CHAPTER II
REVIEW OF LITERATURE

Growth and development are continuous processes leading to morphogenesis characteristic of the species. Both these processes are controlled by genotype and environment, the degree of influence depending on the particular plant characteristic. The net plant growth and its productivity are the result of several physiological processes which are influenced by the genotypes-environmental interaction. An understanding of the same would enable in selection of suitable crop cultivars under specific agro-climatic conditions for higher productivity. Investigations were made in India and abroad to find out the morphophysiological constraints of productivity of soybean (*Glycine max* (L.) Merrill) as affected by aerial and edaphic environments. Relevant literature pertaining to the present investigation is reviewed as follows:

2.1. Assimilate Production and its Partitioning

Sestak (1966) found that the correlation between rate of photosynthesis and chlorophyll content was higher at high irradiance. According to Weber *et al.* (1966), dry matter of soybean was highly correlated with leaf area index.

According to Dornhoff and Shibles (1970), the increase in net photosynthesis was caused by decreased CO$_2$ diffusive resistance and/or (b) increased demand for photosynthate for
seed formation. Harman and Brun (1971) found that CO₂ enrichment during pod fill stage increased photosynthesis and yield.

Juneja and Sharma (1971) found that seed yield/plant was positively correlated with stem thickness, number of branches and pods per plant, number of days to flowering pod fill period.

Benedict (1972) reported two mutants of soybean with photosynthetic rates were 2-11 times higher than the normal green types.

Buttery and Buzzell (1972) emphasized breeding and selection of cultivars having higher assimilation rates.

Egli and Leggett (1973) reported a positive relationship between the growth rate of pericarp and seed with yield in two genotypes. Hsu (1977) found that total dry weight of soybean increased during the growth period where CGR was higher and RGR increased after 83 days of emergence.

Singh and Saxena (1973) reported that lamina and peti-oles and stem dry weight increased up to 63 to 80 days after sowing, but decreased thereafter, while the total dry weight up to 80 to 110 days after sowing.

Fellows et al. (1979) stated that only alterations in the source-sink balance could produce a change in the
distribution patterns of photosynthates to the pods. Harrison et al. (1980) reported that heritability estimates for canopy apparent photosynthesis, during the pod filling period were 36-66 per cent. According to Gastal and Vernet (1979), early maturing cultivar gave a higher average yield than the indeterminate maturing cultivar, while late maturing cultivar gave the lowest yield.

Mienwann and Raper (1979) described predictive model with PAR as input for partitioning of photosynthate to leaves, stems and roots over a normal range of temperature.

According to Nakaseko et al. (1979), distribution of dry matter to leaves was highest during the early growth stages and declined gradually. The distribution of dry matter to vegetative parts was higher indeterminate and late cultivars than in determinate and early ones. Peaks of NAR were found at initial branch elongation and at the young pod stage.

Buttery et al. (1981) stated that photosynthesis is generally considered the main process controlling plant growth and productivity, the relationship between photosynthetic rate and crop yield is complex.

According to Hanson (1981), net rate of assimilate production and CO₂ exchange rates increased when source was reduced relative to sinks, but each genotype tended to maintain a characteristic balance in dry matter distribution.
between leaves, stem and roots. Increased NAR benefitted
source sinks primarily through increased leaf area and speci-
fic leaf weight (SLW).

Uprety et al. (1981) reported that yield was positive-
ly correlated both to total biomass and its partitioning to
sink.

2.2. Growth Analysis

According to Watson (1952), LAI and NAR varied between
and within species with soil nutrition, water, climate and
season. The variation in leaf area was the main cause of
differences in yield. Wallace and Munger (1965) found that
the variation in dry matter accumulation was related to NAR,
LAR and RGR. Hanway and Weber (1971a) found no differences
in the rate of bean filling amongst eight cultivars, although
differences in CGR were present. Bowers et al. (1972) report-
ed that higher light intensities during growth of soybeans
resulted in increase in photosynthesis rate, light saturation,
RUDP carboxylase activity, and specific leaf weight.
Prasad et al. (1978) reported that the genotypic variation in
productivity of a crop was related to NAR, CGR, LAI, PAR
interception by the canopy and partitioning of total photo-
synthates into economic and non-economic sinks.

According to Watson (1952), growth analysis and esti-
mation of LAI, RGR, NAR etc. provides a meaningful
physiological interpretation of crop yield. According to Donald (1962), the harvest index i.e. coefficient of effectiveness in various crops depended on plant type. Wallace and Munger (1965) reported positive association of yield with NAR and LAI. Shibles and Weber (1965) reported that LAI and NAR were positively associated with each other.

Weber et al. (1966) found the maximum seed yield occurred at less than maximum LAI and at generally lower populations and narrower row spacings. Highest seed yield occurred in 100 inch rows with 104,504 plants/acre, while dry weight was maximized in 5 inch rows with 2,09,088 plants/acre. LAI and DW produced at stages 9 were not found good predictors of seed yield.

Radford (1967) described growth analysis techniques. Ojima and Kawashima (1968) noted that high yielding cultivars had a higher rate of photosynthesis.

Koller et al. (1970) found that increasing NAR in soybeans depended on the photosynthetic apparatus and increased diameter of the sink.

According to Scarascia and Losqvio (1977), CGR reached a peak 54-69 days after emergence. NAR, RGR and RLGR declined with increasing age of plants. Peet et al. (1977) noted positive correlations between yield and the photosynthetic rates and RUDP carboxylase levels during the early pod fill stage in nine cultivars.
Svihara and Pastuchova (1979) found that shoot dry matter, leaf area, RGR, NAR, CGR and LAI decreased very markedly and rapidly at senescence and dropping of the lower leaves due to inadequate illumination.

Vignes and Planchon (1979) stated that NAR depended upon leaf temperature and stomatal movements. High temperature reduced net photosynthesis and the efficiency of an agro-system was linked to a great extent, to foliage exuberance under irrigated condition. According to Buss and Aung (1979), no significant genetic variation in RGR or NAR existed in soybean cultivars studied. None was closely associated with yield.

Mehdi et al. (1980) reported that NAR, CGR, RGR, RLGGR and LAI differed among cultivars. Soil moisture reduced NAR and RGR for early maturing cultivars but increased then for late maturing cultivars.

Watanabe (1980) reported that SLW was important for variations in photosynthetic rate. Shibles (1980) stated that soybean cultivars with a wide adaptability had inverse correlations in certain vegetative growth components in response to temperature, different growth habits with variation in the sequence of vegetative and reproductive phases, genetic regulation of time of flowering and maturation, and photo-period responsiveness throughout development.
Kotvics (1981) noted that the earliest lines had significantly lower HI than late ones. Plant weight and seed weight were strongly correlated with HI, hence selection for high yield must be based on both HI and seed yield per plant.

Perraju et al. (1982) worked on the phenotypic and genotypic variation heritability and HI.

Sharma et al. (1982) reported that cultivars differed for leaf area index at pod development and physiological maturity, but not at flowering.

Snyder and Bunce (1983) reviewed the work done on Harvest Index on different crops.

Khanna and Chopra (1988) conducted an experiment to breed for determinate plant type with synchronous flowering, delayed senescence and better partitioning of assimilates for achieving higher seed yield. Initial lag in DMA is followed by a short lag phase of growth characterised by extensive branching and various phenological stages.

Lawn (1988) reported that the greatest potential for physiological improvement lies with improvement of harvest index. For manipulation of harvest index, the manipulation of crop phenology through manipulation of sensitivities to day length and temperature was necessary. Higher productive genotypes are, therefore, likely to be characterised by higher HI, shorter growth duration, reduced sensitivity to
photothermal conditions and more synchronous reproductive ontogeny.

Summerfield and Roberts (1988) reported that legumes are plastic in phenology. Timely flowering and maturity are important and could have the potential if sown at appropriate densities and in time. Genotypic responsiveness to photoperiod, mean temperature combined to dictate time to flowering of crops sown on particular dates in specific locations.

2.3. Structural Attributes

The first attempt to study the genetic variability in relation to environmental variability was made by Fisher (1918). Later on, a number of workers devised different techniques to estimates the components of variance (Wright, 1921; Lush, 1940; Weber and Moorthy, 1952; Johnson et al., 1955a). Subsequently, the estimate of genotypic and phenotypic variance were used to predict the expected genetic response in a particular population followed by selection. This is helpful in determining the proper breeding procedure to be adopted for effective genetic improvement in an existing germplasm.

The idea of determining the relative importance of genetic and environmental variances by partitioning the variances was put forth by Fisher (1918). Later on, new techniques were designed for the determination of variable
components (Wright, 1921; Lush, 1940, 1949; Robinson et al., 1951; Warner, 1952; Lal and Haque, 1972, Kaw and Menon, 1980 and Tawar and Tiwari, 1981). In early fifties, metric traits in soybean crosses were estimated by genetic variability (Weber and Murty, 1952; Johnson et al., 1955a).

Hanway (1956) reported a strong and positive correlation between seed yield and pods per plant.

Characters having lowest variation were days to maturity, breadth of pod, seed size, plant height and stem diameter, and those having highest variations were number of pods per plant, number of seeds per plant and 100-seed weight as observed by Bulah and Aristarchova (1970).

Singh and Mittal (1970) described a wide range of variation with regard to pattern of branching in soybean. Bulah and Aristarchova (1970), Horrie et al. (1971), Lal and Fazlul Haque (1971) reported the variance was least for time of maturing and plant height, and greatest for number of pods per plant, number of seeds per plant and hundred weed weight. Hanway and Weber (1971a) found no difference in the rate of bean filling for eight cultivars. Verma et al. (1972) studied 82 soybean varieties, both exotic as well as indigenous, at three locations. They found significant variation for various developmental traits viz., maturity, flowering, pods per plant, 100-seed weight and grain yield per plant. Variations among soybean varieties enhanced overall variability
though this was attributable to the environment rather than the genotype.

High degree of genotypic coefficient of variation with respect to number of leaves per plant, plant height, number of pods per plant and days to maturity were noted, indicating high degree of genetic variability for these quantitative characters (Lal and Haque, 1972).

Malhotra *et al.* (1972) stated that seed yield was positively correlated with number of primary branches and pods per plant but was negatively correlated with seed index.

Attention has also been given to productivity based agronomic characters of soybean (Shawe *et al*., 1972). Wide variation in the number of pods per plant, 100-seed weight and seed yield, and low variation for pod length were noticed in indigenous and exotic soybean genotypes (Bhatt *et al*., 1968). Significant variation was found in days to maturity, days to flowering, pods per plant and grain yield per plant and wide range of variation for yield per plant was determined by Arora and his associated (1970).

Shawe *et al.* (1972) found considerable variation for developmental traits related to the productivity of soybean. Malhotra (1973) reported low estimates for 100-seed weight and primary branches, moderate for yield and variation for number of pods per plant.
A range from low to moderate genotypic coefficient of variation was determined for days to first flowering. On the other hand, a low genotypic coefficient of variation was noticed for days to maturity, 100-seed weight and primary branches and slightly higher in grain yield, while highest for number of pods per plant (Malhotra, 1973).

Kollman et al. (1974) reported that plants were grown in the field and various numbers of pods were removed as they formed to give an average of 0, 0.8, 1.1, 1.9, 2.4 or 2.7 pods per node. Increasing the sink size resulted in decrease in N and P concentrations in leaf, stem, pod and seed, and in Mg concentrations in stem plus petioles. The increase in K and Ca concentration appeared to be due to a greater decline in dry matter content than in K and Ca content as sink size increased resulting in the concentration of K and Ca.

In a study of many varieties and their F₂ progenies for eight characters in soybean, there was high genotypic variation for number of seeds per plant, followed by plant height and number of pods per plant (Rao, 1974).

Rao (1974) and Kovacheva (1975) observed high genetic variability for plant height, number of pods per plant and seeds per plant.

Wide range of genotypic coefficient of variation was found in grain yield per plant (8.71 to 22.68), number of
pods per plant (27.6 to 114.85), number of pod bearing nodes per plant (8.2 to 9.98), plant height (15.80 to 67.75 cm) and days to 50% flowering (29.45 to 51.75 days) (Kaw and Menon, 1978).

Seed yield per plant and number of branches per plant were most variable characters (Gazhov and Patirana, 1980). High genetic coefficient of variation in seed yield was also found by Mohmoud (1978).

Mehdi et al. (1980) stated that late maturing cultivars produce more nodes per plant, fewer pods per node, more seeds per node and a higher weight per seed than the early maturing cultivars. Mcblain and Hume (1980) found that along bean filling period was a desirable trait in early maturing soybean. According to Reicosky (1980), early varieties had a shorter grain filling period than late varieties. Guzhov and Patirana (1980) and Barbind et al. (1981) reported that genetic variability in seed weight per plant and number of branches, but the same was narrow in case of other characters viz., days to flowering and days to maturity, number of pods per plant and seed weight.

The actual and apparent harvest indices were inversely correlated with biological yield, vegetative yield, the components of vegetative yield, maturity and plant height. Harvest index and seed yield were not consistently related from one season to the next (Schapaugh and Wilcox, 1980).
Hartung et al. (1981) stated that genes delaying flowering and maturity significantly increased the number of main stream nodes, stem length, and seeds per plant, but reduced seed weight. Egli and Leggett (1982) reported significant difference in the effective filling period.

Wide range of phenotypic variability in plant height and grain yield while low range of variation in days to 50% flowering, days to maturity, number of pods per plant and seed yield were observed by Barbind et al. (1981).

In parents, $F_1$ and their derived progenies, highest magnitude of genetic coefficient of variation was observed in parents while low coefficient of variation was recorded in $F_1$ and $F_2$ than the parents. Genetic variability in plant height was found to be higher, followed by 100-seed weight, number of pods per plant and yield per plant (Tawar and Tiwari, 1981).

Tawar and Tiwari (1981) and Perraju et al. (1982) found maximum genetic variability in plant height followed by 100-seed weight.

Maximum variability for number of primary branches, pods per plant and seed yield per plant was obtained by Chouhan and Singh (1982). High degree of genotypic coefficient of variation for number of primary branches and grain yield per plant, while moderate degree in plant height and
low in number of pod bearing nodes per plant, seed density, harvest index, days to flowering, days to maturity and number of grains per pod had been reported by Perera et al. (1982).

High degree of variation in pods per plant, plant height, seed yield and days to flowering was recorded by Sharma et al. (1983). Maximum phenotypic and genotypic coefficient of variations at two locations in parental F$_1$ and F$_2$ populations for plant height, number of pod bearing nodes, number of pods per plant, number of grains per plant, 100-seed weight and grain yield were obtained. On the other hand, days to maturity, number of grains per pod and protein percentage had lowest values (Tawar, 1983).

Highest genotypic variabilities for seed yield per plant, followed by number of pods per plant, plant height and days to maturity were reported by Bargale (1984).

Except seed yield per plant in late genotypes of soybean tested for two seasons, all the characters of late and early genotypes had significant variabilities. The seed yield per plant, number of pods per plant and plant height had high genotypic coefficient of variation in early and late genotypes, while low magnitude of genotypic coefficient of variation was recorded for days to maturity in early and late genotypes (Bekhar, 1984).

Significant variability for pods per plant, plant height and seed yield were found to be the most variable and
seeds per pod and seed size the lowest variable characters in soybean (Chouhan and Singh, 1984).

2.4. Heat units and Production

Nagata (1956) worked on the optimum temperature requirement for flower bud formation in soybeans.

Van Schaik and Probst (1958) worked on the photothermal unit requirements and base temperature for soybean in growth chamber studies.

Tamaki et al. (1974) reported that long day (15 h) condition produced plant with shorter stem, less leaves and branches, flowering and pod set were high but the plants had more chlorophyll, dry matter, the plant grows with short (8 h) and normal day length. Further, carbohydrate in the stem was higher at flower initiation. The pods which matured as long day plant had higher carbohydrate content, while in short day plants it was lowered.

Tamaki et al. (1974) reported that flowering and pod set were considerably accelerated by long day especially when plants treated when young but the flowering period was shorter and the total number of flowers were less than with the other treatments.

Iwata (1975) calculated the photothermal units by substituting the night length from day length of photo-
thermal units and had multiplied the length of dark period instead of light period to the growing degree days and found that the latter method is more applicable than the former one for calculating photothermal units for soybean. He used the primary data of Van Schaik and Probst (1958).

Repkas and Kastrej (1975) reported the relationship of NAR, RGR to sunshine hours, average daily temperature and relative leaf area.

Dennett (1975), Dennett et al. (1979), and Bull (1968) reported that leaf area development was sensitive to the upper limits of daily ambient temperatures. The effects were more critical till the LAI reached three. A fall in maximum temperature by 2.5°C would lead to a longer duration to reach LAI two.

Moursz et al. (1976) reported that leaf area, NAR and whole plant dry matter yields were highest (804 mg) at 24°C. Decrease in air temperature from 24 to 12 increased total water content of leaves from 85.7 to 87.4 per cent.

Sinha (1977) and Summerfield and Wien (1980) reported that variation in photoperiod and maximum and minimum temperatures regimes become progressively more conspicuous away from the Equator. Temperatures are also affected by changes in altitude.
Keating and Shaykewich (1977) reported that seasonal soil heat accumulation (5°C) is 4000 degree day, the satisfactory dry matter production is not likely to be achieved. High ambient temperature above 20°C appears to be deleterious to crop growth.

Abellan et al. (1977) reported in P. vulgaris that seed yield was positively correlated with solar energy and temperature, while negatively correlated with rainfall and humidity.

Auld et al. (1978) reported that the temperature varied during the period from apparent to unfolding and from folding to full expansion.

Kastner and Kastner (1977) reported that number of fruiting nodes per plant and seed yield was primarily affected by the temperature and precipitation during flowering and was increased by low temperature and high rainfall.

Leach (1978) reported that at 30°C photosynthesis declined by about 20 per cent, while both dark respiration and compensation point had increased.

Niladonovic and Corokalo (1978) reported that highest variation existed in the number of pods per plant which was influenced by the temperature, rainfall and variety.
Sprent et al. (1977), Abdalla and Fischbeck (1978) and Said et al. (1967) reported a strong effect of day and night temperature on seed yield.

Kay (1979) reported the average temperature between 18 and 27°C for optimum growth. Genotypes respond favourably to early planting in winter and showed considerable decline in productivity with delayed planting because of high temperature during the reproductive period as reported by Bianceo (1979), Mureno and Martinez (1980).

Breeze and Elston (1979) had studied the thermosensitivity of substrate and its effect on respiration and carbon balance on faba bean.

Dennett et al. (1979) reported that the duration of expansion was inversely related to temperature averaged over 4 days from unfolding. The relationship was dependent on leaf position except for lower leaves. Further, the absolute growth rate was a function of temperature and radiation.

Svitira and Kubora (1980) reported that the climatic factor had significant effect on the biomass production, yield and quality of seed. Warm day during vegetative period promoted the accumulation of good quality of protein in seeds, which was related to an amount of N₂ compound translocated from leaves to the pod.
Seddigh et al. (1984) reported in dry bean that high night temperature enhanced vegetative growth, plant height, number of nodes, number of ancillary branches were not differing significantly among the treatment (check uncontrolled Ca/0°C 16 ± 1°C and 24 ± 2°C) at maturity. They further reported that seed weight per plant increased by 27 and 37 per cent for 16°C and 20.30 per cent for 24°C treatment. The growth of seeds was greatly influenced by night temperature and increased seed size (1000-seed weight) accounted for the increase in seed yield. Number of seeds per plant, pods per plant were not significantly affected by temperature treatment. The number of seeds per pod was significantly more at 24°C.

Russelle et al. (1984) suggested the use of temperature index, as modifying growing degree days as the divisor of growth functions to facilitate experiment comparison within certain experiment and to reduce the effects of differing temperature regimes among experiment on these comparisons.