In this chapter an attempt has been made to review the work done in India and abroad and present the relevant information in the direction i.e. in what way weed management practices and intercropping systems enable the farmers for ensuring higher production potential in a profitable and sustainable manner simultaneously with keeping the weed population under control in an ecologically sound manner.

In this way attempts are being made to use the scarce resources i.e. land within a given time by raising two or more crops together by using the space more effectively through the planting crops of varying architecture.

2.1 BACKGROUND, CONCEPT AND ADVANTAGE OF INTERCROPPING

Intercropping has long been recognized as very common practice throughout the developing tropics. In India, for example, its importance was highlighted almost 57 years ago in a very comprehensive review by Aiyer (1949). Historically, however, it has been regarded as a primitive practice which would give way to sole cropping as a natural and inevitable consequences of agricultural development. More recently, it has been realized that intercropping remains an extremely wide spread practice and is likely to continue so far at least the foreseeable future (Arnon, 1972; Okigbo and Greenland, 1973; Norman, 1974; Francis et al., 1975).

According to Willey (1979), intercropping can be defined as the growing of two or more crops simultaneously on the same area of ground. The crops are not necessarily sown at exactly the same time and their harvest time may be quite different, but they are usually period simultaneous for a significant part of their growing period.
The new concept of intercropping has been developed primarily to maximize production and profits by maintaining a full stand of compatible and companion crops in such a way that there is no reduction in the productivity of both the component crops. This practice also minimizes the risk due to the vagaries of nature and a greater solar energy harvest.

The aim of intercropping research is to optimize the use of natural resources including light, water and nutrients (Donald, 1963).

Intercropping system increase total production in addition to stabilization of production in rainfed areas (Baker, 1979 and Patel et al., 1985).

Guleria and Singh (1980) reported the relative advantage of growing one or two rows of soybean (*Glycine max.* L.) in maize under agro climatic conditions of palampur have been well established.

Intercropping is an approach which offers the opportunity to increase the productivity per unit area and per unit time by efficient utilization of natural resources (Rao et al. 1987).

Patil and Pal (1988) reported that intercropping system are not only helpful in maintaining soil health but also ensures the definite production of one crop arranged in this system. Besides, intercropping system also utilizes the sites moisture, nutrient, light, space on the one hand and decrease the population of weeds by utilizing inter row space on the others.

Ghosh (1989) reported that inclusion of legume crops may help in stabilizing the crop yields by improving soil fertility in long term.

Intercropping of botanically diverse forage species like cereals and legumes appears to be one of the feasible approaches for increasing the herbage yield, utilization of land more efficiently, improving the forage quality and providing stability to production (Tripathi, 1989).
Mandal et al. (1990) reported that yield advantage from intercropping compared to sole cropping is attributed to mutual complementary effects of complementary crops, such as better use of available resources like soil N, moisture and biological nitrogen fixation.

Chatterjee and Mandal (1992) reported that intercropping especially cereal + legume combination can increase production and productivity by better utilization of resources and thereby minimizes the risks and brings stability under rainfed conditions.

Intercropping is the only option to increase cropping intensity and resource utilization through introduction of some variable planting patterns (Pandey et al., 1999). Intercropping not only provide certain insurance against biotic and environmental stresses but also gives extra yield advantage by simple expedient of growing crops (Willey, 1979).

The productivity of the cropping system is not only governed by the inputs applied to the crops but also by the harmony between the crops grown in association or in sequence. Inclusion of legumes in these systems helps in utilizing natural resources efficiently and maintaining the fertility status of soil which may contribute to the productivity of the succeeding crop (Singh and Giri, 2001).

Alok Kumra et al. (2001) reported that an intensive cropping system, which is not only highly productive and profitable but also stable over time and maintains soil fertility, is of grant importance in present conditions.

Raheja (1973) reported that sorghum ear head fly damage was extremely rare when pigeonpea was planted in alternate rows. In another study, he observed that incidence of root rot of cotton caused by *Rhizoctonia solani* fungus was appreciably reduced by intercropping of dew gram (*Vigna aconitifolia* (Jacq.)), the dew gram intercropping caused moderating effect on soil temperature increase, which is unfavourable for the parasitic activity of the fungus.
The diverse system can have a major influence in limiting disease, pests and weeds (Stockdale et al., 2001).

Hedge and Babu (2002) reported that continuous sunflower cropping in the cropping system promotes downy mildew disease incidence, besides general decline in yields but crop rotation with groundnut of finger millet (Eleusine coracana (L.) Gaertn.) or sorghum are effective. They further viewed that in general, rotation with legume crops was beneficial.

Kashina (2003) observed that the disease incidence in cowpea intercropped with maize was significantly lower than in monocropped cowpea. He further noted that wider intra-row spacing reduced disease incidence and severity significantly in both monocrop and intercrop pattern compared with close spacing. The effect of interaction between cropping pattern and intra-row spacing was highly significant on incidence and severity.

Ramesh and Reddy (2004) conducted an experiment on productivity and nutrient use efficiency of Soybean (Glycine max) and sorghum (Sorghum bicolor) intercropping at different levels of nitrogen in rainfed deep vertisols and concluded that soybean + sorghum intercropping was more productive due to mutual complementary effect of component crops.

2.2 INTERCROPPING AS WEED SUPPRESSING TOOL

Different crop plants have variable growth and canopy pattern which makes them competitive to weeds differently. This depends on the characteristics of crops, environmental conditions and weed species present and their density (Dawson, 1970).

It is established that intercropping can increase the competitive ability of crops to reduce the pressure of weeds (Bantilan and Harwood, 1973 and Rao and Shetty, 1977). However, the magnitude of reduction in weed growth in the system depends largely on biological factors like nature of crops and
their relative proportion in the mixture and spatial arrangement of the plants (Ahlawat et al., 1982).

Maize being row crop and sown at relatively wider spacing offers an opportunity in terms of ample space for weeds to come up along with crop and result in an intense crop-weed competition resulting in poor crop yield. Soybean intercropped in available space between rows of maize quickly covers the space and as a result of association, instead of competition (Saxena, 1973 and De et al., 1978), utilizes the unused growth factors and suppresses the emerging weeds through competition and shading, thus minimizing the adverse effect of weeds on main crop. This benefit is in addition to the bonus yield of soybean which makes the system a viable proposition in the valley of Himachal Pradesh as reported by Tripathi and Singh (1987).

Even though certain crop combinations may cause a reduction in weed weight compared to the component sole crops, there is still a need in most cases to do some weeding so that the weeds which are present do not cause yield reductions. In fact, the need for weed control in intercropping may be as great as that for sole cropping (Moody, 1980).

Ahlawat et al. (1982) while carrying out an experiment on studies on weed control in solid and mixed stand of pigeon pea and soybean reported that the soybean crop proved more efficient in suppressing the weed growth. About 45-65% reduction in weed infestation was also recorded by them under intercropping of soybean. Intercropping of soybean and planting geometry affected weed growth, yield of intercrops and land equivalent ratio.

Intercropping suppressed the growth of weeds, reduced weed count as well as dry matter accumulation by weeds (Prasad et al., 1985).

Intercropping of soybean is beneficial from crop weed competition point of view as evident from the recorded data on weed density and weed dry weight as a result of surface coverage by soybean, smothering the emerging weeds resulted in increased competition with weed for growth factors.
especially sunlight and reduced the dry matter accumulation in weeds (Tripathi and Singh, 1987).

Weed management in rainfed agriculture is a serious problem and is very expensive operation. To suppress weeds most of the rainfed crops are intercropped with other short duration crops. Among these crops pulses have the best ability to suppress weeds as the canopy of these crops cover the surface better than others. Besides, the rate of growth of short duration pulses during early stages can overtake the growth of weeds and hence can suppress weeds effectively (Rego et al., 1988).

Koppalkar and Sheelavantar (1990) reported that groundnut+sunflower (4:1) intercropping system is effective in reducing weed infestation.

Thakur et al. (1990) carried out an experiment on dynamics of weed infestation in different cropping system and obtained that growing smother crops in the cropping systems and/or intercropping with cover crops greatly reduced the weed problem and paved the way for non-herbicidal control of weeds by improving ecological weed control efficiency giving higher yields.

Prasad and Srivastava (1991) reported that the intercropping system has been found most efficient in combating weeds problem in addition to yield stabilization and improving the productivity of the production system.

Lindquist et al. (1998) showed that increasing maximum corn leaf area index, rate of canopy closure or height at which leaf area occurs could improve corn tolerance and ability to suppress velvet leaf (Abutilon theophrasti Medik).

Pandey et al. (2003) based on the result of the conducted experiment on the effect of maize-based intercropping system on maize yield and associated weeds under rainfed condition, reported that Maize+ forage meth recorded the lowest weed population, weed dry-biomass and highest weed-control efficiency. Whereas, highest weed population, weed dry biomass and
lowest weed control efficiency were found with maize+pigeon pea intercropping system.

Gangwar and Prasad (2005) reported that the inclusion of certain crops in sequential and intercropping system reduces some obnoxious weeds to a considerable degree, thereby reducing needs of herbicides to a greater extent in areas where such weeds have assumed alarming proportions. For example, Johnson grass \(\textit{Sorghum halepanse}\) can become predominant weed in continuous maize-based system but can be controlled by rotating with cotton (Hosmani and Maiti, 1993). Similarly in maize potato cropping system, inclusion of pearlmillet (for green fodder) or sesame (for green-manure) during summer was also found advantageous in reducing nutgrass in succeeding crops of maize and potato (Tiwary and Singh, 1991).

Singh \textit{et al.} (2005) reported that the growing of crops having vigorous growth such as soybean, groundnut, urdbean and moong bean reduced the weed infestation by smothering effect.

Sharma (2005) while carrying out an experiment on integrated weed management in kharif maize found that practice of growing maize with cowpea (1:1) as intercrop helps in reducing the weed growth. Legume in general as a cover crop usually does not leave the space in between two rows of maize or main crops for weeds.

Intercropping system have been found to suppress weeds through formation of canopies due to competitive planting pattern and thus provides an opportunity to utilize cropping systems as a tool of weed management with non chemical means. Pigconpea + sorghum intercropping system, which is extensively practiced in Karnataka, Maharashtra and Andhra Pradesh is known to reduce weed intensity, apart from efficient land utilization (Gangwar and Prasad, 2005).

Ganeshamurthy \textit{et al.} (2006) reported that most of the rainfed crops are intercropped with short duration legumes in order to suppress the weeds.
They further opined that legumes have the best ability to suppress weeds as the canopy of these crops cover the surface better than others. Besides this, the rate of growth of short duration pulses during early stages can overtake the growth of weeds and hence can suppress the weeds effectively.

### 2.3 EFFECT OF INTERCROPPING ON YIELD OF COMPONENT CROPS

Akanda and Quayyum (1982) observed that there was some decrease in grain of maize under intercropping system with groundnut in comparison to sole cropping of maize.

Jadav and Sawant (1985) observed higher biomass production in maize+ cowpea mixed cropping over maize alone. Similar result was also obtained by Bhagwandas *et al.* (1992) under Madras condition. They found that contribution of cowpea in mixed cropping with cereal to the total biomass was higher in 1:1 row ratio than in 2:1 row ratio.

Reddy *et al.* (1985) reported that soybean pigeonpea and sorghum production can be increased by adopting the intercropping and sequential cropping system.

Narsa Reddy *et al.* (1986) carried out a trial on studies of maize–groundnut intercropping systems under rainfed conditions and observed that the grain yield of maize was not significantly affected by intercropping with two rows of groundnut in uniform row planting. They also observed that the grain and pod yield put together were the highest (37.6 and 9.9 q ha⁻¹) in this treatment because of considerable increase in pod yield of groundnut ranging from 39.4 to 175% over other intercropping systems.

Tewari *et al.* (1987) carried out an experiment to assess the performance of intercrops and herbicides on weed control in maize and found that intercropping of cowpea resulted in substantial increase (26%) in grain yield of maize. Intercropping of cowpea supplemented with one hand weeding produced the same grain yield as obtained under two manual weeding in sole
crop of maize. They further observed that the weed suppression due to cowpea alone was 22.3% and at least one hand weeding in maize could be saved merely by intercropping of cowpea. This finding is in close agreement with the findings of Shetty and Rao (1981) who observed that weed biomass accumulation in sorghum/ cowpea and sorghum/ moong smothering cropping system with hand weeding was less than that observed in sorghum sole crop with two hand weedings.

Tripathi and Singh (1987) found that the association of soybean with maize (1:2) significantly improved all the yield attributes as well as maize grain yield and maize-equivalent yield. They further observed that the control of weeds in all the cropping systems under study with alachlor increased the maize yield significantly, followed by hand weeding over weedy check but intercropping of soybean with maize increased the yield even when weed were allowed to grow unchecked. Soybean when grown in alternate rows with maize resulted in 20 and 21% reduction in weedy check plots in respective years. The corresponding reduction with two rows of soybean was 49 and 43% in both years. It was further recorded that in alachlor treated plots, maize + soybean (1:2) intercropping had 53 and 45% lesser weed density as compared to solid maize during respective years. On the other hand, decrease in weed density due to hand weeding was more than 90% in maize sole as well as in mixed stand of maize and soybean.

Arya and Saini (1989) while conducting an experiment on maize + soybean intercropping system at Ranichuri, Tehri Garhwal (UP) concluded that the highest grain yield of maize was recorded with planting geometry of 2:2 row ratio. Maize intercropped with legume might have been benefited through nitrogen fixation especially in the condition when half of the recommended dose of N was given.

Dhingra et al. (1991) recorded highest maize yield when intercropped with mungbean. An additional yield up to 2.5 to 3.5 qha⁻¹ of mungbean was
obtained in different intercropping system under different planting patterns and total productivity in different intercropping systems was 3.1 to 5.7 qha\(^{-1}\) which was higher than the sole maize. One row of mungbean planted between two normal spaced maize row in north south direction was the best planting pattern.

Mahapatra and Pradhan (1992) observed that the green cob and green fodder yield of maize increased significantly when it was intercropped with cowpea. Among the intercrop combination they found that maize+ Cowpea in 2:2 row ratio was the best in respect of green cob and green fodder yield.

Chittapur et al. (1994) studied the effect of intercropping of fodder legumes in grain maize and found non significant variation in grain yields of maize due to intercropping of fodder legume in 1:1 proportion. They further observed that in general, yield were higher with intercropping of dolichos in all the proportion followed by sunhemp and cowpea. They also observed that there was a gradual decline in the yield of mazie and net returns, when the number of legumes row increased and concluded that the reduction in maize grain yield was probably due to increase inter and intra species competition. Similary fodder legume intercropping also produced significant variation in stover yield of maize in 1:1 and 1:3 proportion.

Dubey (1995) conducted a trial on weed management in soybean-based intercropping system and found that the pure or sole crop of soybean gave significantly maximum grain yield compared with rest of the intercropping systems, supporting the findings of Reddy et al. (1990). He further observed that the plot cleaned manually resulted in significantly higher grain of soybean over rest of the treatments and found at par with oxyfluorfen treated plots, while application of fluchloralin was not proved better. Weedy check plots gave the lowest grain yield.

Dwivedi and Bajpai (1997) conducted a field trial in during the rainy season of 1990-92 with pigeonpea, groundnut and soybean in pure stand or
pigeonpea intercropped with groundnut or soybean in 1:1, 2:2 or 2:4 row ratios and found that soybean and groundnut yields were decreased by intercropping, where as pigeonpea yield was not significantly affected by 1:1 intercropped with groundnut. Mean pigeonpea- equivalent yield, LER and net return were the highest from 1:1 pigeonpea - groundnut intercropping.

Subbaiah et al. (1997) Carried out an experiment to assess the nutrient uptake by crop and weeds in sole groundnut, groundnut-red gram (4:1) and groundnut-sunflower (4:1) intercropping and their effect on pod yield and equivalent yield of groundnut and observed that groundnut-equivalent yield was more due to intercropping either with redgram or sunflower as compared with sole groundnut due to considerable yield of intercrops and better market price. Thus, indicating the superiority of intercropping system to pure crops.

A field study was made by Jana and Saren (1998) involving four intercropping system and 4 levels of irrigation and reported that the maize yield, yield attributes of intercrop maize did not differ from sole maize, but intercrop maize gave 16.2 and 13.8 qha\(^{-1}\) extra pod yield of intercrop groundnut at 1:2 and 2:3 row ratio respectively, similarly in groundnut, substantially higher dry matter accumulation was recorded under sole cropping compared with intercropping registered yield of 34-57% as higher as sole cropping. This being achieved by increased in pods per plant, pod wt/plant and 100-kernel weight. They further observed that on the basis of land equivalent ratio (LER) an intercropping gave 80% yield advantage over sole cropping.

Joshi et al. (1999) carried out and experiment on soybean-pigeonpea intercropping system at Indore and found that all the intercropping treatments showed superiority over sole cropping in total production as evident by soybean equivalent yield. They also observed that the maximum soybean equivalent yield was recorded with two rows of pigeon pea planted between paired rows of soybean (22.5.90 cm). However, it was on par with alternate paired row planting (30/30 cm).
Kumar and Bhanumurthy (2001) suggested that intercropping of maize with cowpea in 2:1 raw ratio produced higher yield than any of the sole crops. In this system, it was found that single row of cowpea for every two rows of maize did not show any competition and rather complimented the maize yield.

A 3-year field study was conducted by Singh and Singh (2001) to evaluate different planting patterns of maize and soybean intercropping and observed that maize yield under all the intercropping pattern was significantly lower than sole stand in all the years; however, the magnitude of reduction varied among different intercropping pattern. Paired row of maize (30/90 cm) + soybean (2:1 row ration) being at par with paired maize row + soybean (2:2 raw ratio) in 30/90 or in 45/90 cm recorded significantly higher maize yield than other planting pattern. Higher yield of maize under sole stand than intercropping was also reported by Khola et al. (1999). Similarly, soybean yield under all the intercropping patterns also decreased significantly compared with sole soybean.

Khan et al. (2002) conducted a field experiment in Srinagar, Jammu and Kashmir, India, in order to evaluate the performance of sole maize (cv. super-1 composite), maize + cowpea for grain (SKAU-C-2) and for fodder (cv. SKAU-C-I), and sole cowpea for grain and fodder at a varied spacing and observed that cowpea (grain) as intercrop did not significantly affect maize yield.

Kumar et al. (2003) based on findings of the experiment conducted on maize + groundnut intercropping system reported that planting pattern did not bring any change in the yield attributes of maize viz. weight of cob, grains/cob and shelling (%) they further observed that planting of groundnut crops in 1:1 ratio recorded significantly higher number of developed pods and their weight.

Kumar et al. (2003) conducted on experiment during rainy season of 1999 and 2000 with maize (Zea mays L.) and ground nut (Arachis hypogaea
L.) intercropping and revealed that planting of component crop in 1:2 ratio recorded significantly higher yield of groundnut where as productivity of maize remained unchanged due to planting pattern since, yield attributes of maize remains unchanged, grain and stover yield were also not affected by planting pattern.

Chakraborty et al. (2003) carried out an experiment during spring season of 1999 and 2000 at Punjab Agricultural University, Ludhiana to study the effect of intercropping groundnut between the rows of sunflowers on their productivity and reported that sunflower and groundnut in intercropping system formed an economically viable combination if groundnut was allowed to continue up to mid-Sept. after the harvest of sunflower in June registering higher productivity ranging from 64 to 85% than sole crop of sunflower and groundnut.

2.4 EFFECT OF INTERCROPPING AND WEED CONTROL MEASURES ON EQUIVALENT YIELD OF COMPONENT CROPS

Singh et al. (1988) reported from a field experiment conducted at Panthnagar during 1982-84 that the highest maize equivalent yield was found in maize + black gram intercropping system than other maize + legumes intercrops.

Sharma and Choubey (1991) carried out an experiment on effect of maize-legume intercropping system on nitrogen economy and nutrient of soil and found that the combined grain yield i.e. maize equivalent of soybean + maize intercropping was superior to Vigna radiata + maize intercrops or pure stands of maize.

Prasad and Rafey (1996) carried out an experiment at ranchi during the wet season of 1990-92 to study the effect of cropping system and weed control on weeds and crop productivity of maize and soybean and found that intercropping of maize with soybean, irrespective of their row ratios, effectively
reduced the weed density and dry weight of weeds at 30 and 60 days after sowing compared to their pure cropping. They further observed that the grain yield of maize under intercropping was on a par with that obtained under its pure cropping but drastic decrease (36-53%) in grain yield of soybean was noticed in intercropping system compared with its sole cropping. Maize equivalent yield in maize + soybean (1:1) intercropping system made commendable improvement (5023 kg ha⁻¹) compared to remaining cropping system. Regarding weed control measure, hand weeding at 15 and 30 days after sowing was comparable with the pre-emergence application of pendimethalin @ 1.0 kg ha⁻¹ in reducing the population of weeds and dry matter production. Hand weeding thrice registered highest maize-equivalent yield (5259 kg ha⁻¹). Which was on a par with that obtained with pendimethalin @ 1.0 kg ha⁻¹ pre-emergence (4793 kg ha⁻¹).

Upasani et al. (2000) reported that the intercropping system irrespective of population-fertilizer level of black gram produced higher maize equivalent yield than sole maize. Intercropping of maize with 100% population and 50% fertilizer applied to black gram resulted in maximum maize equivalent yield (63.11 qha⁻¹). They observed that maize + black gram having 100% population along with 50% fertilizer to black gram exhibited higher LER (1.79), net return (Rs 11091 ha⁻¹), net benefit: cost ratio (1.65) along with monetary advantage of Rs 7843 ha⁻¹ than all other cropping system. This result confirms the findings of Singh et al. (1995).

Singh and Singh (2001) carried out an experiment during kharif season of 1993-95 on productivity potential and economies of maize and soybean intercropping system under rainfed low hill or valley situation of Uttarakhand and found that there was significant variations in mean maize equivalent yield in different intercropping pattern of maize and soybean over their respective sole stands. All the intercropping pattern of maize and soybean as were as sole soybean had more maize-equivalent yield compared with sole maize. This
results support those of Mahapatra and Pradhan (1992) and Sharma et al. (1998).

Similarly, in case of income equivalent ratio (IER), they further reported that IER was always higher under intercropping patterns than the sole stand, indicating an advantage of all the intercropping patterns of maize and soybean over sole crops.

Pandey et al (2003) conducted an experiment during rainy season of 1998 and 99 at research farm of Rajendra agricultural university, pusa, samastipur to study the effect of maize based intercropping system on maize yield and associated weeds under rainfed condition and found that intercropping system reduced the value of yield attributes and grain yield of maize than sole cropping of maize. The reduction in yield attributes and grain yield was of higher magnitude with sesame, while it was lower magnitudes with black gram, groundnut and pigeon pea intercropping systems. They further observed that intercropping systems recorded significantly higher maize equivalent yield, productivity (kg/ha/day) and significant reduction in weed population and weed dry biomass than sole cropping of maize.

Laxminarayana and Munda (2004) conducted on experiment at ICAR research complex, Kolasib, Mizoram to assess the productivity and economics at different rice and maize based cropping system and observed that the highest grain yield interms of maize-equivalent yield (60.64 qha⁻¹) was obtained by maize + ground-mustard cropping system followed by ground-mustard (57.22 qha⁻¹) and maize + soybean-mustard (55.34 qha⁻¹). The highest maize-equivalent yield in maize-based cropping system was owing to high market price and highest yield of the crops. They further observed that inclusion of groundnut as an intercrop in both rice and maize proved stable for increasing productivity, similarly, soybean also showed significant effect on crops as an intercrop in maize than rice. Positive effect of legume crops on soil fertility was also observed, which inturn increased the crop yields either
as sole or intercropping with different cereals. The results confirm the findings of Mandal et al. (1999) and Nanda et al. (1999).

Gare et al. (2004) obtained significantly higher soybean equivalent yield while intercropped with pigeon pea registering equivalent yield of 40.92q ha\(^{-1}\) under 3:1 row ratio planting pattern. This might be due to higher yield of pigeonpea as an intercrop. Similar results were also reported by Dudhane et al. (2002) and Dana wale et al. (1996).

2.5 WEED POPULATION

2.5.1 Maize

Tewari et al. (1987) conducted on experiment to know the effect of intercrops and herbicides on weed control in maize and found that the experimental fields were infested with weed species of *Trianthema monogyna* L. (22.3%), *Digera arvensis* forsk (18.5%), *Phyllanthus nirui* L. (16.5%), *Digitaria sanguinalis* scop (12.1%), *Cyperus rotundus* L. (11.2%), *Panicum dichotomiflorum* Michx (7.8%), *Euphorbia hirta* L. (6.8%) and *Amaranthus viridis* (4.8%).

Prasad and Rafey (1996) while conducting on experiment on weed control in maize + soybean intercropping system under rainfed condition at Ranchi during the wet season of 1990-92 observed that the experimental fields were infested with dominant weeds of jungle rice [*Echinochloa-colonum* (L.)], day flower (*Commelina benghalensis* L.), ground cherry (*Physalis minima* L.), cock’s comb (*Celosia argentea* L.), foxtail grass millet [*Setaria glauca* (L.) Beauv.], purple nut sedge (*Cyprus rotundus* L.) and floss flower (*Ageratum Conyzoides* L.).

The major weed flora observed by Pandey et al. (2003) in the experimental plots of maize included *Eleusine indica* (L.) Gacrt., *Setaria glauca* (L.) P. Beauv., *Echinochloa Colonum* (L.) link and *Cynodon dactylon* (L.) Pers. in grasses; and *Ageratum conyzoides* L., *Amaranthus viridis* L.,

Knowledge of the type and nature of weed species commonly occurring in maize crop is the pre-requisite for their effective and economical management. Generally, three types of weeds species are found in maize crop. (i) Grassy weeds: Echinochloa colonum, Echinochloa crusgalli, Acrachne racemosa, Digitaria sanguinalis, Dactyloctenium aegyptium, Cynodon dactylon, Eleusine indica, Paspalum dilatatum and Panicum repens. (ii) Broad leaved weeds: Trianthema portulacastrum, Trianthema monogyna, Digera arvensis, Commelina benghalensis, Phyllanthus niruri, Xanthium strumarium, Euphorbia hirta, Parthenium hysterophorus, Boerhaavia diffusa and Amaranthus spinosus. (iii) Sedges: Cyperus rotundus, Cyperus esculentus and Cyperus iria. (Sharma, 2005).

2.5.2 Soybean

Dubey (1998) carried out an experiment on weed management in soybean-based intercropping system and observed that the filed was invaded by 27 weed species. The intensity of broad-leaved weeds was higher than that of narrow ones. Amongst the broad-leaved weeds, major species were Alysicarpus vaginalis D.C., Caesulia axillaries R oxb., Celosia-argentia L., Commelina benghalensis L., C. Communis L., Corchorus olitorius L., Eclipta alba (L.) Hassk., Euphorbia geniculata orteg., Phyllanthus niruri L., Psoralea corylifolia L., Tridax procumbens L. and Xanthium strumarium L., Euphorbia hirta L. under sedge group only Cyperus rotundus L. was observed. While Apluda varia-Hack., Cynodon dactylon (L.) Pers., Digitaria adsecndens Hersn, Dinebra arabia Jacq. and Echinochloa crusgalli Beauv., were also present in the field in the lower densrty.

Major weeds observed by Jeyabal et al. (2001) in the experimental plots of soybean were Cyperus rotundus, Cynodon dactylon, Digitaria sanguinalis, Amaranthus viridis, Euphorbia hirta, Cleome viscosa, Parthenium
hysterophorus, *Tridax procumbens*, *Mollugo pentaphylla* and *Phyllanthus niruri*.

Pandya *et al.* (2005) carried out an experiment on the effect of varieties, crop geometries and weed management on nutrient up take by soybean (*Glycine max*) and associated weeds and observed that the fields comprised of monocot weeds were *Echinochloa colonum* (L.) link., *Cynodon dactylon* (L.) Pers. and *Cyperus rotundus* (L.) pers. While dicot weeds were *Trianthema portulacastrum* L., *Commelina benghalensis* L., *Amaranthus spinosus* L., and *Digera arvensis* L. Out of these, *Echinochloa colonum* and *Trianthema portulacastrum* were the most dominant monocot and dicot weeds respectively.

Idapuganti *et al.* (2006) observed that the predominant narrow leaved weed species that infested the soybean fields were *Echinochloa colonum* L., *Cyperus rotundus* L., and *Digitaria sanguinalis* L. Scop. Among broad leaved weeds, *Digera arvensis* Forsk. and *Trianthema portulacastrum* L. were most prevalent. They also found that in weedy check at 60 DAS, monocot population m$^{-2}$ (170.7) was 246% higher than the dicot population (49.3). The predominance of these weeds in north west parts of India was also reported by Balyan and Malik (2003) from Hisar.

2.5.3 Groundnut

Prasad (1994) while conducting a trial on integrated weed management in rainfed groundnut observed that the experimental plots were infested with major weeds – *Cyperus rotundus* L., *Eragrostis tenella* (L.) Beauv., *Panicum colonum* L., *Celosia argentia* L., *Echinochloa* spp., *Digera arvensis* L., *Euphorbia hirta* L., *Amaranthus* spp., *Ageratum conyzoides* L., *Portulaca oleracea* L. and *Commelina benghalensis* L. He further revealed that the density of dicot weeds were more as compared to grasses during both years of experimentation.
The predominant weed species associated with groundnut observed were: Sporobolus spp., Cyperus rotundus L., Chloris inflata link; syn. barbata, Tragus biflorus schult., and Dactyloctenium acgypticum (L.) willd. among monocots; and Digera muricata (L.) Mart; Borrearia articlularis (L.f.) F.N. Williams, Tridax procumbens, Vernonia spp., Euphorbia hirta L. and Achyranthus aspera L. among the dicot weeds. (Sumathi et al. 2000).

Kumar et al. (2003) while conducting an experiment on integrated weed management in irrigated groundnut observed that the experimental fields was infested by the predominant weeds flora viz. Cyperus rotundus, Cenchrus catharticus, Cynidin cynodonlon and Saccharum spontaneum among monocots; and Amaranthus viridis, Solanum nigrum, Commelina benghalensis and Tribulus terrestris among the dicots weeds.

2.6 CRITICAL PERIOD OF CROP WEED COMPETITION

In tropical agriculture, weeds grow very vigorously and create major problems in crop production. Maize, a widely spaced row crop, having slow initial growth, suffers heavily from weed competition. Both crops and weeds compete for the same resources such as nutrients, light, moisture and space. Competition begins when crops and weeds grow in close proximity and the supply of any essential growth factors falls below the demands of both. The overall effect of crop weed competition is a reduction in grain yield. Thus, determination of period or stage at which maximum damage to crop occurs is an important aspect in deciding a weed management programme.

2.6.1 Maize

Maize is the most sensitive to weed competition during the first month after sowing and weed growth before 10 days or after 30 to 40 days appears to have little effect (Gleason, 1956 and Nieto et al., 1968).

The first quarter of the crops life in general, is considered more susceptible for weed competition (COPR, 1981).
Maize is an important kharif season crop and invaded by number of weed species which start competition with crop from very beginning of growth. It is however, well established that first 30 days after sowing are critical period of weed competition in maize (Krishnamurthy et al., 1981).

Maize, because of its slow initial growth rate, is vulnerable to weed competition in the first 30 to 45 days of its growth (Pandey and Mishra, 1982 and Krishnamurthy et al., 1981).

Presence of weeds in cropped field is always harmful as they are competing with crop for all the natural resources. But their presence/unchecked growth during certain period of crop growth is causing higher losses in crop yield. That period of crop growth is called critical period for crop-weed competition which is different for different crops. It is well established that first 30 days after sowing is critical period of weed competition in maize. Therefore, maize crop should be kept weed free for atleast 30-40 days after sowing to obtain full potential of newly developed higher yieldings cultivars (Rajvir Sharma, 2005).

2.6.2 Soybean

Bhan et al. (1972) while carrying out an experiment at Pantnagar revealed the importance of weeding in soybean crop during the first 30 days of crop growth as the yield reduced drastically by 65% due to competition by monocots and sedges. Further work also revealed that maintenance of weed free condition upto 30 to 45 days after sowing in sandy loam soil was essential for obtaining higher yield in soybean (Muniyappa et al., 1975).

Excessive presence of weeds limits the full expression of yield potential of soybean. Early controls of weeds (first 30 days of sowing) in soybean is very critical and if not done, yield losses may reach up to 43% (Bhan et al., 1974).

The first 30-40 days period after sowing soybean is considered to be critical to weed competition (Bhan, 1975).
Soybean crop faces severe competition with weeds during its initial growth period. The first 30-40 days period after planting of soybean is considered to be critical with respect to weed crop competition. (Bhan, 1975, Singh and Singh, 1984). Weed competition during this period may lead to 40-70% reduction in grain yield of Soybean (Bhan et al., 1974 and Dubey et al., 1996) depending upon weed species association.

Singh et al. (1992) revealed that early control of weeds in soybean, when the crop is less than one month old, is of utmost important. If the weeds are checked during this period, soybean gets an advantage over weeds and smoother them afterwards.

2.6.3 Groundnut

According to Hill and Santelmann (1969) the most critical weed competition in groundnut was found to be between 3 to 6 weeks of sowing.

The critical period of crop-weed competition for groundnut has been reported to be from 5-6 weeks after sowing (Zimdahl, 1980 and Naidu et al., 1982).

The first 3 to 4 weeks of crop growth period are critical for weed control in groundnut and uncontrolled weed reduce groundnut yield up to 75%.

Competitions the action of endeavouring to gain what another endeavours to gain at the same time. Among plant communities each plant is in a state of continuous competition with its neighbouring plants for varied growth elements, both above and under ground. Our concern here is with such a competition between weeds and crops an agricultural lands which tends to limit, or even extinct, the weaker competitor; invariably the crops. In fact, without the selfish interference by man, the weeds can easily wipe out the crop plants from earth in comparatively short period (Gupta, 2002).
2.7 LOSSES DUE TO WEEDS

The superiority of weeds to crops, despite man’s best efforts to control them is attributed to their powerful characteristics that have made them dominant over the crops. The global loss of food production due to weeds was estimated to be 287 million tonnes per annum accounting for 11.5% of total world food production (Parker and Fryer, 1975). In India, out of the total annual loss of agricultural produce from various pests, weeds account for 45%, insects 30%, diseases 20% and other pests 5%. Thus the losses caused by weeds exceeds the losses from any other category of pests and it was estimated that annual loss of agricultural production is Rs. 4,200 million due to weeds alone (Joshi, 1973).

Parkar and Fryer (1975) estimated that the world was losing annually 11.5% of the total food production. That is, if all the weeds in food crops were controlled, the current world’s food production would be higher by 11.5%.

Heavy yield reduction due to weeds and response of pulse crops to weeding has been demonstrated by many workers (Dawson, 1977; Singh and Mishra, 1980 and Remison, 1978).

Exhaustive scientific data are available on the losses caused by the uncontrolled growth of weeds in the productivity of different crops. The summarised experimental data showed that there was yield reduction of 34.3% to 39.8% due to weed infestation. On country basis such losses in crop yields have been estimated at 15-30% in wheat, 30-35% in rice and 18-85% each in maize, sorghum, pulses and oilseeds (Mukhopadhyay, 1992).

Rao (1995) reported that the weeds are competitive and adaptable to all adverse environments. There is a sever competition between weeds and plants for nutrients, moisture, light and space which leads to a reduction of agricultural produce up to 45%.
Yaduraju (2001, un published) based on number of trials conducted in different locations (no. of location) in respect of mean potential loss due to weeds in crops reported mean production loss (%) of 48.8%, 63.6% and 53.0% in maize, groundnut and soybean, respectively.

Recent estimates showed that weeds cause an annual loss of about 1980 crores to Indian agriculture, which is more than the combined losses caused by insect, pests and disease. It has been further estimated that losses in crop yields due to weeds in advanced countries are 5% and in the least developed countries, about 25% (Gupta, 2002).

Weeds compete with crop plants for nutrients, space, moisture and air. The degree of weed competition depends upon type and density of weeds flora, duration of weed infestation, competing ability of crop plants, method of cultivation and climatic conditions which affect both weed and crop growth. In India, weeds reduce the crop yield by 10 to 15%. In dryland conditions this loss goes to 30% because in stress conditions weeds thrive better than crop plants (Saraswat et al., 2003).

Depending upon severity of infection, stage of crop-weed competition, nutrient and moisture availability and agro-climatic conditions, the purple nut sedge reduces the crop yield by 10-32 percent. While annual yield loss due to overall weeds in India is 33 percent accounting nearly Rs. 1980 crores. The crops grown during kharif e.g. upland rice, maize, pigeonpea, mungbean, urdbean are more susceptible to this sedge than Rabi crops. Apart from this, the weed secretes some toxic substances (Allelo chemicals) which adversely affect the growth and development of associated crops. Besides yield loss, it also harbours certain insect, pest which feed on prevailing crop and affect the yield (Singh et al., 2005).

2.7.1 Maize

Weed competition in maize has long been recognized as one of the major causes of low productivity in view of its slow growth at initial stage.
(Staniforth 1957; Nizamuddin and Rahman, 1961) reported 33-72% yield reduction in maize due to weeds.

The losses due to weeds in maize fields were estimated at 0.92 crores in Bihar (Nizamuddin and Rahman, 1961), while a total loss of 30 million tones of grain was reported from India (Pannikar, 1961). Similarly Mani (1976) reported the loss due to weeds in maize crop ranged from 29 to 74 percent.

Moolani (1965) and Sidhu et al. (1975) have reported 40 to 72% reduction in yield of maize because of weeds.

Singh et al. (2005) reported that the average reduction in maize yield by purple nutsedge was 12.6 per cent.

Sharma (2005) based on the observation made on integrated weed management in kharif maize reported that wide row spacing in maize coupled with favourable environment-allows luxuriant weed growth which may reduce the yield by 30-100%. Weeds interference in kharif maize causes greater yield loss as availability of adequate moisture due to frequent rains provides congenial conditions for weeds to compete well with crop for moisture, nutrients and light. In addition, maize is generally raised under marginal conditions with meager inputs which make it poor competitor. Hence, timely weed control in maize has become essential for realizing its potential yield (60.9 kg ha\(^{-1}\)).

### 2.7.2 Soybean

Bhan et al. (1974) reported that weed competition during early period (0-40 days) may lead to 40-70 percent reduction in grain yield of soybean.

Patra (1987) reported that the weeds emerge simultaneously and grow vigorously with the soybean crop and so compete for nutrients, space and solar radiation. This leads to reduction in growth and yield of soybean.

Soybean is mainly grown during kharif season. In monsoon season weed infestation is one of the major factors which limits productivity level of
soybean crop. It is estimated that the loss in yield of soybean is 30 to 77% per cent due to improper weed management (Chandel and Saxena, 1988).

The reduction in soybean yield due to weed infestation varies from 20 to 77%, depending on the type of soil, seasons and intensity of weed infestation (Tiwari and Kurchania, 1990).

Soybean yield losses to the extent of 40 to 80% due to weeds have been reported (Tiwari and Kurchania, 1990 and Singh et al., 1992).

Poor yields in rainy season crops including soybean may probably be due to weed infestation. Bhan (1994) also reported 40-60% loss in grain yield of soybean due to weeds.

It has been estimated that 33% of potential production is lost due to weeds competition besides the loss of valuable plant nutrients in the form of weed removal. The reduction in yield of soybean ranged from 10 to 73% due to weed competition as seen from various studies (Hong and Rajagopal, 1996).

Rainy season soybean in northern Indian has been found to be infested with wide range of weed flora that reduced yield by 30-80% along with nutrient depletion of 26-65 kg N, 3-11 kg P₂O₅ and 45-102 kg K₂O ha⁻¹ (Yadu Raju 2002).

Intense weed competition is one of the major constraints in soybean production. The yield reduction of soybean due to weeds varies from 35-50 percent, depending up on the types of weeds, their density and time of the crops weeds competition (Gaddeppagoudar et al., 2004).

2.7.3 Groundnut

The groundnut crop being poor competitor, the yield losses may exceed 50 percent (Chaugule and Khuspe, 1962).

Kulkarni et al. (1963) reported that weed competition causes more than 30% loss in yield of groundnut.
Reddy and Reddy (1990) reported that weed infestation in groundnut is one of the main factors for loss in yields to the tune of 80% under dryland conditions.

Prusty et al. (1990) reported that weeds pose severe problem to groundnut during rain season and cause 80% reduction in pod yield. Under such a situation, chemical weed control offers a better alternative to manual weeding during early stage as it does not affect root nodulation in groundnut (Reddy, 1983).

2.8 EFFECT OF WEED CONTROL ON WEED

Singh et al. (1972) studied the efficacy of herbicides like atrazine, simazine and Lasso (alachlor) and concluded that atrazine is the best herbicide followed by Lasso (alachlor) and both the compounds were also found to be non toxic to the crop.

Singh et al. (1986) recorded minimum weed drymatter (1718 kg ha\(^{-1}\)) and population (43 m\(^{-2}\)) under the plots of maize which were kept weed free upto 60 DAS by interculturing and hoeing and was found significantly superior to other treatments. They also obtained maximum grain yield of maize (5828 kg ha\(^{-1}\)) in the 60 days weed free treatment with an increase of 63.2% over unweeded control and inturn was also significantly superior to the rest of the weed control treatment.

Patra (1987) conducted an experiment on Gangetic alluvial sandy loam soils for two years on weed control in soybean and found that the herbicidal treatment recorded less efficiency of controlling weeds than those of the hand weeding treatments. Amongst the weeding once treatments (during the entire growth period of soybean crop), the dry matter accumulation in weed (at harvest) decrease gradually with delay in weeding, weed growth at harvest in plots weeded twice (at 30 and 45 DAS) or thrice (at 15, 30 and 45 DAS) was comparable with that of the weed free plots (weeded at 7 days intervals).
Prasad and Srivastava (1990) conducted an experiment on weed management in soybean at Ranchi during the wet season of 1987 and 1988 and revealed that the application of herbicides as well as cultural methods drastically reduced dry matter accumulation by weed. They further observed that two hand weeding at 20 and 30 DAS gave the highest yield of soybean which was at par with fluchloralin @ 1.0 kg a.i. ha\(^{-1}\) (PPI), alachlor @ 2.0 kg a.i. ha\(^{-1}\) (PE) or pendimethalin @ 0.5 kg a.i. ha\(^{-1}\) (PE). Weed control efficiency (WCE) of both two hand weedings and fluchloralin treatments was alike, followed by alachlor. Suppression effect of fluchloralin, alachlor and oxadiazon on growth of weeds was also noticed by Ali \textit{et al.} (1984), Prasad \textit{et al.} (1985), Yaduraju \textit{et al.} (1986) and Kolar and Sandhu (1989).

Sharma \textit{et al.} (1992) based on their observation of the experiment conducted on the effect of various herbicides with or without cultural practices on weed and yields of soybean reported that all the weed-control treatments significantly reduced the weed density and weed dry weight over weedy check. Two hand weeding at 30 and 45 DAS provided better weed control than all the other treatments. Among various herbicides, pack sowing + alachlor, pack sowing + pendimethalin, metolachlor and fluchloraline were at par with respect to control of weeds.

Devakumar and Gajendragiri (1998) reported that unweeded plots recorded more weeds at all the stages of crop growth. Hand-weeding reduced the weeds significantly. Two hand-weeding proved the most effective and suppressed the weed growth interms of weed dry matter by 29.0 and 71.2% and 41.4 and 76.2% in both years of experimentation against weedy check.

Gurjar \textit{et al.} (2001) while carrying out an experiment at college of Agriculture, JNKVV, Gwalior to evaluate the performance of different herbicides and cultural practices for weed management in soybean and obtained that all the herbicides were able to check weeds over no weeding at 30 DAS of crop. Lowest number of weeds were counted in weed free plots.
while treatment hand weeding at 20 DAS and weed control were having maximum weed population. Similarly, dry weight of weeds recorded at harvest was less in treated plots as compared to weedy check. Significantly minimum dry weight of weeds was recorded under weed free, alachlor and pendimethalin @ 1.5 kg a.i. ha\(^{-1}\) for both were next in order. The highest value of WCE was found under weed free plot, treatment alachlor @ 1.5 kg ha\(^{-1}\) and pendimethalin @ 1.5 kg a.i. ha\(^{-1}\) were next in order.

Minimum value of weed index (WI) was recorded under treatment Alachlor and Pendimethalin. The highest value of W.I. was obtained under weedy check.

Among the cultural practices hand weeding at 20 and 30 DAS was quite effective for controlling monocot as well as dicot weeds as compared to mechanical hoeing at 20 and 30 DAS. These results coincide with the findings of Bhan (1975) in soybean crop.

Jeyabal et al. (2001) reported that the application of different pre-emergence herbicides had significant effect on weed population. Weed biomass, weed count and nutrient depletion by weeds were reduced by the application of different herbicides on soybean. It was also observed that regardless of season, all the herbicides produced less weed biomass than in hand weeding twice. The weed control efficiency of 94.5% due to application of herbicide (metribuzin) in soybean was earlier reported (Chavar et al. 1999).

Gaddeppagoudar et al. (2004) conducted on experiment on the effect of post-emergence herbicides on weed population and yield of soybean at UAS, Dharwad and observed that the weed population, and weed dry weight were significantly reduced by weed control treatment over weedy check.

Idapuganti (2006) conducted an experiment on integrated weed management in soybean and its residual effect on succeeding wheat during 2003-2004 at New Delhi and reported that the lowest population of monocot weeds (17.3 m\(^{-2}\)) was recorded with quizalofop-ethyl @ 50 gm ha\(^{-1}\) as post-
emergence at 20 days after sowing, closely followed by 2 hand seeding at 20 and 40 DAS (25.3 m$^{-2}$). Among the herbicides, pendimethalin alone was found least effective in controls monocot weeds (112.7 m$^{-2}$) followed by alachlor (83.3 m$^{-2}$). Contrary to this, highest weed population of dicot was recorded with quizalofop-ethyl followed by alachlor. This could be ascribed to graminicide nature of quizalofop-ethyl, resulting in reduction of competition to dicot weeds. It has been further observed that dicot weeds especially Digera arvensis Forsk also exhibited more greenness and vigorous growth after 5 to 10 days of quizalofop-ethyl application.

Regarding weed dry weight and weed control efficiency, it was found that the highest dry weight of weeds was recorded under weedy check followed by pendimethaline, alachlor and quizalofop-ethyl and the lowest was under hand weeding twice at 20 and 40 DAS. The variable effect of weed control treatment on weed dry weight further got reflected through weed control efficiency (WCE). WCE of pedimethalin was the lowest followed quizalofop ethyl and alachlor.

2.9 EFFECT OF WEED CONTROL ON THE YIELD OF COMPONENT CROPS

2.9.1 Maize

Weed control is a greater problem in intercropping then sole cropping. Though manual weeding is a predominant method, the availability of labour and its cost pose the major problem in controlling the weeds in intercropping situation (Palaniappan, 1985).

Tripathi and Singh (1987) reported that the weed control through alachlor (2 kg a.i. ha$^{-1}$) proved significantly superior to hand weeding and weedy check in increasing the plant height, LAI and dry matter accumulation per plant in maize. Hand weeding was the next best treatment. They further observed that effective control of weds by chemicals and hand weeding
resulted in significantly reduced number of barren plant as compared to unweeded check indicating reduced competition between weeds and crops due to effective weed control. As a result of which, there was significant improvement in all yield attributing characters studies and finally reflected in grain yield of maize. Maximum crop weed competition was recorded in weedy check. The average yield reduction in maize due to weeds was 91.0 and 91.5% on the basis of hand weeded and alachlor treated plots, respectively.

A field experiment was conducted by Singh and Prasad (1988) at GB Pant University of Agriculture and Technology, Pantnagar to study the effect of weed control methods on fodder yield of maize and observed that there was a loss of 78% in yield of green fodder of maize due to uncontrolled weed growth. It was also observed that hand-weeding at 30 DAS improved the yield substantially. Herbicides application produced significantly higher yield than that obtained under weedy check.

Shaban et al. (1994) conducted a field trial on clay loam at Shalakan, Kalubia (Egypt) to evaluate the efficiency of the herbicide combinations on soybean intrcropped with maize and found that the best treatments for the control of annual weeds (Portulaca oleracea, Xanthium brasilicum, Datura stramonium, Chenopodium album, Amaranthus viridis, Gynandropsis gynandra and Hibiscus trionum) were Oxyfluorfen (0.3 kg/feddan) + Pendimethalin (0.75 kg), linuron (0.375 kg) + metolachlor (0.72 kg), sad linuron (0.375 kg) + Pendimethalin (0.75 kg). It was also observed that Oxyfluorfen + Pendimethalin at their respective doses produced the longest ear of maize, maize seed index and highest maize yield/ plant and / feddan, as well as greatest soybean seed yield/ feddan (1 feedon = 0.42 ha.).

Mandal et al. (2004) conducted an experiment to study the effect of integrated weed management on yield components, yield and economics of baby corn and observed that yield components like cobs per plant, cob weight with husk and cob weight without husk were significantly higher under the
treatment of application of atrazine @ 1 kg a.i. ha-1 + one hand weeding at 30 days after sowing being at par with the treatment of two hand weedings at 20 and 40 days after sowing. They further reported that all the yield components were lowest in weedy check. Similar results also observed by Prasad et al. (1990) and Sinha et al. (2000). It was also observed that baby corn yield and green fodder yield were higher with preemergence atrazine @ 1 kg a.i. ha-1 + one hand weeding at 30 DAS and was at par with two hand weedings at 20 and 40 DAS and lowest was recorded with weedy check. Similarly result also reported by Prasad et al. (1990) Talatala sinco and Ranchez (1990).

2.9.2 Soybean

Singh et al. (1993) carried out a trial on weed management in soybean and observed that the weed free condition upto 30 to 40 days of sowing and weeding thrice (20, 30 and 40 DAS) resulted in significantly higher plant height with higher number of branches per plant. In respect of nodes and nodules they further found that weed free environment upto 30 or 40 DAS and weeding thrice proved most efficient at different stages of plant growth. The results are in conformity with the findings of Rennie and Dubetz (1984) and Upadhyaya et al. (1988).

Reliance on herbicides for weed control is expected to increase in India due to shortage of agricultural labourers especially in the peak season. Weed-free environment up to critical crop growth stage is essential to harvest a good crop. Pre-emergence herbicide application can help to some extent to control the weeds in early crop-growth stage. Soybean suffers from heavy weed competition, especially in the early growth stages in monsoon season. Crop-weed competition is minimized by pre-emergence spray of herbicide, resulting in higher crop yields (Berevadia et al., 1996).

Chhokar et al. (1997) reported that the weed competition throughout the growing season resulted in 54.1% and 46.6% reduction in grain and straw yields of soybean, respectively. The improvement under weed control
treatments was because of reduced weed competition due to effective weed control and improved nutrition of the crop. They further observed that control of weeds minimize the losses caused by weed growth thereby leading to improvement in nutrition of crop and enhancement in crop yield. Weed control is also a valuable tool for realizing high grain yield even under lower levels of fertilizers, as it curbs the weed growth right in time and will ensure efficient utilization of fertilizers by crop plant therefore, weed should be controlled to avoid losses caused by weeds and for improvement in N and P uptake by crops.

Dubey (1998) reported that manual weeding resulted in significantly higher yields of soybean than weedy check but was on a par with alachlor (10% G @ 2 kg ha\(^{-1}\) as pre-emergence). The results are similar to the findings of Muniyappa et al. (1986). He also observed that one hand weeding at 30 days and alachlor (10% G @ 2 kg ha\(^{-1}\) as pre-emergence) gave 44.83 and 33.79% more grain yield of soybean than weedy check. These findings are confirming results of Upadhyay (1992) and Singh and Bajpai (1994).

Dubey (1998) based on his observation made on growth, yield and economics of soybean as influenced by weed control methods reported that almost all the growth and yield attributing characters viz. plant weight and height, branches, filled and total pods and their yields, total seed/plant and their yield varied significantly with weed control methods. On the basis of 2 year pooled data it was observed that one hand weeding at 30 days was found significantly superior to alachlor (10% G @ 2 kg ha\(^{-1}\)) and weedy check both in terms of producing more growth and yield attributing character.

Dubey (1998) found that all most all the yield characters of soybean were not significantly influenced by different intercropping system except seed in dex or 1000-seed weight (g) and crop biomass (qha\(^{-1}\)) and these two parameters favoured significantly by sole cropping of soybean. But amongst weed-control methods, one hand weeding at 30 days and oxyfluorfen @ 0.235
kg ha\(^{-1}\) pre-emergence produced significantly higher value of some of growth and yield attributes of soybean like plant height, branches and seed yield per plant and crop biomass over fluchloraline @ 1.0 kg ha\(^{-1}\) PPI and weed check.

Kumar et al. (2003) studied the influence of integrated weed management on energetics of soybean and found that the treatment alachlor @ 2 kg ha\(^{-1}\) fb hand weeding with FYM (8805.68 MJ ha\(^{-1}\)) and alachlor @ 2 kg ha\(^{-1}\) fb chlorimuron @ 4 g ha\(^{-1}\) with FYM (8772.32 MJ ha\(^{-1}\)) consumed maximum energy which were markedly higher than others. The energy outputs were relatively higher under alachlor @ 2 kg ha\(^{-1}\) fb hand weeding with FYM followed by single hand weeding with FYM because of higher biological yields. The energy output input ratio was the highest in single hand weeding without FYM (9.09) which indicated its superiority in energy use efficiency (6.82 MJ\(\text{ha}\^{-1}\times 10^{3}\)) over rest of the treatment. It might be due to higher crop biomass and lower energy input. Jain et al. (1998) also reported similar results. The lowest energy output input ratio and utilization efficiency were noted in unweeded check with FYM. All weed control treatments increased the energy use efficiency over unweeded check. Similar findings were also reported by Sharma and Thakur (1989).

Idapuganti et al. (2006) while conducting an experiment on integrated weed control in soybean and its residual effect on succeeding wheat observed that plant population per metre row length, number of filled pods/ plant and 1000-seed weight of soybean was significantly influenced by weed control treatments. On an average, weed free treatment recorded the highest values of these yield attributes, closely followed by two hand weedings at 20 and 40 DAS. They further reported that the improvement in yield attributes was more where weeds were controlled effectively during critical growth period. The weed control measures scaled down competition and created congenial micro-environment for growth and development.
2.9.3 Groundnut

Panwar and Singh (1977) recorded 136% increase in groundnut yield of chemical method over no weeding. They had further stated that timely execution of manual weeding may not be feasible often owing to heavy and erratic distribution of rainfall in kharif season. Moreover, pre-sowing or pre-emergence application of herbicides takes care of weeds at the initial stage of the crop growth at which the crop does not compete with weeds.

A field experiment conducted by Pannu et al. (1989) at HAU, Hissar during the year 1982-83 on the effect of weed control on growth and nutrient uptake by weed and groundnut and observed that groundnut grown in the absence of weed competition attained maximum LAI. The dry weight per-plant also reduced drastically in the treatment where there was a severe weed competition. The regression of groundnut yield on the basis of two years data have also revealed that the groundnut pod yield reduction was positively correlated with the dry weight of weeds.

A field experiment was conducted by Singh and Patel (1991) during rainy season to find out suitable and economic weed control methods in groundnut under high-rainfall conditions of Meghalaya and found that there was significant difference in number of pods/plant in all the weed control treatments as compared with weedy check. The maximum pods/plant (6.25) were recorded in weed free check followed by pre-emergence application of alachlor @ 1.50 kg ha\(^{-1}\) (6.0 pods/plant).

It was further observed that the weed free check recorded the highest pod yield/plant (7.35 gm), while the lowest pod yield/plant (2.65 gm) was recorded under weedy checks. Pre-emergence application of alachlor @ 1.5 kg ha\(^{-1}\) produced maximum pod weight/plant (6.88 gm) among all the herbicidal treatments remained at par with hand weeding twice. Which in turn were significantly superior to weedy checks.
Subbaiah *et al.* (1997) obtained significantly highest pod yield of groundnut in the treatments kept weed-free throughout crop-growth period (12.60 kg ha\(^{-1}\)). They further observed that allowing weeds to compete with crop for 20, 30, 40, 50 and 60 days after sowing resulted in reduction of pod yield by 13, 22, 33, 48 and 62\%, respectively, indicating the sensitivity of this crop to weed competition at all stages of crop growth. Similarly, the reduction in equivalent yield of ground was recorded 9.97, 16.68, 25.05, 35.91 and 46.42\% respectively over weed-free throughout. Unweeded control recorded the lowest groundnut equivalent yield (632.5 kg ha\(^{-1}\)). However, allowing weeds to compete with crops for first 40 days is crucial as greater loss in potential yield of crop is noticed.

Devakumar and Gajendragiri (1998) studied the influence of weed control on yield attributes, pod and oil yields of groundnut and observed that weeds suppressed all the yield attributes of groundnut significantly. Weedings significantly improved these parameters and maximum increase in number of pods, pod weight, 100 kernel weight and shelling (%) was recorded under 2 hand weedings at 15 and 30 days.

Sumathi *et al.* (2000) reported that hand weeding at 20 and 40 days after sowing or chemical weed control with or without the manual weeding recorded significantly more filled pods/plant, higher pod weight, kernel weight and shelling (%) compared with unweeded control. Rathi *et al.* (1986) and Guggari *et al.* (1995) also reported similar and beneficial effect of hand weeding and herbicide application.

Kumar *et al.* (2003) carried out an experiment on integrated weed management in irrigated groundnut and reported that weed free check (2 hand-weeding at 20 and 45 DAS), 3 intercultures at 15, 30 and 45 DAS or chemical weed control with and without manual weeding and interculture and farmers practices recorded higher number of pods/plant, 100-kernel weight and shelling (%) compared with unweeded or weedy check.
Among the herbicides tried, pre-emergence application of pendimethalin and metolachlor at 1.0 kg a.i. ha\(^{-1}\) coupled with two intercultures at 30 and 45 DAS had a pronounced effect on the yield attributes compared with unweeded or weedy check. Guggari et al. (1995) and Sumathi et al. (2000) were also reported beneficial effect of herbicides in the control of weeds in groundnut crop.

### 2.10 ALLELOPATHIC EFFECT

The toxicity of weeds on crops through the phytotoxic exudates was first reported by De Candolle (1832).

Molisch (1937) coined the term “Allelopathy” and defined as “both beneficial and detrimental biochemical interaction between micro-organisms and plants”, whereas Rice (1974) defined it as the direct or indirect harmful effects on another through the production of chemical substances that escape into the environment.

Some crops may be unsuitable to grow as intercropping because they may produce and excrete toxins into the soil. On the contrary negative allelopathy, i.e., stimulating growth of the associated crops by release of hormone like substances is also possible in the neutral and manipulated ecosystems (Turkey, 1969).

Sanchez et al (1973) identified some of the allelopathy toxins in yellow nut sedge (Cyperus esculentus) as the P-hydroxy-benzoic acid, Vanillic acid, Syringic acid, ferulic acid and P-Coumeric acid which inhibit the germination and radicle elongation of crop plants. Some of the growth inhibitory chemicals identified in Johnson grass (Sorghum halepense) are chlorogenic acid, P-Coumerie acid and P-hydroxy benzaldehyde which are capable of affecting the growth and development of other associated plants (Abdul-Wahab and Rice, 1974).
Even addition of fertilizer could not overcome the ill effect of couch grass (*Agropyron repens* L.) completely when other possible competitive mechanisms were effectively eliminated and reduced production of fresh and dry matter of wheat tops. Further, it was indicated that couch grass chiefly reduced P-uptake by wheat, even when available P was present in adequate amount (Minar, 1974). The substances which are exuded by roots of pea (*Pisum arvense* L.) and vetch (*Vicia villosa*), stimulated photosynthesis and absorption of p³² by barley and oat plants (Rakhteenko *et al.* 1973).

The strongest inhibitory effects of aqueous extracts of Eupatorium adenophorum on wheat seed germination, radicle and plumule growth were reported by Tripathy *et al.* (1981). Lantana has shown the inhibitory effects of its leaves, roots and stem extracts individually on growth of fern plants (Wadhwani and Bharadwaj, 1981).

Bhowmic and Doll (1982) reported that both water extracts as well as residue of *Echinochloa crusgalli* inhibited the growth of radicle and coleoptiles of maize and soybean in pots and glass house and resulted in reduced yields both the crops under field conditions.

Tsuzuki and Kawagoe, (1984) reported that when the root exudates were applied to soybean, maize, barley, radish, turnip and oat plants growing in sand culture and plant dry matter were assessed after four months and found that soybean exudates had little effect on dry matter of soybean and maize, but decreased dry matter of turnip and germination test indicated that the aqueous extracts of homogenized soybean tissue reduced germination of soybean. *Medicago sativa*, turnip and radish, but not of rice. Aqueous extract of *M. Sativa*, greatly reduced germination of *M. Sativa*, turnip and radish but not of rice and soybean. Methanol extracts of soybean had greater effects than aqueous extracts on growth of rice seedlings while both extracts of *M. Sativa* completely inhibited rice seedling growth.
Angiras et al. (1991) while conducting an experiment on allelopathic effect of important weed species on germination and growth of maize and soybean seedling found that the seeds and seedlings of maize turned brown when boiled and unboiled extracts of Cyperus, Ageratum and Eupatorium and unboiled extracts of Echinochloa were used. They further observed that the boiled extracts of Lantana, Eupatorium, Cyperus, Ageratum, Johnson-grass and Echinochloa weeds did not affect the germination of maize and soybean. Where as, the unboiled extracts of Echinochloa reduced the germination of both the crops (maize and soybean). The boiled and unboiled extracts of Eupatorium and Ageratum and unboiled extracts of Echinochloa delayed the germination of both the crops by two days. They further reported that the leaf development of maize and soybean was significantly inhibited by boiled extracts of Eupatorium and unboiled extract of Echinochloa. Boiled extracts of Johnson grass promoted the growth of radicale and coleoptile of both the crops. Where as boiled and unboiled extracts of Eupatorium and Ageratum as well as unboiled extract of Echinochloa inhibited the growth of radicle and coleoptile.

2.11 LIGHT INTERCEPTION

Light is considered of prime importance in intercropping involving cereals of different maturity groups (Baker and Yusuf, 1976). Optimum plant population of sole crops are themselves usually capable of achieving a peak value of light interception which leaves little scope for greater spatial interception by intercrops (Willey and Roberts, 1976).

Biscoe and Gallagher (1977) also reported that the total dry matter production was found to be closely related to the amount of photosynthetically active radiation (PAR) intercepted in many crops.

Solar radiation is the ultimate source of all the energy for physical and biological processes occurring on earth. All five determinants of crop growth
proposed by Charles-Edwards (1981), viz., light interception, utilization of intercepted light, dry matter loss due to respiration, partitioning of assimilates to economically harvestable parts and duration of crop growth, are influenced by prevailing environmental conditions of radiation and temperature. Grain yield is the product of radiation interception, conversion efficiency of intercepted radiation to dry matter and partitioning (Monteith, 1977; Jarwal and Singh, 1990).

Singh (1981) reported that the amount of radiation penetrating the ground surface in paired rows of sorghum at 90cm apart was 40 to 45% more than the radiation recorded at 25cm crop height. This increased penetration might have resulted in better plant growth and ultimately higher yield of intercrops in the paired row system of planting. He further observed that there was not much differences in interception of radiation due to method of sowing up to 50cm crop height but at lower height marked differences occurred.

Pilbeam et al. (1991) reported that the differences in total dry matter (TDM) production in legumes were due to both of their light utilization efficiency and the amount of light intercepted. Total dry matter production in lentil (Mckenzie and Hill, 1991) and seed yield in faba bean (Hussain et al., 1988) were both directly related to intercepted solar-radiation. The green area index (GAI) and leaf angle of a crop determine the amount of radiation absorption. Which is decisive in determining TDM production (Ashraf et al., 1994). A large GAI is required to fully intercept incident solar radiation (Thomson and Siddique, 1997).

Mc Lachlan et al. (1993) reported that the shading caused a decrease in total dry matter accumulation of redroot pigweed (Amaranthus retroflexus) and higher relative dry matter distribution to the main stem than to branches.

Ayaz et al. (2004) Studied canopy development, radiation absorption and its utilization for yield in four grain legumes species grown at different
plant population and sowing depths over two seasons in Canterbury, New Zealand and observed that the green area index (GAI), intercepted radiation, radiation use efficiency (RUE) and total interception photo synthetically active radiation (PAR) increased significantly with increased plant-population. They further reported that the highest population of crops reached their peak GAI about 7-10 days earlier than the legume sown at low populations. Cumulative intercepted PAR was also strongly associated with seed yield and crop harvest index (CHI). They also found that the RUE increased (from 1.10 to 1.46) as plant populations increased and was the highest in highest yielding species. The larger leaf canopies produced at higher plant populations reduced the extinction co-efficient ($K$). This suggest that legume should be selected for development of large (GAI), This should maximize PAR interception, DM-production and consequently seed yield.

Dhaliwal and Hundal (2004) carried out a field experiment at Research farm, PAU, Ludhiana during the year 1999-2000 and 2000-2001 to study the growth and radiation interception in Raya or Indian mustard and observed that with an increase in leaf-area index, the photosynthetically active radiation (PAR) interception increased during both the years. The linear regression equation developed by them between leaf-area index ($X$) and photosynthetically active radiation interception ($Y$) by pooling two seasons data was $Y = 67.006+3.819 X^2$ ($R^2=0.86$) similarly, total drymatter was also increased with an increase in photo synthetically active radiation interception. The linear regression equation developed between total dry matter ($X$) and photosynthetically active radiation interception ($Y$) was $Y = 72.103 + 1.105 X - 0.0162 X^2$ ($R^2 = 0.80$).

Sujatha Sankula et al (2004) carried out a trial to evaluate the effect of leaf architecture of corn hybrids on weed management and observed that light transmittance through the corn canopy was affected by leaf architecture in both years of experimentation. Measurement of photosynthetic photon flux
density (PPFD) showed that almost 50% less light reached the ground between rows of horizontal leaf hybrid compared with up right leaf. Further they observed that the greater canopy cover as a result of faster leaf area development and the horizontal architecture of leaves reduced the transmittance of incident solar-radiation from reaching ground. It was also reported that the canopy transmitted photosynthetic photon flux density (PPFD) declined because of horizontal leaf architecture and shade increased, total weed dry matter accumulation decreased under canopy of horizontal leaf. Corn was taller than the weeds in all the plots where herbicides were applied, forcing the weeds to adopt to reduced PPFD conditions. Adoptions to low PPFD include increased leaf area ratio and increased plant height (Patterson, 1985). This results in taller, spindlier plant.

2.12 WEED SEED RAIN

Mickelson and Herrey (1999) reported that wooly cup grass [Eriochloa villosa (Thunb.) kunth.] emerging at V₅ corn stage reduced seed production greater than 95%; yet, 320 to 920 seeds m⁻² were produced. In separate studies, Knezevie et al. (1994) showed that although seed production of barnyard grass [Echinochloa erus-galli (L.)] and redroot pigweed emerging at V₂ to V₅ corn growth stage substantially reduced seed production compared with those at emerged along with corn. Although competition from corn hybrids reduced weed-biomass, weeds that were present at harvest added substantial numbers of seed to the seed bank.

Sujatha Sankula (2004) studied the effect of corn leaf architecture for weed management and found that the seed production of grassy weed was affected by corn leaf architecture. Decreased seed production because of shading was also reported by Benvenuti et al. (1994) and was attributed to a decrease in the number of fruits per plant. Where as quantity of seed per fruit and per cent dormant seeds remained stable.
2.13 FERTILITY STATUS OF SOIL

Bains (1968) reported that the root systems of the cereals – pulse mixture tap different layer of the soil for their nutrient needs and after results in better utilization of the limited supplies of water and plant food in the soils.

Legume intercropping in cereal has been reported to reduce nitrate leaching (Singh et al., 1978, Yadav, 1981). Parallel multiple cropping (a system of growing two dissimilar growth habit crops with minimum competition) of sugarcane and black gram and that of pigeon pea and maize resulted in low NO$_3$ – N content in soil profile compared to sole cropping (Yadav, 1982). Similarly, study conducted on NO$_3$–N leaching pattern at Modipuram showed that the inclusion of cowpea as fodder crop during summer under rice-wheat system not only helped in uptake of the NO$_3$ – N from deeper soil layers but also made its availability in upper profile layer for succeeding crop (Dwivedi 2003).

Sharma and Choubey (1991) Carried out experiment on maize – legume intercropping system in clay-loam soils of Jabalpur and observed that intercropping of soybean with maize under both alternate and paired row spatial arrangements grown without N had greater combined yields than that of pure maize with 30 Kg N ha$^{-1}$. Maize–soybean intercropping system at 30 and 60 Kg N ha$^{-1}$ was quite comparable to pure maize grown with 60 and 120 Kg N ha$^{-1}$, respectively, indicating that there was saving of 30–60 Kg N ha$^{-1}$ with this system. Gangwar and Kalra (1983) also reported saving of 40–50 Kg N ha$^{-1}$ by intercropping of suitable legumes with maize.

They further observed that association of soybean improved the N status of the soil. Better growth of soybean resulted in higher residual N content in soil. Several workers also observed that good growth of legume crops helps in nodulation and ultimately enriches the nitrogen content in soil (Das and Mathur, 1980; Yadav, 1981). It was also expected that P and K were
very actively utilized not only by sole maize but also by different intercropping systems, thereby reducing the contents of nutrients in the soil.

Sharma and Choubey (1992) conducted a field trial to determine the effect of maize + legume intercropping on nitrogen economy and nutrient status of soil and observed that soybean + maize given 60 Kg N produced a similar combined grain yield to pure stand of maize give by 120 Kg N. indicating that introduction of soybean as an intercrop in maize could save upto 60 Kg N ha\(^{-1}\). They further recorded that intercropping maize with soybean or *Vigna radiata* or N-fertilizer application did not significantly affect the residual NPK contents of the soil.

Prasad (1996) reported that nitrogen fixed by legumes crops not only meets their own N requirement but also a sizable quantity (30-90 Kg N ha\(^{-1}\)) is left for the succeeding crop. In maize – based cropping systems, contribution of legumes towards N contribution was equivalent to 13-67.5 Kg ha\(^{-1}\) applied to rice succeeding maize fodder (De et al., 1983).

Summer cropping of groundnut, green gram or cowpea (fodder) in western plains of U.P. is helpful in supplementing 40–60 Kg chemical equivalent N to maize in maize–wheat rotation, which might not only save non-renewable energy but also help to maintain the soil N supply and increase the total productivity of the system (Sharma et al., 1998).

Laxminarayana and Munda (2004) observed that there was maximum reduction of soil fertility under maize–mustard crop sequence because maize was a heavy feeder of different essential nutrients as a sole crop than intercropped with groundnut and soybean. However, inclusion of legume crops in both rice and maize–based cropping systems showed slight improvement in the soil fertility than the sole cropping of cereals. Similar results were also reported by Kumar et al (2001).
2.14 NUTRIENT UPTAKE BY CROPS

Narsa Reddy et al. (1986) based on the findings of experiment on studies maize – groundnut intercropping systems under rainfed conditions reported that the total uptake of nitrogen, phosphorus and zinc was the highest in two rows of groundnut in uniform row planting of maize as compared to other intercropping systems and sole crop of maize.

Pannu et al. (1989) based on the findings of the experiment on weed control in groundnut at HAH Hissar during the year 1982-1983 and reported that the uptake of various nutrients by groundnut crop was reduced where the weeds competed in higher number and for longer duration. The uptake of N, P and K by the crop depended mainly on the dry matter accumulation by weeds. All the weed control treatments i.e. application of herbicide, hand weeding twice (20 and 40 DAS) and herbicide supplemented with hand weeding had been found effective in reducing the dry matter accumulation of weeds and also improves the nutrient uptake (NPK) by crop.

Chandel et al. (1993) further reported that total N yield in maize + soybean intercropping system was higher compared with pure maize and soybean.

Hong and Rajgopal (1996) while conducting a trial on weed control methods in soybean observed that the nutrients uptake by soybean crop was higher under the treatment hand weeding twice followed by chemical thiobencarb @ 1.0 Kg ha$^{-1}$ + one hand weeding. It is attributed to higher dry matter production resulted in higher nutrient uptake. This result is in agreement with the findings of Prabhaparan (1986) and Tekatushio (1983).

Subbaiah (1997) studied the competition for nutrients by crops and weeds in groundnut based intercropping and found that the uptake of N, P and K by the crop was higher due to intercropping than due to pure crop mainly due to increased yield of both main crop and associated crops. The
uptake of N and K by weeds was more in pure in crops, followed by intercropping red-gram, while it was significantly reduced with sunflower. They also observed that delay in weeding resulted in marked reduction in uptake of nutrients by groundnut. Groundnut in weedy check plots remove significantly lowest N, P$_2$O$_5$ & K$_2$O, owing to multifold increase in depletion of nutrients by weeds with removal. Thus, both weeds and crops compete for nutrients to the maximum extent during early stages of their growth.

It was again found that groundnut – red gram cropping system extracted the maximum N (65.60 Kg N ha$^{-1}$) and P$_2$O$_5$ (4.22 Kg ha$^{-1}$), whereas groundnut-sunflower system resulted in highest K$_2$O uptake (27.88 Kg ha$^{-1}$) compared with sole groundnut. This indicates the competitive nature of intercropping systems and reduction in the nutrient uptake by weeds. However, intercropping systems by itself is not enough to curtail heavy nutrients drain by weeds. Similar results were observed by Shinde et al. (1989) in red gram + groundnut intercrops. With delay in weed removal there was reduction in nutrient uptake by companion crops. In unweeded control plots, there was meager uptake of N (16.64 Kg ha$^{-1}$), P$_2$O$_5$ (0.87 Kg ha$^{-1}$) and K$_2$O (8.20 Kg ha$^{-1}$) compared with maximum uptake in plots kept weed-free throughout crop growth period. Weeds depleted higher quantity of N, P and K in pure stand as compared with intercropped treatments.

Shivay et al. (1999) based on the experiment conducted on response of nitrogen in maize-based intercropping system revealed that the maximum N uptake by maize was noted under maize + urdbean intercropping system followed by maize + soybean and in turn were significantly superior to sole maize grown in normal row planting and paired row planting, respectively. Martin et al. (1991) also reported N transfer from nodulating soybean to maize leading to higher nitrogen uptake by maize intercropping with soybean as compared to sole maize.
Manickam et al. (2000) while conducting a field trial on nutrient uptake by crop and weeds as influenced by weed management practices in groundnut based cropping system found that among intercropping, groundnut + green gram accounted the maximum total NPK uptake of 183.5, 4.7 and 58% Kg ha$^{-1}$, respectively, which resulted in increased crop dry matter production. Athman than (1988) also noticed higher NPK uptake by groundnut + green gram intercropping system They further observed that the NPK uptake by groundnut crops under pre-emergence metolachlor @ 1.0 Kg a.i ha$^{-1}$ + one hand weeding at 30 DAS was significantly maximum with 200.9, 6.2 and 65.3 Kg ha$^{-1}$, respectively in N, P and K and resulted in increased crop dry matter production over unweeded control.

Singh and Giri (2001) reported that the productivity and N uptake of maize was significantly higher when it was preceded by intercropping of sunflower and groundnut weed control also enhanced the productivity and N uptake by succeeding maize.

### 2.15 NUTRIENT UPTAKE BY WEED

Channabasappa and Nanjappa (1994) Conducted field trials on red sandy loam soil to assess the effects on nutrient uptake by crops and weeds in maize and soybean mono cropping with NPK rates of 100+50+25 and 37.5+37.5+37.5 Kg ha$^{-1}$, respectively, and maize soybean uniform and double-row intercropping (at row spacing of 75X30 and 45X105 cm, respond) with NPK rates of 100+50+50 Kg and of weed free conditions from 20-65 days after planting and recorded that weeds absorbed fewer nutrients and crops more nutrients in the intercropping system & than in the mono crops, and nutrient uptake by crops decreased with the delay in weeding.

Field investigations were conducted by Manickam et al. (2000) to evaluate the efficacy of integrated weed management practices on nutrient uptake and dry matter production of weeds under groundnut based
intercropping system and observed that intercropping of green gram in groundnut markedly restricted the nutrient removal and dry matter production of weeds, compared to sole groundnut. The pre-emergence application of metolachlor @ 1.0 Kg a.i ha\(^{-1}\) along with one hand weeding at 30 DAS significantly registered the lowest uptake of nutrients (NPK) by weeds and least weed dry matter production, which was 73.2% decreased over unweeded control.

Singh and Singh (2001) reported that weeds associated with groundnut and Urdbean took up least and equal quantity of N. The extent of N uptake by weeds under the crops compared with that of upland rice was 21.1%, it was followed in increasing order by that with soybean and finger millet. Among the control measures, recommended seed rate + hand-weeding caused minimum uptake of N by weeds.

The P uptake by weeds associated with various crops were found in increasing order of urdbean, groundnut and soybean. Among treatments, recommended seed rate + hand-weeding registered the lowest value of P uptake. It was further observed that like N and P, weeds with urdbean consumed least quantity of K, followed in increasing order by that with finger millet. Weeds with groundnut and soybean took up as much K as that with upland rice took up as much as K that with urdbean and fergemillet, respectively among in increasing order of recommended seed rate + hand weeding.

2.16 NUTRIENT LOSS DUE TO WEEDS

To minimize the magnitude of nutrient drain by weeds and more effective utilization of fertilizer by crop plant, control of weeds is required (Mani, 1975).

Mani, (1976) reported that weeds deplete 30–40% of applied nutrients from soil and compete with the crop plants for soil moisture and sunlight too.
Gautam et al (1981) also advocated that for efficient utilization of nutrients, the weeds should be kept under check.

Vishwanath (1987) recorded the nutrient losses due to weeds in Maize up to 62, 24 and 125 Kg ha\(^{-1}\) of N, P and K, respectively.

2.17 NPK REMOVAL BY CROPS AND WEEDS

Yadav et al (1986) conducted a field experiment at HAU, Hissar to determine the effect of herbicides, on removal of nutrients by weeds and their control in groundnut and observed that the removal of nitrogen, phosphorus and potassium by weeds was the maximum in unweeded control and the minimum in weed-free check. They further reported that herbicides applied pre-emergence were more effective in controlling weeds than pre-plant incorporation. Weed-control in groundnut could save 162.8, 21.7 and 141.8 Kg N, P\(_2\)O\(_5\) and K\(_2\)O ha\(^{-1}\), respectively.

Thakur et al (1990) While conducting an experiment at research farm, HPKY. Solan to assess the effect of weed and fertilizer management on nutrient uptake by weeds and maize under rain fed conditions found that removal of N, P and K by weeds was reduced significantly by Various weed control treatments and it was minimum in hand weeded plots [at 21 and 42 DAS] registered minimum dry weights of weeds and was significantly less compared to all other chemical treatments. Unweeded control recorded the highest dry matter of weeds (46.3 qha\(^{-1}\)). It had also been observed that wherever the removal of nutrients was more through weeds the corresponding uptake by maize plants was less and vice-versa. Gautam et al. (1981) also advocate that for efficient utilization of applied nutrients, the weeds should be kept under check.

Maurya et al. (1990) reported that herbicide cause an appreciable decrease in nutrient depletion by weeds growth as a consequence of which
considerable improvement in nutrient uptake of the crop plant and enhancement in crop yield occurs.

Hong and Rajagopal (1996) studied the influence of population and fertilizer levels on weed control method in soybean and found that the nutrient removal by weeds was lowest under weed control treatments due to their effective control of weeds resulting in lower weed dry matter production but in unweeded check, nutrients removal by weeds was the highest due to higher weed dry matter production. This result finds support with the findings of Singh and Mani (1977).

Chhokar et al (1997). Conducted an experiment on nutrient removal by weeds in soybean under integrated weed management practices and found that weeds depleted the soil fertility by taking 53.24 Kg N ha\(^{-1}\) and 9.30 Kg P ha\(^{-1}\) under unweeded check.

### 2.18 COMPETITION FUNCTION

Land equivalent ratio is a good measure for evaluating land productivity, in physical terms, under sole crops vs. intercrops. It is of no value when monetary gains from the two systems are assessed since it had no relationship with income expectations due to changing prices or variables falls in production of the component involved. The total LER of an intercropping system could be unity, or greater than unity, and yet the expected income from the enterprise could be substantially less when compared to the expected income from the high value sole crop.

Barik and Tiwari (1996) while conducting on experiment at college of veterinary science and Animal husbandry, Anjora Durg (MP) to study the performance of different fodder crops viz., maize alone, sweet sudon alone, cowpea alone, maize + cowpea in alternate rows each and sweet sudan + cowpea in two alternate rows each and found maximum yield advantage (LER = 1.33) from maize + cowpea intercrop combination.
Krishna and Raikhelkar (1997) while conducting a trial on crop complementarily and competition in maize when intercropped with different legumes found that the relative crowding co-efficient showed greater intensity of competition in pigeon pea system due more favorable effect (higher value of K = 6.276), where as maize + soybean combination recorded lower value of the co-efficient (K = 1.21) resulting in lower competition. They also observed that the aggressivity value showed that maize was vigorous in growth habit compared with intercrops. The value of competitive ratio (CRA) also revealed the competition was higher (more than twice) in maize + pigeon pen, maize + groundnut and maize + soybean intercropping system.

Studies were conducted by Joshi *et al.* (1999) at Indore during the year 1993-95 to find out the best planting pattern for soybean-pigeonpea intercropping system and based on the results they revealed that planting of soybean and pigeonpea in alternate paired rows (30cm) gave highest land equivalent ratio (1.69), monetary advantage (Rs. 7311 ha⁻¹) and income equivalent ratio (1.44) due to minimum competition between crops.

Khan *et al* (2002) while conducting on experiment on maize + cowpea intercropping system at Srinagar, Jammu and Kashmir reported that the higher land equivalent ratio (LER) was recorded from intercropping system of maize + cowpea than the sole crops. They further recorded the highest maize + cowpea intercropping system.

Chakravarty *et al.* (2003) while conducting an experiment on sunflower + groundnut intercropping system obtained significantly higher land equivalent ratio (LER) more than one for all the intercropping combinations. They further reported that LER did not vary among the planting patterns. Singh (1994) also reported higher land equivalent ratio of 1.88 – 1.93 of this cropping system.

Kumar *et al.* (2005) while conducting an experiment during rainy seasons (Kharif) of 1999, 2000 and 2001 on production potential and
economic feasibility of maize + cowpea intercropping under rainfed conditions reported that land – equivalent ratio (LER) calculated from combined intercrop yield was higher in all intercropping system, than either of the sole crops, i.e. maize and cowpea. This clearly indicated greater biological efficiency of the intercropping treatments. The Significantly highest mean LER (1.41) was recorded in intercropping of maize and cowpea planted in the row ratio of 2:2; followed by maize + cowpea (2:1, LER=1.21) and mixed seed in same row (1:1, LER=1.22).

Adhikari et al. (2005) while conducting on experiment on Bio-economic evaluation of maize and groundnut intercropping in drought-prone area as of Chotanagpur plateau region of Jharkhand observed that higher values of land equivalent ratio (LER), monetary advantage (MA), Competition ratio (CR) and area time equivalent ratio (ATER) were recorded by maize + groundnut (2:2) than maize + groundnut (1:1) row ratio intercropping system, indicating better adaptability of groundnut between the rows of maize at 2:2 ratio than 1:1 row ratio.

2.19 ECONOMICS

Sobti and Bains (1972) studied at Dhaula Kuan (Punjab) on intercropping hybrid maize with legume (cowpea/black gram) and reported that the mean gross and net income was higher in mixed than pure stand.

Chauhan and Dungerwal (1982) conducted an experiment on maize and legume intercropping and found that the planting of maize and legume in multiple parallel fashion gave 76.52 percent higher net return as compared to solid maize.

Balyan and Singh (1986) based on their study at IARI, New Delhi reported that total productivity appreciably increased by 19.4 and 34.8 percent with soybean intercropping in Sorghum as compared to sole
Sorghum. All the planting geometry fetched considerably more net return than sole crop of sorghum.

Jayaraman et al. (1988) reported the highest profits from mixed biomass system than cultivation of single crops.

Singh and Patel (1991) studied to find out suitable and economic weed control methods in groundnut and reported that pre-emergence application of alachlor @ 1.5 Kg ha$^{-1}$ was found to be the most economical giving the highest net return (Rs 6,266 ha$^{-1}$) over the control, followed by butachlor @ 1.5 Kg ha$^{-1}$ (Rs 6,120 ha$^{-1}$). However, the highest additional return (Rs 8,088 ha$^{-1}$) over the control was observed from weed free check, but net return was reduced due to high additional cost of cultivation of weed control methods. Considering the pod yield and net return due to weed control methods they concluded that pre-emergence application of alachlor @ 1.50 Kg ha$^{-1}$ and butachlor @1.5 Kg ha$^{-1}$ were the most profitable for controlling weeds in groundnut under humid subtropical, high rainfall condition of mid hills of Meghalaya.

Mahapatra and Pradhan (1992) studied the effect of intercropping on yield advantage and economics and recorded that among the intercropping combinations, maize + cowpea (2:2) was found to be the best in respect of yield, net return, LER and benefit: cost ratio.

Dubey (1995) revealed that soybean was the most suitable crop to fit in any cropping system and get higher premium in the market

Dubey et al. (1996) reported that the gross monetary return was significantly the lowest in weedy check among all the treatments of weed control in soybean. It increased under hand weeding, inter-culture operations and pre-emergence application of butachlor @ 2.5 Kg ha$^{-1}$ either alone or supplemented with hand weeding or intercultural operations.
They further observed that B:C ratio reduced or increased when hand weeding or mechanical weed control were supplemented with pre-emergence application of butachlor as compared to butachlor alone. On the basis of B: C ratio, they concluded that mechanical weed control proved more remunerative than other weed control treatment.

Velu and Sankaran (1996) studied herbicidal weed management in soybean and found that hand weeding twice recorded highest net return which was closely followed by higher doses of pendamethalin and fluchloralin and their mixture with hand weeding. The increased net return was due to increased grain yield of soybean resulted from weed free conditions obtained in these treatments.

Dubey (1998) based on the findings of the experiment conducted on weed management in soybean – based intercropping systems reported that among the different weeding methods, only one weeding at 30 days was proved the best treatments and both the herbicides i.e. oxyfluorfen (PE) and fluchloralin (PPI) were found on to be equally effective. Kurchania et al. (1995) also suggested that manual weeding is the most effective and beneficial method over others. It was concluded that among various weeding methods, manual weeding proved superior in getting maximum net profits followed by oxyfluorfen.

Dubey (1998) observed that the hand – weeded plots gave significantly higher gross profit, which was statistically at par with alachlor (10%G) @ 2 Kg ha⁻¹ and both were superior to weedy check. Singh and Sharma (1990) also reported similar results. Net income showed the trend of gross return. Tewari et al. (1994) also reported similar results. However, benefit: cost ratio was not significantly influenced by different weeding methods, higher ratio was obtained with alachlor (10% G) @ 2 Kg ha⁻¹ as pre-emergence, followed by manual weeding.
Singh and Singh (2001) while conducting an experiment on productivity potential and economics of maize and soybean intercropping system under rain fed low hill or valley situation of uttaranchal recorded that the paired maize rows (30/90 cm) + soybean (2:2) and paired maize rows (45/90 cm) + soybean (2:2) intercropping pattern produced the maximum and statistically identical gross and net returns and benefit: cost ratio. Among different intercropping patterns, one additional maize row after every 2 rows of soybean (1:2) recorded the lowest gross and net returns but was superior to sole maize. Variations in different economic indices under different intercropping patterns were also reported by Rafey and Prasad (1996) and Pandey et al. (1999).

Monetary advantage of intercropping sunflower with groundnut was observed over sole sunflower or sole groundnut by Charkrabarty et al. (2003). Simon et al. (1992) and Singh (1994) also recorded higher returns from sunflower and groundnut intercropping than their sole crop.

Kumar et al. (2003) based on their findings of the experiment on integrated weed management in irrigated groundnut concluded that chemical weed control with either pendimethalin or metalochlor in groundnut field is economically viable method whenever the labour scarcity arises during the peak season. Patel et al. (1994) also emphasized the need for adoption of herbicide spray with inter culture for higher pod yield and monetary returns from groundnut.

Gare et al. (2004) conducted an experiment of the effect of pigeon pea and sorghum intercrop on yield of soybean under rainfed condition in sub-Montana zone of Maharashtra and found that gross monetary returns were significantly influenced by intercropping system. The intercropping of soybean + pigeon pea (3:1) row ratio recorded significantly higher gross monetary returns (Rs 36,843 ha⁻¹), net monetary return (Rs 20,429 ha⁻¹) and B:C ratio (1.95).
Prakash et al. (2004) carried out an experiment at Almora to find out the most productive and remunerative relay intercropping combination of maize and tomato and found that, all the relay intercropping combinations enhanced the total production intern of maize – equivalent yield by 4.5 - 4.9 times over maize sole (7656 Kg ha⁻¹). They also observed that relay intercropping of tomato in maize in the row ratio of 1:1 recoded the highest total production interms of maize-equivalent yield (52883 Kg ha⁻¹), gross-returns (Rs 264422 ha⁻¹), net returns (Rs 198820 ha⁻¹) and land equivalent ratio (LER-1.86). It was also observed by them that all the intercropping combinations recorded higher benefit: cost ratio (3.17- 4.03) than sole maize treatments (1.63-1.74).

Mandal et al (2004) while conducting a field trial on the effect of integrated weed management on yield components, yield and economics of baby corn (Zea mays) at Rajendranagar, Hyderabad revealed that gross return, net return and benefit:– cost ratio were significantly influenced by the weed control treatments. Application of atrazine @ 1 Kg a.i.ha⁻¹ + one hand weeding at 30 DAS had maximum gross return, being (73%) more than the crop raised in weedy check and consequently, higher net return was return was all recorded under the same weed control treatment and inturn were significantly superior to the rest of the weed control treatment and lowest was with weedy check. Angiras and Singh (1991) and Sharma et al. (1998) also observed that application of pre-emergence herbicide with one hand weeding gave highest net return than only manual and chemical weed control in maize. Similar is the case with Benefit: cost ratio was observed.

Kumar (2005) conducted an experiment on relative performance of quality protein maize and normal maize under intercropping system with cabbage and found that highest average yield equivalence of 26.21 t ha⁻¹ was recorded under intercrop of QPM with cabbage having 264.5% increase over sole maize followed by normal maize and cabbage intercropping system. They
further observed that the highest per hectare net return of Rs 82,408 was obtained in intercrop of QPM and cabbage followed by normal maize + cabbage intercropping (Rs 81,896 ha⁻¹). The lowest average net return of Rs 15,005 ha⁻¹ was recorded under sole maize.

Kumar et al. (2005) obtained significantly higher mean gross return (Rs.15, 236 ha⁻¹) and benefit: cost ratio (2:21) with maize + cowpea (2:2) intercropping system than sole maize and other treatments tried. Similarly, monetary advantage was also highest with maize + cowpea (2:2) intercropping system.