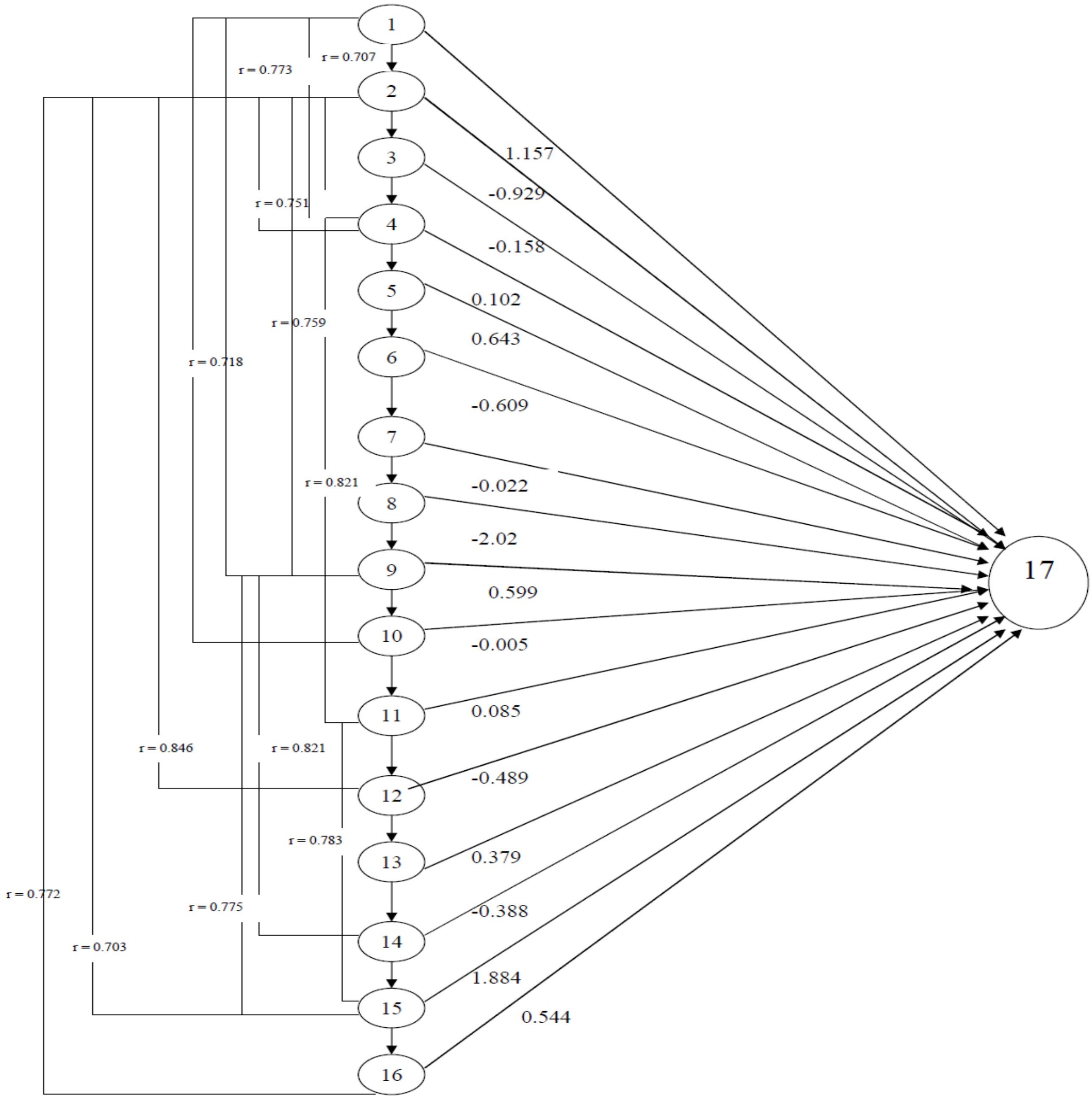

**Figure 2. Path diagram showing the path coefficients and correlation coefficients of seed yield and morpho-physiological traits in soybean genotypes under shorter photoperiod.**

1= Leaf Area Index at Vegetative, 2=Leaf Area Index at Flowering, 3=Leaf Area Index at Pod , 4= Specific Leaf Weight at Vegetative, 5=Specific Leaf Weight at Flowering, 6= Specific Leaf Weight at Pod, 7= Crop Growth Rate at 30-45 days after sowing, 8= Crop Growth Rate at 45-60 days after sowing , 9= Relative Growth Rate at 30-45 days after sowing, 10= Relative Growth Rate at 45-60 days after sowing, 11= Net Photosynthetic Rate at vegetative, 12= Net Photosynthetic Rate at Flowering, 13= Net Photosynthetic Rate at Pod, 14= Transpiration Rate at vegetative, 15= Transpiration Rate at Flowering, 16= Transpiration Rate at Pod, 17= Seed Yield.

## CHAPTER IV

## DISCUSSION

An understanding of the physiological changes that have occurred in cultivar development in the past would be helpful in the continued production of high yielding cultivars of various crop species. Crop yields have increased largely through efforts to increase the plant adaptability to environmental conditions, resistance to pests and diseases, genetic yield potential and efforts to improve management practices.

Inspite of these efforts, reports by several National and International institutes suggest that agricultural productivity is on a yield plateau. As the amount of land available for agriculture is decreasing day by day due to urbanization, and as energy and production costs are increasing, yield per unit land area must be improved to keep up with increasing population and to improve standards of living. The development of cultivars with improved disease, insect and pest resistance has also made a significant contribution to the increase in yield. However, the physiological changes in the plant particularly, the performance of genotypes in different photoperiods and the changes thereof that may contribute for yield formation are not clearly understood. Keeping this in view, the present study was aimed to find out the performance of soybean genotypes under variable photoperiods and to understand various morpho-physiological characters associated with yield.

Crop growth and yield are under the control of genes which are modulated by their continuous interaction with the environment. It was observed that the crop performance with respect to morphological, physiological and yield attributes was better in longer photoperiod as compare to shorter photoperiod. The early maturing genotypes (EC 457161), followed by medium (SL983) and late maturing genotypes (SL958) gave maximum seed yield during both the sowing indicating the adaptability of these genotypes under variable photoperiods.

### MORPHO-PHYSIOLOGICAL CHARACTERS

Significant differences were observed among the different maturing group genotypes with respect to various morphological characters such as, Leaf area, leaf area index, specific leaf weight, dry matter production and its distribution in different plant parts. The expression of most of the morphological characters was better in late maturing genotypes as compared to medium and early maturing genotypes in response to variable photoperiods ( normal and late sown). The green leaves represent the source and its intensity is measured in terms of leaf number, leaf area index and leaf area duration. These are important in determining the yield.

Leaf area fairly gives a good idea of the photosynthetic capacity of the plant. In the present investigation, leaf area increases with an advancement in crop growth from vegetative to pod stage and decreased thereafter till harvest which may be due to ageing and senescence of leaves during both the photoperiodic conditions (longer and shorter). Panwar *et al* (1986) and Nijhawan (1986) reported that in greengram, both leaf area and leaf area index attained the maximum values at 45 DAS and started declining thereafter till harvest. The data indicated a wide genotypic variability with respect to leaf area. This is in agreement with the reports of several workers (Nijhawan and Chandra 1980, Thandapani 1985 and Dodwad 1997). It is evident from the data of both the photoperiodic conditions that the genotypes which yielded high during both sowing maintained significantly higher leaf area over other genotypes, thereby indicating the importance of leaf area in yield determination. The reason for decreased leaf area under shorter photoperiod was due to decrease in size of leaf. But in longer photoperiodic condition leaf area showed the increasing pattern due to obtain of maximum light radiation. Wallace *et al* (1972) also found that high yielding genotypes possessed 10 per cent higher leaf area than the low yielders. Similarly, Basuchaudhari (1987) found that the seed yield is associated with high leaf area index in soybean.

Leaf area index is an important yield determining factor for soybean crops because it is a major determinant of light interception and transpiration. In our present finding, value of leaf area index increased until flowering and there after subsequently declined in both the photoperiodic conditions. The rate of declining was maximum under shorter photoperiod as compared to longer photoperiod due to minimum canopy taken by crops under shorter photoperiodic condition. The leaf area index at vegetative, flowering and pod stage were found to have positive significant correlation with seed yield in all the genotypes during both the photoperiods because leaf area index is directly related to canopy light interception and photosynthetic rate. This suggests that the maintenance of high leaf area index, particularly at the time of flowering is necessary for higher productivity in soybean under variable photoperiods. Gill *et al* (1992) also observed a positive correlation of seed yield with leaf area index in greengram. Similar reports have been made by Renganayaki and Sreerangasamy (1992) in blackgram.

The specific leaf weight (SLW) is an indicator of leaf thickness. Significant variation was observed among the different maturing genotypes with respect to specific leaf weight. However, it was highest significant with seed yield at early growth stages and declined thereafter upto harvest under variable photoperiods. Kalubame and Pandey (1979) also found that specific leaf weight in greengram was initially highest and started declining thereafter upto the harvest. A significant genotypic variability was observed with respect to specific leaf weight among diverse greengram genotypes (Nijhawan 1986). The genotypes which were high yielder's maintained significantly higher specific leaf weight over all other genotypes at all the stages.

Correlation studies revealed that seed yield had a significant positive association with specific leaf weight during both the photoperiods (longer and shorter). The reason for such result was maximum thickness of leaf trapped more light and ultimately resulted in more assimilates production. Singh and Singh (1982) reported that specific leaf weight made a substantial contribution to seed yield and was found to be strongly associated with seed yield in greengram. Similar to our findings, Dornhoff and Shibles (1970) suggested that specific leaf weight may be considered as an important character for higher productivity in soybean.

Crop growth rate (CGR) is influenced by leaf area index, leaf photosynthetic rate, leaf angle and the index of the amount of light interception. Significant difference was observed in crop growth rate at all the stages among the different maturing genotypes. In general, crop growth rate increased with an advancement of crop growth. The late maturing genotypes maintained significantly higher crop growth rate over other genotypes due to more vegetative growth under longer photoperiods. Among the early maturing genotypes (EC457161), medium (SL 983) and late maturing genotypes (SL 958) registered significantly higher crop growth rate during both the photoperiods.

However, relatively higher crop growth rate was noticed during normal sowing as compared to late sowing under variable photoperiods. A high genotypic variability has also been reported with respect to crop growth rate among the diverse greengram genotypes by Nijhawan (1986) and Dodwad (1997). Correlation studies indicated a significant positive association of crop growth rate (30 –45 DAS and 45-60 DAS) with seed yield during both the photoperiodic conditions. This clearly shows the importance of this parameter in getting higher productivity in soybean. These results are in agreement with the reports of Gill *et al* (1992), who found a significant positive correlation between seed yield and crop growth rate in greengram. Similar pattern of association has also been reported by Prasad *et al* (1979) in chickpea and Kenneth and Hell (1980) in soybean. The relative growth rate (RGR) reveals the efficiency of dry matter production per unit dry matter already existing and it reveals the efficiency index of a genotype. Relative growth rate was higher during later stage (45- 60) as compared to early stage (30 - 45 DAS) under variable photoperiods. Reddy and Saxena (1983) also reported similar results in soybean. Sharma and Sharma (1992) reported a positive correlation between relative growth rate and net assimilation rate.

The amount of Total Dry Matter (TDM) produced is an indication of the overall efficiency of utilization of resources and better light interception. Dry matter production and its partitioning, particularly to the reproductive organs is an important yield determining character in any crop. Therefore, the pattern of distribution of dry matter in different plant parts would give a better understanding of the genotypes. Leaf dry weight increased with an advancement of crop growth from vegetative to pod initiation stage and declined thereafter upto the harvest irrespective of the genotypes during both the photoperiods. This may be due to shedding and senescence of leaves towards maturity.

The late maturing genotypes however, possessed significantly higher leaf dry weight at all the stages, thereby indicating the fact that leaf dry weight is an important character for higher productivity in soybean. The late maturing genotypes (SL 958), followed by medium (SL 983) and early maturing genotypes (EC 457161) during both the photoperiods maintained significantly higher leaf dry weight. The leaf dry weight was relatively less in late sown as compared to normal sown which may be attributed to relatively poor growth of the crop due to shorter photoperiods during the crop growth period.

Correlation studies revealed that leaf dry weight had significant positive association with seed yield during both the photoperiodic conditions, thereby indicating the importance of this parameter in determining productivity, besides confirming the consistency of the association with seed yield over the sowing. Singh and Singh (1982) also reported a significant association of seed yield with leaf dry weight in greengram. The stem dry weight increased continuously from vegetative to harvest irrespective of sowing and genotypes. Late maturing genotypes possessed significantly higher stem dry weight in both the photoperiods and thus indicating its importance in yield determination. To confirm this, stem dry weight was found to have significant positive association with seed yield during both the sowing.

Among the early maturing genotypes (EC 457161), medium (SL 983) and late maturing genotypes (SL 958) which were high yielders during both sowing possessed significantly higher stem dry weight. Ravi (1984) reported that high yielding greengram genotypes were more efficient in the accumulation and partitioning of dry matter in the reproductive structures. Similar results were also found by Ganguly and Bhattacharya (2001) in chickpea genotypes.

It is evident from the present study that the production of total dry matter (TDM) increased progressively with an advancement of crop growth in longer photoperiod as compared to shorter photoperiod because longer photoperiods responds more to vegetative growth. This may be due to increased accumulation and effective translocation of photo assimilates with the advancement of crop growth. The genotypes which performed better maintained significantly higher amount of total dry matter as compared to other genotypes in both the photoperiods.

Among the early maturing genotypes (EC 457161), medium (SL 983) and late maturing genotypes (SL 958) during both sowing possessed significantly higher total dry matter. This clearly indicates the existence of a wide genotypic variability. Besides, it is evident from the data that during late sowing, there was a substantial reduction of total dry matter as compared to normal sowing due to lesser growth under shorter photoperiodic conditions. This may be attributed to the overall reduction in the dry weight of leaf, stem and reproductive parts in late sowing due to the adverse photoperiodic situations. Similarly, several other workers have also reported a wide genotypic variability in the total dry matter accumulation among greengram genotypes (Thandapani 1985, Rathanaswamy *et al* 1986 and Nijhawan 1986 and Dodwad *et al* 1998).

Correlation studies revealed that total dry matter at harvest exhibited significant positive association with seed yield in both the photoperiods. This strongly suggests that total dry matter, particularly at harvest is one of the most important factors influencing productivity in soybean, irrespective of genotypes as well as growing situations (normal and late). Kuo *et al* (1977) and Ravi (1984) also indicated that high yielding greengram genotypes were more efficient in the production of higher TDM and its efficient partitioning. Similarly, several other workers also found a significant positive association of total dry matter with seed yield in greengram (Lampang *et al* 1987, Malik *et al* 1987 and Soybean (Liaw and Chen 1988, Mehetre and Jamadagni 1996).

Bhattacharya (1996) opined that total dry matter production, particularly during post flowering period plays an important role in determining yield potential in mungbean. Chowdhary *et al* (2000) also reported that in greengram, dry matter accumulation after flowering significantly influenced the grain yield and they further opined that most of the photosynthates produced at this stage were used for pod and grain development.

## BIOPHYSICAL PARAMETERS

Photosynthesis is the primary process which forms the basis for yield determination. Single leaf photosynthesis is the basis for dry matter production, which in turn determines the yield. However, under field conditions, the crop growth rate is dependent on total canopy photosynthesis rather than the photosynthetic rate per unit leaf area. In the present investigation, a significant variability was observed among the different maturing group genotypes with respect to photosynthetic rate at vegetative, flowering and pod initiation stages under variable photoperiods (longer and shorter).

Our findings depicted that the rate of photosynthesis increased till flowering and there after declined under both the photoperiodic conditions but the rate of declining was more in shorter photoperiods as compared to longer. Under shorter photoperiodic condition proper light interception and radiation use efficiency are low which resulted to lower photosynthetic rate. Venkateshwarlu and Balasubramanian (1993) and Koti (1997) also reported significant variability in photosynthetic rate in greengram and soybean, respectively.

In general, the genotypes which performed better in both the photoperiods maintained significantly higher photosynthetic rate over all other genotypes. Among them, early (EC 457161), medium (SL 983) and late (SL 958) during both the photoperiods had the maximum value. Photosynthetic rate was found to have significant positive correlation with seed yield, thereby clearly indicating the importance of this parameter in improving the yield potential of genotypes. Kuo *et al* (1977) also reported a significant positive association between the seed yield and the photosynthetic rate in greengram. Similarly, Rao and Ghildiyal (1985) established a positive relationship between the dry matter production, photosynthetic rate and seed yield in greengram.

It is obvious that higher photosynthetic rate leads to higher production of dry matter and yield and this has also been proved from the results of the present investigation. Hence, it may be inferred that for increasing productivity in soybean, maintenance of higher photosynthetic rate is very essential. Significant variation was also observed with respect to stomatal conductance and the rate of transpiration among the genotypes. Like the photosynthetic rate, stomatal conductance and transpiration rate were also significantly higher in late maturing group genotypes as compared to other genotypes. Higher transpiration rate and stomatal conductance in late maturing genotypes was due to maximum leaf area and leaf area index. Under shorter photoperiod condition it was observed that values of transpiration rate and stomatal conductance were low because of reduces size of leaf.

Venkateshwarlu and Balasubramanian (1993), Goswami *et al* (2000) also observed significant variations with respect to photosynthetic rate, stomatal conductance and transpiration rate among greengram genotypes. Both the stomatal conductance and transpiration rate showed a significant positive correlation with seed yield, thereby indicating the importance of these two parameters towards higher productivity in soybean. Again, these two parameters recorded significant positive association with photosynthetic rate and thus indicating a close association among themselves. Rao and Ghildiyal (1985) also recorded a positive relationship between the photosynthetic rate, dry matter production and seed yield in greengram. Similarly, Kuhad *et al* (1990), Pannu and Singh (1987) found that decline in photosynthetic rate was closely associated with reduction in stomatal conductance and transpiration rate, which ultimately resulted in lower yield in greengram. All these reports are in agreement with the results of the present investigation.

Chlorophyll fluorescence is widely accepted as an indication of the energetic behaviour of a photosynthetic system. Photosynthetic activity was studied in terms of quantum yield (Fv/Fm) and total chlorophyll. The Fv/Fm ratio can be considered as a measure of the quantum efficiency of the electron transport in PSII indicates the physiological state of the photosynthetic apparatus in intact plant leaves. By measuring the yield of chlorophyll fluorescence, information about changes in the efficiency of photochemistry and heat dissipation can be obtained. This demonstrates photochemical efficiency of among soybean genotypes increases upto flowering stage and thereafter decline under variable photoperiods. Present findings observed that photochemical efficiency was low under shorter photoperiod as compared to longer due to less amount of heat emitted after absorption of chlorophyll molecules.

Chlorophyll is the primary pigment involved in photosynthesis. Result of the present investigation revealed that the genotypes differed significantly and the chlorophyll content increased from vegetative to pod initiation stage and declined thereafter upto harvest irrespective of the genotypes. The decrease in chlorophyll content towards maturity may be attributed mainly to the senescence and ageing of leaves. Present results reported that chlorophyll content (SPAD) was higher in longer photoperiod due to maximum photosynthetic rate and canopy of the crop during the growth period as compared to shorter photoperiod. Chandrababu (1990) also found genotypic variation in leaf chlorophyll content in greengram. Jayapragasam *et al* (1998) indicated that the higher chlorophyll content was associated with higher yield in some promising hybrids of greengram and blackgram. Our present finding depicted that under the longer photoperiodic condition soybean plant have taken longer days for flowering, pod initiation and maturity as compared to shorter photoperiodic condition.

Correlation studies revealed significant positive association of total chlorophyll content in leaf at all the stages with seed yield. The results clearly demonstrate the importance of maintaining higher chlorophyll content, particularly at later stages of crop growth (pod initiation), which may be considered as one of the important biochemical parameters for yield determination in soybean. Such a situation would help in maintaining leaves active for a longer period which can supply photosynthates to the developing pods. Hence, there is a need to identify genotypes having higher leaf area duration coupled with higher chlorophyll content, particularly at later stages of crop growth for getting higher productivity.

## YIELD AND YIELD ATTRIBUTES

Soybean is generally grown in *kharif* during which the yield levels are higher. Recently, attempts have been made to evaluate the performance of genotypes under late condition to understand the effect of photoperiods. It is well known that temperature influences yield and yield attributes and in addition, environmental variables prevailing in different seasons have profound effect on morpho- physiological traits, which determine yield potential in soybean. Variable photoperiodic conditions contribute to shedding of reproductive organs and the seed yield is determined basically by the number of flowers a plant can produce and the percentage of those it can develop into mature seed. The number of flowers and number of pods were lowest in late condition (shorter photoperiod) and hence resulted in lower seed yield. In soybean, number of flowers and pod set per cent is a varietal character and is also affected by variable photoperiods.

The early maturing genotypes (EC 457161), medium (SL983) and late maturing group genotypes (SL 958) had more number of pods as compared to other genotypes during both the photoperiods. Sharma *et al* (1989) and Singh *et al* (1994) reported a positive correlation between number of pods and seed yield in soybean. Yohe and Poelhman (1972), Khan and Rafiq (1989) and Borah and Hazarika (1995) found a wide genotypic variability with respect to number of pods per plant among greengram genotypes and significant positive association of number of pods per plant with seed yield was found. This clearly shows the importance of this parameter in determining the yield potential in soybean, irrespective of the types of genotypes and the growing conditions. Present investigation showed that number of pods per plant, 100 seed weight and seed yield were more in longer photoperiodic condition as compared to shorter photoperiod. Number of pods and seed weight reduced due to change in assimilatory capacity of growth during shorter photoperiod and also reduced the cotyledonary cell numbers, resulting in slower seed growth and decreased seed size. The results indicated that late maturing genotypes produced higher number of pods per plant, 100 seed weight, grain yield (g/plant) and seed (kg/ha) due to proper utilization of photosynthate under longer crop duration.

Seed weight was found to be more in longer photoperiods than in shorter photoperiods in all most all genotypes. Higher 100 - seed weight in normal sowing was due to the better availability of assimilates which lead to higher dry mater production coupled with higher partitioning efficiency towards seed development in response to longer photoperiod. The shorter photoperiod have caused a reduction in 100-seed weight due to less availability of photoassimilates, reduced enzymatic activities and ability of sink organ to import photo assimilate. Hundred seed weight was highly correlated with seed yield during both the photoperiodic conditions indicating that it is an important trait to be considered for increasing the yield potential, was less during shorter photo period. Mahto and Mahto (1997) also found a similar association in blackgram. Similarly, Raje and Rao (2000) found a significant positive association of number of seeds per plant with seed yield in greengram.

Harvest index reveals the efficiency of translocation of assimilates towards economic parts and therefore, harvest index and seed yield are closely related. Jain (1975) reported that the harvest index is the most important component for improved plant type and higher productivity in grain legumes. The morphological frame of the plant must be reconstructed in such a way that the total dry matter produced is more efficiently partitioned between the grains and the vegetative parts.

In the present study, harvest index differed significantly among the genotypes during both the photoperiods. It was found to be positively correlated with seed yield in both the conditions. Similarly, Jepson *et al* (1978) showed a positive correlation between HI and seed yield in 32 genotypes of soybean. During both the photoperiods, significantly higher seed yield was recorded in the genotypes, early (EC 457161), medium (SL 983) and late maturing group genotypes (SL 958). Bhattacharya and Ram (1992), Koti (1997) and Verma and Sawaji (1994) in soybean Goswami (2000), Dodwad *et al* (1998), Singh and Malhotra (1970) Yohe and Poehlman (1972), Borah and Hazarika (1995) in greengram, Kumar (2002) in mothbean and Reddi *et al* (2004) also reported significant differences for seed yield among the genotypes during different seasons.

From the foregoing, it is clear that among various yield components, number of pods per plant, 100- seed weight and harvest index are the most important traits for yield determination in soybean as all these parameters exhibited a significant positive association with seed yield, irrespective of the nature of genotypes and the growing conditions.

**Biochemical parameters**

Based on the above discussion on the various morpho-physiological and yield parameters, two genotypes from early maturing group genotypes and each of three from medium and late maturing groups genotypes were selected for biochemical analysis. The total soluble sugars contribute to the energy reserves and transportable carbohydrates generated during photosynthesis. Soluble sugar is the substrate for starch synthesis and there is a close relationship between the soluble sugar content and starch synthesis in plants. In the present study, total soluble sugar content showed an increase from vegetative to pod initiation stage in all the genotypes of different maturing groups.

The level of soluble sugar content was a sign of the supply ability of leaves and reflected transformation and ability of grains to use assimilates (Saratha *et al* 2001). Wilcox (2001) indicated that the soluble sugar content plays a very important role in carbohydrate metabolism and has a close relationship with photosynthesis and production. Wang *et al* (2007) reported that the photosynthate exists in the form of water soluble carbohydrate and its main components are soluble sugar, starch and cellulose.

Starch is the major storage form of carbohydrates. The starch content in leaves increased from vegetative to pod initiation stage in all the soybean genotypes varying in maturity date. Total soluble proteins from leaves showed an increase till flower initiation stage then a drastic decline was recorded in all the soybean genotypes under variable photoperiods.

Total nitrogen content in general increased from vegetative stage till flower initiation and then declined owing to remobilization induced by reproductive structures accompanied by senescence induced protein degradation leading to reduced total nitrogen content in the leaves.

Legumes have always been a special target for the study of nitrogen metabolism, due to high protein content, their levels of nitrate reductase activity and formation of nodules where symbiosis with rhizobium takes place. In the present investigation, nitrate reductase activity decreased towards the maturity in all the soybean genotypes under variable photoperiods. Nitrate reductase activity was maximum in late maturing genotypes followed by medium and early maturing genotypes at all the growth stages under variable photoperiods.

Soluble sugars, including monosaccharides and oligosaccharides, are the main photosynthetic product and the main substrate for metabolism (Bodeln *et al* 2010). Carbohydrate content accounts for 90-95% of the dry matter in a plant. Soluble sugar is not only the main photosynthate of higher plants, but the main form of carbohydrate metabolism and temporary storage (Voldeng *et al* 1997). Content of soluble sugar in leaves is an important form, and a sign of the supply ability of leaves or a physiological index of leaf status (Shiraiwa and Ushio 1995).

The level of these biomolecules in these organs increased during development is indicative of high metabolic status. In the present study, leaf total soluble protein and total nitrogen content in leaves and stem increased from vegetative stage till flower initiation and then declined during both the photoperiodic conditions. This might be due to remobilization induced by reproductive structures leading to reduced total nitrogen content in the leaves.

The enhanced decline in these reserves might account for the greater availability for developing sinks. Comprehensively, total nitrogen content form a major assimilate source for seed filling and also may be a function of the sink strength. Also, Khanna-Chopra and Sinha (1987) reported that in chickpea, of the total nitrogen, 65% was accumulated before the commencement of pod development and only 35% during pod development. At flower initiation, leaves contained the highest amount of nitrogen and the stem comes next. During fruit development, nitrogen was mobilized from leaves and, to a less extent, from stems to the pods. Plant accumulated nitrogen mainly during the vegetative period of growth and the majority of nitrogen translocated to the seeds upto 70% is remobilized from vegetative pools.

Nitrogen remobilization occurs not only from leaf to leaf during vegetative stages but also from leaf to seed during reproductive stages (Schiltz *et al* 2005). Main vegetative tissues for assimilation of nitrogen are leaves and stem. During rapid pod initiation stage, the seeds become the major sink of the plant having high demand of both carbon and nitrogen. This leads to redistribution of dry matter stored in vegetative parts such as stem and leaves to the sink. This ability of cultivars to reallocate may also be a function of the strength of the sink for assimilates (Basu and Singh 2003).

Plant accumulate nitrogen mainly during the vegetative period of growth and after anthesis nitrogen uptake rates rapidly slow down (Gotz *et al* 2007).The results by Ali and Bano (2008) also reported that protein and sugar content in chickpea leaves increased at the flower initiation, thereafter, degradation of chlorophyll and protein content became more pronounced in older leaves as compared to younger leaves. Subsequent to the flower initiation stage, a significant decrease in protein content was noted in the young as well as the old leaves during both the photoperiods. Degradation of leaf proteins during foliar senescence is required in order to remobilize leaf nitrogen (N) and export it to developing grain and other sinks (Feller and Fischer 1994).

Significant variability was observed among the different maturing group genotypes with respect to total soluble sugars, starch, protein and nitrogen content in leaf and stem at different growth stages under variable photoperiods. Jain (1975) and Mitra *et al* (1987) and Phul and Sharma (1993) in soybean reported significant variability of seed protein content in greengram. Similarly Koti (1997) reported significant variability of seed protein content in soybean genotypes. The activity nitrogen metabolic enzymes in leaves such as glutamate synthase, glutamine synthetase and glutamate dehydogenase were found maximum during longer photoperiod as compare to shorter photoperiod due to proper assimilation of metabolic reserves in longer photoperiodic condition. Similarly, the activity of these enzymes was highest at early stages of growth but decreases due to advancement of the crop. The result also illustrated the similar trend in stem.

The PEP carboxylase activity showed a decreasing trend from vegetative to post-flowering stage. Under total soluble sugars in podwall in general increased up to maximum till 20 DAF and declined afterwards during both the photoperiods. In seeds, total soluble sugars in general depict an increase from 10 to 30 DAF. The accumulation of biochemical reserves like total soluble sugars, starch and protein content is also phasic. During initial phase (10-20 DAF) podwall acted as a major sink as indicated by higher level of these reserves while seeds during this period acted as only minor sink. During second phase of pod development (20-30 DAF) seeds start acting as major sink for these reserves.

The reserves located in the podwall are broken down into mobilizable products due to activity of various hydrolytic enzymes and are translocated into seeds, especially cotyledons, which now form major sink and active metabolic sites for (re)synthesis of reserves. Similar results have been reported for various legumes such as pea, soybean, french beans, chickpea and broad bean (Setia *et al* 1987). In legumes, seed protein accumulation is a function of available nitrogen to the seed (Salon *et al* 2001).

Seed weight and protein content are mostly determined by the availability of assimilates (source strength) but variability in sink strength (assimilate demand) also plays an important rate (Burstin *et al* 2007). Increased nitrogen remobilization and/or translocated from all vegetative organs is important factor for increasing and stabilizing seed protein content (Gallardo *et al* 2008). According to Mickelson *et al* (2003), grain protein content is probably associated with their ability to accumulate higher amounts of nitrate in their leaves during vegetative growth and then to efficiently remobilize the stored nitrate during grain filling.

In the present study, the level of total soluble sugars, starch and protein content increased upto 20 DAF in podwall following a decline under both the photoperiodic conditions. On the other hand, in developing seeds initial slow accumulation of these reserves then a sudden increase was observed during later stages of development. The level of these reserves were higher in late maturing genotypes followed by medium maturing genotypes and least in early maturing genotypes contributing to higher sink strength under variable photoperiods.

The activity of carbon metabolizing enzymes, invertase was determined in podwall and developing seeds. Invertase activity in podwall decreased towards the maturity during both the photoperiods. At 10 DAF, invertase activity was recorded highest in late maturing genotypes than medium-and early maturing genotypes. In developing seeds, invertase activity showed a decline from 10 to 30 DAF in all the genotypes under variable photoperiods.

In our study, high activity of acid invertase in the podwall of late maturing genotypes during later stages might result in longer cell division phase resulting in its larger size and biomass. It can be responsible for providing more reserves for the developing seed hence determining its strength. Setia and Malik (1985) also reported that invertase activity in podwall was high during 7-14 DAA in chickpea. Unlike in pod, invertase activity was extremely low in seeds. The enzyme is known to be involved in breakdown of sucrose which is a predominant form of carbon translocated from vegetative parts to the developing reproductive structures.

Shorter photoperiodic condition causes both reductions in the rate of protein synthesis as well as the changes in the type of proteins produced. Among biochemical techniques, Sodium Dodecyl Sulphate Polyacrylamide Gel Electrophoresis (SDS PAGE) is widely used due to its validity and simplicity for detection of proteins. Electrophoretic analysis of total proteins in seeds from the photoperiodic conditions revealed that bands were more intense in longer photoperiod as compare to shorter photoperiod. The results are in corroboration with the results of Mansourifar *et al* (2011).

## REFERENCES

Basu P S and Singh D N (2003) Physiology and abiotic stresses in chickpea. In: Ali M, Kumar S and Singh N B (eds) *Chickpea Res in India*. Pp:137-66. IIPR, India.

Basuchaudhari P (1987) Above ground characteristics of soybean crop. *Ann Agric Res* **8:** 135-40.

Beevers L and Hageman R H (1969) Nitrate reduction in higher plants. *Annu Rev Plant Physiol***20**: 495-522.

Beevers L and Poulson R (1972) Protein synthesis in cotyledons of *Pisum sativum* L. I. Changes in cell-free amino acid incorporation capacity during seed development and maturation. *Plant Physiol* **49:** 476-81.

Bhattacharya A (1996) Influence of dry matter allocation and their rates during pre and post flowering phases in various plant parts on mungbean seed yield. *Leg Res* **19:** 179-84.

Bhattacharyya P K and Ram H H (1992) Yield components in determinate vs indeterminate soybean. *Soy Genetics Newsletter* **19**: 52-54.

Blackman V H (1990) The compound interest law and plant growth. *Annual Rev Bot* **33**: 353-60.

Borah H K and Hazarika M H (1995) Genetic variability and character association in some exotic collection of greengram. *Madras Agric J* **82**: 268-71.

Burstin J, Marget P, Huart M, Moessner A, Mangin B, Duchene C, Desprez B, Munier-Jolain and Duc J (2007) Development genes have pleiotropic effects on plant morphology and source capacity, eventually impacting on seed protein content and productivity in pea. *Plant Physiol* **144:** 768-81.

Chandrababu R (1990) *Physiological basis for yield improvement in greengram (Vigna radiata (L.) Wilezek) cultivars*. Ph.D. dissertation. TamilNadu Agricultural University, Coimbatore, India.

Chaudhary B D (1981) An ideotype for soybean – A review, *Agric Rev* **2:** 79-94.

Chowdhury Md, Haffiz Ullah M U and Mohammad Z U (2000) Dry matter production in mungbean (*Vigna radiate* L. Wilczek) as influenced by bradirhizobium inoculation and phosphorus application. *Leg Res* **23:** 15-20.

Dodwad I S (1997) *Genetic variation for morpho-physiological traits influencing seed yieldin greengram (Vigna radiata L. Wilezek).* M.Sc. (Agri.) Thesis. University of Agricultural Sciences, Dharwad, India.

Dodwad I S, Salimath P M and Patil S A (1998) Evaluation of greengram collections for pod and seed characters. *Leg Res* **21:** 183-87.

Dornhoff R G M and Shibles R M (1970) Varietal differences in net photosynthesis of soybean leaves. *Crop Sci* **10**: 42-45.

Feller U and Fischer A (1994) Nitrogen metabolism in senescing leaves. *Crit Rev Plant Sci* **13:** 241-73.

Gallardo K, Thompson R and Burstin J (2008) Reserve accumulation in legume seeds. *C R Biologies* **331:** 755-62.

Ganguly S B and Bhattacharya (2001) Effect of physiological traits on chickpea yield under normal and late seeding. *Leg Res* **24:** 6-10.

Gill D S, Verma M M and Brar G S (1992) Physiological parameters determining yield in mungbean. *Crop improvement* **19:** 29-33.

Gopal Singh B and Narain Singh J (1982) Effect of seasonal changes on growth parameters of greengram (*Vigna radiate* (L.) Wilezek). *Indian J Plant Physiol* **25**: 382-89.

Goswami R K (2000) *Physiological indices for higher productivity in greengram [Vigna radiate (L.) Wilczek]*. Ph. D. dissertation. University of Agricultural Sciences, Dharwad, India.

Gotz K P, Staroske N, Radchuk R, Neil Emery R J, Wutzke K D, Herzog H and Weber H (2007) Uptake and allocation of carbon and nitrogen in *Vicia narbonensis* plants with increased seed sink strength achieved by seed-specific expression of an amino acid permease. *J Exp Bot* **58:** 3183-95.

Gregory G (1917) Analysis of agricultural yield. In: Evans L T (ed) *Crop Physiology*. Pp 121-23 Cambridge University Press, London.

Jain H K (1975) *Genetic analysis of yield and protein content in greengram (Phaseolus aureus Roxb.)* Ph.D. dissertation. Indian Agricultural Research Institute, New Delhi, India.

Jayapragasam M, Sreerangasamy S R and Thangaraj M (1998) Biochemical studies in the progenies of the interspecific cross between greengram (*Vigna radiate* L. Wilczek) and blackgram (*Vigna mungo* L. Hepper). *Indian J Plant Physiol* **3:** 121-24.

Jepson R G, Johnson R R and Hadley H H (1978) Variation in mobilization of plant nitrogen to the grain in nodulating and non – nodulating soybean genotypes. *Crop Sci* **18**: 1055-62.

Kalubarme M H and Pandey R K (1979) Note on the growth analysis of greengram genotypes. *Indian J Agric Sci* **49**: 975-77.

Kenneth J J and Hell A E (1980) Drought adoption of cowpea. Influence of drought on plant growth and relation with seed yield. *J Agron* **72**: 428-33.

Khan I A and Rafiq A (1989) Relationship of yield and its components characters in mungbean. *Leg Res* **12:** 173-76.

Khanna-Chopra R and Sinha S K (1987) C*hickpea: Physiological Aspects of Growth and Yield.* In: Saxena M C and Singh K B (ed). *The Chickpea*. Pp: 163-89. CAB International, Wallingford, UK.

Koti R V (1997) *Influence of seasons on phenology, reproductive efficiency and physiological indices in soybean genotypes*. Ph.D. Thesis. University of Agricultural Sciences, Dharwad, India

Kuhad M S, Sheoran I S, Kundu B S and Nandwal A S (1990) Relative performance of pentafoliate and trifoliate mungbean (*Vigna radiate* L. Wilczek) under water stress. *Indian J Plant Physiol* **33**: 168-71.

Kumar D (2002) New plant type with unbranded growth habit in mothbean. *Indian J Pulses Res* **15:** 179-80.

Kuo C G, Wang L J, Cheng A C and Chou M H (1977) Physiological basis for mungbean yield improvement. In: *Proceedings of the first International Symposium on Mungbean,* University of Philippines, Los Banos, 16 -19 August, 1977, pp. 205-213.

Lampang A A N, Pichitpron S, Sirisingh S And Vanakijmongkol N (1987) Mungbean growth pattern in relation to yield. In: *Proceedings of the Second International Symposium on Mungbean.* Pp 164 –168 Bankkok,Thailand, 16 -20 November.

Liaw S I and Chen C Y (1988) The characteristics of dry matter production and seed yield of winter and summer crop soybean. *J College sci and Engin* **25**: 27-48.

Mahto R.N and Mahto J C (1997) Correlation and regression study in blackgram for yield attributes under rainfed conditions. *Environ and Eco* **15**: 556-58.

Malik B A, Tahir M, Khan I A, Zubair M and Choudhary A H (1987) Genetic variability, character correlation and path analysis of yield components in mungbean (*Vigna radiate*). *Pak J Bot* **19**: 89-97.

Mansourifar C, Shaban M, Ghobadi M and Ajirlu A R (2011) Effect of drought stress and N fertilizer on yield, yield components and grain storage proteins in chickpea (*Cicer arietinum* L.) cultivars. *Afr J Plant Sci* **5**: 634-42.

Mehetre S S and Jamadagni (1996) Biomass partitioning and growth characters in relation to plant architecture in soybean. *Soy Genetics Newsletter* **23**: 92-97.

Mickelson S, See D, Meyer F D, Garner J P, Foster C R, Blake T K and Fischer A M (2003) Mapping of QTL associated with nitrogen storage and remobilization in barley (*Hordeum vulgare* L.) leaves. *J Exp Bot* **54:** 801-12.

Nijhawan D C (1986) A quantitative analysis of growth attributes in mungbean (*Vigna radiata* (Roxb.) Wilezek). *Leg Res* **11**: 53-58.

Nijhawan D C and Chandra S (1980) The physiology of plant growth with particular reference to the concept of photosynthetic efficiency in mungbean (*Vigna radiate* (Roxb.) Wilezek). *Indian J Plant Physiol* **23**: 40-46.

Pannu R K and Singh D P (1987) Influence of water deficits on morpho – physiological and yield behaviour of mungbeans (*Vigna radiate* L. Wilezek). *Proceedings of the second International Symposium on mungbean.* Pp. 253 – 259. Bangkok,Thailand, 16-20 November.

Panwar J D S, Shukla D S and Sirohi G S (1986) Growth and developmental aspects in relation to yield of mungbean (*Vigna radiata* L. Wilczek). *Indian J Plant Physiol* **29:** 312-16.

Prasad V V S, Pandey R K and Saxena M C (1979) Physiological analysis of yield variation in gram (*Cicer arietinum* C.) genotypes. *Indian J Plant Physiol* **21**: 228-34.

Raje R S and Rao S K (2000) Association analysis for yield and its components in mungbean (*Vigna radiate* L. Wilezek). *Leg Res* **23**: 42-48.

Rao T R K and Ghildiyal M C (1985) Analysis of potosynthetic source and sink relationship in mungbean (*Vigna radiata* L. Wilczek). *Indian J Plant Physiol* **28:** 135-144.

Rathnaswamy R, Thangaraj M, Shanmugam A S and Rangaswamy S R (1986) Characters limiting productivity in *Vigna radiate*. *J Madras Agric* **73:** 433-438.

Ravi C K (1984) *Physiological studies on flower and pod development in greengram (Vigna radiate (L.) Wilczek).* M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore, India.

Reddi D M, Rao Y K, Murthy S S N and Reddy M V (2004) Genetic variability and divergence of in mungbean. *Indian J Pulses Res* **17:** 77-79.

Reddy A S and Saxena M C (1983) Studies on growth analysis of soybean. *J Andhra Agric* **30:** 213-15.

Renganayaki K and Sreerangasamy S R (1992) Path coefficient analysis in blackgram. *J Madras Agric* **79**: 634-39.

Salon C, Munier- Jolein N G, Duc G, Voisin A S, Grandgirard D, Lamure D, Emery R J N and Ney B (2001) Grain legume seed filling in relation to nitrogen acquisition: a review and prospects with particular reference to pea. *Agronomie* **21:** 539-52.

Saratha K, Hume D J and Godfrey C (2001) Genetic improvement in short season soybeans: matter accumulation, partitioning, and leaf area duration. *Crop Sci* **41:** 391-98.

Schiltz S, Munier-Jolein N, Jeudy C, Burstin J and Salon C (2005) Dynamics of exogenous nitrogen partitioning and nitrogen remobilization from vegetative organs in pea revealed by $^{15}$N *in vivo* labeling throughout seed filling. *Plant Physiol* **137:**1463-73.

Setia N and Malik C P (1985) Changes in Some Enzymes of Carbohydrate Metabolism in Developing Pod and Seed of Chickpea (*Cicer arietinum* L.). *Phyton* **25:** 93-99.

Setia R C, Setia N and Malik C P (1987) The podwall structure and function in relation to seed development in some legumes. *Phyton* **27:** 205-20.

Sharma J P and Sharma S P (1993) Influence of genotypes and plant densities on physiological parameters, grain yield and quality of soybean (*Glycine max* L.), *Indian J Agron* **38:** 311-13.

Sharma S R, Nema V P, Rathore R S, Khandwe R K and Sharma O P (1989) Effect of growth stimulators on yield and oil content of soybean. *J Oilseeds Res* **6:** 23-21.

Shiraiwa T and Ushio H (1995) Accumulation and partitioning of nitrogen during seed filling in old and modern soybean cultivars in relation to seed production. *Japan J Crop Sci* **64:** 754-59.

Singh A P, Sharma S, Bargale M, Sharma H K and Sharma S (1994) Association analysis for yield and its components in soybean. *Crop Res* **7:** 247-51.

Singh K B and Malhotra R S (1970) Interrelationships between yield and yield components in mungbean. *Indian J Genetics and Plant Breeding* **30:** 244-250.

Thandapani V (1985) Leaf growth attributes as comparative physiological factors for the genotypes of greengram in relation to yield. *J Madras Agric* **72:** 126-32.

Venkateshwarlu S and Balasubramanian V (1993) Photosynthesis during reproductive phase of rainfed greengram. *Indian J Plant physiol* **36:** 174-77.

Verma V D and Sawaji B V (1994) Screening of soybean germplasm for photoperiodic insensitivity under natural conditions in Vidarbha region of Maharashtra, *Soy Genetics newsletter* **21:** 137-41.

Voldeng H D, Cober E R and Hwne D (1997) Fifty-eight year’s genetic improvement of short-season soybean cultivars in Canada. *Crop Sci* **37:** 428-31.

Wallace D H, Osbun J L and Munger H M (1972) Physiological genetics of crop yield. *Adv in Agron* **24:** 97-146.

Wang X H, Xu K Z, Li D Y, Zhang Z A, Wu Z H, Chen Z Y and Zhang X R (2007) Variation of soluble sugar content and specific leaf weight during the genetic improvement of soybean cultivars. *Soybean Sci* **26:** 879-84.

Westoby M, Jurado E and Leishman M (1992) Comparative evolutionary ecology of seed size. *Trends Ecol Evol* **7:** 368-72.

Wilcox J R (2001) Sixty years of improvement in publicly developed elite soybean lines. *Crop Sci* **41:** 1711-16.

Yohe J M and Poehlman J M (1972) Genetic variability in the mungbean *Vigna radiata* (L.) Wilezek. *Crop Sci* **12:** 461-64.

## CHAPTER V

## SUMMARY

Soybean is one of the important legume crops and major source of high quality protein for human daily diet and livestock feed in the world. Both photoperiod and temperature control the duration of pre and post flowering phase and are expected to affect source-sink relationships. Further, Photoperiod has shown to affect the growth and development of soybean (Adam *et al* 2001) at a greater extent. Present investigations were aimed at evaluating the relative performance of different maturing group genotypes with respect to different physiological indices for higher productivity under variable photoperiods. It was also aimed to elicit information on variations with respect to morpho-physiological and biochemical parameters among diverse soybean genotypes and their relationship with productivity to designate ideal plant type characters for higher productivity. To achieve the objectives, field experiments were conducted during *kharif* season of 2012 and 2013 at Punjab Agricultural University, Ludhiana. The experiment were laid out in randomised block design with three replications consisting of 15 genotypes to screen for various morpho – physiological traits, yield and yield components in first year and on the basis of results obtained from the first year experimentation. Further, two genotypes from early maturing genotypes and each of three from medium – and late maturing genotypes were selected for biochemical analysis.

The performance with respect to morpho-physiological characters, yield and yield attributes was poor during the shorter photoperiod as compared to longer photoperiod. Leaf area (LA) and leaf area index (LAI) increased progressively from vegetative to pod initiation and declined thereafter up to harvest. Significantly higher leaf area and leaf area index was recorded in late maturing genotypes. Leaf area index at all the growth stages showed a significant positive correlation with seed yield during both the photoperiods. Leaf dry weight differed significantly at all the stages among genotypes and was relatively less during shorter photoperiods. A progressive increase in leaf dry weight was observed with an advancement of crop growth from vegetative to pod initiation stages and thereafter decreased up to harvest. The genotypes which yielded more maintained significantly higher leaf dry weight, while, low yielders had the minimum leaf dry weight at all the stages.

Leaf dry weight had a significant positive association with seed yield during both the photoperiodic conditions. Stem dry weight increased progressively with an advancement of crop growth vegetative up to harvest. At all stages, late maturing genotypes maintained significantly higher stem dry weight over all other genotypes. Stem dry weight at all the growth stages showed a significant positive association with seed yield during both the photoperiods. The genotypes differed significantly with respect to specific leaf weight and specific leaf area at all the stages. Specific leaf weight increased upto pod initiation stage under variable photoperiods and declined steadily thereafter up to the harvest. Higher specific leaf weight was recorded in late maturing genotypes as compared to all other genotypes. A significant positive association was noticed between the specific leaf weight at all the growth stages with seed yield during both the photoperiods.

Significant differences were found among the genotypes for relative growth rate and crop growth rate at all the stages. In general, relative growth rate and crop growth rate increased with an advancement of crop growth. The genotypes which yielded high possessed significantly higher relative growth rate and crop growth rate over other genotypes. Relative growth rate and crop growth rate (30-45 DAS and 45-60 DAS) were found to have significant positive correlation with seed yield during both the photoperiods. The genotypes differed significantly with respect to photosynthetic rate. Among the genotypes, early (EC 457161), medium (SL 983) and late (SL 958) during both the photoperiods recorded significantly higher photosynthetic rate as compared to other genotypes. A significant positive correlation was observed between the photosynthetic rate and seed yield during both the photoperiodic conditions. The genotypes differed significantly with respect to stomatal conductance and transpiration rate at all the growth stages under variable photoperiods. Both the parameters exhibited a significant positive correlation with seed yield.

Chlorophyll content and photochemical efficiency in leaf differed significantly between the genotypes. However, leaf chlorophyll content and photochemical efficiency at all stages showed a significant positive association with seed yield during both the photoperiods. Phenophasic development viz., days to flower initiation, days to pod initiation and maturity were later in late maturing genotypes in compared to medium-and early maturing genotypes under variable photoperiods. Seed yield and yield components differed significantly between the genotypes. Among the genotypes, early (EC 457161), medium (SL 983) and late (SL 958) during both the photoperiods recorded significantly higher seed yield as compared to other genotypes. Number of pods per plant, 100-seed weight and harvest index showed a significant positive association with seed yield during both the photoperiods.

Metabolic reserves viz., leaf and stem total soluble sugars, starch at reproductive phase of plant development were higher which acted as source which direct assimilates partitioning towards the growing sinks. On the other hand, total soluble proteins and nitrogen content after flowering stage owing to remobilization of nitrogen from vegetative tissue such as stem and leaves to the sink. These reserves were found to be higher in late maturing genotypes as compare to other maturing groups. Nitrogen metabolizing enzymes i.e. glutamine synthetase, glutamate synthase and glutamate dehydogenase showed variation in response to genotypes of different maturing groups in leaf and stem in both the photoperiodic conditions. Highest activity of theses enzymes was found in late maturing genotypes as compared to medium and early maturing genotypes during both the photoperiods. Higher leaf nitrate reductase activity was also found in late maturing genotypes than other medium- and early maturing genotypes and decreased towards the maturity during both the photoperiodic conditions. In podwall, the levels of total soluble sugars, starch and total soluble proteins increased up to maximum till 20 DAF and declined afterwards during both the photoperiods. In late maturing genotypes, these metabolic reserves were higher than medium-and early-maturing genotypes under variable photoperiods.

Finally, it can be concluded that for selection of better genotypes under variable photoperiods, the following important physiological parameters viz., total dry matter, crop growth rate, relative growth rate, photosynthetic rate, chlorophyll content, leaf area index, specific leaf weight, 100 Seed weight, numbers of pods per plant and harvest index may be considered since, these parameters were found to have significant positive correlation with seed yield. Of the evaluated 15 diverse maturing genotypes, it is found that the early maturing genotypes EC 457161, medium SL 983 and late SL 958 are superior in terms of yield as well as in other morpho-physiological traits. Of all genotype SL 958 is the best performing one.

# APPENDIX

**Table 1: Leaf area (cm$^2$ plant$^{-1}$) of soybean genotypes at different growth stages under variable photoperiods.**

| **MATURING GROUP** | **GENOTYPES** | **Vegetative** | | **Flower initiation** | | **Pod initiation** | |
|---|---|---|---|---|---|---|---|
| | | **NS** | **LS** | **NS** | **LS** | **NS** | **LS** |
| **EARLY** | **SL 688** | 587.92 | 306.55 | 858.15 | 731.71 | 2096.38 | 1214.21 |
| | **SL778** | 589.89 | 279.09 | 808.19 | 617.21 | 2071.85 | 1840.56 |
| | **SL 795** | 624.53 | 366.24 | 1039.34 | 726.03 | 2338.68 | 1952.31 |
| | **EC 457161** | 696.67 | 466.36 | 1087.76 | 760.96 | 2834.71 | 1672.28 |
| | **EC457286** | 685.99 | 361.99 | 1097.82 | 735.74 | 2763.17 | 1458.51 |
| | **Mean** | **624.75** | **356.05** | **978.25** | **708.98** | **2335.41** | **1627.57** |
| **MEDIUM** | **SL 525** | 764.68 | 359.32 | 1042.11 | 883.24 | 2677.19 | 1656.37 |
| | **SL 744** | 695.56 | 337.35 | 1079.61 | 726.43 | 2760.57 | 1745.87 |
| | **SL 955** | 641.88 | 331.58 | 843.08 | 692.84 | 2410.69 | 1105.21 |
| | **SL 983** | 784.61 | 558.89 | 1272.62 | 674.63 | 2885.42 | 1998.07 |
| | **SL1123** | 572.89 | 369.31 | 1038.39 | 752.63 | 2023.61 | 1395.47 |
| | **Mean** | **691.92** | **391.29** | **1055.16** | **745.95** | **2551.5** | **1580.20** |
| **LATE** | **SL900** | 617.98 | 303.86 | 917.69 | 586.27 | 2399.69 | 1698.81 |
| | **SL 958** | 774.56 | 413.22 | 1335.94 | 871.05 | 3056.25 | 2168.23 |
| | **DS 12-5** | 672.27 | 389.57 | 1148.14 | 741.09 | 2461.53 | 1339.31 |
| | **DS 12-13** | 731.21 | 281.51 | 1150.62 | 856.31 | 2439.65 | 1594.92 |
| | **DS 26-14** | 693.81 | 434.19 | 1009.64 | 778.41 | 2847.95 | 1936.97 |
| | **Mean** | **697.97** | **364.47** | **1112.41** | **766.63** | **2641.01** | **1747.65** |
| | **LSD (5%)** | **167.28** | **153.58** | **244.85** | **322.53** | **347.41** | **694.82** |

**NS= Normal sown**
**LS=Late sown**

**Table 2: Leaf area index of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | SL 688 | 1.8 | 1.4 | 1.6 | 1.4 | 2.8 | 1.6 |
| | SL778 | 2.2 | 2.0 | 2.4 | 1.7 | 2.7 | 1.9 |
| | SL 795 | 2.5 | 2.3 | 3.1 | 1.8 | 2.6 | 2.3 |
| | EC 457161 | 2.8 | 2.1 | 3.8 | 2.4 | 3.0 | 2.2 |
| | EC457286 | 2.6 | 1.8 | 3.6 | 2.3 | 2.8 | 2.0 |
| | **Mean** | **2.4** | **1.9** | **2.9** | **1.9** | **2.8** | **2.1** |
| MEDIUM | SL 525 | 2.6 | 2.2 | 3.5 | 2.1 | 3.2 | 2.3 |
| | SL 744 | 2.8 | 2.4 | 4.1 | 2.3 | 3.4 | 1.7 |
| | SL 955 | 2.5 | 1.8 | 3.1 | 1.9 | 3.1 | 1.0 |
| | SL 983 | 3.1 | 2.6 | 3.9 | 3.1 | 3.6 | 2.7 |
| | SL1123 | 2.4 | 1.6 | 1.6 | 1.5 | 2.4 | 2.0 |
| | **Mean** | **2.7** | **2.1** | **3.3** | **2.2** | **3.1** | **2.0** |
| LATE | SL900 | 2.4 | 2.1 | 3.0 | 1.9 | 2.7 | 1.3 |
| | SL 958 | 3.2 | 2.8 | 4.2 | 2.7 | 3.9 | 2.6 |
| | DS 12-5 | 2.6 | 2.2 | 2.8 | 2.6 | 2.8 | 2.1 |
| | DS 12-13 | 2.7 | 2.2 | 3.9 | 1.5 | 3.3 | 2.0 |
| | DS 26-14 | 2.9 | 2.3 | 2.6 | 1.9 | 3.2 | 2.2 |
| | **Mean** | **2.8** | **2.3** | **3.3** | **2.1** | **3.2** | **2.0** |
| | **LSD (5%)** | **0.54** | **0.65** | **0.75** | **0.55** | **0.63** | **0.53** |

**NS= Normal sown**
**LS=Late sown**

**Table 3: Specific leaf weight (mg cm$^2$) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | Genotypes | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | **SL 688** | 3.79 | 2.39 | 4.03 | 1.83 | 4.28 | 3.12 |
| | **SL778** | 3.45 | 2.36 | 4.67 | 2.51 | 2.63 | 3.21 |
| | **SL 795** | 4.53 | 2.13 | 4.78 | 2.63 | 3.53 | 2.62 |
| | **EC 457161** | 5.49 | 3.03 | 5.81 | 2.06 | 5.04 | 3.64 |
| | **EC457286** | 4.89 | 3.09 | 5.53 | 1.72 | 4.43 | 2.57 |
| | **Mean** | **4.43** | **2.60** | **4.96** | **2.15** | **3.98** | **3.03** |
| MEDIUM | **SL 525** | 4.18 | 2.35 | 5.82 | 3.36 | 4.56 | 4.24 |
| | **SL 744** | 4.57 | 2.91 | 6.04 | 2.05 | 5.43 | 5.11 |
| | **SL 955** | 4.12 | 1.89 | 3.89 | 2.38 | 4.07 | 2.82 |
| | **SL 983** | 5.94 | 3.58 | 6.43 | 2.31 | 6.91 | 3.39 |
| | **SL1123** | 3.49 | 1.89 | 3.25 | 1.85 | 4.41 | 3.56 |
| | **Mean** | **4.46** | **2.52** | **5.09** | **2.39** | **5.08** | **3.82** |
| LATE | **SL900** | 3.78 | 2.45 | 5.61 | 3.36 | 4.59 | 3.43 |
| | **SL 958** | 5.43 | 4.69 | 6.65 | 3.91 | 5.55 | 3.96 |
| | **DS 12-5** | 4.82 | 3.21 | 4.15 | 3.63 | 3.18 | 3.11 |
| | **DS 12-13** | 3.29 | 2.58 | 4.79 | 1.85 | 4.11 | 3.09 |
| | **DS 26-14** | 5.12 | 3.23 | 5.62 | 2.31 | 4.96 | 3.61 |
| | **Mean** | **4.33** | **3.23** | **5.36** | **3.19** | **4.48** | **3.44** |
| | **LSD (5%)** | **1.21** | **0.636** | **0.949** | **0.763** | **1.31** | **1.08** |

**NS= Normal sown**
**LS=Late sown**

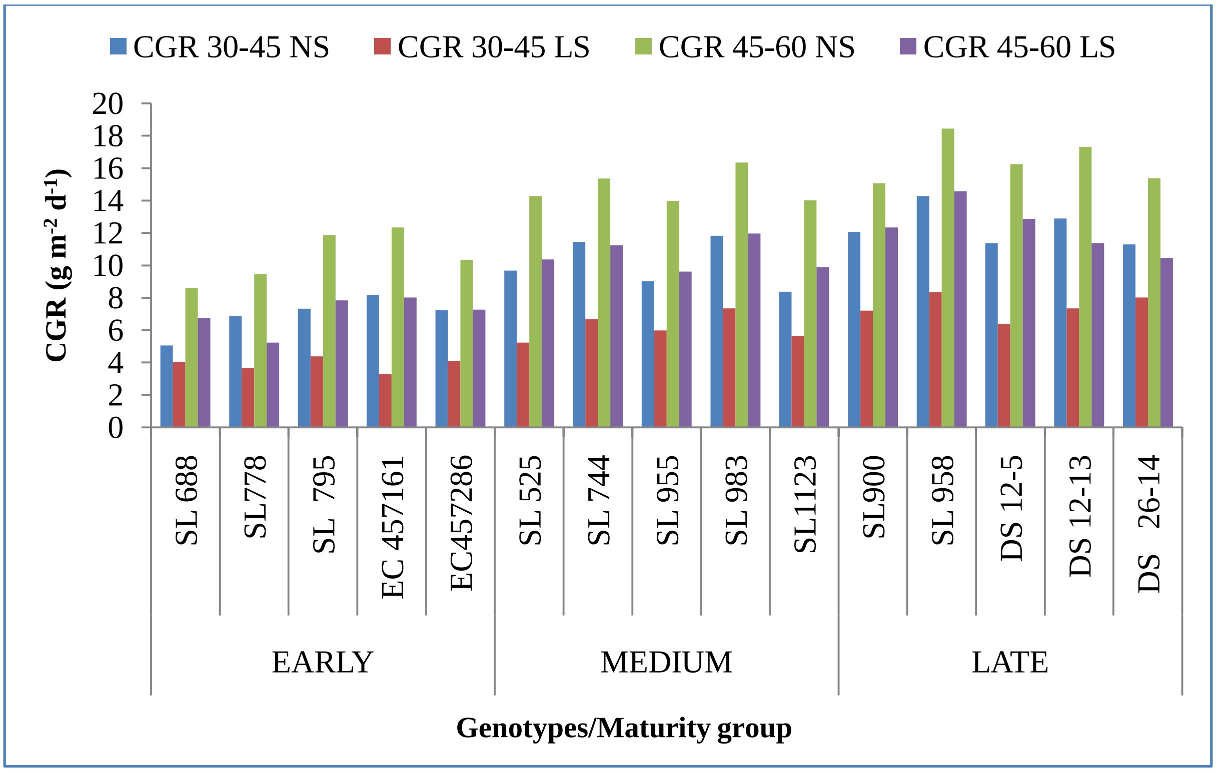

**Figure 1:** Crop growth rate of soybean genotypes at 30-45 and 45-60 DAS under variable photoperiods

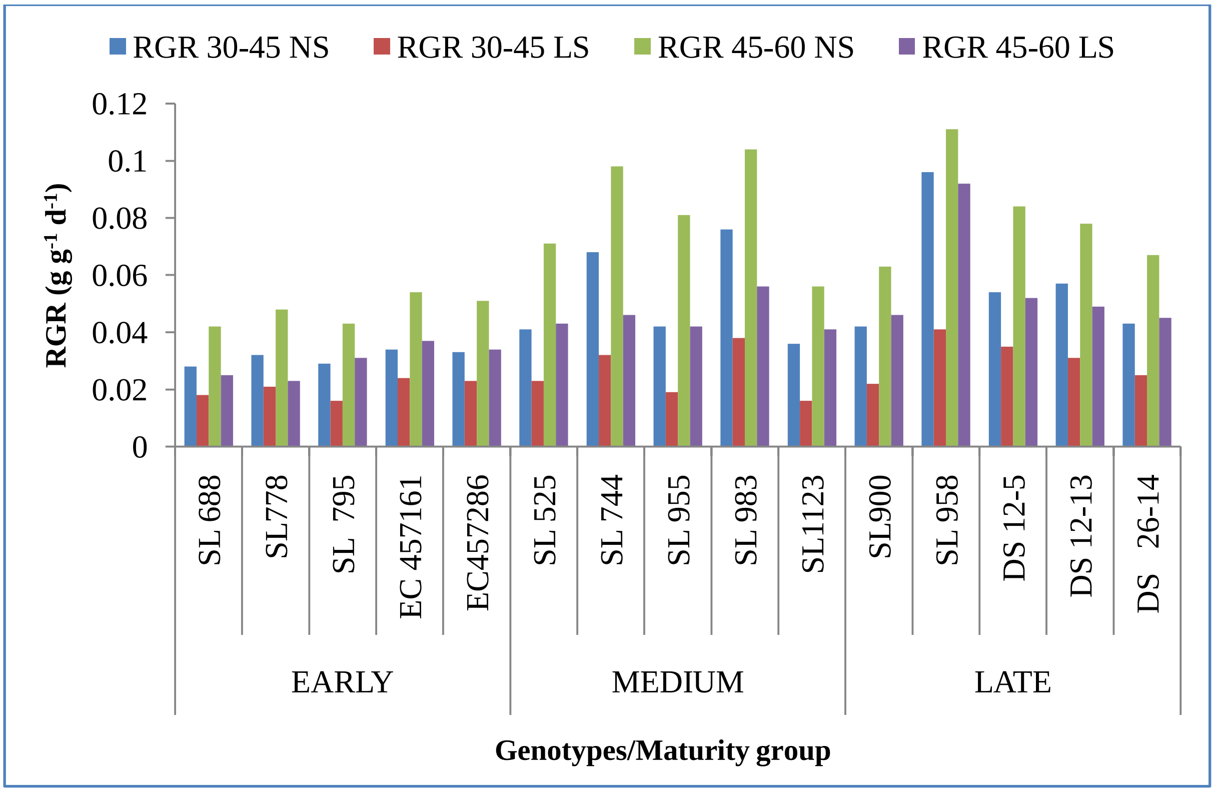

**Figure 3:** Relative growth rate of soybean genotypes at 30-45 and 45-60 DAS under variable photoperiods

**Table 4: Net photosynthesis (µmol $Co_2$ $m^{-2}s^{-1}$) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | **NS** | **LS** | **NS** | **LS** | **NS** | **LS** |
| **EARLY** | **SL 688** | 8.85 | 6.85 | 18.07 | 9.58 | 5.02 | 3.96 |
| | **SL778** | 8.47 | 6.48 | 16.53 | 9.96 | 5.39 | 4.62 |
| | **SL 795** | 9.27 | 7.27 | 20.09 | 9.58 | 4.89 | 2.92 |
| | **EC 457161** | 11.34 | 9.34 | 27.25 | 12.05 | 8.53 | 5.37 |
| | **EC457286** | 13.67 | 11.67 | 24.25 | 11.25 | 6.19 | 5.15 |
| | **Mean** | **10.32** | **8.32** | **21.24** | **10.48** | **6.00** | **4.40** |
| **MEDIUM** | **SL 525** | 10.02 | 8.02 | 24.97 | 12.57 | 6.11 | 4.93 |
| | **SL 744** | 13.48 | 11.49 | 24.87 | 12.82 | 7.26 | 5.67 |
| | **SL 955** | 9.83 | 7.83 | 21.29 | 10.26 | 5.37 | 4.96 |
| | **SL 983** | 16.04 | 14.06 | 25.14 | 12.97 | 7.37 | 6.22 |
| | **SL1123** | 10.14 | 8.14 | 22.28 | 9.39 | 5.18 | 4.06 |
| | **Mean** | **11.90** | **9.91** | **23.71** | **11.60** | **6.26** | **5.17** |
| **LATE** | **SL900** | 8.91 | 6.92 | 21.81 | 9.15 | 6.09 | 4.92 |
| | **SL 958** | 15.17 | 12.74 | 25.36 | 14.98 | 8.26 | 5.85 |
| | **DS 12-5** | 14.74 | 13.17 | 22.36 | 12.15 | 7.48 | 3.72 |
| | **DS 12-13** | 11.95 | 9.97 | 21.51 | 9.39 | 6.78 | 4.47 |
| | **DS 26-14** | 12.19 | 10.18 | 22.28 | 9.98 | 7.25 | 4.03 |
| | **Mean** | **12.59** | **10.60** | **22.66** | **11.13** | **7.17** | **4.60** |
| | **LSD (5%)** | **2.78** | **2.68** | **1.98** | **1.16** | **1.45** | **1.37** |

**NS= Normal sown**
**LS=Late sown**

**Table 5: Stomatal conductance (μ mol $Co_2$ $m^{-2}$ $s^{-1}$) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | SL 688 | 0.439 | 0.294 | 0.269 | 0.312 | 0.084 | 0.052 |
| | SL778 | 0.578 | 0.433 | 0.604 | 0.316 | 0.086 | 0.039 |
| | SL 795 | 0.434 | 0.289 | 0.552 | 0.345 | 0.074 | 0.049 |
| | EC 457161 | 0.553 | 0.408 | 0.683 | 0.427 | 0.091 | 0.061 |
| | EC457286 | 0.611 | 0.466 | 1.031 | 0.296 | 0.083 | 0.065 |
| | **Mean** | **0.523** | **0.378** | **0.628** | **0.339** | **0.084** | **0.053** |
| MEDIUM | SL 525 | 0.482 | 0.337 | 0.615 | 0.381 | 0.106 | 0.081 |
| | SL 744 | 0.583 | 0.438 | 0.718 | 0.315 | 0.119 | 0.103 |
| | SL 955 | 0.477 | 0.332 | 0.655 | 0.289 | 0.091 | 0.065 |
| | SL 983 | 0.639 | 0.494 | 0.749 | 0.345 | 0.123 | 0.086 |
| | SL1123 | 0.454 | 0.309 | 0.607 | 0.337 | 0.094 | 0.084 |
| | **Mean** | **0.527** | **0.382** | **0.669** | **0.333** | **0.107** | **0.084** |
| LATE | SL900 | 0.557 | 0.411 | 0.519 | 0.332 | 0.093 | 0.079 |
| | SL 958 | 0.675 | 0.529 | 0.848 | 0.246 | 0.121 | 0.104 |
| | DS 12-5 | 0.659 | 0.514 | 0.589 | 0.262 | 0.096 | 0.045 |
| | DS 12-13 | 0.564 | 0.419 | 0.758 | 0.322 | 0.087 | 0.064 |
| | DS 26-14 | 0.599 | 0.454 | 0.625 | 0.414 | 0.106 | 0.072 |
| | **Mean** | **0.611** | **0.465** | **0.668** | **0.315** | **0.101** | **0.073** |
| | **LSD (5%)** | **0.147** | **0.146** | **0.189** | **0.165** | **0.062** | **0.031** |

**NS= Normal sown**
**LS=Late sown**

**Table 6: Transpiration rate (m mol $H_20$ $m^{-2}$ $g^{-1}$) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | **SL 688** | 5.24 | 3.35 | 5.94 | 2.94 | 3.22 | 2.07 |
| | **SL778** | 6.05 | 4.17 | 5.06 | 2.26 | 3.43 | 2.26 |
| | **SL 795** | 6.14 | 4.25 | 5.89 | 3.18 | 2.96 | 2.38 |
| | **EC 457161** | 6.39 | 4.51 | 9.86 | 4.15 | 4.09 | 3.74 |
| | **EC457286** | 6.94 | 5.06 | 7.28 | 3.54 | 3.88 | 2.42 |
| | **Mean** | **6.15** | **4.27** | **6.81** | **3.21** | **3.52** | **2.57** |
| MEDIUM | **SL 525** | 5.91 | 4.02 | 7.03 | 4.05 | 2.99 | 2.76 |
| | **SL 744** | 6.61 | 4.73 | 7.56 | 4.64 | 4.31 | 3.46 |
| | **SL 955** | 5.11 | 3.22 | 5.98 | 3.25 | 4.61 | 3.15 |
| | **SL 983** | 7.19 | 5.31 | 8.23 | 4.89 | 5.94 | 3.54 |
| | **SL1123** | 5.45 | 3.56 | 6.08 | 4.05 | 4.26 | 2.41 |
| | **Mean** | **6.05** | **4.17** | **6.98** | **4.18** | **4.42** | **3.06** |
| LATE | **SL900** | 5.89 | 4.01 | 6.74 | 4.01 | 5.44 | 3.08 |
| | **SL 958** | 7.98 | 5.34 | 8.52 | 4.96 | 6.84 | 3.65 |
| | **DS 12-5** | 7.48 | 6.06 | 8.03 | 4.65 | 3.71 | 3.64 |
| | **DS 12-13** | 7.42 | 5.58 | 7.11 | 4.01 | 3.23 | 2.72 |
| | **DS 26-14** | 6.46 | 4.58 | 8.39 | 3.91 | 4.61 | 3.63 |
| | **Mean** | **7.05** | **5.11** | **7.76** | **4.31** | **4.77** | **3.34** |
| | **LSD (5%)** | **1.16** | **1.15** | **1.65** | **1.29** | **0.62** | **0.94** |

**NS= Normal sown**
**LS=Late sown**

**Table 7: Chlorophyll kinetics (Fv/Fm) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | SL 688 | 0.787 | 0.661 | 0.801 | 0.582 | 0.614 | 0.604 |
| | SL778 | 0.798 | 0.621 | 0.784 | 0.556 | 0.619 | 0.613 |
| | SL 795 | 0.779 | 0.549 | 0.811 | 0.554 | 0.619 | 0.607 |
| | EC 457161 | 0.807 | 0.613 | 0.816 | 0.774 | 0.676 | 0.637 |
| | EC457286 | 0.801 | 0.557 | 0.809 | 0.625 | 0.665 | 0.626 |
| | **Mean** | **0.794** | **0.600** | **0.804** | **0.618** | **0.639** | **0.617** |
| MEDIUM | SL 525 | 0.778 | 0.605 | 0.797 | 0.584 | 0.648 | 0.585 |
| | SL 744 | 0.786 | 0.569 | 0.801 | 0.591 | 0.645 | 0.632 |
| | SL 955 | 0.792 | 0.652 | 0.784 | 0.586 | 0.604 | 0.569 |
| | SL 983 | 0.796 | 0.657 | 0.811 | 0.633 | 0.652 | 0.625 |
| | SL1123 | 0.783 | 0.555 | 0.794 | 0.553 | 0.619 | 0.591 |
| | **Mean** | **0.787** | **0.608** | **0.797** | **0.589** | **0.634** | **0.600** |
| LATE | SL900 | 0.778 | 0.641 | 0.804 | 0.574 | 0.636 | 0.611 |
| | SL 958 | 0.805 | 0.668 | 0.809 | 0.647 | 0.672 | 0.629 |
| | DS 12-5 | 0.791 | 0.582 | 0.791 | 0.554 | 0.649 | 0.592 |
| | DS 12-13 | 0.785 | 0.618 | 0.802 | 0.602 | 0.643 | 0.628 |
| | DS 26-14 | 0.792 | 0.594 | 0.796 | 0.578 | 0.628 | 0.595 |
| | **Mean** | **0.790** | **0.621** | **0.800** | **0.591** | **0.646** | **0.611** |
| | **LSD (5%)** | **0.069** | **0.012** | **0.005** | **0.054** | **0.0043** | **0.041** |

**NS= Normal sown**
**LS=Late sown**

**Table 8: Chlorophyll content (SPAD) of soybean genotypes at different growth stages under variable photoperiods**

| MATURING GROUP | GENOTYPES | Vegetative | | Flower initiation | | Pod initiation | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| EARLY | **SL 688** | 38.0 | 36.3 | 39.4 | 37.4 | 41.6 | 37.3 |
| | **SL778** | 36.4 | 35.3 | 40.0 | 36.6 | 40.2 | 39.2 |
| | **SL 795** | 38.0 | 33.8 | 40.2 | 38.1 | 40.1 | 39.1 |
| | **EC 457161** | 39.2 | 38.6 | 45.7 | 43.5 | 44.1 | 42.1 |
| | **EC457286** | 38.4 | 37.6 | 41.5 | 38.8 | 43.6 | 41.0 |
| | **Mean** | **38.0** | **36.3** | **41.4** | **38.9** | **41.9** | **39.8** |
| MEDIUM | **SL 525** | 37.6 | 35.7 | 42.3 | 40.5 | 43.0 | 40.6 |
| | **SL 744** | 38.2 | 37.8 | 41.3 | 41.1 | 43.5 | 42.1 |
| | **SL 955** | 35.1 | 33.9 | 37.3 | 39.1 | 39.4 | 38.0 |
| | **SL 983** | 39.3 | 36.7 | 43.9 | 38.3 | 44.2 | 42.9 |
| | **SL1123** | 35.9 | 35.4 | 40.7 | 36.5 | 42.9 | 41.9 |
| | **Mean** | **37.2** | **35.9** | **41.1** | **39.1** | **42.6** | **41.1** |
| LATE | **SL900** | 37.9 | 36.7 | 37.5 | 37.4 | 40.3 | 38.8 |
| | **SL 958** | 40.2 | 39.7 | 41.1 | 40.6 | 44.5 | 41.8 |
| | **DS 12-5** | 35.3 | 34.2 | 38.7 | 36.7 | 40.3 | 36.7 |
| | **DS 12-13** | 37.9 | 35.4 | 39.2 | 36.9 | 38.7 | 36.2 |
| | **DS 26-14** | 38.8 | 36.5 | 37.3 | 35.4 | 41.4 | 37.3 |
| | **Mean** | **38.0** | **36.5** | **38.8** | **37.4** | **41.0** | **38.2** |
| | **LSD (5%)** | **2.23** | **2.47** | **2.39** | **2.11** | **2.29** | **2.69** |

**NS= Normal sown**
**LS=Late sown**

**Table 9: Phenophasic development of soybean genotypes under variable photoperiods.**

| MATURING GROUP | GENOTYPES | Days To Flowering | | Days To Pod Initiation | | Days To Maturity | |
|---|---|---|---|---|---|---|---|
| | | NS | LS | NS | LS | NS | LS |
| **EARLY** | **SL 688** | 59 | 41 | 84 | 66 | 132 | 109 |
| | **SL778** | 58 | 36 | 83 | 63 | 131 | 113 |
| | **SL 795** | 56 | 37 | 81 | 64 | 130 | 110 |
| | **EC 457161** | 58 | 40 | 83 | 67 | 132 | 111 |
| | **EC457286** | 58 | 40 | 83 | 66 | 132 | 109 |
| | **Mean** | **58** | **39** | **83** | **65** | **131** | **110** |
| **MEDIUM** | **SL 525** | 65 | 44 | 87 | 69 | 139 | 116 |
| | **SL 744** | 64 | 44 | 88 | 70 | 138 | 115 |
| | **SL 955** | 64 | 42 | 87 | 68 | 136 | 115 |
| | **SL 983** | 66 | 45 | 91 | 71 | 139 | 117 |
| | **SL1123** | 62 | 42 | 87 | 67 | 135 | 115 |
| | **Mean** | **64** | **43** | **88** | **69** | **137** | **115** |
| **LATE** | **SL900** | 67 | 46 | 91 | 71 | 141 | 118 |
| | **SL 958** | 69 | 49 | 93 | 73 | 143 | 120 |
| | **DS 12-5** | 68 | 47 | 93 | 72 | 140 | 119 |
| | **DS 12-13** | 68 | 47 | 95 | 71 | 140 | 117 |
| | **DS 26-14** | 68 | 48 | 94 | 72 | 139 | 119 |
| | **Mean** | **68** | **47** | **93** | **72** | **140** | **118** |
| | **LSD (5%)** | **1.34** | **1.84** | **1.35** | **1.09** | **1.33** | **1.28** |

**NS= Normal sown**
**LS=Late sown**

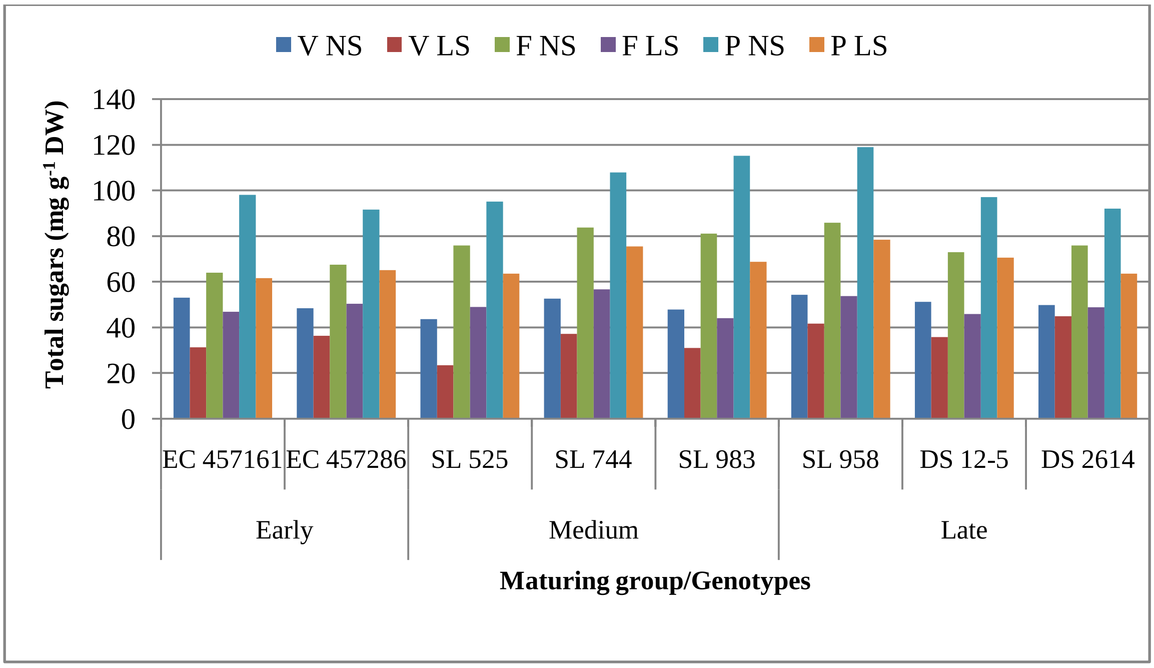

**Figure 3:** **Total soluble sugars (mg g$^{-1}$ DW) from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

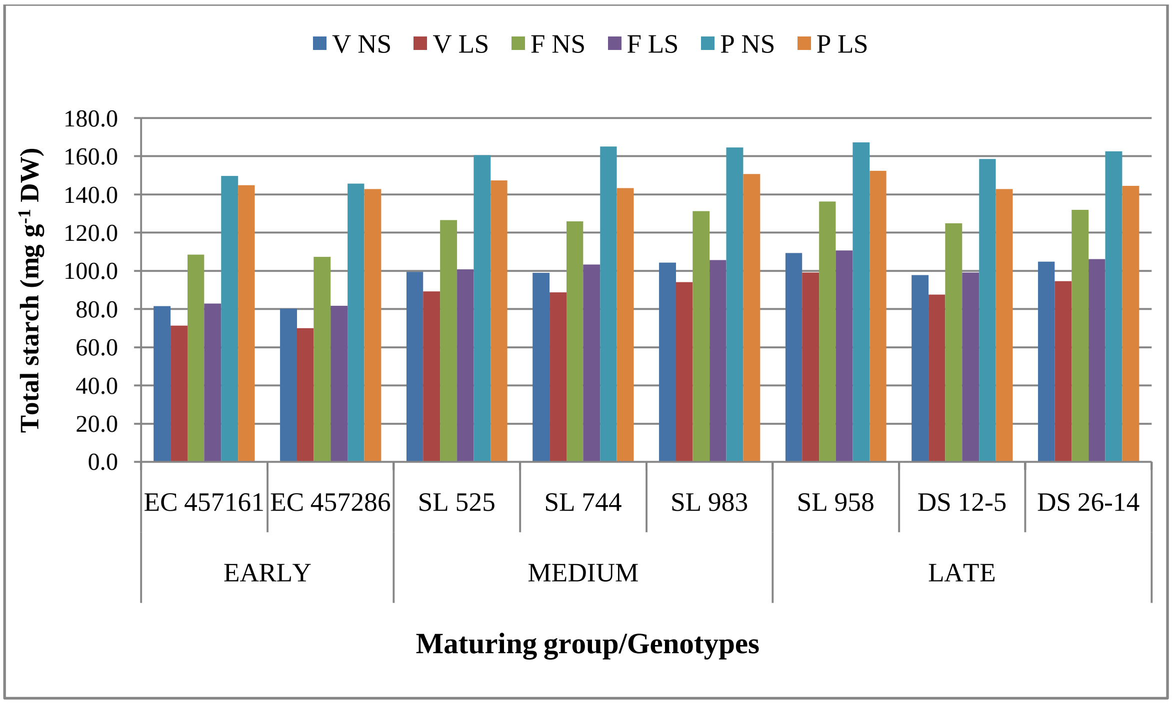

**Figure 4:** **Total starch content (mg g$^{-1}$ DW) from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

**NS= Normal sown**

**LS=Late sown**

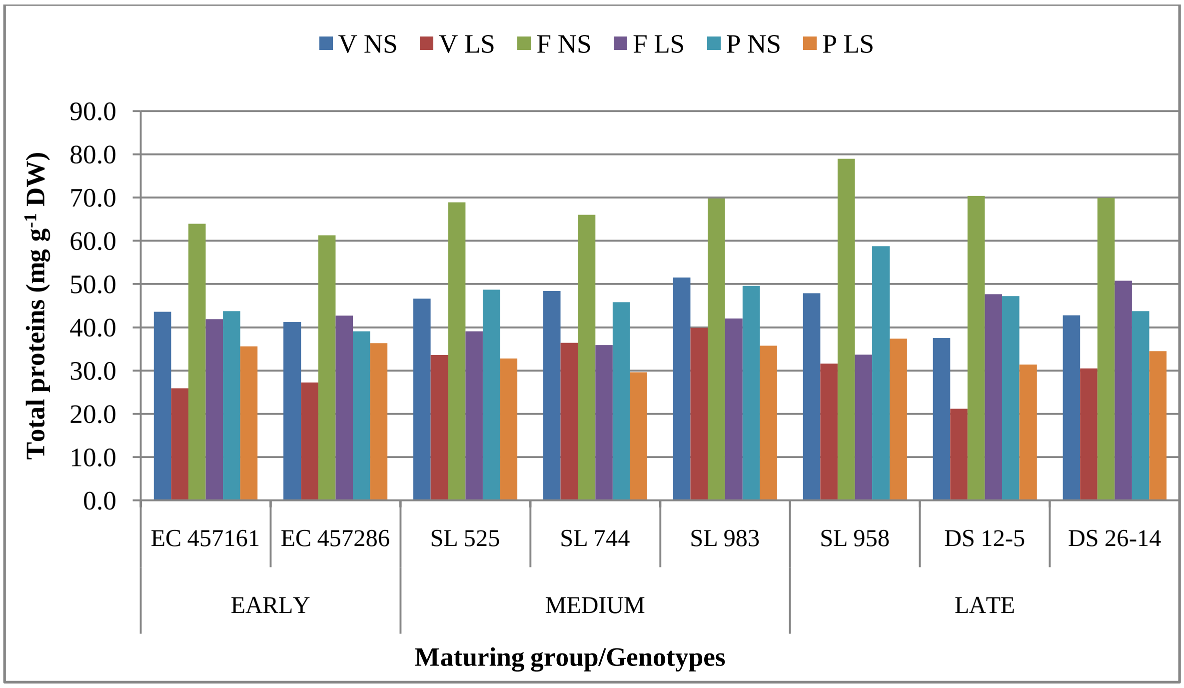

**Figure 5:** **Total proteins (mg $g^{-1}$ DW) from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

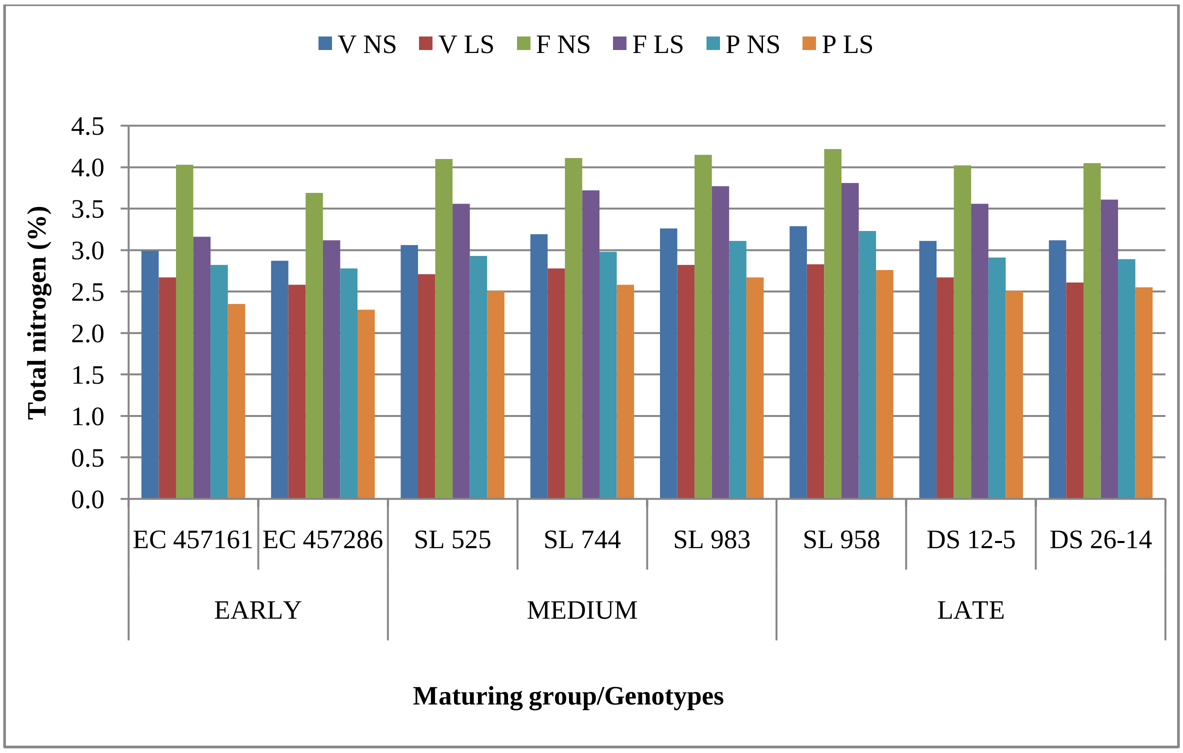

**Figure 6:** **Total nitrogen (%) from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**
**NS= Normal sown**
**LS=Late sown**

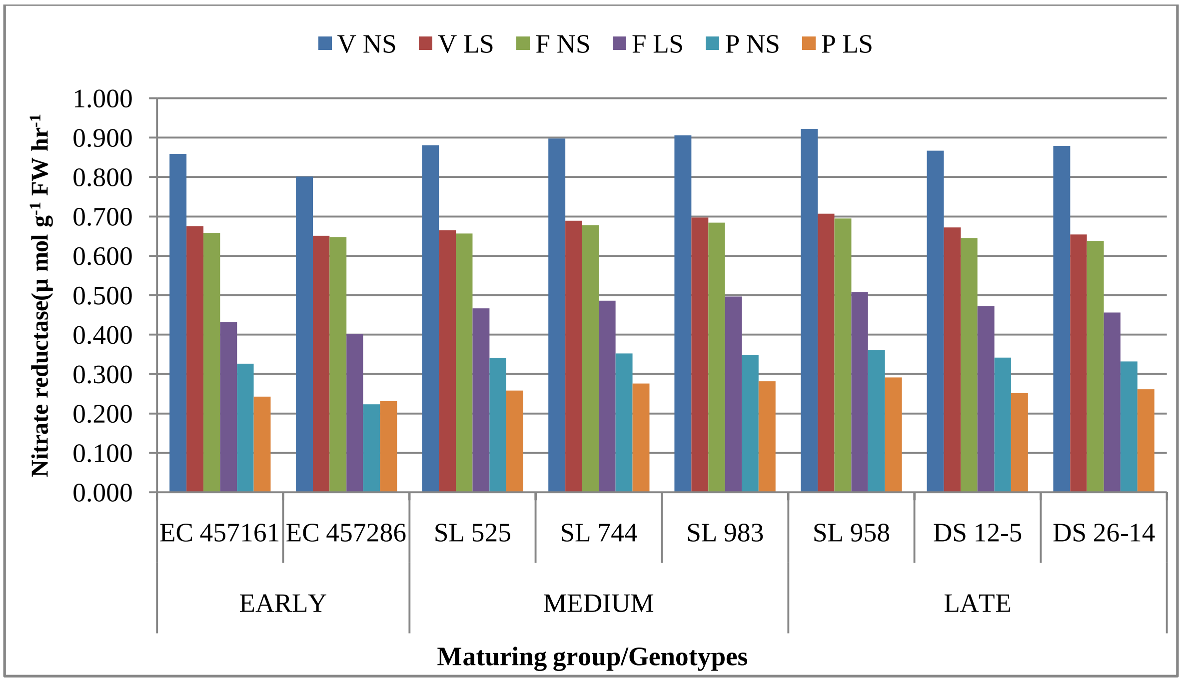

**Figure 7:** Nitrate reductase activity from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.

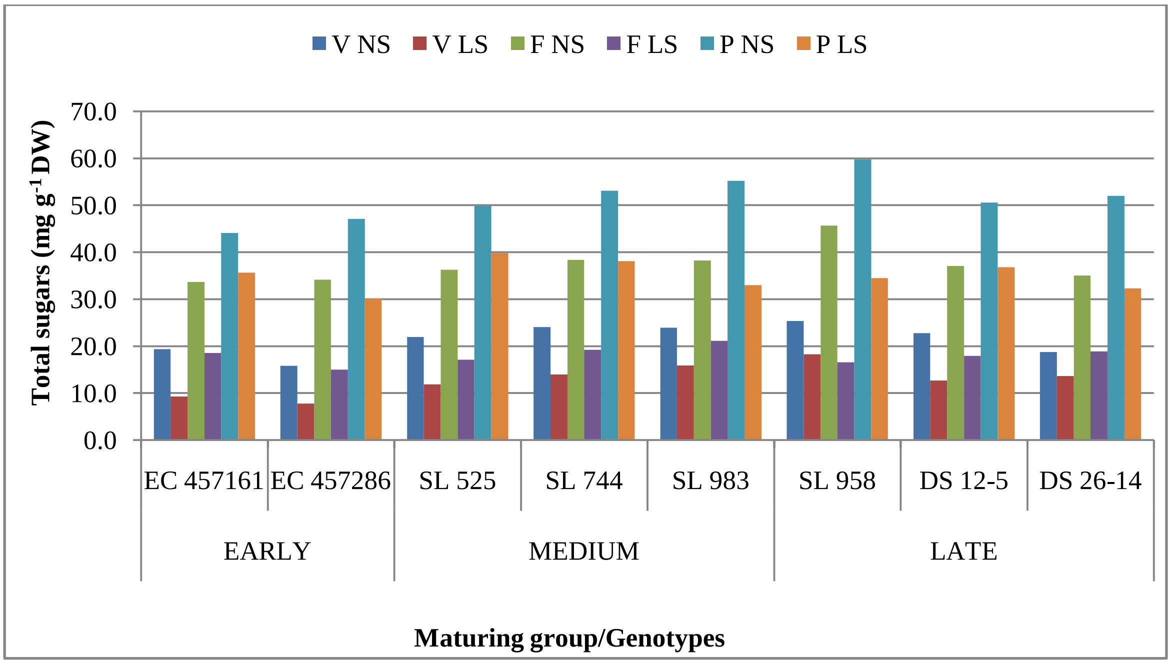

**Figure 8:** Total sugars (mg $g^{-1}$ DW) from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.

**NS= Normal sown**
**LS=Late sown**

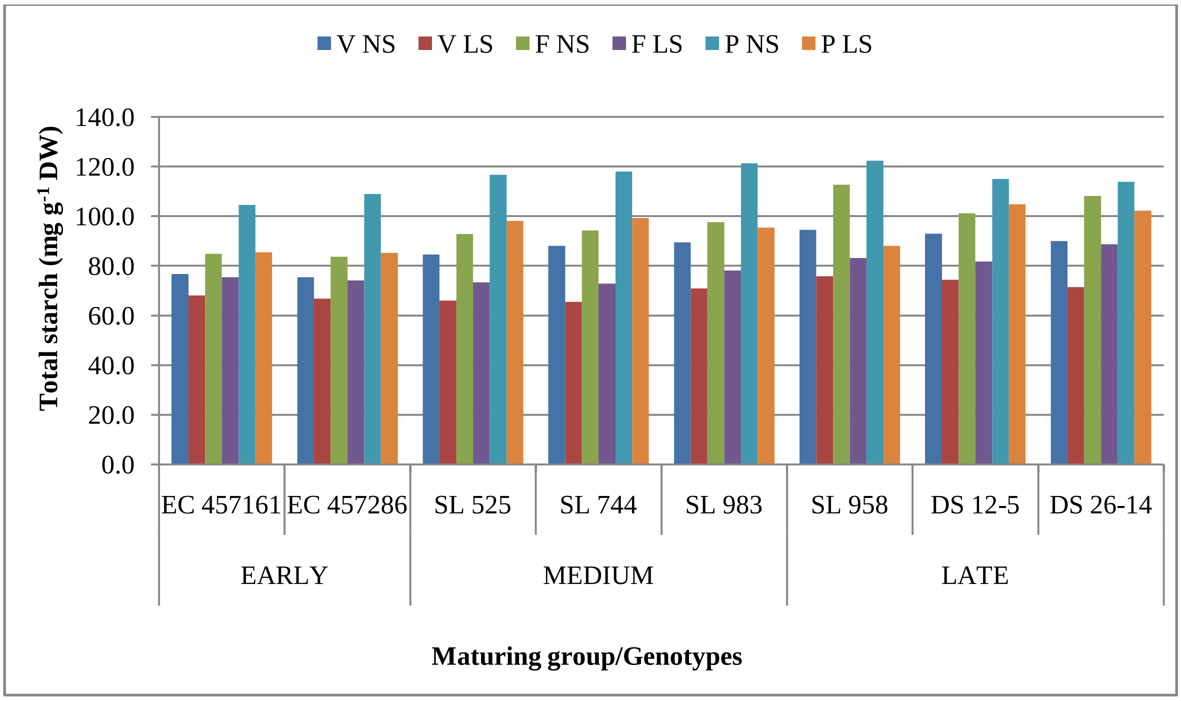

**Figure 9:** **Total starch content (mg $g^{-1}$ DW) from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

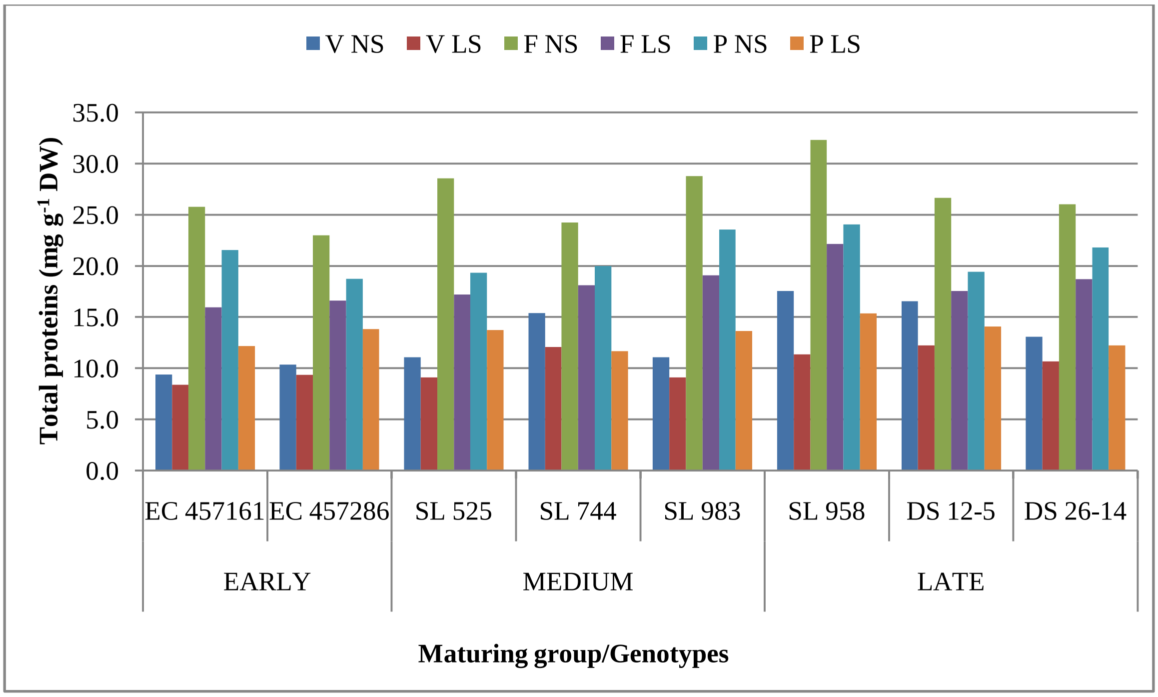

**Figure 10:** **Total proteins content (mg g-1 DW) from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**
**NS= Normal sown**
**LS=Late sown**

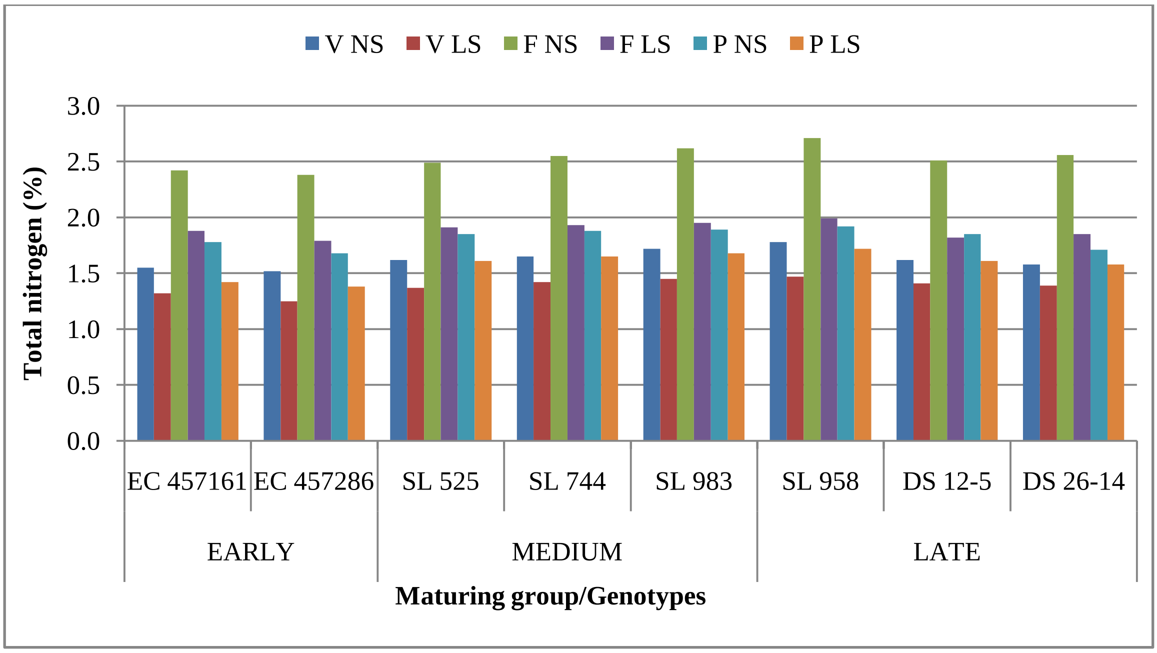

**Figure 11:** Total nitrogen (%) from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.

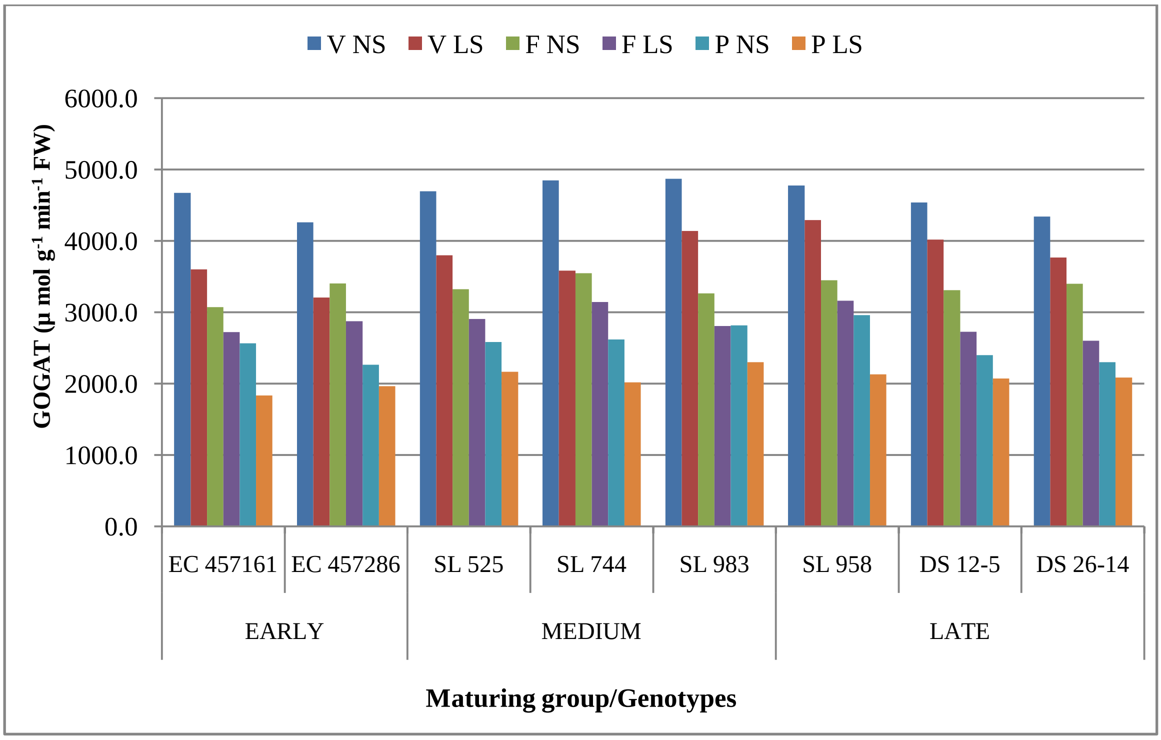

**Figure 12:** Glutamate synthase (GOGAT) activity from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiod
NS= Normal sown
LS=Late sown

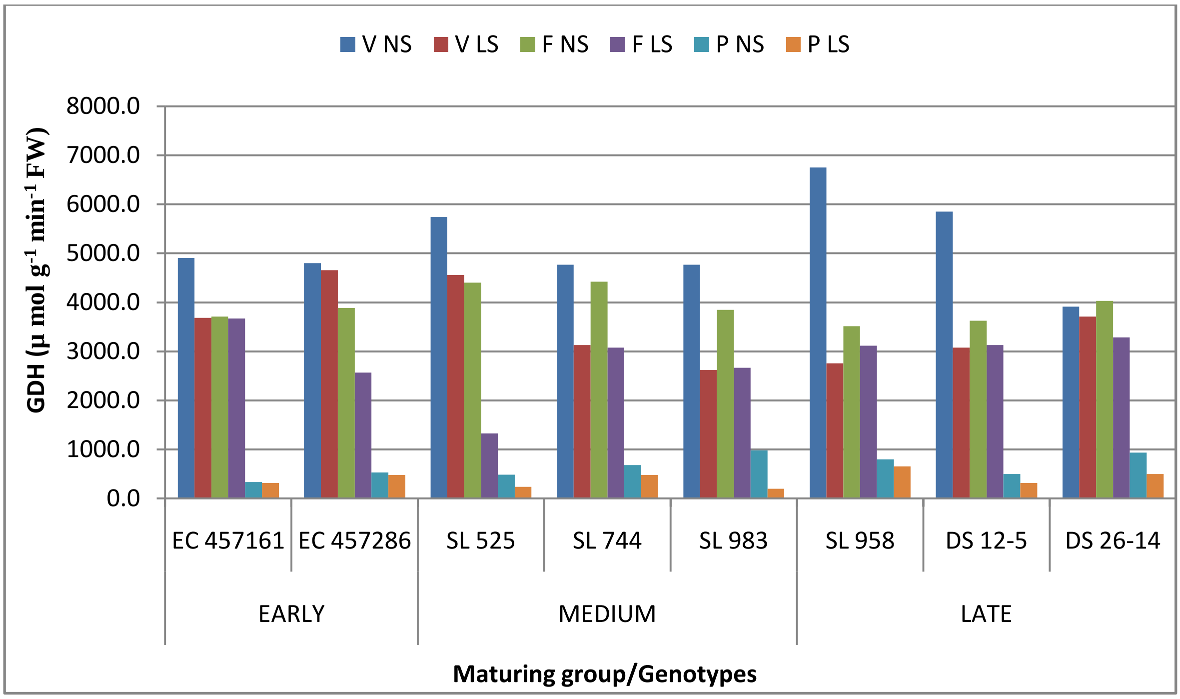

**Figure 13:** **Glutamate dehydogenase (GDH) activity from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

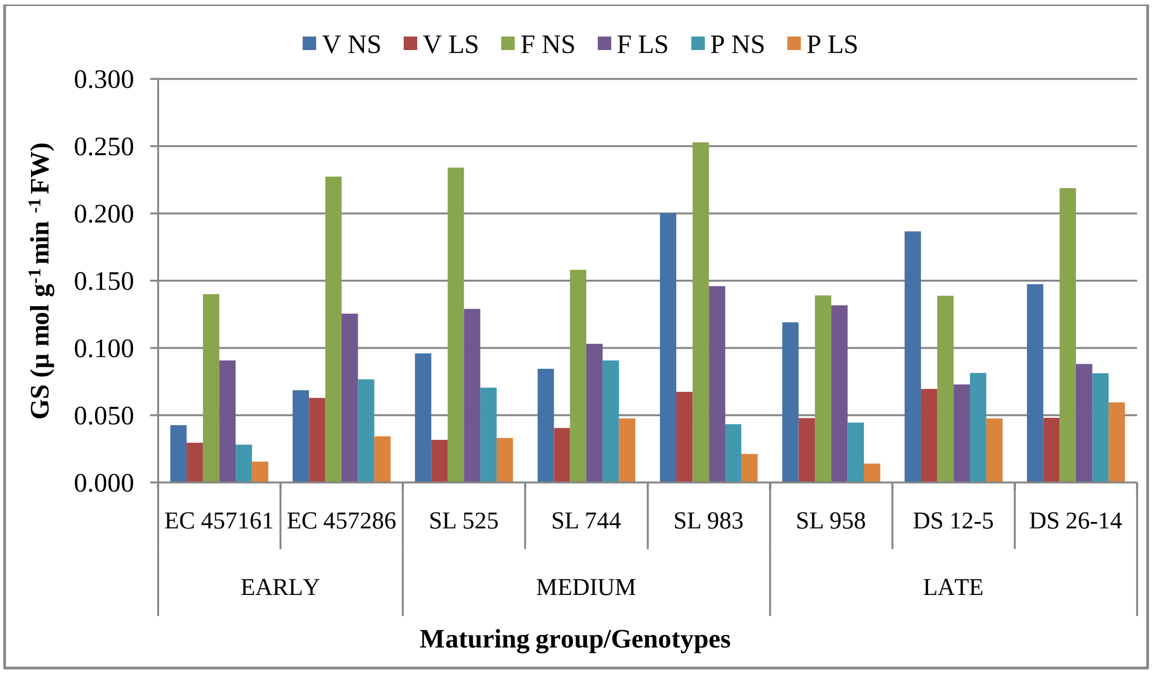

**Figure 14:** **Glutamine synthetase (GS) activity from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**
**NS= Normal sown**
**LS=Late sown**

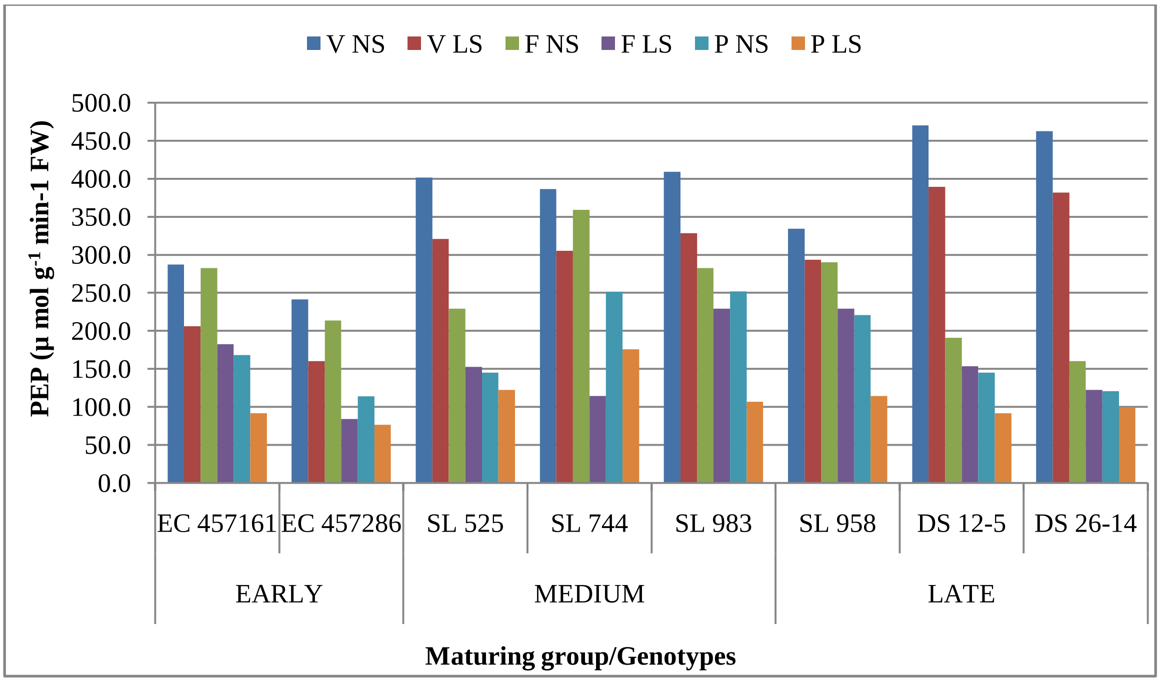

**Figure 15: PEP carboxylase activity from leaves at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

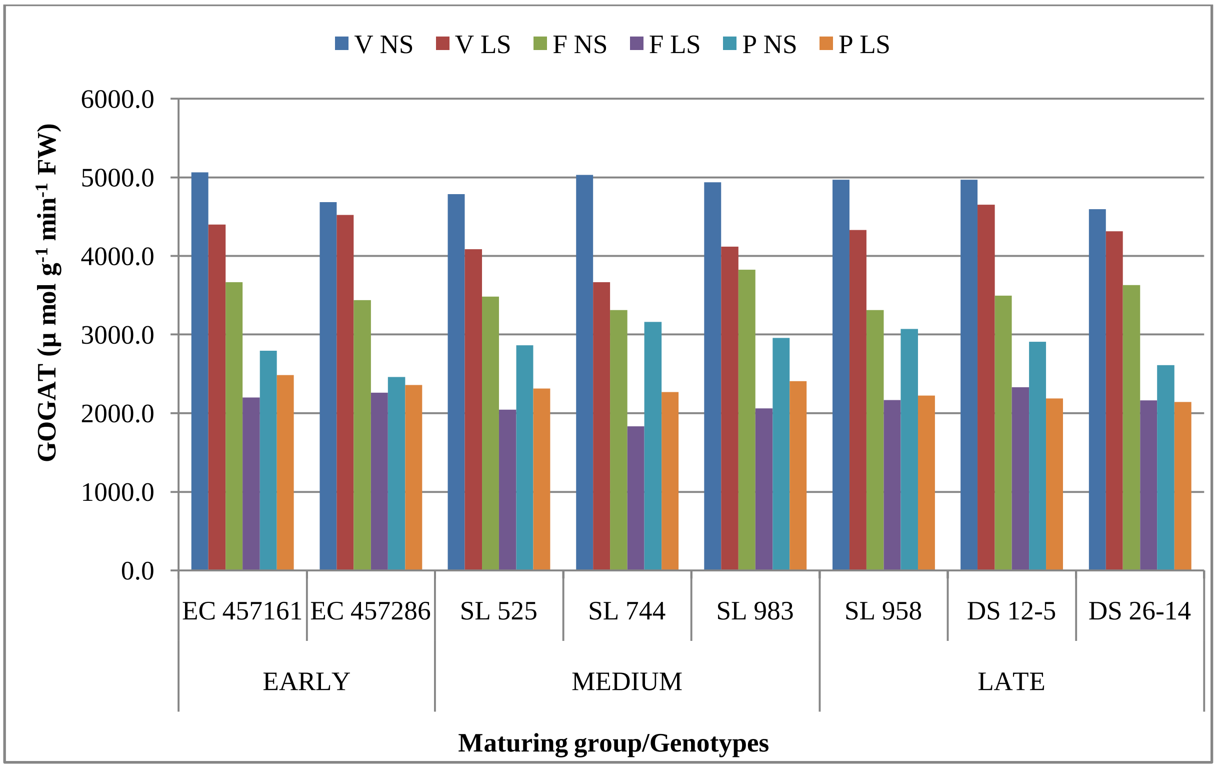

**Figure 16: Glutamate synthase (GOGAT) activity from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.**

**NS= Normal sown**

**LS=Late sown**

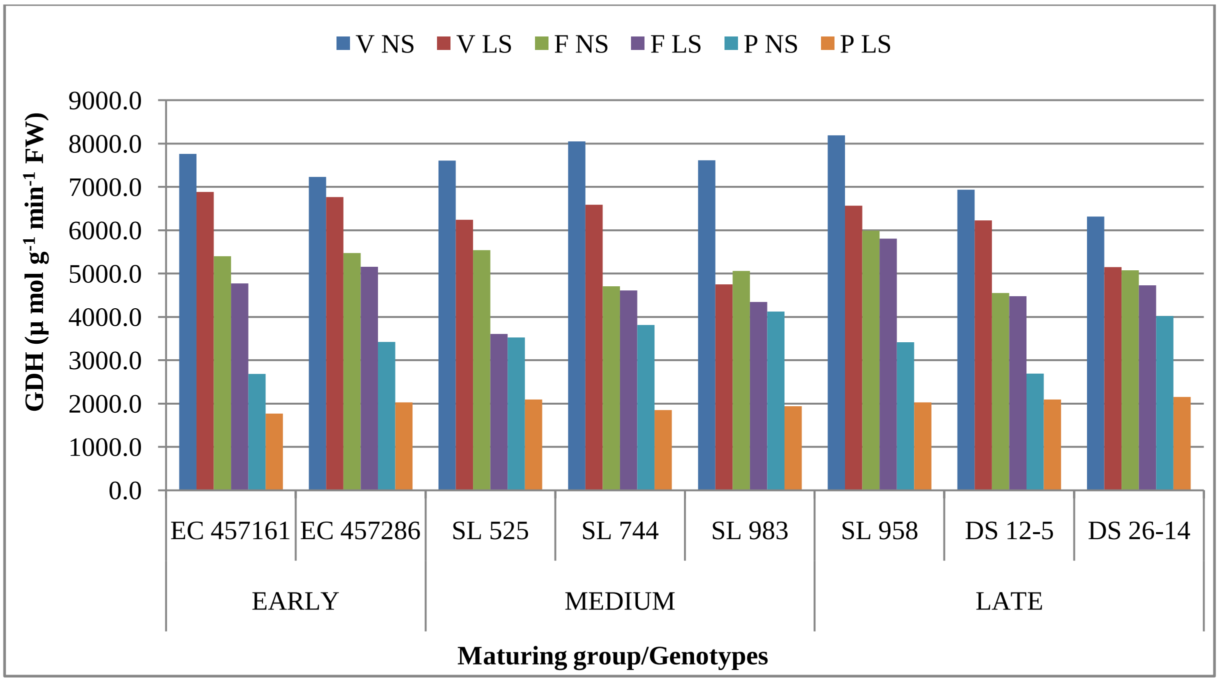

**Figure 17:** Glutamate dehydogenase (GDH) activity from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.

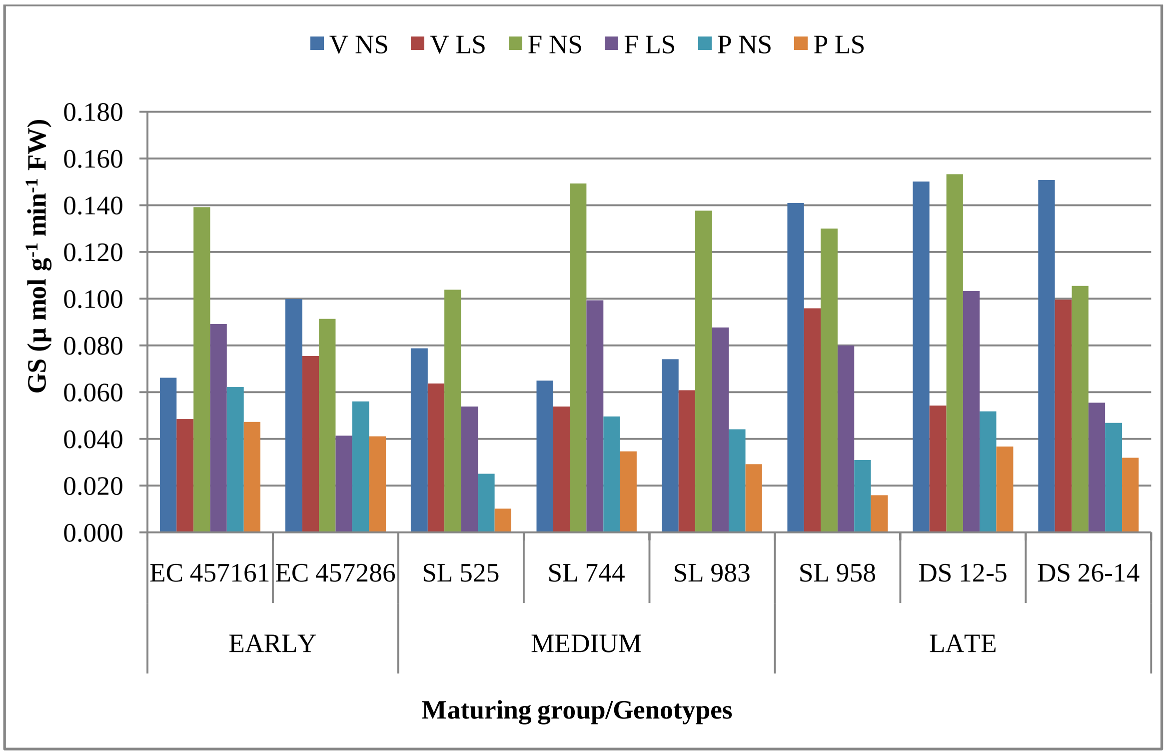

**Figure 18:** Glutamine synthetase (GS) activity from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods.
**NS= Normal sown**
**LS=Late sown**

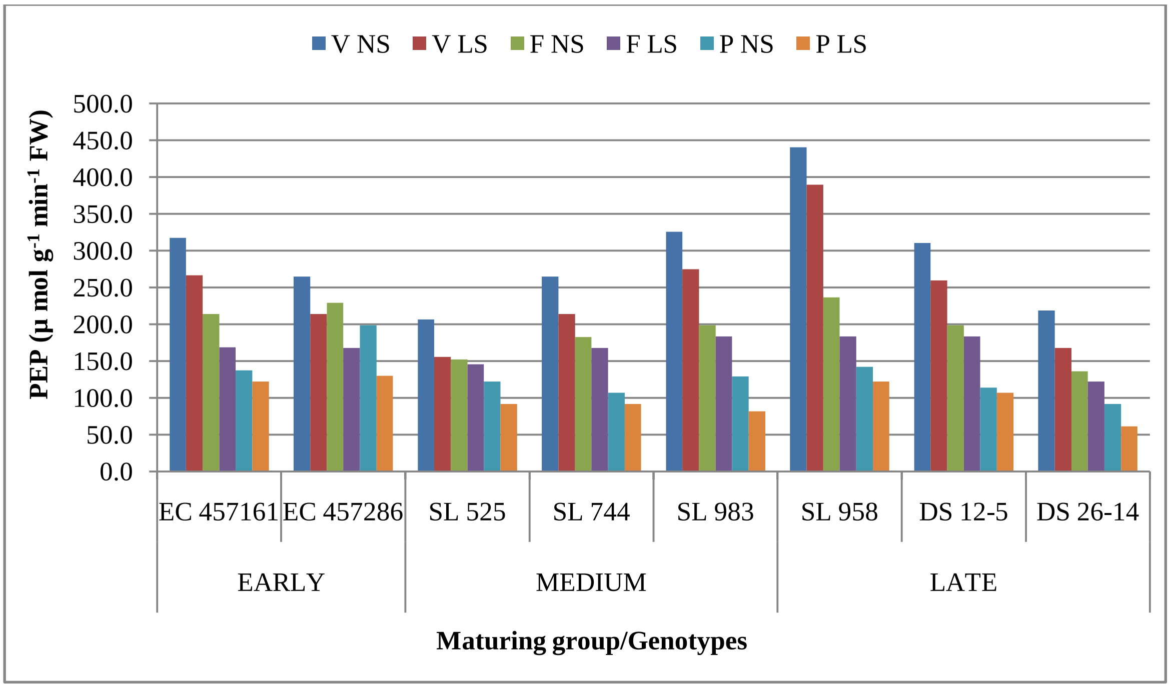

**Figure 19:** **PEP carboxylase activity from stem at Vegetative (V), Flower initiation (F) and Pod initiation (P) of soybean genotypes under variable photoperiods**

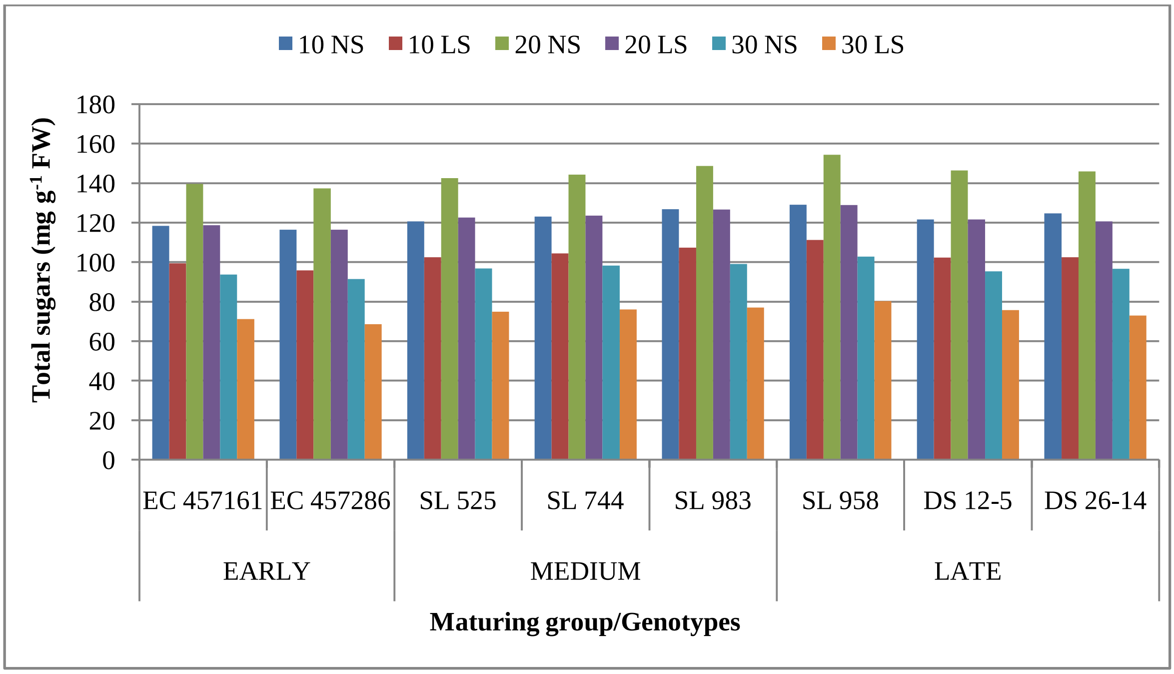

**Figure 20:** **Total sugars content from podwall at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods**
**NS= Normal sown**
**LS=Late sown**

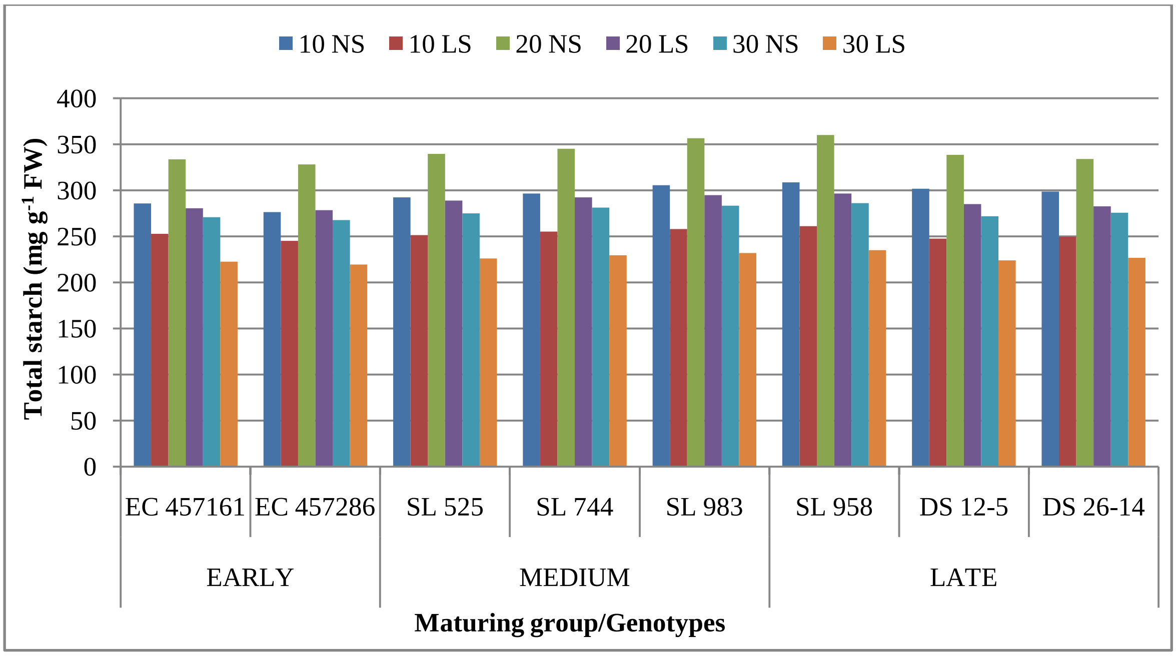

**Figure 21:** Total starch content from Podwall at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods.

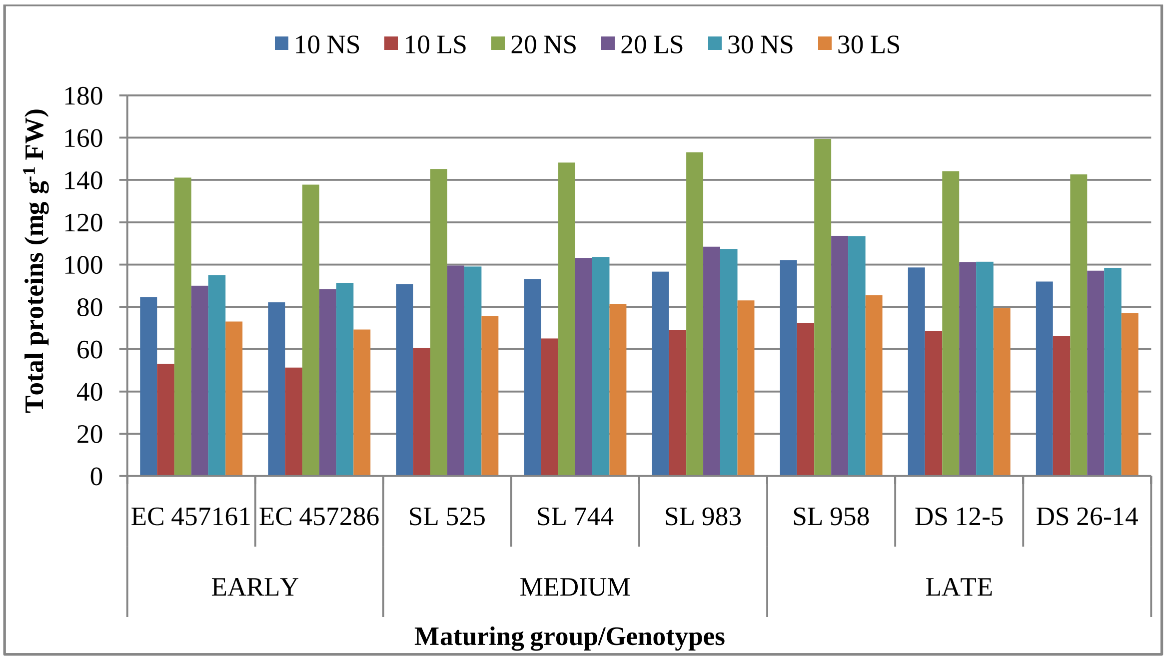

**Figure 22:** Total proteins content from Podwall at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods.
NS= Normal sown
LS=Late sown

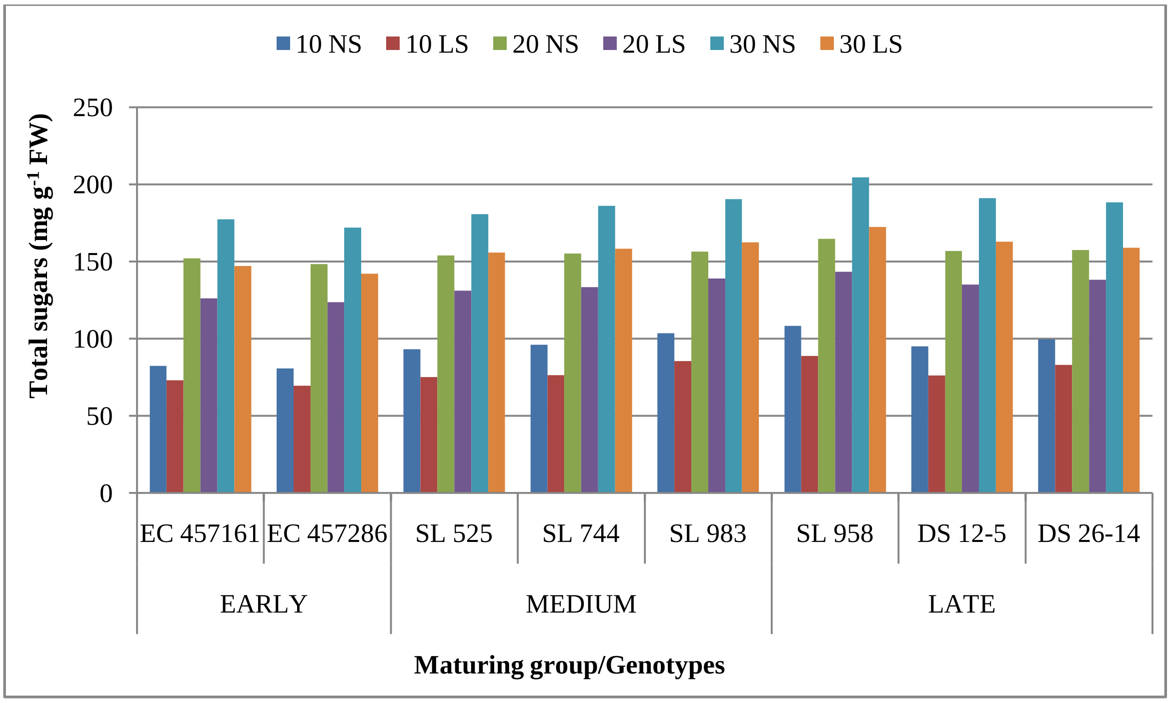

**Figure 23:** **Total sugars content from seed at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods**

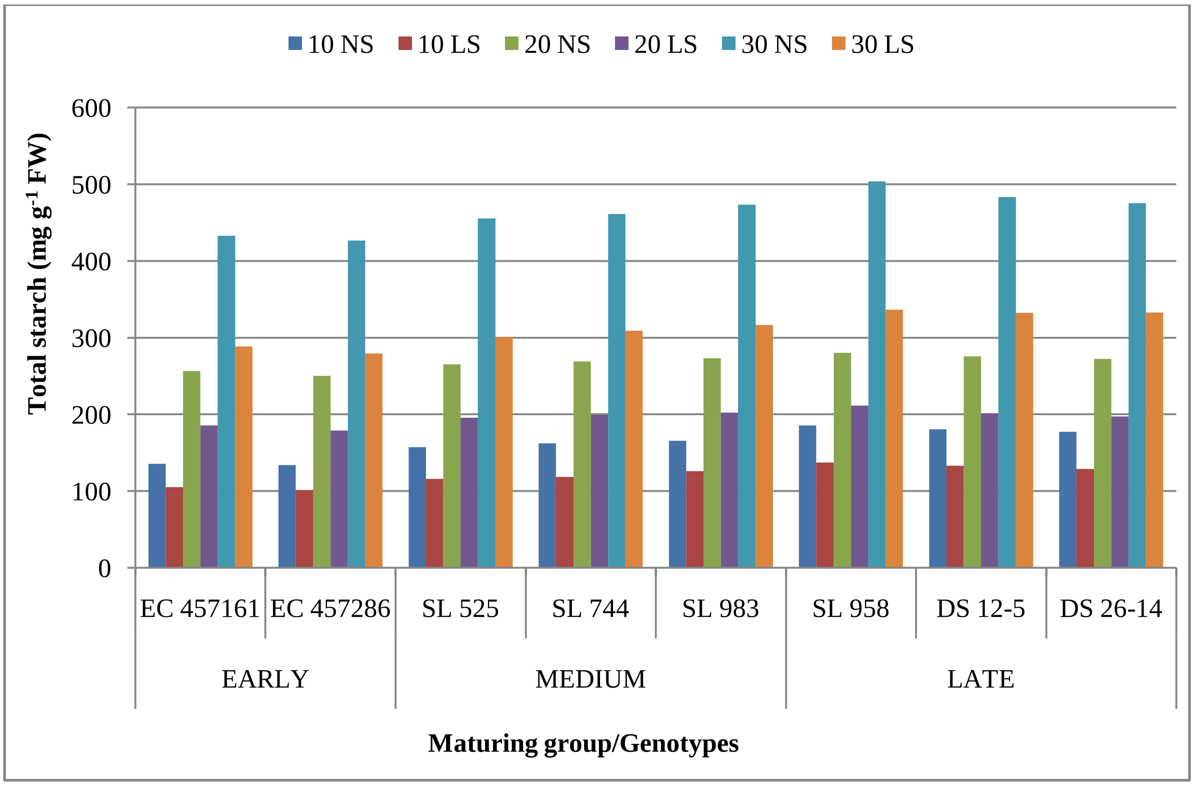

**Figure 24:** **Total starch content from seed at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods.**
**NS= Normal sown**
**LS=Late sown**

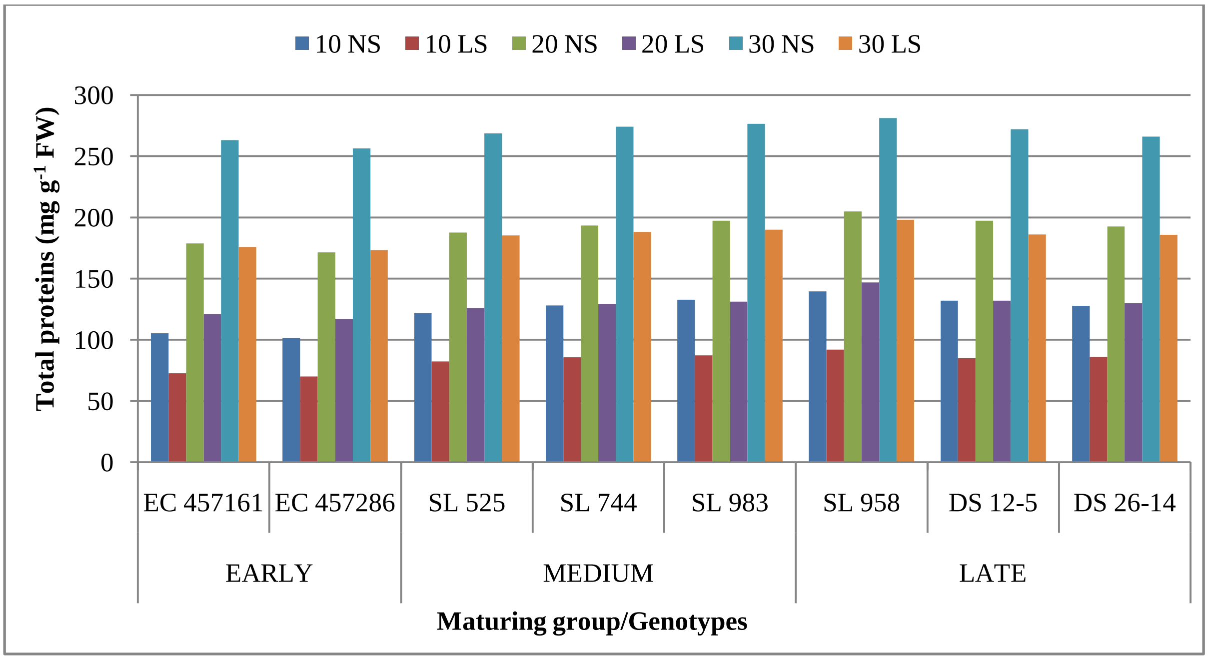

**Figure 25:** **Total proteins content from seed at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods**

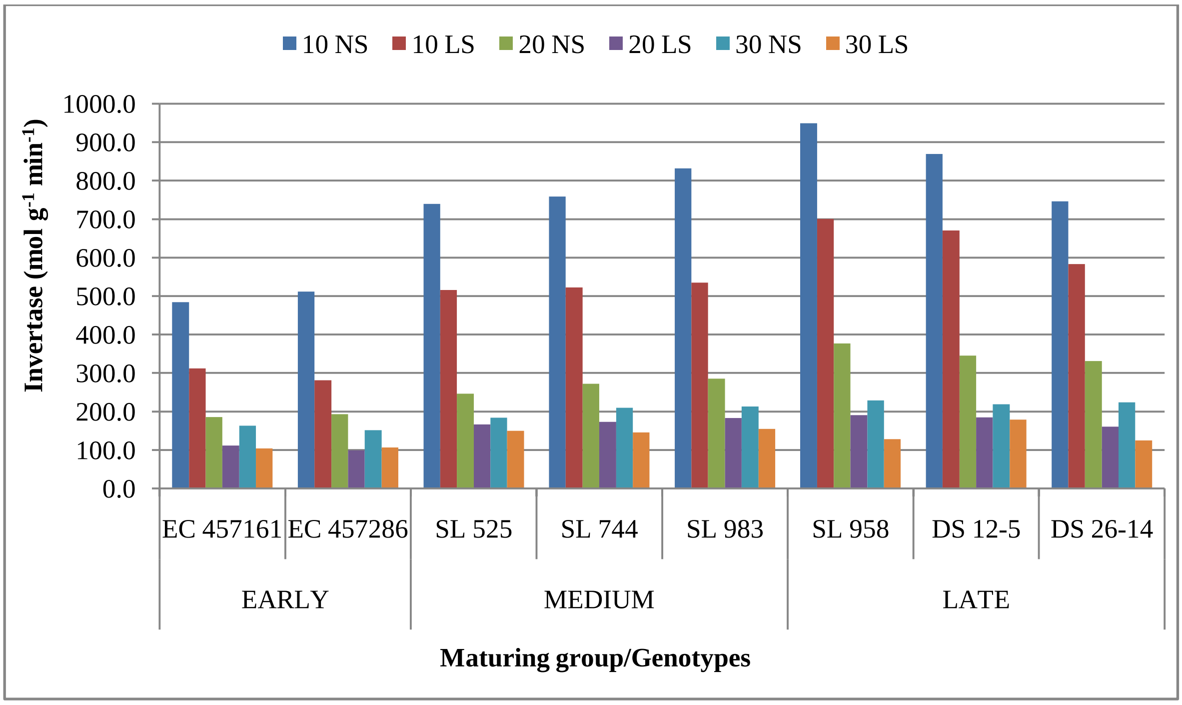

**Figure 26:** **Invertase activity from podwall at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods.**

**NS= Normal sown**

**LS=Late sown**

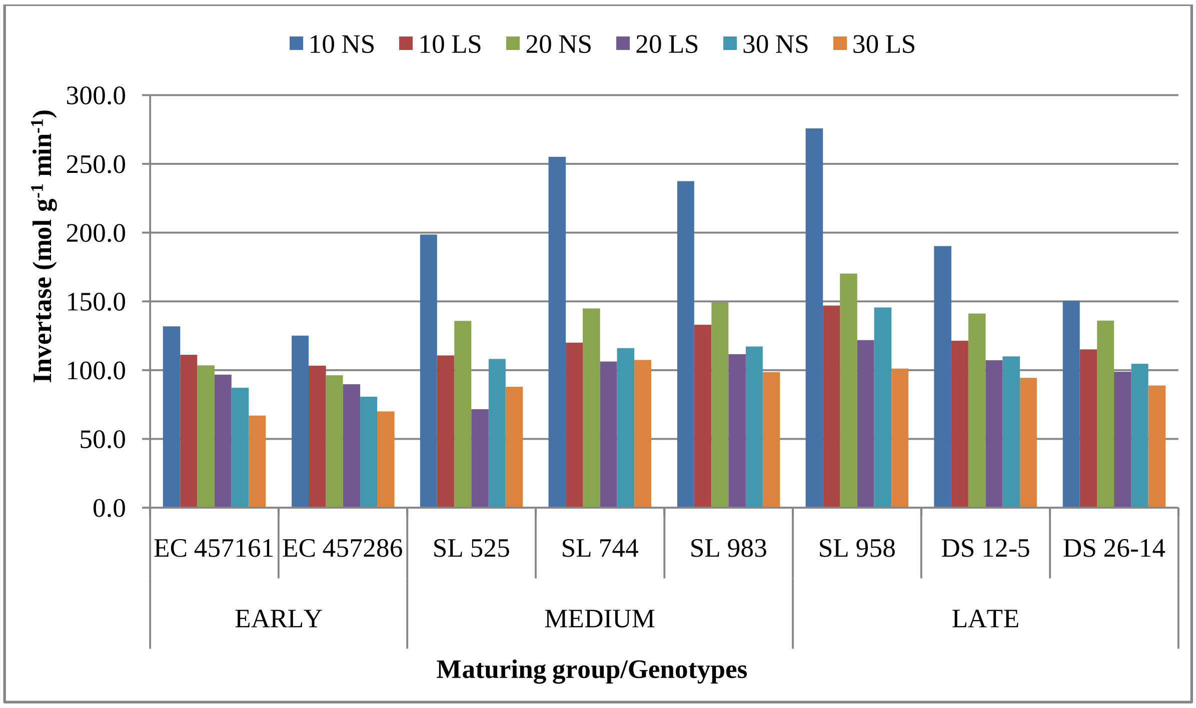

**Figure 27:** **Invertase activity from seed at 10, 20 and 30 DAF of soybean genotypes under variable photoperiods.**
**NS= Normal sown**
**LS=Late sown**

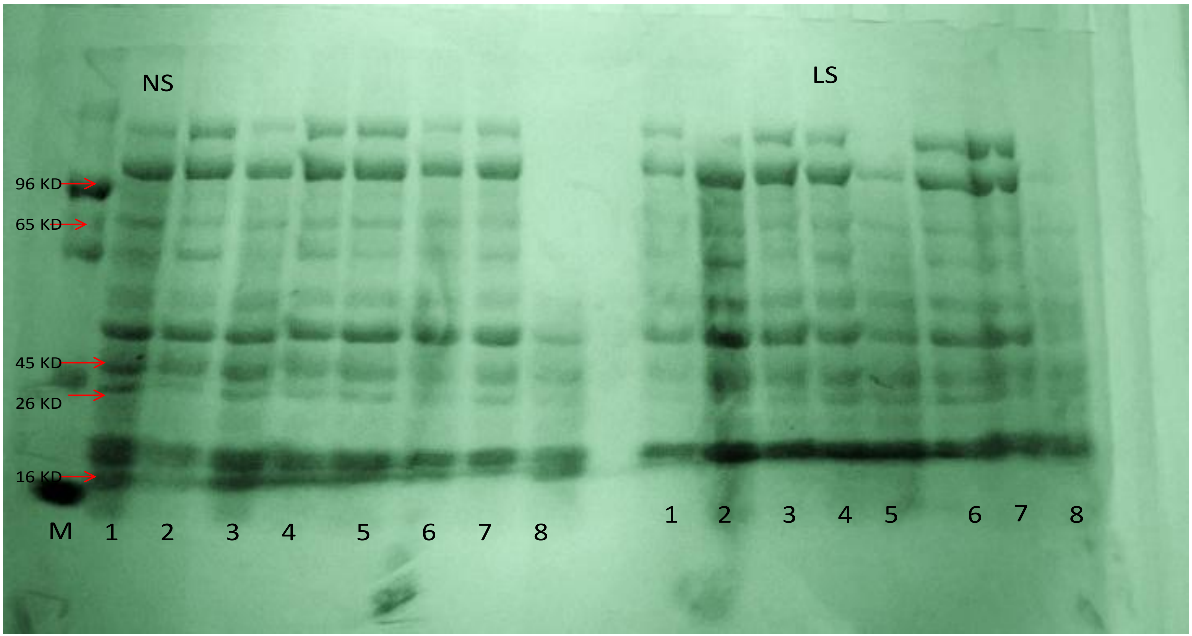

**Plate 1: 28 Comparative SDS-PAGE Protein Profiles of total protein in Soybean genotypes under variable photoperiods**
**Lane : M Page Ruler TM (Prestained protein ladder)**
**Lane :1-EC 457161, 2-EC 457286, 3-SL 525, 4-SL 744, 5- SL 983, 6- SL 958, 7- DS 12-5, 8- DS 26-14**

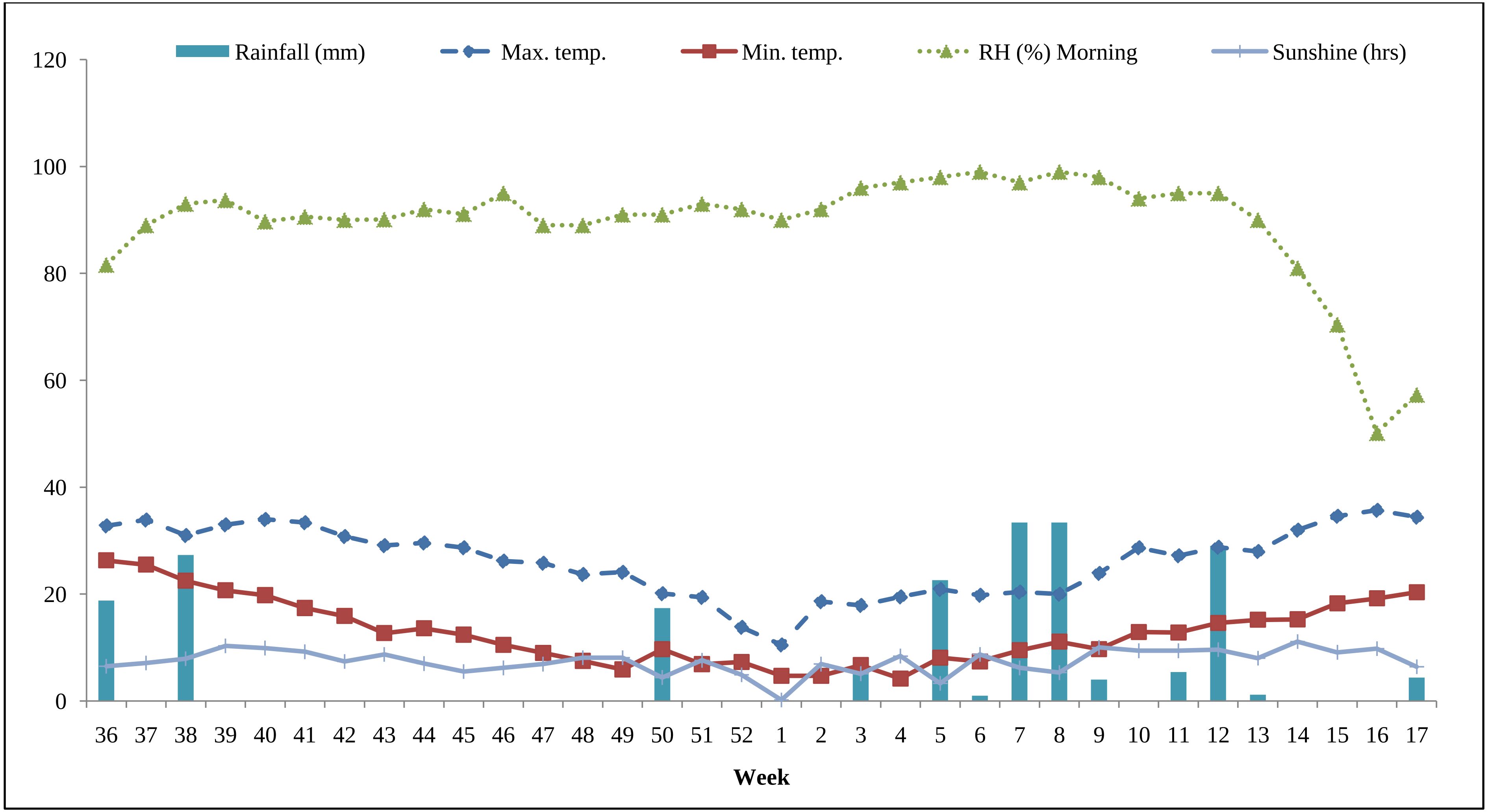

**Figure 28: Standard Meteorological Week (SMW) during the crop season (*Kharif*) 2012**

# VITA

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**Year of award** : 2008
**% marks** : 61.09%
**Master's degree** : M.Sc Botany
**University** : CCS, University, Meerut
**Year of award** : 2010
**% marks** : 74.8%
**Ph.D** : Botany
**University** : Punjab Agricultural University, Ludhiana, Punjab
**Year of award** : 2014
**OCPA** : 7.14/10.00
**Awards/Distinctions/ Fellowships/Scholarships** : Rajiv Gandhi National Fellowship during Ph.D
Qualified ICAR-NET - 2014