CHAPTER II

REVIEW OF LITERATURE
Soybean (*Glycine max* (L) Merr.), rich in protein and oil is an important crop, introduced for cultivation in Madhya Pradesh around sixties as an oilseed crop to augment the edible oil resources of the country. The agroclimatic conditions of Indian sub continent with all its seasonal variations, suit ideally for good production of soybean. The identification and evaluation of high yielding varieties had made its cultivation feasible, but the overall productivity is still low. The main causes of low production of soybean are inadequate growth rate and supply of nutrients, poor plant population, poor water management and inefficient marketing of the products (Manjhi, 1982).

The fertilizer management and crop water requirement in soybean are the important concern of researchers as the scope of vertical expansion in yield is easier than increasing the area (Ritchie, 1969). This chapter deals with the brief resume of work done by past researchers on nutritional, especially in terms of nitrogen and phosphorus and evapotranspiration, aspects of soybean crop.

2.1. Growth pattern

The soybean plant is very sensitive to changes in its environment in general and nutrient fertilizer in particular. Under favorable conditions of temperature and moisture the
soybean seedling emerges in 4 to 7 days after seeding. Initiation of floral primordia begins within about 3 weeks and flowering within 6 to 8 weeks and pods are normally visible about 10 to 14 days after the start of flowering when varieties are grown within their areas of adoption (Howell, 1960). Soybean plants at first increase in dry weight slowly and then more rapidly, the vegetative growth ceases at about the time of seed enlargement. The dry weight decreases thereafter and the dry weight of plants at maturity is slightly less than the maximum which is attained 3 or 4 week earlier.

Soybean leaf area increases rapidly and linearly up to the end of blooming and attains the maximum leaf area index of 5 to 8. Subsequently, at the time of maturity the leaf area index declines due to senescence of lower leaves during seed filling (Shibles et al., 1975). Further, they have reported that the dry matter accumulation in soybean exhibits a linear trend between mid bloom and late seed filling with the maximum vegetative dry weight at about mid bean filling and then decline during late bean filling.

The dry weight of leaf lamina and petiole increases with the advancement of age up to 65 to 80 days after sowing, and decreases thereafter because of shedding of lower leaves. The dry weight of the whole plant attains a maximum value at 80 to 110 days after sowing, but decreases towards maturity because of senescence of older leaves. The dry weight of stem, grain and husk increases with increase in age, reaching a maximum at
maturity (Singh and Saxena, 1973 b). According to them, about 66 to 81 per cent of the total dry matter was accumulated by the 65th day of sowing. They further reported that the nitrogen application increased the dry matter accumulation in various plant parts and consequently in the whole plant, when compared with the control, at all the growth stages. Phosphorus application did not bring any remarkable improvement in the dry matter accumulation in different plant parts as well as in the whole plant.

Nitrogen application at 75 kg/ha caused significant increase in plant height, dry matter per plant and leaf area index, over no nitrogen (Balyan and Singh, 1986b;1987), but further increase in nitrogen dose up to 150 kg/ha did not show measurable improvement in dry matter and leaf area index. However, the plant height was increased. Jayapaul and Ganesaraja (1990) recorded significantly increased plant height with increasing levels of nitrogen (0, 20 and 40 kg N/ha). Significant increase in dry matter production with increasing levels of nitrogen in soybean was also reported by Bishnoi and Dutt (1983) and Chandel et al. (1988).

Increased plant height with increasing nitrogen doses was observed in the first year of study, but in second year plant height was not affected significantly (Rao et al., 1972), whereas, phosphorus levels did not affect the plant height during both the years of study.
Beneficial effects of phosphorus nutrition on growth and development of soybean have been reported by many workers (Kesawan and Morachan (1973), Lutz and Jones (1975), pahalwan (1980) and Nimje and Seth (1988).

Vyas et al. (1987) have recorded significant response of phosphorus levels in plant height during first year but it was ineffective in the second year of study. Jayapaul and Ganesaraja (1990) recorded significantly increased plant height with increasing level of phosphorus (0, 40, 80 and 120 kg P2O5/ha). Upadhyay et al. (1988) observed increased leaf area index and dry matter per plant with increased phosphorus fertilization.

2.2. Yield attributes and yield

2.2.1. Nitrogen levels

It has been recognized that symbiotically fixed nitrogen alone can not meet the crop requirement in an intensive production system. Along with the symbiotically fixed nitrogen soil and/or fertilizer nitrogen appeared to be necessary for obtaining higher yield of soybean (Weber, 1966; Bhangoo and Albritton, 1972; 1976; Johnson and Hume, 1972; Harper, 1974). However, some other workers have reported that there is no significant effect of nitrogen fertilizer on soybean yield (Mederski et al., 1958; Beard and Hoover, 1971; welch et al., 1973).
Gandhi (1956) has recommended 22 kg N/ha for obtaining higher yield of soybean, whereas, Jethmalani et al. (1969) and Mahabal Ram et al. (1973) have recommended 20 kg N/ha for inoculated soybean, but in the absence of inoculation 100-120 kg N/ha, in the form of calcium ammonium nitrate, should be given.

Response of soybean to nitrogen on number of filled pods per plant and test weight of 100 seeds was recorded up to 180 kg/ha in Rabi and 60 kg N/ha in Kharif at Tirupati (Ram et al., 1972). Chatterjee et al. (1972) and Veeraswamy and Rathnaswamy (1974) have also reported the beneficial effects of nitrogen fertilization on the performance of soybean.

Lathwell and Evans (1951) found that high levels of nitrogen during flowering were necessary for attaining maximum yields of soybean. Brevedan et al. (1978) observed that increasing the nitrogen application to plants during the period from initial bloom to the end of bloom increased the seed yield by 33 per cent in the greenhouse and by 28 to 32 per cent under field conditions, but yields were not affected significantly by higher levels of nitrogen during pod filling stage. Ghorashy et al. (1972) observed that application of nitrogen at the rate of 85 kg/ha either at the time of planting or at flowering gave the highest yield.

In soybean the highest grain yield, number of pods per plant and test weight of 100 seeds were obtained with application of 120 kg N/ha followed by 80, 40 and 0 kg N/ha (Thakur and Hasan, 1972), whereas, Singh and Saxena (1972) did not obtain any
appreciable improvement in yield under inoculated condition. But, they observed that in the absence of inoculation, there was linear to exponential increase in yield with an increase in nitrogen levels and highest yield was obtained under 240 kg N/ha. Reddy and Chatterjee (1973) have also recorded higher yield of soybean with 80 kg N/ha as compared to yield with 20 kg N/ha, when grown as mixed crop with sorghum. Sorensen and Panas (1978) recorded significant increase in seed yield with increasing nitrogen levels.

Kl-Kady et al. (1982) observed that increasing nitrogen supply increased the seed yield, number of pods, 100 seed weight and protein content of seed, whereas, Katoch et al. (1983) have found that seed yield and its attributes in leguminous crops were not influenced significantly by nitrogen application, but the straw yield increased with increase in nitrogen doses. Bishnoi and Dutt (1983) have obtained significant increase in 1000 grain weight as well as in grain yield with increasing levels of nitrogen and values at different levels (0, 40, 80 and 120 kg N/ha) differed significantly from each other. However, Kaliya et al. (1984) have reported that soybean did not respond significantly to the different levels of nitrogen, but the straw yield was significantly higher with 50 kg N/ha over control and 100 kg N/ha. Number of grains per pod and 1000 grain weight were also not affected, but number of pods per plant and grain yield per plant were higher with nitrogen application than the same under control conditions.
Vinod Kumar et al. (1985) have obtained significant response of nitrogen upto 80 kg N/ha over 40 kg N/ha and control, but further increase in nitrogen doses up to 120 and 160 kg N/ha did not show significant variation over 80 kg N/ha. Similarly, Balyan and Singh (1986) also found significant increase in grain and straw yield up to 75 kg N/ha over control but further increase of nitrogen dose up to 150 kg N/ha did not show significant increase either in grain yield or straw yield. Singh and Prasad (1986) have found significant increase in yield of fodder soybean with 120 kg N/ha over no fertilizer, applied either alone or in combination with 60 kg P2O5/ha. Ahuja and Singh (1987) have also found appreciable increase in grain yield of soybean at different levels of nitrogen (0, 40 and 80 kg/ha) application when cropped with sorghum as intercrop.

Chandel and Saxena (1988) are of the opinion that in light textured soil, a starter dose of 15 to 20 kg N/ha should be applied and in case of yellow soybean if nodulation is poor, top dressing of 20 kg N/ha should be applied before flowering to improve the yields, whereas, Singh (1989) has suggested that an application of 20-30 kg N/ha as a starter dose will be sufficient to meet the nitrogen requirement of the crop in the initial stage in low fertility soils.

Paikera et al. (1988) obtained higher seed yield with the application of 40 kg N/ha than 20 or 60 kg N/ha. Further, they observed higher number of pods per plant, number of seeds per pod and 1000 grain weight with 40 kg N/ha. Application of 40 kg/ha
recorded significantly higher number of pods/plant, seeds/pod and 100 seed weight over 20 kg N/ha and control (Jayapaul and Ganesaraja, 1990) but the seed yield was comparable with 20 kg N/ha.

Reddy et al. (1990) have observed the highest seed with the application of 60 kg N/ha over 40, 20 and control. However, Chandel et al. (1988) have observed that application of 40 kg N/ha or more (80 or 160 kg/ha) significantly increased the grain yield of non-nodulated soybean as compared to the yield with 20 kg N/ha or no nitrogen.

2.2.2. Phosphorus levels

Application of phosphorus plays an important role in soils containing low phosphorus. In India, the quantity of phosphorus recommended for soybean varies from 60 to 100 kg P2O5/ha (Singh and Singh, 1968; Jethamlani et al., 1969; Singh and Saxena, 1969; Mahabal Ram et al., 1973).

The beneficial effects of phosphorus application on yield, yield attributes and quality of seed have been reported by many investigators (Anthony, 1967; De Mooy et al., 1973; Tomar and Dev, 1973; Shivshankar et al., 1974; Roy and Mishra, 1975; Jones et al., 1977 and Shinde et al., 1979). Yields were significantly increased by the application of phosphorus upto 58 kg/ha over no phosphorus for the first two seasons and upto 29 kg/ha for subsequent seasons (Chesney, 1973). But, Lutz et al. (1973) obtained no significant response of phosphorus fertilization on
seed and straw yield of soybean. Similarly Singh and Saxena (1973a) obtained no significant response of phosphorus with higher available soil phosphorus, whereas phosphorus application at the rate of 52.2 kg P2O5/ha resulted in significantly higher yield over control and 17.4 kg P2O5/ha, in soils containing low phosphorus.

Significantly higher seed yield and number of pods per plant were observed under 45 kg P2O5/ha over control in rabi season, whereas they were unaffected during kharif season and 100 seed weight was also not affected in both the seasons (Rao et al., 1972). While in another experiment Lutz and Jones (1975) found significant response of phosphorus on seed yield and 100 seed weight.

The importance of phosphorus nutrition of soybean for obtaining higher yields, has also been emphasized by several workers (Welch et al., 1949; Tiwari, 1965; Mishra and Singh, 1967; Nema et al., 1985; Mandal et al., 1986).

Under Palampur mid-hill conditions 100 kg P2O5/ha increased the seed and straw yield (on the soil with low status of available P2O5) over 50 kg P2O5/ha (Kaliya et al., 1984), but 100 and 150 kg P2O5/ha had non-significant effects. They further reported that the number of pods per plant, grain yield per plant and 1000 grain weight were also favourably affected with phosphate fertilization. Ahuja and Singh (1987) also have found increased grain yield of soybean with increasing phosphorus application.
Marked increase in grain yield, branches per plant, pods per plant and 1000 seed weight over control were observed by Vyas et al. (1987), but further increase in phosphorus level did not show marked variation.

Upadhyay et al. (1988) have found that the grain and straw yield were increased with increasing levels of phosphorus upto 46 and 69 kg P2O5/ha respectively, but the test weight was not affected. Similarly Dwivedi et al. (1989) obtained linear response of phosphorus application upto 80 kg/ha. Mathur and Suresh Lal (1989) also found increased seed yield upto 50 kg and straw yield upto 100 kg P2O5/ha, over control.

Application of 90 kg P2O5/ha resulted in highest seed yield, but it was similar to 60 kg P2O5/ha and both were significantly superior over control and 30 kg P2O5/ha (Reddy et al., 1990). Singh and Bajpai (1990) have reported that the grain yield of soybean increased significantly with the increasing phosphorus levels upto 60 kg P2O5/ha. They also stated that the yield attributes of soybean viz; number of pods/plant, grains/plant and weight of 100 grains increased significantly due to phosphorus fertilization. Jayapaul and Ganesaraja (1990) found that the different levels of phosphorus (0, 40, 80 and 120 kg/ha) significantly increased the number of pods/plant, seeds/pod and 100 seed weight. The highest grain yield was recorded under 120 kg P2O5/ha, but it was comparable with 40 and 80 kg P2O5/ha.
2.2.3. Nitrogen and phosphorus interaction

In a field experiment with different combinations of N:P:K the combination of 20:20:40 kg/ha N:P:K proved the best (Saxena et al., 1971). Whereas, Rao and Pathak (1972) obtained the highest yield of soybean with 60 kg N, 320 kg P2O5, 160 kg K2O and 1.5 kg Mo over other combinations.

Agrawal and Narang (1975) and Rana and Chand (1977) have reported that the application of 10-20 kg N with 80 kg P2O5/ha gave maximum average seed yield of soybean. On the other hand Raddi (1974) found 60 kg N and 45 kg P2O5/ha as optimum dose, though the yield increased with higher doses but it was neither statistically significant nor economical. Rehman et al. (1978) have observed that maximum seed yield of soybean was recorded from 40:40:40 kg N:P:K/ha. However, Singh and Singh (1982) found 30:30:0 kg N:P:K as economical dose for soybean taken as intercrop with Setaria.

Manjhi (1982) obtained higher yields of soybean with 20:40:40 kg N:P:K/ha, while Raikwar et al. (1984) concluded that application of 20 kg N/ha was profitable in combination with 90 kg P2O5/ha over other combinations. Bhatnagar (1985) have observed that a good crop of soybean can be raised with low fertilizer dose of 20:60:40 kg N:P:K/ha. However, Sharma and Dixit (1987) recorded higher seed and straw yield as well as higher number of pods per plant, number of seeds per plant and weight of 1000 seeds under 10 kg N and 40 kg P2O5/ha applied through fertilizer along with FYM.
Raghuwanshi et al. (1988) found that a fertility level of 20:40:20 kg N:P:K/ha was optimum for good yield of soybean. However, Patro and Senapati (1988) have observed that soybean responded very well to phosphate application and a package of 40:80:40 (N:P:K) kg/ha has to be adopted. Nayak et al. (1989) observed that the yield and pods per plant of soybean were significantly increased with increased levels of fertility and maximum seed yield was recorded at 60:60:40 kg N:P:K/ha.

Kacha et al. (1990) have recorded the highest seed and straw yields at 30 kg N with 60 kg P2O5/ha, whereas the protein content was highest with highest level of fertility (40 kgN+80 kg P2O5/ha).

2.3. Nutrient uptake (N and P)

Nutrient uptake is a function of soil water availability and root proliferation. The content of seeds are fairly constant and change little during development, whereas the pods, stem and leaves decline in nitrogen content during pod filling. The seeds contained 6.2 to 6.3% nitrogen and 0.84% phosphorus (Ohlrogge, 1960).

The nitrogen and phosphorus content in the seed and straw of gram improved considerably with the application of nitrogenous and phosphatic fertilizers but especially with phosphatic fertilizer (Singh, 1971). The phosphorus content of lamina and petiole, at the pod development stage, increased with phosphorus
application, on the other hand, an increase in phosphorus content
of lamina was perceptible up to the level of 52.2 kg P2O5/ha and
of the petiole up to the level of 34.8 kg P2O5/ha (Singh and
Saxena, 1973 a). Rao and Pathak (1973) reported that application
of fertilizer nitrogen improved the N concentration in grain of
different soybean cultivars.

Nitrogen contents in leaves, stems, pod husk and grains were
enhanced with increasing levels of nitrogen. About 70% of
absorbed nitrogen by the crop was retained in the seed alone,
with only 8 to 12% in leaves, 9 to 11% in pod husk and 5 to 6% in
stem (Vinod Kumar et al., 1985). Further they have observed that
uptake of nitrogen in leaves, stems, pod husk and grain increases
significantly up to 80 kg N/ha, whereas total nitrogen uptake was
enhanced till the level of 120 kg N/ha.

Application of nitrogen at 25 kg/ha significantly increased
the nitrogen uptake over control, but further increase in
nitrogen doses up to 150 kg/ha did not show significant
improvement in nitrogen uptake (Balyan and Singh, 1986 b; 1987).
Nitrogen application through fertilizer at increasing rates caused
a significant increase in nitrogen content of seed and straw and
phosphorus content of straw but the differences in concentration
of phosphorus in seed was not much conspicuous. Similarly the
total nitrogen and phosphorus uptake increased progressively by
the application of nitrogen at the rates of 10 and 20 kg/ha over
control (Sharma and Dixit, 1987).
Chandel et al. (1988) have also observed increased nitrogen uptake with increasing levels of nitrogen application. At 60 DAS, nitrogen and phosphorus uptake by soybean increased significantly with each increment in nitrogen levels up to 40 kg N/ha and the highest uptake of 92.1 kg/ha was recorded at 60 kg N/ha. At harvest, nitrogen and phosphorus uptake at 60 kg N/ha was significantly superior to 0, 20, and 40 kg N/ha (Reddy et al., 1990). Kacha et al. (1990) recorded highest uptake of nitrogen by seed and straw at fertility level of 30 kg N+60 kg P2O5/ha over lower fertility levels.

Chandel and Saxena (1988) reported that a good crop of soybean is able to take up to 240–245 kg nitrogen per hectare. Out of this, it has a capacity to meet the requirement of 100–150 kg nitrogen from atmosphere by way of symbiotic fixation. Whereas, Singh (1989) has found that a good crop of soybean yielding about 300 kg/ha will remove about 300 kg nitrogen per hectare from soil. Pasricha and Tondon (1990) have observed that a crop yielding 2500 kg/ha is estimated to absorb only 125 kg N from soil. Bishnoi and Dutt (1980) found that the phosphorus content (ranged between 0.80 to 0.85%) remained unaffected with the nitrogen levels of 0, 40, 80 and 120 kg/ha.

Nitrogen concentration of soybean plant at flowering was significantly increased only up to 40 kg P2O5/ha, whereas phosphorus content was increased up to 80 kg P2O5/ha (Nimje and Seth, 1988). Further, they have observed that phosphorus fertilization of soybean significantly improved the nitrogen and
phosphorus uptake at flowering stage, similarly the uptake of nitrogen and phosphorus at harvesting stage significantly increased as a result of phosphorus fertilization. Phosphorus application significantly increased the nitrogen and phosphorus uptake with successive increase in levels of phosphorus from 0 to 90 kg P2O5/ha at 60 DAS (Reddy et al., 1990). At harvest no appreciable difference in nitrogen uptake was recorded between 90 kg and 60 kg P2O5/ha, whereas the phosphorus uptake increased up to 90 kg P2O5/ha. Mathur and Suresh Lal (1989) observed that the phosphorus concentration in grain was not affected significantly with increasing levels of phosphorus, whereas in straw it was significantly increased with increasing levels of phosphorus applied through single super phosphate. Further, they have observed the increased uptake of phosphorus with increase in phosphorus levels.

2.4. Seed quality (oil and protein)

Since oil and protein together account for approximately 60 per cent of the dry weight of seeds of most soybean genotypes, a negative correlation between these two components is not surprising (Herbert and Richard, 1962). Mishra and Singh (1970) have found that nitrogen and phosphorus application decreased the oil content of soybean seeds. However, Chesney (1973) and Lutz et al. (1973) have observed non significant effect of nitrogen and phosphorus levels on oil and protein contents of seeds. Application of nitrogen and phosphorus have been observed to increase the seed protein and oil content by Agrawal and Narang.
Further, Lutz and Jones (1975) stated that the oil content appeared to be highest where phosphorus was not applied and gradually decreased with increasing rates of phosphorus, whereas, percentage of protein generally increased as the dose of phosphorus was increased. Moreover, the beneficial role of phosphorus in increasing the protein and oil contents of soybean seeds has also been reported by other workers (Costache and Nica, 1968; Singh and Singh, 1968; Dabson and Acquaah, 1984).

Bishnoi and Dutt (1980) reported significantly increased protein content of seeds with each increase in levels of nitrogen (0, 40, 80 and 120 kg N/ha), while oil content was not affected with nitrogen levels. Katoch et al. (1983) also observed that the protein content of seeds increased significantly with the rise (0, 30 and 60 kg N/ha) in the rates of nitrogen application. On the other hand Balyan and Singh (1986a; 1987) have reported that with an increase in nitrogen levels up to 150 kg/ha, the protein yield increased substantially in both the years of study. Similarly the progressively increased seed protein content were observed with increased levels of fertility 60:60:40 kg N:P:K/ha as compared to lower fertility levels (Nayak et al., 1989). Protein content of seed increased significantly with each increase in nitrogen levels 0, 20 and 40 kg N/ha (Jayapaul and Ganesaraja, 1990), phosphorus levels were also observed to increase the protein content of seed.
2.5. Association of yield and yield parameters

A strong and positive correlation was observed between seed yield with pods per plant and primary branches. Primary branches was also positively associated with pods per plant (Malhotra et al., 1972). Positive and significant association of seed yield with number of primary branches, number of pods per cluster and total number of pods was observed also by Wakenkar et al. (1974). Similar results have also been reported by Ready and Saxena (1983), Basuchaudhari et al. (1986) and Chaudhary and Singh (1987).

2.6. Evapotranspiration and water use efficiency

Water use depends primarily on the evaporative demand of the atmosphere. Low humidity, bright sunshine and dry winds increase water use. There are many reports concerning increase in water use efficiency (defined as dry matter accumulation per unit crop evapotranspiration) due to improved crop management practices (fertilization, planting density, antitranspirant use etc) and plant breeding. These have been reviewed by Viets (1962) and Begg and Turner (1976). However, most of the increase in water use efficiency is due to increase in transpiration (a factor of total crop evapotranspiration) from greater soil water extraction and from greater plant cover reducing soil evaporation, and to increase in dry matter production. Similarly, for crops growing on residual moisture, high water use efficiency on grain basis is often attributed to lower loss of water by direct soil evaporation from a continually dry surface (Blum, 1972).
Penman (1956) reported that when supply of water is plentiful, the climate and particularly the net radiation determines the water use. Mason et al. (1980) have reported that before the actual evaporation dropped below potential evaporation, soybean (CV.Bragg and Rusa) could absorb approximately 60 per cent of the total extractable water in the top 1.2 m of soil. The soil water in the surface layers was used in preference to that in the deeper layer until the decreased water availability in the upper layer forced appreciable amount of water to move from the layers below 1.2 m. Reicosky and Deaton (1979) observed that non irrigated determinate soybean can extract soil water from much deeper layers (up to 1.5 m) under severe stress conditions.

Reddy et al. (1973) observed increased evapotranspiration demands of soybean as the crop age increased. It was 1.8 mm in early stage of crop growth, which gradually increased and reached a maximum of 5.45 mm on 70th day, when the crop was in pod development stage. They further observed that evapotranspiration of K-16 soybean of 100 days duration, grown from September to December and yielding about 20 q/ha, was about 312 mm and the average daily evapotranspiration was about 3.86 mm under Tirupati conditions. The crop coefficient (a ratio of ET/ED) varied between 0.20 to 1.20.

When the question of highest water demand for soybean is concerned, it was the seed filling stage at which it requires from 0.5 to 0.8 cm of water per day (Hinson and Hartwig, 1977).
That is why when soybean was compared with other crops like maize, it was found that the soil from surface to a depth of 90 cm had a significantly higher moisture content under maize than that under soybean. But below 90 cm depth, the soil moisture extraction pattern approached similarity under both the crops (Bhargava et al., 1976).

Anand Reddy et al. (1980) reported that under Hyderabad conditions the soybean crop requires about 25 to 30 cm of water to meet the evapotranspiration losses grown on sandy loam soils, whereas it was 56 cm for groundnut. Weed infestation in soybean increases the total water loss through evapotranspiration. Jana et al. (1984) observed maximum evapotranspiration (320.2 mm) when the crop was infested with weeds and minimum (280.7 mm) when the crop was weed free and the consumptive use efficiency (CUE) was maximum (8.98 kg/ha/mm) under weed free treatments and minimum (5.49 kg/ha/mm) in weed infested plots.

The quantum of water used and water use efficiency are greatly influenced by variety of the crop. In an experiment under Indore conditions Nigam et al. (1990) found that early maturing soybean cultivars namely SS-2 and JS 81-1498 (maturity period of 80 days) produced 1072 and 1920 kg/ha seed, used only about 242 to 246 mm of water from 100 cm soil profile with the water use efficiency value of 4.44 and 7.86 kg/ha/mm. Whereas, Ankur, JS 72-44 and JS 72-280 cultivars used 270 mm of water with water use efficiency of 6.53, 5.16 and 5.32 kg/ha/mm respectively. The highest water use efficiency and seed yield (7.87 kg/ha/mm and 2028 kg/ha respectively) was recorded with cultivars PK 416.
Subbaian et al. (1977) observed a significant positive relationship between degree days (accumulated from commencement of flowering to cessation of flowering) and seed yield. They also observed that the seed yield increased with increase in mean daily temperature during the flowering period. They also observed that there was no significant correlation between seed yield and rainfall or sunshine hours recorded at different crop growth stages.

2.7. Water stress

In rainfed agriculture, drought or water stress at different growth stages is one of the major constraints and it is generally considered as a period of moisture deficiency (Sastri et al., 1981). The deficiency may occur during any physiological stage of crop growth. As the growth period as well as water requirement vary from crop to crop in a given region, the effect of drought during different physiological stages of different crops varies considerably.

Technological advancement in agriculture, for example, chemical fertilizer, crop breeding and pest control, is an important contributor in increased food production provided climate favours (Yao, 1973). The crop production potential is largely determined by climatic variables and in tropical countries like India, the crop production is mainly dependent on the moisture regime. In rainfed agriculture the moisture regime is governed by the rainfall during South-West monsoon season (Sastri, 1983). Moreover, drought conditions prevail during
monsoon season due to prolonged dry spells causing water stress conditions to various crops. Several definitions of drought are available in literature (Subrahmanyan, 1967; Van Baal, 1953; Palmer, 1965 and Ramana Rao et al., 1981). However, no universally accepted definition has so far been developed. A new method of agricultural drought classification was proposed earlier (Sastri et al., 1980) but the effect of drought during different physiological stages has not been examined.

Water stress during different physiological stages affect the crop yield. Doss et al. (1974) found that water had to be supplied throughout the growing season to obtain higher yields and stress during any part of the season reduces the yield, but the greatest reduction occurs when moisture becomes limiting during the pod filling stage. According to some other studies water stress during early pod filling stage causes greatest reduction in number of pods and seeds at harvest (Saliba et al., 1982; Pandey et al., 1984). Similarly moisture stress during flowering increases abortion of flowers and young pods. According to Green et al. (1965) the reduction of dry matter accumulation in the seeds with late season moisture stress may be the result of premature loss of leaf area and shortening of the pod filling period. Water stress during seed maturation can result in poor seed quality as is evident by green cotyledons and wrinkled seed coats. The difference in final yield of soybean varies markedly from year to year due to stress and non-stress period during growth period (Huck et al., 1986).
According to Scott (1985) water stress during vegetative growth reduces the rate of dry matter accumulation, plant height and leaf area index. If the leaf water potential decreases due to less water uptake or more atmospheric demand, leaf enlargement and nitrogen fixation decrease. These effects of moisture stress on vegetative growth are reflected in smaller leaves, reduced stem diameter and reduced plant height which collectively make less photosynthate available for later seed development. Some other workers, (Shivkumar and Shaw, 1978; Scott and Batchelor, 1979 and Ramseur et al., 1985) also observed that the soybean leaf area growth was reduced during water stress period. Shoot growth rate in soybean was adversely affected due to stress during vegetative and reproductive phase (Huck et al., 1983).

As regards the effect of water stress on soybean crop Patel et al. (1983 and 1986) found that grain yield production was affected when drought occurred during any of the crop stages and has a cumulative effect, if drought occurred at two or more stages. They also found that water stress during seedling stage is more detrimental to soybean than during vegetative stage as the germination and thereby the plant population get affected.