BI0-EFFICACY OF CLOMAZONE HERBICIDE FOR WEED MANAGEMENT IN SOYBEAN [*Glycine max* (L.) Merrill]

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By

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CERTIFICATE

This is to certify that the thesis entitled "**BIO-EFFICACY OF CLOMAZONE HERBICIDE FOR WEED MANAGEMENT IN SOYBEAN [*Glycine max* (L.) Merrill]**" submitted by **Mr. HANUMANTHAPPA D. C.** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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Introduction

I. INTRODUCTION

Soybean (*Glycine max* (L.) *Merrill*) is one of the important grain legume crop is rightly termed as gold from the soil in USA and a miracle crop of 20th century in India. It is an outstanding crop for its nutritive value with 43 per cent biological protein (rich in lysine) and 20 per cent fat. It is also a rich source of vitamins, minerals, salts and essential amino acids. In addition, soybean can withstand short period of drought at initial stages and short spells of water logging. Further in association with *Bradyrhizobium japonicum,* it enriches the soil by fixing the atmospheric nitrogen to an extent of 280 kg N per ha. Soybean is a versatile crop with innumerable possibilities of improving agriculture and supporting industries.

Soybean is being grown all over the world for its several uses as food, fuel and beverages. The crop is presently grown over an area of 73.5 m.ha with production of 162.5 m tonnes and the productivity of 2209kg per ha in the world (Anon., 2001)

Even though soybean was introduced in India as early as 1880 A.D, its cultivation was confined to small area till 1970's. The increased use of soybean for a number of industrial purposes has resulted in its extensive cultivation. The phenomenal expansion of area and production of soybean and soybean industry has earned a prominent position for India on the world map of soybean industry. In India, there are 148 soybean processing units, out of which Madhya Pradesh alone is having more than 70 units followed by Maharashtra (33), Gujarat (18), Andhra Pradesh. (8), Uttar Pradesh (7), Rajasthan (6) and Karnataka (3). In India, it is grown over an area of 5.7 million ha with an annual production of 5.5 million tonnes with the average productivity of 947 kg per ha (Anon., 2001).

In Karnataka, its area during 1990's was around 16000 ha and has tremendously increased to one lakh ha during 1999-2000. There is still great scope for increasing its area further as a *Kharif* crop in different cropping systems.

Soybean is extensively grown during *Kharif* season. The environmental conditions prevailing during *Kharif* are more conducive for excessive weed infestation. The reduction in yield due to weed competition was to an extent of 34 to 79 per cent (Tiwari and Kurchania , 1990, Reddy *et al.,* 1990, Bhan and Mishra, 1993 and Babalad *et al.,* 1999). They compete for nutrients, moisture and solar energy which would have been otherwise available to the crop.

Weed competition depends upon method of soybean cultivation, type of weed species, time of weed emergence etc. Manual weed control in soybean is tiresome, time consuming, expensive and climatic conditions may not permit for cultural weed control timely. Besides, the urge towards scientific farming during recent years emphasizes the need for chemical weed control in soybean.

The dependency on chemical weed control is showing increasing trend day by day and it offers a practically effective and economic means of reducing weed competition at right time to obtain higher returns.

Extensive research has been done on the use of conventional voluminous pre-emergent and post emergent herbicides in soybean for management of weeds. Based on this, alachlor, pendimethalin and metolachlor have been recommended in different parts of the country.

Recently, new molecules like substituted diazines isoxazolidinone herbicides are being developed for the use in various crops including soybean, blackgram and oilseeds. These herbicides are being considered as economical

and ecofriendly compounds due to their greater selectivity, non residual toxicity, wider spectrum of weed control and environmental compatible.

Clomazone is one of the substituted diazines isoxazolidinone group herbicide. The available information on clomazone herbicide usage in soybean as a better weed control measure and to compare with the existing practices is scanty. With this information in view, an investigation on "Bio-efficacy of Clomazone herbicide for weed management in soybean (*Glycine max* (L.) Merrill.)" was carried out with the following objectives:

1. To study the bio-efficacy of clomazone over other recommended herbicides for controlling weeds in soybean

2. To know the effect of herbicides on soil enzyme activity and on growth and yield of soybean

3. To study the residual phytotoxic effect of clomazone and other recommended herbicides on succeeding crops and

4. To workout the economics of weed control in soybean.

Review of Literature

II. REVIEW OF LITERATURE

Man has been battling with weeds ever since he started growing crops and this fight is going on even today. Weed problem tends to be greater in the tropics than in temperate zone because of tropical climate, greater weed density and vigorous growth besides, innumerable weed species. These grow at the expense of the crop. As a consequence of this, the crop suffers in growth and yield. The relative competitive ability of the crop on one hand and weeds on the other decide the resulting damage or otherwise.

The degree of damage from weeds is related to the type of species and density of the weeds growing in a crop community. Therefore, before undertaking a purposeful work on weed control, it is essential to study the weed flora and the competition between crop and weeds.

Research information relating to the following aspects of soybean is reviewed in this chapter and presented under the following headings.

- Weed flora in soybean
- Crop weed competition
- Methods of weed control
- Economics of weed control
- Residual effect of herbicides

2.1 WEED FLORA IN SOYBEAN

The weed flora observed in soybean at Dharwad consists, monocot weeds like *Cynodon dactylon, Panicum crusgalli, Commelina benghalensis, Echinochloa colonum, Setaria glauca* and sedges *Cyperus rotundus* and some

of dicot weeds observed were *Solanum nigrum, Mocwgo lotoides, Desmodium diffusum, Amaranthus viridis, Convolvulus arvensis, Corchorus trilocularis, Ageratum conyzoides, Celosia argentea, Euphorbia hirta, Achyranthes aspera and Phyllanthus niruri* L. (Aman.,1977)

The most common weed flora found in soybean at Madhya Pradesh were *Echinochloa crusgalli* (L) Beauv., *Digitaria adscendens. Brachiaria repens, Setaria glauca, Setaria tomentosa, Saccharum spontaneum* L., and *Cyperus* sp. (Tiwari and Kurchania, 1990).

The predominant weed species infesting the soybean crop were *Galinsora parviflora, Commelina benghalensis. Digitaria sanguinalis* and *Ageratum conyzoides* at *Parabhani* on *black* soil (Prakash *et al.,* 1991). Whereas, Vidrina *et al* (1993) noticed that *Cassia obtisifolia, Spomea headraces, Spomea lucunosa* and *Sida spinosa* were the most troublesome weeds in soybean.

Tuteja *et al.* (1995) reported that *Celosia argentea* L. *Euphorbia hirta* L. *Echinochloa* Spp. *Commelina benghalensis* L., *Eclipta alba* L., *Saccharum spontaneum* L. and *Cynodon dachylon*(L) were the predominant weed species observed in soybean field.

Weed species in soybean under Bangalore conditions on Alfisols were *Achyranthus aspera, Acanthospermum hispidum* DC., *Ageratum conyzoides* (L.), *Alternanthera pungens, Alternanthera sessilis, Amaranthus viridis, Argemone mexicana* L., *Borreria hispida, Borreria sticta* L., *Celosia argentea, Celosia cristata, Cleome monophylla* L., *Commelina benghalensis* L., *Heliotropium procumbens* L., *Mullugo pentaphylla* L. *Phyllanthus braternus Webster* and *Phyllanthus niruri* L. among dicots. *Cynodon dactylon* (L) Pers., *Dactyloctenium aegyptium* Beau., *Dicanthium annulatum* (Forks) Stapt.,

Digitaria marginata Link., *Echinochloa colona, Eleusine indica* and *Eragrostis cilianensis* among monocots and *Cyperus rotundus* L. among sedges. (Shekara, 1991., Basavaraju and Nanjappa, 1996., Kamalabai and Nanjappa, 1994 and Shylaja, 1996).

At Dharwad, on medium black soils the prominent weeds observed in soybean were *Commelina benghalensis, Dinebra retroflexa, Panicum isachne, Digitaria marginata* are among grasses and among dicots *Ageratum conyzoides, Oldenlandia rugosus, Parthenium hysterophorus,Portulaca oleracea, Amaranthus viridis* and sedges *Cyperus rotundus* and *Cynodon dactylon* (Babalad *et al.*, 1999).

At Akola (Maharashtra), *Acalypha indica, Amaranthus viridis, Cardiospermum heliocarpium, Celosia argentea, Commelina benghalensis, Cynotis axillaris, Digera arvensis, Euphorbia hirta, E.microphylla, Lagasca mollis, parthenium hysterophorus and Phyllanthus niruri* among broad leaf weeds and *Cynodon dactylon. Cyperus rotundus, Dinebra retroflexa, Echinochloa colonum,* and *Poa annua* among narrow leaf weeds were observed in soybean (Kondhare *et al.*, 1999).

Vyas *et al.* (2000) reported that, the dominating weeds in soybean were *Cyperus rotundus* L. *Digitaria sanguinalis*(L) Scop., *Cynotis axillaries* Roem, *Commelina benghalensis* L. and *Echinochloa colonum* Link, among the monocots and *Caesulia axillaris* Roxb., *Anotis monthulani Hook. and Phyllanthus medaraspetensis* L. among dicots.

2.2 CROP WEED COMPETITION

The crop weed competition can be specifically defined as a natural force, where in crop plants and weeds tend to attain a maximum combined growth

and yield with the development of each species, being to some extent, at the expense of the other. This occurs when the demands of both the species for moisture, nutrients, light and possibly carbon dioxide exceeds the available supply (Nanjappa, 1980). The relationship between weed suppression and high yield may be partly due to less weed competition in those plots and partly due to generally greater competitiveness of high yielding genotypes (Charles, 1993).

Seed yields of soybean in plots kept free of weeds for initial 30 days and thereafter were on par with weed free throughout the crop growth (Singh and Kolar, 1994).

2.2.1 Critical stages of crop weed competition

The time or duration of crop weed competition to a greater extent decides the loss caused by weeds to crops. Generally crops during their early stages of growth are most susceptible to weeds. Hence, elimination of weed competition during this period would enable the plants to perform better and consequently can record more yield. Critical periods of growth for weed competition need to be determined to realize maximum benefits from weed control practices.

Channabasappa and Nanjappa (1990) recorded higher seed yield in plots kept weed free for 20 days after sowing and allowing weeds in association with crop beyond 30 days after sowing resulted in reduction in yield.

Varshney (1991) reported that soybean seed yields could be enhanced by 83.3 per cent in plots which are maintained weed free upto 40 days after sowing and delayed weeding resulted in drastic yield reduction.

Bhan and Mishra (1993) reported that the critical period of crop weed competition in soybean is 15 to 30 days after sowing.

Arya *et al.* (1994) opined that maintaining a weed free up to 40 days after sowing resulted in the higher soybean grain and straw yields (2.7 and 5.4t ha^{-1}, respectively).

Ponnuswamy *et al.* (1996) observed that competition offered by weeds after 45 days after sowing did not significantly reduce the soybean yield, similarly weed infestation or infested condition upto 15 days after sowing did not reduce the yield significantly. This brings out the important fact that first 40 days from sowing is more critical period for weed control in soybean and good control of weeds during this period offered maximum advantages to the crop.

2.2.2 Effect of crop weed competition on growth, yield and yield components of soybean.

Many workers have emphasized the effect of weeds on the growth and yield components which ultimately decides the yield. The yield reduction may occur as a result of competition between the crop and weed for nutrients, water, space and light (Klingman, 1961). Weed competition caused the decline in the size of the grains and test weight (Kurchania *et al.*, 1996, Pandey *et al.*, 1996 and Singh *et al.*, 1999). Whereas, Padmavathi *et al.* (1995) and Somanagouda (1997) reported that increased weed competition did not affect the test weight.

At Dharwad, on medium deep black soil, the reduction in yield under unweeded control was 34 and 42 per cent during 1997 and 1998, respectively over weed free check (Bablad *et al.*, 1999). At Indore, on deep black soils

Billore *et al.* (1999) noticed 24 tc 86 per cent improvement in soybean yield due to adoption of various weed control methods over unweeded control.

2.2.3 Nature of crop weed competition

Weeds, like any other crop plants require light, moisture, nutrients, space and CO_2 for their growth and development. Further, the crop plants vary greatly in their ability to compete with weeds and associated plants (Moolani and Sachan, 1966).

2.2.3.1 Competition for nutrients

Aman (1977) observed a maximum uptake of 65 kg N per ha by the soybean crops in weed free plot as against 29 kg N per ha in weed infested plot. Rao and Agarwal (1984) reported that the weeds in general accumulated greater nutrients, particularly nitrogen and potassium when compared to crop plants.

Maurya *et al.* (1990) reported that weeds under weedy check accumulated greater nutrients (26.15,2.76 and 70.99 kg N, P_2O_5 and K_2O ha^{-1}, respectively) compared to two hand weedings (0.24, 3.037 and 0.74 kg N, P_2O_5 and K_2O ha^{-1}, respectively). The nutrient depletion by weeds in soybean was 26.1, 2.7 and 79.9 kg N, P_2O_5 and K_2O per ha, respectively (Bhan and Mishra, 1993).

Chokkar *et al* (1997) reported that weeds in soybean depleted the soil fertility by removing 53.24 kg N per ha and 9.30kg P_2O_5 per ha under unweeded check. According to Kannan and Gurumurthy (1999) nutrient depletion by weeds in soybean was 26.1, 2.7 and 79.9, N, P and K kg per ha, respectively.

2.2.3.2 Competition for moisture

Weeds pose a greater challenge to the growth of soybean particularly when grown under rainfed condition. The competition for soil moisture between weed and crop is crucial, causing a significant reduction in the yield. The transpiration co-efficient of some weeds at flowering stage were 813 for *Cynodon dactylon* and 1402 for *Tridax procumbens*. While, the transpiration co-efficient for crops like jowar, wheat, maize and rice were found to be 437, 557, 337 and 811 respectively (Kanitkar *et al.*, 1960).

The weeds reduce the survival and growth of crop by competing for light, soil moisture and nutrients (Davier and Gardiner, 1985)

2.2.3.3 Competition for light

Competition for light can be visualized under the situation where soil moisture and nutrients are available in plenty (Stahler, 1941). Under these situations crop and weeds would be growing simultaneously, but the weeds due to their vigorous growth and better competing ability than crops, out grow the crop plants in short span of time and shade the crop plants depriving them of much needed solar energy or light. Iwata *et al.* (1983) found that weeds reduce the growth and yield of soybean due to competition for light.

2.2.3.4 Competition for space

Weeds compete with the crop for space both in rhizosphere and atmosphere. Crop plants growing along with weeds develop limited root volume, uptake less moisture and mineral nutrients from the soil as compared to the weed free crop plants. In the presence of weeds, crop plants will have

limited space to develop their shoots, which limits the interception of solar radiation resulting in poor yield.

2.2.3.5 Competition for carbon dioxide

Competition for carbon dioxide may occur when the weed infestation is high. Weeds can deplete carbon dioxide to a very low level compared to crops. When carbon dioxide content is increased artificially from 350 to 700 ppm, the competitive ability of C_3 crop like soybean increased compared to its associated C_4 weed namely *Sorghum halepense* (Reddy and Reddi, 2000).

2.3 METHODS OF WEED CONTROL

Various methods used to control weeds in soybean have their own merits and demerits, so the final choice of any weed control method will depend largely on their effectiveness and economic viability.

2.3.1 Mechanical methods

Mechanical methods of weed control are being employed ever since man started cultivating crops. Although herbicides are fast replacing the traditional methods of weed control, however, the later method is still practiced in India. The mechanical methods include tillage, hoeing, hand weeding, digging, burning and flooding.

Bajpai *et al.* (1984) observed that hand weeding resulted in higher seed yield of soybean (548 to 577 kg ha^{-1}) compared to weedy check. Prakash, *et al.* (1991) opined that two hand weedings at 30 and 45 days after sowing was effective in controlling the weeds and enhancing the seed yield of soybean (25.6 q ha^{-1}) as compared to weedy check (8.7 q ha^{-1})

Sharma *et al.* (1992) reported that hand weeding at 30 and 40 days after sowing produced higher soybean yield (931 g m^{-2}) compared to weedy check (486.76 g m^{-2}). Two hand weedings at 30 and 50 days after sowing resulted in highest seed yield (1514 kg ha^{-1}) in soybean (Chandrakar and Urkurkur, 1993).

Two hand weeding at 30 and 40 days after sowing showed significantly lower weed population and weed dry weight (22 g m^{-2} and 44.6g m^{-2}, respectively) and higher weed control efficiency (86.2%) at Pantnagar (Manjeet Singh and Chandel, 1995). The seed yield was highest (1756 kg ha^{-1}) by following hand weeding twice at 15 and 30 days after sowing (Ramamoorthy *et al.*, 1995).

Nimje (1996) opined that two hand weedings at 20 and 40 days after sowing resulted in higher weed control efficiency (55.1%) and weed suppressing efficiency (55.3%) resulted in higher yield of soybean. Narasimha Reddy *et al.* (1998) recorded significantly higher weed control efficiency with two hand weedings at 25 and 40 days after sowing.

2.3.2 Chemical method

Employing herbicides for weed control constitutes chemical method of weed control. The potential use of herbicides would be to delay weed growth or to check its growth during cropping season.

The progressive modernization of agriculture involving intensive use of herbicides is gaining popularity in recent years due to lower cost, easy and timely application and effectiveness in controlling weeds.

Several investigations were carried out to find out appropriate herbicide that would be effective at lower dose and also gives economic return to the farmers (Mukherjee and Bhattacharya, 1999).

2.3.2.1 Clomazone (Command 50% EC)

Clomazone belongs to substituted diazines isoxazolidinone group. Pre-emergence application of clomazone at 0.8 to 1.4 kg a.i. per ha was effective in controlling annual grasses and broad leaved weeds (Davier and Gardiner, 1985). Sniper *et al.* (1986) recorded excellent yield of soybean by using pre-emergence application of clomazone at 0.5 kg a.i. per ha.

Clomazone alone @ 0.84 kg a.i. per ha as pre-sowing incorporation effectively controlled *Amaranthus retoflexus* and *Cyperus esculentus* but not *Sopmeca hederacea* (Ilinicki *et al.*,1988).

Argenta and Lopes (1991) studied the clomazone effects on pigment accumulation, photosynthetic and respiratory rates of soybean seedlings and found that these processes were not affected by clomazone treatment.

Clomazone at 1.1 kg a.i. per ha as pre-emergence application to the soil surface controlled 80 per cent itch grass whereas pre-sowing incorporation controlled 51.2 per cent itch grass (Griffin, 1991). Krausze *et al.* (1992) opined that clomazone @ 0.56 to 3.36 kg a.i. per ha as pre-emergence application resulted in significant increase in soybean yield (2720 kg ha^{-1}).

Negi and Saini (1994) reported that maximum grain yield with clomazone (1.0 kg a.i. ha^{-1}) and it was found to be the most effective herbicide in controlling weeds except weed free treatment. Basavaraju and Nanjappa

(1996) reported that, a pre-emergence application of clomazone at 1.0 kg a.i. per ha gave significantly higher seed yield (3315 kg ha-1).

Pre-emergence application of clomazone @ 1.5 kg a.i. per ha, pre-plant incorporation of fluchloralin @ 1 kg a.i. per ha, pre-emergence application of alachlor (10G) @ 2 kg a.i. per ha and alachlor (50EC) at 2 kg a.i. per ha, and two hand weedings at 30 and 40 DAS were found effective in controlling weeds in soybean and gave higher grain yield at Indore (Joshi and Billore ,1998).

Rani and Ramana (1998) reported that, among different herbicides tried fluchloralin, alachlor, clomazone and lactofen, pre-emergence application of clomazone, @ 1.0 kg a.i. per ha, gave higher yield and best weed control efficiency. Vyas *et al.* (2000) reported that clomazone at 1.5 kg a.i. per ha, gave a more effective level of weed control and higher seed yield.

2.3.2.2 Alachlor (Lasso 50% EC)

Alachlor belongs to acetamide group which constitutes a prominent group of herbicides. These amides are also called acetanilides. When applied as pre-emergent spray, inhibit seed germination and/or seedling growth. It is commonly used to control most of the annual grasses and certain broad leaved weeds in soybean.

Application of alachlor @ 2.24 kg a.i. ha^{-1} resulted in control of grasses and broad leaved weeds by 100 and 90 per cent respectively (Bhowmik and Mcglew, 1985). When alachlor @ 2.0 kg a.i. per ha, was applied as pre-emergence resulted in efficient control of weeds and enhanced the yield of soybean at Almora (Vedprakash *et al.*, 1991).

Similarly at Bangalore, alachlor at 2.0 kg a.i. per ha, recorded higher seed yield (1447 kg ha^{-1}) (Shekara and Nanjappa, 1993). Kamalabai and Nanjappa (1994) reported that sowing soybean at 22.5 cm along with lower dose of alachlor @ 1.0 kg a.i. per ha, as pre-emergence spray controlled weeds to greater extent (87.8%) and resulted in maximum seed yield (3439 kg ha^{-1}).

Pre-emergence application of alachlor @ 2.0 kg a.i. per ha, resulted in significantly lower weed population and its dry matter, higher dry matter accumulation in plants and number of pods per plant as a result higher seed yield (19.53q ha^{-1}) when compared with weedy check (Chandel *et al.*, 1995).

Manjeet Singh and Chandel (1995) reported that alachlor @ 2.0 kg a.i. ha^{-1} as pre-emergence spray was effective in reducing weed population (By 52.3%) but not as effective as hand weeding.

Shylaja (1996) opined that highest weed control efficiency (91.3%) and hence maximum soybean seed yield (1967 kg ha^{-1}) was with pre-emergence application of alachlor at 2.0 kg a.i. per ha. Highest soybean seed yield (3400 kg ha^{-1}) was recorded in pre-plant incorporation of alachlor at 2.0 kg a.i. per ha, (Basavaraju and Nanjappa, 1997).

Chavan *et al.* (1999) reported that pre-emergence application of alachlor @ 2.0 kg a.i. per ha was found effective in controlling weeds of *kharif* soybean.

2.3.2.3 Pendimethalin

Pendimethalin belongs to dinitro-aniline group. It is used mainly for the control of annual grasses and certain broad leaved weeds in soybean, corn, cotton, Tobacco and rice crops.

Highest seed yield (1916 kg ha^{-1}) of soybean was obtained by pre-emergence application of pendimethalin at 1.0 kg a.i.ha^{-1}, (Dubey *et al.*, 1984).

Singh *et al.*, (1991) reported that application of pendimethalin at 1.0 kg a.i. ha^{-1}, resulted in 47 per cent weed control efficiency and higher seed yield (1168 kg ha^{-1}), but weed control efficiency (54%) and grain yield (1379 kg/ha^{-1}) was significantly less when compared with alachlor at 1.0 kg a-i/ha.

Chandel *et al.* (1995) opined that pre-emergence application of pendimethalin (0.5 kg a.i. ha^{-1}) resulted in better control of weeds and gave higher seed yield when compared with weedy check but, increase in yield and control of weeds were not as effective as alachlor.

There was a better control of grassy weeds in soybean and to some extent broad leaved weeds by the application of pendimethalin (1.0 kg a.i. ha^{-1}) and it produced significantly higher grain yield (870 kg ha^{-1}) when compared with weedy check (435 kg ha^{-1}) (Mishra and Bhan, 1996).

At Dharwad, two inter cultivations plus two hand weedings at 30 and 45 DAS, pre-emergence application of alachlor @ 2.00 kg a.i. per ha or pendimethalin @ kg a.i. per ha gave effective weed control and produced higher grain yield in soybean under rainfed condition (Bandiwaddar , 1997).

2.3.2.4 Chlorimuron- ethyl

Chlorimuron-ethyl belongs to sulfonyl urea group. These sulfonyl-urea group of herbicides are referred to be a new generation herbicides and are applied at very low concentration for effective control of weed. Among this sulfonyl–urea group, chlor-sulfuron herbicides are predominantly used in soybean.

There was only a significant difference in the dry weight of dicot weeds, but not with grassy and sedges dry weight at harvest, whereas chlorimuron applied @ 6 to 24g ha^{-1} as post-emergence herbicides. It provides a fair broad leaved weeds control in soybean and crop had shown wide range of tolerance to this herbicide (Anon., 1992).

Chokkar *et al.* (1996) reported that post-emergence application of chlorimuron at 6.0 g a.i. per ha, proved very effective against most of broad leaved weeds only.

Tiwari *et al.* (1996) opined that all the broad leaf weeds were susceptible to chlorimuron-ethyl at all the levels. There was no significant difference in yield at different levels of chlorimuron ethyl (3 to 48 g a.i. ha^{-1}). The weed control efficiency was 52 to 68 per cent .

The weed control efficiency of chlorimuron-ethyl was higher @ 9 and 12 g a.i. ha^{-1} than 6 g a.i. ha^{-1}. Weed control efficiency of chlorimuron-ethyl applied at one and 3 DAS was almost similar, but WCE was reduced when applied at 7 DAS irrespective of application (AICRPWC, 1994 and 1996).

Chlorimuron @ 12 g a.i. per ha applied at 20 DAS provided an average of 89 per cent *Trianthema portulacastrum* control and it failed to provide any control of barnyard grass. But, sequential application of pre-plant trifluralin @ 1000 g a.i. per ha and post-emergence chlorimuron @ 4 or 8 g a.i. per ha provided an average of 94 per cent *Trianthema portulacastrum* and 9 per cent barnyard grass control in soybean in sandy loam soil (Balyan and Pahwa, 1998). Balyan and Malik (1998) also indicated the better control of *Trianthema portulacastrum* when applied at 20 DAS rather than 30 DAS and to effectiveness against barnyard grass.

Sahadeva Singh and Bhan (1998) noticed significant reduction in weed density and weed dry weight with the application of chlorimuron @ 15 to 25 g a.i. ha^{-1} in soybean.

At Dharwad, *Commelina benghalensis*, predominate weed in soybean fields of medium black soils could be effectively controlled by chlorimuron. Chlorimuron can be used as pre, as well as post-emergence application up to 10 DAS at 9 and 12 g a.i. ha^{-1} for effective control of both grassy and dicot weeds in soybean (Babalad *et al.*, 1999).

2.3.2.5 Metribuzin (Sencor 70%WP)

Metribuzin belongs to substituted triazoles. Kurchania *et al.* (1989) reported that metribuzin @ 0.3 kg a.i. per ha as pre-emergence application provided 39% weed control compared to 94% control from hand weeding at 20 days after sowing.

Reddy *et al.* (1990) opined that metribuzin @ 0.5 kg a.i. per ha pre emergence application resulted in higher seed yield than with the higher doses of the herbicide.

Metribuzin @ 0.5 kg a.i. per ha or higher dose controlled more than 90 per cent of *Common hempnettle* (*Galeopsis tetrahit*) (Ivany *et al.*, 1992). Pre-emergence application of metribuzin @ 0.63 kg a.i. per ha gave good control of *Euphorbia heterophylla* (Willard and Griffin, 1993).

2.3 INFLUENCE OF HERBICIDES ON SOIL BIOCHEMICAL ACTIVITIES

Microbial activity occupy an unique position in biological cycles in terrestrial habitats as they are essential for maintenance of soil fertility and

plant growth. During cropping season more than one pesticide may go into soils and affect the microbial equilibrium and enzyme activity.

Among all the selected enzymes urease is of much importance as a urea hydrolyser. Preference to urea over other ammonical fertilizer adds to the importance of this enzyme. Dehydrogenase is considered to play a very essential role in the process of organic material oxidation. Phosphatases also equally plays an important role in phosphate solubilization and mineralization in soil.

Herbicides applied at recommended rates generally have no harmful effects on microscopic population due to its biochemical activities. Only at higher concentrations, they are toxic, often first sign of inhibition does not appear until herbicide levels of 100 times the accepted rates are added to soil (Martin Alexander, 1961).

In silt clay loam and loamy sand, the effects of 25 selected herbicides and their combination in amounts comparable to those used in agriculture was studied by Lewis *et al.* (1978) and they concluded that there was no significant inhibition of dehydrogenase activity.

Heinonen-Tanki *et al.* (1985) found that chlorsulfuron and glyphosate applied at normal rate (NR) and 3 times NR had little effect on soil dehydrogenase activity and nitrification in clay soil.

Pozo *et al.* (1994) reported that the presence of 2 to 10.0 kg a.i. per ha of alachlor increased the total number of bacteria and fungi but aerobic nitrogen fixing bacteria and nitrogenase activity decreased at alachlor concentrations of 3.5 to 10.0 kg a.i. per ha. Acid and alkaline phosphatases, arylsulfatase and dehydrogenace activity decreased significantly initially at

concentrations of 5.0-10.0 kg a.i. per ha but recovered to levels similar to those in the control.

The effect of chlorsulfuron and metsulfuron (Junnila *et al.*, 1994) on dehydrogenase activity was very small. Sulfonylurea herbicides (Chlorsulfuron, metsulfuron methyl, sulfometuron-methyl and bensulfuron-methyl) have low impact on micro-organisms in relation to their mode of action and low doses needed for effective weed control (Allievi, 1996).

Chandrashekhar Rao and Saroja Raman (1998) reported that pendimethalin, anilophos, butachlor, benthiocarb and pretilachlor used at recommended rate were non-inhibitory in their effect on dehydrogenase activity in flooded rice soils.

Alachlor, propaquizofop, imazethapyr and fenoxyprop stimulated the urease activity on soil enzymes (Ramesh *et al.*, 1999 and 2000).

The sulfonyl urea herbicide, triasulfuron applied upto two fold the recommended agricultural rate had no effect on the total population of micro-orthropods, mites and spring tails in two soils *viz.*, clay and sandy loam soils (Rebecchi *et al.*, 2000).

2.4 ECONOMICS OF WEED CONTROL

The choice of any weed control method depends to a great extent on the cost involved and its relative efficiency to control weeds. Herbicides can be profitably used as an alternative to hand weeding in situation where labour is scarce and costly (Vachani *et al.*, 1963).

Average net return was higher with hand weedings at 20 and 40 days after sowing (Rs.8223 ha^{-1}) over other treatments (Rs.5496 ha^{-1}) in soybean (Singh and Sharma, 1990).

Chandrakar and Urkurkur (1993) reported that two hand weeding at 30 to 50 days after sowing gave significantly higher net returns (Rs.2820/ha) in soybean. Chandel *et al.* (1995) reported that two hand weedings at 30 and 45 days after sowing resulted in more net return (Rs.8286 ha^{-1}) followed by alachlor at the rate of 2.0 kg a.i. ha^{-1} (Rs.6943 ha^{-1}) and pendimethalin at 0.5 kg a.i. ha^{-1} (Rs.4758 ha^{-1}) during 1989.

Net return (Rs.1779 ha^{-1}) was significantly lower in weedy check and highest (Rs.5162 ha^{-1}) in treatment where intercultural was done at 30 days after sowing. Application of chlorimuron-ethyl resulted in higher net return of Rs.2793 per ha during 1992 (Dubey *et al.*, 1996).

Billore and Joshi (1998) reported that pendimethalin @ 1.0 kg a.i. per ha produced dwarf plants with the best yield attributes and seed yield. Whereas, hand weeding gave the highest stover yield. However, the highest net returns were achieved with pendimethalin followed by hand weeding and clomazone @ 1.5 kg a.i. per ha.

Maximum profit per rupee invested and additional net returns were obtained with pre-plant incorporation of alachlor granules @ 2.0 kg a.i. per ha followed by metribuzin @ 0.25 kg a.i. per ha (Shylaja, 1996).

2.5 RESIDUAL EFFECT OF HERBICIDES

2.5.1 Alachlor

Abd-El-Rauof *et al.* (1985) reported that residual effect of alachlor applied to soybean crop grown as a preceding crop showed insignificant effects on succeeding crops such as wheat and soybean.

The germination count, plant height and dry matter of sorghum grown as an indicator plant was not significantly affected by the residual effect of alachlor applied to soybean, grown as a preceding crop. It can be concluded that under field conditions a lapse of three months period was sufficient enough to bring down the concentration of herbicide applied to preceding crop (Anon., 1995a).

2.5.2 Pendimethalin

Pendimethalin could not be detected in black and red soils of sunflower and groundnut trials after harvest of crops (after 90 to 120 days). In another experiment, results revealed that pendimethalin applied to preceding crop (wheat) did not leave any adverse level of their residues in succeeding crops (Anon., 1994).

Gautam *et al.* (1994) revealed that about 50 per cent of the pendimethalin residue dissipated within 7 days after application in groundnut applied @ 1.0 and 2.0 kg a.i. per ha and on 45th day about 98 per cent of residue has been eliminated in both doses. Over 90 per cent of pendimethalin was lost within 40 days and 60 days when pendimethalin was applied @ 1.0 and 1.5 kg a.i. ha^{-1} respectively to soybean crop (Anon., 1995b).

2.5.3 Clomazone

No visible phytotoxic symptoms on soybean were observed with clomazone (0.56 to 3.36 kg a.i. ha^{-1}) and chlorimuron (0.02-0.14 kg a.i. ha^{-1}) treatment and no reduction in soybean density, height or yield. Some differences in wheat yield were observed between treatments but they were not significant. Maize population density, number of ears, ear weight and yield showed no adverse effects of herbicide residues (Krausze *et al.*, 1992).

Kumar (1997) reported that germination count, drymatter accumulation, shoot and root length of maize, fingermillet, greengram, cowpea, tur, sunflower, groundnut, bhendi, greenpea and cucumber were not affected by residues of chlorimuron @ 6 to 15 g a.i. per ha as early post emergence, alachlor @ 1.0 kg a.i. per ha and pendimethalin @ 1.0 kg a.i. per ha as pre-emergence spray of herbicides applied to soybean.

From these available reviews, it can be summarized that weed flora vary from location to location in the same crop and cause devastating effect on crop yield by competing for moisture, nutrients, space and light. Weed competition during initial 20 to 40 days is very serious and results higher crop losses.

The cost of chemical weed control is actually less than that of manual weeding. This has been a major incentive to many farmers for switching over to herbicides. Moreover, most of the herbicides used for soybean will not persist in soil more than one season. Inspite of several advantages realized by the use of herbicides, manual methods are essential to avoid possible pit falls and hazards of excessive dependence on chemical methods.

Material and Methods

III. MATERIAL AND METHODS

The details of the material used and methods adopted in the study on "Bio-efficacy of clomazone herbicide for weed management in soybean (*Glycine max* (L.) Merrill)" at Main Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2001 are described in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

The experiment was carried out at the Main Research Station, Dharwad, which is located at a latitude of 15° 07^{1} and longitude of 75° 21^{1} E and with an altitude of 678m above mean sea level.

3.2 SOIL CHARACTERISTICS OF EXPERIMENTAL SITE

The soil of the experimental site belongs to chromoustert which is black clay loam in nature. The topography of the experimental site was fairly uniform. Composite soil sampling was made from the experimental site from 0 to 15 cm depth before sowing of the crop. The physical and chemical properties of the soil along with the methods employed and values obtained are presented in Table 1.

The soil of the experimental site is medium deep black with clay, silt, fine sand and coarse sand content of 68.2 ,22.5,4.7 and 4.6 per cent, respectively.

The field capacity and wilting coefficient of the soil is 36 and 16 per cent, respectively with the bulk density of 1.22 Mg/m^{3}. The pH and electrical conductivity of the soil is 7.5 and 0.5 dS/m. The soil is medium in organic carbon (0.43%), available nitrogen (221 kg ha^{-1}), available P_2O_5 (31 kg ha^{-1}) and available K_2O content (330 kg ha^{-1}).

Table 1: Physical and chemical properties of soil of the experimental site

Particulars	Values	Methods employed
1. Physical properties		
a. Particle size distribution		International pipette method (Piper, 1966)
Coarse sand (%)	4.6	
Fine sand (%)	4.7	
Silt (%)	22.5	
Clay (%)	68.2	
b. Field capacity (%)	36.0	Field method (Dastane, 1967)
c. Wilting co-efficient (%)	16.0	Sunflower method (Dastane, 1967)
d. Bulk density (Mg/m^3)	1.22	Core sampler method (Dastane, 1967)
2. Chemical properties		
a. Soil reaction (pH) (1:2.5)	7.5	Potentiometric method (Piper, 1966)
b. Electrical conductivity (dSm^{-1})	0.5	Electrical conductivity bridge
c. Organic carbon (%)	0.43	Walkley and Black's wet oxidation method (Jackson, 1973)
d. Available N ($kg\ ha^{-1}$)	221.0	Alkaline permanganate method (Subbaiah and Asija, 1956)
e. Available P_2O_5 ($kg\ ha^{-1}$)	31.0	Olsen's method (Jackson, 1973)
f. Available K_2O ($kg\ ha^{-1}$)	330.0	NH_4OAC extract method (Jackson, 1967)

3.3 CLIMATIC CONDITIONS

The Main Research Station is situated in the Northern Transitional Zone (Zone 8) of the state. The zone receives the rainfall from both South-West and North-East monsoons and hence, the rainfall is well distributed from June to November with lower coefficient of variation. The monthly meteorological data of rainfall, temperature and relative humidity for the year 2001 and average of the past 51 years (1950-2000) as recorded at the meteorological observatory of the Main Research Station, Dharwad is furnished in Table 2 and depicted in Fig 1.

The total rainfall received during the experimental year (2001) was 269.6 mm which was 515.13 mm lesser than the average of a past 51 years (1950-2000).

3.3.1 Climatic conditions during the period of experimentation

During the period of experimentation (8th July to end of September 2001) a rainfall of 144.8mm was received. The mean maximum and minimum temperatures during the period of experimentation ranged from 26.8°C (July) to 30.1°C (September) and 20.2°C (September) to 21.1°C (July) respectively. The mean relative humidity was highest during the months of July to August(80%) and lowest in the month of September (72%).

3.4 CROPPING HISTORY OF THE EXPERIMENTAL SITE

Previous crops grown in the experimental site during 2000-2001 were soybean (*kharif*) and wheat (*rabi*).

Table 2: Monthly meteorological data for the year 2001 and average of past 51 years (1950-2000) of Main Research Station, University of Agricultural Sciences, Dharwad

Months	Rainfall (mm)		Temperature (°C)				Mean relative humidity (%)	
			Mean maximum		Mean minimum			
	2001	1950-2000	2001	1950-2000	2001	1950-2000	2001	1950-2000
January	0.00	0.10	29.90	29.21	15.00	14.11	55.00	63.90
February	0.00	0.00	34.00	34.61	16.80	15.95	50.00	51.25
March	0.00	7.37	35.30	35.76	18.50	18.78	45.00	56.92
April	52.10	47.90	35.70	37.10	22.00	21.32	55.00	78.28
May	23.10	84.61	34.80	36.59	21.50	21.45	59.00	67.16
June	32.50	113.10	30.30	29.48	21.30	21.20	75.00	82.00
July	33.10	153.11	26.80	27.04	21.10	20.95	81.00	87.88
August	58.10	98.67	27.20	27.02	20.90	20.63	81.00	86.83
September	53.60	104.97	30.10	28.74	20.20	20.17	72.00	82.86
October	17.00	135.39	30.10	30.10	19.90	19.27	65.00	77.04
November	0.00	33.75	31.00	29.39	17.90	15.41	55.00	68.68
December	0.00	5.76	29.60	29.15	13.70	13.41	55.00	64.58
Total	269.60	784.73	-	-	-	-	-	-

D = Deficit/excess from average of 1950-2000

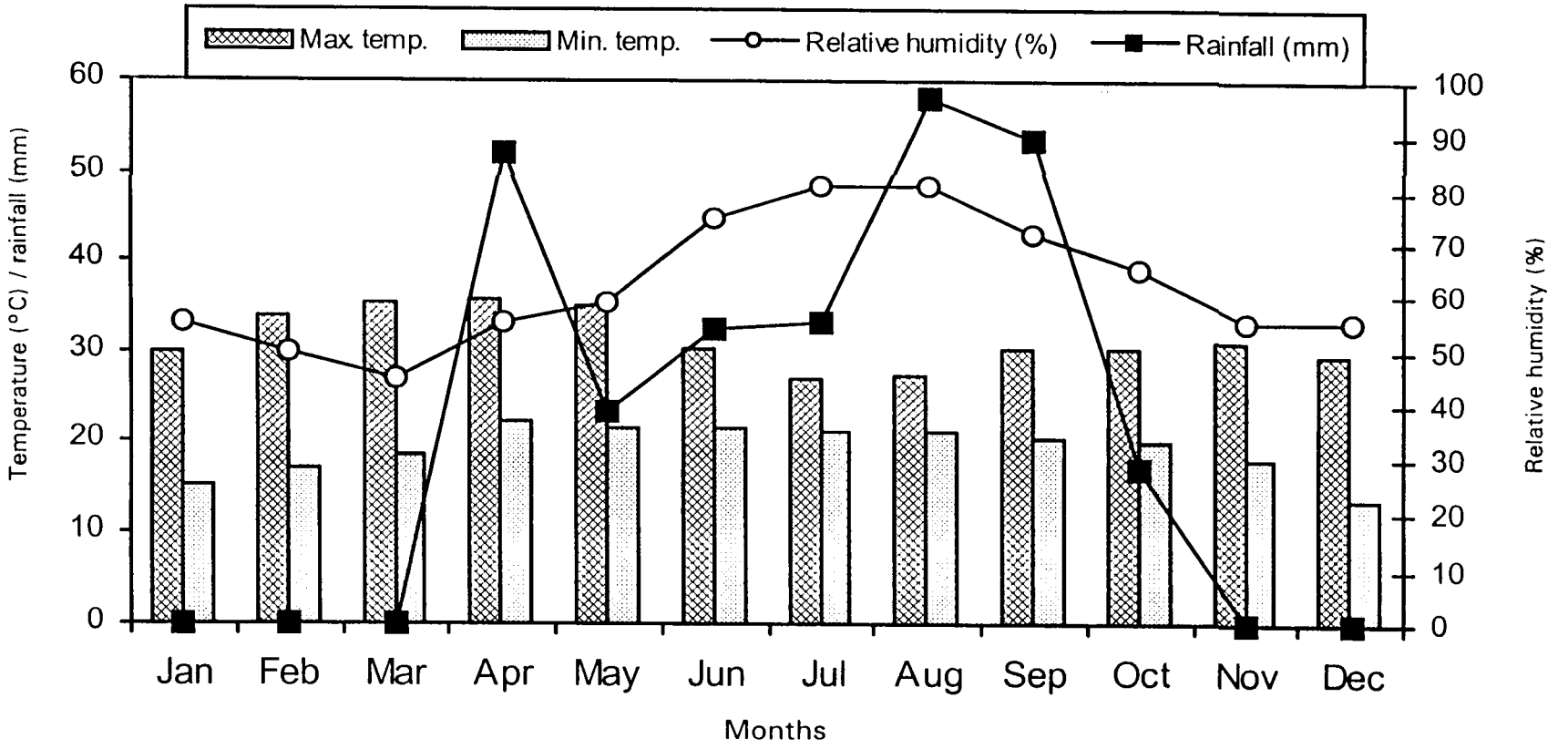

Fig. 1. Monthly meteorological data for the year 2001 and average of 51 years (1950-2000) as recorded at the Meteorological Observatory, MRS, UAS, Dharwad

3.5 EXPERIMENTAL DETAILS

3.5.1 Treatments

There were twelve treatment combinations comprising of pre-emergence application of clomazone @ 625,750, 875 and 1000 g a.i. ha^{-1}, clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} and clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250g a.i. ha^{-1}, alachlor @ 2500 g a.i.ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1}, chlorimuron @ g a.i. ha^{-1}, one hand weeding and one intercultivation, weed free and weedy check.

Treatment details

T_1 : clomazone @ 625 g a.i.ha^{-1} as pre-emergence

T_2 : clomazone @ 750 g a.i.ha^{-1} as pre-emergence

T_3 : clomazone @ 875 g a.i.ha^{-1} as pre-emergence

T_4 : clomazone @ 1000 g a.i.ha^{-1} as pre-emergence

T_5:clomazone @ 500 g a.i.ha^{-1} + Chlorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_6:clomazone @ 500 g a.i.ha^{-1} + Metriburin @ 250g a.i.ha^{-1} as pre-emergence

T_7: Alachlor @ 2500 g a.i.ha^{-1} as pre-emergence

T_8: Pendimethalin @ 1000 g a.i.ha^{-1} as pre-emergence

T_9:Chorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_{10}: One hand weeding at 20 DAS + one intercultivation at 40 DAS

T_{11}: Weed free check

T_{12}: Weedy check.

3.5.2 DESIGN AND LAYOUT

The experiment was laid out in a randomized block design with three replications. The plan of layout of the experiment is given in Fig.2.

3.5.3 Plot size

Gross plot : 5.0 m x 3.6m = 18.00 m^2

Net plot : 4.0 m x 2.4 m = 9.6 m^2

3.5.4 Crop variety

Soybean variety JS-335 was used. This is recently developed and released variety with a pedigree of JS-78 x JS -71-05. This is high yielding variety with tolerance to pod shattering for 10 to 15 days.

3.6 CULTURAL PRACTICES

3.6.1 Land preparation

The land was ploughed twice with tractor and fine seed bed was prepared with two harrowings. The experimental area was laid out as per the plan.

3.6.2 Fertilizer application

The entire quantity of recommended fertilizer dose of 20 kg N, 80kg P_2O_5 and 40 kg K_2O ha^{-1} were applied in the form of urea, single super phosphate and muriate of potash, which were incorporated into the soil just before sowing.

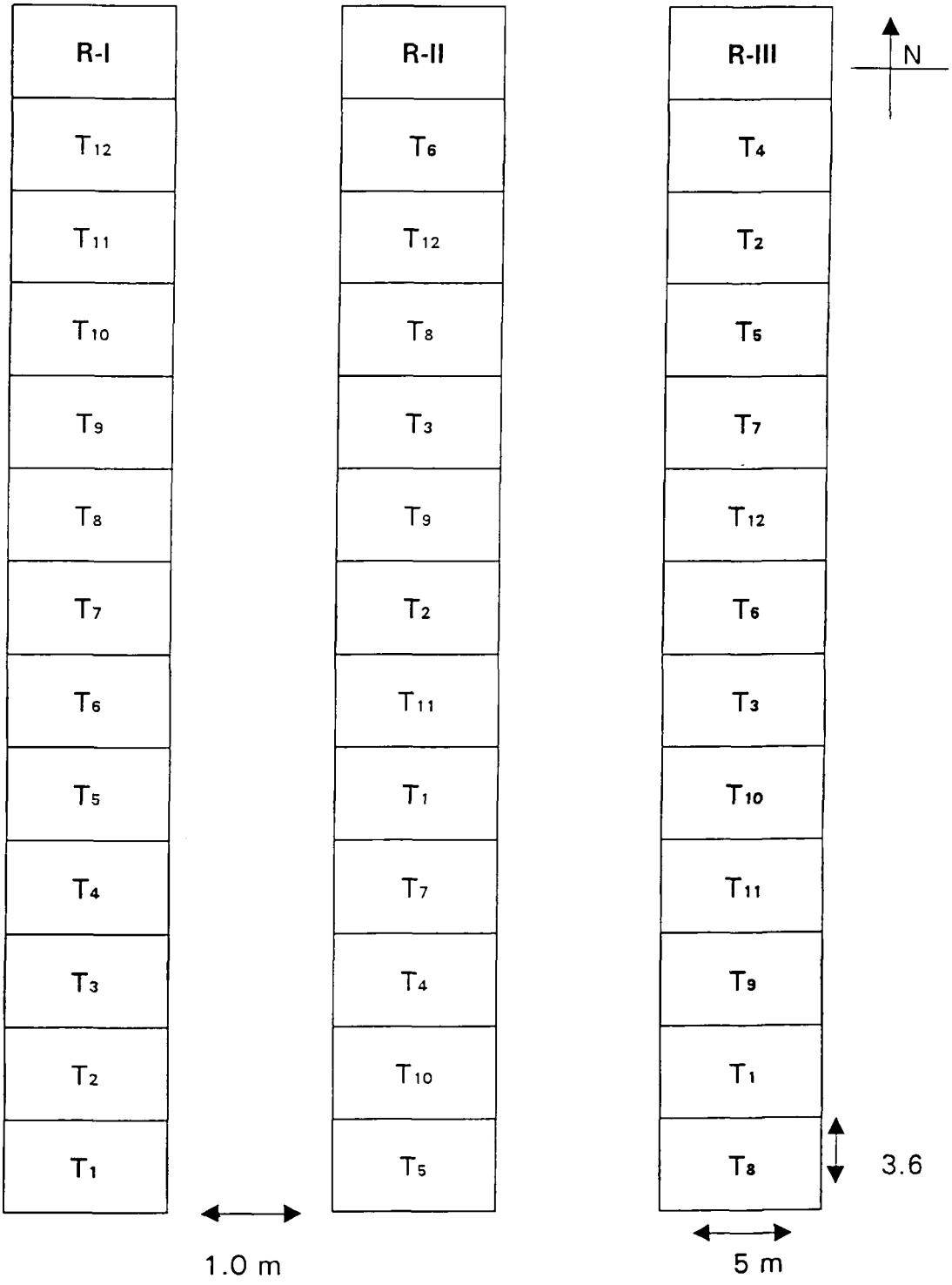

Fig. 2: Plan of Layout of the Experiment

3.6.3 Sowing

The spacing adopted was 30 cm between furrows. The soybean seeds were sown at an interval of 10 cm and at a depth of 4 to 5cm on 8th July, 2001. The seeds used at the rate of 75 kg ha^{-1}.

3.6.4 Pre-emergence spraying of herbicides

Immediately after sowing (on 8th July 2001) the herbicides were sprayed with the help of hand operated knapsack sprayer with the spray volume of 750 l per ha as per the treatment.

3.6.5 After care

In hand weeding + intercultivation treatment (Treatment 10), one hand weeding was done at 20 DAS and one intercultivation was carried out at 40 DAS. In weed free condition treatment, the weeds were removed frequently by removing the weeds manually as and when they emerged to create weed free condition.

3.6.5.1 Plant protection

To control insect pests on soybean, chlorpyriphos @ 2ml per l of water was sprayed at 40 days after sowing and chlorphyriphos @ 2 ml per l + contaf @ 1 ml per l at pod development stage to manage key insect pests of soybean *viz.*, *Spodoptera* sp. and *Cydia ptychora* and rust in soybean.

3.6.5.2 Harvesting

The plants were cut at ground level from the net plot on 25th September 2001 and sun dried. After drying, plants were threshed by beating with sticks manually. Seed yield and the straw yield per plot were recorded separately.

3.7 BIOMETRIC OBSERVATIONS

In the net plot, one square meter area was marked and weed counts were recorded at different growth stages. Destructive sampling area was utilized for dry matter production studies of both crop and weeds. At the time of harvest, seed yield, stalk yield, growth and yield component observations and dry weight of weeds were recorded from the net plot.

3.7.1 Observations on crop growth

3.7.1.1 Plant height

The plant height (cm) was recorded on five randomly selected plants at 30, 60 days after sowing and at harvest. Plant height was measured from ground level to the base of fully opened youngest leaf.

3.7.1.2 Number of branches per plant

Number of branches of each plant were counted on five randomly selected plants, averaged and expressed as number of branches per plant.

3.7.1.3 Number of leaves per plant

The number of fully opened trifoliate leaves were counted on five randomly selected plants at 30 and 60 days after sowing. It was expressed as number of leaves per plant.

3.7.1.4 Leaf area (LA) (dm^2 $plant^{-1}$)

Leaf area was measured by disc method as suggested by Vivekanandan *et al.* (1972). Fifty leaf discs of known size were taken using a cork borer (punch) from randomly selected 25 leaves from five plants. Both discs and

remaining leaf blades were oven dried at 80°C and leaf area was calculated at 30 and 60 days after sowing using the formula ;

$$LA = \frac{Wa \times A}{Wd}$$

Where, LA = leaf area (dm^2/plant)

Wa = Oven dry weight of all leaf lamina (inclusive of 50 disc weight) in g

Wd = Weight of 50 discs in g

A = Area of 50 discs in dm^2

The mean of five plants was recorded and expressed as leaf area $plant^{-1}$.

3.7.1.5 Leaf area index (LAI)

Leaf area index was worked out by dividing the leaf area per plant by land area occupied by plant and is defined as assimilatory surface per unit land area according to Sestak *et al.* (1971).

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Land area occupied by plant } (dm^2)}$$

The leaf area index was estimated at 30 and 60days after sowing.

3.7.1.6 Absolute growth rate (AGR)

Absolute growth rate is measure of dry matter produced per unit time and expressed in g per plant per day. It was calculated by using the formula (Radford, 1967);

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weight of plants (g) at time t_1 and t_2 respectively.

$t_2 - t_1$ = Time interval between two stages

3.7.1.7 Relative growth rate (RGR)

It is the increase in dry weight per unit dry weight per unit time and is expressed as grams per gram per day (Blackman, 1919) and was calculated using the formula;

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 are dry weight of plant (g) at time t_1 and t_2 respectively.

$t_2 - t_1$ = Time interval between two stages

$\log_e$ = Natural logarithm

3.7.1.8 Net assimilation rate (NAR)

It is the rate of increase in dry weight per unit leaf area per unit time (Watson *et al.*, 1952) and is expressed as g per dm^2 per day. It was calculated by using the formula as suggested by Radford (1967);

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where, W_1 and L_1 are dry weight per plant (g) and leaf area (dm^2) at time t_1, respectively.

W_2 and L_2 are dry weight per plant (g) and leaf area (dm^2) at time t_2, respectively.

t_2-t_1 = Time interval between two stages

Loge = Natural logarithm

3.7.1.9 Crop growth rate (CGR)

CGR is the rate of drymatter produced per unit land area per unit time (Watson *et al.*, 1952) and is expressed as g per dm^2 per day. It was calculated by using the formula;

$$CGR = NAR \times LAI$$

Where, NAR = Net assimilation rate (g dm^{-2} day^{-1})

LAI = Leaf area index

3.7.1.10 Drymatter production and distribution

Five randomly selected plants were cut from sample plot area at ground level and partitioned into different parts *viz.*, leaves, stem and pods. These samples were first air dried and then oven dried at 80°C till constant dry weight was obtain and expressed in gram per plant.

3.7.2 OBSERVATION ON WEED GROWTH

3.7.2.1 Weed control and crop toxicity ratings

Weed control and phytotoxicity ratings were computed by employing EWRS (European Weed Research System) ratings (Anon., 1981). Weed control

ratings were recorded by visual observation at 20 and 40 DAS and at harvest. Crop toxicity ratings were also recorded by visual observation thrice at ten days interval starting from three days after spraying of herbicides.

3.7.2.2 Weed count

Observations on monocots, dicots, sedges and total weed population were recorded from the marked one square metre area in the net plot at 20 and 40 DAS and at harvest.

3.7.2.3 Drymatter production of weeds

Monocots, dicots and sedges were removed separately from 0.25 m^2 destructive sampling area. They were oven dried at 65°C to a constant weight and dry weight was recorded at 20 and 40 days after sowing and at harvest and expressed in grams.

At the time of harvest, for the dry matter production of weeds in net plot weeds were removed, dried and dry weight was recorded and was converted to hectare basis.

3.7.2.4 Weed control efficiency

Weed control efficiency on dry weight basis was calculated using the formula;

$$WCE\ (\%) = \frac{X - Y}{X} \times 100$$

Where,

WCE = Weed control efficiency (%)

X = Oven dry weight of weeds recorded from weedy check (g)

Y = Oven dry weight of weeds recorded from treated plots (g)

3.7.2.5 Weed index

The weed index was calculated on seed yield basis using the formula;

$$WI\ (\%) = \frac{\text{Yield from weed free plot} - \text{Yield from treatment plot for which weed index to be worked out}}{\text{Yield from weed free plot}} \times 100$$

3.7.3 Yield and yield attributing characters

3.7.3.1 Seed yield

Yield from the net plot was recorded by taking the weight of seeds after threshing, cleaning and drying. The seed yield of net plot was converted into kg per hectare.

3.7.3.2 Haulm yield

After harvest of net plots, the yield of above ground dry matter was recorded after drying and before threshing. Haulm yield per net plot was computed by substracting the seed yield per net plot area. From this net plot, Haulm yield was converted to yield per hectare and expressed in kg per hectare.

3.7.3.3 Number of pods per plant

At harvest, the number of pods were counted from five randomly selected soybean plants in the net plot area and mean was worked out.

3.7.3.4 Pod weight per plant

The number of pods counted from five tagged plants were weighed and averaged and expressed as pod weight per plant in grams.

3.7.3.5 Number of seeds per plant

The number of seeds were counted from five randomly tagged soybean plants in the net plot area and the mean was worked out.

3.7.3.6 Number of seeds per pod

The number of seeds per pod were counted from ten randomly selected pods and mean was worked out.

3.7.3.7 Seed yield per plant

The number of seeds counted form five tagged plants were weighed and average was worked out as seed yield per plant in gram.

3.7.3.8 Hundred seed weight

Hundred seeds were randomly selected from the net plot yield and weight was recorded as test weight in grams.

3.7.3.9 Harvest index (HI)

The harvest index was worked out by using the formula;

$$H.I. = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Total biological yield (kg ha}^{-1})}$$

3.7.4 Nutrient uptake by crops and weeds

Soybean plant and weed samples collected from each plot at the time of harvest were dried and then ground in a willey mill to pass through 40 mesh sieve. The ground material was collected in butter paper bags and later used for chemical analysis.

Total nitrogen content in the composite sample (stem, leaves and pods) was estimated by modified micro kjeldhal's method (Jackson, 1973) and expressed in percentage on drymatter.

For analysis of phosphorus and potassium, plant samples were pre digested with concentrated HNO_3 and triacid mixture (HNO_3: $HCLO_4$: H_2SO_4 at 10:4:1) were used for digestion of composite weed and plant samples. Phosphorus content in samples was determined by vanado molybdo-phosphoric yellow colour method using spectro photometer at 470 nm (Jackson, 1973).

Potassium content in plant sample was determined by flame photometric method (Jackson, 1973) and was expressed in percentage.

Nitrogen, phosphorus and potassium uptake was calculated for plants and weeds for each treatment separately using the formula and expressed in kg ha^{-1};

$$\text{Nutrient uptake} = \frac{\text{Nutrient concentration (\%)}}{100} \times \text{Biomass (kg ha}^{-1}\text{)}$$

3.8 SOIL ENZYME ACTIVITIES

3.8.1 Dehydrogenase activity

Dehydrogenase activity in the soil samples at 20 DAS was determined by following the procedure as described by Casida *et al.* (1964). Ten g of soil and 0.2g $CaCO_3$ were thoroughly mixed and dispensed into conical flasks. Each flask was added with 1ml of 1.5 per cent 2, 3, 5-triphenyl tetrazolium chloride (TTC), 1ml of 1 per cent glucose solution and 8ml of distilled water which was sufficient to leave a thin film of water above the soil layer. The flasks were stoppered with rubber bungs and incubated at 30°C for 24 hours. At the end of incubation, the contents of the flask were rinsed down into small

beaker and a slurry was made by adding 10ml of methanol. The slurry was filtered through whatman No.42 filter paper. Repeated rinsing of soil with methanol was continued till the filtrate ran free of red colour. The filtrate was made upto 50 ml with methanol in volumetric flask. The intensity of red colour was measured at 485nm against a methanol blank using spectrophotometer. *The standard curve preparation*: graded concentration of TTC (0.0-500µg) were prepared in methanol. In each tube 5ml of phosphate buffer (7.4 pH) and adequate amount (150mg) of fresh sodium dithionate ($Na_2S_2O_4.H_2O$) was added. When the reduction was complete the pink colour intensity of graded concentration of TPF was read as before. The results were expressed as µg of Triphenyl Formazon (TPF) formed per g of soil per day.

3.8.2 Urease activity

The urease activity of soil at 20 DAS was determined by the procedure as adopted by Pancholy and Rice (1973), except the ammonia liberated due to hydrolysis of urea in the reaction mixture was determined by Nesslerization (Jackson, 1973).

Ten g of freshly collected soil samples were placed in 100ml erlenmeyer flask to which 1ml of toluene was added and allowed to stand for 15 min to permit complete penetration in to soil. To each of these flasks were added 20ml of phosphate buffer (pH 6.7) and 10ml of 10 per cent urea solution. For control flasks urea solution was replaced with equal quantity of distilled water. The contents of the flasks was shaken for 5min and incubated at 30°C for 24 hrs. After incubation, the contents of the flasks were filtered though whatman No.42 filter paper. The remaining soil in the flask was added with 15ml of 1N KCl containing 150 ppm $HgCl_2$, shaken for 5 min and filtered. The volume of

the total filtrate was made upto 100 ml in a volumetric flask using distilled water.

The amount of ammonia present in the filtrate was measured by Nesslerization. One ml of filtrate of each sample was transferred to a 25ml volumetric flasks to which two ml of 10 per cent sodium tartarate solution and 0.5 ml of Nessler's reagent were added and volume was made up to the mark. Yellow colour developed after 30min was measured at 410nm using spectrophotometer against respective reagent blank.

The results obtained were expressed as μg of ammonia liberated per g of soil per day with reference to a standard curve obtained by using graded concentration (0-50 μg ml^{-1}) of $(NH_4)_2 SO_4$.

3.8.3 Phosphatase activity

Phosphatase activity of soil sample was determined by following the procedure of Eivazi and Tabatabai (1979).

One g of soil sample was placed in 50ml Erlenmeyer flask, to which 0.2ml toluene followed by four ml of modified universal buffer (pH 6.5) were added 1ml of para-nitrophenyl phosphate solution made in modified universal buffer was added to the flasks and contents of the flasks mixed by swirling for two minutes. The flasks were stoppered and incubated at 37°C for one hour. After incubation, one ml of 0.5M $CaCl_2$ and four ml of 0.5M NaoH were added to the flask, swirled and filtered through whatman No.42 filter paper. The intensity of yellow colour developed was measured at 420nm against the reagents blank using spectrophotometer (Shimadzu model uv-240).

Controls were also performed for each soil sample following the same procedure described above except that the paranitrophenyl phosphate solution

was added after the addition of 0.5 M $CaCl_2$ and 0.5M NaOH and just before filtration. The phosphatase activity in the soil samples was expressed as µg paranitrophenol per gram soil per hour with reference to the standard curve prepared by using graded concentrations of paranitrophenol solution.

3.9 STUDIES ON RESIDUAL TOXICITY

After the harvest of main crop, bio-assay studies were made to study the *in-situ* evaluation of residual effect of herbicides on succeeding crops such as sorghum, chickpea, safflower, bhendi and wheat in net plot area. Fifty seeds of each crop were sown in each plot and observations on germination count (%), shoot length (cm), root length (cm) and oven dry weight (g) of plants were recorded at 20 days after sowing.

3.10 TRANSFORMATION OF DATA

Data on weed count showed high variation. To make the analysis of variance more valid the data on weed count were subjected to square root transformation by using formula $\sqrt{x+0.5}$ (Chandel, 1984).

3.11 STATISTICAL ANALYSIS AND INTERPRETATION OF DATA

The data were analysed statistically for test of significance following the procedure described by Gomez and Gomez (1984). The results have been discussed at the probability level of five per cent.

3.12 CORRELATION STUDIES

Correlation co-efficients were worked out for seed yield versus weed dry weight at harvest and yield attributing characters in soybean as per the procedure outlined by Gomez and Gomez (1984).

3.13 ECONOMIC ANALYSIS

Economics of weed control was worked out by considering the current price of inputs and produce (soybean), gross returns ($Rs.ha^{-1}$), net returns ($Rs.ha^{-1}$) and benefit cost ratio were worked out by using the following formulae;

Gross return ($Rs.ha^{-1}$) = Seed yield (kg ha^{-1}) x Market price of seed kg^{-1}

Net return ($Rs.ha^{-1}$) = Gross returns ($Rs.ha^{-1}$) - cost of cultivation ($Rs.ha^{-1}$)

$$\text{Benefit cost ratio} = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$$

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the field experiment on bio-efficacy of clomazone herbicide for weed management in soybean (*Glycine max* (L.) Merrill) conducted during *kharif* season of 2001 at Main Research Station, Agriculture College, Dharwad are presented in this chapter.

4.1 WEEDS OBSERVED IN THE EXPERIMENTAL FIELD

The important weed species observed in the experimental field includes monocots like *Commelina benghalensis* L., *Cynodon dactylon* L., *Dinebra retroflexa* L., *Digitaria longifolia* L., *Echinochloa colona* and *Panicum isachne* dicot weed species like *Acanthospermum hispidum* DC., *Achyranthus aspera, Ageratum conyzoides* (L.), *Amaranthus viridis, Celosia argentea, coccullus villosus, Digera arvense, Euphorbia geniculata* Ort., *Hibiscus ponderiformis, Mollugo diestica, Phyllanthus niruri* L. and *Sida acuta* and among sedges *Cyperus rotundus*.

4.2 STUDIES ON WEED CONTROL RATINGS AND CROP TOXICITY RATINGS

Visual observations recorded on weed control ratings at 20 and 40 days after sowing and at harvest and crop toxicity ratings at 10, 20 and 30 days after spraying the herbicides are presented in table 3.

4.2.1 Weed control ratings

Differences in weed control ratings were noticed among weed control treatments. Weed free condition was excellent throughout the crop growth period. One hand weeding at 20 DAS + one intercultivation operation at 40 DAS gave poor weed control at 20 DAS, later on it gave acceptable level of

Table 3: Weed control and crop toxicity ratings (EWRS)* as influenced by weed control treatments at different crop growth periods in soybean.

Treatments	Weed control rating			Crop toxicity rating		
	20 DAS	40 DAS	At harvest	I	II	II
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	5	6	6	1	1	1
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	4	5	5	1	1	1
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	3	3	3	1	1	1
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	3	3	3	2	1	1
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	3	3	4	1	1	1
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	3	3	4	1	1	1
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	3	3	4	1	1	1
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	5	5	5	1	1	1
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	4	4	4	1	1	1
T_{10} : One HW at 20 DAS and one IC at 40 DAS	9	2	2	1	1	1
T_{11} : Weed free check	1	1	1	1	1	1
T_{12} : Weedy check	9	9	9	1	1	1

Weed control rating

	Score	% activity
	1	100
	2	99.9-98.0
	3	97.9-95.0
Limit of	4	94.9-90.0
Acceptability	5	89.9-82.0
	6	81.9-70.0
	7	69.9-55.0
	8	64.9-30.0
	9	29.9-00.0

crop toxicity rating

1. No symptom/healthy plants
2. Very mild symptoms, slight stunting
3. Mild but clearly recognizable symptom
4. More severe not necessarily with negative effect on yield
5. Thinning out, heavy clorosis or tunting

6,7,8,9,10 Heavy damage to total kill

* European Weed Research System

PE= Pre-emergence

weed control. Among herbicidal treatments pre-emergence application of clomazone at different levels (750, 875 and 1000 g a.i. ha^{-1}), alachlor @ 2500 g a.i. ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1}, chlorimuron @ 9 g a.i. ha^{-1}, clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} and clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} recorded acceptable level of weed control. Whereas pre-emergence application of clomazone @ 650 g a.i. ha^{-1} and weedy check gave poor weed control.

4.2.2 Crop toxicity ratings

There were no phytotoxic symptoms of herbicide in all the treatments except a very mild toxic symptom (slight leaf scorching) was observed in the treatment receiving clomazone @ 1000 g a.i. ha^{-1} applied as pre-emergence in the initial stages, however the crop was recovered with in a weeks time.

4.3 WEED COUNT

The count on monocot weeds, dicot weeds, sedges and total weed population from one square meter marked area in the net plot were taken at 20, 40 DAS and at harvest are presented in Table 4.

4.3.1 Monocot weed population

Monocot weed population differed significantly due to weed control treatments at all the crop growth periods. All the weed control treatments recorded significantly lower monocot weed population (0.71 to 4.40 m^{-2}) over weedy check (3.97 to 5.72 m^{-2}).

At 20 DAS, one hand weeding at 20 DAS + one intercultivation at 40 DAS and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly lower monocot weed population (0.88, 1.09m^{-2}, respectively) over

Table 4: Monocot, Dicot, Sedge and Total weed count m^{-2} at different crop growth stages in soybean as influenced by weed control treatments

Treatments	20 DAS				40 DAS				At harvest			
	Monocot **	Dicot	Sedge	Total	Monocot **	Dicot	Sedge	Total	Monocot **	Dicot	Sedge	Total
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	2.03* (3.62)	2.82 (7.48)	1.17 (0.87)	3.55 (11.97)	3.16 (9.45)	3.45 (11.37)	1.46 (1.64)	4.79 (22.47)	3.79 (13.84)	3.93 (14.93)	1.34 (1.31)	5.53 (30.10)
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	2.39 (5.19)	2.60 (6.27)	0.88 (0.27)	3.51 (11.73)	2.73 (6.97)	3.71 (13.28)	1.34 (1.31)	4.75 (21.56)	3.14 (9.63)	3.92 (14.97)	1.34 (1.31)	5.15 (25.98)
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	1.17 (0.87)	2.18 (4.24)	1.22 (1.00)	2.59 (6.11)	2.62 (6.36)	3.15 (9.42)	0.71 (0.0)	4.21 (15.78)	3.01 (8.69)	3.37 (10.86)	1.22 (1.00)	4.59 (20.55)
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	1.09 (0.70)	2.09 (3.99)	0.71 (0.0)	2.27 (4.69)	2.30 (4.76)	2.44 (5.48)	0.88 (0.27)	3.28 (10.51)	2.82 (7.48)	3.33 (10.63)	1.05 (0.61)	4.41 (18.72)
T_5 : Clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} as PE	2.23 (4.49)	1.56 (1.93)	1.44 (1.57)	2.97 (7.99)	3.04 (8.74)	2.57 (6.10)	1.17 (0.87)	4.04 (15.71)	3.03 (8.66)	2.89 (7.91)	1.46 (1.64)	4.34 (18.21)
T_6 : Clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} as PE	1.56 (1.93)	1.56 (1.93)	1.05 (0.61)	2.26 (4.47)	2.22 (4.43)	2.44 (5.48)	1.22 (1.00)	3.58 (10.91)	2.79 (7.33)	2.65 (6.30)	1.05 (0.87)	3.88 (14.50)
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	1.17 (0.87)	2.40 (5.26)	0.71 (0.0)	2.61 (6.13)	2.68 (6.66)	3.56 (12.20)	1.05 (0.60)	4.48 (19.46)	3.93 (14.93)	3.38 (10.92)	1.05 (0.61)	5.19 (26.46)
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	2.70 (6.79)	3.29 (10.30)	1.00 (0.5)	4.29 (17.59)	3.73 (13.41)	3.02 (8.64)	1.46 (1.63)	4.95 (23.68)	4.05 (15.87)	2.66 (6.57)	1.22 (1.00)	4.99 (24.41)
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	2.97 (8.33)	1.77 (2.65)	0.71 (0.0)	3.39 (10.99)	3.74 (13.49)	2.67 (6.61)	1.22 (1.00)	4.68 (21.10)	4.04 (15.86)	2.79 (7.26)	1.05 (0.61)	4.98 (24.34)
T_{10} : One HW at 20 DAS and one IC at 40 DAS	0.88 (0.27)	0.71 (0.00)	0.71 (0.00)	0.88 (0.27)	2.30 (4.80)	2.53 (5.92)	0.88 (0.27)	3.41 (10.99)	2.65 (6.51)	2.41 (5.32)	0.88 (0.50)	3.56 (12.12)
T_{11} : Weed free check	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
T_{12} : Weedy check	3.97 (15.26)	6.49 (41.62)	1.95 (3.32)	7.50 (60.10)	5.40 (28.62)	7.40 (54.23)	2.18 (4.58)	9.38 (87.43)	5.72 (33.27)	7.09 (49.81)	2.27 (3.74)	9.35 (86.82)
S. Em±	0.21	0.22	0.14	0.22	0.34	0.34	0.14	0.34	0.29	0.35	0.12	0.30
LSD (0.05)	0.62	0.64	0.40	0.65	1.01	1.01	0.42	1.00	0.85	1.04	0.36	0.88

Note : HW = Hand weeding, IC = Intercultivation
Figures in parenthesis are original values, * Transformed values $\sqrt{x+0.5}$
** Not included sedges
PE = Pre-emergence DAS = Days after sowing

other treatments except clomazone @ 875 g a.i. ha^{-1} (1.17m^{-2}) and alachlor @ 2500 g a.i. ha^{-1} (1.17 m^{-2}) which were on par.

Whereas, at 40 days after sowing, application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1} showed significantly lower monocot weed population (2.22 m^{-2}) over rest of the treatments except clomazone @ 1000 g a.i. ha^{-1} (2.30 m^{-2}) and one hand weeding at 20 DAS + one intercultivation operation at 40 DAS (2.30 m^{-2}), which were on par. These were on par with clomazone @ 875 g a.i. ha^{-1} (2.62 m^{-2}), alachlor @ 2500 g a.i. ha^{-1} (2.68m^{-2}), clomazone at 750 g a.i. ha^{-1} (2.73m^{-2}) clomazone @ 500 g a.i. ha^{-1} + chlorimuron 9 g a.i. ha^{-1} (3.04 m^{-2}) and clomazone at 500 g a.i. ha^{-1} + metribuzin at 250 g a.i. ha^{-1} (2.22 m^{-2}). The same trend was observed at harvest.

4.3.2 Dicot weed population

Dicot weed population differed significantly due to weed control treatments at all the crop growth periods. All the weed control treatments registered significantly lower dicot weed population (0.711 to 3.930 m^{-2}) over weedy check (6.49 to 7.09 m^{-2}).

At all the growth stages weed free check registered significantly lower weed population. Among herbicides pre-emergence application of clomazone at 500 g a.i. ha^{-1} + Metribuzin at 250 g a.i. ha^{-1} and clomazone at 500 g a.i. ha^{-1} + chlorimuron at 9 g a.i. ha^{-1} recorded significantly lower dicot population (1.56 and 1.56 m^{-2}, respectively) over weedy check (6.49 m^{-2}) and clomazone @ 625 g a.i. ha^{-1} (5.69 m^{-2}). Whereas, clomazone @ 1000 g a.i. ha^{-1} (2.09 m^{-2}) and @ 875 g a.i. ha^{-1} (2.19 m^{-2}) also gave lower dicot weed population at 20 DAS.

At 40 days after sowing, pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin at 250 g a.i. ha^{-1} (2.44 m^{-2}), clomazone @ 1000 g a.i. ha^{-1} (2.44 m^{-2}), one hand weeding at 20 DAS + one intercultivation operation at 40 DAS (2.53 m^{-2}) and clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (2.67 m^{-2}) recorded significantly lower dicot population over weedy check (9.400 m^{-2}) but were on par with chlorimuron @ 9 g a.i. ha^{-1} (2.67 m^{-2}), pendimethalin @ 1000 g a.i. ha^{-1} (3.02 m^{-2}), clomazone @ 875 g a.i. ha^{-1} (3.15 m^{-2}) and alachlor @ 2500 g a.i. ha^{-1} (3.56 m^{-2}).

At harvest, one hand weeding at 20 DAS and one intercultivation at 40 DAS (2.41 m^{-2}) and pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (2.65 m^{-2}) and pendimethalin @ 1000 g a.i. ha^{-1} (2.66 m^{-2}) recorded significantly lower dicot weed population over weedy check (7.09 m^{-2}), clomazone @ 625 g a.i. ha^{-1} (3.93 m^{-2}) and 750 g a.i. ha^{-1} (3.92 m^{-2}) but were on par with chlorimuron @ 9 g a.i. ha^{-1} (2.79 m^{-2}), clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (2.89 m^{-2}), clomazone @ 1000 (3.33 m^{-2}), 875 g a.i. ha^{-1} (3.37 m^{-2}) and alachlor @ 2500 g a.i. ha^{-1} (3.38 m^{-2}).

4.3.3 Sedges population

Sedges population varied significantly due to weed control treatments at all the crop growth periods. All the weed control treatments recorded significantly lower sedge population (0.71 to 1.46 m^{-2}) over weedy check (1.95 to 2.27 m^{-2}).

Pre-emergence application of clomazone @ 1000 g a.i. ha^{-1}, chlorimuron @ 9 g a.i.ha^{-1}, alachlor @ 2500 g a.i. ha^{-1} and one hand weeding at 20 DAS + intercultivation at 40 DAS did not record any sedge population at 20 DAS over

other treatments except clomazone @ 750 g a.i.ha^{-1} (0.88 m^{-2}) which was on par.

At 40 DAS, pre-emergence application of clomazone @ 875 g a.i. ha^{-1} recorded significantly lower sedges population over clomazone @ 625 g a.i. ha^{-1} (1.46 m^{-2}), pendimethalin @ 1000 g a.i. ha^{-1} (1.46 m^{-2}) and was on par with one hand weeding at 20 DAS + one intercultivation at 40 DAS (0.88 m^{-2}), clomazone @ 1000 g a.i. ha^{-1} (0.88 m^{-2}), alachlor @ 2500 g a.i. ha^{-1} (1.05 m^{-2}) and clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (1.17 m^{-2}). Whereas, weedy check (2.18 m^{-2}) recorded significantly higher sedge population.

One hand weeding at 20 DAS + one intercultivation at 40 DAS recorded lowest values of sedge population over pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i.ha^{-1} and weedy check (1.46 and 2.27 m^{-2}, respectively) and was on par with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 2500 g a.i. ha^{-1} (1.05 m^{-2}), chlorimuron @ 9 g a.i. ha^{-1} (1.05 m^{-2}), alachlor @ 2500 g a.i. ha^{-1} (1.05 m^{-2}) and clomazone @ 1000 g a.i. ha^{-1} (1.05 m^{-2}) at harvest. Whereas weed free condition did not record any sedges population at all the crop growth periods.

4.3.4 Total weed population

Total weed population also differed significantly due to weed control treatments at all the crop growth periods. All the weed control treatments recorded significantly lower weed population (0.71 to 5.53 m^{-2}) over weedy check (7.5 to 9.35 m^{-2}). Weed free check recorded significantly lower values of total weed population at all the stages of crop growth.

Among different treatments, one hand weeding at 20 DAS + one intercultivation at 40 DAS recorded significantly lower total weed population (0.88 m^{-2}) over other treatments. Among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (2.27 m^{-2}), clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (2.26 m^{-2}), clomazone @ 875 g a.i. ha^{-1} (2.27 m^{-2}) and alachlor @ 2500 g a.i. ha^{-1} (2.61 m^{-2}) recorded significantly lower total weed population over weedy check (7.50 m^{-2}) and were on par with clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (2.97 m^{-2}) at 20 DAS.

At 40 DAS, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly lower total weed population (3.28 m^{-2}) over pendimethalin @ 1000 g a.i. ha^{-1} (4.95 m^{-2}), clomazone @ 625 g a.i. ha^{-1} (4.79 m^{-2}), clomazone @ 750 g a.i. ha^{-1} (4.75 m^{-2}) and was on par with one hand weeding at 20 DAS and one intercultivation at 40 DAS (3.41 m^{-2}). Whereas significantly higher total weed population was registered in weedy check (9.38 m^{-2})

At harvest, one hand weeding at 20 DAS + one intercultivation at 40 DAS showed significantly lower total weed population (3.56 m^{-2}), it was on par with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (3.88 m^{-2}), clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} and clomazone @ 1000 g a.i. ha^{-1} (4.41 m^{-2}). Whereas significantly higher total weed population was recorded in weedy check (9.35 m^{-2}).

4.4 DRYMATTER PRODUCTION IN WEEDS

The observations on dry matter accumulation in monocot, dicot and sedges and total drymatter production in weeds recorded from 0.25 m^2 sampled area at 20, 40 DAS and at harvest are presented in Table 5.

Table 5: Monocot,dicot and total weed dry weight (g 0.25 m^{-2}) at different crop growth stages in soybean as influenced by weed control treatments

Treatments	20 DAS				40 DAS				At harvest			
	Mono cot **	Dicot	Sedge	Total	Mono cot **	Dicot	Sedge	Total	Mono cot **	Dicot	Sedge	Total
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	0.33	0.54	0.12	0.99	3.08	2.80	0.36	6.24	12.67	11.14	0.62	24.43
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	0.24	0.29	0.10	0.62	1.62	2.66	0.39	4.67	8.98	8.96	0.75	18.69
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	0.04	0.25	0.14	0.43	1.49	1.67	0.00	3.17	8.31	7.33	0.37	16.01
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	0.16	0.13	0.00	0.29	1.20	1.51	0.11	2.72	7.03	6.02	0.22	13.27
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	0.07	0.12	0.26	0.46	2.22	1.53	0.23	3.98	9.63	8.17	0.79	18.59
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	0.03	0.18	0.19	0.41	1.58	1.04	0.29	3.05	11.49	4.32	0.44	16.25
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	0.07	0.15	0.09	0.31	2.05	1.61	0.19	3.86	8.15	8.82	0.14	17.11
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	0.74	0.72	0.15	1.51	13.26	2.06	0.47	15.79	18.19	6.58	0.43	27.20
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	0.43	0.08	0.00	0.51	9.58	1.61	0.36	11.55	15.89	6.78	0.29	22.36
T_{10} : One HW at 20 DAS and one IC at 40 DAS	0.01	0.00	0.01	4.59	1.23	0.88	0.10	2.21	6.29	3.01	0.30	9.59
T_{11} : Weed free check	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T_{12} : Weedy check	1.47	3.51	0.66	5.64	19.83	17.92	1.17	38.92	33.49	38.20	1.65	73.34
S. Em±	0.04	0.03	0.02	0.06	1.74	0.52	0.13	1.92	1.19	1.09	0.18	1.79
LSD (0.05)	0.11	0.08	0.07	0.18	5.09	1.52	0.38	5.63	3.49	3.21	0.53	5.26

PE = Pre-emergence DAS = Days after sowing ** Not included sedges

4.4.1 Drymatter production in monocot weeds

Drymatter production in monocot weeds varied significantly due to weed control treatments at all the crop growth periods. All the weed control treatments showed significantly lower monocot weed dry weight (0.00 to 18.19 g 0.25 m^{-2}) over weedy check (1.47 to 33.49 m^{-2}).

Weed free check treatment did not record any dry weight of weeds at all the stages over rest of the treatments. Among the different treatments, one hand weeding at 20 DAS + one intercultivation at 40 DAS, pre-emergence application of clomazone @ 500 g a.i.ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1} (0.027 g 0.25m^{-2}), clomazone @ 875 g a.i. ha^{-1} (0.04g 0.25 m^{-2}), alachlor @ 2500 g a.i. ha^{-1} (0.07g 0.25 m^{-2}) and clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (0.07g 0.25 m^{-2}) recorded significantly lower weed dry weight over weedy check (1.47g 0.25 m^{-2}) and were on par with clomazone @ 1000 g a.i. ha^{-1} (0.16g 0.25 m^{-2}) at 20 DAS.

At 40 days after sowing, all the weed control treatments did not differ significantly with each other and recorded significantly lower weed dry weight (0.00 to 3.08 g 0.25 m^{-2}) over weedy check (19.83 g 0.25m^{-2}) but pre-emergence application of chlorimuron @ 9 g a.i. ha^{-1} (9.58 g 0.25 m^{-2}) and pendimethalin @ 1000 g a.i. ha^{-1} (13.26 g 0.25 m^{-2}) noticed significantly higher weed dry weight.

At harvest, one hand weeding at 20 DAS + one intercultivation operation at 40 DAS and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} were next best to weed free check and noticed significantly lower monocot weed dry weight. Among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly lower monocot weed dry weight (7.03 g 0.25 m^{-2}) over pendimethalin @ 1000 g a.i.

ha^{-1} (18.19g 0.25 m^{-2}) and chlorimuron @ 9g g a.i. ha^{-1} (15.89g 0.25 m^{-2}) and it was on par with alachlor @ 2500 g a.i. ha^{-1} (8.146g 0.25 m^{-2}) and clomazone @ 875 g a.i. ha^{-1} (8.309g 0.25 m^{-2}). Whereas, significantly higher monocot dry weight was observed in weedy check (33.49 g 0.25m^{-2}).

4.4.2 Drymatter production in dicot weeds

Drymatter production of dicot weeds varied significantly due to weed control treatments at all the crop growth periods. All the weed control treatments recorded significantly lower dicot weed dry weight (0.00 to 11.14 g 0.25 m^{-2}) over weed check (3.51g to 38.20g 0.25m^{-2}).

Weed free check treatments recorded significantly lower dicot weed dry weight at all the stages over rest of the treatments except one hand weeding at 20 DAS + one intercultivation at 40 DAS, which was on par.

At 20 DAS, among herbicides, pre-emergence application chlorimuron @ 9 g a.i. ha^{-1} recorded significantly lower dicot weed dry weight (0.08g 0.25 m^{-2}) over pendimethalin @ 1000 g a.i. ha^{-1} (0.72g 0.25 m^{-2}) and clomazone @ 625 g a.i. ha^{-1} (0.53g 0.25 m^{-2}) and was on par with clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (0.12g 0.25 m^{-2}), clomazone @ 1000 g a.i. ha^{-1} (0.13g 0.25 m^{-2}) and alachlor @ 2500 g a.i. ha^{-1} (0.15g 0.25 m^{-2}) at 20 DAS. The highest dicot weed dry weight (3.51 0.25l m^{-2}) was observed in weedy check.

One hand weeding at 20 DAS + one intercultivation operation at 40 DAS, pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1} and clomazone @ 1000 g a.i. ha^{-1} recorded at par dicot weed dry weight of 0.88 to 3.00, 1.04 to 4.32 and 1.51 to 6.02 g 0.25 m^{-2} respectively to weed free check (0.00 g 0.25 m^{-2}). Significantly higher dicot

weed dry weight was recorded in weedy check (17.92g to 38.20g 0.25m^{-2}) at both 40 DAS and at harvest.

4.4.3 Drymatter production in sedges

Drymatter production in sedges differed significantly due to weed control treatments at all the crop growth stages. The dry weight of sedges was not recorded in weed free check at all the stages. All the weed control treatments registered significantly lower dry weight of sedges (0.00 to 0.78 g 0.25 m^{-2}) as compared to weedy check (0.66 to 1.65 g 0.25 m^{-2}).

Among herbicides, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} and clomazone @ 875 g a.i.ha^{-1} were on par with respect to sedges dry weight and it did not differ significantly with weed free check (0.00 to 31 g 0.25 m^{-2}) at all the crop growth stages. The higher dry weight was recorded in weedy check (0.66 g to 3.51 g 0.25m^{-2}) at 20 DAS and at harvest respectively. At harvest clomazone @ 750 g a.i. ha^{-1} (0.75 g 0.25 m^{-2}) and @ 625 g a.i. ha^{-1} (0.62 g 0.25 m^{-2}) also gave more sedges dry weight.

4.4.4 Total drymatter production of weeds

The total drymatter production of weeds differed significantly at all the stages of crop growth. Among herbicides-pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} gave significantly lower total weed dry matter accumulation at all the crop growth stages (0.29 g to 13.31 g 0.25 m^{-2}), which was on par with alachlor @ 2500 g a.i. ha^{-1} (0.310 g to 17.31 g 0.25 m^{-2}), clomazone @ 875 g a.i. ha^{-1} (0.43 g to 16.02 g 0.25 m^{-2}), clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (0.41 g to 16.25 g 0.25 m^{-2}), clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (0.46 g to 18.59 g 0.25 m^{-2}) whereas one hand weeding at 20 DAS + one intercultivation at 40

DAS was also on par with other treatments at 40 DAS and at harvest (2.21 g to 9.59 g 0.25 m^{-2}). The weedy check recorded significantly higher total weed drymatter production (5.64 to 73.34 g 0.25 m^{-2}).

4.5 CROP GROWTH OBSERVATION

4.5.1 Plant height

The observations on plant height recorded at 30 and 60 DAS and at harvest are presented in Table 6.

The plant height did not differ significantly at 30 DAS but it differed significantly at 60 DAS and at harvest. In all the stages weed free check recorded significantly higher plant height (17.35 cm to 31.60 cm) over weedy check (15.59 cm to 24.03 cm) and clomazone @ 625 g a.i. ha^{-1} (15.82 cm to 27.00 cm) and was on par with pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (28.83 cm to 31.07 cm), one hand weeding at 20 DAS and one intercultivation at 40 DAS (28.40 cm to 30.93 cm) and clomazone @ 875 g a.i. ha^{-1} (28.67 to 30.13 cm). Alachlor @ 2500 g a.i. ha^{-1} was on par with the above treatments at harvest (31.27cm).

4.5.2 Number of branches per plant

The observations on number of branches per plant at 30 and 60 days after sowing and at harvest are presented in Table 6.

Number of branches per plant did not differed significantly due to weed control treatments at 30 DAS but they differ significantly at 60 DAS and at harvest.

Table 6: Plant height and number of branches per plant at different crop growth stages in soybean as influenced by weed control treatments

Treatments	Plant height (cm)			Number of branches plant^{-1}		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	15.82	24.90	27.00	0.27	2.13	3.20
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	16.11	27.07	28.73	0.33	2.60	3.60
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	16.98	28.67	30.13	0.33	2.60	4.40
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	17.28	28.83	31.07	0.53	3.13	4.20
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	16.33	25.57	28.80	0.33	2.40	3.80
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	16.31	25.37	27.67	0.33	2.47	3.60
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	17.27	27.53	31.27	0.73	3.00	3.47
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	16.79	27.50	28.37	0.33	2.67	3.00
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	16.91	27.50	29.43	0.40	2.80	4.47
T_{10} : One HW at 20 DAS and one IC at 40 DAS	17.01	28.40	30.93	0.20	2.73	3.20
T_{11} : Weed free check	17.35	29.30	31.60	0.67	3.33	5.13
T_{12} : Weedy check	15.59	22.90	24.03	0.33	1.87	2.40
S. Em±	0.84	0.45	0.54	0.13	0.24	0.19
LSD (0.05)	NS	1.32	1.59	NS	0.71	0.58

Note : DAS=Days after sowing PE = Pre-emergence
NS = Non significant

At all the crop growth periods weed free check recorded significantly higher number of branches per plant (3.33 to 5.133) over weedy check (0.33 to 2.4) and clomazone @ 625 g a.i. ha^{-1} (0.27 to 3.2) was on par with pre-emergence application of clomazone @1000 g a.i. ha^{-1} (3.13 to 4.2), clomazone @ 875 g a.i. ha^{-1} (2.6 to4.4), chlorimuron @ 9 g a.i. ha^{-1} (2.8 to 4.47) and alachlor @ 2500 g a.i. ha^{-1} (3.00 to 3.47).

4.5.3 Number of leaves per plant

The observations on number of leaves per plant at 30 and 60 days after sowing are presented in Table 7.

Number of leaves did not differed significantly due to weed control treatments at 30 DAS but they differed significantly at 60 days after sowing. Among the treatments, pre-emergence application of clomazone @ 875 g a.i. ha^{-1} registered significantly higher number of leaves (17.40) and it was on par with pre-emergence application of clomazone @ 750 g a.i. ha^{-1} (17.20), clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (17.00), weed free check (16.80),alachlor @ 2500 g a.i. ha^{-1} (16.60), and chlorimuron @ 9 g a.i. ha^{-1} (15.80). The lower number leaves observed in weedy check (9.20) and pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (11.20) at 60 DAS.

4.5.4 Number of pods per plant

significant differences were observed with respect to number of pods per plant at 60 DAS and at harvest due to weed control treatments and are presented in Table 7.

Table 7: Number of leaves and number of pods per plant at different crop growth stages in soybean as influenced by weed control treatments

Treatments	Number of leaves plant^{-1}		Number of pods plant^{-1}	
	30 DAS	60 DAS	60 DAS	At harvest
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	4.13	14.40	18.27	22.87
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	4.20	17.20	18.87	23.60
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	4.67	17.40	20.67	24.87
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	4.73	11.00	22.60	27.20
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	4.47	17.00	19.93	23.53
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	4.00	11.20	15.13	21.87
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	4.93	16.60	22.00	24.47
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	4.60	12.60	18.27	22.87
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	4.73	15.80	18.07	23.80
T_{10} : One HW at 20 DAS and one IC at 40 DAS	4.97	15.40	20.47	26.60
T_{11} : Weed free check	6.33	16.80	23.00	27.27
T_{12} : Weedy check	3.87	9.20	10.00	14.40
S. Em±	0.53	0.43	0.53	0.75
LSD (0.05)	NS	1.28	1.55	2.20

Note : DAS = Days after sowing
NS = Non-significant
PE = Pre-emergence

All the weed control treatments recorded significantly higher number of pods per plant (15.13 to 27.27) over weedy check (10.00 to 14.40). significantly higher number of pods were noticed in weed free check (23.00 to 27.27) and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (22.60 to 27.20) and were on par with alachlor @ 2500 g a.i. ha^{-1} (22.00 to 24.47), clomazone @ 875 g a.i. ha^{-1} (20.67 to 24.87) and one hand weeding at 20 DAS and one intercultivation operation at 40 DAS (20.47 to 26.60). Significantly lower number of pods per plant was noticed with weedy check (10.00 to 14.40) and clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 2500 g a.i. ha^{-1} (15.13 to 21.87).

4.5.5 Drymatter production and its accumulation in different plant parts

4.5.5.1 Drymatter accumulation in stem

The drymatter accumulation in stem at 30 and 60 DAS and at harvest are presented in Table 8.

Weed control treatments recorded significantly higher stem drymatter accumulation (0.70 to 5.45 g $plant^{-1}$) over weedy check (0.62 to 2.64 g $plant^{-1}$).

Among weed control treatments weed free condition recorded significantly higher drymatter accumulation in stem (0.88 to 5.45 g $plant^{-1}$) at all the crop growth stages.

Stem drymatter accumulation was non-significant at 30 DAS but differed significantly at 60 DAS and at harvest. Weed free check recorded significantly higher dry matter accumulation in stem (4.58 to 5.45 g $plant^{-1}$) at both 60 DAS and at harvest and it was on par with pre-emergence application of clomazone

Table 8: Drymatter accumulation in stem and leaves at different crop growth stages in soybean as influenced by weed control treatments

Treatments	Stem (g plant^{-1})			Leaves (g plant^{-1})	
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	0.71	2.99	4.28	0.69	2.15
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	0.75	3.00	4.52	0.68	2.28
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	0.80	3.78	5.04	0.77	2.60
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	0.88	4.05	5.17	0.95	2.24
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	0.77	3.59	5.02	0.71	2.38
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	0.78	3.00	5.00	0.73	2.04
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	0.85	4.02	5.28	0.82	2.90
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	0.73	3.10	4.99	0.78	2.12
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	0.70	3.08	4.65	0.68	2.82
T_{10} : One HW at 20 DAS and one IC at 40 DAS	0.79	4.02	5.15	0.59	2.55
T_{11} : Weed free check	0.88	4.58	5.45	0.95	3.21
T_{12} : Weedy check	0.62	1.69	2.64	0.56	0.96
S. Em±	0.08	0.11	0.14	0.05	0.15
LSD (0.05)	NS	0.34	0.42	0.15	0.45

Note : DAS = Days after sowing
NS = Non-significant
PE = Pre-emergence

@ 1000 g a.i. ha^{-1} (4.05 to 5.17 g $plant^{-1}$), alachlor @ 2500 g a.i. ha^{-1} (4.02 to 5.28 g $plant^{-1}$), one hand weeding at 20 DAS and one intercultivation at 40 DAS (4.02 to 5.15 g $plant^{-1}$), in turn they did not differ significantly with pre-emergence application of clomazone @ 875 g a.i. ha^{-1} (3.78 to 5.04 g $plant^{-1}$). Whereas, the significantly least drymatter accumulation in stem was observed with weedy check (1.69 to 2.64 g $plant^{-1}$) and pre-emergence application of clomazone @ 625 g a.i. ha^{-1} (2.99 to 4.28 g $plant^{-1}$) and clomazone @ 750 g a.i. ha^{-1} (2.99 to 4.52 g $plant^{-1}$).

4.5.5.2 Drymatter accumulation in leaves

Drymatter accumulation in leaves recorded at 30 and 60 DAS are presented in Table 8.

All the weed control treatments recorded significantly higher leaf dry weight (0.68 to 4.14 g $plant^{-1}$). Among weed control treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (0.95 to 3.24 g $plant^{-1}$) and weed free check (0.95 to 3.21g $plant^{-1}$) recorded significantly higher leaf dry weight over other treatments and were on par with pre-emergence application of alachlor @ 2500 g a.i.ha^{-1} (0.82 to 2.90 g $plant^{-1}$) at all the crop growth stage, in turn they did not differ significantly with chlorimuron @ 9 g a.i.ha^{-1} (2.82g $plant^{-1}$) and clomazone @ 875 g a.i.ha^{-1} (2.60 g $plant^{-1}$) at 60 DAS. Whereas, significantly lower drymatter accumulation was registered in weedy check (0.56 to 0.96 g $plant^{-1}$) at both 30 and 60 DAS and pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (0.96 g $plant^{-1}$) at 60 DAS.

4.5.5.3 Drymatter accumulation in pods

The pod dry weight per plant differed significantly due to weed control treatments and are presented in Table 9.

At harvest pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher pod weight per plant (4.96 g plant^{-1}) and it was on par with pre-emergence application of clomazone at 875 g a.i.ha^{-1} (4.67 g), alachlor @ 2500 g a.i.ha^{-1} (4.64 g), weed free check (4.5 g) and clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (4.47 g) whereas, significantly lower pod dry weight per plant was observed in weedy check (1.82 g plant^{-1}), clomazone at 625 g a.i.ha^{-1} (3.37 g plant^{-1}) and pendimethalin at 1000 g a.i.ha^{-1} (3.35 g plant^{-1}) which noticed significantly lower pod weight per plant over other weed control treatments and were on par with each other.

4.5.5.4 Total drymatter production

Total drymatter production recorded at 30 and 60 DAS and at harvest are presented in Table 9.

Total drymatter production differed significantly at all the crop growth periods due to weed control treatments (1.42 to 15.24 g plant^{-1}) over weedy check (1.21 to 6.62 g plant^{-1}). Among the weed control treatments weed free check recorded significantly higher total drymatter production per plant (1.87 to 15.24 g plant^{-1}) at all the stages, which was on par with pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (1.86 to 14.27 g) followed by alachlor @ 2500 g a.i.ha^{-1} (1.70 to 13.34 g) and clomazone @ 875 g a.i.ha^{-1} (1.60 to 12.27 g). Whereas, significantly lower TDM was recorded with weedy check (1.21 to 6.62 g) and was on par with pre-emergence application of clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (1.54 to

Table 9: Drymatter accumulation in pods and total drymatter accumulation per plant at different crop growth stages in soybean as influenced by weed control treatments

Treatments	Pod weight (g plant^{-1})		Total drymatter accumulation (g plant^{-1})		
	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	3.04	3.37	1.43	8.19	10.32
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	3.23	3.71	1.47	8.50	10.76
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	3.94	4.67	1.60	10.33	12.27
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	4.82	4.96	1.86	12.12	14.27
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	3.64	4.01	1.52	9.61	11.89
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	2.62	4.47	1.54	7.66	9.97
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	4.21	4.64	1.70	11.14	13.34
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	3.25	3.35	1.55	8.47	10.69
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	3.44	3.72	1.42	9.33	11.78
T_{10} : One HW at 20 DAS and one IC at 40 DAS	4.11	3.59	1.42	10.68	11.11
T_{11} : Weed free check	4.35	4.50	1.87	13.15	15.24
T_{12} : Weedy check	1.27	1.82	1.21	3.93	6.62
S. Em±	0.11	0.22	0.11	0.22	0.48
LSD (0.05)	0.31	0.63	0.32	0.65	1.41

Note : DAS = Days after sowing
PE = Pre-emergence

9.970 g) and clomazone at 625 g a.i.ha^{-1} (1.43 to 10.32 g) and remaining treatments were intermediate with each other.

4.5.6 Growth functions

The observations on leaf area and leaf area index computed at 30 and 60 days after sowing (DAS) are presented in Table 10.

4.5.6.1 Leaf area plant^{-1}

All the weed control treatments significantly influenced the leaf area per plant at 30 and 60 DAS.

At 30 DAS, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly higher leaf area (2.633 dm^2 plant^{-1}) as compared to weedy check (1.639 dm^2 plant^{-1}) and was on par with weed free check, pendimethalin @ 1000 g a.i. ha^{-1} and alachlor @ 2500 g a.i. ha^{-1} (2.605, 2.342 and 2.333, dm^2 plant^{-1} respectively).

At 60 DAS, clomazone @ 1000 g a.i. ha^{-1} applied as PE showed significantly higher leaf area (7.65 dm^2 plant^{-1}) as compared to weedy check (2.143 dm^2 plant^{-1}) but, clomazone @ 1000 g a.i. ha^{-1}, weed free check, chlorimuron @ 9 g a.i. ha^{-1} and alachlor @ 2500 g a.i. ha^{-1} were on par with each other. Among the herbicidal treatments, significantly lower leaf area was noticed in pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} and clomazone @ 500 g a.i.ha^{-1} + Metribuzin @ 250 g a.i.ha^{-1} (4.645 and 4.875 dm^2 plant^{-1}, respectively).

4.5.6.2 Leaf area index (LAI)

Leaf area index differed significantly due to different weed control treatments at both the crop growth stages. Significantly higher LAI at 30 and 60 DAS was noticed with pre-emergence application of clomazone @ 1000 g

Table 10: Leaf area and leaf area index at different crop growth stages in soybean as influenced by weed control treatments

Treatments	Leaf area (dm^2 $plant^{-1}$)		Leaf area index (LAI)	
	30 DAS	60 DAS	30 DAS	60 DAS
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	2.033	5.130	0.678	1.710
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	1.885	4.965	0.629	1.650
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	2.081	5.735	0.694	1.912
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	2.633	7.650	0.878	2.550
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	2.133	5.832	0.711	1.944
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	2.136	4.875	0.712	1.625
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	2.233	6.514	0.744	2.171
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	2.342	4.646	0.781	1.549
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	2.005	7.111	0.668	2.370
T_{10} : One HW at 20 DAS and one IC at 40 DAS	1.808	6.100	0.603	2.033
T_{11} : Weed free check	2.605	7.199	0.869	2.400
T_{12} : Weedy check	1.639	2.143	0.546	0.714
S. Em±	0.155	0.362	0.052	0.120
LSD (0.05)	0.454	1.062	0.151	0.355

Note : DAS = Days after sowing
PE = Pre-emergence

a.i. ha^{-1} (0.878 and 2.550, respectively). Whereas, weedy check noticed significantly lower leaf area index (0.546 and 0.714, respectively).

At 30 DAS, clomazone @ 1000 g a.i.ha^{-1} as PE and weed free check recorded significantly higher LAI (0.878 and 0.869, respectively) as compared to one hand weeding at 20 DAS + one intercultivation at 40 DAS (0.603). Whereas, pre-emergence application of pendimethalin @ 1000 g a.i.ha^{-1} and alachlor @ 2500 g a.i.ha^{-1} as PE did not differ significantly with each other.

At 60 DAS, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher LAI (2.550) as compared to clomazone @ 625 g a.i.ha^{-1} as PE (1.710) and was on par with weed free check, chlorimuron @ 9 g a.i.ha^{-1} and alachlor @ 2500 g a.i.ha^{-1} (2.400, 2.370, 2.171, respectively). Whereas, pendimethalin @ 1000 g a.i.ha^{-1} recorded significantly lower leaf area index (1.549) among herbicidal treatments.

4.5.6.3 Absolute growth rate (AGR)

The observations on absolute growth rate computed during 0 to 30 and 30 to 60 days after sowing (DAS) are presented in Table 11.

Absolute growth rate (g $plant^{-1}$ day^{-1}) differed significantly due to different weed control treatments during both the stages of crop growth. At both the stages, weed free check recorded significantly higher AGR (0.063 and 0.376 g $plant^{-1}$ day^{-1}, respectively) as compared to rest of the treatments except application of clomazone @ 1000 g a.i. ha^{-1} as PE during 0 to 30 DAS, which was on par. Among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher AGR (0.062 and 0.342, g $plant^{-1}$ day^{-1} respectively)l at both 0 to 30 and 30 to 60 DAS over rest

Table 11: Absolute growth rate (AGR) and relative growth rate (RGR) at different crop growth stages in soybean as influenced by weed control treatments

Treatments	AGR (g plant^{-1} day^{-1})		RGR (g g^{-1} day^{-1})	
	0-30 DAS	30-60 DAS	0-30 DAS	30-60 DAS
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	0.048	0.225	0.012	0.058
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	0.046	0.234	0.013	0.058
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	0.053	0.291	0.016	0.062
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	0.062	0.342	0.020	0.063
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	0.050	0.270	0.014	0.062
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	0.051	0.204	0.014	0.054
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	0.056	0.315	0.017	0.063
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	0.052	0.231	0.015	0.057
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	0.047	0.264	0.023	0.063
T_{10} : One HW at 20 DAS and one IC at 40 DAS	0.047	0.309	0.011	0.067
T_{11} : Weed free check	0.063	0.376	0.021	0.065
T_{12} : Weedy check	0.040	0.091	0.006	0.039
S. Em±	0.004	0.010	0.004	0.003
LSD (0.05)	0.011	0.028	NS	0.008

Note : NS = Non-significant
PE = Pre-emergence
DAS = Days after sowing

of the treatments. While, weedy check recorded, significantly lower AGR (0.040 and 0.091 g plant^{-1} day^{-1} respectively).

4.5.6.4 Relative growth rate (RGR)

The observations on relative growth rate recorded during 0 to 30 and 30 to 60 days after sowing (DAS) are presented in Table 11.

Relative growth rate (g g^{-1} day^{-1}) did not differ significantly during 0 to 30 DAS. Whereas, it differed significantly during 30 to 60 DAS. Among different treatments weed free check, one hand weeding at 20 DAS + one intercultivation at 40 DAS recorded significantly higher RGR (0.065 g g^{-1} day^{-1}) over weedy check (0.039 g g^{-1} day^{-1}) and it did not differed significantly with rest of the treatments. Whereas, significantly lower RGR was observed with pre-emergence application of clomazone @ 500 g a.i.ha^{-1} + Metribuzin @ 250 g a.i.ha^{-1} (0.054 g g^{-1} day^{-1}) among herbicidal treatments.

4.5.6.5 Net assimilation rate (NAR)

The observations on net assimilation rate recorded during 0 to 30 and 30 to 60 DAS are presented in Table 12. NAR (g dm^{-2} day^{-1}) differed significantly due to weed control treatments at both the stages of crop growth. During both the stages, weed free check recorded significantly higher NAR (0.023 and 0.84 g dm^{-2} day^{-1} respectively) over weedy check but was on par with rest of the treatments. Among the herbicidal treatments, clomazone @ 1000 g a.i. ha^{-1} as PE recorded higher NAR (0.022 and 0.84 g dm^{-2} day^{-1} respectively).

4.5.6.6 Cumulative growth rate (CGR)

The observations recorded on cumulative growth rate during 0 to 30 and 30 to 60 DAS are presented in Table 12. cumulative growth rate (g dm^{-2} day^{-1})

Table 12: Net assimilation rate (NAR) and cumulative growth rate (CGR) at different crop growth stages in soybean as influenced by weed control treatments

Treatments	NAR (g dm^{-2} day^{-1})		CGR (g dm^{-2} day^{-1})	
	0-30 DAS	30-60 DAS	0-30 DAS	30-60 DAS
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	0.017	0.067	0.011	0.115
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	0.016	0.076	0.010	0.121
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	0.019	0.074	0.013	0.160
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	0.022	0.084	0.018	0.184
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	0.018	0.074	0.013	0.142
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	0.018	0.061	0.013	0.099
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	0.020	0.079	0.015	0.172
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	0.018	0.069	0.014	0.107
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	0.016	0.065	0.011	0.155
T_{10} : One HW at 20 DAS and one IC at 40 DAS	0.015	0.089	0.009	0.178
T_{11} : Weed free check	0.023	0.084	0.020	0.202
T_{12} : Weedy check	0.012	0.048	0.006	0.035
S. Em±	0.001	0.004	0.002	0.010
LSD (0.05)	0.003	0.012	0.005	0.029

Note : PE = Pre-emergence
DAS = Days after sowing

differed significantly due to weed control treatments at both the stages of crop growth. During both the stages, weed free check recorded significantly higher CGR (0.020 and 0.202 g dm^{-2} day^{-1}) over weedy check (0.006 and 0.035 g dm^{-2} day^{-1}, respectively) but was on par with rest of the treatments. Among the herbicidal treatments, clomazone @ 1000 g $a.i.ha^{-1}$ recorded significantly higher CGR (0.018 and 0.184 g dm^{-2} day^{-1}) over other treatments.

4.6 STUDIES ON CROP YIELD

The data on seed yield per ha, haulm yield, weed dry weight, weed control efficiency and weed index at harvest are presented in Table 13 and dipicted in Fig.3 and 4.

4.6.1 Seed yield

The seed yield differed significantly due to weed control treatments. All the weed control treatments recorded significantly higher seed yield (1029 to 1429 kg ha^{-1}) over weedy check (705 kg ha^{-1}). Weed free check and one hand weeding at 20 DAS + one intercultivation operation at 40 DAS registered significantly higher seed yield (1429 and 1389 kg ha^{-1} respectively) and were on par with pre-emergence application of clomazone @ 1000 g $a.i.ha^{-1}$ (1298 kg ha^{-1}), clomazone @ 500 g $a.i.ha^{-1}$ + chlorimuron @ 9 g $a.i.ha^{-1}$ (1287 kg ha^{-1}), clomazone @ 875 g $a.i.ha^{-1}$ (1284 kg ha^{-1}) and clomazone @ 750 g $a.i.ha^{-1}$ (1280 kg ha^{-1}). Whereas, weedy check recorded significantly lower yield

4.6.2 Haulm yield

Haulm yield differed significantly due to weed control treatments. All the weed control treatments recorded significantly higher (1742 to 2739 ha^{-1}) haulm yield over weedy check (993 kg ha^{-1}). Pre-emergence application of

Table 13: Seed yield, haulm yield, harvest index, weed dry weight, weed control efficiency and weed index at harvest in soybean as influenced by weed control treatments

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index	Weed dry weight (kg ha^{-1})	WCE (%)	WI (%)
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	1130	1742	0.394	825	71.84	20.99
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	1280	1900	0.402	805	72.53	10.47
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	1284	1745	0.426	700	76.21	10.07
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	1298	1900	0.408	531	81.85	9.23
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	1287	2493	0.339	743	74.65	09.98
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	1027	2155	0.320	650	77.81	27.97
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	1201	2739	0.321	831	71.61	15.76
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	1067	2162	0.332	1088	62.80	25.47
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	1189	2604	0.314	894	69.35	16.88
T_{10} : One HW at 20 DAS and one IC at 40 DAS	1389	2537	0.354	384	86.94	2.75
T_{11} : Weed free check	1429	2264	0.388	0.00	100.0	0.00
T_{12} : Weedy check	704	993	0.417	2933	0.00	50.66
S. Em±	56.5	115	0.02	73	2.48	3.94
LSD (0.05)	165.8	340	0.05	214	7.26	11.55

Note : PE = Pre-emergence

LEGEND

T_1 : Clomazone @ 625 g a.i.ha^{-1} as pre-emergence

T_2 : Clomazone @ 750 g a.i.ha^{-1} as pre-emergence

T_3 : Clomazone @ 875 g a.i.ha^{-1} as pre-emergence

T_4 : Clomazone @ 1000 g a.i.ha^{-1} as pre-emergence

T_5: Clomazone @ 500 g a.i.ha^{-1} + Chlorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_6: Clomazone @ 500 g a.i.ha^{-1} + Metriburin @ 250g a.i.ha^{-1} as pre-emergence

T_7: Alachlor @ 2500 g a.i.ha^{-1} as pre-emergence

T_8: Pendimethalin @ 1000 g a.i.ha^{-1} as pre-emergence

T_9: Chorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_{10}: One hand weeding at 20 DAS + one intercultivation at 40 DAS

T_{11}: Weed free check

T_{12}: Weedy check.

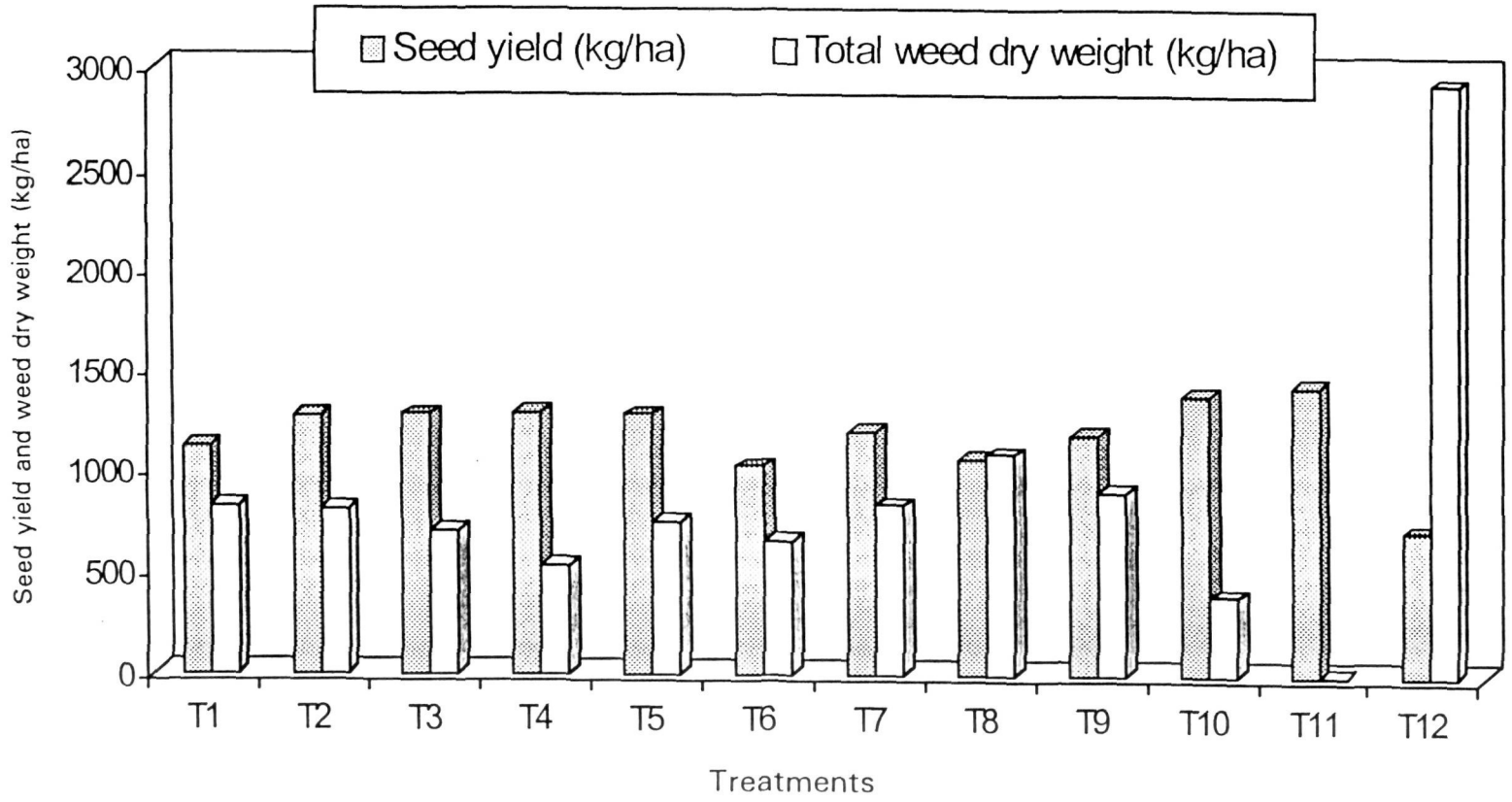

Fig. 3. Seed yield (kg/ha) and weed dry weight (kg/ha) as influenced by weed control treatments in soybean

LEGEND

T_1 : Clomazone @ 625 g a.i.ha^{-1} as pre-emergence

T_2 : Clomazone @ 750 g a.i.ha^{-1} as pre-emergence

T_3 : Clomazone @ 875 g a.i.ha^{-1} as pre-emergence

T_4 : Clomazone @ 1000 g a.i.ha^{-1} as pre-emergence

T_5: Clomazone @ 500 g a.i.ha^{-1} + Chlorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_6: Clomazone @ 500 g a.i.ha^{-1} + Metriburin @ 250g a.i.ha^{-1} as pre-emergence

T_7: Alachlor @ 2500 g a.i.ha^{-1} as pre-emergence

T_8: Pendimethalin @ 1000 g a.i.ha^{-1} as pre-emergence

T_9: Chorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_{10}: One hand weeding at 20 DAS + one intercultivation at 40 DAS

T_{11}: Weed free check

T_{12}: Weedy check.

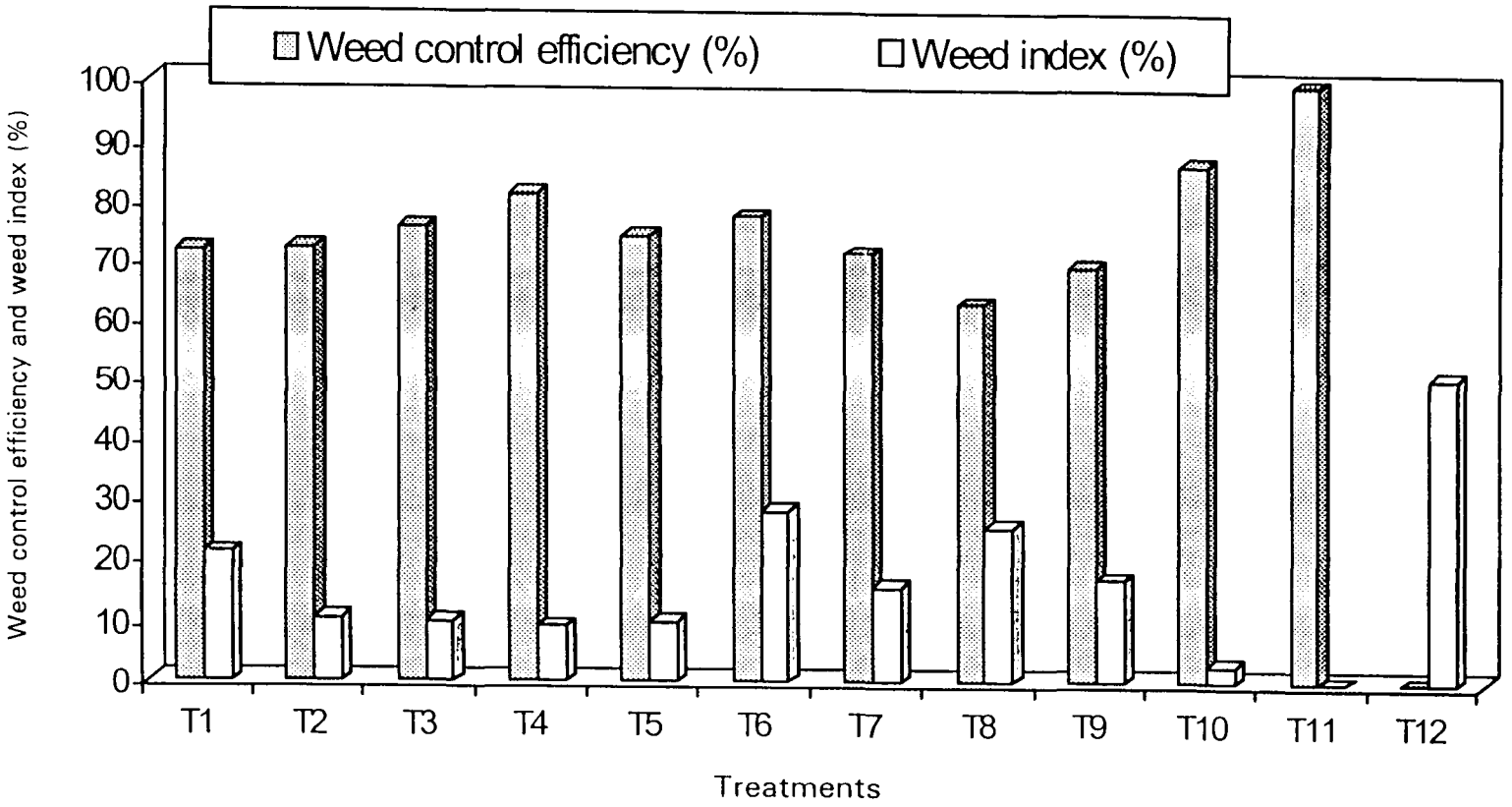

Fig. 4. Seed control efficiency (%) and weed index (%) as influenced by weed control treatments in soybean

alachlor @ 2500 g a.i.ha^{-1} recorded significantly higher haulm yield (2739 kg ha^{-1}) and it was on par with pre-emergence application of chlorimuron @ 9 g a.i. ha^{-1} (2604 kg ha^{-1}), one hand weeding at 20 DAS and one intercultivation operation at 40 DAS (2537 kg ha^{-1}) and clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (2493 kg ha^{-1}). However, clomazone @ 625 g and 750 g a.i. ha^{-1}, and clomazone @ 1000 g a.i. ha^{-1} (1742, 1900, 1745 and 1900 kg ha^{-1}, respectively) did not differ with each other.

4.6.3 Harvest index (HI)

The harvest index was computed and data are presented in Table 13. The HI differed significantly due to weed control treatments. Significantly higher harvest index was noticed with pre-emergence application of clomazone @ 875 g a.i. ha^{-1} (0.426) over pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1}, alachlor @2500 g a.i. ha^{-1} and chlorimuron (0.320, 0.321 and 0.314, respectively) and rest of the treatments were on par with each other.

4.6.4 Weed dry weight at harvest

Total weed dry weight at harvest also differed significantly due to weed control treatments. All the weed control treatments differed significantly due to weed control treatments. All the weed control treatments produced significantly lower total weed dry weight (0.00 to 1088 kgha-1) over weedy check (2934 kg ha^{-1}) . weed free check did not record any weed dry weight. Significantly lower total weed dry weight was recorded with one hand weeding at 20 DAS + one intercultivation operation at 40 DAS (384 kg ha^{-1}) and it was on par with pre-emergence application of clomazone at 1000 g a.i. ha^{-1} (531 g a.i. ha^{-1}), clomazone at 500 g a.i. ha^{-1} + metribuzin at 250 g a.i. ha^{-1} (650 kg ha^{-1}) and clomazone at 875 g a.i.ha^{-1} (700 kg ha^{-1}) and remaining treatments

showed intermediate weed dry weight (743 to 831 kg ha^{-1}). However, pre-emergence application of pendimethalin @ 1000 g a.i.ha^{-1} (1088 kg ha^{-1}) and chlorimuron @ 9 g a.i. ha^{-1} (894 kg ha^{-1}) did not differ significantly with each other.

4.6.5 Weed control efficiency

Weed control efficiency (100%) was significantly higher with weed free check over other treatments and the next best treatment was one hand weeding at 20 DAS + one intercultivation operation at 40 DAS (86.94%) and it was on par with pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (81.85%), clomazone at 500 g a.i. ha^{-1} + Metribuzin at 250 g a.i. ha^{-1} (77.85%) and clomazone @ 875 g a.i. ha^{-1} (76.21%). Significantly lower weed control efficiency was recorded in weedy check (0.00%) and pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} (62.78%) and which was on par with pre-emergence application of chlorimuron @ 9 g a.i. ha^{-1} (69.35%).

4.6.6 Weed index (WI)

The weed index was computed based on seed yield and data are presented in Table 17. Weed index varied significantly due to different weed control treatments. Weedy check recorded significantly higher weed index (50.66%) over rest of the treatments.

Among the weed control treatments, significantly lower WI (2.75%) was noticed with one hand weeding at 20 DAS + one intercultivation at 40 DAS over pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1} and clomazone @ 625 g a.i. ha^{-1} and was on par with clomazone @ 1000 g a.i. ha^{-1} as PE (9.28%),

clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1}, clomazone @ 875 g a.i. ha^{-1} and clomazone @ 750 g a.i. ha^{-1}.

4.7 STUDIES ON YIELD COMPONENTS

The observations on yield components *viz.*, number of pods per plant, pod weight per plant, number of seeds per plant, number of seeds per pod, seed yield per plant and hundred seed weight are presented in Tables 7, 9 and 14.

4.7.1 Number of pods per plant

Significant differences were observed in number of pods per plant due to weed control treatments (Table 7). All the weed control treatments recorded significantly higher number of pods per plant (21.87 to 27.27) over weedy check (14.40). Significantly higher number of pods per plant were noticed in weed free check (27.27) and pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (27.20) but, were on par with one hand weeding at 20 DAS + one intercultivation operation at 40DAS (26.60) which inturn did not differ significantly with clomazone @ 875 g a.i.ha^{-1} (24.87) and alachlor @ 250 g a.i.ha^{-1} (24.47).

4.7.2 Pod weight per plant

Pod weight per plant differed significantly due to weed control treatments (Table 9). All the weed control treatments recorded significantly higher pod weight per plant (3.48 to 4.96 g) over weedy check (1.82 g). Among the weed control treatments pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher pod weight per plant (4.96 g) and it was on par with pre-emergence application of clomazone @ 875 g a.i.ha

Table 14: Yield components at harvest in soybean as influenced by weed control treatments

Treatments	Number of seeds pod^{-1}	Number of seeds plant^{-1}	Seed weight (g plant^{-1})	100 seed weight (g)
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	1.76	42.27	3.39	8.37
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	1.78	42.73	3.84	8.47
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	1.75	43.80	3.85	8.50
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	2.08	56.47	3.90	8.17
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	1.70	40.40	3.86	8.47
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	1.66	36.87	3.08	8.93
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	2.00	54.93	3.51	8.80
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	1.78	37.53	3.20	8.07
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	1.66	40.60	3.57	8.20
T_{10} : One HW at 20 DAS and one IC at 40 DAS	1.86	52.73	4.17	8.60
T_{11} : Weed free check	2.07	56.27	4.29	8.60
T_{12} : Weedy check	1.65	24.47	2.07	8.40
S. Em±	0.06	1.49	0.16	0.26
LSD (0.05)	0.18	4.38	0.47	NS

Note : NS = Non-significant.
PE = Pre-emergence

^{1} (4.9 g), alachlor @ 2500 g a.i.ha^{-1} (4.64 g), weed free check (4.50 g) and clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (4.467) significantly lower pod weight per plant was recorded with weedy check (1.82 g).

4.7.3 Number of seeds per pod

Number of seeds per pod differed significantly due to weed control treatments (Table 14). Among weed control treatments pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} and weed free check recorded significantly higher number of seeds per plant (2.08 and 2.07 respectively) and were on par with pre-emergence application of alachlor @ 2500 g a.i.ha^{-1} (1.99) which inturn did not differ significantly with one hand weeding at 20 DAS + one intercultivation operation at 40 DAS. However remaining other treatments were on par with weedy check (1.652 to 1.781) and lower seeds per pod were recorded with weedy check (1.65).

4.7.4 Number of seeds per plant

The number of seeds per plant differed significantly due to weed control treatments. Among weed control treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1}, weed free check, alachlor @ 2500 g a.i.ha^{-1} and hand weeding at 20DAS + one intercultivation operation at 40 DAS recorded significantly higher number of seeds (54.47,56.27,54.93 and 52.73 respectively) over other treatments and inturn did not differ significantly with pre-emergence application of clomazone @ 875 and 750 g a.i.ha^{-1} (43.8 and 42.73 respectively). Whereas significantly lower number of seeds per plant was recorded in weedy check (24.47) and pre-emergence application of clomazone @ 500 g a.i.ha^{-1} + metribuzin at 250 g a.i.ha^{-1} (36.87).

4.7.5 Seed yield per plant

Seed yield per plant also differed significantly due to weed control treatments. All the weed control treatments recorded significantly higher seed yield (3.08 to 4.29 g per plant) over weedy check (2.070 g plant^{-1}). Among weed control treatments weed free check (4.290 g plant^{-1}) and one hand weeding at 20 DAS and one intercultivation at 40 DAS (4.17 g plant^{-1}) recorded significantly higher seed yield and were on par with pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (3.90 g plant^{-1}), clomazone @ 500 g a.i.ha^{-1} + clorimuron @ 9 g a.i.ha^{-1} (3.86 g plant^{-1}), clomazone @ 875 g a.i.ha^{-1} (3.85 g plant^{-1}) and clomazone @ 750 g a.i.ha^{-1} (3.840 g plant^{-1}). The significantly higher seed yield per plant was observed in weedy check (2.070 g plant^{-1}).

4.7.6 Hundred seed weight

No significant difference was observed with respect to hundred seed weight among weed control treatments.

4.8 NUTRIENT UPTAKE (kg ha^{-1})

4.8.1 Nutrient uptake by soybean (kg ha^{-1})

The data on the uptake of nitrogen, phosphorus and potassium by soybean as influenced by weed control treatments are presented in Table.15. The uptake of nutrients by soybean crop showed significant differences due to various weed control treatments after harvest.

Table 15: Nutrient uptake (Kg ha^{-1}) by soybean and weeds at harvest as influenced by weed control treatments.

Treatments	Soybean			Weeds		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	65.60	10.16	51.31	14.79	4.09	17.27
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	91.16	10.93	65.92	12.68	4.04	14.62
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	100.76	14.18	85.93	9.00	3.10	12.04
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	110.14	16.19	96.25	6.95	2.77	9.86
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	101.23	11.18	75.64	9.83	3.20	13.72
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	92.81	13.24	61.08	7.88	3.13	10.92
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	95.77	12.68	68.13	10.87	3.25	14.07
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	85.42	10.27	62.21	15.70	4.50	19.23
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	92.75	10.07	61.18	8.84	4.06	16.11
T_{10} : One HW at 20 DAS and one IC at 40 DAS	105.08	13.30	94.19	6.44	2.26	8.16
T_{11} : Weed free check	113.26	16.28	96.92	0.00	0.00	0.00
T_{12} : Weedy check	44.85	6.08	37.19	67.88	10.08	54.27
S. Em±	3.95	0.98	3.82	1.37	0.59	0.72
LSD (0.05)	11.58	2.88	11.19	4.01	1.74	2.10

Note : PE = Pre-emergence

LEGEND

T_1 : Clomazone @ 625 g a.i.ha^{-1} as pre-emergence

T_2 : Clomazone @ 750 g a.i.ha^{-1} as pre-emergence

T_3 : Clomazone @ 875 g a.i.ha^{-1} as pre-emergence

T_4 : Clomazone @ 1000 g a.i.ha^{-1} as pre-emergence

T_5: Clomazone @ 500 g a.i.ha^{-1} + Chlorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_6: Clomazone @ 500 g a.i.ha^{-1} + Metriburin @ 250g a.i.ha^{-1} as pre-emergence

T_7: Alachlor @ 2500 g a.i.ha^{-1} as pre-emergence

T_8: Pendimethalin @ 1000 g a.i.ha^{-1} as pre-emergence

T_9: Chorimuron @ 9g a.i.ha^{-1} as pre-emergence

T_{10}: One hand weeding at 20 DAS + one intercultivation at 40 DAS

T_{11}: Weed free check

T_{12}: Weedy check.

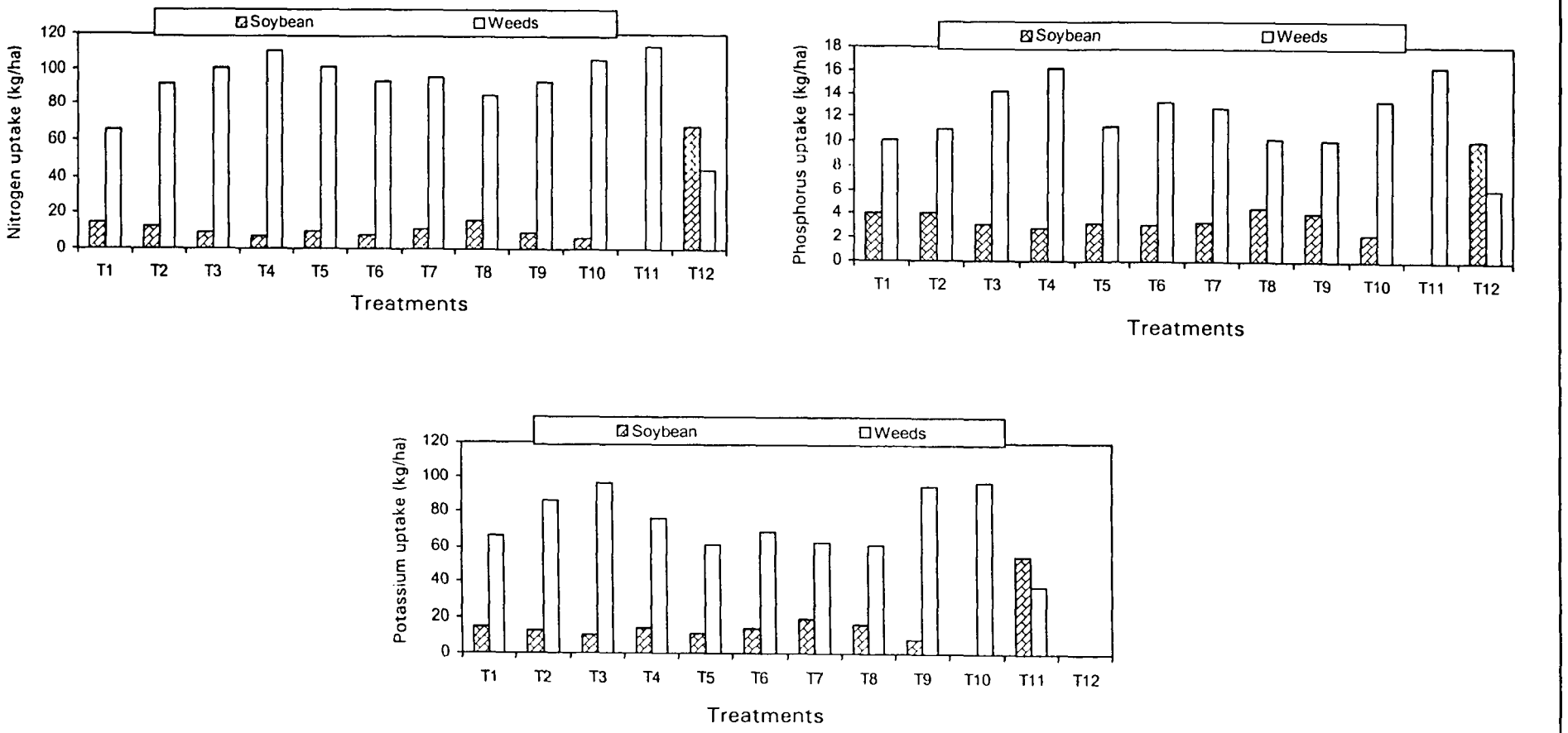

Fig. 5. Nutrient uptake (kg/ha) by weeds and soybean crop as influenced by weed control treatments

4.8.1.1 Nitrogen

The total nitrogen uptake by soybean differed significantly with the different weed control treatments. Weed free check (113.26 kg ha^{-1}) and pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher uptake of nitrogen by crop (110.14 kg ha^{-1}) and was on par with one hand weeding at 20 DAS + one intercultivation at 40DAS (105.08 kg ha^{-1}) and clomazone @ 875 g a.i.ha^{-1} PE (100.76 kg ha^{-1}). Whereas, weedy check recorded significantly lower uptake of nitrogen by crop (44.85 kg ha^{-1}). Among herbicidal treatments, pre-emergence application of clomazone @ 625 g a.i.ha^{-1} recorded significantly lower uptake of nitrogen by crop (65.60 kg ha^{-1}).

4.8.1.2 Phosphorus

Significant differences among the treatments with respect to phosphorus uptake by soybean crop were found at harvest. All the weed control treatments registered significantly higher uptake of phosphorus over weedy check. Weed free condition recorded significantly higher uptake of phosphorus (16.28 kg ha^{-1}) and was on par with pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (16.19 kg ha^{-1}), clomazone @ 875 g a.i.ha^{-1} (14.18 kg ha^{-1}) and which inturn did not differ significantly with one hand weeding at 20 DAS + one intercultivation at 40 DAS and pre-emergence application of clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (13.30 and 13.24 kg ha^{-1} respectively). Whereas, weedy check recorded significantly lower uptake of phosphorus (6.08 kg ha^{-1}).

4.8.1.3 Potassium

With regard to potassium uptake, weed control treatments differed significantly with each other. Weed free condition recorded significantly higher

uptake of potassium by crop (96.92 kg ha^{-1}) over weedy check (37.19 kg ha^{-1}) and was on par with one hand weeding at 20 DAS + one intercultivation at 40 DAS (94.19 kg ha^{-1}), pre-emergence application of colomazone @ 1000 and 875 g a.i. ha^{-1} (96.25 and 85.93 kg ha^{-1}, respectively).

4.8.2 Nutrient uptake by weeds (kg ha^{-1})

The data on the uptake of nitrogen, phosphorus and potassium by weeds as influenced by weed control treatments are presented in Table 15 and dipicted in Fig.5. Nutrient uptake by weeds shown significant differences due to various weed control treatments at harvest.

4.8.2.1 Nitrogen

Weedy check recorded significantly higher nitrogen uptake (67.88 kg ha^{-1}) over rest of the treatments. Significantly lower nitrogen uptake by weeds was recorded in one hand weeding at 20 DAS + one intercultivation at 40 DAS (6.44 kg ha^{-1}) over other treatments and was on par with pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (6.95 kg ha^{-1}). The later treatment recorded significantly lower uptake of nitrogen by weeds among herbicidal treatments and it did not differ significantly with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @250 g a.i. ha^{-1} and chlorimuron @ 9 g a.i. ha^{-1} (7.88 and 8.84 kg ha^{-1}, respectively). Whereas, pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} showed significantly higher nitrogen uptake by weeds (15.07 kg ha^{-1}) and was on par with pre-emergence application clomazone @ 625 g a.i. ha^{-1} (14.79 kg ha^{-1}) among herbicidal treatments.

4.8.2.2 Phosphorus

Weedy check recorded significantly higher uptake of phosphorus (10.08 kg ha^{-1}) over remaining treatments.

Among weed control treatments, one hand weeding at 20 DAS + one intercultivation operation at 40 DAS recorded significantly lower phosphorus uptake by the weeds (2.26 kg ha^{-1}) and was on par with pre-emergence application of clomazone @ 1000 and 875 g a.i. ha^{-1} (2.77 and 3.10 kg ha^{-1}, respectively) and clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1} (3.13 kg ha^{-1}). Whereas, significantly higher phosphorus uptake by weeds was observed with pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} (4.50 kg ha^{-1}) and clomazone @ 625 g a.i. ha^{-1} (4.09 kg ha^{-1}).

4.8.2.3 Potassium

The data on potassium uptake by weeds indicated the significant differences due to weed control treatments with the highest uptake of potassium by the weeds in the weedy check (54.27 kg ha^{-1}) and significantly lower was recorded in one hand weeding at 20 DAS + one intercultivation at 40 DAS (8.16 kg ha^{-1}) and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (9.86 kg ha^{-1}). Among herbicide treatments, significantly higher uptake of potassium by the weeds was recorded in pre-emergence application of pendimethalin @ 1000 g a.i. ha^{-1} (19.23 kg ha^{-1}) and was on par with chlorimuron @ 9 g a.i. ha^{-1} (16.11 kg ha^{-1}) and clomazone @ 625 g a.i. ha^{-1} (17.29) which were on par.

4.9 CORRELATION STUDIES

Correlation between seed yield and number of pods per plant, pod weight per plant, number of seeds per plant, seed weight per plant, 1000 seed weight, weed number and weed dry weight at harvest as estimated by " r " values are presented in Table 16.

The seed yield showed significantly positive correlation with number of pods per plant (r = 0.837), pod weight per plant (r = 0.628), number of seeds per plant (r = 0.770), seed weight per plant (r = 0.996) and 100 seed weight (r = 0.094) and had negative correlation with weed number (r = 0.834) and weed dry weight (r = 0.808).

4.10 ECONOMICS

Economics of weed control treatments on cost of weed control, gross return, net return and benefit cost ratio of different weed control treatments are presented in Table 17.

Among different weed control treatments, weed free check recorded highest cost of weed control (Rs.2376 ha^{-1}) over other treatments. Among herbicidal treatments, pre-emergence application of alachlor @ 2500 a.i.ha^{-1} (Rs.1758 ha^{-1}) and pendimethalin @ 1000 g a.i. ha^{-1} (Rs.1538 ha^{-1}) recorded higher cost of weed control. The lowest cost of weed control was recorded in pre-emergence application of clomazone @ 625 g a.i. ha^{-1} (Rs.546 ha^{-1}).

Gross returns were significantly higher (Rs.12867 ha^{-1} and Rs.12498 ha^{-1}, respectively) with weed free check and one hand weeding at 20 DAS + one intercultivation at 40 DAS and were on par with pre-emergence application of clomazone @ 750, 875 and 1000 g a.i. ha^{-1} (Rs.11520, 11559 and 11679

Table 16: Correlation of grain yield with yield components, number of weeds and weed dry weight

Parameter	Correlation co-efficient values (r)
Number of pods plant^{-1}	0.837**
Pod weight plant^{-1}	0.628**
Number of seeds plant^{-1}	0.770**
Seed weight plant^{-1}	1.000**
100 seed weight	0.094**
Number of weeds m^{-2}	-0.834**
Weed dry weight (g 0.25m^{-2})	-0.808**

Table 17: Economics of weed control treatments in soybean.

Treatments	Cost of weed control (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C ratio
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	546	10167	2926	1.40
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	633	11520	4192	1.57
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	720	11559	4144	1.56
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	808	11679	4176	1.56
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	1178	11580	3707	1.47
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	1058	9243	1490	1.19
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	1758	10819	2365	1.28
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	1538	9606	1373	1.21
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	828	10701	2974	1.42
T_{10} : One HW at 20 DAS and one IC at 40 DAS	1440	12498	4363	1.54
T_{11} : Weed free check	2376	12867	3772	1.41
T_{12} : Weedy check	-	6343	-353	0.95
S. Em±	-	508	508	0.06
LSD (0.05)	-	1491	1491	0.19

Note : PE = Pre-emergence

ha^{-1}, respectively) and clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (Rs.11580 ha^{-1}) which inturn did not differ significantly with alachlor @ 2500 g a.i. ha^{-1} (Rs.10819 ha^{-1}). Significantly lower gross return (Rs.6343 ha^{-1}) was recorded in weedy check. Pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} (Rs.9243 ha^{-1}) noticed significantly lower gross returns among herbicide treatments.

Significantly higher net returns (Rs.4363 ha^{-1}) were recorded in one hand weeding at 20 DAS + one intercultivation operation at 40 DAS and pre-emergence application of Clomazone @ 750, 875 and 1000 g a.i. ha^{-1} (Rs.4192, 4144 and 4176 ha^{-1}, respectively). Whereas, significantly lower net returns (Rs.353 ha^{-1}) was recorded in weedy check. Among different rates of clomazone, pre-emergence application of clomazone @ 750 g a.i. ha^{-1} recorded highest net returns (Rs.4192 ha^{-1}) and lower with clomazone @ 625 g a.i. ha^{-1} as PE (Rs.2926 ha^{-1}).

Significantly higher benefit cost ratio (Rs.1.57) was obtained with pre-emergence application of clomazone @ 750 g a.i. ha^{-1} and was on par with clomazone @ 875 and 1000 g a.i. ha^{-1} applied as PE (Rs.1.56), and one hand weeding at 20 DAS + one intercultivation at 40 DAS (1.54) which inturn did not differ significantly with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1} (Rs.1.47). Whereas, weedy check and pre-emergent application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1} among herbicides noticed significantly lower benefit cost ratio (Rs. 0.95 and Rs. 1.19, respectively).

4.11 SOIL ENZYME ACTIVITY

The observations on Dehydrogenase, urease and phosphotase activity in the soil measured at 20 DAS are presented in table 18.

Table 18: Urease, phosphatase and Dehydrogenase activities at 20 days after sowing as influenced by weed control treatments

Treatments	Urease activity (µg NH_4 g soil $^{-1}$ day $^{-1}$)	Phosphatase activity (µg of paranitro-phenol gm^{-1} soil per hour)	Dehydrogenase activity (µg TPF g soil $^{-1}$ day $^{-1}$)
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	113.76	38.61	23.36
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	117.72	32.02	24.40
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	115.15	30.90	27.41
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	115.30	33.27	24.65
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	120.10	39.10	27.56
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	115.30	41.06	20.87
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	114.37	35.50	26.45
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	117.71	40.72	25.79
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	118.39	40.47	25.05
T_{10} : One HW at 20 DAS and one IC at 40 DAS	114.04	36.12	24.36
T_{11} : Weed free check	117.05	38.85	28.38
T_{12} : Weedy check	117.03	36.99	28.94
S. Em±	1.626	4.53	2.237
LSD (0.05)	NS	NS	NS

Note : NS = Non-significant
PE = Pre-emergence

4.11.1 Dehydrogenase activity

Dehydrogenase activity was not significantly affected by the application of herbicides *viz.*, clomazone at 625 to 1000 g a.i. ha^{-1}, clomazone at 500 g a.i. ha^{-1} + chlorimuron at 250 g a.i. ha^{-1}, clomazone at 500 g a.i. ha^{-1} + Metribuzin at 250 g a.i. ha^{-1}, alachlor at 2500 g a.i. ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1} and chlorimuron at 9 g a.i. ha^{-1} as pre-emergence compared to non-herbicide treatments.

4.11.2 Urease activity

Urease activity was also remained unaffected due to application of herbicides as compared to herbicidal free treatments.

4.11.3 Phosphate activity

Phosphate activity also showed non-significant due to weed control treatments.

4.12 STUDIES ON RESIDUAL EFFECTS OF WEED CONTROL TREATMENTS ON SUCCEEDING CROPS

The observations on germination count, total drymatter production, root length and shoot length of succeeding crops *viz.*, sorghum, chickpea, soybean, bhendi and wheat are presented in Table 19 and 20 respectively.

Germination count, total dry matter production, root and shoot length of sorghum, chickpea, safflower, bhendi and wheat recorded at 20 days after sowing did not differ significantly due to residual effect of weed control treatments.

Table 19: Residual effect of weed control treatments of soybean on germination count (%) and total drymatter production (g plant^{-1}) of succeeding crops

Treatments	Sorghum		Chickpea		Safflower		Bhendi		Wheat	
	G	TDMP	G	TDMP	G	TDMP	G	TDMP	G	TDMP
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	96.33	2.167	96.67	0.267	80.67	0.320	72.00	0.200	96.00	0.483
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	97.67	2.333	96.00	0.260	77.00	0.307	73.00	0.210	96.00	0.450
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	97.00	2.733	96.00	0.260	79.00	0.400	72.67	0.227	96.00	0.483
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	97.00	2.867	97.33	0.263	73.33	0.397	70.00	0.233	94.67	0.450
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	98.00	2.633	97.67	0.263	79.33	0.423	69.33	0.217	96.67	0.450
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	96.00	2.767	96.00	0.290	79.33	0.377	69.33	0.240	95.00	0.417
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	98.00	2.733	97.00	0.260	82.33	0.313	72.33	0.230	95.33	0.450
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	97.33	2.700	97.00	0.230	77.33	0.250	67.33	0.240	95.67	0.467
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	90.67	2.533	91.00	0.243	82.33	0.233	69.00	0.223	95.67	0.450
T_{10} : One HW at 20 DAS and one IC at 40 DAS	95.33	3.267	95.00	0.243	74.67	0.317	71.33	0.230	97.00	0.467
T_{11} : Weed free check	97.00	2.967	97.00	0.230	80.33	0.323	73.33	0.230	97.67	0.483
T_{12} : Weedy check	97.33	1.733	96.00	0.220	78.33	0.287	67.00	0.183	95.33	0.383
S. Em±	4.63	0.274	4.65	0.015	3.28	0.055	2.14	0.012	2.96	0.030
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note : G = Germination count (%)
TDMP = Total dry matter production
NS = Non-significant
PE = Pre-emergence

Table 20 : Residual effect of weed control treatments of soybean on root and shoot length (cm) of succeeding crops

Treatments	Sorghum		Chickpea		Safflower		Bhendi		Wheat	
	R	S	R	S	R	S	R	S	R	S
T_1 : Clomazone @ 625 g a.i. ha^{-1} as PE	3.69	4.48	6.18	8.56	9.53	5.61	3.49	3.89	3.20	3.58
T_2 : Clomazone @ 750 g a.i. ha^{-1} as PE	3.20	5.24	6.68	9.01	9.20	5.73	3.19	3.63	3.21	3.35
T_3 : Clomazone @ 875 g a.i. ha^{-1} as PE	3.64	4.89	6.22	8.81	9.31	5.27	3.91	4.10	2.89	3.76
T_4 :Clomazone @ 1000 g a.i.ha^{-1} as PE	3.51	4.86	6.46	9.49	8.85	5.00	3.90	3.91	3.23	3.55
T_5 : Clomazone @ 500 g a.i. ha^{-1}+ chlorimuron @ 9 g a.i. ha^{-1} as PE	3.64	4.69	6.57	9.09	9.31	5.78	3.57	3.77	3.22	3.64
T_6 : Clomazone @ 500 g a.i. ha^{-1}+ metribuzin @ 250 g a.i. ha^{-1} as PE	3.68	5.04	6.61	8.86	9.02	5.33	4.01	3.64	2.57	3.76
T_7 : Alachlor @ 2500 g a.i. ha^{-1} as PE	3.83	4.78	6.74	8.73	9.33	5.63	3.65	3.87	2.89	3.71
T_8 : Pendimethalin @ 1000 g a.i. ha^{-1} as PE	3.80	5.07	6.55	9.04	8.81	5.19	3.71	3.66	2.91	3.97
T_9 : Chlorimuron @ 9g a.i. ha^{-1} as PE	3.67	4.77	6.44	8.60	8.71	5.05	3.57	3.68	2.89	4.03
T_{10} : One HW at 20 DAS and one IC at 40 DAS	3.87	4.97	6.55	8.86	9.57	5.53	3.57	3.65	2.89	4.21
T_{11} : Weed free check	3.46	4.66	6.55	9.31	9.13	6.30	3.80	3.91	2.90	4.11
T_{12} : Weedy check	3.70	4.83	6.13	8.65	8.83	4.85	3.30	3.65	2.18	4.17
S. Em±	0.13	0.17	0.14	0.23	0.22	0.35	0.19	0.11	0.25	0.19
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note : R = Root length (cm) NS = Non-significant
S = Shoot length (cm) PE = Pre-emergence

Discussion

V. DISCUSSION

Weeds compete with the crop plants utilizing considerable amount of nutrients and moisture, depriving the opportunity for the crop to express its potential yield. Thus efficient weed control is a pre-requisite for increasing productivity. Therefore, the present investigation was undertaken to find out the effect of clomazone herbicide for weed control in soybean and also to compare its bio-efficiency with other recommended herbicides, conventional hand weeding and intercultural operation, so as to minimize the weed infestation and to obtain better soybean yield. The results have been discussed on the following aspects in this chapter.

1. Weather and crop growth.
2. Influence of weed control treatments on crop yield and yield components.
3. Influence of weed control treatments on crop growth.
4. Influence of weed control treatments on weed growth.
5. Influence of weed control treatments on soil enzyme activity.
6. Influence of weed control treatments on nutrient uptake by crop and weeds.
7. Economics of weed control treatments.
8. Residual effect of herbicides on succeeding crops.

5.1 WEATHER AND CROP GROWTH

The rainfall during the crop growth period was less than the normal in the months of July (-120.01 mm), August (-40.57 mm) and September (-

51.37mm) which was rather undesirable. This might be one of the reasons for poor plant growth and yield in all the plots irrespective of treatments including weedy check. Low rainfall during the critical crop growth stages has led to reduced photosynthesis and increased competition between crop and weeds for moisture. The temperature was more than normal during the crop growth (+0.18°C during August and +1.36°C during September) with deficit of relative humidity during critical crop growth stages i.e, less than the normal in the months of July (-6.8%), August (-5.83%) and September(-10.86%) might have slightly affected crop growth and yield.

5.2 INFLUENCE OF WEED CONTROL TREATMENTS ON CROP YIELD AND YIELD COMPONENTS

In the present study, significant differences existed in yield and yield components as a consequence of weed control treatments. The seed yield was significantly higher with weed free condition (1429 kg ha^{-1}) and one hand weeding at 20 DAS with one intercultivation at 40 DAS (1389 kg ha^{-1}). These were found on par with pre-emergence application of clomazone @ 1000g a.i.ha^{-1} (1298 kg ha^{-1}), clomazone @ 500 g a.i.ha^{-1} + clorimuron @ 9 g a.i.ha^{-1} (1289 kg ha^{-1}) and clomazone @ 750 and 875 g a.i.ha^{-1} (1280 and 1284 kg ha^{-1}, respectively). Similarly, Billore *et al.* (1999 a and 1999 b) reported higher grain yield of soybean in weeds free conditions. The effectiveness of clomazone in controlling weed in soybean was reported by Negi and Saini (1994), Basavaraju and Nanjappa (1996), Rani and Ramana (1998), and Vyas *et al.* (2000). Among the herbicidal treatments pendimethalin @ 1000 g a.i.ha^{-1} and clomazone @ 625 g a.i.ha^{-1} recorded significantly lower seed weight (1067 and 1130 kg/ha respectively) owing to the inefficiency of these herbicides in controlling weeds, causing severe competition between crop and weed resulting in lower pod weight per plant and lower seed yield per plant.

This shows that the reduction in yield was apparently due to reduction in growth and yield components caused by weed infestation. The remaining higher levels of clomazone treatments gave higher seed yield (1280 to 1298 kg/ha) which may be due to better control of weeds. Weedy check recorded significantly lower seed yield (705 kg/ha) due to heavy weed infestation, which hindering the uptake of nutrients and reduced photosynthesis by shading effect as opined by Klingman (1961) and Marold and Krausze (1987).

Weed index indicated that the yield reduction due to weed competition was 50.66 per cent in weedy check as compared to weed free treatment. Similar results were reported by Billore and Joshi. (1998) and Billore *et al.* (1999). Among the herbicides, pre-emergence application of clomazone @ 1000g a.i.ha^{-1} recorded lowest weed index (9.2 %) and was statistically on par with application of clomazone @ 750 and 875 g a.i.ha^{-1} as PE (10.47% and 10.07%, respectively). The effectiveness of clomazone @ 625 g a.i.ha^{-1} was not appreciable with the present investigation. This was mainly due to its ineffectiveness in controlling weeds, resulted in severe weed competition for moisture, nutrients and light consequently affected the crop yield. Weed growth at early stages of crop growth has an appreciable effect on available soil moisture to crop (Patterson, 1995). Therefore, keeping the plots free from weeds at early stages of crop growth is most appropriate way for obtaining higher yields. This has been reflected on the productivity of soybean in the present investigation. The differences in grain yield could be attributed to variations in yield components as well as growth components.

All yield components except hundred seed weight, differed significantly due to weed control treatments. Weed free check and pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded more number of pods per plant (27.27 and 27.20, respectively) and were on par with one hand weeding

at 20 DAS plus one intercultivation at 40 DAS, pre-emergence application of clomazone @ 875 g a.i.ha^{-1} and alachlor @ 2500 g a.i.ha^{-1} (26.60, 24.87 and 24.47, respectively) as compared to weedy check (14.40). This was due to better utilization of available resources by the crop, because of weed suppression. Among the herbicidal treatments, application of clomazone @ 500 g a.i.ha^{-1} plus metribuzin @ 250 g a.i.ha^{-1} recorded lower number of pods (21.87 per plant). Pre-emergence application of clomazone @ 1000 g a.i.ha^{-1}, weed free check, alachlor @ 2500 g a.i.ha^{-1}, one hand weeding at 20 DAS plus one intercultivation at 40 DAS recorded significantly more number of seeds per plant (54.47,56.27,54.93 and 52.73, respectively). These were on par with pre-emergence application of clomazone @ 875 g a.i.ha^{-1} (43.80 per plant) and 750 g a.i.ha^{-1} (42.27 plant^{-1}). The same trend was also observed for number of seeds per pod(2.08, 0.06, 2.00 and 1.85, respectively).

Pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} and @ 875 g a.i.ha^{-1} recorded higher pod weight per plant (4.96 g and 4.67 g, respectively) and were on par with alachlor @ 2500 g a.i.ha^{-1} (4.64g) and weed free check (4.50g). Among the herbicidal treatments, clomazone @ 500 g a.i.ha^{-1} plus metribuzin @ 250 g a.i.ha^{-1} recorded lower number of seeds per plant (36.87), number of seeds per pod (1.66) and seed yield per plant (3.08 g). In weedy check all the above yield components were adversely influenced.

The differences in yield components due to different treatments was mainly attributed to variations in growth components like plant height, number of branches, leaf area and leaf area index, which inturn were influenced to a greater extent by weed infestation.

5.3 INFLUENCE OF WEED CONTROL TREATMENTS ON CROP GROWTH

The prerequisite for getting higher yields in any crop depends on its growth, total dry matter production and its accumulation in different plant parts.

Weed free check recorded tallest plants (29.30 cm) at 60 DAS and at harvest (31.60 cm) and among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} and @ 875 g a.i.ha^{-1} recorded significantly higher plant height (28.83 cm and 28.67 cm, respectively) at 60 DAS and at harvest (31.07 cm and 30.13 cm, respectively). This was due to better control of weeds in the early stages of crop growth by these herbicides, which provide a good opportunity for the crop to utilize the available resources *viz.*, nutrients, light and moisture.

Weed free check (13.15 to 15.24g plant $^{-1}$) and pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (12.12 to 14.27g plant $^{-1}$) recorded significantly higher total dry matter production per plant, this is attributed to better utilization of resources due to weed free environment and weed competition with crop. Whereas, lowest plant height (15.59 to 24.03cm) and significantly lower total dry matter production (1.21 to 6.62g plant^{-1}) was found in weedy check at all the crop growth stages. This was attributed to severe competition of weeds with crop for resources. Among the herbicidal treatments pre-emergence application of clomazone @ 625g a.i.ha^{-1} recorded lower plant height (15.82 to 27.00 cm) and gave on par dry matter to clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} (1.43 to 10.32 g plant^{-1}) due to inability of the herbicide to control weeds at critical stages.

The distribution of dry matter into assimilatory source, leaves and reproductive parts mainly pods indicated greater efficiency of the plant. The

distribution of dry matter into stem, leaf and pod differed significantly. Leaves recorded more dry weight than stem and pods implying the translocation of photosynthates from source to sink was higher during early reproductive stage but it affected adversely on pod dry matter at later stages due to scarcity of moisture. The highest dry matter distribution in leaf was recorded in pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} (3.24g plant $^{-1}$) and weed free check (3.2 g plant^{-1}). Whereas pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded significantly higher dry matter accumulation in pod (4.96 g plant^{-1}) at harvest. This was mainly due to the fact that weed free conditions provided the crop to fully exploit the available resources like nutrients, moisture and light, which resulted in better accumulation of dry matter in leaf and stem in the earlier stages and translocated to the pods at later stages.

Among the clomazone herbicide doses, pre-emergence application @ 625 g a.i.ha^{-1} recorded the lower dry matter distribution in pod (3.37 g plant^{-1}) due to heavy weed infestation in these plots, which resulted in lesser plant height, number of branches per plant, leaf area, LAI resulted in poor crop growth and poor translocation efficiency. The results indicate that, clomazone @ 875 to 1000g a.i. ha^{-1} applied as PE were found effective in reducing the weed competition and maintaining higher assimilatory source which resulted in higher photosynthesis, translocation and consequently higher total dry matter production. Similar inverse relationship in leaf area, total dry matter production and accumulation in different plant parts with weed competition was observed by Kurchania *et al.* (1996) and Billore *et al.* (1999a).

Observations on phytotoxicity at 1 to 10 scale indicated that the spraying of clomazone @ 1000g a.i.ha^{-1}as pre-emergence expressed very mild symptoms (leaf scorching) at initial stages, but at later stages it was masked.

These results are in conformity with Argenta and Lopes (1991) and Shylaja (1996). The other herbicide treatments used in the investigation did not show any phytotoxicity. These results are in conformity with Thro *et al* (1990) and Hu-fan *et al* (1995).

5.4 INFLUENCE OF WEED CONTROL TREATMENTS ON WEED GROWTH

In the present investigation most predominantly infested weeds were *Digera arvense, cocculus villosus, Hibiscus ponderiformis* and *Pyllanthes niruri* among dicots, *Commelina benghalensis* and *Dinebra retroflexa* among monocots and *cyperus rotundus* and *Cynodon dectylon* among sedges. Similar type of weed flora were observed by Basavaraju and Nanjappa (1996), Shylaja (1996), Babalad *et al.* (1999) and Vyas *et al.* 2000. Weed population differed significantly at all the crop growth periods. Monocotes, dicots, sedges and total weed population was significantly higher in weedy check as compare to rest of the treatments. While, in weed free treatment better control of weeds was maintained.

Among the herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} recorded lowest monocot weed population (1.09 to 2.82/m^2) whereas clomazone @ 500 g a.i.ha^{-1} plus metribuzin @ 250 g a.i.ha^{-1} recorded lowest dicot population (1.56 to 2.4 m^{-2}). Application of alachlor @ 2500 g a.i.ha^{-1} although recorded relatively lower weed population but at later stages of crop growth it recorded higher monocot weed population (1.17 to 3.93 m^{-2}). Pre-emergence application of clomazone 1000 g a.i.ha^{-1} or 875 g a.i.ha^{-1} recorded a good control of monocot weeds (1.09 to 2.82 m^{-2}) and sedges (0.71 to 1.05m^{-2}). From this it is understood that pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} or 875 g a.i.ha^{-1} could provide a

Plate 1. Luxuriant growth of weeds in weedy check

Plate 2. Good control of weeds in plot treated with pre-emergence application of clomazone @ 750 g a.i. ha^{-1}

Plate 3. Good control of weeds in plot treated with pre-emergence application of clomazone @ 875 g a.i. ha^{-1}

Plate 4. Excellent control of weeds in plot treated with pre-emergence application of clomazone @ 1000 g a.i. ha^{-1}

Plate 5. Excellent control of weeds in plot treated with one hand weeding at 20 DAS + one intercultivation at 40 DAS

Plate 6. Excellent control of weeds in plot treated with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha^{-1}

Plate 7. Good control of weeds in plot treated with pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1}

Plate 8. Good control of weeds in plot treated with pre-emergence application of alachlor @ 2500 g a.i. ha^{-1}

season long weed control. These results are in conformity with the findings of Davier and Gardinar (1985).

Pre-emergence application of pendimethalin @ 1000 g a.i.ha^{-1}, chlorimuron @ 9 g a.i.ha^{-1} and clomazone @ 625 g a.i.ha^{-1} recorded significantly higher number of monocot weeds (92.03 to 4.05m^{-2}), dicot weeds (2.82 to3.93m^{-2}) and sedge population (1.17 to 1.34m^{-2}) and failed to provide effective weed control.

In this investigation dicot weeds were predominant (upto 7.40m^{-2}) than monocot weeds (upto 5.72m^{-2}) and sedge population (upto 2.27.m^{-2}) when all the treatments were taken into consideration.

Pre-emergence application of clomazone @ 500 g a.i.ha^{-1} plus metribuzin @ 250 g a.i.ha^{-1} and clomazone @ 1000 g a.i.ha^{-1} were found to be effective in controlling both monocot and dicot weeds and also sedges. Whereas, pendimethalin @ 1000 g a.i.ha^{-1} and chlorimuron @ 9 g a.i.ha^{-1} gave good control of dicots but fairly controlled monocot weeds.

Pre-emergence application of chlorimuron @ 9 g a.i.ha^{-1} was found to control the dicot weed population (1.77 to 2.79m^{-2}) and sedge population (0.71 to 1.05m^{-2}) to a greater extent as compared to monocot weed population (2.97 to 4.05m^{-2}). This is because of these herbicides are effective only against dicot weeds but not on monocot weeds. Similar kind of observations were made by Chokkar *et al.* (1996), Pandey *et al.* (1996) and Tiwari *et al.* (1996).

Dry weight of monocot weeds, dicot and sedges differed significantly at all the crop growth stages. There was significantly lesser weed dry weight was recorded in weed free check. Among herbicidal treatments, pre-

emergence application of clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1} recorded lower dry weight of monocot at initial stages but clomazone @ 1000 g a.i.ha^{-1} recorded overall less dry weight at later stages (0.16 to 7.03 g 0.25 m^{-2}). Whereas clomazone at 500 g a.i.ha^{-1} plus Metribuzin at 250 g a.i.ha^{-1} recorded lower dry weight of dicots (0.18 to 4.32 g 0.25 m^{-2}) and clomazone @ 1000 g a.i.ha^{-1} recorded lower sedges dry weight (0.00 to 0.22 g 0.25 m^{-2}).

The total weed dry weight differed significantly due to weed control treatments at all the crop growth stages. Weed free check did not record total weed dry weight and was on par with one hand weeding at 20 DAS plus one intercultivation at 40 DAS, which recorded lower total weed dry weight (4.58 to 9.59 g 0.25m^{-2}) at all the crop growth stages. Similar kind of observations were made by Ramamoorthy *et al.*(1995).

Among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i.ha^{-1} registered lower total dry weight of weeds (0.29 to 13.3 g 0.25 m^{-2}) because of better action of clomazone at that level against both monocot and dicot weeds. This agrees with the earlier findings of Vyas *et al.*(2000). The total dry weight of weeds increased linearly at decreasing levels of clomazone but pendimethalin @ 1000 g a.i.ha^{-1} (1.58 to 27.20 g 0.25 m^{-2}) and clomazone @ 625 g a.i.ha^{-1} (0.00 to 24.43 g 0.25 m^{-2}) recorded higher total weed dry weight. This difference in the controlling ability by different herbicides was mainly due to the ability of controlling particular weeds by the herbicide.

Weed control efficiency (WCE) is an important parameter to decide the efficacy of different herbicides and cultural practices in weed management and is mainly dependent on weed dry weight. The crop yield is directly proportional to the weed control efficiency. The significantly higher weed control efficiency

was obtained with weed free condition followed by one hand weeding at 20 DAS plus one intercultivation at 40 DAS (86.94%). This was on par with pre-emergence application of Clomazone @ 1000 g a.i.ha^{-1} (81.85%). This higher WCE was mainly due to better weed control upto harvest resulting in lower weed population and lower weed dry weight. The highest WCE with these treatments showed least competition between crop and weeds at critical periods of crop growth and realized maximum benefit from weed control treatments. This certainly helped the crop in getting adequate supply of moisture, nutrients and light (Nanjappa, 1980). Relatively lower weed control efficiency was registered in pre-emergence application of pendimethalin @1000 g a.i.ha^{-1} (62.78%) and chlorimuron @ 9 g a.i.ha^{-1} (69.35%) was mainly due to ineffectiveness of these herbicides to control monocot weeds, which contributed higher total weed dry weight at harvest. These results corroborate with the earlier findings (Anon., 1995b).

5.5 EFFECT OF HERBICIDES ON SOIL ENZYME ACTIVITY

Application of herbicides to soil may have a number of secondary effects on soil biochemical processes, which further may adversely affect the soil health. From the point of view of possible health hazards and plant toxicity, it important to ascertain what effects each new herbicide causes on soil microbial processes. As new herbicides are developed, their behaviour and non target effects in response to variable soil and climatic conditions and cultural practices must be investigated prior to their use by farmers. In this study, the effect of clomazone and some recommended herbicides on soil dehydrogenase, urease and phosphatase activities were studied at 20 DAS.

The spraying of clomazone @ 625, 750, 875 and 1000 g a.i.ha^{-1} as pre-emergence, metribuzin @ 250 g a.i.ha^{-1}, alachlor @ 2500 g a.i.ha^{-1},

pendimethalin @ 1000 g a.i.ha^{-1} and chlorimuron @ 9 g a.i.ha^{-1} did not affect the soil dehydrogenase, urease and phosphotase activities. These results are in conformity with the results of Ramesh *et al.* (1999 and 2000). They reported that the application of imazethapyr and propaquizolfop had no effect on soil urease and dehydrogenase activity. Similarly, Allievi (1996) found little impact of sulfonyl urea herbicides *viz.*, chlorsulfuron, metsulfuron-methyl, sulfometuron-methyl and bensulfuron-methyl on soil microorganisms.

5.6 INFLUENCE OF WEED CONTROL TREATMENTS ON NUTRIENT UPTAKE (N, P AND K Kg ha^{-1}) BY CROP AND WEEDS

In production situations where mobile soil elements like water and nitrates are not limiting the growth, root length density has hardly an effect on the total uptake of these elements by the crop (Noordwijk and Van, 1983). The fraction of nutrient ions that is taken up by species is related to its share in the total root system (Anon., 1996). Weeds are vigorous growers and they demand large amounts of plant nutrients. In fact it is common observation that weeds grow best on the most of fertile soils obviously, since plant nutrient content of the soil is frequently a limiting factor for crop growth, removal of the competition for such nutrients will make more of them available to the growing crop (Anon., 1996). It is a common experience that crop infested with weeds show N deficiency. Certain weeds not only cause depletion of soil nitrogen by their absorption, but also induce nitrification. Nut sedge exudes perfumed carbon compounds into the soil which enhances the multiplication of denitrifying bacteria (Reddy and Reddi, 1997).

The uptake of N, P and K by the soybean crop decreased with increase in weed population and increased with decrease in weed competition (Table 15). The soybean in weed free check removed the significantly higher plant

nutrients 113.26 kg N ha^{-1}, 16.28 kg N ha^{-1} and 96.92 kg N ha^{-1}, respectively) whereas, the significantly lower uptake (44.85 kg, 6.08 kg and 37.18 kg N, P and K per ha respectively) was recorded in weedy check. Similar observations were also made by Singh and Kolar (1994). Among the herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded highest uptake of nutrients by soybean crop (110.14, 16.19 and 96.25 kg N, P and K respectively) compared to all other treatments. The uptake of nitrogen, phosphorus and potassium by weeds at harvest was also differed significantly due to various weed control methods (Table 15). There was an inverse relationship between the soybean crop and weeds as for as nutrient uptake was concerned. In weedy check, weeds removed significantly higher quantities of nitrogen, phosphorus and potassium while, uptake by the crop was minimum. The main reason for this kind of behaviour was that the weeds in weedy check were not controlled effectively and the increase in the number of weeds per unit area enable them to absorb more nutrients. Similarly, Singh *et al.* (1994), reported the maximum uptake of nitrogen (67 kg ha^{-1}), phosphorus (12kg ha^{-1}) and potassium (92 kg ha^{-1}) by weeds under uncontrolled conditions. Among the treatments, lowest uptake of nitrogen (6.44 kg ha^{-1}). Phosphorus (2.26 kg ha^{-1}) and potassium (8.16 kg ha^{-1}) by weeds was observed in one hand weeding at 20 DAS plus one intercultivation at 40 DAS. Maurya *et al.* (1990) reported the highest nutrient uptake by weeds (26.15kg N, 2.76kg P_2O_5 and 70.99 kg K_2O per ha) under weedy check as against two hand weedings (10.24 kg N, 0.039 kg P_2O_5 and 0.74 kg K_2O per ha). Among the herbicidal treatments, pre-emergence application of clomazone @ 1000a.i.ha^{-1} recorded lower uptake N, P and K (6.95,2.77 and 9.86 kg N, P and K per ha respectively) by the weeds and which was on par with clomazone @875 kg a.i ha^{-1} for nitrogen (9.00 kg ha^{-1}) and phosphorus (3.10 kg ha1).

Clomazone effect was found better in keeping the weed population at low level and hence reduced the competition for the nutrients during early stages of crop growth which was reflected at later stages in reducing the weed population and there by less removal of nutrients by the weeds.

5.7 ECONOMICS OF WEED CONTROL TREATMENTS

Significantly higher gross return (Rs.12867 and Rs.12498 ha^{-1}) were recorded with weed free check and one hand weeding at 20 DAS + one intercultivation at 40 DAS. Among herbicidal treatments, pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (Rs.11679 ha^{-1}) gave higher gross returns. The highest gross returns were mainly attributed by higher seed yield, obtained due to highest weed control efficiency. Significantly higher net return (Rs.4363 and 4192 ha^{-1}) and benefit cost ratio (Rs.1.54 and 1.57) were recorded with one hand weeding at 20 DAS + one intercultivation operation at 40 DAS and pre-emergence application of clomazone @ 750 g $a.i.ha^{-1}$, respectively. This is confirmed with the earlier findings of Billore and Joshi (1998) and Dubey *et al.* (1996).

Significantly lower net returns were recorded with weedy check and pre-emergence application of pendimethalin @ 1000 g $a.i.ha^{-1}$ (Rs.353 and 1373 ha^{-1}, respectively). This was mainly due to less seed yield and more cost of cultivation.

5.8 RESIDUAL TOXIC EFFECT OF HERBICIDES ON SUCCEEDING CROPS

Germination count, drymatter accumulation, root and shoot length of sorghum, chickpea, safflower, bhendi and wheat were not affected by residual effect of the herbicides used in the investigation. This may be due to faster rate of degradation/leaching or photolysis of herbicides applied to previous

crop. The results are in agreement with Gautam *et al.* (1994), Abd-El-Rauof *et al.* (1985), Anon. (1994, 1995a and 1995b).

RESULTS OF PRACTICAL UTILITY

1. Clomazone @ 750 g a.i.ha^{-1} to 1000 g a.i.ha^{-1} gave comparable yield to weed free condition
2. Clomazone has no phytotoxicity @ 625 g a.i.ha^{-1} to 1000 g a.i.ha^{-1} as PE application on soybean and residual phytotoxicity on succeding crops *viz.*, sorghum, chickpea, safflower, bhendi and wheat, and also no adverse effect on dehydrogenase, urease and phosphatase activity measured at 20 days after sowing, hence it can be safely used for weed control in soybean.
3. Clomazone @ 750 g a.i.ha^{-1} to 1000 g a.i.ha^{-1} applied as pre-emergence were found most effective in control of both monocots and dicots and produced higher yield.
4. Clomazone @ 750 g a.i.ha^{-1} pre-emergence application was found economically feasible for effective weed control.

FUTURE LINE OF WORK

- Integrated use of clomazone and its reduced levels along with interculture operation need to be studied.
- The studies on bio-efficacy of clomazone with different species of weeds needs to be assessed in order to use the herbicide where it is essential.

Summary

VI. SUMMARY

A field experiment entitled "Bio-efficacy of clomazone herbicide for weed management in soybean (*Glycine max* (L.) Merrill)" was conducted during *kharif* season of 2001 at Main Research Station, at AICRP on Soybean field unit, soybean scheme, Agriculture College Farm, University of Agricultural Sciences, Dharwad to select a suitable dose of clomazone herbicide and to compare its bio-efficacy with other recommended herbicides and physical / Mechanical methods of controling weeds in soybean. The treatments included were clomazone @ 625, 750, 875 and 1000 g a.i. ha^{-1} pre-emergence spray, pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + metribuzin @ 250 g a.i. ha-1, clomazone @ 500 g a.i. ha^{-1} + chlorimuron @ 9 g a.i. ha^{-1}, alachlor @ 9 g a.i. ha^{-1}, pendimethalin @ 1000 g a.i. ha^{-1}, chlorimuron @ 9 g a.i. ha^{-1}, one hand weeding at 20 DAS + one intercultivation at 40 DAS and weed free condition. These treatments were compared with weedy check in randomised block design with three replications. The silent findings of above investigation are summarized here.

The important weed flora observed in the experimental plots were monocots *viz., Commelina benghalensis* L., *Cynodon dactylon* L. and *Echinochloa colona,* dicot weed species like *Acanthospermum hispidum* Dc., *Achyranthuy aspera, Coccullus villosus, Digera arvense, Euphorbia geniculata* Ort., *Hibiscus ponderiformis, Mollugo diestica* and *Phyllanthus niruri* L. and *Cyperus rotundus* among sedge.

In the experimental plot, dicot weeds were predominant, followed by monocot weeds and sedge. Weed free check recorded significantly lower number of weeds and weed dry weight. Among herbicidal treatments, pre-emergent application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly

lower weed population (2.27 to 4.41 m^{-2}) and dry weight of weeds (0.29 to 13.29 g 0.25 m^{-2}) throughout the crop growth periods. Whereas, pre-emergence application of clomazone @ 625 g a.i. ha^{-1} recorded significantly higher weed population (3.55 to 5.53 m^{-2}) and weed dry weight (0.99 to 24.43 g 0.25m^{-2}), as they were infective in controlling the weeds. However, higher doses of clomazone application i.e., @ 875 and 1000 g a.i. ha^{-1} gave better control of weeds when compared to lower doses @ 625 and 750 g a.i. ha^{-1}.

Weed free check and one hand weeding at 20 DAS + one intercultivation at 40 DAS recorded significantly highest weed control efficiency (100% and 86.94% respectively). Among the herbicidal treatments, the significantly higher weed control efficiency (81.85%) was noticed with application of clomazone @ 1000 g a.i. ha^{-1} a pre-emergent.

Significantly maximum drymatter accumulation in plants were noticed in weed free check and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (1.86 to 15.24 g $plant^{-1}$). Whereas, significantly lower dry matter accumulation was recorded in weedy check (1.21 to 3.93 g $plant^{-1}$), pre-emergence application of clomazone @ 500 g a.i. ha^{-1} + Metribuzin @ 250 g a.i. ha^{-1} and clomazone @ 625 g a.i. ha^{-1} (4.54 to 9.97 and 1.43 10.32 g $plant^{-1}$, respectively).

The clomazone as pre-emergence spray did not show any phytotoxicity on soybean @ 625 to 1000 g a.i. ha^{-1}.

Weed free condition and pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} recorded significantly higher plant height, number of branches and number of leaves. Whereas, lower was recorded with weedy check.

Weed free check recorded higher growth functions (leaf area, LAI, AGR, RGR, NAR and CGR) at 30 and 60 days after sowing. These indices were adversely affected in weedy check and pre-emergence application of clomazone @ 625 g a.i. ha^{-1} among herbicides.

Weed free check and one hand weeding @ DAS + one intercultivation at 40 DAS recorded highest seed yield (1429 kg ha^{-1} and 1389 kg ha^{-1} respectively) and these were on par with pre-emergence application of clomazone at higher doses (750 to 1000 g a.i. ha^{-1}) which recorded an yield of 1280 to 1298 kg ha^{-1}.

The yield components *viz.*, number of pods per plant, pod weight per plant, number of seeds per plant and seed yield per plant showed significantly higher with weed free check, one hand weeding at 20 DAS + one intercultivation at 40 DAS and pre-emergence application of clomazone @ 875 and 1000 g a.i. ha^{-1} (higher levels). While, weedy check showed significantly lower values of yield components.

An inverse relationship was found between the crop and weeds with respect to uptake of nutrients (nitrogen, phosphorus and potassium). Significantly higher amount of nutrient uptake by the crop was noticed in weed free condition (113.26 kg N, 16.28 kg P and 96.92 kg K per ha). Whereas, lower uptake was noticed in weedy check (44.85 kg N, 6.08 kg P and 37.19 kg K per ha). Among herbicidal treatment, significantly higher amount of nutrient uptake by the crop was noticed in pre-emergence application of clomazone @ 1000 g a.i. ha^{-1} (110.14 kg N ha^{-1}, 16.19 kg P ha^{-1} and 96.25 kg K ha^{-1}) and was on par with pre-emergence application of clomazone @ 875 g a.i. ha^{-1} (100.76 kg N ha^{-1}, 14.18 kg P ha^{-1} and 85.93 kg K ha^{-1}), whereas, weeds recorded lower amounts of nutrients uptake in these treatments. The

highest amount of nutrients uptake by weeds (67.88 kg N, 10.08 kg P and 54.27 kg K per ha) was recorded in the weedy check.

Significantly higher gross returns were recorded with weed free check and one hand weeding at 20 DAS + one intercultivation at 40 DAS and were on par with pre-emergence application of clomazone @ 750 to 1000 g a.i. ha^{-1}. Clomazone @ 750 g to 1000 g a.i. ha^{-1} as pre-emergence gave significantly higher net return and B:C ratio. When B:C ratio and cost involved for weed control were considered clomazone @ 750 g a.i. ha^{-1} proved superior over other treatments.

Clomazone applied as pre-emergence @ 625 to 1000 g a.i. ha^{-1}, alachlor @2500 g a.i. ha^{-1}, chlorimuron @ 9 g a.i.ha^{-1}, pendimethalin @ 1000 g a.i.ha^{-1} and metribuzin @ 250 g a.i.ha^{-1} used in the investigation did not adversely affect the soil dehydrogenase, urease and phosphotase activities measured at 20 DAS.

Germination count, drymatter production, root and shoot length of succeeding crops viz., sorghum, chickpea, safflower, bhendi and wheat were recorded at 20 days after sowing and they were not significantly affected by residual effect of weed control treatments in soybean.

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Appendices

Appendix I: Price of inputs and outputs in calculating cost and returns

Sl. No.	Item	Unit	Price (Rs.)
I.	Inputs		
1.	Seeds	Kg	20.00
2.	Fertilizer		
	i. Urea (46% N)	Kg	4.60
	ii. SSP (16% P_2O_5)	Kg	8.80
	iii. Muriate of potash (60%K_20)	Kg	4.20
3.	Herbicides		
	i. Clomazone (command 50% EC)	Litre	350.0
	ii. Alachlor (Lasso 50% EC)	Litre	330.0
	iii. Pendimethalin (Stomp 36%SL)	Litre	515.0
	iv. Chlorimuron ethyl (Kloben 25%WP)	Gram	20.0
	v. Metribuzin (Sencor 70% WP)	Kg	1700.0
4.	Labour		
	i. Men	Day	36.0
	ii. Women	Day	36.0
5.	Bullock pair	Day	150.0
II.	Output		
	Seed	Kg	9.0

Appendix II: List of herbicides used in the experiment along with common name, trade name, chemical name and address of the manufactures

SL. No.	Common name	Trade name	Chemical name	Address of the manufactures
1.	Clomazone	Command (50%EC)	(2-chloropheneyl) methyl-4-4 dimethyl-3-isoxazolidinone	Rallies India Ltd. Rally House, 21D, Sukhadvala Marg, Bombay-400001
2.	Metribuzin	Sencor (70% WP)	4- amino-6 (1,1-dimethyl ethyl) –3-(methyl thio) – 1,2,4-triazin -5	Bayers India Ltd., Bombay
3.	Alachlor	Lasso (50%EC)	2(chloro)2,5-diethylene-N-(Methoxymethyl) acetanilide	Monsanto chemical of India Ltd., Wakefield house, 11, prout Road, Ballard Estate, Bombay-400038
4.	Pendimethalin	Stomp (36%EC)	N-(1-ethyl propyl), 3-4 dimethyl-2,6-denitrobemeneamitene	Cynamid India Ltd, Nyloc lHouse, 254,Dr. Annicbesant Road, Bombay-400025
5.	Chlorimuron ethyl	Classic (25%WP)	2-(4-choro-6-methoxy pyrimidine-2y) aminocylfonyl benzoic acid ethyl ester	Dupont (India)Ltd., community center panchashila park, New Delhi-110017

BIO-EFFICACY OF CLOMAZONE HERBICIDE FOR WEED MANAGEMENT IN SOYBEAN (*Glycine max* (L.) Merrill)

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ABSTRACT

A field experiment was conducted at Main Research Station, University of Agricultural Sciences, Dharwad on vertisols during *kharif* 2001 to study the bio-efficacy of clomazone herbicide for weed management in soybean. The experiment was laid out in randomized block design with 12 treatments comprising of pre-emergence (PE) application of clomazone @ 625, 750, 875 and 1000 g a.i.ha^{-1}, clomazone @ 500 g a.i.ha^{-1} + chlorimuron @ 9 g a.i.ha^{-1}, clomazone @ 500 g a.i.ha^{-1} + metribuzin @ 250 g a.i.ha^{-1}, alachlor @ 2500 g a.i.ha^{-1}, pendimethalin @ 1000 g a.i.ha^{-1}, chlorimuron @ 9 g a.i.ha^{-1}, one hand weeding + one intercultivation, weed free and weedy checks. The treatments were replicated thrice.

Clomazone did not cause any phytotoxicity on soybean. Clomazone @ 750 to 1000 g a.i.ha^{-1} applied as PE were found effective in reducing both population and dry weight of weeds. These treatments also recorded higher weed control efficiencies.

There was an improvement in growth and yield components of soybean with the application of clomazone. Clomazone @ 750 to 1000 g a.i.ha^{-1} recorded significantly higher seed yield as compared to clomazone @ 625 g a.i.ha^{-1}. Weedy check recorded significantly lower seed yield. Application of clomazone @ 750 to 1000 g a.i.ha^{-1} also recorded significantly higher nutrients uptake by crop compared to clomazone @ 625g a.i.ha^{-1} and pendimethalin @ 1000 g a.i.ha^{-1} and vice-versa with uptake of nutrients by weeds.

Significantly higher net return and B:C ratios were realized with clomazone @ 750 g a.i.ha^{-1} compared to clomazone @ 625 g a.i.ha^{-1}, alachlor @ 2500 g a.i.ha^{-1}, pendimethalin @ 1000 g a.i.ha^{-1} and clorimuron @ 9 g a.i.ha^{-1}.

Application of clomazone @ 625 to 1000 g a.i.ha^{-1} had no adverse effect on urease, dehydrogenase and phosphatase activities at 20 days after sowing and also on succeeding crops.

Based on the results, it could be concluded that clomazone @ 750 g a.i.ha^{-1} applied as PE was economically feasible for effective weed control in soybean.