EVALUATION OF DICLOSULAM AND HALOXYFOP FOR WEED CONTROL IN SOYBEAN [*Glycine max* (L.) Merrill]

Thesis

Submitted to the
Govind Ballabh Pant University of Agriculture & Technology,
Pantnagar-263 145 (U.S. Nagar), Uttarakhand, INDIA

By

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Doctor of Philosophy
(Agronomy)

AUGUST, 2010

ACKNOWLEDGEMENT

I am overwhelmed with rejoice to avail this rare opportunity to evince my profound sense of reverence and gratitude to Dr. S. C. Saxena, Professor, Department of Agronomy and Chairman of my Advisory Committee for his inspiring guidance, constant encouragement, untired cooperation, constructive criticism and soothing affection during the course of investigation and preparation of this manuscript.

I express my deepest gratitude and veneration to the esteemed members of my Advisory Committee, Dr. V.P. Singh, Professor, Department of Agronomy and Dr. Rohitashav Singh, Professor, Department of Agronomy and Dr. S. K. Guru J.R.O., Department of Plant Physiology for their constructive and valuable suggestions and guidance during the whole course of this investigation and preparation of this manuscript.

I am thankful to Dr. S. K. Saini, Professor and Head, Department of Agronomy and Dean, College of Agriculture, Dr. B. K. Kumbhar, Professor and Dean Post Graduate Studies, Dr. Dheer Singh, Joint Director, N. E. Borlaug Crop Research Centre and university Librarian for providing necessary facilities during the course of investigation.

I am deeply obliged and thankful to all the staff members of Department of Agronomy for their continuous co-operation and timely help rendered during my Post Graduate Studies in the Department.

I have immense thank to Sri Ram Prakash, Field Assistant, Sri Ali Mohammed, Lab Attendant, Processing Lab, Department of Agronomy and field workers for their immense support for the fulfillment of my thesis experimental work.

At this juncture of time my heart is full and I feel short of words at my command to express my regards and respect to my beloved parents.

It is indeed a pleasure to acknowledge the love, affection, inspiration, encouragement, help and cheerful company from my friends Mr. & Mrs. Major T.D. Joshi, Mr. & Mrs. Deepak Pathak, Prabhat, Vipin, Jitendra Bhaskar, Dixit, Satendra, Atul gupta, Geetanjali, Bhawana and Pawanika. I can not forget the love and co-operation received from my seniors especially B. S. Karki Sir, Ghimre Sir, Dr. Pathak, Dr. Radheyshyam, Dr. Vikram, Dr. Rajneesh, Dr. Bhardwaj and Kuldeep sir and Dr. Vineeta and all seniors of Agronomy for completion of this investigation. I would like to thank to all my loving juniors especially Santosh Yadav, Mr. & Mrs. Parth Brath Yadav, Ashok Joshi and Dubey for their love and cooperation.

I am also thankful to the almighty to encourage and support me for timely cooperation while working during the whole programme and also at typing this manuscript neatly.

Pantnagar

June, 2007

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CERTIFICATE

This is to certify that the thesis entitled **"EVALUATION OF DICLOSULAM AND HALOXYFOP FOR WEED CONTROL IN SOYBEAN [*Glycine max* (L.) Merrill]"** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** with major in **Agronomy** and minor in **Plant Physiology,** of the College of Post-Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Rakesh Chandra Nainwal, Id. No. 27938,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

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

Pantnagar
August, 2010

(S.C. Saxena)
Chairman
Advisory Committee

C E R T I F I C A T E

We, the undersigned, members of the Advisory Committee of **Mr. Rakesh Chandra Nainwal**, **Id. No. 27938,** a candidate for the degree of **Doctor of Philosophy** with major in **Agronomy** and minor in **Plant Physiology,** agree that the thesis entitled **"EVALUATION OF DICLOSULAM AND HALOXYFOP FOR WEED CONTROL IN SOYBEAN [*Glycine max* (L.) Merrill]"** may be submitted in partial fulfilment of the requirements for the degree.

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CONTENTS

Introduction

INTRODUCTION

Soybean a native of eastern Asia, is an ancient oil yielding legume crop with several food, feed and industrial uses. It is grown in many parts of the world as a source of vegetable oil and protein. For thousands of years, Chinese are using soybean as staple crop.

Soybean is a leguminous crop rich in quality protein (40-42%), oil (20-22%), soluble carbohydrates (15%) and minerals like calcium and iron. It is a good source of isoflavones and therefore, helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). It is economically viable oilseed crop and recognized as 'Golden bean'.

Soybean has occupied first rank among oil seeds in India since 2005 onwards. Soybean occupies 9.7 m ha with 9.7 m t production (Anonymous, 2009). However, productivity of soybean in India is very low (1006 kg ha^{-1}) largely due to poor plant stand, uncontrolled weed and infestation of insects and diseases etc. Weed population is the most critical in deciding the soybean productivity. In India, soybean is mainly grown in rainy season when the occurrence of different types of weeds (monocot and dicot) is very high. Weed infestation resulted in 54-65 per cent reduction in soybean yield depending upon weed species, intensity and stage of infestation (Chandel, 1989 and Fundora *et al.*, 1991). The common monocot weeds of soybean include *Echinochloa colona*, *Eleusine indica*, *Dactylactenium aegypticum*, *Cynodon dactylon*, *Cyperus rotundus*, *Cyperus iria* and *Sorghum halepanse*. The common dicot weeds are *Trianthema monogyna*, *Celosia argentia*, *Eclipta alba*, *Amaranthus viridis*, *Phyllanthus niruri* and *Commelina benghalensis*. Soybean crop suffers with heavy infestation of weeds at the early growth period. Therefore, to harvest a good yield, weed control during early stages of crop growth is essential.

Several non-chemical and chemical methods have been tried to control weeds in soybean. Conventional methods of controlling weeds undoubtedly accomplish the job effectively but are expensive and time taking. Availability of man power is also a serious problem these days. On the other hand mechanical weed control is not feasible in rainy season due to uncertain weather conditions. Hence there is immense need to look for effective chemical weed control in soybean.

The development of new herbicide molecules opened new ways for controlling weeds in soybean, besides providing higher degree of weed control at cheaper rate.

There are several pre emergence herbicides commonly used for effective weed control in soybean. But, these need to be applied with in very short period of time after planting. In monsoon season, if rains capture this critical period then pre emergence application cannot be accomplished. This necessitates the search of some post emergence chemicals for effective and economic weed control in soybean crop. Herbicide selection is based on the ability of the product to control important weeds without causing significant crop injury.

In view of above facts, the present investigation entitled "Evaluation of diclosulam and haloxyfop for weed control in soybean (*Glycine max* (L.) Merrill)" was planned with the following objectivities:

1. To study the effect of diclosulam and haloxyfop on weed growth,
2. To study the effect of diclosulam and haloxyfop on growth, yield attributes and yield of soybean,
3. To study the effect of diclosulam and haloxyfop on soybean quality.

Review of Literature

Among the various constraints in soybean cultivation, weeds are considered the most important in reducing the yield and quality of soybean. The losses may vary with the intensity, density and type of weed flora present under different agro-climatic conditions. Hence, an attempt has been made to receive the work done in India and abroad on weed management in soybean in order to formulate a technically sound research programme.

Associated weed flora with soybean

In India, the occurrence of weed species varied largely depending upon the different edaphic and climatic situations. Weed surveys conducted at Pantnagar (U.S. Nagar) Uttarakhand, indicated that major weed flora associated with soybean crop includes *Trianthema monogyna* (63.3%), *Celosia argentia* (11.8%), *Echinochloa colona* (45%) and *Cyperus rotundus* (18.7%) (AICRPWC, 1992).

Sharma and Thakur (1993) from Jabalpur (M.P.) reported the major weed species from soybean field were *Echinochloa colona* (21.6%), *Cyperus iria* (20.3%) and *Eclipta alba* (9.2%). Chandel and Saxena (1995) further reported that under Pantnagar conditions dominant weed flora consisted of *Cyperus rotundus* (45%), *Echinochloa* species (35%), *Trianthema portulacastrum* (10%) and *Sorghum halepense* (10%).

Balyan and Malik (2003) reported from CCS Haryana Agriculture University, Hisar that soybean field was dominated with *Trianthema portulacastrum*, *Echinochloa colona*, *Celosia argentia*, *Digera arvensis*, *Physalis minima*, *Cyperus rotundus* and *Dactyloctenium aegyptium*. On an average per cent cover of non-grassy and grassy weeds were 62.5 and 37.5 per cent, respectively. The relative cover of *Echinochloa colona*, *Cyperus rotundus* and *Dactyloctenium aegyptium* were 83, 10 and 7 per cent, respectively.

Singh *et al.* (2003) found that *Echinochloa colona* (86.7%) *Trianthema monogyna* (3.3%) and *Celosia argentia* (2.7%) were major weed species in experimental field. While others were *Eleusine indica*, *Dactyloctenium aegyptium*, *Cleome viscosa*, *Cucumis trigonus* and *Commelina benghalensis*.

Vyas and Jain (2003) conducted an experiment on soybean at Sehore, (M.P.) and observed that major weeds in experimental field were *Caesulia axillaries* (30.3%), *Cyperus rotundus* (15.5%), *Digitaria sanguinalis* (14.2%), *Echinochloa colona* (11.8%), *Commelina benghalensis* (7.9%), *Acalypha indica* (5.7%) and *Anotic monthuloni* (4.7%).

Singh *et al.* (2004) reported major weeds in soybean field were *Cyperus rotundus* (30.0%), *Echinochloa colona* (24.0%), *Commelina benghalensis* (16.4%) and *Celosia argentea* (11.5%). Other weeds (18.1%) observed were *Cucumis spp., Eleusine indica*, *Cleome viscosa, Dactyloctenium aegyptium, Digitaria sanguinalis, Digera arvensis,* *Parthenium hysterophorus, Trianthema monogyna, Eclipta alba* and *Brachiaria mutica.*

Pandya *et al.* (2004) noted that major weed species which infested soybean field comprised *Trianthema portulacastrum* (26.5%), *Commelina benghalensis* (12.0%), *Parthenium hysterophorus* (12.4%), *Amaranthus virdis* (5.1%), *Digera arvensis* (4.0%), *Echinochloa colona* (24.5%), *Cynodon dactylon* (14.2%) and *Cyperus rotundas* (4.4%). Rajput and Kushwah (2004) observed that major weed flora in soybean field were *Cyperus rotundus, Echinochloa crusgalli, Cynodon dactylon, Euphorbia* species, *Commelina benghalensis, Corchorus* species and *Parthenium hysterophorus.*

Singh *et al.* (2004) observed that in soybean field *Echinochloa colona* (27.2%), *Celosia argentea* (25.0%), *Trianthema monogyna* (16.3%), *Cyperus rotundus* (14.7%), and *Cleome viscosa* (9.8%) as major weeds and other weed spp. were (7.1%) mainly *Dactyloctenium aegyptium, Eleusine indica, Cucumis spp.* and *Commelina benghalensis.*

Dominant weed species in soybean field were *Echinochloa crusgalli, Cyperus rotundus, Cynodon dactylon, Alyscarpus rugosus, Corchorus species, Acalypha indica, Euphorbia species, Commelina benghalensis, Parthenium hysterophorus, Phyllanthus niruri, Setaria glauca* and *Eclipta alba* (Behera *et al.*, 2005).

Idapuganti *et al.* (2005) found that soybean field was infested with *Echinochloa colona* (58.0%), *Cyperus rotundus* (17.9%), *Trianthema* *portulacastrum* (4.8%) and *Digitaria arvensis* (17.3%). Singh (2005) reported that at 45 DAS major weed flora in soybean field were *Cyperus rotundus* (50%), *Dactyloctenium aegyptium* (20%), *Eragrostis pilosa* (15%) and *Commelina benghalensis* (8%).

Infestation of narrow leaved weeds and sedges were more than broad leaved weeds. The weed flora of the experimental area prominently comprised *Caesulia axillaris*, *Echinochloa colona, Cyperus iria, Cyperus rotundus, Commelina benghalensis, Digitaria sanguinalis* and *Acalypha indica* constituting on an average 24.6, 15.2, 13.5, 13.0, 11.8 and 4.8 per cent of total weed flora (Kushwah and Vyas, 2006).

Malik *et al.* (2006) observed that field was infested with broadleaf weeds (80%) including *Celosia argentia* and *Digera arvensis* and grassy weeds including *Echinochloa colona, Dactyloctenium aegyptium* and *Cyperus rotundus*. Grasses and sedge together constituted 20 per cent of the total weed population.

Pandya *et al.* (2006) reported that *Commelina benghalensis, Digera arvensis, Trianthema portulacastrum, Cynodon dactylon, Parthenium hysterophorus, Amaranthus spinosus, Echinochloa colona,* and *Cyperus rotundus* were major weed species in soybean field under Udaipur condition. Rathore *et al.,* (2006) reported the major weed species in soybean field were *Cyperus rotundus* (23.6%), *Echinochloa colona* (18.4%), *Commelina benghalensis* (13.1%), *Physalis minima* (13.1%), *Parthenium hysterophorus* (13.1%) and *Xanthium strumarium* (5.2%).

Singh *et al.* (2006) found that *Echinochloa colona, Echinochloa crusgalli, Cynodon dactylon* and *Dinebra arabica* among the grasses and *Celosia argentia, Digera arvensis, Commelina benghalensis* and *Trianthema portulacastrum* were among broad leaf weeds.

Billore *et al.,* (2007) from NRC soybean, Indore observed that predominant weed flora encountered during the season were *Echinochloa* species, *Digitaria* species, *Commelina benghalensis, Dinebra retroflexa* among monocot weeds; *Cyperus rotundus* among sedge; and *Euphorbia geniculata, Digera arvensis* and *Eclipta alba* among dicot weeds.

Yield losses due to weeds

Of the several constraints, weed competition is mainly responsible for low productivity of soybean. Weeds are most problematic because it has adapted to selection in agro ecosystems in following several ways.

1. Genetic variants within a species,
2. Somatic polymorphism of plant parts,
3. Success in diverse habitat micro-sites,
4. Temporal adaptations within the community, and
5. Floristic diversity of a community at higher levels than the species.

In addition, congenial soil moisture conditions, suitable temperature (30-35°C), better nutrient availability during '*kharif*' season provides unique opportunity for weeds to appear simultaneously with crop and make crop devoid of essential nutrients, light moisture and space, thereby causing substantial reduction in crop yield, produce quality, land value and increase cost of cultivation. Different factors on which the magnitude of yield losses due to weeds depends on, type of weed flora, intensity of weeds, duration and stage of weed infestation, competing ability of crop plant and different agro-ecological conditions that affected weed and crop growth.

The weeds, if not controlled at critical period of crop weed competition, reduce the yield by 20-27 per cent depending upon the time and intensity of infestation. (Muniyappa *et al.*, 1986; Tiwari and Kurchania, 1990). Dharm *et al.,* (1992) reported 41-84 per cent reduction in grain yield due to weed infestation in Karnal (Haryana).

Kurumawanshi *et al.* (1995) reported that besides several good characters of soybean crop in competitiveness with weeds, still the weeds affect the crop and reduce yield to the extent of 18.83 to 42.37 per cent. Weeds, if not controlled at critical period, crop weed competition during first 30 DAS, reduces the yield of soybean from 58 to 85 per cent depending upon type and weed intensity infestation (Singh and Singh, 1987; Kohle *et al.*, 1998).

Jain *et al.* (1997) reported that soybean crop is often infested with grassy, broad-leaved weeds and sedge which compete with crop, resulting in decreased in yield to the tune of 26 to 71 per cent depending upon the type and intensity of weeds and their occurrence.

Kurchania *et al.* (2001) reported that 20 to 77 per cent yield loss in soybean while Singh *et al.* (2001) reported that uncontrolled weeds caused on an average reduction of 79.8 per cent in grain yield of soybean.

Chandel and Saxena (2001) reported that weed reduce soybean yield by 58 to 85 per cent while Yaduraju (2002) reported 30 to 80 per cent soybean yield loss due to weeds infestation.

Singh *et al.* (2002) found that uncontrolled weeds may result in more than 85 per cent reduction in grain yield of soybean.

Singh *et al.* (2004) reported that unchecked weeds may cause as high as 84 per cent reduction in grain yield of soybean.

Gupta *et al.* (2006) and Billore *et al.* (1999) reported that soybean suffer from perceptible yield erosion 35 to 80 per cent on account of infestation with weeds.

Chemical method of weed control

The effective and economical weed control in soybean on large scale is not possible through manual operation or mechanical means due to uncertain weather and soil conditions. Weeds within lines are not controlled which may lower the yield and encourages weed infestations for the next crop. Sometimes crops sown at closer spacing or crops not sown in lines do not permit mechanical weeding or hoeing. So all these factors again pressurize for the use of herbicides which cannot be completely replaced by other methods of weed control. Use of herbicides not only improve crop yield but also make available significant labour for other productive use of right technology. The effects of various herbicides of weeds and grain yield of soybean are summarized here:

Effect of herbicides

Early studies of weed control in soybean have largely shown that there is no substitute for cultural or mechanical methods to control weed flora completely. Introduction of chemical in agriculture has, however, offered a wide spectrum of herbicides, which can accomplish weed control at much lower cost in shorter time than cultural methods. Use of herbicides not only improves crop yield but also makes available significant labour for other productive use of right technology (Kurchania *et al.*, 1989).

Fluchloralin

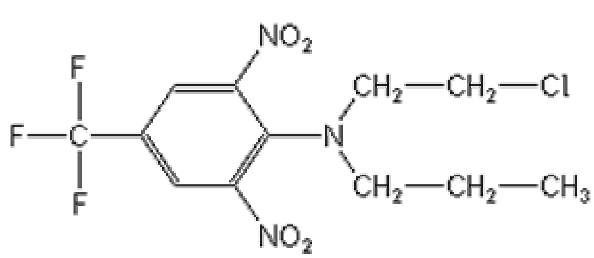
Common name : Fluchloralin

Trade name : Basalin

Chemical family : Chloroaniline

Application sites : Dry and succulent peas and beans, cotton, okra, peanuts, soybeans, and sunflowers.

Formulations : Emulsifiable concentrate



Method of application: Pre plant broadcast or banded spray, using ground equipment. Soil incorporation recommended.

Foliar absorption: Not applicable; fluchloralin is soil-incorporated.

Translocation: Residues are taken up and translocated through the roots and shoots of cotton and soybean plants. Parent compound and some metabolites have been identified in cotton and soybean foliage following exposure of the roots to fluchloralin.

Mode of action: Believed to affect seed germination and other physiological growth processes.

Environmental characteristics

Adsorption and leaching in basic soil types: Fluchloralin (unaged)and fluchloralin residues (aged 30 days) are relatively immobile to slightly mobile in loamy sand and sandy soils, but the degraded 2,6-dinitro-4-trifluoromethylphenol is highly mobile in loamy sandy soil and mobile in sandy clay loam soil. Fluchloralin is slightly mobile in runoff from plots (5-12% slope) of silt loam soil.

Loss from photodecomposition and/or volatilization: Fluchloralin photodegrades rapidly (half-life 27 minutes) in water (pH 5.6) when exposed to artificial sunlight. Photodegradation of solid fluchloralin film is slower (half-life 48 hours in artificial sunlight). No valid volatilization data are available.

Effect of fluchloralin

The effects of Fluchloralin a pre-emergent dinitroaniline herbicide, applied at 1000 g ai per ha, on the root and shoot length, root and shoot dry weight, nodule number and dry weight, and shoot N content and nitrogenase activity in soybean (cv. Pusa 22) was investigated in a pot experiment under greenhouse conditions and it was seen that fluchloralin in combination with the rhizobial culture and (or) the PGPRs produced better root and shoot length and dry weight, nodule number and dry weight, and total shoot N content and nitrogenese activity compared to the inoculated but no pesticide treatment and the uninoculated control (Gupta *et al.*, 2002).

Borse *et al.* (2000) reported the effects of various herbicides (anilofos, fluchloralin, pendimethalin, alachlor and metribuzin) applied as pre and post-emergence on weed density, and on the yield and yield components of soyabean. The efficacy of the herbicidal treatments was compared with that of hand weeding at 20 and 40 days after sowing. Plant height, number of branches, number of pods per plant, weight of pods per plant, number of grains, weight of grains per plant, and dry matter were highest in the weed-free plot. All the weed control treatments significantly reduced weed density. The pre-emergence application of alachlor 10 G at 2.0 kg ha^{-1}, pre-plant incorporation of fluchloralin 45 EC at 1.0 kg ha^{-1}, and pre-plant incorporation and post-emergence application of anilofos 5 G or 30 EC at 1.5 kg ha^{-1} were equally effective in increasing grain yield.

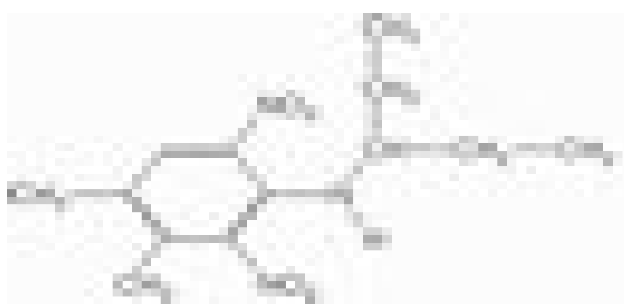
Singh *et al.* (2001) studied the effects of various weed control practices on the performance of soybean cv. PK-327 and associated weeds (predominantly *Echinochloa crusgalli, Launaea asplenifolia, Phyllanthus niruri, Cynodon dactylon, Amaranthus viridis* and *Cyperus rotundus*). The treatments consisted of hand weeding at 20 days after sowing (DAS), hand weeding at 20 and 40 DAS, alachlor 50 EC (4 liters ha^{-1}) sprayed at pre-emergence, and fluchloralin 45 EC (1.65 liters ha^{-1}) applied to soil at 1 day before sowing. Weed population was evaluated at 15, 45 and 75 DAS. Hand weeding at 20 and 40 DAS resulted in the highest number of pods per plant, 1000-grain weight, average grain yield and weed control efficiency (63.07%). Between the herbicides, fluchloralin 45 EC exhibited greater weed control efficiency and resulted in higher grain yield than alachlor 50 EC.

Chafale *et al.* (2002) studied the effect of selective herbicides like pendimethalin and fluchloralin @ 1.0 kg ha^{-1} with and without cultural practices on growth, quality and yield of soybean. The results showed that either pre-emergence application of pendimethalin or fluchloralin @ 1 kg ha^{-1} with one hoeing at 40 DAS recorded significantly higher grain and straw yields over other treatments of cultural practices. The higher yield attributed to maximum plant height, no. of branches and no. of leaves per plant. The quality parameter like test weight, oil and protein content in seed were significantly increased due to these treatments.

Pendimethalin

Common name	:	Pendimethalin
Trade names	:	AC-92553; ANK-553; Accotab, Go-Go-San, Prowl, Herbadox, Penoxalin, Sipaxol, Sovereign, Stomp and Way-Up, Pendiguard.
Chemical name	:	N-(1-ethylpropyl)-3,4-dimethyl-2,6, dinitrobenzene -amine .
Formulation	:	EC, GR, WG
Type of herbicide	:	Selective translocated
Method of application	:	Pre-emergence or (early post emergence) in corn, PPI or PE in potato and soybean.

Chemical structure:



Crop selectivity: It generally incorporate in to soil before seeding soybean, canola, rice, maize, sunflower, cotton, sugarcane, vegetables, plantation crops. It is also used for desuckering tobacco by direct application to the plants after topping.

Biochemistry of pendimethalin: Microtubule assembly inhibition.

Mode of action: Pendimethalin disrupts cell division and cell elongation in shoot and root meristems of susceptible plants.

Germination of plants is unaffected by the herbicide; growth inhibition and sub-sequent death occur following germination of the seed or shortly after emergence from the soil.

Monocot (grasses and sedges) plants that emerge are stunted and twisted and show a red-purple colouration. Root effects observed as a characteristic swelling of the tip. Shoot-growth inhibition occurs in susceptible monocots after absorption by the coleoptiles node, when this meristematic region is in contact with or passes through the area treated with pendimethalin.

In dicots, the hypocotyl is the most sensitive site of absorption. Typical symptoms of the aerial parts of susceptible dicot (broadleaf) weed plants that emerge include severe stunting, intense green colouration, and a leathery appearance of the cotyledons. Root growth affected when the root meristem absorbs the herbicide from the soil; however, plant kill occurs only when the shoot meristem of monocots or dicots contacts the herbicide and growth is severely disrupted. Effect on the shoot from the root absorption is a secondary effect, since translocation from root to shoot is minimal.

The mechanism of action of pendimethalin involves inhibition of microtubule formation in cells. This causes disruption of cell division as the microtubule spindle fibres that guide chromosomes are absent, the cell plate does not appear, and cells do not divide.

The microtubules are also responsible for microfibril orientation in the cell wall; in their absence, microfibrils become disoriented and cells expand to a rounded rather than elongated shape.

Generally, incorporation of pendimethalin will increase activity against monocot weeds by allowing absorption at the sensitive shoot meristem (the coleoptile node) and the root meristems. Effectiveness on dicot species can be reduced by incorporation because of dilution of the herbicide in the soil profile; in this case, the concentrated band near the soil surface will have greater effect through its action on the most sensitive site, the hypocotyl. Thus, the herbicidal effect of pendimethalin varies according to the relative location of the sensitive meristems and herbicide placement in the soil. This is also a major factor in the tolerance of certain crops to pendimethalin.

Effect of pedimethalin

Rani and Kodandaramaiah (1997) reported from Guntur (A.P.) that pre-emergence application of Pendimethalin at 1.0 kg a.i. ha^{-1} reduced weed biomass significantly and was *at par* with manual weed control. Bhalla *et al.* (1998) reported from Jabalpur (M.P.) that the most effective level of weed control (42.6%) was obtained using Pendimethalin at 1.5 kg a.i. ha^{-1}.

Billore and Joshi (1998) found that Pendimethalin at 1.0 kg a.i. ha^{-1} resulted in highest reduction in weed biomass and greater weed control efficiency next to hand weeding treatment. They also reported that Pendimethalin produced dwarf plants with best yield attributes and seed yield.

Kewat (1998) at Jabalpur revealed that Pendimethalin remained biological active upto 25 to 26 days in sandy loam soil following its application at 1.0 and 1.5 kg a.i. ha^{-1} and nearly 75 per cent pendimethalin was lost in 45 days.

Bhan and Kewat (2002) indicated that it was safe to apply pendimethalin at 1.0 to 1.5 kg ha^{-1} for effective weed control in soybean. The half life of pendimethalin at 0.5 to 1.5 kg ha^{-1} was 23 days but it increased from 34 to 43 days with the increase in dose from 2.0 to 2.5 kg ha^{-1} pendimethalin, when applied at same dose, its efficacy against weeds was however, reduced in heavy soils. Pendimethalin when applied at 1.0 to 2.5 kg ha^{-1} the population of dominant weeds i.e. *Phyllanthus niruri* and *Echinochloa crusgalli* were curbed to a great extent. However, other weeds like *Commelina communis* and *C. axillaris* were not controlled by pendimethalin. Pendimethalin at 1.0 to 2.0 kg ha^{-1} produced soybean seed yield comparable to weed free, however, pendimethalin at 2.5 kg ha^{-1} caused phytotoxicity to soybean seedlings resulted lower grain yield.

Singh *et al.* (2003) reported that highest soybean yield was recorded in weed free plots. Pre-emergence application of acetachlor at 1.5 and 2.0 kg ha^{-1}, alachlor at 2.5 kg ha^{-1}, pendimethalin and metolachlor each at 1.5 kg ha^{-1} produce soybean grain yields similar to weed free treatment.

Kalpana and Velayutham (2004) found that lowest weed population in plots treated with clomozone + pendimethalin (375+750 g ha^{-1}), clomozone and pendimethalin each at 1.0 kg ha^{-1} resulted in higher grain yield of soybean recording 1556, 1497 and 1504 kg ha^{-1} as compared to pre-emergence application of alachlor (1536 kg ha^{-1}) and two hand weeding (1533 kg ha^{-1}).

Singh (2007) reported that pre-emergence application of pendimethalin at 0.45 kg ha^{-1} and clomazone at 1.0 kg ha^{-1} integrated with one hand weeding 30 DAS recorded the highest grain yield.

Gupta and Saxena (2008) reported that at 60 DAS lowest weed density was recorded with pendimethalin at 1.0 kg ha^{-1} followed by alachlor at 1.0 kg ha^{-1}. At 60 DAS, WCE was 97.89 and 98.82 per cent respectively for pendimethalin at 1.0 kg ha^{-1}+one hand weeding at 30 DAS and clomazone at 1.0 kg ha^{-1}+ one hand weeding at 30 DAS because of weed removal after 30 DAS and thereafter weed re-emergence was very less thus low weed dry matter. Further reported that pendimethalin at 1.0kg ha^{-1} + one HW at 30 DAS resulted in 21.31 per cent higher grain yield over weedy (check).

Haloxyfop-ethyl

Common name	:	Haloxyfop
Trade name	:	Verdict
Chemical name	:	(*RS*)-2-{4-[3-chloro-5-(trifluoromethyl)-2 pyridyloxy] phenoxy} propionic acid

Chemical structure:

Formulation: EC

Crop selectivity: Sugar beet, fodder beet, potato, leaf vegetables, flax, onion, sunflower, soybean, vines and strawberries.

Method of application: Post emergence

Biochemistry of haloxyfop-ethyl: Fatty acid synthesis inhibitor by inhibition of acetyl CoA carboxylase (ACCase).

Mode of action: Haloxyfop-ethoxy ethyl and haloxyfop-P-methyl are selective herbicides, absorbed by the foliage and roots, and hydrolysed to haloxyfop, which is translocated to meristematic tissues, and inhibits their growth.

Effect of Haloxyfop

Tiwari and Kurchania (1990) reported that weed competition decreased yield of soyabean by 77%. Fluchloralin @ 1.0 kg ha^{-1} pre-sowing incorporated 37.5 per cent weeds reduction, and was economical compared with hand weeding. Papong and Kaowaikul (1995) reported that pre emergence herbicide (alachlor, metolachlor, oxyfluorfen and oxadiazon) and post emergence herbicide (haloxyfop-methyl, fluazifop-butyl and propaquizafop) mixed with fomesafen showed excellent control of grass and broadleaf weeds. The use of pre emergence or post emergence herbicide for weed control in soybean increased yield significantly compared with control (non-treated).

Singh *et al.* (2002) reported that haloxyfop at 75 and 100 g ha^{-1} had better weed control efficacy than at 25 and 50 g ha^{-1}. Early application of this herbicide (14 DAS) was more effective than delayed application. Grain yield at 75 and 100 g ha^{-1} applied at 14 DAS was at par with weed free treatment whereas, Tiwari *et al.* (2007) reported that the post-emergence application of haloxyfop ethoxy-ethyl at 50 g/ha or higher rates (75 and 100 g ha^{-1}) effectively control of grassy weeds.

Balyan and Malik (2003) reported that grassy weeds, particularly barndyard grass were controlled effectively by haloxyfop. Application of haloxyfop at 150 to 250 g ha^{-1} provided 70 to 95 per cent control grassy weeds. Tank mix application of fomesafen with haloxyfop at 200 + 150 g ha^{-1} and chlorimuronethyl with haloxyfop at 6 + 150 g or 9 +150 g ha^{-1} provided satisfactory control of both grassy and non grassy weeds. The control ranged from 85 to 95 per cent of broadleaf and 70 to 85 per cent of grassy weeds.

Tiwari *et al.* (2007) reported that post emergence application of haloxyfop ethoxy ethyl checked yield reduction up to 91 per cent when applied at 50 to 75 g ha^{-1} and proved superior to its lowest (25 g ha^{-1}) and highest doses (100 g ha^{-1}). Excellent control of grassy weeds by application of haloxyfop ethoxy ethyl at 50 to 75 g ha^{-1} could be reason for minimum yield reduction in soybean. The weed control efficiency indicated haloxyfop ethoxy ethyl at lowest rate (25 g ha^{-1}) paralyzed the weed biomass production up to 70 per cent, but where it increased to 77 and 79 per cent applied at higher rates (50 and 75 g ha^{-1}).

At Dharwad, haloxyfop ethyl recorded higher seed yield which was superior over check herbicide. On zonal mean basis haloxyfop ethyl at 75 g ha^{-1} yielded 9 per cent higher than quizalofop ethyl. Weed control efficiency of haloxyfop ethyl at 75 g ai ha^{-1} was comparable with check herbicide pendimethalin at 1 kg ha^{-1} at 30 DAS and better at 60 DAS. At Pune seed yield of haloxyfop ethyl at 75 g ha^{-1} (3086 kg ha^{-1}) which was *at par* with pendimethalin and weedy check. At Sehore, yield obtains with haloxyfop ethyl at 100 g ha^{-1} was *at par* with check herbicide pendimethalin and weedy check. At Indore, haloxyfop ethyl at 100 g ha^{-1} yielded 13.12 q ha^{-1} which was *at par* with quizalofop ethyl 1271 kg ha^{-1} (AICRP on soybean, 2008-2009).

Diclosulam

Common name : Diclosulam

Trade name : Spider, Strongarm, XDE-564, Crosser and Diclocular.

Chemical name : N-(2, 6-dichlorophenyl)-5-ethoxy-7-fluoro [1,2,4] triazolo [1, 5-c] pyrimidine-2-sulfonamide

Formulation: WDG

Chemical structure:

Crop selectivity: Soybean and peanut

Method of application: PE and PPI.

Biochemistry of diclosulam: Inhibit the acetolactate synthase (ALS) enzyme. The primary site of activity is within the chloroplast in plant meristems. Selectivity is attributed to limited translocation in soybean and peanut and rapid metabolism in to a non active form.

Mode of action: Taken up by both roots and foliage and translocated to new growing points. Lethal amount of diclosulam accumulate in meristems, halting cell division and resulting in plant death. Very little diclosulam accumulate in plant roots.

Effect of Diclosulam

Singh *et al.* (2002) reported that diclosulam was not effective in reducing *Echinochloa colona.* When diclosulam was tank mixed with haloxyfop there was no change in the efficacy diclosulam, but haloxyfop lost its efficacy against *Echinochloa colona.*

Reddy (2000) from Mississippi reported that diclosulam controlled 83 to 93 per cent of *Euphorbia hyssopifolia, Sida spinosa* and at least 82 per cent of *Ipomoea hederacea* var. *integriuscla* and *Ipomoea lacunose.*

Price and Wilcut (2002) from North Carolina reported that diclosulam alone or dimethenamid plus diclosulam control yellow nutsedge and ragweed by 65 to 100 per cent and ≥99 per cent respectively. Further reported in conventional tillage peanut diclosulam control 95 per cent of *Eclipta spp.* Diclosulam with or without dimethenamid control entire leaf and pitted morningglory by at least 81 per cent which is similar to control level reported in Texas (Dotray *et al.,* 2000).

Grichar *et al.* (2006) reported that diclosulam alone applied preplant incorporated, pre emergence, or post emergence controlled Palmer amaranth and pitted morningglory greater than 81per cent, devil's-claw at least 80 per cent, Texas panicum 33 to 97 per cent, and yellow nutsedge 48 to 88 per cent four weeks after treatment (WAT).

At Pantnagar diclosulam at 22 g ha^{-1} as PE produced maximum yield (2491 kg ha^{-1}) and was *at par* with two hand weeding and significantly superior over check herbicide pendimethalin and imazethapyr. Weed control efficiency of diclosulam at 22 and 30 g ha^{-1} was 100 per cent at 30 and 60 DAS. At Sehore diclosulam at 22 g ha^{-1} as PE produced maximum yield (2659 kg ha^{-1}) and was significantly superior over check herbicide pendimethalin and was *at par* with pendimethalin + IC -cum-HW at 30 DAS. At Pune diclosulam at 14, 22 and 30 g ha^{-1} was significantly superior over check herbicide – Imazethapyr and was *at par* with checks-pendimethalin, pendimethalin + IC-cum- HW and two hand weeding (AICRP on soybean, 2007-2008).

At Pantnagar significantly higher seed yield (2732 kg ha^{-1}) was obtain with test herbicide diclosulam at 22 g ha^{-1} as compare to all treatment except diclosulam at 30 g ha^{-1} and two hand weeding. Maximum weed control efficiency at 30 and 60 DAS were recorded with diclosulam at 30 g ha^{-1}. Application of diclosulam at 22 g ha^{-1} yielded maximum and significantly higher than diclosulam at 18 g ha^{-1}, haloxyfop ethyl at 75 and 100 g ha^{-1}, pendimethalin at 1 kg ha^{-1} and weedy check at Indore. At Sehore application of diclosulam at 30 g ha^{-1} yielded maximum and significantly higher than diclosulam at 18 g ha^{-1}, haloxyfop ethyl at 75 and 100 g ha^{-1}, quizalofop ethyl at 50 g ha^{-1} and weedy check. On zonal mean basis diclosulam at 30 g ha^{-1} yielded maximum and was closely followed by diclosulam at 22 g ha^{-1} (AICRP on soybean, 2008-2009).

Effect of herbicides on plant growth

The study carried out by Prajapati and Patel (2001) revealed that LAI was increased up to 60 DAS and thereafter, it was decreased under all weed control methods and maximum values of fresh and dry weight plant^{-1}, LAI, NAR, CGR, RGR and grain yield recorded under weed free condition, followed by application of pendimethalin.

Field research was conducted by Nelson and Renner (2001) to evaluate the effect of post emergence applied to soybean [*Glycine max* (L.) Merr.]. Soybean injury caused by post emergence herbicide tank mixtures resulted in delayed vegetative development when measured 7 DAT, delayed reproductive development at 20 and 80 DAT, reduced height and reduced above ground dry weight at 35 and 56 DAT compared with non treated plants. Leaf area index was reduced by post emergence up to 52 DAT.

Effect of herbicides on seed quality

Donald and Meggitt (1970) studied the herbicide effects on soybean [*Glycine max* (L.) Merrill] seed oil content and fatty acid composition and found no significant differences in their response to herbicide treatments. None of the treatments significantly altered the percentage oil content in the seed. However, small but significant changes in fatty acid composition, yield, and injury were observed. Increases in the percent stearic acid content were correlated with decreases in the percent linoleic acid content. Considering all treatments, there was no general correlation of changes in fatty acid composition with yield or injury.

Singh and Sharma (1990) found that alachlor as pre emergence provided effective weed control and increased oil and protein content of soybean. Similarly, Porwal *et al.* (1990) also reported that alachlor, fluchloralin and oxyflurofen gave significantly higher seed protein and oil content than control, but equivalent to manual weeded plots.

Chhokar *et al.* (1995) from Haryana observed that pre-emergence application of Pendimethalin followed by hand weeding at 35 DAS resulted into higher oil content 19.9 per cent in soybean.

Farag *et al.* (2006) studied the influence of some herbicides as single applications or mixtures for controlling weeds in soybean and reported that fatty acid composition of soybean oil was obviously altered by herbicide application. The soybean oil produced under the influence of different herbicides varied in their degree of unsaturation and can be used for human and industrial purpose.

Hardcastle *et al.* (1974) reported that metribuzin applied in the soybean (*Glycine max* (L.) Merr.) induced significant changes in total fatty acid concentration of soybean oil. Minor changes in soybean oil quality were induced by metribuzin but percent protein was not influenced.

Materials

&

Methods

The details of experimental materials and methods used during the entire course of investigation are given below:

3.1 Site of the Experiment

The field experiment was conducted during '*Kharif*' season of 2008 and 2009 in D3 block, at the Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (U.S. Nagar), Uttarakhand, India. This Centre is situated at 29° 03'N latitude and 79°30' E longitude and at an altitude 243.83 m above mean sea level. Geographically Pantnagar comes under humid sub-tropical zone and is situated at the foothills of '*Shivalik range*' of Himalayas. It falls under the '*Tarai*' which is narrow belt in the foothills of Himalayas.

3.2 Climate and Weather

Pantnagar has a sub-humid tropical climate with its extremities. Summers are very hot and dry and winters are very cold. The monsoon period starts from second fortnight of June and continues with appreciable amount up to September with its soaring peak in mid July to mid August. The total annual rainfall during 2008 and 2009 was 2382 mm and1109.6 mm, respectively of which 77.3 per cent (1842.4 mm) and 83.8 per cent (929.6 mm) was received between

July and September of both years, respectively. During hot summers (June), average maximum temperature usually varies from 30.6 to 39.0°C. The mean relative humidity remains around 83-95 per cent at 7 A.M. from first week of July till first week of November. The weather parameters like minimum and maximum temperature, relative humidity, rainfall and bright sunshine hours prevailing during the course of investigation were recorded at Meteorological Observatory located at Norman E. Borlaug Crop Research Centre, Pantnagar are depicted in Fig 3(a) and 3(b) and cited in Appendix I(a) and I(b).

During *'Kharif'* 2008 the maximum and minimum temperature ranged from 32.3 to 25.2°C and 25.5 to 10°C, respectively and during *'Kharif'* 2009 the maximum and minimum temperature ranged from 36.2 to 25.3°C and 27.1 to 8.8°C, respectively. Total rainfall during crop season was 1842.4 mm in 2008 and 929.6 mm in 2009. The maximum and minimum sunshine hours per day were 9.5 during 4th week of September and 1.1 during 2nd week of August during 2008, respectively. During 2009, the maximum and minimum sunshine hours per day were 9.7 during 3rd week of October and 0.7 during 2nd week of August, respectively

During 2008, the relative humidity at 7 AM was maximum (95%) during 3rd week of July and minimum 82 per cent during 2nd week of October. The relative humidity at 2.00 PM was maximum (84%) during 2nd week of August and 3rd week of July and minimum

(40%) during 4th week of October. During 2009, the maximum relative humidity at 7 AM was (92%) during 2nd week of August and minimum 77 per cent during 1st week of July. The relative humidity at 2.00 PM was maximum (86%) during 2nd week of August and minimum (50%) during 1st week of July (Fig 3.1 a & b).

3.3 Soil Characteristics

Table 3.1: Physico-chemical properties of experimental soil

Particulars		Value		Method of determination
		2008	**2009**	
Texture		Clay loam	Clay loam	International pipette method (Piper, 1950)
pH (1:2 soil water suspension)		7.3	7.35	Beckman Glass Electrode meter (Jackson,1973)
Organic carbon (%)		0.68	0.69	Modified Walkley & Black method (Jackson,1973)
Total N ($kgha^{-1}$)	Sowing	225.79	229.91	Modified Kjeldahl method (Jackson,1973)
	Harvesting	213.24	220.30	
Available P_2O_5($kgha^{-1}$)	Sowing	11.36	12.11	Olsen's method Olsens *et al.* (1954)
	Harvesting	11.99	12.57	
AvailableK_2O ($kgha^{-1}$)	Sowing	147.84	151.23	Flame photometer method (Jackson, 1973)
	Harvesting	149.02	153.25	

The experimental soil was clay loam. A detail of physico-chemical properties of experimental soil is given (Table 3.1).

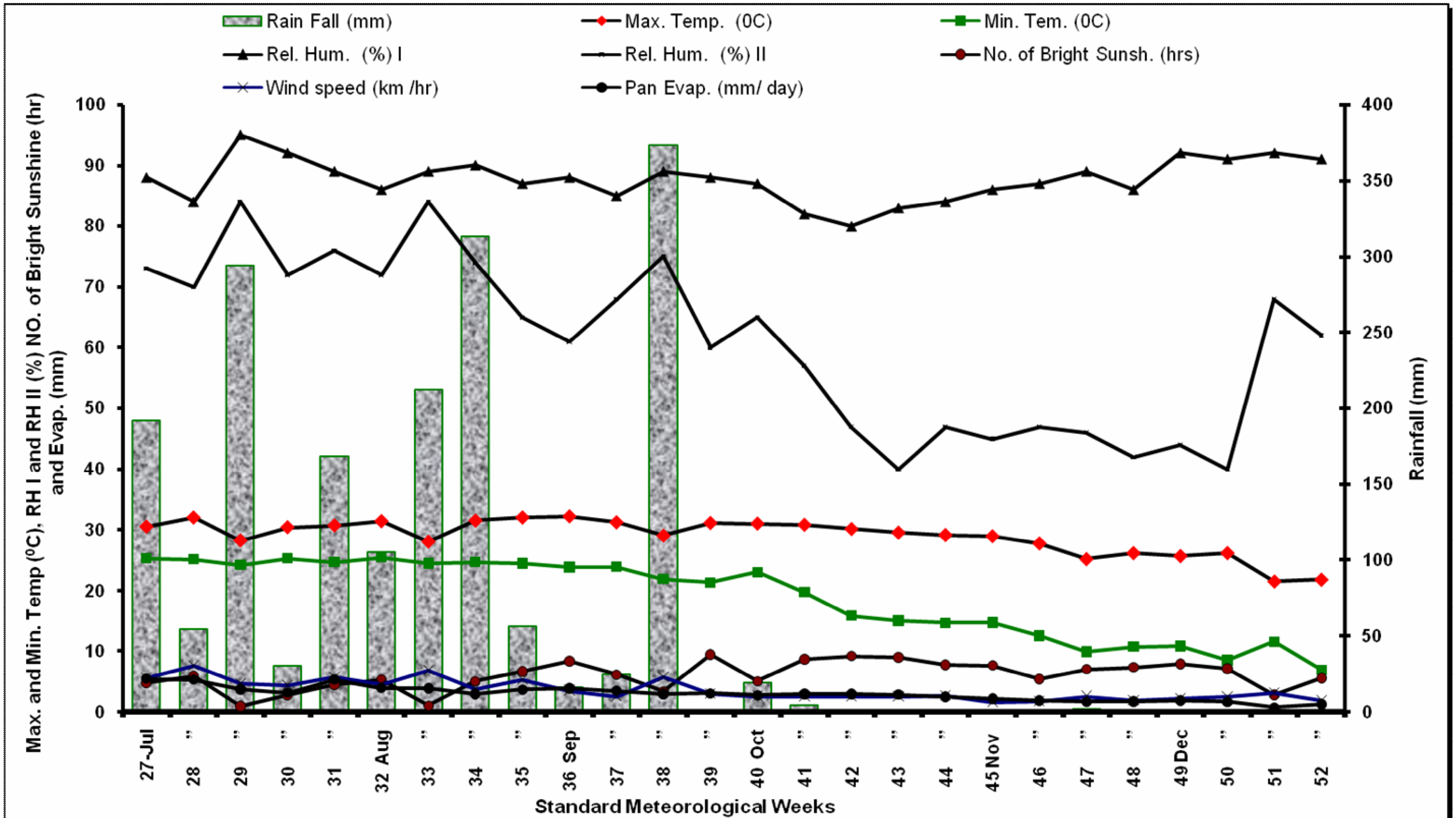


Fig 3.1 (a): Weekly Meteorological parameters during '*Kharif*' season 2008 (from July 2008 to December 2008)

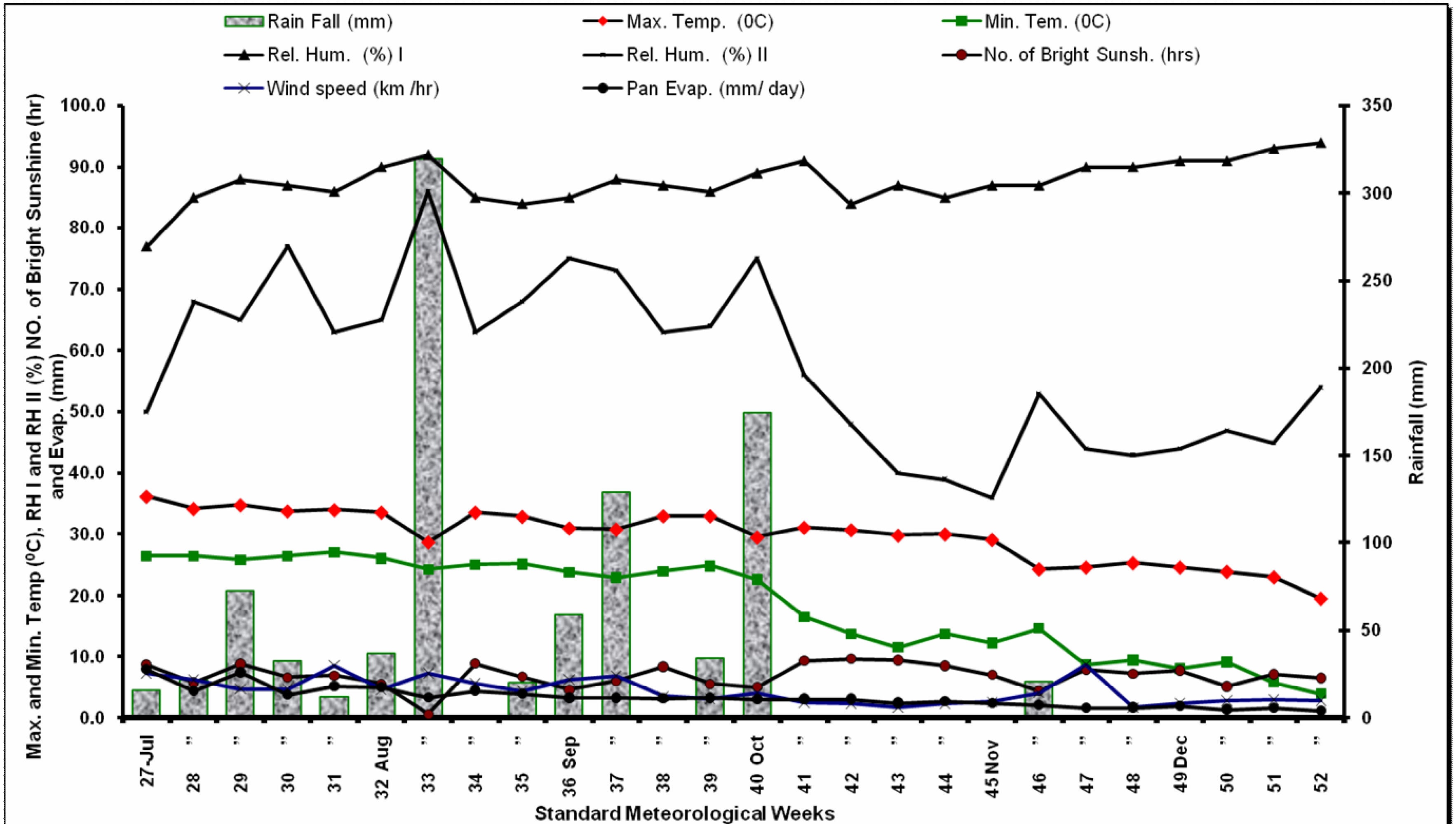


Fig 3.1 (b): Weekly Meteorological parameters during '*Kharif*' season 2009 (from July 2009 to December 2009)

3.4 Experimental Details

The experiment consisted of 10 treatments laid out in 'Randomized Block Design' with four replications (Fig. 3.2). These treatments have been given in Table 3.2 below:

Table 3.2: Treatment details

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Formulation	Symbol
Control (Weedy check)	-	-	-	T_1
Weed free	-	-	-	T_2
Fluchloralin (PPI)	1000	Before sowing	45 EC	T_3
Pendimethalin (PE)	1000	2	30 EC	T_4
Diclosulam (PE)	26	2	84 WDG	T_5
Diclosulam (PE) + HW	18	2 +20	84 WDG	T_6
Fluchloralin (PPI) + Diclosulam (PE)	1000+18	Before sowing +2	45 EC+84WDG	T_7
Haloxyfop (PoE)	100	20	10 EC	T_8
Fluchloralin (PPI) + Haloxyfop (PoE)	1000+100	Before sowing+21	45 EC+10 EC	T_9
Diclosulam (PE) + Haloxyfop (PoE)	18 + 100	2 + 20	84 WDG+10 EC	T_{10}

PPI- Pre plant incorporation PE- Pre emergence PoE- Post emergence

EC- Emulsifiable concentrate WDG- water dispersible powder DAS-Days after sowing

HW-Hand weeding

3.5 Method of Application of Herbicides

Knowledge on the method and rate of application and appliances required for herbicide application has greater impact on the effectiveness of weed control.

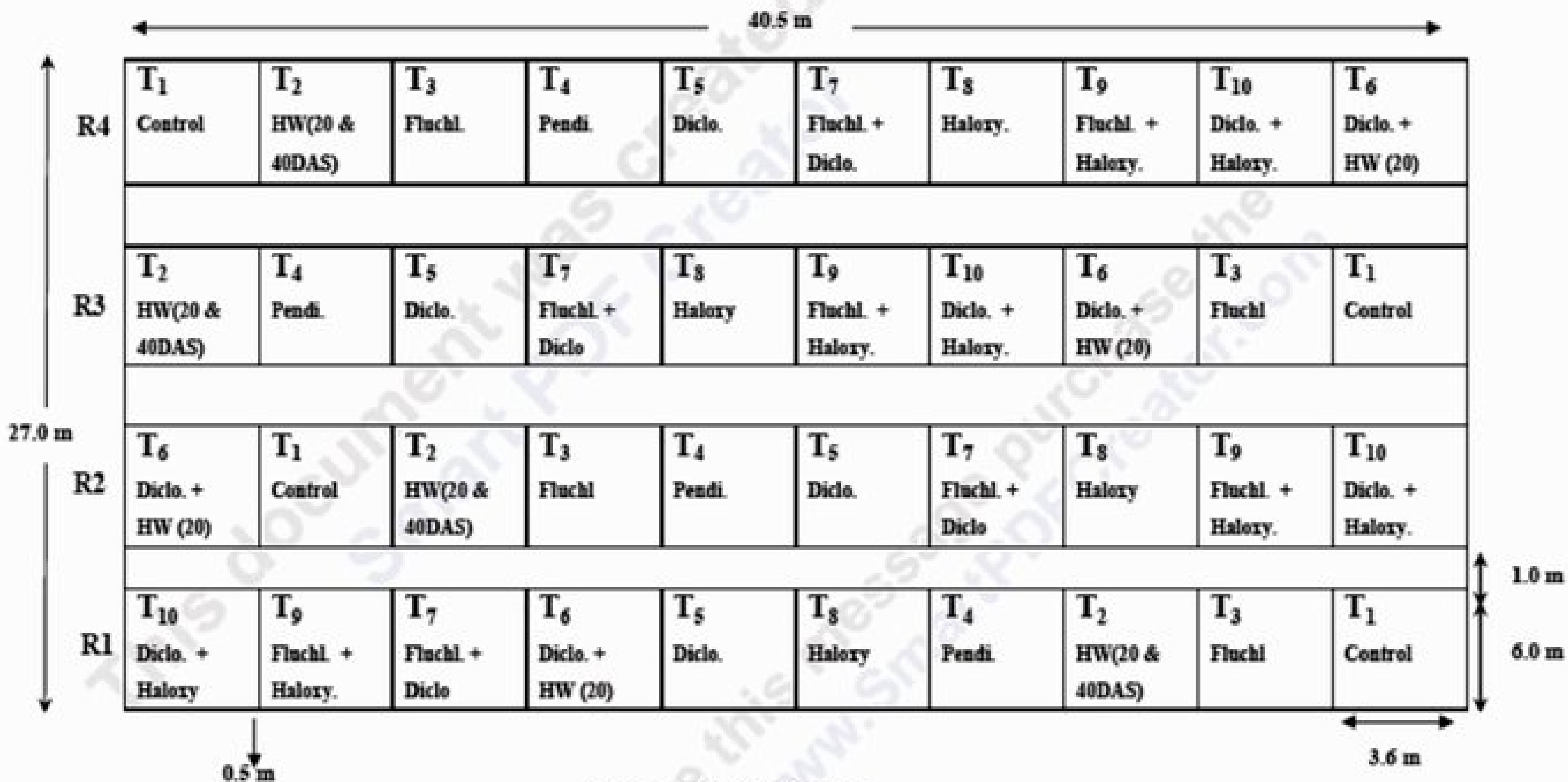


Fig. 1 : Lay out plan

Design: Randomized Block Design, **Treatment:** 10, **Replications:** 4, **Total plot:** 40

Gross plot size: 6m x3.6 m, **Net plot size:** 5.0m x 2.7 m, **Row spacing:** 0.45m, **Rows per plot:** 8

Note: HW = Hand weeding Diclo. = Diclosulam Fluchl.= Fluchloralin Haloxy. =Haloxyfop

In the field experiment, the herbicides were applied in aqueous solution using 800 liter of water per hectare. Diclosulam and pendimethalin at their respective doses were applied as pre-emergence (PE) while haloxyfop ethyl was applied as post-emergence (PoE) and fluchloraliln was incorporated into the soil before planting. Pre-emergence herbicides were sprayed immediately 24 hours after sowing while post emergence herbicides were sprayed at 20 DAS. The amount of herbicides was calculated on the basis of land area to be sprayed and rate of herbicides needed to be applied.

The crop was kept weed free by manual weeding in weed-free plots as per requirement. Chemicals were sprayed with the help of foot compression sprayer.

3.6 Cultural Operations

Summer ploughing was done in the month of May. Preparation of the field was done in second week of June. One deep ploughing followed by two harrowing and leveling with tractor drawn leveler was done. Basal dose of 100 kg ha^{-1} (216 g per 21.6 m^2) Di-ammonium phosphate (18% N, 46% P_2O_5) was applied uniformly in experimental plot. Soybean cv. PS 1347 was planted on 10th July, 2008 and 1st August, 2009 in first and second year respectively, at 45 cm row spacing @ 75 kg seeds per hectare (162 g per 21.6 m^2). Before planting, seeds were treated with thiram (75% WP) 2 g + bavestin @ 1.0 g kg^{-1} seeds and then inoculated with *Bradyrhizobium japonicum* culture 500 g per 75 kg seeds.

A week after germination in plots plant population of 0.4 million per hectare was maintained by thinning. Crop was sprayed two times with mixture of Thiodan 35 EC (Endosulfan 0.1%) + Metasystox 25 EC (Methyl-O-dematon 0.1%) solution in ratio of 1:1 at about 45 and 60 DAS to protect the crop against insects. The crop was harvested on 12th November, 2008 and 14th November, 2009 in first and second year respectively, when all leaves dried and started falling in mass. The harvesting was done by cutting the plants close to the ground level with help of sickle. Harvested crop was allowed to sundry for 3-4 days and then threshed manually with stide and grains were sun-dried to bring the uniform moisture (12 per cent).

3.7 Description of variety used in the experiment

The variety used in the experiment was PS 1347. It is bushy and dwarf type variety released from Pantnagar during 2006. This variety matures in 115-120 days. The pubescence is tawny and flowers are white in colour. Seeds are bold and yellow in colour. It is resistant to yellow mosaic virus and bacterial pustules. Its yield potential is 35-38 quintals per hectare.

3.7 Observations and sampling procedure

3.7.1 Studies on weeds

3.7.1.1 Weed survey

Identification of weeds was done at 30 days after sowing and reported as monocot and dicot with their species.

3.7.1.2 Total weed population

Weed density was measured in a unit area by using a quadrate of 0.50 m x 0.50 m (0.25 m^{-2}) size. The total number of weeds falling within the quadrate was counted in each plot. The observations were recorded on 30, 60 and 90 DAS and finally data was reported as number of weeds m^{-2}.

3.7.1.3 Total dry matter of weeds

Weeds falling within the quadrate in each plot were cut close to the ground and dried in hot air oven at 70±1°C to constant weight. The dry matter of weeds was recorded at 30, 60 and 90 DAS. Data were computed for a square meter area.

3.7.1.4 Weed control efficiency (WCE)

Weed control efficiency was worked out considering dry matter production of weeds and expressed in percentage. It was calculated using the formula suggested by Mani *et al.*, (1973) as:

$$\text{WCE} = \frac{\text{Weed dry matter in weedy (check) - Weed dry matter in treated plot}}{\text{Weed dry matter in weedy (check)}} \times 100$$

3.7.1.5 Weed index (WI)

Weed index (WI) or weed competition index, gain in crop yields due to weed control as percentage of yield from weed-free crop. It can be calculated by the method given by Gill and Vijayakumar (1966) with the formula given below:

$$WI = \frac{\text{Yield from weed free plot} - \text{Yield from treated plot}}{\text{Yield from weed free plot}} \times 100$$

3.8 Studies on crop

3.8.1 Growth analysis

The pattern of plant assimilatory material accumulation in plant was computed by using growth analysis formula as reported by Radford (1967).

3.8.1.1 Absolute growth rate (*AGR*)

The growth rate of a plant or crop growth rate (*AGR*) indicates the rate at which the crop is growing at any instant in time (t) is defined as "the increase of plant material per unit of time". This was calculated using the formula:

$$AGR = \frac{w_2 - w_1}{t_2 - t_1} \text{ (g day}^{-1}\text{)}$$

Where,

W_2 = Plant dry weight at time t_2

W_1 = Plant dry weight at time t_1

3.8.1.2 Relative growth rate (*RGR*)

The relative growth rate (*RGR*) of a plant at any instant in time (t) is a defined as "the increase of plant material per unit of material present per unit time". This was calculated according to formula given as under:

$$RGR = \frac{\log_e w_2 - \log_{3e} w_1}{t_2 - t_1} = (g\ g^{-1} day^{-1})$$

Where,

W_2 = Plant dry weight at time t_2,

W_1 = Plant dry weight at time t_1

3.8.1.3 Net assimilation rate (*NAR*)

The most useful measure of average of photosynthesis is the net assimilation rate which is defined as "the actual gain in dry matter per unit leaf area in unit time". The following formula was used to calculate the net assimilation rate:

$$NAR = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1} = (g\ cm^{-2} day^{-1})$$

Where,

W_2 = Dry weight (g $plant^{-1}$) of plant sample at time t_2
W_1 = Dry weight (g $plant^{-1}$) of plant sample at time t_1
A_2 = Leaf area cm^2/ plant at time t_2
A_2 = Leaf area cm^2/ plant at time t_1

3.8.1.4 Total leaf area per plant (cm^2/ plant)

The leaves of each plant were separated in to three categories small, medium and large and five leaves were taken from each category and taken their leaf area from leaf area meter and average them. The respective average value multiplied with the total number of leaves of each category and sum of those entire three categories was taken as total leaf area of the plant.

3.8.1.5 Leaf area index *(LAI)*

The leaf area index (*LAI*) is essentially a measurement of leafiness. It is defined as the area of leaf surface (one side) per unit areas of ground surface and was calculated using formula:

$$LAI = \frac{\text{Total leaf area per plant}}{\text{Land area per plant}}$$

3.8.1.6 Leaf area ratio (*LAR*)

Leaf area ratio of an individual plant at an instant in time (t) is defined as 'the ratio of the assimilating material per unit of plant material present'. This was calculated by using the formula:

$$LAR = \frac{(A_2 - A_1)}{(w_2 - w_1)} \times \frac{(\log_e W_2 - \log_e W_1)}{(\log_e A_2 - \log_e A_1)} = (cm^2\ g^{-1})$$

Where,

A_2 = total leaf area at time t_2

A_1 = total leaf area at time t_1

W_2 = Dry weight (g $plant^{-1}$) of plant sample at time t_2

W_2 = Dry weight (g $plant^{-1}$) of plant sample at time t_1

3.8.1.7 SPAD meter value (Leaf chlorophyll content)

Chlorophyll content of leaf was recorded at 30, 60 and 90 days after sowing with the help of SPAD meter (Minolta, Japan). SPAD meter gives the SPAD value which is directly related with greenness or chlorophyll content of leaf. For this study, 5 leaves were randomly selected from the net plot area and SPAD value was recorded and then average value is recorded.

3.8.2 Growth parameters

3.8.2.1 Plant height

Plant height of three plants was measured in full from ground surface to the growing tip randomly selected in rows other than that of net plot area avoiding border rows. Height was measured at 30, 60 and at 90 DAS. It was averaged to get per plant height (cm).

3.8.2.2 Number of trifoliate leaves per plant

For counting number of trifoliate, three plants from each plot were randomly selected and trifoliate were counted at 30, 60 and at 90 DAS stages of crop growth and were reported as number of trifoliate leaves per plant.

3.8.2.3 Dry matter accumulation

Plant samples were taken at 30, 60 and at 90 DAS. Three plants were selected in rows other than that of net plot area avoiding border rows and were cut close to the ground surface. The dry matter was recorded after drying the plants in the hot air oven at 70 ± 1 °C for 48 hours, till constant moisture remains in the plant tissues and data was reported as dry matter (g) per plant.

3.8.3 Toxicity rating

Phytotoxicity effects on crop were recorded in 0 to 10 scales at 5, 10, 15, 20, 30 and 40 days after spraying of herbicide. Zero means no phytotoxicity and ten means complete killing of the crop. Different toxicity symptoms like tip burning, chlorosis, necrosis, epinasty and hyponasty of leaves were observed on crop plants.

3.9 Studies on yield and yield attribute

3.9.1 Number of primary branches per plant

Total number of primary branches of randomly selected three plants was counted at harvest. Average was worked out to find primary branches per plants.

3.9.2 Number of pods per plant

Three plants were randomly selected from each plot at harvest. Total number of pods was recorded and average was reported as number of pods per plants.

3.9.3 Number of grains per pod

Total numbers of grains were counted from randomly selected three pods and average number of grains per pod was reported.

3.9.4 Seed index

Weight of randomly selected 100 grains was recorded in grams from the harvested grains of each plot.

3.9.5 Grain yield (kg ha^{-1})

The grains obtained from net plots were air dried and the weight was recorded and reported as kg ha^{-1}.

3.9.6 Straw yield (kg ha^{-1})

The straw yield was obtained by subtracting the weight of grains from the weight of total produce recorded before threshing.

3.9.7 Harvest index (%)

It is ratio of biological yield (grain + straw) to economic yield (grain. It can also be expressed as percentage and calculated as follows:

Harvest index (%) = Grain yield/Biomass yield

3.10 Studies on the quality of soybean grain

3.10.1 Protein content

Nitrogen was estimated by Micro Kjeldahl method (Jackson, 1973) and per cent protein in grains was calculated by multiplying the nitrogen content of grain with 6.25.

Nitrogen (%)

$$= \frac{\text{Sample titre - Blank titre} \times \text{Normality of HCL} \times \text{Vol. of digest}}{\text{Aliquate of the digest taken} \times \text{Weight of the sample taken} \times 1000} \times 100$$

3.10.2 Oil content

Grain sample was taken from the produce of each plot and oil content was determined by Soxhlet Extraction apparatus using petroleum ether as extractant (A.O.C.S., 1964).

The sample material (grain of soybean) was put in oven dry for 2 hours at 60^{0}C temperature. After that, whole grain material was crushed in to a fine powder form, this crushed grain material was packed in a filter paper having 2 g each and covered by one other filter paper and stapled, then after taking the weight of whole packet put it in a soxhlet assembling chamber. In assembly unit up to 2/3 petroleum ether filled in 250 ml. round bottom flask. Run the assembly for 6-7 hours at 50-60^{0}C temperature. The ether move in assembly channel which were loaded by oil content present in grain sample and partially saturated vaporized ether recovered in another flask. Finally, take the weight of remaining material. The oil content is equal to the weight losses in grain material.

Oil content = sample weight – waste material

$$\text{Oil percentage in grain sample} = \frac{\text{Weight of soil (g)}}{\text{Weight of grain sample (g)}} \times 100$$

3.10.3 Fatty acid composition of soybean oil

Four soybean seeds were dried at 60^0 C for 48 hours and crushed to a fine powder and put into the test tube covered with stopper. For extraction of oil, 240 microlitres of petroleum ether (boiling point 40^0 C to 60^0 C) was added and left for 12 hours. Then 500 microlitres of methylating solution (0.135 g sodium methoxide in 50 ml methanol) was added and stirred with the help of the vertex for 5 minutes and left the sample for transesterification for 1 hour. Then, 100 microlitres of double glass distilled water was added and the samples were centrifuged for 5 minutes at 2000 rpm (centrikon laboratory centrifuge CIC 620-630). As a result, two distinct layers were formed and fatty acid esters were recovered from the upper layer of the solution. One microlitre of fatty acid methylester was taken from the upper layer of the bilayer solution which was injected and separated by Hewlett Packard (model 5980 series II) gas chromatograph (GC) equipped with a flame ionization detector (FID) and high performance capillary column (30 ml length, 0.32 mm diameter, film thickness 0.5 µm, column name: HP-INNO Wax (cross linked polyethylene glycol) and fitted with a data processor called integrator.

Gas chromatograph operation under standard conditions was as follows:

1. Electricity was supplied through voltage stabilizer.
2. Hydrogen, oxygen and nitrogen gas cylinders were checked and opened.
3. Gas chromatograph and integrator were switched on.
4. Flow rate of nitrogen, hydrogen and air were follows. The flow of nitrogen around 20-25 ml per minute and 1.5 to 1.8 ml per minute through the column.

The flow rate of hydrogen was doubles that of nitrogen i.e. 40-45 ml per minute and flow rate of air was 10 times of hydrogen i.e. 400-450 ml per minute. Nitrogen was supplied first before giving the temperature to oven. The programme was loaded to GC by keyboard.

5. Temperature

(a) Initial oven temperature = 100^0 C

(b) Final oven temperature = 200^0 C

(c) Injector temperature = 720^0 C

(d) Detector temperature = 720^0 C

(e) Rate of temperature increase in oven was 15^0 C per minute

6. Analysis time: 10.50 minutes

7. Sensitivity attenuation = -1

8. Area under individual peaks were directly obtained by the integrator in terms of percentage of fatty acids composition of soybean seed oil, results presented were the mean values of three replications.

3.11 Statistical analysis

The allocation of the treatments to different plots in each block was done with the help of random number Tables. The data was statistically analyzed for randomized block design (Cochran and Cox; 1959). The overall differences were tested by 'F' test at five per cent level of significance. Critical differences at 5 per cent level of probability were worked out for comparing treatments in case of significant 'F' test. Before analysis, data pertaining to weed number, dry matter were transformed as log (X+1).

Experimental Results

Chapter 4 EXPERIMENTAL RESULTS

In this chapter, results of the experiment obtained during the course of investigation are summarized with the help of suitable data in tables and graphs.

4.1 Studies on weeds in soybean

4.1.1 Weed flora

Weed flora of the experimental field was collected, identified and classified as monocots and dicots. Monocot group of weeds again was classified into annual and perennial weeds. There were total 15 species comprising of 8 monocots and 7 dicots. *Echinochloa colonum* among the monocot weed species and *Celosia argentia* among the dicot weed species were the predominant weed species which constituted a major part and remained dominant in weedy plots throughout the crop growth. However, during the investigation *Cyperus rotudus* also occupied a great part of the total weed population throughout the crop season.

4.1.2 Weed density

Weed density as affected by different weed control treatments at different growth stages of the crop are given in Table 4.1 (a & b) and their analysis of variance in Appendix II and III.

Total number of weeds per square metre under various weed control treatments was recorded at 30, 60 and 90 days after sowing. The differences in weed population due to various treatments were significant at all the growth stages during both the years. The crop in weedy check was severely infested with weeds through its life cycle, except in weed free treatment where increase in weed density was recorded at all the growth stages during both the years.

4.1.2.1 Monocot weed density

Density of monocot weeds was significantly influenced by different weed control treatments at different growth stages of crop. The highest monocot weed density was recorded in weedy plot at 90 DAS during both the years.

During 2008, the weed population of monocot weeds was relatively higher than that of 2009. The density of monocot weeds was reduced, irrespective of herbicidal treatments.

At 30 DAS, weed population was significantly lower than control (T_1) during 2008. However, during 2009 application of fluchloralin followed by haloxyfop (T_9) and application of fluchloralin (T_3) recorded statistically similar density of monocot weeds with control (T_1). Among the other weed control treatments, application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded the lowest density of monocot weeds during both the years. During 2008, diclosulam supplemented with one hand weeding at 20 DAS (T_6) was found *at par* with application of diclosulam at its higher rate (T_5) and combined application of diclosulam followed by haloxyfop (T_{10}). During 2009, the lowest population of monocot weeds was recorded in diclosulam supplemented with one hand weeding at 20 DAS (T_6) and was significantly *at par* with other herbicidal treatments except control (T_1).

Among the weed control treatments diclosulam supplemented with one hand weeding at 20 DAS (T_6) reduced 95 and 87 per cent reduction in monocot weed density over control at 30 DAS during 2008 and 2009, respectively (Table 4.1 a & b).

At 60 days after sowing, all the treatments, except application of fluchloralin (T_3) recorded significantly lower number of monocot weeds than weedy check during both the years. Application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded the lowest number of monocot weeds in both years. During 2008, application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) was *at par* with application of diclosulam at its higher rate (T_5) and application of diclosulam followed by haloxyfop as post emergence (T_{10}). However, during 2009 application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) showed significantly lowest density of monocot weeds than all other herbicidal treatments. Diclosulam at its higher rate (T_5) and diclosulam followed by haloxyfop (T_{10}) recorded equal number of monocot weeds which were also *at par* with application of fluchloralin followed by diclosulam (T_7), fluchloralin followed by haloxyfop (T_9) and alone haloxyfop (T_8).

Table 4.1(a): Effect of weed control treatments on density of monocot weeds (no. m^{-2}) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Monocot weed		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	5.2 (173)	5.8 (332)	6.0 (413)
T_2 (Weed free)	-	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
T_3 (Fluchloralin)	1000	Before sowing	4.5 (87)	5.7 (304)	5.8 (334)
T_4 (Pendimethalin)	1000	2	3.6 (35)	5.0 (146)	5.7 (309)
T_5 (Diclosulam)	26	2	2.1 (8)	3.7 (39)	5.3 (196)
T_6 (Diclosulam + HW)	18	2 +20	2.1 (8)	3.5 (42)	5.2 (195)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	3.2 (23)	4.5 (91)	5.3 (194)
T_8 (Haloxyfop)	100	21	3.4 (30)	5.4 (227)	5.7 (309)
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	3.3 (27)	5.4 (215)	5.6 (277)
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2.5 (12)	3.8 (43)	5.3 (190)
S.Em. ±			0.2	0.1	0.04
C.D. at 5%			0.4	0.3	0.1

Original values are given in parenthesis.

At 60 DAS, diclosulam at its higher rate (T_5) reduced the highest monocot weed density (88%), followed by diclosulam supplemented with one hand weeding at 20 DAS (T_6) and diclosulam followed by haloxyfop (T_{10}) (both 87%) during 2008. However, during 2009 diclosulam supplemented with one hand weeding at 20 DAS (T_6) reduced the maximum monocot weed density over control, followed by diclosulam followed by haloxyfop (T_{10}) (82%) and diclosulam at it's higher rate (T_5) (80%).

At 90 days after sowing, all the treatments produced significantly lower population of monocot weeds than control (T_1) during both the years. The lowest number of monocot weeds was recorded with application of diclosulam supplemented with one hand weeding at 20 DAS (T_6). During 2008, diclosulam supplemented with one hand weeding at 20 DAS (T_6) produced statistically equal number of monocot weeds to the treatment diclosulam at its higher rate (T_5), fluchloralin followed by diclosulam (T_7) and diclosulam followed by haloxyfop (T_{10}), where statistically equal number of monocot weeds were recorded. However, during 2009 diclosulam supplemented with one hand weeding at 20 DAS (T_6) was *at par* with diclosulam followed by haloxyfop (T_{10}), fluchloralin followed by diclosulam (T_7) and diclosulam at its higher rate (T_5). Application of haloxyfop (T_8) produced equal number of monocot weeds as produced by fluchloralin followed by haloxyfop (T_9).

Table 4.1(b): Effect of weed control treatments on density of monocot weeds (no.m^{-2}) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Monocot weed		
			30 DAS	**60 DAS**	**90 DAS**
T_1 (Control)	-	-	4.8 (82)	4.7 (111)	4.8 (126)
T_2 (Weed free)	-	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
T_3 (Fluchloralin)	1000	Before sowing	3.8 (46)	4.2 (65)	4.3 (75)
T_4 (Pendimethalin)	1000	2	2.9 (18)	3.6 (40)	3.8 (47)
T_5 (Diclosulam)	26	2	2.5 (27)	3.0 (22)	3.2 (26)
T_6 (Diclosulam + HW)	18	2 +20	2.4 (11)	2.3 (9)	3.0 (19)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	2.6 (31)	3.3 (27)	3.5 (34)
T_8 (Haloxyfop)	100	21	3.0 (30)	3.4 (29)	3.6 (39)
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	3.4 (58)	3.3 (29)	3.6 (35)
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2.6 (22)	3.0 (20)	3.0 (20)
S.Em. ±			0.6	0.2	0.1
C.D. at 5%			1.6	0.5	0.4

Original values are given in parenthesis.

The minimum monocot weed density was recorded by diclosulam followed by haloxyfop (T_{10}) which was 54 per cent less over control during 2008. However, during 2009 the minimum monocot weed density was recorded by diclosulam supplemented with one hand weeding at 20 DAS (T_6) which was 85 per cent less over control followed by diclosulam followed by haloxyfop (T_{10}) (84%) (Table 4.1 a & b).

4.1.2.2 Dicot weed density

Data regarding dicot weed density as affected by different weed control treatments at different growth stages of crop are given in Table 4.2 (a & b) their analysis of variance is given in Appendix III. The differences in population of dicot weeds due to various treatments were significant at all the growth stages.

At 30 DAS, the density of dicot weeds was significantly influenced by weed control treatments over control (T_1) during both of the years. Among the herbicidal treatments application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded the lowest number of weeds during 2008 however, during 2009 it was *at par* with application of diclosulam at its higher rate (T_5) and *at par* with diclosulam followed by haloxyfop (T_{10}), fluchloralin followed by diclosulam (T_7) and pendimethalin(T_4). The maximum reduction in dicot weed density (97% and 99%, during 2008 and 2009, respectively) was observed in diclosulam supplemented with one hand weeding at 20 DAS (T_6) over control at 30 DAS (Table 4.2 a & b).

Table 4.2 (a): Effect of weed control treatments on density of dicot weeds (no. m^{-2}) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Dicot weed		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	4.7 (112)	4.2 (68)	4.5 (89)
T_2 (Weed free)	-	-	0.0 (0)	0.0 (0)	0.0 (0)
T_3 (Fluchloralin)	1000	Before sowing	3.0 (21)	3.9 (49)	4.2 (67)
T_4 (Pendimethalin)	1000	2	3.0 (16)	3.5 (34)	4.1 (59)
T_5 (Diclosulam)	26	2	2.0 (7)	2.6 (13)	3.4 (31)
T_6 (Diclosulam + HW)	18	2 +20	1.3 (3)	2.3 (9)	3.1 (22)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	3.0 (15)	2.7 (15)	3.7 (41)
T_8 (Haloxyfop)	100	21	4 (68)	3.9 (51)	4.1 (61))
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	4 (37)	3.9 (47)	4.1 (62))
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2 (6)	3.3 (27)	3.6 (37)
S.Em. ±			0.2	0.1	0.1
C.D. at 5%			0.5	0.3	0.3

Original values are given in parenthesis.

During both of years at 60 days after sowing, the lowest population of dicot weeds was recorded with the application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) which was *at par* with diclosulam at its higher rate (T_5). During 2008, all the herbicidal treatments produced significantly lower number of dicot weeds than weedy plot except application of fluchloralin (T_3), haloxyfop (T_8) and fluchloralin followed by haloxyfop (T_9) which were equal to each other. However, during 2009 the dicot weed population of weedy plot was *at par* with application of fluchloralin (T_3), haloxyfop (T_8), fluchloralin followed by haloxyfop (T_9) and pendimethalin (T_4) in decreasing number of weeds. At 60 DAS, the maximum reduction in dicot weed density (87% and 84% during 2008 and 2009, respectively) was observed in diclosulam supplemented with one hand weeding at 20 DAS (T_6) over control at 60 DAS.

At 90 days after sowing in all the herbicidal treatments except application of fluchloralin (T_3) significant less number of dicot weeds were observed than control (T_1) plot during 2008. However, during 2009, application of haloxyfop (T_8), application of fluchloralin followed by haloxyfop (T_9) and fluchloralin (T_3), *at par* with each other recorded significantly higher number of dicot weeds than other weed control treatments except control (T_1).

The lowest numbers of dicot weeds were recorded with application of diclosulam supplemented with one hand weeding at

Table 4.2 (b): Effect of weed control treatments on density of dicot weeds (no. m^{-2}) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Dicot weed		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	5.3 (221)	3.9 (50)	4.1 (57)
T_2 (Weed free)	-	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
T_3 (Fluchloralin)	1000	Before sowing	2.8 (16)	3.8 (45)	3.9 (50)
T_4 (Pendimethalin)	1000	2	2.3 (15)	3.6 (37)	3.7 (41)
T_5 (Diclosulam)	26	2	0.4 (1)	2.5 (11)	2.9 (18)
T_6 (Diclosulam + HW)	18	2 +20	0.4 (1)	2.1 (8)	2.6 (13)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	1.8 (17)	2.5 (12)	3.5 (33)
T_8 (Haloxyfop)	100	21	3.0 (73)	3.8 (43)	4.0 (51)
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	2.5 (25)	3.7 (39)	3.9 (46)
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0.6 (3)	3.3 (26)	3.1 (22)
S.Em. ±			0.6	0.1	0.1
C.D. at 5%			1.9	0.4	0.3

Original values are given in parenthesis.

20 DAS (T_6) during both the years. Diclosulam supplemented with one hand weeding at 20 DAS (T_6) reveals significantly similar population of dicot weeds with application of diclosulam at its higher rate (T_5) during both the years.

At 90 DAS, the maximum dicot weed density reduction (75 and 77%, in 2008 and 2009, respectively) was observed in the plots applied with diclosulam supplemented with one hand weeding at 20 DAS (T_6) over control (T_1).

4.1.3 Weed Dry Matter

Data pertaining to the total weed dry matter reveals that weed dry matter was influenced by herbicidal treatments at different growth stages of the crop (Table 4.3 a & b) and their analysis of variance is given in Appendix IV. Differences in dry matter of weeds due to various treatments were significant at all the stages during both the years.

Dry matter of weeds increased with increased crop growth in almost all the weed control treatments during both the years. At all the stages, the highest weed dry matter accumulation was obtained in weedy (control) plot during both the years.

At 30 days after sowing, all the herbicidal treatments produced significantly lower weed dry matter than weedy plot during 2008 however, during 2009 application of haloxyfop (T_8) was *at par* with control (T_1) plot. Among the herbicidal treatments, the lowest weed dry matter accumulation was recorded with application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) and it was found *at par* with dry matter accumulation with application of diclosulam at it's higher rate (T_5) and combined application diclosulam followed by haloxyfop (T_{10}) during both the years.

During 2008, diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded 50 per cent reduction in weed dry matter, followed by diclosulam at it's higher rate (T_5) and diclosulam followed by haloxyfop (T_{10}), which reduced 42 and 41 per cent weed dry matter respectively, over control (T_1). However, during 2009 diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded 96 per cent reduction in weed dry matter over control (T_1) followed by diclosulam at it's higher rate (T_5) and diclosulam followed by haloxyfop (T_{10}) which recorded 95 and 94 per cent less weed dry matter over control (T_1).

At 60 days after sowing, all the treatments observed significantly lower dry matter of weeds than control (T_1) during both the years. Application of haloxyfop (T_8), fluchloralin (T_3) and combined application of fluchloralin followed by haloxyfop (T_9) remained *at par* with each other produced significantly higher dry matter of weeds than all other treatments except weedy (T_1) during both the years. The lowest dry matter of weeds was observed in diclosulam supplemented with one hand weeding at 20 DAS (T_6) during both the years. In 2008

Table 4.3 (a): Effect of weed control treatments on total weed dry matter at different growth stages of soybean (g m^{-2}) (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Weed dry matter		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	4.6 (94.3)	5.8 (321.8)	6.4 (612.4)
T_2 (Weed free)	-	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
T_3 (Fluchloralin)	1000	Before sowing	4.3 (73.0)	5.5 (246.5)	6.2 (513.9)
T_4 (Pendimethalin)	1000	2	4.2 (65.9)	5.3 (199.8)	6.1 (461.5)
T_5 (Diclosulam)	26	2	4.0 (54.3)	5.2 (179.2)	5.8 (339.1)
T_6 (Diclosulam + HW)	18	2 +20	3.9 (47.3)	4.9 (127.1)	5.8 (324.9)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	4.0 (55.4)	5.2 (251.0)	5.8 (341.3)
T_8 (Haloxyfop)	100	21	4.4 (77.2)	5.6 (275.5)	6.3 (539.2)
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	4.3 (69.9)	5.6 (261.7)	6.2 (501.4)
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	4.1 (57.0)	5.2 (177.3)	5.8 (339.0)
S.Em. ±			0.02	0.01	0.02
C.D. at 5%			0.1	0.1	0.1

Original values are given in parenthesis the lowest dry matter of weeds was produced with diclosulam supplemented with one hand weeding at 20 DAS (T_6), followed by the application of diclosulam at it's higher rate (T_5), fluchloralin followed by diclosulam (T_7), diclosulam followed by haloxyfop (T_{10}) and pendimethalin (T_4), which were *at par* with each other. Diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded 61 per cent less weed dry matter over control (T_1).

During 2009, diclosulam supplemented with one hand weeding at 20 DAS (T_6) was *at par* with application of diclosulam at higher rate (T_5) recorded significantly lower weed dry matter than other weed control treatments. Diclosulam supplemented with one hand weeding at 20 DAS (T_6) efficiently reduced the 91 per cent weed dry matter over control (T_1).

At 90 days after sowing, during 2008 all the herbicidal treatments except alone application of haloxyfop (T_8) produced significantly lower dry matter accumulation of weeds than weedy (T_1). However, during 2009 the weed dry matter of weedy plot was significantly equal with application of haloxyfop (T_8), fluchloralin followed by haloxyfop (T_9) and fluchloralin (T_3) with decreasing dry matter accumulation of weeds. The lowest weed dry matter accumulation was observed with diclosulam supplemented with one HW at 20 DAS (T_6) which produced equal dry matter to diclosulam at higher rate (T_5), fluchloralin followed by diclosulam (T_7) and

Table 4.3 (b): Effect of weed control treatments on total weed dry matter (g m^{-2}) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Weed dry matter		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	4.8 (126.0)	6.9 (973.5)	6.9 (1013.9)
T_2 (Weed free)	-	-	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
T_3 (Fluchloralin)	1000	Before sowing	2.9 (20.0)	6.4 (615.7)	6.4 (637.0)
T_4 (Pendimethalin)	1000	2	2.6 (14.5)	5.7 (450.4)	6.1 (454.2)
T_5 (Diclosulam)	26	2	1.8 (5.5)	5.2 (207.7)	5.6 (271.1)
T_6 (Diclosulam + HW)	18	2 +20	1.6 (4.5)	4.5 (89.1)	5.1 (161.0)
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	2.1 (8.0)	5.3 (225.1)	5.9 (400.2)
T_8 (Haloxyfop)	100	21	4.5 (107.0)	6.5 (673.0)	6.8 (860.3)
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	3.1 (23.0)	6.1 (582.5)	6.5 (701.0)
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2.6 (15.5)	5.4 (244.7)	6.0 (448.8)
S.Em. ±			0.22	0.3	0.2
C.D. at 5%			0.7	0.7	0.6

Original values are given in parenthesis diclosulam followed by haloxyfop (T_{10}) during 2008. Whereas, during 2009 the lowest weed dry matter accumulation by diclosulam supplemented with one HW at 20 DAS (T_6) produced significantly equal dry matter of weeds with application of diclosulam at it's higher rate (T_5). During 2008, diclosulam supplemented with one HW at 20 DAS (T_6) recorded 47% less weed dry matter however during 2009, diclosulam supplemented with one HW at 20 DAS (T_6) recorded 84% less weed dry matter over control (T_1).

4.1.4 Weed control efficiency

Data pertaining to the weed control efficiency of the different herbicidal treatments at different growth stages of the crop are given in Table 4.4 (a & b).

The highest weed control efficiency was observed in weed free (T_2) treatment (100%) in all of the stages during both of the years. Among the herbicidal treatments diclosulam supplemented with hand weeding at 20 DAS (T_6) recorded the highest weed control efficiency at all growth stages of soybean during 2008. However, during 2009 combined application of fluchloralin followed by diclosulam (T_7) recorded the higher weed control efficiency at 30 and 60 DAS, whereas at 90 DAS, combined application of diclosulam followed by haloxyfop (T_{10}) recorded the higher weed control efficiency. Among the herbicidal treatments, haloxyfop showed comparatively lower weed control efficiency to control the weeds.

Table 4.4 (a): Effect of weed control treatments on weed control efficiency (%) and weed index (%) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Weed control efficiency			Weed index
			30 DAS	60 DAS	90 DAS	
T_1 (Control)	-	-	0	0	0	86
T_2 (Weed free)	-	-	100	100	100	0
T_3 (Fluchloralin)	1000	Before sowing	18	14	12	72
T_4 (Pendimethalin)	1000	2	30	36	16	70
T_5 (Diclosulam)	26	2	42	44	44	28
T_6 (Diclosulam + HW)	18	2 +20	50	61	47	16
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	40	45	44	35
T_8 (Haloxyfop)	100	21	23	19	18	61
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	26	22	25	56
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	41	38	45	18

Table 4.4 (b): Effect of weed control treatments on weed control efficiency (%) and weed index (%)at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Weed control efficiency			Weed index
			30 DAS	60 DAS	90 DAS	
T_1 (Control)	-	-	0	0	0	87
T_2 (Weed free)	-	-	100	100	100	0
T_3 (Fluchloralin)	1000	Before sowing	79	17	53	65
T_4 (Pendimethalin)	1000	2	81	41	37	40
T_5 (Diclosulam)	26	2	86	62	55	18
T_6 (Diclosulam + HW)	18	2 +20	95	68	81	11
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	96	85	72	26
T_8 (Haloxyfop)	100	21	36	8	19	66
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	85	34	37	59
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	93	66	84	21

4.1.5 Weed index

Data pertaining to weed index of different herbicidal treatments at harvest of the crop are given in Table 4.4 (a & b) and depicted in Fig. 4.1 (a & b).

The control (T_1) treatment recorded the highest weed index value (86% in 2008 and 87% in 2009) as compared to other treatments and the lowest values of weed index was obtained with weed free (T_2) treatment followed by diclosulam supplemented with hand weeding at 20 DAS (T_6) during both of the years. During 2008, alone application of fluchloralin (T_3) recorded the higher weed index value among the herbicidal treatments, however, during 2009, this higher value of weed index was recorded by the application of haloxyfop (T_8).

4.2 Growth parameters of soybean

The observations recorded at successive stages on crop growth are processed statistically to assess the degree of variance due to treatments have been presented with the help of tables under following heads:

4.2.1 Plant height

Different weed control treatments significantly affected the plant height of soybean at all growth stages during both the years except 60 and 90 days after sowing in second year (2009) (Table 4.5 a & b, Appendix V).

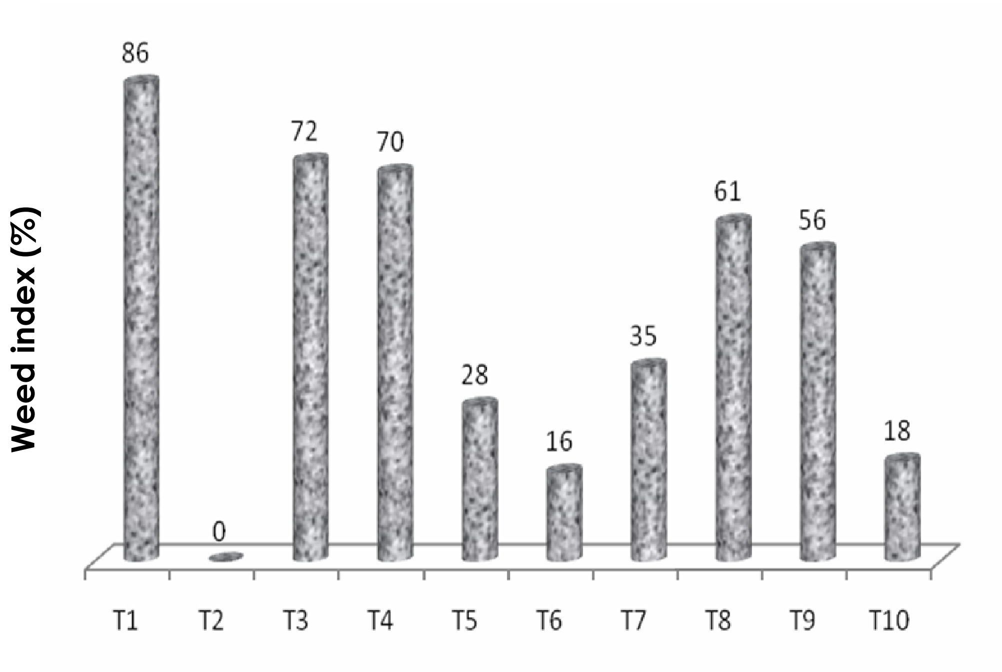


Fig. 4.1 (a): Effect of weed control treatments on weed index during 2008

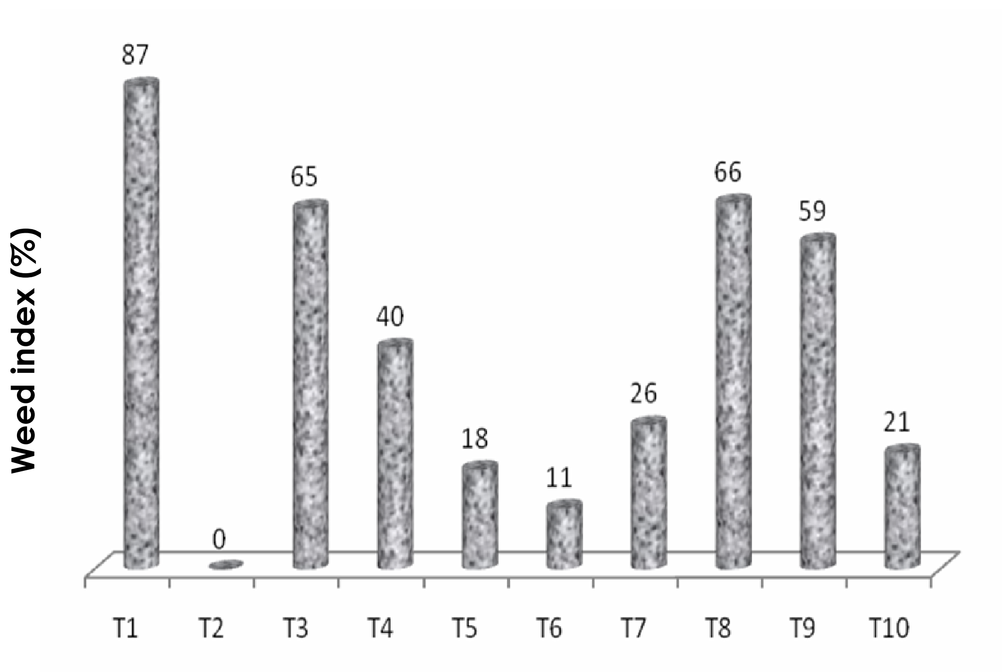


Fig. 4.1 (b): Effect of weed control treatments on weed index during 2009

In general, plant height increased with crop age up to 60 DAS and thereafter it remained as static or slightly declined. Maximum plant height was recorded in weed free treatment at all growth stages during both the years.

During 2008, at 30 DAS the initial plant height of soybean plant of weed free (T_2) plot found statistically similar with plant height in all the treatments except, application on diclosulam and combined application of fluchloralin followed by haloxyfop (T_9). However, during 2009 plant height of weed free (T_2) was *at par* with diclosulam supplemented with hand weeding at 20 DAS (T_6), diclosulam at it's higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and application of pendimethalin (T_4). In later stages at 60 and 90 days after sowing, the highest soybean plant height was obtained in weed free (T_2) treatment which was significantly higher than all other treatments except diclosulam supplemented with hand weeding at 20 DAS (T_6), diclosulam followed by haloxyfop (T_{10}) and diclosulam at it's higher rate (T_5) in decreasing order.

At 30 DAS, the lowest plant height was obtained in control (T_1) which was *at par* with application of higher dose of diclosulam (T_5) and fluchloralin followed by haloxyfop (T_9) during 2008 whereas, during 2009 plant height of control (T_1) was *at par* with remaining all treatments except weed free (T_2). At 60 DAS, the lowest plant height of control (T_1) plot was *at par* with application of fluchloralin (T_3) while at

Table 4.5 (a): Effect of weed control treatments on plant height (cm) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Plant height		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	16.3	65.7	64.8
T_2 (Weed free)	-	-	21.4	75.5	76.4
T_3 (Fluchloralin)	1000	Before sowing	19.9	68.5	66.1
T_4 (Pendimethalin)	1000	2	19.8	69.3	71.6
T_5 (Diclosulam)	26	2	17.7	73.4	73.8
T_6 (Diclosulam + HW)	18	2 + 20	20.2	74.0	74.9
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	20.8	71.3	71.7
T_8 (Haloxyfop)	100	21	20.0	69.9	68.1
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	17.7	71.5	71.1
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	21.4	73.5	74.6
S.Em. ±			0.6	1.0	1.2
C.D. at 5%			01.6	2.8	3.5

Table 4.5 (b): Effect of weed control treatments on plant height (cm) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Plant height		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	18.3	32.0	36.5
T_2 (Weed free)	-	-	20.5	34.2	39.8
T_3 (Fluchloralin)	1000	Before sowing	17.7	32 .7	35.1
T_4 (Pendimethalin)	1000	2	18.9	31.1	36.2
T_5 (Diclosulam)	26	2	19.1	30.3	36.2
T_6 (Diclosulam + HW)	18	2 + 20	19.1	31.9	36.7
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	18.6	32.5	35.4
T_8 (Haloxyfop)	100	21	16.8	29.8	34.7
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	18.6	33.0	36.3
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	19.1	34.0	33.5
S.Em. ±			0.6	1.4	1.8
C.D. at 5%			1.8	NS	NS

90 DAS, it was *at par* with application of fluchloralin (T_3) and haloxyfop (T_8).

Weedy condition of control (T_1) recorded 15 and 8 per cent reduction in plant height during 2008 and 2009, respectively due to weed infestation at 90 DAS.

4.2.2 Number of trifoliate per plant

Perusal of the data revealed that the number of trifoliates per plant increased with crop age (Table 4.6 a & b, Appendix VI).

Differences in number of trifoliates per plant due to different treatments were significant at all the growth stages during both years except 60 DAS during second year (2009).

During 2008, at 30 DAS weed free (T_2) plot had the highest number of trifoliates per plant which was *at par* with all treatments except the combined application of fluchloralin followed by haloxyfop (T_9) and control (T_1). At 60 DAS, weed free (T_2) recorded the highest number of trifoliates per plant which was significantly superior than all other weed control treatments except diclosulam supplemented with one hand weeding at 20 days after sowing (T_6) and alone application of higher dose of diclosulam (T_5), which were *at par* with weed free (T_2) plot. It was followed by diclosulam followed by haloxyfop (T_{10}), fluchloralin followed by haloxyfop (T_7) and pendimethalin (T_4) in decreasing order. At 90 DAS, the highest numbers of trifoliates per plant were also recorded by weed free (T_2) and it was *at par* with

Table 4.6 (a): Effect of weed control treatments on trifoliate/plant at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Trifoliate/plant		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	5.6	13.5	15.2
T_2 (Weed free)	-	-	7.0	28.6	28.5
T_3 (Fluchloralin)	1000	Before sowing	6.4	19.4	21.1
T_4 (Pendimethalin)	1000	2	6.1	24.1	25.1
T_5 (Diclosulam)	26	2	6.2	27.1	27.9
T_6 (Diclosulam + HW)	18	2 + 20	6.6	28.2	27.9
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	6.1	25.0	27.5
T_8 (Haloxyfop)	100	21	5.8	14.9	15.9
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	5.6	20.0	19.3
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	5.8	25.3	24.9
S.Em. ±			0.4	1.1	1.0
C.D. at 5%			1.3	3.1	3.0

Table 4.6 (b): Effect of weed control treatments on trifoliate/plant at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Trifoliate/plant		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	4.4	12.7	12.0
T_2 (Weed free)	-	-	6.2	21.4	23.3
T_3 (Fluchloralin)	1000	Before sowing	4.9	17.1	14.8
T_4 (Pendimethalin)	1000	2	5.5	19.2	19.0
T_5 (Diclosulam)	26	2	5.7	20.7	21.5
T_6 (Diclosulam + HW)	18	2 + 20	6.0	17.2	22.5
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	5.6	19.3	20.0
T_8 (Haloxyfop)	100	21	5.5	15.8	13.3
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	5.1	16.3	15.3
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	5.6	18.2	20.8
S.Em. ±			0.3	2.4	0.9
C.D. at 5%			0.7	NS	2.6

diclosulam at it's higher rate (T_5), diclosulam supplemented with hand weeding at 20 DAS (T_6) and fluchloralin followed by haloxyfop (T_7).

The lowest number of trifoliates per plant was obtained in weedy plot which was *at par* with T_8 (application of haloxyfop) at both (60 and 90 DAS) growth stages. Per cent increase in number of trifoliates in weed free (T_2) over control (T_1) was 20, 53 and 47 per cent, at 30, 60 and 90 DAS, respectively.

During 2009, at all growth stages (30, 60 and 90 DAS), the trend of total number of trifoliates per plant was almost similar to that of 2008. However, per cent increase in number of trifoliates was higher in initial stage (30 DAS) in second year but in later both (60 and 90 DAS) stages, it was lower than first year. Per cent increase in number of trifoliates in weed free (T_2) over control (T_1) was 29, 40 and 49 per cent, at 30, 60 and 90 DAS, respectively.

4.2.3 Plant dry matter (g per plant)

Different weed control treatments affected the plant dry matter yield significantly, at all the crop growth stages, during both the years (Table 4.7 a & b, Appendix VII).

In general, dry matter accumulation per plant increased with crop age up to the harvest (Table 4.7 a & b). During both the years, the highest plant dry matter was recorded in weed free plot (T_2) while the lowest dry matter was obtained in weedy plot (T_1) during different stages (30, 60 and 90 DAS) of growth.

During 2008, at 30 DAS, the maximum plants dry matter accumulation was obtained in weed free (T_2) and diclosulam supplemented with hand weeding at 20 DAS (T_6). The soybean plant dry matter accumulation in these plots was significantly higher than in all other treatments except diclosulam followed by haloxyfop (T_{10}), diclosulam at it's higher rate (T_5) and fluchloralin followed by haloxyfop (T_7). At 60 and 90 DAS, the higher plant dry matter accumulation was recorded in weed free plot which was significantly superior to all other weed control treatments. It was more or less followed by diclosulam supplemented with hand weeding at 20 DAS (T_6), diclosulam at its higher rate (T_5), fluchloralin followed by haloxyfop (T_7) and diclosulam followed by haloxyfop (T_{10}) in both growth stages.

During 2009, at 30 days after sowing the maximum plant dry matter accumulation was obtained in weed free plot which was significantly superior to other treatments except diclosulam supplemented with hand weeding at 20 DAS (T_6), diclosulam at higher rate (T_5) and diclosulam followed by haloxyfop (T_{10}). At 60 and 90 days after sowing, the highest plant dry matter was obtained in weed free plot *at par* with diclosulam supplemented with hand weeding at 20 DAS (T_6) and diclosulam at its higher rate (T_5) at 60 days after sowing however, at 90 days after sowing it was only *at par* with diclosulam supplemented with hand weeding at 20 DAS (T_6).

The lowest dry matter accumulated by control (T_1) was significantly lower than all other treatments in all growth stages,

Table 4.7 (a): Effect of weed control treatments on dry matter production/plant (g/plant) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Dry matter (g/plant)		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	2.0	11.9	19.1
T_2 (Weed free)	-	-	3.5	18.1	33.7
T_3 (Fluchloralin)	1000	Before sowing	2.8	13.2	23.5
T_4 (Pendimethalin)	1000	2	2.7	15.6	27.0
T_5 (Diclosulam)	26	2	3.3	16.4	29.2
T_6 (Diclosulam + HW)	18	2 + 20	3.5	16.9	30.5
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	3.1	15.9	29.0
T_8 (Haloxyfop)	100	21	2.5	14.2	23.9
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	2.9	14.4	23.7
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	3.4	15.7	27.5
S.Em. ±			0.2	0.3	0.4
C.D. at 5%			0.5	0.9	1.2

however, in initial stage (at 30 DAS) it was found at *par with* alone application of haloxyfop (T_8) after 21 DAS as post emergence, during 2008.

During 2009, the lowest dry matter accumulation per plant was by control (T_1) during all growth stages. At initial stage of plant growth at 30 DAS the lowest plant dry matter was *at par* with fluchloralin (T_3), control (T_1), fluchloralin followed by haloxyfop (T_9), haloxyfop (T_8) and pendimethalin (T_4). At 60 DAS, it was significantly lower than other weed control treatments except (T_7), however, during 90 DAS, it was *at par* with fluchloralin (T_3), haloxyfop (T_8) and fluchloralin followed by haloxyfop (T_9). Per cent increase in dry matter accumulation per plant of soybean with weed free (T_2) over control (T_1) 75, 52 and 76 per cent at 30, 60 and 90 DAS, respectively during 2008. However, during 2009 this increase in dry matter accumulation of weed free (T_2) over control (T_1) was 78, 57 and 65 per cent at 30, 60 and 90 DAS, respectively.

Per cent increase in dry matter accumulation per plant of soybean in weed free (T_2) over control (T_1) was recorded 75, 52 and 76 per cent at 30, 60 and 90 DAS, respectively during 2008. However, during 2009, this increase in dry matter accumulation of weed free (T_2) over control (T_1) was 78, 57 and 65 per cent at 30, 60 and 90 DAS, respectively.

Table 4.7 (b): Effect of weed control treatments on dry matter production/plant (g/plant) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Dry matter (g/plant)		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	1.8	9.7	16.6
T_2 (Weed free)	-	-	3.2	15.3	27.4
T_3 (Fluchloralin)	1000	Before sowing	2.1	10.6	18.4
T_4 (Pendimethalin)	1000	2	2.4	12.3	21.9
T_5 (Diclosulam)	26	2	2.6	13.4	23.9
T_6 (Diclosulam + HW)	18	2 +20	3.0	14.4	25.7
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	2.3	11.6	20.9
T_8 (Haloxyfop)	100	21	2.1	12.3	18.9
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	2.2	12.3	19.3
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2.6	12.7	22.0
S.Em. ±			0.2	0.9	0.9
C.D. at 5%			0.7	2.5	2.7

4.3 Phytotoxic studies (Chlorosis, Necrosis, Tip burning, Epinasty and Hyponasty)

The data regarding the phytotoxic study of the herbicides on the soybean plant was collected by studying the different phytotoxic symptoms *viz.* chlorosis, necrosis, tip burning, epinasty and hyponasty on the plant and presented in Table 4.8 (a, b, c, d and e). During the study there were no symptoms of phytotoxicity on soybean plant observed during both the years. However, higher dose of diclosulam (T_5) had caused epinasty to crop plants up to a greater extent than other weed control treatments during both the years at 15 DAS, however, as plant growth increases up to 25 DAS it started recover itself and up to 30 DAS the plant was fully recovered (Table 4.8 d). Whereas, fluchloralin (T_3), diclosulam supplemented with HW at 20 DAS (T_6), fluchloralin followed by diclosulam (T_7), fluchloralin followed by haloxyfop (T_9) and diclosulam followed by haloxyfop (T_{10}) also showed slight chlorosis during both the years at 15 to 20 DAS and after 25 DAS they also fully recovered. Pendimethalin (T_4) and haloxyfop (T_8) recorded no phytotoxicity symptom like chlorosis during any stage of growth of the soybean plant during both the years.

4.4 Physiological studies

4.4.1 Leaf area per plant

Data pertaining to the leaf area at various growth stages of the crop was affected by different herbicidal treatments are given in Table 4.8 (a & b) and their analysis of variance is given in Appendix VIII.

Table 4.8 (a): Effect of weed control treatments on chlorosis in soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008						2009					
			Days after sowing											
			5	10	15	20	30	40	5	10	15	20	30	40
T_1 (Control)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_2 (Weed free)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_3 (Fluchloralin)	1000	Before sowing	0	0	0	0	0	0	0	0	0	0	0	0
T_4 (Pendimethalin)	1000	2	0	0	0	0	0	0	0	0	0	0	0	0
T_5 (Diclosulam)	26	2	0	0	0	0	0	0	0	0	0	0	0	0
T_6 (Diclosulam + HW)	18	2 +20	0	0	0	0	0	0	0	0	0	0	0	0
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	0	0	0	0	0	0	0	0	0	0	0	0
T_8 (Haloxyfop)	100	21	0	0	0	0	0	0	0	0	0	0	0	0
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0	0	0	0	0	0	0	0	0	0	0	0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.8 (b): Effect of weed control treatments on necrosis in soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008						2009					
			Days after sowing											
			5	10	15	20	30	40	5	10	15	20	30	40
T_1 (Control)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_2 (Weed free)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_3 (Fluchloralin)	1000	Before sowing	0	0	0	0	0	0	0	0	0	0	0	0
T_4 (Pendimethalin)	1000	2	0	0	0	0	0	0	0	0	0	0	0	0
T_5 (Diclosulam)	26	2	0	0	0	0	0	0	0	0	0	0	0	0
T_6 (Diclosulam + HW)	18	2 +20	0	0	0	0	0	0	0	0	0	0	0	0
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	0	0	0	0	0	0	0	0	0	0	0	0
T_8 (Haloxyfop)	100	21	0	0	0	0	0	0	0	0	0	0	0	0
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0	0	0	0	0	0	0	0	0	0	0	0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.8 (c): Effect of weed control treatments on tip burning in soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008						2009					
			Days after sowing											
			5	10	15	20	30	40	5	10	15	20	30	40
T_1 (Control)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_2 (Weed free)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_3 (Fluchloralin)	1000	Before sowing	0	0	0	0	0	0	0	0	0	0	0	0
T_4 (Pendimethalin)	1000	2	0	0	0	0	0	0	0	0	0	0	0	0
T_5 (Diclosulam)	26	2	0	0	0	0	0	0	0	0	0	0	0	0
T_6 (Diclosulam + HW)	18	2 +20	0	0	0	0	0	0	0	0	0	0	0	0
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	0	0	0	0	0	0	0	0	0	0	0	0
T_8 (Haloxyfop)	100	21	0	0	0	0	0	0	0	0	0	0	0	0
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0	0	0	0	0	0	0	0	0	0	0	0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.8 (d): Effect of weed control treatments on epinasty in soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008						2009					
			Days after sowing											
			5	10	15	20	30	40	5	10	15	20	30	40
T_1 (Control)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_2 (Weed free)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_3 (Fluchloralin)	1000	Before sowing	2	1	0	0	0	0	2	1	0	0	0	0
T_4 (Pendimethalin)	1000	2	0	0	0	0	0	0	0	0	0	0	0	0
T_5 (Diclosulam)	26	2	3	2	1	0	0	0	3	2	1	0	0	0
T_6 (Diclosulam + HW)	18	2 +20	1	1	0	0	0	0	1	1	0	0	0	0
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	2	1	0	0	0	0	2	1	0	0	0	0
T_8 (Haloxyfop)	100	21	0	0	0	0	0	0	0	0	0	0	0	0
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	2	1	0	0	0	0	2	1	0	0	0	0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	1	1	0	0	0	0	1	1	0	0	0	0

Table 4.8 (e): Effect of weed control treatments on hyponasty in soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008						2009					
			Days after sowing											
			5	10	15	20	30	40	5	10	15	20	30	40
T_1 (Control)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_2 (Weed free)	-	-	0	0	0	0	0	0	0	0	0	0	0	0
T_3 (Fluchloralin)	1000	Before sowing	0	0	0	0	0	0	0	0	0	0	0	0
T_4 (Pendimethalin)	1000	2	0	0	0	0	0	0	0	0	0	0	0	0
T_5 (Diclosulam)	26	2	0	0	0	0	0	0	0	0	0	0	0	0
T_6 (Diclosulam + HW)	18	2 +20	0	0	0	0	0	0	0	0	0	0	0	0
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	0	0	0	0	0	0	0	0	0	0	0	0
T_8 (Haloxyfop)	100	21	0	0	0	0	0	0	0	0	0	0	0	0
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0	0	0	0	0	0	0	0	0	0	0	0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0	0	0	0	0	0	0	0	0	0	0	0

Different treatments of weed control significantly affected the leaf area of soybean at all the growth stages during both the years except at 30 DAS in second year of the experiment (2009).

In general, the leaf area per plant increased with the advancement of the plant age and reached at its maximum at 70-75 DAS. During 2008, differences in leaf area per plant were significant at its all growth stages. The highest leaf area of the plant was obtained in weed free treatment which was *at par* with control (T_1), diclosulam at higher dose (T_5) and diclosulam supplemented hand weeding with at 20 DAS (T_6) at 30 DAS however at 60 and 90 DAS it was significantly higher than other treatments. During 60 DAS, diclosulam followed by hand weeding at 20 DAS (T_6) being *at par* with application of pendimethalin (T_4), diclosulam at higher dose (T_5), fluchloralin followed by diclosulam (T_7) and diclosulam followed by haloxyfop (T_{10}) produced significantly higher leaf area among other herbicidal treatments. However, during 90 DAS the significantly higher leaf area of the treatment in diclosulam supplemented with one hand weeding at 20 DAS (T_6) *at par* with diclosulam at higher dose (T_5), pendimethalin (T_4), fluchloralin followed by diclosulam (T_7), fluchloralin followed by haloxyfop(T_9), diclosulam followed by haloxyfop (T_{10}) and control (T_1).

During 2009 at 30 DAS, the highest leaf area was recorded in weed free (T_2) treatment, whereas, the lowest leaf area was recorded with control (T_1) treatment, however, the differences in leaf area per

Table 4.8 (a): Effect of weed control treatments on leaf area/plant (cm^2/plant) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Leaf area/ plant		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	628	924	989
T_2 (Weed free)	-	-	654	1196	1213
T_3 (Fluchloralin)	1000	Before sowing	377	710	793
T_4 (Pendimethalin)	1000	2	539	1001	1070
T_5 (Diclosulam)	26	2	603	991	1070
T_6 (Diclosulam + HW)	18	2 +20	589	1051	1080
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	498	971	1042
T_8 (Haloxyfop)	100	21	449	809	900
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	498	919	1035
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	492	948	1025
S.Em. ±			33	39	43
C.D. at 5%			95	113	126

Table 4.8 (b): Effect of weed control treatments on leaf area/plant (cm^2/plant) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Leaf area/ plant		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	688	971	1018
T_2 (Weed free)	-	-	770	1371	1288
T_3 (Fluchloralin)	1000	Before sowing	472	1085	1042
T_4 (Pendimethalin)	1000	2	643	1226	1170
T_5 (Diclosulam)	26	2	688	1291	1270
T_6 (Diclosulam + HW)	18	2 +20	714	1401	1330
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	680	1124	1139
T_8 (Haloxyfop)	100	21	568	1084	1075
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	665	1123	1135
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	743	1192	1150
S.Em. ±			90	50..0	38
C.D. at 5%			NS	145	111

plant were not significant. Whereas, at 60 and 90 DAS, diclosulam supplemented with one hand weeding at 20 DAS (T_6) being *at par* with weed free and application of diclosulam at it's higher rate produced significantly higher leaf area per plant. Treatments fluchloralin followed by diclosulam (T_7), application of haloxyfop (T_8), fluchloralin followed by haloxyfop (T_9) and fluchloralin (T_3) being *at par* with each other produced significantly lower leaf area than other treatments except control (T_1) at both growth stages (60 and 90 DAS) during 2009.

4.4.2 Leaf area index (LAI)

Data pertaining to the leaf are index at various growth stages of the crop was affected by different herbicidal treatments are given in Table 4.9 (a & b) and their analysis of variance is given in Appendix IX.

All the weed control treatments were found to have significantly higher LAI as compared to control (T_1) at different growth stages of crop during both the years, except at 30 days during 2009. The highest leaf area index was recorded in weed free (T_2) treatment at 30 DAS during both of the years but non-significant in 2009. During 2008 at 60 and 90 DAS, diclosulam followed by hand weeding at 20 DAS (T_6), pendimethalin (T_4), diclosulam at higher rate (T_5), fluchloralin followed by diclosulam (T_7), diclosulam followed by haloxyfop (T_{10}) and weedy (T_1) being at par with each other showed higher leaf area index than other weed control treatments except weed free (T_2).

Table 4.9 (a): Effect of weed control treatments on leaf area index at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Leaf area index		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	1.20	2.10	2.20
T_2 (Weed free)	-	-	1.46	2.66	2.67
T_3 (Fluchloralin)	1000	Before sowing	0.84	1.58	1.76
T_4 (Pendimethalin)	1000	2	1.31	2.23	2.38
T_5 (Diclosulam)	26	2	1.34	2.20	2.38
T_6 (Diclosulam + HW)	18	2 +20	1.40	2.34	2.40
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	1.11	2.16	2.32
T_8 (Haloxyfop)	100	21	1.00	1.80	2.00
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	1.11	2.04	2.30
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	1.10	2.11	2.28
S.Em. ±			0.07	0.09	0.09
C.D. at 5%			0.21	0.27	0.25

Table 4.9 (b): Effect of weed control treatments on leaf area index at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Leaf area index		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	1.53	2.16	2.26
T_2 (Weed free)	-	-	1.71	3.05	2.86
T_3 (Fluchloralin)	1000	Before sowing	1.05	2.41	2.31
T_4 (Pendimethalin)	1000	2	1.43	2.72	2.60
T_5 (Diclosulam)	26	2	1.53	2.87	2.82
T_6 (Diclosulam + HW)	18	2 +20	1.59	3.11	2.96
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	1.51	2.50	2.53
T_8 (Haloxyfop)	100	21	1.26	2.41	2.39
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	1.48	2.48	2.51
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	1.65	2.65	2.56
S.Em. ±			0.20	0.11	0.09
C.D. at 5%			NS	0.32	0.25

During 2009, the highest LAI was recorded in treatment diclosulam followed by hand weeding at 20 DAS (T_6) being *at par* with weed free (T_2) and application of diclosulam at its higher rate (T_5) at both growth stages (60 and 90 DAS). Fluchloralin followed by diclosulam (T_7), haloxyfop (T_8) and fluchloralin (T_3) being *at par* with weedy (T_1) produced significantly lower leaf area index than other treatments at both growth stages (60 and 90 DAS) during 2009.

4.4.3 SPAD meter value (Leaf chlorophyll content)

Data pertaining to SPAD meter values (leaf chlorophyll content) at various growth stages are presented in Table 4.10 (a &b), which were significantly not differed due to weed control treatments (Appendix X) during both of the year 2008 and 2009.

Initially SPAD meter values (leaf chlorophyll content) of soybean plant was low at 30 days stage and increased with the advancement of the crop age up to 60 days stage. The highest and the lowest SPAD meter value (leaf chlorophyll content) were obtained in weed free and weedy treatment respectively, at all growth stages during both of the years.

4.5 Crop growth analysis

4.5.1 Crop growth rate (CGR)

The data on crop growth rate (CGR) are summarized in Table 4.11 (a & b) and their analysis of variance is given in Appendix XI (a & b).

Table 4.10 (a): Effect of weed control treatments on SPAD meter values (leaf chlorophyll content) at different growth stages of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	SPAD meter values		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	35.0	41.3	39.4
T_2 (Weed free)	-	-	38.5	43.9	42.8
T_3 (Fluchloralin)	1000	Before sowing	36.1	42.0	40.0
T_4 (Pendimethalin)	1000	2	36.9	42.3	41.2
T_5 (Diclosulam)	26	2	38.0	42.4	42.1
T_6 (Diclosulam + HW)	18	2 +20	38.4	43.2	42.4
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	36.1	42.4	41.7
T_8 (Haloxyfop)	100	21	35.0	41.9	39.7
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	35.2	42.1	40.7
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	38.4	42.6	42.3
S.Em. ±			1.3	1.2	0.9
C.D. at 5%			NS	NS	NS

Table 4.10 (b): Effect of weed control treatments on SPAD meter values (leaf chlorophyll content) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	SPAD meter values		
			30 DAS	60 DAS	90 DAS
T_1 (Control)	-	-	35.5	40.5	39.8
T_2 (Weed free)	-	-	39.4	44.2	42.8
T_3 (Fluchloralin)	1000	Before sowing	36.5	41.0	40.4
T_4 (Pendimethalin)	1000	2	38.1	41.6	41.3
T_5 (Diclosulam)	26	2	38.6	42.8	41.9
T_6 (Diclosulam + HW)	18	2 +20	38.6	43.6	42.3
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	38.1	41.9	41.4
T_8 (Haloxyfop)	100	21	35.6	40.6	40.1
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	35.9	41.1	40.9
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	38.6	43.5	42.0
S.Em. ±			1.0	0.9	0.8
C.D. at 5%			NS	NS	NS

The crop growth rate was significantly influenced by different weed control treatments during both the years of investigation at all the growth stages of crop. The growth rate increased with advancement of the crop age up to 60 days stage, thereafter it started decreasing.

During 2008, the highest crop growth rate was recorded in weed free treatment at 30-60 DAS and 60-90 DAS. Treatments diclosulam followed by hand weeding at 20 DAS (T_6), diclosulam at higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and fluchloralin followed by diclosulam (T_7) being *at par* with each other, recorded significantly higher CGR than other herbicidal treatments except weed free (T_2) at both growth stages 30-60 and 60-90 stages.

During 2009, weed free treatment recorded significantly higher CGR which was *at par* with diclosulam followed by hand weeding at 20 DAS (T_6), diclosulam at higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and pendimethalin (T_4) at both growth stages. The lowest CGR was recorded in control (T_1) during both the years at all growth stages.

4.5.2 Relative growth rate (RGR)

The data on relative growth rate was computed for different weed control treatments are presented in Table 4.11 (a & b) and their analysis of variance in Appendix XI (a & b).

Table 4.11 (a): Effect of different weed control treatments on CGR (g day^{-1}) and RGR (g $g^{-1}day^{-1}$) at different growth stages of soybean (2008)

Treatments	Dose (gha-1)	Stage of application (DAS)	CGR		RGR	
			30-60	60-90	30-60	60-90
T_1 (Control)	-	-	0.33	0.24	0.026	0.013
T_2 (Weed free)	-	-	0.49	0.52	0.028	0.015
T_3 (Fluchloralin)	1000	Before sowing	0.34	0.34	0.026	0.015
T_4 (Pendimethalin)	1000	2	0.41	0.38	0.028	0.014
T_5 (Diclosulam)	26	2	0.44	0.42	0.027	0.014
T_6 (Diclosulam + HW)	18	2 + 20	0.45	0.45	0.027	0.015
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	0.43	0.44	0.027	0.015
T_8 (Haloxyfop)	100	21	0.39	0.32	0.026	0.014
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0.38	0.31	0.027	0.013
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0.43	0.41	0.026	0.014
S.Em. ±			0.01	0.01	0.0004	0.0004
C.D. at 5%			0.03	0.04	NS	0.001

Difference in treatment mean with respect of relative growth rate was non-significant at all the stages during both the years except 60-90 DAS stage during 2008.

In general, relative growth rate decreased with advancement in the crop age. During 2008, at 30-60 DAS stage weed free (T_2) recorded maximum relative growth rate, however, it was non-significant. At 60-90 days after sowing maximum relative growth rate was recorded with weed free (T_2) which was equal to application of fluchloralin (T_3), diclosulam followed by hand weeding at 20 DAS (T_6) and fluchloralin followed by diclosulam (T_7). Relative growth rate was significantly equal to other weed control treatments except combined application of fluchloralin followed by haloxyfop and weedy treatment, which recorded significantly lower relative growth rate than other weed control treatments.

During 2009, weed free (T_2) recorded the higher relative growth rate at 30-60 DAS and at 60-90 DAS weed free (T_2) and diclosulam supplemented with HW at 20 DAS (T_6) recorded the higher values for relative growth rate. Whereas the lower values for relative growth rate was recorded by control (T_1) treatment at 30-60 DAS and at 60-90 DAS equal values of relative growth rate was recorded by control (T_1) and fluchloralin (T_3) which were lower than remaining weed control treatments. However, these values for relative growth rate were significantly not differed for the values of other weed control

Table 4.11 (b): Effect of different weed control treatments on CGR (g day^{-1}) and RGR (g g^{-1}day^{-1}) at different growth stages of soybean (2009)

Treatments	Dose (gha-1)	Stage of application (DAS)	CGR		RGR	
			30-60	60-90	30-60	60-90
T_1 (Control)	-	-	0.26	0.23	0.0262	0.0141
T_2 (Weed free)	-	-	0.40	0.40	0.0271	0.0148
T_3 (Fluchloralin)	1000	Before sowing	0.28	0.26	0.0269	0.0141
T_4 (Pendimethalin)	1000	2	0.33	0.32	0.0268	0.0146
T_5 (Diclosulam)	26	2	0.36	0.35	0.0268	0.0147
T_6 (Diclosulam + HW)	18	2 + 20	0.38	0.38	0.0270	0.0148
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	0.31	0.31	0.0268	0.0146
T_8 (Haloxyfop)	100	21	0.29	0.27	0.0265	0.0143
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	0.27	0.26	0.0263	0.0142
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	0.33	0.33	0.0266	0.0147
S.Em. ±			0.03	0.03	0.0006	0.001
C.D. at 5%			0.07	0.08	NS	NS

treatments. During 2009, at 60-90 DAS stage the maximum RGR of weed free (T_2) was equal to the RGR value of diclosulam supplemented with hand weeding at 20 DAS (T_6).

4.5.3 Net assimilation rate (NAR)

Data pertaining to the net assimilation rate are given in Table 4.12 (a & b) and their analysis of variance in Appendix XI (a & b).

The net assimilation rate signifies the gain in dry matter yield of the plant per unit of leaf area per unit time. In general, net assimilation rate decreased with age of plants. The treatment difference in respect of net assimilation rate was non-significant at 30-60 DAS stage during 2008 however, during 60-90 DAS stage it was significant. During 2009 the treatment difference in respect of NAR were non-significant at both the growth stages of the plant.

During 2008, at 30-60 DAS treatments weed free (T_2) and diclosulam supplemented with hand weeding at 20 DAS (T_6) being equal to each other recorded the higher value for net assimilation rate which was significantly similar to NAR value recorded in other weed control treatments. At 60-90 days stage treatments weed free (T_2), diclosulam supplemented with hand weeding at 20 DAS (T_6) and diclosulam followed by haloxyfop (T_{10}) being *at par* to each other recorded significantly higher value for NAR than other weed control treatments except than alone application of fluchloralin (T_3) and application of fluchloralin followed by diclosulam (T_7). The lowest

Table 4.12 (a): Effect of different weed control treatments on NAR (g $cm^{-2}day^{-1}$ x10^4) and LAR (cm^2g^{-1}) at different growth stages of soybean (2008)

Treatments	Dose (gha-1)	Stage of application (DAS)	NAR		LAR	
			30-60	60-90	30-60	60-90
T_1 (Control)	-	-	3.5	2.4	78.0	51.8
T_2 (Weed free)	-	-	4.9	4.3	66.2	36.0
T_3 (Fluchloralin)	1000	Before sowing	4.0	3.9	54.0	33.8
T_4 (Pendimethalin)	1000	2	4.3	3.5	64.3	39.7
T_5 (Diclosulam)	26	2	4.4	4.2	60.3	37.0
T_6 (Diclosulam + HW)	18	2 + 20	4.9	4.3	62.3	35.5
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	4.4	3.9	61.0	35.6
T_8 (Haloxyfop)	100	21	4.1	3.6	57.2	37.7
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	4.3	3.0	66.0	43.8
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	4.8	4.3	58.7	37.2
S.Em. ±			0.2	0.2	2.9	1.7
C.D. at 5%			NS	0.6	8.5	5.0

values of net assimilation rate were recorded by control (T_1) in both growth stages and during 60-90 DAS stage, it was *at par* with application of fluchloralin followed by haloxyfop (T_9).

During 2009, the higher values for net assimilation rate at 30-60 DAS and 60-90 DAS stages were recorded with weed free (T_2) treatment, however, the lowest values for NAR were recorded with control (T_1).

4.5.4 Leaf area ratio (LAR)

Data pertaining to the leaf area ratio are given in Table 4.12 (a & b)and their analysis of variance in Appendix XI (a & b).

Significant effect of weed control treatments on the leaf area ratio (LAR) was recorded at all the growth stages during both the years except at 30-60 days stage of 2009. Irrespective of the treatments, leaf area ratio declined with advancement in age of the crop. The significantly higher value for LAR was recorded with control (T_1) than other weed control treatments in all growth stages of the crop during 2008. However during 2009 at 60-90 days stage control (T_1) treatment being *at par* with application of fluchloralin followed by haloxyfop (T_9) recorded significantly higher values than other treatments.

During 2008, application of fluchloralin (T_3) being *at par* with application of haloxyfop (T_8), diclosulam followed by haloxyfop (T_{10}), diclosulam at higher dose (T_5), fluchloralin followed by diclosulam (T_7) and diclosulam supplemented with one hand weeding at 20 DAS (T_6)

Table 4.12 (b): Effect of different weed control treatments on NAR (g $cm^{-2} day^{-1} \times 10^4$) and LAR ($cm^2 g^{-1}$) at different growth stages of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	NAR		LAR	
			30-60	60-90	30-60	60-90
T_1 (Control)	-	-	2.3	2.1	123.5	71.8
T_2 (Weed free)	-	-	3.2	3.1	90.3	47.0
T_3 (Fluchloralin)	1000	Before sowing	2.7	2.5	104.0	55.8
T_4 (Pendimethalin)	1000	2	2.7	2.8	99.8	53.5
T_5 (Diclosulam)	26	2	2.8	2.8	99.0	53.5
T_6 (Diclosulam + HW)	18	2 + 20	2.7	3.0	98.0	52.3
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	2.9	2.9	83.8	49.8
T_8 (Haloxyfop)	100	21	2.7	2.5	101.5	56.8
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	2.4	2.3	110.8	63.8
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2.8	2.8	97.5	52.5
S.Em. ±			0.2	0.3	8.6	4.5
C.D. at 5%			NS	NS	NS	13.1

recorded significantly lower values for the leaf area ratio at both growth stages. However, during 2009 weed free treatment being *at par* with other weed control treatments except application of fluchloralin followed by haloxyfop (T_9) and control (T_1) recorded significantly lower values for the leaf area ratio at 60-90 days stage.

4.6 Yield attributes

4.6.1 Number of primary branches per plant

Data on branches per plant differ significantly in 2009 but remained non-significant during 2008 (Table 4.13 a &b, Appendix XIII a & b). Maximum number of branches per plant was recorded in weed free plot of both years, however, during 2008 it was differ non-significantly.

During 2009, weed free (T_2) plot resulted in maximum number of branches per plant which was statistically equal to the number of branches per plant recorded in all other weed control treatments except alone application of haloxyfop (T_8), fluchloralin followed by haloxyfop (T_9) and control (T_1) which were also *at par* with each other. The lowest number of branches per plant (3.1) was recorded in control (T_1).

4.6.2 Number of pods per plant

Treatments differed significantly in respect of number of pods per plant during 2008 and 2009 (Table 4.13 a &b, Appendix XIII a & b). Relatively higher number of pods per plant was recorded during first

Table 4.13 (a): Effect of weed control treatments on various yield attributes of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Branches/ plant	Pods/ plant	Grain/pod	Seed index
T_1 (Control)	-	-	4.5	34.3	2.5	11.8
T_2 (Weed free)	-	-	6.5	71.3	2.8	12.2
T_3 (Fluchloralin)	1000	Before sowing	5.7	50.4	2.7	11.9
T_4 (Pendimethalin)	1000	2	4.2	48.5	2.5	11.0
T_5 (Diclosulam)	26	2	6.3	60.7	2.6	12.0
T_6 (Diclosulam + HW)	18	2 + 20	5.5	57.2	2.8	12.5
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	5.1	45.8	2.7	12.7
T_8 (Haloxyfop)	100	21	3.7	47.5	2.5	11.6
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	4.6	43.7	2.6	12.0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	5.3	60.0	2.8	12.4
S.Em. ±			0.73	5.5	0.09	0.4
C.D. at 5%			NS	15.9	NS	NS

year (2008) as compared to second year (2009). During 2008, weed free (T_2) recorded maximum number of pods per plant which was *at par* with diclosulam at its higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and diclosulam supplemented with hand weeding at 20 DAS (T_6) and remain significantly higher than all other weed control treatments.

During, 2009, the maximum number of pods per plant obtained in weed free plot was significantly higher than all other treatment except diclosulam supplemented with hand weeding at 20 DAS (T_6), diclosulam followed by haloxyfop (T_{10}) and diclosulam at its higher rate (T_5). The lowest number of pods per plant was obtained in control plot. Per cent increase in number of pods of soybean per plant in weed free treatment over control was almost similar 52 and 67 per cent, during 2008 and 2009, respectively.

4.6.3 Number of grains per pod

Data on number of grains per pod did not differ significantly in both the years of experiment viz. 2008 and 2009 (Table 4.13 a & b, Appendix XIII a & b).

During 2008, weed free treatment recorded the maximum number of grains per pod which was equal with diclosulam supplemented hand weeding with at 20 DAS (T_6), diclosulam at its higher rate (T_5) and diclosulam followed by haloxyfop (T_{10}), whereas equal number of grain of per pod of control (T_1) alone application of fluchloralin (T_3) and haloxyfop (T_8) recorded lower number of grain per pod.

Table 4.13 (b): Effect of weed control treatments on various yield attributes of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Branches/ plant	Pods/ plant	Grain/ pod	Seed index
T_1 (Control)	-	-	3.1	16.5	2.3	11.8
T_2 (Weed free)	-	-	5.3	49.8	2.8	12.5
T_3 (Fluchloralin)	1000	Before sowing	4.4	30.3	2.3	11.9
T_4 (Pendimethalin)	1000	2	4.7	34.3	2.5	11.0
T_5 (Diclosulam)	26	2	4.7	36.5	2.5	12.0
T_6 (Diclosulam + HW)	18	2 + 20	5.2	47.9	2.5	12.3
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	4.6	33.6	2.3	11.9
T_8 (Haloxyfop)	100	21	3.3	19.4	2.3	11.6
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	3.3	29.5	2.0	12.0
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	4.9	46.8	2.5	12.4
S.Em. ±			0.53	4.72	0.25	0.37
C.D. at 5%			1.5	13.7	NS	NS

The similar trend of grain per pod of soybean was also obtained in 2009.

4.6.4 Seed index

Data pertaining to 100 grain weight presented in Table 4.13 (a &b) which were significantly not differed due to weed control treatments (Appendix XIII a & b) during both of the year 2008 and 2009.

Weed free treatment recorded the highest 100 grain weight of soybean whereas, the lowest 100 grain weight was obtained in control plot in both the years. During 2008 the 100 grain weight was ranged in between 11.0 to 12.7 whereas, during 2009 the 100 grain weight was ranged in between 11.0 to 12.5.

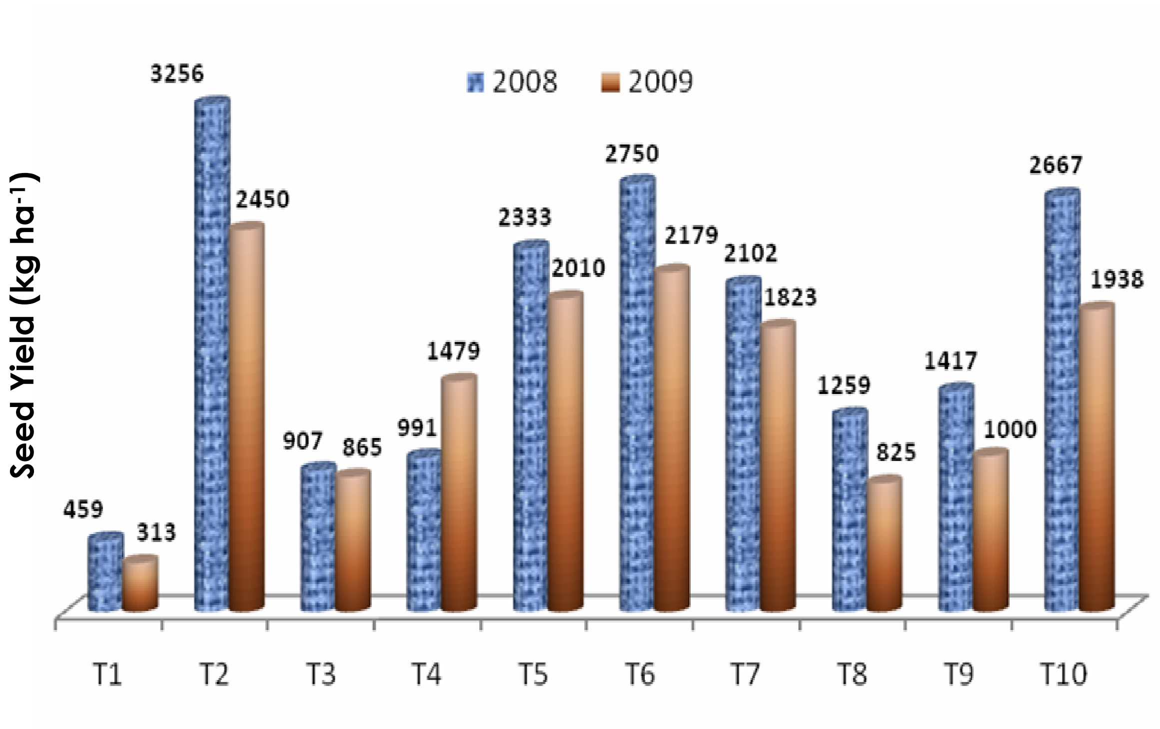
4.6.5 Seed yield

Data pertaining to the seed yield recorded under different treatments are presented in Table 4.14 and depicted in Fig. 4.6. Their analysis of variance is given in Appendix XIV.

Significant effect of all the weed control treatments on seed yield was recorded during both the years. Weed free treatment provided significantly higher seed yield (3256 kg ha^{-1}) as compared to all other treatments during 2008 however, during 2009 it (2450 kg ha^{-1}) was *at par* with application of diclosulam supplemented with one hand weeding with at 20 DAS (T_6) and alone application of diclosulam at its higher rate (T_5). Diclosulam supplemented with hand weeding at

Table 4.14: Effect of weed control treatments on grain (kg ha^{-1}) and straw yield (kg ha^{-1}) and harvest index (%) of soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008			2009		
			Seed yield	Straw yield	Harvest index	Seed yield	Straw yield	Harvest index
T_1 (Control)	-	-	459	2306	17	313	915	25
T_2 (Weed free)	-	-	3256	5144	39	2450	3854	39
T_3 (Fluchloralin)	1000	Before sowing	907	1208	44	865	2073	29
T_4 (Pendimethalin)	1000	2	991	2380	29	1479	2896	34
T_5 (Diclosulam)	26	2	2333	4083	36	2010	3190	40
T_6 (Diclosulam + HW)	18	2 +20	2750	4931	36	2179	3521	39
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	2102	3398	38	1823	3115	37
T_8 (Haloxyfop)	100	21	1259	1801	42	825	1521	35
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	1417	1551	50	1000	2021	33
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	2667	5019	35	1938	3238	37
S.Em. ±			145	501	4	164	298	3
C.D. at 5%			428	1452	13	477	864	9



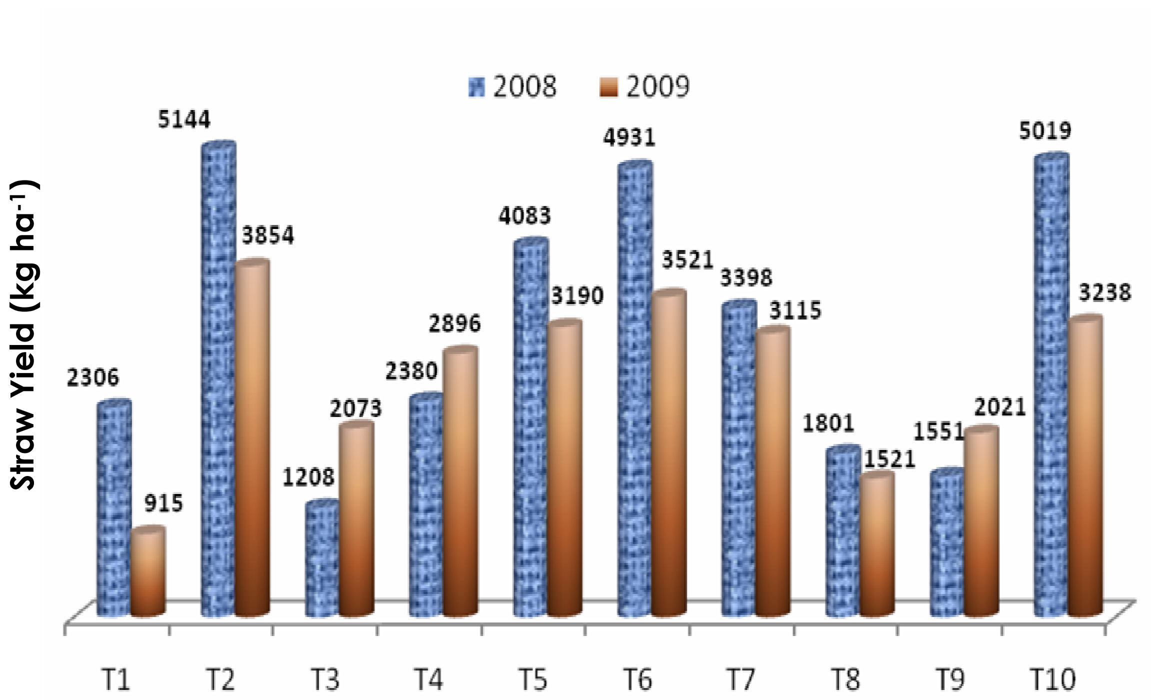


Fig.4.7 Effect of weed control treatments on straw yield of soybean

20 DAS (T_6), combined application with diclosulam followed by haloxyfop (T_{10}) and alone application of diclosulam at its higher dose (T_5) being *at par* with each other recorded significantly higher seed yield than other treatments except weed free (T_2) during both the years however, during 2009, combined application of fluchloralin followed by diclosulam (T_7) also produced significantly equal yield to these treatments.

On an average, the uncontrolled growth of weeds resulted into 86 and 87 per cent reduction during 2008 and 2009, respectively in seed yield of soybean when compared with weed free treatment.

4.6.6 Straw yield

The data on straw yield recorded under different treatments are summarized in Table 4.14 and depicted in Fig. 4.7 and their analysis of variance in Appendix XIV.

Significant effect of all the weed control treatments on straw yield was recorded during both the years. Weed free (T_2), diclosulam supplemented with hand weeding with at 20 DAS (T_6), alone application of diclosulam at its higher dose (T_5) and combined application with diclosulam followed by haloxyfop (T_{10}) being *at par* with each other recorded significantly higher straw yield as compared to the remaining treatments during both the years. However, during 2009 combined application of fluchloralin followed by diclosulam (T_7) also produced statistically equal yield with weed free (T_2) treatment.

Uncontrolled growth of weeds caused straw yield reduction to the tune of into 55 and 76 per cent, as compared to weed free treatment during 2008 and 2009, respectively.

4.6.7 Harvest index

Data pertaining to the seed yield recorded under different treatments are presented in Table 4.14 and their analysis of variance is given in Appendix XIV.

Harvest index was significantly influenced by all the weed control treatments during both the years. All the weed control treatments provided significantly higher harvest index over control (T_1). During 2008, the highest harvest index was obtained in combined application of fluchloralin followed by haloxyfop (T_9) and remained *at par* with alone application of fluchloralin (T_3), alone application of haloxyfop (T_8) and weed free (T_2). However, during 2009, the highest harvest index was obtained with application of diclosulam at its higher dose (T_5) and remained *at par* with all other weed control treatments except weedy (T_1) and alone application of fluchloralin (T_3).

4.7 Quality parameters of soybean

4.7.1 Protein content

Treatments differences for seed protein content were significant during 2009 however it was non significant during 2008 (Table 4.15, Appendix XV, Fig. 4.8).

Table 4.15: Effect of weed control treatments on oil (%) and protein (%) content of soybean

Treatments	Dose (gha^{-1})	Stage of application (DAS)	2008		2009	
			Oil content	Protein content	Oil content	Protein content
T_1 (Control)	-	-	18.2	38.4	17.4	37.3
T_2 (Weed free)	-	-	19.7	39.9	19.6	41.0
T_3 (Fluchloralin)	1000	Before sowing	18.3	38.4	19.0	37.0
T_4 (Pendimethalin)	1000	2	18.3	38.3	18.3	38.8
T_5 (Diclosulam)	26	2	18.8	38.0	18.0	38.8
T_6 (Diclosulam + HW)	18	2 +20	19.5	38.1	18.9	38.9
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing +2	19.0	38.1	19.2	40.3
T_8 (Haloxyfop)	100	21	19.0	38.1	19.0	37.4
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	18.3	38.3	20.2	38.4
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	19.1	38.4	20.4	37.5
S.Em. ±			0.43	0.50	0.4	0.5
C.D. at 5%			NS	NS	1.3	1.5

During both the years, the highest seed protein content was recorded in weed free (T_2) and during 2009, it was *at par* with other treatments except alone application of haloxyfop (T_8) and fluchloralin (T_3).

The lowest protein content in soybean seed was observed in control (T_1) plot in both of the years. During 2008 the values for protein content of diclosulam supplemented hand weeding with at 20 DAS (T_6), fluchloralin followed by diclosulam (T_7) and haloxyfop (T_8) recorded equal and higher values of protein content from control (T_1). During 2009, all the treatments except application of fluchloralin (T_3) and haloxyfop (T_8) recorded significantly higher protein content over weedy (T_1).During 2009, pendimethalin (T_4) and diclosulam at higher rate (T_5) being equal (38.8%) and *at par* with diclosulam supplemented with hand weeding with at 20 DAS (T_6) and fluchloralin followed by diclosulam (T_7) recorded higher values for protein content over remaining weed control measures except weed free (T_2).

Per cent increase in protein content in soybean seed in weed free plot over weedy plot was 4 and 9 per cent during 2008 and 2009, respectively (Table 4.15).

4.7.2 Oil content

Different weed control treatments significantly affected the oil content of soybean seed during 2009 however, during 2008 the values for protein content of different weed control treatments were non significant (Appendix XV). Data revealed that (Table 4.15, Fig. 4.9) almost equal oil content in soybean seed was obtained in both the years.

Among the weed control treatments, T_2 (weed free) recorded higher oil content of soybean seed. During 2008 the values for oil content of application of fluchloralin (T_3), pendimethalin (T_4) and fluchloralin followed by haloxyfop (T_9) were equal and higher with control (T_1) but lower with remaining weed control treatments. However, during 2009 diclosulam followed by haloxyfop (T_{10}) being *at par* with fluchloralin followed by haloxyfop (T_9), weed free (T_2), fluchloralin followed by diclosulam (T_7), haloxyfop (T_8) and fluchloralin (T_3) recorded the higher values of oil content. The lowest value for oil content was recorded by control (T_1) during both the years.

In general, the oil content of weed free plot was 8 and 11 per cent greater than control during 2008 and 2009.

4.7.3 Fatty acid composition of soybean oil

The data pertaining to fatty acid composition of soybean oil have been set out in Table 4.16 (a) & (b) and depicted in Fig. 4.10 (a) & (b). Their analysis of variance is presented in Appendix XVI (a & b).

The predominance fatty acids in general were stearic, palmitic, oleic, linoleic and linolenic acid among which stearic and palmitic acid come under saturated fatty acid and rest others (oleic, linoleic and linolenic acid) come under unsaturated fatty acid.

4.7.3.1 Saturated fatty acid (Stearic and palmitic acid)

The difference due to weed control treatments in saturated fatty acids were significant during second year (i.e. 2009) of investigation however, during 2008 it was found non-significant. The saturated fatty acids ranged from 10 to 12 per cent.

The weed free accumulated the highest saturated fatty acid content during both the years, however during 2009 it was significantly higher than other weed control treatments except combined application of fluchloralin followed by haloxyfop (T_9).

The weedy plot recorded the lowest content of saturated fatty acid among the other weed control treatments which was *at par* with application of diclosulam supplemented with hand weeding at 20 DAS (T_6) and alone application of diclosulam at its higher rate (T_5).

4.7.3.2 Oleic acid

Variations in oleic acid due to different weed control treatments were significantly during both the years. The range of oleic acid content from 13.7 to 19.7 per cent.

During both the years, the highest oleic acid was accumulated with application of fluchloralin followed by diclosulam (T_7) which was *at par* with fluchloralin followed by haloxyfop (T_9) and diclosulam at higher rate (T_5) during 2008 however, during 2009, it was *at par* with fluchloralin followed by haloxyfop (T_9). The lowest oleic acid was recorded with alone application of haloxyfop (T_8) which was

Table 4.16 (a): Effect of different weed control treatments on fatty acid composition (%) of soybean (2008)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Fatty acid composition			
			Saturated fatty acid	Oleic acid	Linoleic acid	Linolenic acid
T_1 (Control)	-	-	10.18	15.10	63.70	10.17
T_2 (Weed free)	-	-	12.02	16.98	64.01	8.02
T_3 (Fluchloralin)	1000	Before sowing	10.93	17.10	62.68	10.56
T_4 (Pendimethalin)	1000	2	10.98	17.32	61.95	10.49
T_5 (Diclosulam)	26	2	10.98	18.44	62.29	10.01
T_6 (Diclosulam + HW)	18	2 + 20	10.17	16.51	62.23	11.49
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	11.28	19.69	60.31	9.36
T_8 (Haloxyfop)	100	21	11.19	13.85	66.19	8.93
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	11.70	18.60	61.15	9.57
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	11.19	16.71	62.93	9.16
S.Em. ±			0.45	0.75	0.94	0.62
C.D. at 5%			NS	2.17	2.74	1.79

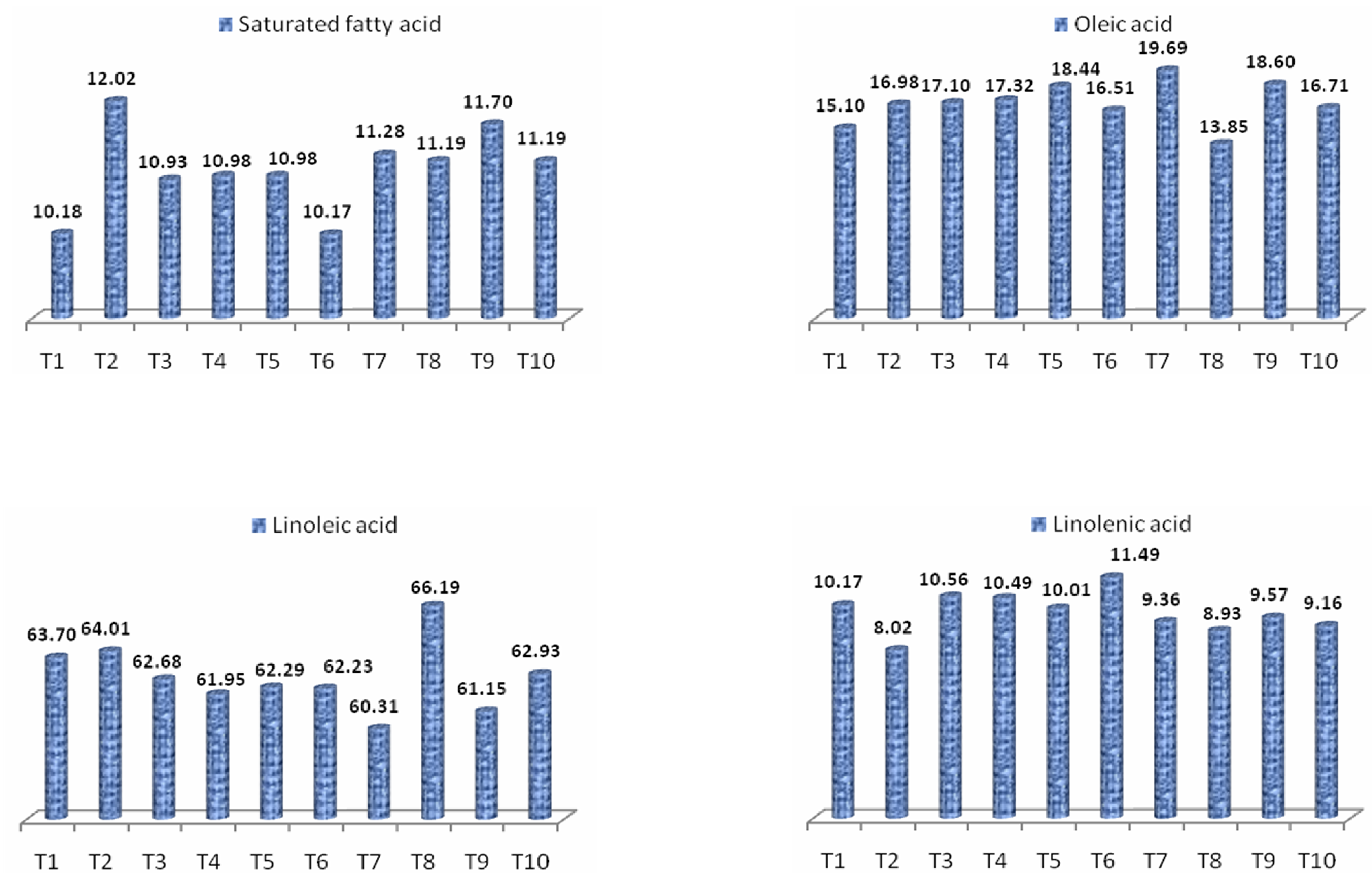


Fig. 4.10 (a) Effect of different weed control treatments on fatty acid composition of soybean (2008)

significantly lower than other weed control treatments except weedy (T_1) during both of the years.

4.7.3.3 Linoleic acid

The differences in the comparisons of linoleic acid among the different weed control treatments were found to be significant during both the years. The range of linoleic acid was observed from 60 to 66 per cent.

Among the weed control treatments alone application of haloxyfop (T_8) accumulated the highest linoleic acid which was significantly higher than other treatments during 2009 however, during 2008 the higher linoleic acid content was *at par* with weedy (T_1) and weed free (T_2) treatment. The lowest linoleic acid content was recorded with fluchloralin followed by diclosulam (T_7) which was *at par* with other weed control treatments except weed free (T_2) and weedy (T_1) during 2008, however during 2009 it was significantly equal with fluchloralin followed by haloxyfop (T_9) and diclosulam supplemented with hand weeding at 20 DAS (T_6).

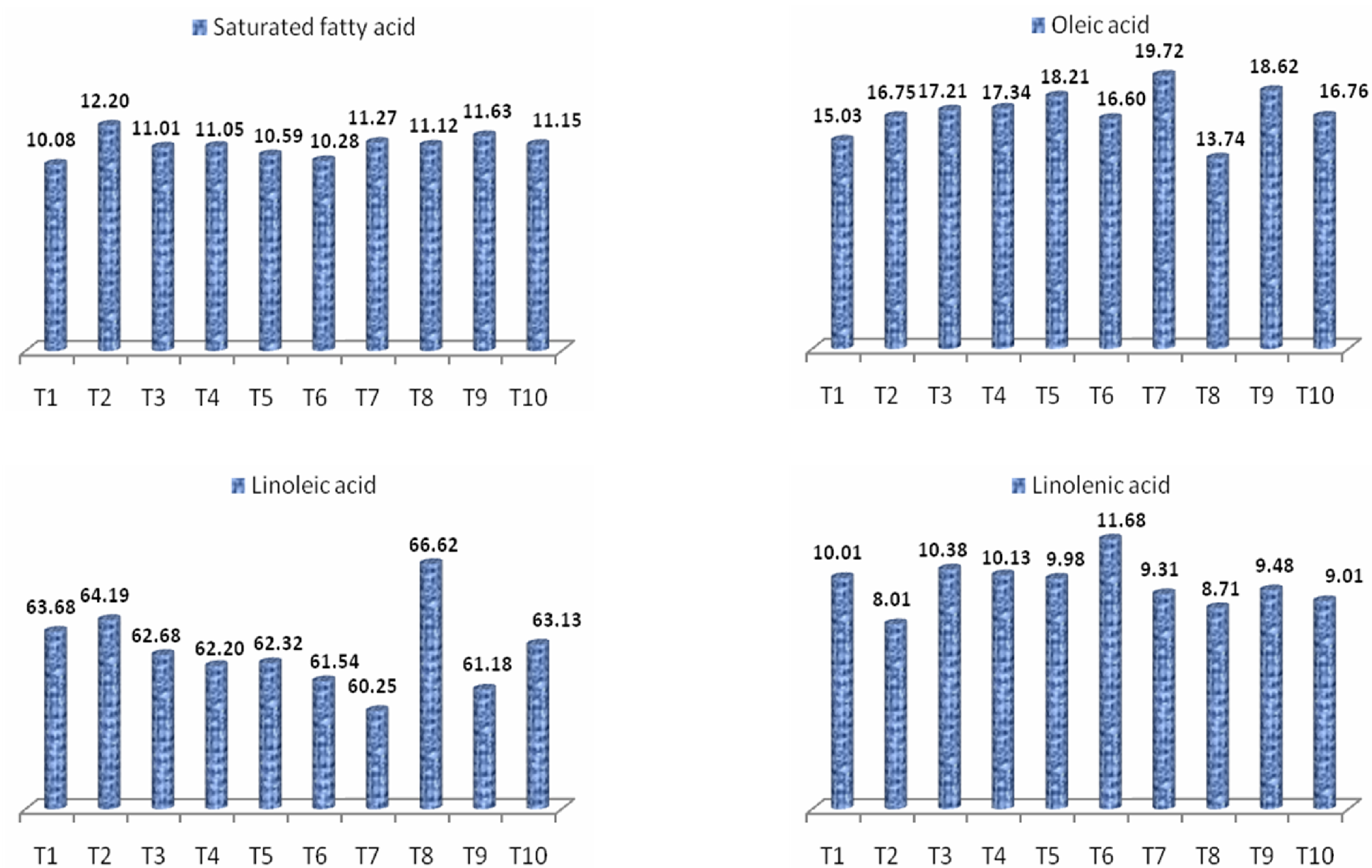
4.7.3.4 Linolenic acid

Variations in linolenic acid content due to different weed control treatments were significantly during both the years. The range of linolenic acid content from 8 to 12 per cent.

The highest linolenic acid was recorded from T_6 (diclosulam supplemented with hand weeding at 20 DAS) was significantly higher

Table 4.16 (b): Effect of different weed control treatments on fatty acid composition (%) of soybean (2009)

Treatments	Dose (gha^{-1})	Stage of application (DAS)	Fatty acid composition			
			Saturated fatty acid	Oleic acid	Linoleic acid	Linolenic acid
T_1 (Control)	-	-	10.08	15.03	63.68	10.01
T_2 (Weed free)	-	-	12.20	16.75	64.19	8.01
T_3 (Fluchloralin)	1000	Before sowing	11.01	17.21	62.68	10.38
T_4 (Pendimethalin)	1000	2	11.05	17.34	62.20	10.13
T_5 (Diclosulam)	26	2	10.59	18.21	62.32	9.98
T_6 (Diclosulam + HW)	18	2 + 20	10.28	16.60	61.54	11.68
T_7 (Fluchloralin + Diclosulam)	1000+ 18	Before sowing + 2	11.27	19.72	60.25	9.31
T_8 (Haloxyfop)	100	21	11.12	13.74	66.62	8.71
T_9 (Fluchloralin + Haloxyfop)	1000+100	Before sowing + 21	11.63	18.62	61.18	9.48
T_{10} (Diclosulam + Haloxyfop)	18 + 100	2 + 21	11.15	16.76	63.13	9.01
S.Em. ±			0.21	0.46	0.46	0.24
C.D. at 5%			0.61	1.32	1.34	0.69


Saturated fatty acid
10.08
12.20
11.01
11.05
10.59
10.28
11.27
11.12
11.63
11.15
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10
Oleic acid
15.03
16.75
17.21
17.34
18.21
16.60
19.72
13.74
18.62
16.76
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10
Linoleic acid
63.68
64.19
62.68
62.20
62.32
61.54
60.25
66.62
61.18
63.13
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10
Linolenic acid
10.01
8.01
10.38
10.13
9.98
11.68
9.31
8.71
9.48
9.01
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10

than other weed control treatments during 2009, however during 2008 it was *at par* with fluchloralin (T_3), pendimethalin (T_4), weedy (T_1) and diclosulam at higher rate (T_5).

Weed free treatment recorded the lowest linolenic acid content during both the years which was significantly lower than other treatments during 2009 however during 2008, it was *at par* with haloxyfop (T_8), diclosulam followed by haloxyfop (T_{10}), fluchloralin followed by diclosulam (T_7) and fluchloralin followed by haloxyfop (T_9).

4.8 Correlation studies

4.8.1 Correlation studies between different physiological growth parameters and seed yield of soybean

The data computed for correlation coefficient between physiological parameters like leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) with seed yield are presented in Table 4.17 (a). The 'r' values revealed that the LAI had positive and significant correlation with CGR, RGR, NAR and seed yield during 2009.

Similarly 'r' value obtained of CGR with NAR and seed yield of soybean revealed that CGR had significant positive correlation with these parameters during both years. However, during 2009 CGR was also significant positively correlated with RGR. NAR was also positively and significantly correlated with seed yield however, it was negatively and significantly correlated with LAR during both years.

During 2009, RGR was positively significantly correlated with NAR and seed yield however, during 2008 it was negatively significantly correlated with LAR. During 2009, LAR had negative significant correlation with seed yield.

4.8.2 Correlation studies between different growth parameters and seed yield of soybean

The ‘r’ value obtained for different growth parameters with each other and with seed yield revealed that plant height had positive and significant correlation with trifoliate and dry matter accumulation per plant, chlorophyll content and seed yield during 2008. Whereas trifoliates per plant was positively and significantly correlated with dry matter accumulation per plant and chlorophyll content of the plant during both the years, however during 2009 trifoliates per plant was also positively and significantly correlated with leaf area of the plant as well as seed yield (Table 4.17 b).

Dry matter accumulation per plant showed positive and significant correlation with chlorophyll content and seed yield during both the years, however during 2009 it was also positively and significantly correlated with leaf are per plant. Others parameters like chlorophyll content and leaf area per plant had positive and significant correlation with seed yield during both years, however during 2008 the correlation between leaf are per plant and seed yield was non significant. During 2009 chlorophyll content had also positive and significant correlation with leaf are per plant.

Table 4.17 (a):Correlation between different physiological growth parameters of soybean to seed yield

Physiological growth parameters	Correlation coefficient (r)									
	2008					2009				
	CGR	RGR	NAR	LAR	Seed yield	CGR	RGR	NAR	LAR	Seed yield
LAI	0.648	0.064	0.258	0.022	0.671	0.940**	0.884*	0.816*	-0.647	0.897*
CGR		0.747	0.864*	-0.723	0.900*		0.951**	0.936**	-0.810	0.965**
RGR			0.781	-0.854*	0.530			0.927**	-0.793	0.957**
NAR				-0.908*	0.813*				-0.946**	0.949**
LAR					-0.570					-0.854*

* Significant at 5 % probability

** Significant at 1 % probability

Table 4.17 (b): Correlation between different growth parameters of soybean to seed yield

Growth parameters	Correlation coefficient (r)									
	2008					2009				
	Trifoliate/plant	Dry matter/ plant	SPAD value	Leaf area/ plant	Seed yield	Trifoliate /plant	Dry matter/ plant	SPAD value	Leaf area/ plant	Seed yield
Plant height	0.845*	0.913*	0.969**	0.797	0.922**	0.350	0.557	0.424	0.515	0.346
Trifoliate plant^{-1}		0.919**	0.930**	0.636	0.793		0.938**	0.980**	0.899*	0.991**
Dry matter plant^{-1}			0.931**	0.709	0.902*			0.957**	0.955**	0.946**
Chlorophyll content				0.763	0.929**				0.908*	0.980**
Leaf area plant^{-1}					0.677					0.894*

* Significant at 5 % probability

** Significant at 1 % probability

4.8.3 Correlation studies between different yield attributes and seed yield of soybean

The data computed for correlation coefficient between different yield attributes *viz.* number of branches and pods per plant, number of grain per pod, seed index with seed yield are presented in Table 4.17 (c). The value 'r' obtained revealed that among the yield attributes number of branches per plant was positively and significantly correlated with number of pods per plant of soybean during 2009.

Among the other yield attributes, number of pods per plant had positive and significant correlation with seed yield during both the years.

Table 4.17 (c): Correlation between different yield attributes of soybean to seed yield

Growth parameters	Correlation coefficient (r)							
	2008				2009			
	Pods/ plant	Grain/ pod	Seed index	Seed yield	Pods/ plant	Grain/ pod	Seed index	Seed yield
Branches plant^{-1}	0.755	0.708	0.523	0.683	0.915 *	0.781	0.390	0.902
Pods plant^{-1}		0.693	0.310	0.865*		0.681	0.608	0.925*
Grain pod^{-1}			0.779	0.804			0.305	0.719
Seed index				0.659				0.515

* Significant at 5 % probability

** Significant at 1 % probability

Discussion

The salient findings of the experiment presented in preceding chapter provide a detailed account of the effect of weed control treatments on weeds and on the performance of soybean in terms of dry matter production, growth, yield and yield contributing characters as well as seed quality. An attempt has been made to evaluate and explain the findings recorded in the present investigation with a view to find out the "cause and effect relationships" between growth, development and yield as far as possible and to trace out the information of practical value. The essential aspect of the following discussion would pertain primarily to control the weeds and seed yield which has the greatest importance in this context.

The final build up of yield is the cumulative function of yield components, some characters contribute (pods per plant, grain per pod and seed index) more while other less. There are some characters (trifoliate per plant etc.) which do not have any substantial direct effect on yield but contribute to the characters which are responsible for yield. Growth of the plant is governed indirectly by the climatic factors such as temperature, rainfall, relative humidity and sunlight. These factors perform various functions together in the activities of plants and it can hardly be said that one is more important than other.

Growth and yield performance of a crop is an exercise of energy transformation, in which solar energy is converted into more useful form of chemical energy. The efficient utilization of solar energy as well as other essential resources for plant growth and development like plant nutrients can be enhanced by controlling the interference of weeds and reducing their disturbance in plant life. As weeds not only compete with plant for moisture, light, nutrients and space, but they also hamper operation of equipment, harbor crop pests such as insects and diseases, and contaminate harvested grain with foreign matter and weed seeds and thus effect the plant growth and ultimately reduce the yield of plant. Some weeds also produce and release allelochemicals that adversely affect the growth of crop plants. Losses in both yield and quality of crops due to weeds always create a huge problem in all agricultural areas. Therefore, among the agronomic manipulation weed management is of paramount importance for the proper utilization of input resources and the growth development of crop.

Effect of various treatments on weed control, weed growth, growth parameters and seed yield of soybean crop are discussed in this chapter under different heads.

5.1 Studies on weeds

Various weed species were found in the experimental field at different growth stages of soybean, out of which *Celosia argentia* was major dominant dicot weed and *Echinochloa colona* among the monocot weed through out of the crop growth. Other economically important weeds were *Eleusine indica, Cyperus rotundus and Commelina benghalensis*. Dicot weeds dominated over monocot weeds throughout the crop season. Because of profuse branching habit and ground cover of dicot weeds like *C. argentia*, causes the shading effect for main crop. It was also noted that shading decreases the partitioning of plant biomass into reproductive parts like pods and seeds resulting in decreased partitioning to these organs. Dominance of these weeds has also been reported by Malik *et al.* (2006).

Weed density in different weed control treatments was significantly affected at all the stages of study. Majority of the weeds emerged by 30 days of crop growth and thereafter increased up to harvest. However the main competition between crop and weeds found maximum during 45 to 60 days after sowing of plant growth. Possibly after 60 DAS, the vigorous growth of the soybean cover the ground effectively and shaded the weeds, resulting into reduced photosynthesis and causing the weak relationship of source to sink and thereby less dry matter accumulation by weeds. Singh (2005) also reported that the critical period of weed control was 45 DAS in soybean.

During the all growth stages, among the weed control treatments except weed free (T_2), application of diclosulam followed by hand weeding at 20 DAS (T_6) recorded the lowest density of monocot and dicot weeds during both the years followed by application of diclosulam at its higher rate (T_5) and combined application of diclosulam followed by haloxyfop (T_{10}), controlled monocot and dicot both type of weeds effectively resulted into less number of weed plants per unit area and showed the better efficacy of diclosulam over other herbicides used. Pre emergence herbicides absorbed by germinating weeds inhibit cell division in the meristematic tissues resulting in death of most of the weeds within a few days of their emergence, disruption of microtubule and inhibit synthesis of seedlings followed by chlorosis and inhibition of elongation of leaves therefore, most of the weeds died with in a few days of their emergence. Similar types of results are also produced by Grichar *et al.* (2006) and AICRP report on Soybean (2007-08 and 2008-09). Maximum weed density was observed in control (T_1), which include all type of weeds because there was no control on the growth of weeds and their faster growth as compared to soybean in the initial stages.

Post emergence spray of haloxyfop was found effective against grassy weeds. As application of haloxyfop (T_8) was observed superior to fluchloralin (T_3) and pendimethalin (T_4), which were used as standard check during the study, to control the monocot weeds. The selective action is the reason for better control of monocot weeds with application of post emergence application of haloxyfop. It showed the better efficacy of haloxyfop to control the monocot weeds over fluchloralin and pendimethalin. Similar results were reported by Singh *et al.* (2002).

Balyan and Malik (2003) also reported that grassy weeds were effectively controlled by haloxyfop.

In general, the dry matter accumulation of weeds increased with the advancement of the crop age up to the maturity. The highest weed dry matter accumulation by weeds was recorded in control (T_1) at all the stages of crop during both the years. The increase in population and dry matter of weeds to such a high level under unweeded control may be attributed to uninterrupted weed growth through out the crop season. The average rate of dry matter production of weeds in control (T_1) plot was 3.1, 7.6 and 9.7 g/m^2/day during 0 to 30, 30 to 60 and 60 to 90 days after sowing, respectively during 2008 and 4.2, 28.0, 1.3 g/m^2/day during 0 to 30, 30 to 60 and 60 to 90 days after sowing, respectively during 2009. It showed the rate of dry matter accumulation was more up to 60 days after sowing than at later stages. Competition between crop and weeds was intense during 30 to 60 days after sowing during both years. The reason of longer time of competition between weeds and crop was might be due to presence of Celosia argentia which grows with the crop for longer period and complete its life cycle along with the soybean crop. Singh *et al.* (2002) also reported that the weed growth rate was higher during 30 to 60 days after sowing and declined gradually with the advancement in the age of the crop.

The lowest weed dry matter accumulation was obtained in diclosulam followed by hand weeding at 20 DAS (T_6) among the herbicidal treatments at all the stages of crop during both the years, followed by application of diclosulam at its higher rate (T_5) and combined application of diclosulam followed by haloxyfop (T_{10}), showed the effective control of weeds over other herbicidal treatments. The lower weed dry matter accumulation might be due to the reduction in level of nutrients by weeds. Further the lowest population and dry matter accumulation of weeds may be ascribed probably due to vigorous growth and higher crop canopy of soybean. Extensive canopy of crop precluded penetration of solar radiation up to the weeds and smothered from leading to lower weed dry weight. Diclosulam controlled effectively monocot and dicot weeds which is evident from lower weed dry matter per unit area at these stages.

Among the weed control treatments, the highest weed control efficiency was obtained in weed free (T_2) and the highest weed index was obtained in control (T_1) during both the years. The highest weed index of less growth of soybean plant in control (T_1) might be due to the lowest yield of soybean crop in that treatment because of uncontrolled growth of all type of weeds. Weed control efficiency of mostly treatments was higher at initial stage but later on it started decline in subsequent growth stages due to greater increase in weed dry matter in control (T_1) as compare to all other treatments. Among the herbicides used during the experimentation the better weed control efficiency was obtained by using diclosulam than other. Similar results were obtained by AICRP report on Soybean (2007-08 and 2008-09).

5.2 Growth and yield of soybean

Weeds compete with crops for the same resources like nutrient, water, space, light and CO_2. The over all effect of crop weed competition is a reduction in biomass of crop and reduction in seed yield. Uncontrolled growth of weeds caused significant reduction in grain yield of soybean. The lowest grain yield (459 and 313 kg ha^{-1} during 2008 and 2009, respectively) was recorded in control (T_1). On an average, the uncontrolled growth of weeds resulted into 86 and 87 per cent reduction during 2008 and 2009, respectively in seed yield of soybean when compared with weed free treatment. It was due to lowest growth parameters, yield attributes and grain yield of soybean in control (T_1).

Reduction in growth parameters was mainly due to high crop-weed competition for light, space, moisture and nutrients. Kurumawanshi *et al.* (1995) reported that besides several good characters of soybean crop in competitiveness with weeds, still the weeds affect the crop and reduce the yield to the extent of 18.83 to 42.37 per cent. Weeds, if not controlled at critical period, crop weed competition during first 30 DAS, reduces the yield of soybean from 58 to 85 per cent depending upon type and weed intensity infestation (Singh and Singh, 1987; Kohle *et al.*, 1998). The lowest yield in control (T_1) was associated with the highest average dry matter accumulation of weeds at all growth stages during both years.

Weed free (T_2) treatment produced the highest seed yield of soybean (3256 and 2450 kg ha^{-1} during 2008 and 2009, respectively). The highest seed yield of soybean in weed free (T_2) was associated with the highest crop dry matter production, number of primary branches per plant, number of pods per plant and seed index. Improvements in yield contributing characters and thereby seed yield due to weed control treatments might be attributed to significantly lower weed density and weed dry matter, which created favorable condition for better plant growth and development in the crop. At the same time highest plant dry matter accumulations in weed free (T_2). Further hand weeding was done manually in weed free (T_2) makes the soil porous and creates favorable environment for root growth and nodule formation in addition to effective control of weeds. Thus higher seed yield, obtained under weed free (T_2) was obviously due to cumulative effect of reduced weed competition and higher values of yield attributes.

It was observed that weed control treatments resulted in higher leaf area per plant, plant height, plant dry matter production, number of trifoliates, CGR, RGR, NAR and LAI over control. Increase in plant height, leaf area and number of trifoliates per plant due to less interference of weeds, resulting in higher plant dry matter production. The increase in dry weight per plant has been observed in present study which possibly resulted in increased leaf area. Similar findings have been reported by Prajapati and Patel (2001).

The LAI, which is function of total leaf surface of plant and the land area is, therefore expected to follow the pattern similar to total leaf area of the plant as the land area has been a constant value. Therefore, a symmetrical behaviour of leaf area index and total leaf area per plant has been observed. The LAI per plant increased probably due to more number of trifoliates, correlated with increase in total photosynthetic surface and increased LAI of the plant during vegetative phase, thus contributed towards the higher foliage development and also increased the dry matter accumulation at different growth stages.

High leaf area and dry matter production in plants resulted in increased growth parameters like CGR, RGR and NAR. Higher values of CGR, RGR, NAR and LAR during 30-60 days after sowing as compared to 60-90 days after sowing were observed. This was because during early stage plants receiving optimum input resources were having well developed assimilatory surface, so they had higher rate of CGR, RGR, NAR and LAR but on later stage due to development of higher leaf area mutual shading was observed due to this over all rate of assimilation per unit of assimilatory surface was decreased.

The less interference of weeds in weed control treatments not only increase the values of different physiological parameters during crop growth period but also contributed to higher dry matter production and resulting in higher seed yield. As all growth physiological parameters viz.

LAI, CGR, RGR, NAR and growth parameters viz. number of trifoliate, leaf area and dry matter production per plant were positively correlated with seed yield.

The number of pods per plant, number of grain per pod, seed index, seed yield and straw yield of soybean were maximum with weed free and in the herbicidal treated plots especially diclosulam like diclosulam supplemented with HW at 20 DAS (T_6), diclosulam at higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and fluchloralin followed by diclosulam (T_7). As in these treatments weed crop competition was reduced due to herbicidal treatments and herbicide effectively suppress the growth of weeds and provide the proper opportunity to crop for their growth and development.

As reduction of crop weed competition, there is more chance of proper utilization of resources and resulting the increased synthesis and translocation of metabolites for the pod development and grain formation. Higher seed index was also maintained because of high mobilization of photosynthates from source to sink. All the yield attributes had their pronounced effect in increasing the seed yield of soybean. Singh *et al.* (2001) also reported that controlling weeds caused on an average increase of seed yield of soybean. Thus, more number of pods per plant, number of grain per pod and seed index showed positive and additive effect in influencing the seed yield with weed controlling treatments as compare to control.

5.3 Effect on seed quality

Quality of soybean seed is decided by proportion of various nutrients accumulated and or developed into an essential molecule. This property is a function of several of soil-plant-environmental continuum. In the following head the quality parameters of soybean seed as influenced by weed control treatment have been discussed briefly.

Oil and protein content in soybean seed during 2008 were non significantly affected due to various weed control treatments whereas, in 2009 different weed control treatments resulted into significant affect on seed quality (oil and protein content). All the weed control treatments, except application of fluchloralin (T_3) and haloxyfop (T_8) during 2009 produced significantly higher oil content in seed than control (T_1).

Weed free (T_2) condition gave 8 and 11 per cent higher oil content than control during 2008 and 2009, respectively. It has been observed that oil content in seed increased with weed control treatments. This might be due to better weed control led to reduce crop weed competition for nutrients, light and thus crop dry matter was improved.

Weed free (T_2) condition resulted in 4 and 9 per cent higher protein content in seed than control (T_1) during 2008 and 2009, respectively. All the weed control treatments except weed free (T_2), diclosulam supplemented with HW at 20 DAS (T_6) and fluchloralin followed by diclosulam produced significantly equal protein content to control (T_1). It has been observed that higher protein content usually accompanied with higher nodule number and nodule dry weight due to less interference of weeds and proper growth of soybean plant. This might have led to more nitrogen fixation from atmosphere which was chiefly translocated to reproductive structure i.e. seed. Porwar *et al.* (1999) also reported higher oil and protein content in seed by using weed control treatments as compare to weedy.

In general, on mean basis oil content in seed during 2009 was higher than during 2008. This may be due to less vegetative growth of the soybean plant and due to forced maturity of crop and this may affect the oil biosynthesis. During 2009, the protein content of seed was also marginal higher. On mean basis there is marginal change in oil and protein content of the seed during the period of experimentation (oil content 18.8 and 19.0 and protein content 38.4 and 38.5 in during 2008 and 2009, respectively). It showed these traits not much affected by weed control measures however during 2009, oil and protein content was significantly affected by various herbicidal treatments over control. This might also due to sufficient vegetative growth and proper nutrients transportation for vegetative growth, particularly mineral-nitrogen was mainly transported to vegetative organs (stem and leaves) which resulted high dry matter production and nitrogen accumulation.

Effect of herbicidal treatments on fatty acid composition of soybean oil was significant during both years however during 2008 total saturated fatty acid was significantly not influenced by these weed control treatments. The range of total saturated fatty acid 10 to 12 per cent. The higher total fatty acid was recorded in weed free (T_2).

The percentage of fatty acid composition of soybean seeds revealed that the effect of different herbicide treatments had considerable effect on fatty acids composition of the oil extracted from the seeds of soybean plants. The different herbicidal treatments caused variable change in fatty acid contents, the total saturated fatty acid of soybean were decreased at different herbicidal treatments, might be due to reducing rate of lipid metabolism by herbicides. Farag *et al.* (2006) also reported that fatty acid composition of soybean oil was altered by herbicides application.

Summary
&
Conclusion

A field experiment entitled "Evaluation of diclosulam and haloxyfop for weed control in soybean (*Glycine max* (L.) Merrill)" was conducted on a sandy loam soil during the '*kharif*' season of 2008 and 2009 at the Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand) to evaluate the different weed control treatments in terms of weed management, growth, yield and yield attributes and seed quality of soybean to find out the most suitable herbicide or combination of herbicides for effective weed control and to achieve maximum seed yield of soybean. Ten weed control treatments were tested in a randomized block design with four replications.

The salient features of findings are summarized below:

6.1 Effect on weeds

1) The main weed flora of experimental plot was *Echinochloa colona, Celosia argentia, Cyperus rotundus* and *Eleusine indica* etc. Out of this *Celosia argentia* infestation among the dicot weeds while *Echinochloa colona* among the monocot weeds were maximum from sowing to maturity of soybean crop.

2) At 30 DAS, During 2008, diclosulam supplemented with hand weeding at 20 DAS (T_6) was found *at par* with alone application

of diclosulam at its higher rate (T_5) and combined application of diclosulam followed by haloxyfop (T_{10}) recorded the lowest density of monocot weeds. During 2009, the lowest population of monocot weeds in diclosulam followed by hand weeding at 20 DAS (T_6) was significantly equal to other herbicidal treatments except control (T_1).

3) At 60 DAS, During 2008, application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) was *at par* with alone application of diclosulam at its higher rate (T_5) and combined application of diclosulam followed by haloxyfop as post emergence (T_{10}) recorded the lowest density of monocot weeds. However, during 2009 application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) showed significantly lower number of monocot weeds than all other herbicidal treatments.

4) At 30 DAS, diclosulam supplemented with one hand weeding at 20 DAS (T_6) recorded the lowest number of dicot weeds during 2008 however, during 2009 it was equal with application of diclosulam at its higher rate (T_5).

5) At 60 DAS, during 2008 the lowest population of dicot weeds was recorded with application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) which was *at par* with diclosulam at its higher rate (T_5). During 2009 the dicot weed population of weedy plot was *at par* with application of fluchloralin (T_3), haloxyfop (T_8), fluchloralin followed by haloxyfop (T_9) and pendimethalin (T_4).

6) At 30 DAS, the lowest weed dry matter accumulation was recorded with alone application of diclosulam supplemented with one hand weeding at 20 DAS (T_6) and it was found *at par* with dry matter accumulation with alone application of diclosulam at its higher rate (T_5) and combined application diclosulam followed by haloxyfop (T_{10}) during both the years.

7) At 60 DAS, application of haloxyfop (T_8), fluchloralin (T_3) and combined application of fluchloralin followed by haloxyfop (T_9) remained *at par* with each other produced significantly higher dry matter of weeds than all other treatments except control (T_1) during both the years.

8) At 90 DAS, the lowest dry matter accumulation was observed with diclosulam supplemented with hand weeding at 20 DAS (T_6) which produced equal dry matter to the diclosulam at higher rate (T_5), fluchloralin followed by diclosulam (T_7) and diclosulam followed by haloxyfop (T_{10}) during 2008. While during 2009 the lowest dry matter accumulated by diclosulam supplemented with hand weeding at 20 DAS (T_6) produced significantly equal dry matter of weeds with alone application of diclosulam at it's higher rate (T_5).

9) Diclosulam supplemented with hand weeding at 20 DAS (T_6) recorded the highest weed control efficiency at all growth stages of soybean during 2008. However, during 2009 combined

application of fluchloralin followed by diclosulam (T_7) recorded the higher weed control efficiency at 30 and 60 DAS, whereas at 90 DAS, combined application of diclosulam followed by haloxyfop (T_{10}) recorded the higher weed control efficiency.

10) The lowest values of weed index were obtained with weed free (T_2) treatment followed by diclosulam supplemented with hand weeding at 20 DAS (T_6) during both of the years.

6.2 Effect on crop growth

1) Weedy condition of control (T_1) caused 15 and 8 per cent reduction in plant height and 47 and 49 per cent reduction in number of trifoliates during 2008 and 2009, respectively due to weed infestation at 90 DAS.

2) Per cent increase in dry matter accumulation per plant of soybean with weed free (T_2) over control (T_1) 76 per cent at 90 DAS, during 2008. However during 2009, this increase in dry matter 65 per cent at 90 DAS, respectively.

3) The increase in leaf area in all the treatments continued up to 90 DAS. However, the rate of increment of leaf area was highest at 30-60 DAS as compared to 60-90 DAS. Weed free (T_2) and diclosulam supplemented with hand weeding at 20 DAS (T_6) had the highest leaf area production rate as compared to rest of the treatments.

4) Peak CGR, RGR, NAR and LAR values were observed at 30-60 days stage in all the treatments.

5) The leaf area ratio of various weed control treatments was increased up to 60 DAS of the crop growth and thereafter declined.

6.3 Effect on crop yield attributes and yield

1) Significantly higher number of pods per plant was recorded in weed free (T_2) which was *at par* with diclosulam at its higher rate (T_5), diclosulam followed by haloxyfop (T_{10}) and diclosulam supplemented with hand weeding at 20 DAS (T_6) during both the years. Per cent increase in number of pods of soybean per plant in weed free treatment over control was 51 and 52 per cent, during 2008 and 2009, respectively.

2) Diclosulam supplemented with hand weeding with at 20 DAS (T_6), combined application with diclosulam followed by haloxyfo p (T_{10}) and alone application of diclosulam at its higher dose (T_5) being *at par* with each other recorded significantly higher seed yield than other treatments except weed free (T_2) during both the years however, during 2009, combined application of fluchloralin followed by diclosulam (T_7) also produced significantly equal yield to these treatments.

3) The uncontrolled growth of weeds in control (T_1) resulted into 86 and 87 per cent reduction in seed yield of soybean during 2008 and 2009, respectively when compared with weed free treatment.

4) Weed free (T_2), diclosulam supplemented hand weeding with at 20 DAS (T_6), alone application of diclosulam at it's higher dose (T_5) and combined application with diclosulam followed by haloxyfop (T_{10}) being *at par* with each other recorded significantly higher straw yield as compared to other treatments during both the years.

5) Uncontrolled growth of weeds in control (T_1) caused reduction in straw yield to the tune of into 55 and 76 per cent, as compared to weed free treatment during 2008 and 2009, respectively.

6.4 Effect on seed quality

1) Weed free (T_2) recorded the highest value of protein content during both years, during 2009 it was significantly higher than other weed control measures except fluchloralin followed by diclosulam.

2) During 2008, among the weed control treatments, weed free (T_2) recorded the highest value for oil content. During 2009 diclosulam followed by haloxyfop (T_{10}) being *at par* with remaining weed control measures recorded significantly higher values for oil content over control (T_1), diclosulam at higher rate (T_5) and pendimethalin (T_4).

3) Weed free (T_2) accumulated the highest saturated fatty acid content during both the years. During 2009 it was significantly higher than other weed control treatments except combined application of fluchloralin followed by haloxyfop (T_9).

4) The highest oleic acid was accumulated with application of fluchloralin (T_3). It was followed by diclosulam (T_7) which was *at par* with fluchloralin followed by haloxyfop (T_9) and diclosulam at higher rate (T_5) during 2008. However, during 2009, application of fluchloralin (T_3) was *at par* with fluchloralin followed by haloxyfop (T_9).

5) Among the weed control treatments application of haloxyfop (T_8) resulted in the highest linoleic acid accumulation being significantly higher than other treatments during 2009. However, during 2008 it was *at par* with that of weedy (T_1) and weed free (T_2) treatment.

6) The linolenic acid recorded from diclosulam supplemented with hand weeding at 20 DAS (T_6) was significantly higher than that of other weed control treatments during 2009, however during 2008 it was at par with fluchloralin (T_3), pendimethalin (T_4), weedy (T_1) and diclosulam at higher rate (T_5).

On the basis of present investigation, it is concluded that pre emergence application of diclosulam @ 18 g/ha coupled with one hand weeding at 20 DAS was most effective for control of both monocot and dicot weeds and sustaining higher soybean yield. In case of labour scarcity alone application of diclosulam at higher dose i.e. 26 g/ha can be done.

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Appendices

APPENDIX –I (a)

Weekly weather conditions at Pantnagar during July to December 2008

Week No. & Month	Date with duration	Max. Temp. (^0C)	Min. Tem. (^0C)	Rel. Hum. %		Total Rain Fall (mm)	No. of rainy days	No. of Bright Sunsh. (hrs)	Wind speed (km /hr)	Pan Evap. (mm/ day)
				07:12 AM	14:12 PM					
27 Jul	02-08	30.6	25.4	88	73	192.2	5	4.8	5.7	5.5
28 ”	09-15	32.1	25.2	84	70	054.6	5	6.0	7.7	5.4
29 ”	16-22	28.3	24.3	95	84	293.8	7	1.0	4.8	3.8
30 ”	23-29	30.5	25.4	92	72	030.8	4	2.8	4.5	3.2
31 ”	30-5A	30.8	24.8	89	76	168.6	4	4.5	5.9	5.4
32 Aug	06-12	31.5	25.5	86	72	105.6	2	5.4	4.6	4.0
33 ”	13-19	28.1	24.5	89	84	212.6	6	1.1	7.0	3.9
34 ”	20-26	31.6	24.8	90	74	313.4	5	5.1	3.8	3.0
35 ”	27-2S	32.1	24.5	87	65	056.4	2	6.7	5.4	3.7
36 Sep	03-09	32.3	23.9	88	61	016.4	1	8.4	3.6	3.9
37 ”	10-16	31.3	24.0	85	68	024.8	2	6.2	2.7	3.5
38 ”	17-23	29.1	22.0	89	75	373.2	4	3.4	5.9	3.0
39 ”	24-30	31.2	21.4	88	60	000.0	0	9.5	3.1	3.1
40 Oct	01-07	31.1	23.1	87	65	019.6	2	5.1	2.7	2.8
41 ”	08-14	30.9	19.8	82	57	004.8	1	8.7	2.6	3.0
42 ”	15-21	30.2	15.9	80	47	000.0	0	9.2	2.6	3.0
43 ”	22-28	29.6	15.1	83	40	000.0	0	9.0	2.6	2.9
44 ”	29-4N	29.2	14.7	84	47	000.0	0	7.8	2.8	2.5
45 Nov	05-11	29.0	14.8	86	45	000.0	0	7.7	1.7	2.2
46 ”	12-18	27.8	12.6	87	47	000.0	0	5.5	1.8	1.9
47 ”	19-25	25.2	10.0	89	46	002.4	1	7.1	2.7	1.7
48 ”	26-2D	26.2	10.8	86	42	000.0	0	7.4	2.0	1.8
49 Dec	03-09	25.7	10.9	92	44	000.0	0	7.9	2.3	1.9
50 ”	10-16	26.2	8.6	91	40	000.0	0	7.2	2.6	1.7
51 ”	17-23	21.5	11.6	92	68	000.0	0	2.9	3.2	0.8
52 ”	24-31	21.8	7.0	91	62	000.0	0	5.6	2.0	1.3

APPENDIX –I (b)

Weekly weather conditions at Pantnagar during July to December 2009

Week No. & Month	Date with duration	Max. Temp. (⁰C)	Min. Tem. (⁰C)	Rel. Hum. %		Total Rain Fall (mm)	No. of rainy days	No. of Bright Sunsh. (hrs)	Wind speed (km /hr)	Pan Evap. (mm/ day)
				07:12 AM	14:12 PM					
27 Jul	02-08	36.2	26.5	77	50	015.8	1	08.8	07.4	08.0
28 ”	09-15	34.2	26.5	85	68	022.0	2	05.8	06.3	04.4
29 ”	16-22	34.8	25.9	88	65	072.6	3	08.9	04.8	07.5
30 ”	23-29	33.8	26.5	87	77	033.0	2	06.7	04.8	03.8
31 ”	30-5A	34.0	27.1	86	63	012.2	1	07.0	08.7	05.2
32 Aug	06-12	33.6	26.1	90	65	037.0	4	05.6	04.7	05.1
33 ”	13-19	28.7	24.3	92	86	319.8	6	00.7	07.4	03.4
34 ”	20-26	33.6	25.1	85	63	Trace	0	09.0	05.7	04.5
35 ”	27-2S	32.9	25.2	84	68	020.2	3	06.8	04.5	04.0
36 Sep	03-09	31.0	23.9	85	75	059.0	3	04.7	06.3	03.3
37 ”	10-16	30.8	23.0	88	73	129.0	1	06.1	07.0	03.3
38 ”	17-23	33.0	24.0	87	63	000.4	0	08.4	03.6	03.2
39 ”	24-30	33.0	24.9	86	64	034.2	1	05.6	03.2	03.3
40 Oct	01-07	29.5	22.7	89	75	174.4	3	05.1	04.2	03.0
41 ”	08-14	31.1	16.6	91	56	000.0	0	09.4	02.6	03.1
42 ”	15-21	30.7	13.8	84	48	000.0	0	09.7	02.4	03.1
43 ”	22-28	29.8	11.6	87	40	000.0	0	09.5	01.8	02.5
44 ”	29-4N	30.0	13.8	85	39	000.0	0	08.6	02.4	02.7
45 Nov	05-11	29.1	12.3	87	36	Trace	0	07.1	02.7	02.4
46 ”	12-18	24.3	14.7	87	53	020.6	1	04.5	04.2	02.1
47 ”	19-25	24.6	08.8	90	44	000.0	0	08.0	08.8	01.6
48 ”	26-2D	25.3	09.5	90	43	000.0	0	07.3	01.8	01.7
49 Dec	03-09	24.6	08.1	91	44	000.0	0	07.8	02.5	02.0
50 ”	10-16	23.9	09.2	91	47	000.0	0	05.2	02.9	01.4
51 ”	17-23	23.0	05.8	93	45	000.0	0	07.2	03.1	01.6
52 ”	24-31	19.5	04.0	94	54	000.0	0	06.6	02.9	01.2

APPENDIX –II

Analyses of variance for monocot weed density (number m^{-2}) at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.0054	0.0025	0.0019	0.6866	0.3074	0.4637
Treatments	9	8.0442*	11.8091*	12.6474*	6.0020*	6.4207*	6.6762*
Error	27	0.0066	0.0033	0.0007	1.2595	0.1330	0.0071

*Significant at 5% level of significance

APPENDIX –III

Analyses of variance for dicot weed density (number m^{-2}) at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.1292	0.3188	0.3262	4.1612	0.1484	0.0064
Treatments	9	7.8282*	6.2260*	6.6757*	10.5779*	5.9082*	5.9039*
Error	27	0.0951	0.0641	0.0330	1.6304	0.0071	0.0040

*Significant at 5% level of significance

APPENDIX –IV

Analyses of variance for weed dry weight (g) at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.00001	0.00028	0.00010	0.93360	0.71388	0.11860
Treatments	9	7.16175*	11.83294*	14.92772*	7.66772*	15.41749*	16.18187*
Error	27	0.00013	0.00007	0.00015	0.20070	0.25348	0.19137

*Significant at 5% level of significance

APPENDIX –V

Analyses of variance for plant height of soybean (cm) at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	1.5671	12.2187	2.4937	7.3999	111.1391	28.2653
Treatments	9	11.2734*	35.0833*	60.9756*	3.8390*	8.4900	10.6918
Error	27	1.2572	3.8802	5.8791	1.5068	8.2140	13.5592

*Significant at 5% level of significance

APPENDIX –VI

Analyses of variance for number of trifoliates per plant of soybean at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.6037	8.7929	8.7929	1.1361	32.2949	4.0334
Treatments	9	0.8349*	116.239*	116.239*	1.2238*	26.0798	69.2111*
Error	27	0.7368	4.4837	4.4837	0.2379	22.8026	3.1444

*Significant at 5% level of significance

APPENDIX –VII

Analyses of variance for plant dry matter of soybean (g plant^{-1})at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.2913	5.1515	1.8915	0.1526	1.7892	1.7812
Treatments	9	0.9834*	122.6191*	71.4884*	0.7016*	13.4179*	48.9188*
Error	27	0.1270	9.8474	0.6502	0.2061	2.8951	3.4084

*Significant at 5% level of significance

APPENDIX –VIII

Analyses of variance for leaf area of soybean plant at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	9588.9	424.2	17766.9	69064.4	2414.6	9459.2
Treatments	9	29847.8*	68731.1*	50462.2*	30075.3	74663.5*	44490.2*
Error	27	4327.6	6093.1	7545.4	32157.3	9946.3	5818.6

*Significant at 5% level of significance

APPENDIX –IX

Analyses of variance for leaf area index of soybean plant at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	0.0047	0.00001	0.0089	0.3426	0.0013	0.0050
Treatments	9	0.1483*	0.3387*	0.2371*	0.1490	0.3472*	0.2110
Error	27	0.0021	0.0034	0.0034	0.1588	0.0048	0.0029

*Significant at 5% level of significance

APPENDIX –X

Analyses of variance for SPAD meter value (chlorophyll content) of soybean leaves at different stages of crop growth

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		30DAS	60DAS	90 DAS	30DAS	60DAS	90 DAS
Replication	3	22.626	5.065	8.970	11.050	3.903	5.066
Treatments	9	8.471	2.035	5.932	8.417	7.296	3.880
Error	27	7.015	6.017	3.110	3.958	2.989	2.369

*Significant at 5% level of significance

APPENDIX –XI (a)

Analyses of variance crop growth rate (CGR) and relative growth rate (RGR) of soybean at different growth stages of crop growth (2008)

Source of variation	d.f.	Mean sum of squares			
		CGR		RGR	
		30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Replication	3	0.000068	0.0000274	0.00000009	0.00000004
Treatments	9	0.000912*	0.00259*	0.00000015	0.0000002*
Error	27	0.0000497	0.0000688	0.00000007	0.00000005

*Significant at 5% level of significance

APPENDIX –XI (b)

Analyses of variance crop growth rate (CGR) and relative growth rate (RGR) of soybean at different growth stages of crop growth (2009)

Source of variation	d.f.	Mean sum of squares			
		CGR		RGR	
		30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Replication	3	0.000213	0.000108	0.00000018	0.00000025
Treatments	9	0.000906*	0.00124*	0.00000003	0.00000029
Error	27	0.000249	0.000307	0.00000013	0.00000043

*Significant at 5% level of significance

APPENDIX –XII (a)

Analyses of variance for net assimilation rate (NAR) and leaf area ratio (LAR) of soybean at different growth stages of crop growth (2008)

Source of variation	d.f.	Mean sum of squares			
		NAR		LAR	
		30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Replication	3	0.00000000007	0.00000000016	33.60938	29.32474
Treatments	9	0.0000000006	0.0000000016*	176.3906*	113.8893
Error	27	0.0000000001	0.00000000019	33.9404	11.78105

*Significant at 5% level of significance

APPENDIX –XII (b)

Analyses of variance for net assimilation rate (NAR) and leaf area ratio (LAR) of soybean at different growth stages of crop growth (2009)

Source of variation	d.f.	Mean sum of squares			
		NAR		LAR	
		30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
Replication	3	0.0000000000971	0.000000000173	137.2688	35.30052
Treatments	9	0.000000000240	0.000000000412	466.7118	207.2891*
Error	27	0.00000000198	0.000000000266	293.7109	81.46661

*Significant at 5% level of significance

APPENDIX –XIII (a)

Analyses of variance for yield attributes of soybean (2008)

Source of variation	d.f.	Mean sum of squares			
		Branches/plant	Pods/plant	Grain/Pod	Seed index
Replication	3	1.439079	247.637	0.000666	3.599674
Treatments	9	3.28403	442.1754*	0.00689	0.886665
Error	27	2.146585	120.3774	0.00348	0.638122

*Significant at 5% level of significance

APPENDIX –XIII (b)

Analyses of variance for yield attributes of soybean (2009)

Source of variation	d.f.	Mean sum of squares			
		Branches/plant	Pods/plant	Grain/Pod	Seed index
Replication	3	1.315666	239.7458	0.291667	2.424479
Treatments	9	2.61655*	516.8503*	0.180556	0.711209
Error	27	1.106776	88.94389	0.25463	0.551288

*Significant at 5% level of significance

APPENDIX –XIV

Analyses of variance for seed yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) of soybean

Source of variation	d.f.	Mean sum of squares					
		2008			2009		
		Seed yield	Straw yield	Harvest index	Seed yield	Straw yield	Harvest index
Replication	3	12600.53	1762974	180.0245	49903.47	798538.7	0.000588
Treatments	9	3481906*	9338521*	338.5582*	2149056*	5333270*	0.00115*
Error	27	84482.61	1002061	76.09913	119521.8	436228.8	0.00045

*Significant at 5% level of significance

APPENDIX –XV

Analyses of variance for oil and protein content (%) of soybean

Source of variation	d.f.	Mean sum of squares			
		2008		2009	
		Oil content	Protein content	Oil content	Protein content
Replication	3	1.861068	1.683854	0.661979	1.222917
Treatments	9	1.272786	1.227431	3.525065*	2.545139*
Error	27	0.740083	1.015596	0.780143	1.704398

*Significant at 5% level of significance

APPENDIX –XVI (a)

Analyses of variance for fatty acid composition of soybean seed (2008)

Source of variation	d.f.	Mean sum of squares			
		Saturated fatty acid	Oleic acid	Linoleic acid	Linolenic acid
Replication	3	0.859342	9.75599	19.33125	1.78877
Treatments	9	1.330783	11.47754*	10.68924*	3.854682*
Error	27	0.806717	2.226439	3.562153	1.527467

*Significant at 5% level of significance

APPENDIX –XVI (b)

Analyses of variance for fatty acid composition of soybean seed (2009)

Source of variation	d.f.	Mean sum of squares			
		Saturated fatty acid	Oleic acid	Linoleic acid	Linolenic acid
Replication	3	0.153255	3.54681	1.771875	0.223828
Treatments	9	1.547363*	11.75	12.7691*	4.10555*
Error	27	0.172135	0.83099	0.852894	0.228928

*Significant at 5% level of significance

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ABSTRACT

Name	:	Rakesh Chandra Nainwal	**Id. No.**	:	27938
Semester and year of admission	:	I[st] Semester, 2007-08	**Degree**	:	Ph. D.
Department	:	Agronomy	**Major**	:	Agronomy
Advisor	:	Dr. S. C. Saxena	**Minor**	:	Plant Physiology
Thesis Title	:	**"Evaluation of diclosulam and haloxyfop for weed control in soybean (*Glycine max* (L.) Merrill)"**			

A field experiment was conducted to evaluate the weed control treatments on growth, yield and quality of soybean during the '*kharif*' 2008 and 2009, at N. E. Borlaug Crop Research Centre of G.B. Pant Univ. of Agriculture and Technology, Pantnagar (U.S. Nagar). Ten weed control treatments were tested in randomized block design with four replications, pendimethalin and diclosulam were sprayed on the day after sowing the crop as pre emergence application. Fluchloralin was incorporated into the soil before planting the crop. Haloxyfop was applied at 21 DAS as post emergence. Soybean variety PS 1347 was sown on July 10 and August 1 was harvested on November 12 and 14 during 2008 and 2009, respectively. Seed @ 75 kg seed ha^{-1} were sown in rows 45 cm apart.

The experimental field was predominately infested with *Echinochloa colona, Celosia argentia, Cyperus rotundas* weed species which constituted a major part and remained dominant in weedy check plots throughout the crop growth. Diclosulam either alone at higher rate or supplemented with HW 20 DAS or combined with haloxyfop effectively controlled the both type of weeds (mono and dicot). However, haloxyfop applied as post emergence could only control the monocot weeds. The highest weed control efficiency and the lowest weed biomass were recorded in weed-free treatment followed by application of diclosulam 18g ha^{-1} supplemented with HW at 20 DAS. Application of diclosulam as pre-emergence also performed better over the standard check either applied pendimethalin as pre- or pre-plant incorporation of fluchloralin before the sowing of the seed.

All the weed control treatments resulted in to higher physiological growth parameters *viz.* CGR, RGR, NAR, LAI and LAR as compared to weedy check. Weed free recorded the highest value of protein and oil content during both years. Different weed control treatments significantly affected the fatty acid composition of the soybean seed. Among the different herbicide, the highest seed yield was recorded with application of diclosulam supplemented with HW at 20 DAS and application of diclosulam followed by haloxyfop.

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गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिक विश्वविद्यालय, पन्तनगर, जिला ऊधम सिंह नगर, उत्तराखण्ड के नॉरमन ई0 बोरलॉग फसल अनुसंधान केन्द्र में खरीफ ऋतु, 2008 एवं 2009 में सोयाबीन की वृद्धि, उपज तथा गुणवत्ता पर खरपतवार नियंत्रण के उपचारों के मूल्यांकन हेतु एक क्षेत्र परीक्षण प्रायोजित किया गया। दस खरपतवार नियंत्रण के उपचारों का यादृच्छिकी खण्ड अभिकल्पना (आर0बी0डी0) में चार बार पुनरावृत्ति की गई, जिसमें जमाव से पूर्व प्रयोग किये जाने वाले पेन्डिमिथालीन एवं डिक्लोसुलम का बुवाई के पश्चात् छिड़काव किया गया। फ्लूक्लोरिन को मृदा में फसल की बुवाई के पूर्व ही मिला दिया गया था। हैलोक्सीफॉप को बुवाई के 21 दिन पश्चात्, जमाव के बाद प्रयोग किये जाने वाले खरपतवारनाशी की तरह प्रयोग किया गया। सोयबीन प्रजाति ‘‘ 1347 फसल व ा 2008 व 2009 में क्रमशः 10 जुलाई व 1 अगस्त को बोई तथा 12 व 14 नवम्बर को कटाई की गई। इसकी बुवाई 75 कि.ग्रा./हे0 की दर से पंक्तियों की दूरी 45 सेमी. पर की गयी। प्रायोगिक क्षेत्र में सम्पूर्ण फसल वृद्धि के दौरान इकाइनोक्लोवा कोलोना (छोटी साई), सिलोसिया अरजेन्सिया (सफेद मुर्ग) तथा साइप्रस रोटन्ड्स (मोथा) खरपतवार युक्त में मुख्य रूप से प्रभावी रहे। डिक्लोसुलम स्वयं उच्च दर पर या बुवाई से 20 दिन बाद निराई–गुड़ाई द्वारा पूरक या हैलोक्सीफॉप के साथ सम्मिलित रूप से एक एवं द्विबीजपत्रांक खरपतवारों को प्रभावशीलता से नियंत्रित किया है। यद्यपि जमाव के बाद प्रयोग किये गये हैलोक्सी फॉप मात्र एक बीज पत्रांक खरपतवार को ही नियंत्रित कर सका। उच्चतर खरपतवार नियंत्रण क्षमता तथा निम्नतर खरपतवार जैविक द्रव्यमान खरपतवार मुक्त उपचार में दर्ज की गई जिसको 20 दिन बाद निराई–गुड़ाई द्वारा पूरक डिक्लोसुलम 18 ग्रा./हे. की दर से उपचार ने अनुसारित किया है। डिक्लोसुलम का जमाव से पूव छिड़काव ने जमाव से पूर्व प्रयुक्त पेन्डिमिथलीन तथा फ्लूक्लोरिन का मृदा में ही मिलाव के उपचारों पर भी श्रे ठ प्रर्दशन किया है।

सभी खरपतवार नियंत्रण उपचारों ने खरपतवार युक्त उपचार पर उच्चतम पादप कार्यिकी वृद्धि जैसे संचित वृद्धि दर (ब्लत), अपेक्षित वृद्धि दर (त्ळत), शुद्ध समावेशित दर (छ।त), पत्ती क्षेत्र निर्देशिका (स्।प्) तथा पत्ती क्षेत्र दर (स्।त) पर निर्णायक रही। खरपतवार मुक्त उपचार में दोनों ही व ाें में उच्चतम प्रोटीन तथा तैलीय मात्रा दर्ज की गई। विभिन्न खरपतवार नियंत्रण उपचारों ने सोयबीन बीज के वसा अम्लों के संघटक को सार्थकता से प्रभावित किया है।

विभिन्न खरपतवार नाशियों में उच्चतम बीज उपज बुवाई के 20 दिन बाद निराई–गुड़ाई द्वारा पूरक डिक्लोसुलम एवं डिक्लोसुलम, हैलोक्सीफॉप द्वारा अनुसरित में दर्ज की गई।

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परामर्शदाता

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