NITROGEN USE ECONOMY THROUGH INTEGRATED WEED MANAGEMENT IN SOYBEAN

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CERTIFICATE

Mr. T. KRISHNA MOHAN RAO has satisfactorily prosecuted the course of research and that the thesis entitled "NITROGEN USE ECONOMY THROUGH INTEGRATED WEED MANAGEMENT IN SOYBEAN" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any university.

Date: 3-2-1998

Place : Hyderabad

(Dr. C. NARASIMHA REDDY)
MAJOR ADVISOR

CERTIFICATE

This is to certify that the thesis entitled "**NITROGEN USE ECONOMY THROUGH INTEGRATED WEED MANAGEMENT IN SOYBEAN**" submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the **Acharya N.G. Ranga Agricultural University, Hyderabad**, is a record of the bonafide research work carried out by **Mr. T. KRISHNA MOHAN RAO** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged.. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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DECLARATION

I, **T. KRISHNA MOHAN RAO** hereby declare that the thesis entitled **"NITROGEN USE ECONOMY THROUGH INTEGRATED WEED MANAGEMENT IN SOYBEAN"** submitted to the **ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY** for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier.

Date : 3 -02-1998

Place : Hyderabad

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ABSTRACT

A field experiment was conducted during rabi, 1996-97 to optimize the use of nitrogen through integrated weed management practices in soybean at Agricultural College Farm, Rajendranagar, Hyderabad. The experiment was laid in split-plot design with five weed management practices as main plot treatments and four nitrogen levels as sub-plot treatments with three replications. The integrated weed management treatments consisted of pre-emergence of application of pendimethalin, fluchloralin and metolachlor, each at 1.0 kg a.i. ha^{-1} fb intercultivation (IC) with push-hoe at 25 DAS, intercultivation twice at 20 and 40 DAS, and unweeded check and nitrogen levels included 0, 30, 60 and 90 kg ha^{-1}.

In the field, annual monocots and dicots accounted for 61 and 39 per cent of total weed population respectively. Among the weed management treatments, application of metolachlor and pendimethalin both at 1.0 kg a.i. ha^{-1} fb IC significantly reduced the weed density and dry matter and nutrient uptake by weeds over that of unweeded check. Weed density was significantly higher with no nitrogen application and 90 kg N ha^{-1}, and dry matter production and nutrient uptake increased significantly with increase in nitrogen level from 0 to 30, 60 and 90 kg ha^{-1}. Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC resulted significantly highest weed control efficiency

throughout the crop growth and it was higher at 30 kg N ha^{-1} at 25 DAS, at 60 kg N ha^{-1} at harvest.

The integrated weed management treatments involving pendimethalin, metolachlor and fluchloralin, each @ 1.0 kg a.i. ha-1 + IC resulted in higher dry matter production of crop over no weeding. The plant dry matter was significantly higher in the crop received 60 kg N ha^{-1}. Nutrient uptake by crop increased significantly with increase in nitrogen level from 0 to 30, 60 and 90 kg ha^{-1}.

Application of pre-emergence herbicide pendimethalin at 1.0 kg a.i. ha^{-1} fb IC significantly increased pod and seed number over that of other treatments. Among nitrogen levels, significant increase in pod and seed number and yield was observed upto 60 kg ha^{-1}. Pendimethalin and metolachlor application both at 1.0 kg a.i. ha^{-1} fb IC and intercultivation alone gave significantly higher seed yield (84, 75 and 75 % respectively) over that of unweeded check and among the weed control treatments fluchloralin application @ 1.0 kg a.i. ha-1 resulted lower seed yield. Among the weed control treatments IWMI was significantly higher with application of pendimethalin (46.6 %) and metolachlor (43.3 %), both at 1.0 kg a.i. ha^{-1} fb IC. Nitrogen use efficiency was significantly higher in the crop applied with nitrogen at 30 and 60 kg ha^{-1}. Seed protein content was significantly higher with weed management treatments over no weeding and it increased significantly with increase in nitrogen level from 0 to 90 kg N ha^{-1}.

The interaction effect of weed control treatments and nitrogen levels on seed yield significantly higher with application of pendimethalin and metolachlor both @ 1.0 kg a.i. ha^{-1} + IC at low levels of nitrogen as compared to that of unweeded control at higher nitrogen levels.

Application of metolachlor at 1.0 kg a.i. ha^{-1} fb IC resulted higher B:C ratio (0.70) which was followed by IC twice (0.68). The crop received 60 kg N ha^{-1} gave higher B:C ratio (0.65) followed by that applied with 90 kg N ha^{-1} (0.54).

LIST OF SYMBOLS AND ABBREVIATIONS

@	:	at the rate of
a.i.	:	active ingredient
AICRP-WC	:	All India Co-ordinated Research Programme on Weed Control
B:C	:	Benefit-cost
C^o	:	degree centigrade
CD	:	Critical difference
cm	:	centimeter
d^{-1}	:	per day
DAS	:	days after sowing
dsm^{-1}	:	deci siemen per meter
EC	:	Emulsifiable concentrate
et al	:	and other people
fb	:	followed by
Fig	:	Figure
g	:	gram
ha^{-1}	:	per hectare
hrs	:	hours
IC	:	Intercultivation
i.e.,	:	which is to say; in other words
kg^{-1}	:	per kilogram
K or k_2O	:	Potassium
m	:	meter
max	:	maximum
min	:	minimum
mm	:	milli meter
N	:	Nitrogen
NS	:	Not significant
P or P_2O_5	:	Phosphorus
ppm	:	parts per million
q	:	quintal
Rs.	:	Rupees
S.Ed.	:	Standard Error of deviation of mean
sig.	:	significant
viz.,	:	namely
%	:	per cent

INTRODUCTION

CHAPTER I

INTRODUCTION

The oilseed production in India has doubled from 10.6 million tonnes to 23.90 million tonnes in the last one decade, but the indigenous production is inadequate to meet the demand of edible oils and import of vegetable oils has become imminent (The Hindu, 1996). There is a need to boost productivity and production of oilseeds, since the current productivity per hectare being about one third of the World's best levels. Soybean occupies 2.8 million hectares in India with National average yield of 900 kg ha^{-1} (Mishra and Bhan, 1996).

The potential of soybean for cultivation in Andhra Pradesh has received the attention of farmers in recent years (Naidu and Pillai, 1991). The need to substitute two principal crops, viz., cotton and tobacco, whose area has been shrinking in recent years due to higher pest load, lower returns and wide fluctuations in market values triggered the introduction of soybean in resource rich Krishna-Godavari Zone and in black cotton soils of Adilabad district in Northern Telangana of A.P.

Nitrogen is the major factor determining the seed yield of soybean and it has to be supplemented initially for establishment of seedlings until the plants develop their root nodules. High cost on this input calls for improved management practices to make available large portion of nitrogen applied to crop thereby enhancing the nitrogen use efficiency under weed free environment (Santharam and Shivashankar, 1982).

Soybean being slow growing crop in the initial stages, upto 30-35 days, suffers severely due to weed competition particularly for nutrients, moisture, space and sunlight. The yield losses to the extent of 75 and 35 per cent have been reported due to weeds in monsoon and summer seasons respectively (Muniyappa *et al.*, 1986). The extent of nitrogen demand by weeds was found to be 45.8 kg ha^{-1} (Rao, 1997). Hence weed management is considered to be a valuable tool for realizing higher seed yield even under lower levels of fertilizer application, as timely weed control and efficient utilisation of fertilizer by crop plants can be achieved (Chhokar *et al.*, 1997). Since manual weeding is laborious and uneconomical, chemical weed control has become a viable alternative. However, continued use of herbicides leads to resurgence of secondary weeds, besides causing residual and pollution hazards. Hence integrated weed management involving 1/2 or 3/4th recommended dose of herbicides followed by hand weeding or interculture is gaining importance. In addition, soybean can also be grown during non-conventional season profitably compared to *kharif*. This also helps in seed multiplication during summer and forms a source of good quality seeds for ensuing *kharif* season (Babalad *et al.*, 1996). Very little information is available on economising nitrogen usage through integrated weed management in soybean. Hence, in the light of above mentioned facts, the present investigation was undertaken with the following objectives.

1. To study the nature of weed flora associated with soybean,
2. To determine the weed dry matter, uptake pattern of nutrients as influenced by nitrogen levels and integrated weed management,

3. To find out the independent and interaction effect of nitrogen levels and integrated weed management on growth and yield of soybean,

4. To determine the residual effect of herbicides used on succeeding crop ragi through bioassay,

5. To find out the economics of nitrogen use efficiency through integrated weed management in soybean.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Reduction in crop yield has a direct correlation with weed competition, which in turn depends on the type of weed species, severity and duration of infestation. On the otherhand, investment on fertilizers has become one of the major components of expenditure in obtaining assured returns from crops. The response of soybean crop to weed competition and nitrogen input under different variables are influenced by the weed management practices. The available literature with respect to different herbicides and nitrogen levels in soybean is reviewed hereunder.

2.1 LOSSES DUE TO WEEDS

The losses due to weeds could be grouped as quantitative yield and qualitative losses.

The quantitative yield losses include seed yield loss in actual terms. Early emerging weeds cause yield losses to an extent of 35-50 % (Bhan *et al.*, 1972) and 71 per cent in monsoon and 35 per cent in summer (Muniyappa *et al.*, 1986). Yield reduction due to uncontrolled weeds was 55 (Varshney, 1989) and 26.57 (Gogoi *et al.*, 1991) per cent. Similar yield losses due to weeds have been reported by Singh and Singh (1994), Kurmavansi *et al.* (1995), Umarani and Selvaraj (1996) and Rao (1997).

Qualitative yield losses refer to reduction in quality of oil and protein content etc. Jain *et al.* (1995b) reported no adverse influence on protein and oil content of seeds, where as Umarani and Selvaraj (1996) observed the reduction in seed vigour and germination by 0.9, 1.9, 3.6 and 5.1 per cent under 25, 50, 75 and 100 per cent weed densities.

2.2 WEED SPECTRUM

The weed flora distributed in vertisols during *kharif* were *Echinocloa crusgalli*, *Ammania baccifera*, *Caesulia axillaris*, *Celosia argentia*. *Commelina benghalensis*. *Physalis minima*, *Cynodon dactylon*, *Cyperus iria*. *Digera alternifolia*, *Digitaria longiflora*, *Euphorbia geniculata*, *Saccharum spontaneum*. *Phyllanthus niruri*. *Setaria glauca*, and *Corchorus* spp. (AICRP-WC, Annual report, 1990-91; Jain and Tiwari, 1992; Sharma *et al.*, 1992; AICRP-WC. Annual Report, Bangalore Centre, 1993, Shekara and Nanjappa, 1993; Tomar *et al.*, 1994; Jain *et al.*, 1995a and Jain *et al.*, 1996).

In alfisols, the weed species consisted of *Cynodon dactylon*. *Cyperus rotundus*. *Acanthospermum hispidum*. *Amaranthus viridis*. *Leucas aspera*. *Euphorbia hirta*. *Tridax procumbens*. *Fimbristylis* spp (Santharam and Shivashankar, 1982; Gogoi *et al.*, 1991 and Chhokar *et al.*, 1995).

The weed species associated with soybean on vertisols during rabi season were *Cynodon dactylon*, *Cyperus rotundus*, *Chloris barbata*. *Commelina benghalensis*. *Dactyloctenium aegyptium*. *Digitaria sanguinalis*. *Dinebra retroflexa*. *Echinocloa colonum*, *Panicum ramosum* among monocots and *Achyranthus aspera*, *Amaranthus viridis*, *Aristalochea bracteata*, *Corchorus olitorius*, *Digera arvensis*. *Eclipta alba*, *Euphorbia hirta*. *Hibiscus ficulneus*, *Phyllanthus maderaspatensis*, *Physalis minima*, *Portulaca oleracea*. *Solanum nigrum*, *Trichodesma indicum* (Maurya *et al.*. 1990 and Rao, 1997).

2.3 CROP-WEED COMPETITION

The effect of weeds on crop growth for its resources result in crop-weed competition with ultimate reduction in yield (Rao, 1986). Weed free condition of 30 to 40 days after sowing resulted in similar yield as that of weed free crop (Bhan, 1975 and 1976). Weed population and biomass was significantly reduced by weed free conditions upto 21 DAS resulting in more yields (AICRP-WC, Annual report, 1989-90). Varshney (1989) reported higher test weight and seed yield by reducing crop-weed competition upto 45 DAS. Under irrigated ecosystem, the crop should be kept weed free upto six weeks from sowing to check the crop weed competition (AICRP-WC, Bangalore centre, Annual Report, 1993). Singh and Singh (1994) observed higher yield losses with crop-weed competition for initial 45 days than at initial 30 days. Higher yield attributes were observed with initial 45 days weed free period. which was on par with weed free upto harvest (Chhokar *et al.*, 1995). The crop-weed competition during initial 30 days was with *parthenium* sp and sedges, 30-50 days with grasses and throughout the crop growth period (60-105 DAS) with other broad-leaved weeds (Mishra and Bhan, 1996).

2.4 WEED MANAGEMENT PRACTICES

2.4.1 Manual and mechanical weed control

Manual weeding twice (40 and 60 DAS) and once (40 DAS) registered the weed indices 7.2 and 12.0 per cent respectively, indicating the importance of early weeding (Muniyappa *et al.*, 1986). Singh and Sharma (1990) reported higher weed control efficiency and grain yield with hand weeding twice at 20 and 40 DAS. Similar result was obtained at 30 and 45 DAS by Singh *et al.*, (1992). Buhler *et al.* (1992) obtained higher weed control with two intercultivations, substituting 50 to 75 per cent of herbicides. Weed dry matter was effectively reduced with one hand weeding at 20 DAS compared to weedy check resulting in higher weed control efficiency (Jain and Tiwari, 1995; Ramamoorthy *et al.*, 1995; and Halvankar *et al.*, 1995). Interculture with desi-plough or kulpa at 30 DAS effectively reduced the weed density and was found to be comparable with that of herbicidal application (Dubey *et al.*, 1996).

2.4.2 Chemical weed control

Herbicides are modern tools, which can substantially improve the efficiency of weed management. The chemical weed control with selective herbicides is gaining importance in soybean over cultural and mechanical methods.

2.4.2.1 Fluchloralin

Fluchloralin belongs to dinitroaniline group, which selectively controls annual grasses and broad-leaved weeds affecting seed germination and physiological growth processes, especially in the radicle (The Pesticide Manual, 1994).

Jain and Tiwari (1992) reported significantly lower weed index (12.4 %) with fluchloralin application at 1.0 kg a.i. ha^{-1} over weedy check (45.2 %). Seed yield obtained with application of fluchloralin at 1.0 kg a.i. ha^{-1} was 67.0, 43.4 and 20.3 per cent more over one hand hoeing, two hand hoeings and closer planting + alachlor application at 1.0 kg a.i. ha^{-1}

respectively (Singh *et al.*, 1994a). Pre plant incorporation of fluchloralin at 1.0 kg a.i. ha^{-1} proved to be effective in significantly reducing the weed population and bio-mass resulting in high weed control efficiency (Negi and Saini, 1994 and Agrawal *et al.*, 1995). Weed biomass, recorded under weed free treatment (18.66 g m^{-2}) was at par with that in fluchloralin (21.50 g m^{-2}) at 1.0 kg a.i. ha^{-1} applied plot (Kurmawanshi *et al.*, 1995). Several workers have reported that pre-plant incorporation of fluchloralin at 1.0 kg a.i. ha^{-1} effectively reduced the weed population and biomass and resulted in higher weed control efficiency (Varshney, 1990; AICRP-WC, project coordinator's report, 1991; Upadhayaya, 1992 and Sharma *et al.*, 1992).

2.4.2.2 Pendimethalin

Pendimethalin belongs to dinitroaniline group with selective pre-emergence activity on annual grasses and broad-leaved weeds and inhibits the cell-division and cell-elongation of emerging weed seedlings (The Pesticide Manual, 1994).

Pre-emergence application of pendimethalin at 1.0 kg a.i. ha^{-1} resulted in significant reduction in weed density and population (Singh and Singh, 1987). Singh *et al.* (1992) reported lower weed dry matter (36.6 g m^{-2}) with application of pendimethalin at 0.5 kg a.i. ha^{-1} compared to weedy check (61.6 g m^{-2}). Significantly higher weed control efficiency (72.6 %) at 50 DAS resulted with pre-emergence application of pendimethalin at 1.0 kg a.i. ha^{-1} (Sharma *et al.*, 1992 and AICRP-WC, Annual report, 1993-94). Weed density and dry matter observed in the crop received pendimethalin at 0.5 kg a.i. ha^{-1} was on par with twice weeding at 15 and 35 DAS (Praharaj and Dhingra, 1995). Similar findings were made with pendimethalin application at 1.0 kg a.i. ha^{-1} by several workers (Akhtar *et al.*, 1990; Maurya *et al.*, 1990 and Mishra and Bhan, 1996).

2.4.2.3 Metolachlor

Metolachlor belongs to the group of chloroacetanilides and has selective pre-emergence herbicide activity, which inhibits the germination of annual grasses, sedges and broad-leaved weeds affecting their hypocotyls and roots (The Pesticide Manual, 1994).

Higher weed control efficiency of 73.9 per cent was obtained with metolachlor at 1.0 kg a.i. ha^{-1} compared to 56.1 per cent with 0.5 kg ha^{-1} (Ved Prakash *et al.*, 1991). Sharma *et al.* (1992) also reported significantly higher weed control efficiency (80.7 %) with metolachlor applied at 1.0 kg a.i. ha^{-1}. In alfisols, application of metolachlor at 1.0 kg a.i. ha^{-1} resulted 66 per cent lesser weed dry weight compared to weedy check (Shekara and Nanjappa, 1993 and Negi and Saini, 1994). Singh *et al.* (1994) observed the higher weed control efficiency with metolachlor at 1.0 kg a.i. ha^{-1} by initial check on weeds during the crop growth. Similar findings were reported on application of metolachlor at 1.5 and 2.0 kg a.i. ha^{-1} (AICRP-WC, Project Co-ordinator's report, 1995). Mishra and Bhan (1996) reported higher control of sedges during the early stages upto 30 DAS with metolachlor at 2.0 kg a.i. ha^{-1}.

2.5 EFFECT OF INTEGRATED WEED MANAGEMENT (IWM)

Integrated weed management is a weed population management system, where herbicides in combination with physical methods keep the weeds below the levels at which they cause the economic injury (Reddy and Reddi, 1995).

2.5.1 Weeds

Gogoi *et al.* (1991) recorded lowest weed population (15 m^{-2}) and dry matter (84.5 g m^{-2}) and higher weed control efficiency (72.8 %) with fluchloralin application at 1.0 kg a.i. ha^{-1} fb hand weeding at 30 DAS. Pre-emergence application of pendimethalin at 0.5 kg a.i. ha^{-1} fb hand weeding at 30 DAS reduced the total weed dry matter (0.1 g m^{-2}) compared to that of herbicide alone (36.6 g m^{-2}) (Singh *et al.*, 1992). Supplementing one intercultivation with Kulpa at 25 DAS to metolachlor application at 1.0 kg a.i. ha^{-1} resulted 56.6 per cent weed control efficiency (Singh *et al.*, 1994). Similar observations involving integrated weed management practices with pendimethalin and metolachlor application were made by Singh and Singh (1994). Significantly less dry matter was recorded with application of pendimethalin at 1.0 kg a.i. ha^{-1}, fluchloralin at 0.66 kg a.i. ha^{-1} and metolachlor at 1.0 kg a.i. ha^{-1} followed by one intercultivation at 30 DAS (AICRP-WC, project coordinator's report, 1995). Similar findings were recorded on weeds by Chandel *et al.* (1995), Srinivasarao *et al.* (1995) and Balasubramaniam and Arumugam (1996).

2.5.1 Soybean crop

Plant height was significantly more (81.2 cm) with fluchloralin application at 1.0 kg a.i. ha^{-1} fb hand weeding at 30 DAS and was at par

(74.3 cm) with weedy check and that received pendimethalin at 0.5 kg a.i. ha^{-1} fb hand weeding at 30 DAS (Singh *et al.*, 1992). In contrary, Padmavathi (1994) reported reduction in plant height with fluchloralin application at 0.75 kg a.i. ha^{-1} fb hand weeding at 30 DAS. Halvankar *et al.* (1995) observed significant increase in plant height with application of fluchloralin, pendimethalin and metolachlor at 1.0 kg a.i. ha^{-1} fb hand weeding at 30 DAS. Integration of one hand weeding at 30 DAS with fluchloralin at 1.0 kg a.i. ha^{-1}, pendimethalin at 0.5 kg ha^{-1} and metolachlor at 1.0 kg a.i. ha^{-1} significantly increased the plant dry matter (Chandel *et al.*, 1995).

The yield attributing characters did not vary significantly with application of fluchloralin at 0.75 kg a.i. ha^{-1} and pendimethalin at 1.0 kg a.i. ha^{-1}, both fb hand hoeing at 20 DAS. (AICRP- WC, Annual report, 1993-94). Application of Pendimethalin at 0.5 kg a.i. ha^{-1} integrated with hand weeding at 30 DAS enhanced the pod number $plant^{-1}$ by 46 per cent over unweeded check (Singh *et al.*, 1992). Halvankar *et al.* (1995) reported that pod number $plant^{-1}$ increased on supplementing hand weeding at 30 DAS with fluchloralin, pendimethalin and metolachlor, all application at 1.0 kg a.i. ha^{-1} (44.7, 42.6 and 42.1 respectively). 100 seed weight did not vary significantly with application of herbicides.

Application of pendimethalin @ 1.0 kg a.i. ha^{-1} fb hand weeding at 45 DAS increased the yield by 20 per cent over control and it was on par with twice hand weeded crop at 30 and 60 DAS (Dubey *et al.*, 1984). On the otherhand, application of metolachlor at 1.0 kg a.i. ha^{-1} fb interculture at 25 DAS recorded 25 per cent more yield as compared to that of herbicide application without interculture (Tiwari *et al.*, 1988). Significantly higher seed yield was obtained with application of fluchloralin at 1.0 kg a.i. ha^{-1} fb hand weeding at 45 DAS over that of weedy check (Tomar *et al.*, 1994 and Satao and Chandurkar, 1994). Application of herbicides, fluchloralin at 0.75 kg a.i. ha^{-1}, pendimethalin at 0.75 kg a.i. ha^{-1} and metolachlor at 0.5 kg a.i. ha^{-1}, each fb hand weeding at 40 DAS were equally effective in obtaining higher yields as compared to that of twice hand weeding (AICRIP-WC, Project coordinator's report, 1995 and Balasubramanian and Arumugam, 1996).

2.6 EFFECT OF NITROGEN

The contribution of symbiotic and mineral nitrogen sources to total plant nitrogen is determined by legume nitrogen requirement and mineral nitrogen supply (George and Singleton, 1992).

2.6.1 Weed growth

Santharam and Shivashankar (1982) reported higher weed population of monocots (59.0 m^{-2}) and Dicots (30.2 m^{-2}) and dry matter accumulation (163.0 g m^{-2}) at recommended dose of nitrogen (37.5 kg ha^{-1}) than at 75 per cent of the recommended dose of nitrogen (42.0 m^{-2}, 23.8 m^{-2} and 124.6 g m^{-2} respectively) and observed greater weed growth at higher fertility levels.

2.6.2 Crop growth

Bhangoo and Albritton (1976) recorded optimum range of 56 to 112 kg N ha^{-1} for higher efficiency of fixed nitrogen and applied nitrogen and maximum utilisation by crop was observed at bean filling stage (Diebert *et al.*, 1979).

Significant increase in plant height was reported at 50 (Khelkar *et al.*, 1991) and 60 (Majumdar and Behera, 1991 and Pradhan *et al.*, 1995) kg N ha^{-1}. Contrarily Trivedi and Sharma (1997) reported that plant height did not vary significantly with increase in nitrogen levels.

Durai Singh and Gopalaswamy (1991) reported significantly higher crop dry matter production (1.829 kg ha^{-1}) at 40 kg N ha^{-1} compared to 20 kg N ha^{-1}, while it was more in summer than in *kharif.* Leaf and dry matter production $plant^{-1}$ was significantly more with increase in nitrogen application from 30 to 90 kg ha^{-1} as compared to that of no nitrogen application (Jadhav *et al.*, 1994).

Yield attributes, pod number $plant^{-1}$, seed number pod^{-1} and 1000 grain weight significantly increased with 40 kg N ha^{-1} (Paikera *et al.*, 1988 and Durai Singh and Gopalswamy, 1991), at 50 kg N ha^{-1} (Dahatonde and Shava, 1992).

Yield attributes increased significantly with increased levels of nitrogen, maximum being recorded at 60 kg N ha^{-1} (Nayak *et al.*, 1989). Similar observations were made at 40 kg N ha^{-1} (Durai Singh and Gopalaswamy, 1991) and at 50 kg N ha^{-1} (Dahatonde and Shava, 1992). Similar findings were recorded by Vara *et al.* (1994) and Trivedi and Sharma (1997).

Majumdar and Behera (1991) recorded increase in grain yield with application of 60 kg N ha^{-1} over that of the crop received no nitrogen. Application of graded levels of nitrogen, from 0 to 100 kg ha^{-1} increased the seed yield (Naidu and Pillai, 1991). Application of 40 (Singh *et al.*, 1994) or 45 (Patel and Chandravanshi, 1996) or 50 (Trivedi and Sharma,

1997) kg N ha^{-1} significantly increased the seed yield over that of no nitrogen application.

2.7 NUTRIENT UPTAKE BY WEEDS

Nutrient uptake by weeds depend on their dry matter accumulation and nutrient concentration in dry matter. Significant reduction in NPK uptake was observed with twice hand weeding at 20 and 40 DAS as compared to that of weedy check (Singh and Sharma, 1989). At 60 DAS the uptake by grassy weeds was higher than that of broad leaved weeds. Maurya *et al.* (1990) recorded a saving of 62 per cent N, 30 per cent P and 65 per cent K with mechanical hoeing twice at 20 and 45 DAS. Application of preemergence herbicides, fluchloralin, pendimethalin and metolachlor, each at 1.0 kg a.i. ha^{-1} significantly reduced the NPK uptake (Shekara and Nanjappa, 1993). Pre-plant soil application of fluchloralin at 0.9 kg ha^{-1} + 2 hoeings + one hand weeding at 25 DAS recorded least NPK uptake (Satao and Chandurkar, 1994 and Jain *et al.*, 1995). Integrating hoeing at 25 DAS with preemergence application of pendimethalin at 1.0 kg a.i. ha^{-1} or metolachlor at 0.75 kg a.i. ha^{-1} significantly reduced NPK uptake (17.93, 4.59, 12.98 and 16.42, 3.66, 10.80 kg ha^{-1} respectively) over that of weedy check (45.77 kg N, 19.17 kg P and 36.01 kg K ha^{-1}; Rao, 1997).

2.8 NUTRIENT UPTAKE BY SOYBEAN

Pal and Saxena (1976) observed maximum nitrogen accumulation in reproductive sinks of crop due to continued assimilation and translocation from vegetative plant parts during 60-80 DAS. Hand weeding twice recorded the highest NPK uptake by soybean (130.26, 11.70 and 96.89 kg ha^{-1}

respectively) as against 57.97, 4.78 and 41.59 kg ha^{-1} NPK in weedy check (Maurya *et al.*, 1990). Shekara and Nanjappa (1993) reported maximum NPK uptake by the crop with pre-emergence application of herbicides, fluchloralin, pendimethalin and metolachlor each at 1.0 kg a.i. ha^{-1} as compared to weedy check. Higher uptake of nutrients in soybean was observed with pre-emergence of application metolachlor at 0.75 kg a.i. ha^{-1} (Singh *et al.*, 1994) and pendimethalin at 0.5 kg a.i. ha^{-1} fb hand weeding at 30 DAS (Arumugam *et al.*, 1995). Progressive increase in nitrogen uptake by crop was observed with increase in nitrogen levels (Pandey *et al.*, 1995 and Patel *et al.*, 1996). It has been reported that weedy condition throughout the crop growing season resulted in 53.3 and 53.7 per cent reduction in N and P uptake respectively by crop, while pre-emergence application of pendimethalin at 1.0 kg a.i. ha^{-1} fb by hand weeding at 35 DAS recorded similar N and P uptake by the crop as that of season long weed-free grown crop (Chhokar *et al.*, 1997).

2.9 PROTEIN AND OIL CONTENT

2.9.1 Weed management

Weed competition had no significant adverse effect on protein and oil content of soybean seed, as these characters are genetically controlled (Singh and Singh, 1994). Chhokar *et al.* (1995) reported significant increase in oil content (19.6 %) by keeping the crop weed free upto 45 DAS compared to that of weedy check (19.0 %). The application of herbicides had no adverse influence on qualitative parameters like protein and oil content of seeds which ranged from 38.30 to 41.2 per cent and 19.10 to 21.10

per cent respectively (Jain *et al.*, 1995). Similar findings were reported by Umarani and Selvaraj (1996)

2.9.2 Nitrogen

Boswell and Anderson (1976) reported highest crude protein content (39.4 %) at 56 kg N ha^{-1} and lowest in control (34.0 %) and the nitrogen content was inversely related to seed oil content. The protein and oil content of seeds increased with increase in nitrogen levels and were maximum (40.8 and 20.0 % respectively) at 60 kg N ha^{-1} (Nayak *et al.*, 1989). Similar observations were made by Khelkar *et al.* (1991), Pradhan *et al.* (1995) and Trivedi and Sharma (1997).

2.10 BIOASSAY

Ragi was used to detect pendimethalin at 1.0 kg a.i. ha^{-1}, whose activity remained in soil for 115 days, as measured by the per cent germination (AICRP-WC, project coordinator's report, 1991). The germination of ragi was drastically affected (16.7 %) compared to control (100 %) (AICRP-WC, Annual Progress Report, Hyderabad Centre, 1993). Ragi was highly sensitive to fluchloralin residues upto 0.01 ppm concentration. Further, ragi crop has been reported to be an ideal bioassay for detection of pendimethalin beyond 0.1 ppm concentration (Padmavathi Devi *et al.*, 1994). Herbicide residues in soil after harvest of soybean were not in amounts that could affect the germination of ragi (Rao, 1997).

2.11 ECONOMICS

Pre-emergence application of pendimethalin fb working with Kulpa at 25 DAS resulted in highest net profit of Rs. 1,627 ha^{-1} with maximum benefit cost ratio of 1.6 compared to 1.4 with herbicide application alone (Poston *et al.*, 1992). Shekara and Nanjappa (1993) recorded higher B:C ratio (Rs, 8.00) with pre-emergence application of metolachlor at 1.0 kg a.i. ha^{-1} which was followed by fluchloralin at 1.0 kg a.i. ha^{-1} (Rs. 6.00). On the otherhand, the B:C ratio (Rs. 4.00) was minimum in the hand weeding twice. Mechanical weeding twice at 30 and 50 DAS gave the maximum net profit of Rs. 5.92 $rupee^{-1}$ investment (Chandrakar and Urkurkar, 1993). Maximum net returns were obtained with pre-emergence application of metolachlor at 1.0 kg a.i. ha^{-1} fb hand weeding at 30 DAS (Chandel *et al.*, 1995). Halvankar *et al.* (1995) reported higher returns with fluchloralin at 1.0 kg a.i. ha^{-1} + hand weeding at 30 DAS and twice hand weeding at 30 and 45 DAS. The pre-emergence application of metolachlor at 0.75 kg a.i. ha^{-1} fb hoeing at 25 DAS resulted in highest profit of Rs. 1,377 ha^{-1} with B:C ratio of 2.62 (Rao, 1997).

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

3.1 EXPERIMENTAL SITE

The experiment entitled "Nitrogen use economy through integrated weed management in soybean" was conducted during *rabi* 1996-97 at the College Farm, College of Agriculture, Rajendranagar, Hyderabad. The farm is situated at an altitude of 542.6 m above mean sea level with a geographical bearing of 18`-50^{0} N latitude and 77'-53^{0}E longitude.

3.2 WEATHER CONDITIONS

The mean weekly meteorological data pertaining to rainfall, minimum and maximum temperature, relative humidity and hours of sunshine recorded during the experimental period are furnished in Appendix A and depicted in Fig.1.

3.3 SOIL PROPERTIES

Before start of experiment, soil samples were collected at random from 0-15 cm depth, shade dried, passed through a 2 mm sieve and the sieved sample was used for analysis of mechanical, physical and chemical characteristics by following the standard procedure (Jackson, 1973).

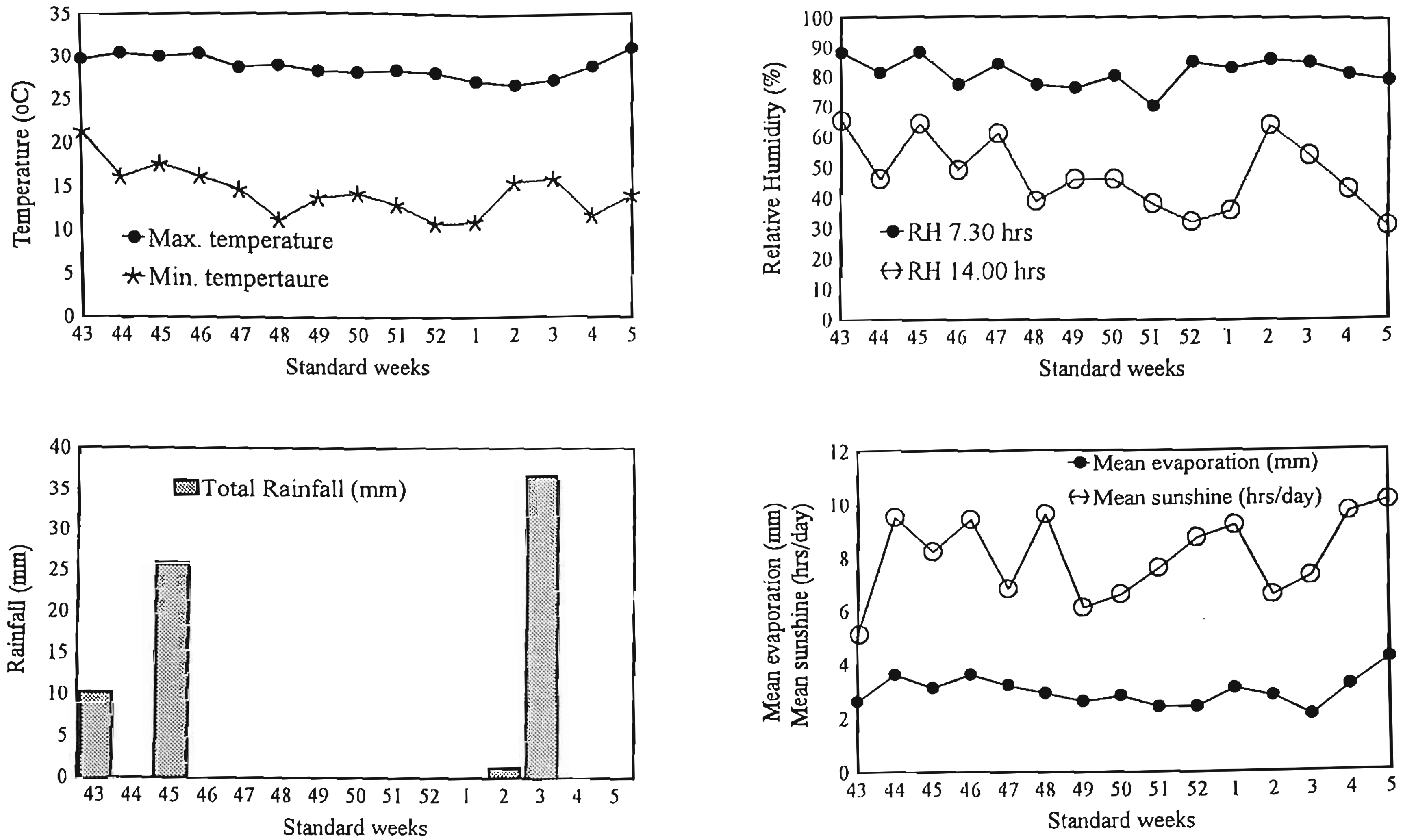


Fig. 1: **Weekly meteorological data during crop growth period**

3.3.1 Characteristics of soil

Characteristics	Content	Reference
Mechanical composition, %		
Sand	68.51	Bouyoucos hydrometer method (Bouyoucos, 1962)
Silt	17.14	
Clay	14.35	
Textural class	Sandy loam	
Chemical composition		
pH (1:2.5 soil:water)	7.9	Combined electrode pH meter (Jackson, 1973)
EC (dSm^{-1})	0.61	Digital EC meter (Jackson, 1973)
Organic carbon (%)	0.34	Web digestion method (Walkley and Black, 1934)
Available nitrogen ($kg\ ha^{-1}$)	163.10	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P_2O_5 ($kg\ ha^{-1}$)	38.67	Olsen's method (Olsen et al., 1954)
Available K_2O ($kg\ ha^{-1}$)	325.05	NN NH_4OAC method (Jackson, 1973)

The analysis indicated that the soil was low in organic carbon content and available nitrogen, medium in available P_2O_5 and high in available K_2O and was grouped under soil order Alfisol.

3.4 PREVIOUS CROPS GROWN

The following crops were grown in the experimental field previously.

Year	Season	Crop
1994-95	*Kharif*	Fallow
	Rabi	Wheat
1995-96	*Kharif*	Jowar
	Rabi	Maize
1996-97	*Kharif*	Fallow
	Rabi	The present experiment with soybean

3.5 EXPERIMENTAL DETAILS

3.5.1 Design of the experiment

The experiment was laid out in a split-plot design with three replications. The experimental lay out is given in Fig. 2.

3.5.1.1 Plot size

(a) Gross plot size : 4.5 m x 3.8 m

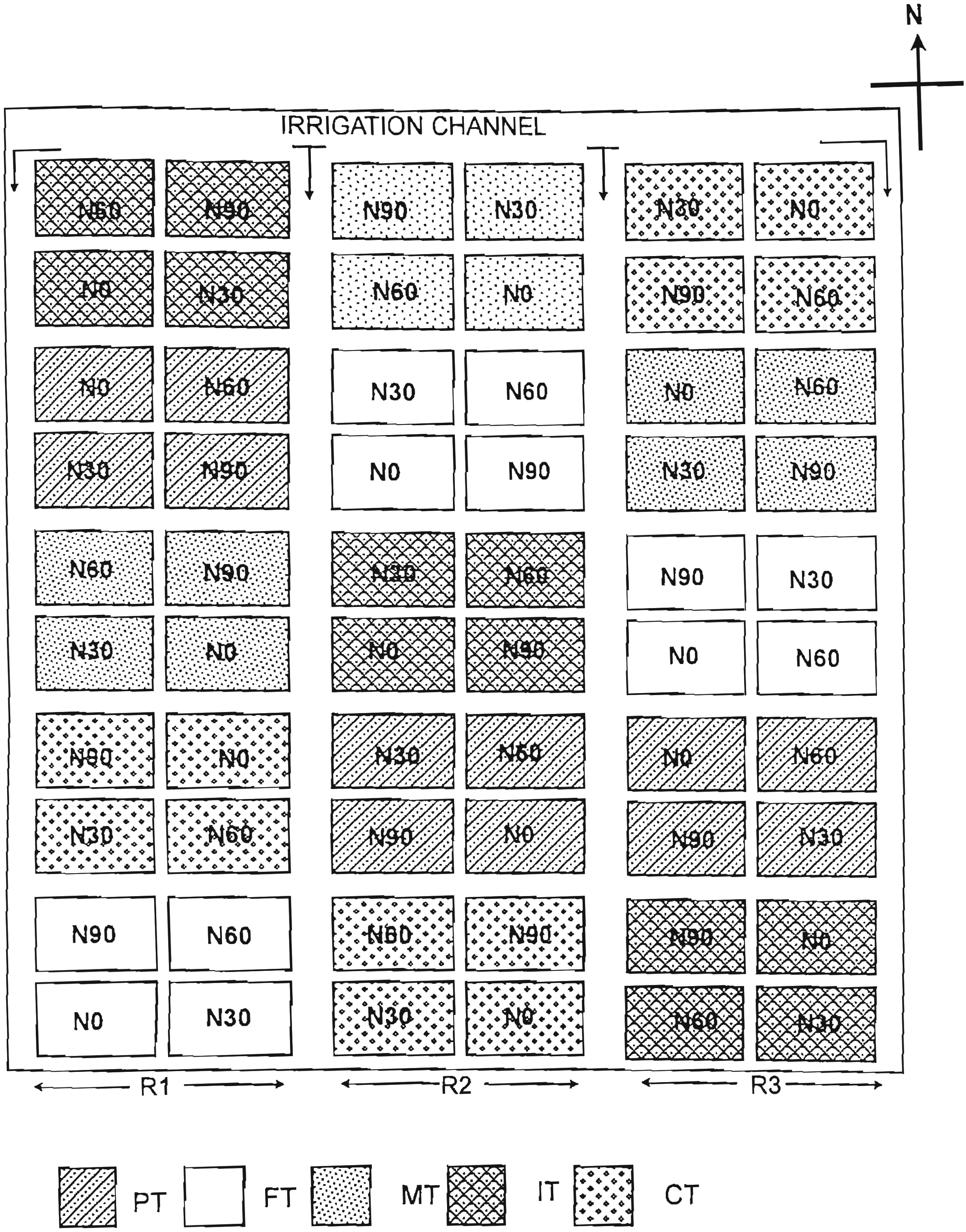
(b) Net plot size : 3.0 m x 3.6 m

3.5.1.2 Spacing adopted

30 cm x 10 cm

3.5.2 Main plot treatments : Weed control treatments (5)

Treatments	Notation
Pendimethalin @ 1.0 kg ai/ha + Intercultivation (IC) with push-hoe at 25 DAS	PT



Design : Split plot design

Plot size : Gross 4.5 m x 3.8 m
Net 3.0 m x 3.6 m

Treatments : 20

Fig. 2 : Layout Plan of the Experiment

Fluchloralin @ 1.0 kg ai/ha + IC with push-hoe at 25 DAS	FT
Metolachlor @ 1.0 kg ai/ha + IC with push-hoe at 25 DAS	MT
IC with push-hoe at 20 and 40 DAS	IC
Unweeded check	UC

3.5.3 Sub-plot treatments : Nitrogen levels (4)

Treatments	Notation
Nitrogen, 0 kg/ha	N_0
Nitrogen, 30 kg/ha (half the recommended dose)	N_{30}
Nitrogen, 60 kg/ha (recommended dose)	N_{60}
Nitrogen, 90 kg/ha (50 per cent more than the recommended dose)	N_{90}

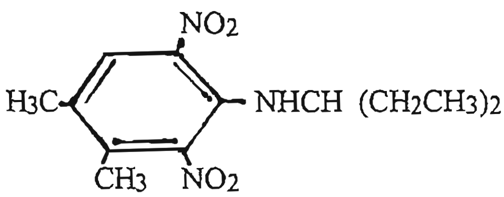
3.5.4 Details of the herbicides used

Three herbicides, pendimethalin, fluchloralin and metolachlore were tried in the experiment. The information of these herbicides is furnished below.

3.5.4.1 Pendimethalin

Common name	: Pendimethalin
Trade Name & Formulation	: Stomp 30 % EC
Chemical Name	: N - (1-ethyl propyl) - 3, 4 - dimethyl-2-6-dinitrobenzenamine

Structural Formula :



Group : Dinitroaniline

Time of application : Pre-emergence, soil applied, and mode of action translocated

Manufacturing company : M/s Cynamid India Ltd., Bombay

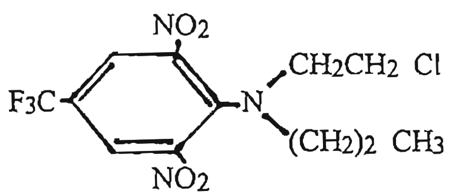
3.5.4.2 Fluchloralin

Common Name : Fluchloralin

Trade Name& Formulation: Basalin 45 % EC

Chemical Name : N-(2-chloro-ethyl) -2-6-dinitro-N-propyl-4-(trifluoro methyl)benzenamine

Structural formula :



Group : Dinitroaniline

Time of application & Mode of action : Pre-plant incorporation, soil applied, translocated

Manufacturing Company : M/s BASF (India) Ltd., Bombay.

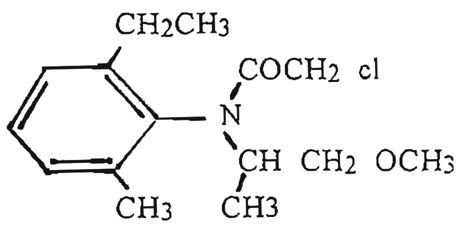
3.5.4.3 Metolachlor

Common Name : Metolachlor

Trade Name and Formulation : Dual 50 % EC

Chemical Name : 2-chloro-N-(2-ethyl-6-methyl phenyl)-N-(2-methoxy-1-methyl ethyl)-acetamide.

Structural formula :



Group : Acetamide

Time of application : Pre-emergence, soil applied. and mode of actiontranslocated

Manufacturing company : M/s Hindustan Ciba-Geigy Ltd., New Delhi.

3.5.4.4 Time and method of herbicide application

Herbicides were applied with Knapsack sprayer as per requirement to the treated area as water spray by using a spray fluid @ 600 litres ha^{-1}.

Fluchloralin was applied just before levelling and incorporated into the soil. Pendimethalin and metolachlor were applied 24 hours after sowing as pre-emergence application.

3.5.5 Varietal characters

The variety used in the investigation was MACS-201. It is a medium tall maturing in 80-85 days (early) having a yield potential of 18-20 q ha^{-1}.

3.6 AGRONOMIC PRACTICES

3.6.1 Field preparation

The experimental field was ploughed with tractor drawn disc plough and then worked with tractor drawn cultivator and levelling was done finally after the removal of stubbles and weed trash from the field.

3.6.2 Layout

The field was laid out into 60 plots using a bund former. The treatments were allotted at random to different plots of each replication.

3.6.3 Fertilizer application

Uniform dose of phosphorus @ 40 kg ha^{-1} and potassium @ 20 kg ha^{-1} in the form of single super phosphate and Muriate of potash, respectively, along with half the dose of nitrogen (as per the treatments) in the form of urea were applied as basal dose at the time of sowing.

The remaining half of the nitrogen dose was top dressed as per the treatments in the form of urea one month after sowing.

3.6.4 Seeds and sowing

Bold and healthy seeds were selected and treated with thiram @ 3 g/kg seed to protect the crop from seed borne diseases. The seeds were sown on 28th October, 1996 at a spacing of 30 cm x 10 cm by hand dibbling two seeds per hill at a depth of 5 cm.

3.6.5 After care

Thinning was done at 10 DAS to maintain optimum plant population by way of leaving one healthy seedling per hill.

3.6.6 Intercultivation

Intercultivation with push-hoe was taken up as per the treatmental schedule after recording the species wise weed counts and the sampling of crop and weeds for dry matter production.

3.6.7 Irrigation

The crop was irrigated immediately after sowing to ensure good seedling emergence and the subsequent irrigations were given as and when required. The crop received a total of six irrigations during the crop season.

3.6.8 Plant protection

The crop was sprayed once each with endosulfan (0.07 %) at 19 DAS for control of leaf caterpillar and with monocrotophos (0.05 %) at 46 DAS as a prophylactic measure. In general, crop growth was good and healthy during the entire crop growing period.

3.6.9 Harvesting and threshing

The crop was harvested at physiological maturity when the leaves turned yellow and started dropping and also when the pods started drying and breaking open when pressed. All the plants from the net plot area were harvested and dried under sun for 2-3 days and then threshed and the produce was cleaned. Dry weight of seeds and haulms were recorded separately.

3.7 Experimental observations

3.7.1 Observations on weeds

3.7.1.1 Weed density

Species wise weed counts were taken at 30, 60 DAS and at harvest in permanently marked one square metre area in the net plot of each plot. The data were statistically analysed after subjecting these values to square root transformations by using the following formula (Rao, 1983).

$$X = \sqrt{x + 1}$$

Where,

X = Transformed value
x = Original value

3.7.1.2 Preponderance of weed species

Preponderance of weed species or relative density of each weed species was calculated at 30 and 60 DAS and harvest by using the formula (Shetty and Rao, 1980).

$$P_w \quad \frac{N_x}{m} \times 100$$

Where,

P_w = Preponderance of weed species

N_x = Density of weeds of a species in one m^2 area

m = Total number of weeds in each m^2 area

3.7.1.3 Dry matter production of weeds

The weeds were collected from an area of 0.25 m^2 from outside the net plot area earmarked for this purpose at 25, 50 and 75 DAS and harvest and shade dried and kept in oven at 65°C until a constant weight was obtained. Treatmentwise dry matter of total weeds was recorded and expressed as g m^{-2}.

3.7.1.4 Weed control efficiency (W.C.E)

From the dry weight of weeds, weed control efficiency was calculated at 25, 50 and 75 DAS and harvest by using the following formula (Umrani and Boi, 1982).

$$\text{W.C.E.(\%)} = \frac{\text{Dry matter of weeds in unweeded plots (g m}^{-2}\text{)} - \text{Dry matter of weeds in treated plots (g m}^{-2}\text{)}}{\text{Dry matter of weeds in unweeded plot (g m}^{-2}\text{)}} \times 100$$

3.7.1.5 Weed index (W.I)

Weed index was computed by using the following formula (Gill and Vijayakumar, 1966).

$$\text{W.I. (\%)} = \frac{X - Y}{x} \times 100$$

Where,

X = Yield from minimum weed competition plot

Y = Yield from the treatment for which WI is to be worked out

3.7.1.6 Integrated weed management index (IWMI)

Integrated weed management index was calculated based on the yield obtained from integrated weed management treatments and yield obtained from the weedy check, using the formula.

$$IWMI\ (\%) = \frac{Y_I - Y_W}{Y_I} \times 100$$

Where,

Y_I = Yield due to integrated weed management

Y_W = Yield from weedy check

3.7.1.7 Nitrogen use efficiency (NUE)

Nitrogen use efficiency (kg grain kg N^{-1} ha^{-1}) was calculated by using the following formula (Rajput and Singh, 1981).

$$NUE = \frac{\text{Absolute response in economic crop yield } (Y_f - Y_o)}{\text{Dose of fertilizer applied}}$$

Where,

Y_f = Crop yield in fertilized plot

Y_o = Crop yield in unfertilized plot

3.7.2 Observations on crop

3.7.2.1 Pre-harvest observations

3.7.2.1.1 Germination percentage

Plot wise germination count was taken at 7 DAS. The germination percentage was calculated based on the following formula to find out the effect of herbicides on the germination of the crop.

$$\text{Germination \%} = \frac{\text{Number of seedlings emerged}}{\text{Expected (theoritical) population}} \times 100$$

3.7.2.1.2 Phytotoxicity scoring

Phytotoxic effect of herbicides on the crop plants was assessed on 10 and 30 days after application of pre-emergence herbicides based on European Weed Research Council Recommendations (Singh and Rao, 1976).

Different scoring was given based on the extent of damage observed in each treatment as per the above recommendations.

Phytotoxicity scoring chart (Singh and Rao, 1976)

Rating	Percentage	Crop injury verbal description
1.	0	No reduction or no injury
2.	1.0 - 3.5	Very slight discolouration
3.	3.5 - 7.0	More severe but not lasting
4.	7.0 - 12.5	Moderate to more lasting
5.	12.5 - 20.0	Medium and lasting
6.	20.0 - 30.0	Heavy

7.	30.0 - 50.0	Very heavy
8.	50.0 - 90.0	Nearly destroyed
9.	100	Completely destroyed

3.7.2.1.3 Selection of sampling plants for non-destructive growth parameters

Ten plants were randomly selected within the net plot area and tagged for recording the periodic biometric observations at various stages of crop growth.

3.7.2.1.4 Plant height

Bio-metric observations on plant height (cm) were taken at 30 and 60 DAS and harvest. Plant height was measured from the base of each plant to the tip of its terminal bud at vegetative stage and to the tip of the inflorescence at reproductive stage.

3.7.2.1.5 Dry matter production

The plant samples were collected at 25, 50 and 75 DAS and harvest. Ten plants were collected from each plot, shade dried and then oven dried to a constant weight at 65°C. The dry weights were recorded and the average of ten plants was taken and expressed as g plant^{-1}.

3.7.2.2 Post-harvest observations

3.7.2.2.1 Border rows and the sampling area

One row on either side of the plot and one plant on either side of each row were eliminated to avoid the border effect. Two rows were earmarked outside the net plot area excluding the border rows for destructive sampling. Samples were drawn from these two rows to estimate dry matter production and nutrients uptake by crop.

3.7.2.2.2 Seed and haulm yields

Seed and haulm obtained from each net plot were shade dried to constant weight and their respective yields were recorded as kg ha^{-1}.

3.7.2.2.3 Number of pods

The total number of pods from ten sampled plants was counted and expressed as average number of pods per plant.

3.7.2.2.4 Number of seeds pod^{-1}

Number of seeds from all the pods produced from ten plants was counted and averaged to get number of seeds per pod.

3.7.2.2.5 100-seed weight (g)

From each treatmental produce, 100 seed were randomly selected and their weight was recorded.

3.7.2.2.6 Harvest index (H.I)

Harvest index (%) was expressed as the ratio of seed yield to biological yield and was calculated as given below (Singh and Stoskopf, 1971).

$$\text{H.I. (\%)} = \frac{\text{Seed yield}}{\text{biological yield}} \times 100$$

3.8 PLANT CHEMICAL ANALYSIS

Oven dried plant samples collected were finely ground in a willey mill and used for chemical analysis.

Plant samples were analysed for total nitrogen by using microkjeldhal method (Piper, 1966), after destroying organic matter by Conc. H_2SO_4 and H_2O_2. Phosphorus and potassium content were estimated in the extract after digesting the sample with triacid mixture of HNO_3 : H_2SO_4 : $HClO_4$ (9:2:1). Phosphorus content was determined by using Vanadomolydo phosphorus yellow colour method on a Klett summerson colourimeter and potassium content was determined using Elico flame photometer (Chopra and Kanwar, 1976).

3.8.1.1 Nutrient uptake

The uptake of nitrogen, phosphorus and potassium was calculated by multiplying the nutrient content with the respective dry matter production of the crop and weeds under different treatments.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter production (kg ha}^{-1}\text{)}}{100}$$

3.8.1.2 Protein content

Nitrogen content in soybean seed was estimated by microkjeldhal method as explained earlier and the nitrogen content was multiplied with a factor of 6.25 to obtain protein content (Jackson, 1973).

3.8.1.3 Oil content

The seeds were oven dried at 60°C for six hours to a constant weight and 15 g of this sample was fed to nuclear magnetic resonance spectroscopes (NMR) (Model -Oxford 4000 NMR oil analyser, Oxford analytical instruments, U.K.). The instrument was standardised with equal quantity of seed sample and the reading obtained for each sample was noted as oil content (per cent).

3.9 RESIDUAL EFFECT OF HERBICIDES USED IN THE STUDY

After the harvest of crop, the presence of herbicides used viz., pendimethalin, fluchloralin and metolachlor in soil was tested by ragi bio-assay method (AICRP-WC, Annual progress report, 1993).

Post harvest soil samples of two kg each were collected, processed and transferred to earthen pots. 2 g of ragi seeds were sown in each earthern pot and watered to field capacity. The germination percentage was recorded one week after sowing.

3.10 ECONOMIC ANALYSIS

The total cost of cultivation per hectare of soybean was estimated at prevailing market prices for individual treatments based on total labour and inputs used.

Gross and monetary returns were calculated by multiplying the economic yield with prevailing market prices for seed (Perin *et al.*, 1979). Net monetary returns were calculated by deducting the cost of cultivation from gross monetary returns for each treatment.

Benefit cost ratio was calculated by using the following formula.

$$\text{B:C ratio} = \frac{\text{Net profit}}{\text{Cost of cultivation}}$$

3.11 STATISTICAL ANALYSIS

The data on crop and weeds were analysed statistically by applying the technique of analysis of variance for split plot design and the significance was tested by F-test (Snedecor and Cochran, 1967).

RESULTS

CHAPTER IV

RESULTS

The data obtained from investigation entitled "Nitrogen use economy through integrated weed management in soybean" were subjected to statistical analysis and are presented hereunder.

4.1 WEATHER CONDITIONS

The observations recorded on the weather elements during the crop growth period are furnished in Appendix A and depicted in Fig. 1. The mean minimum and maximum temperatures were 14.5°C and 28.8°C respectively. The mean relative humidity at 7.30 hrs and 14.00 hrs was 81.3 and 47.6 per cent respectively. The mean number of sunshine hours day^{-1} was 8.0. The total rainfall received during the crop growth period was 74.2 mm in 3 rainy days.

4.2 OBSERVATIONS ON WEED GROWTH

4.2.1 Weed spectrum

During the entire crop growth period, the predominant weed species observed were two sedges, six grasses and seven dicot weeds. They are enumerated below along with their families.

Weed flora observed in the experimental field

Botanical name	Family
Sedges	
1. *Cyperus rotundus*, Linn.	Cyperaceae
2. *Fimbristylis miliacea*, Vahl.	Cyperaceae

Grasses

3. *Cynodon dactylon*, Pers.	Gramineae
4. *Commelina benghalensis*, Linn.	Commelinaceae
5. *Dinebra retroflexa*, Panz.	Gramineae
6. *Panicum repens*, Linn.	Gramineae
7. *Dactyloctenium aegyptium*, Beauv.	Gramineae
8. *Digitaria sanguinalis*, (L.) Scop.	Gramineae

Broad-leaved weeds

9. *Parthenium hysterophorus*, Linn.	Compositae
10. *Digera arvensis*, Forsk.	Amaranthaceae
11. *Euphorbia geniculata*, Orteg.	Euphorbiaceae
12. *Euphorbia hirta*, Linn.	Euphorbiaceae
13. *Amaranthus spinosus*, Linn.	Solanaceae
14. *Datura fastuosa*, Linn.	Solanaceae
15. *Melilotus indica*	*Leguminaceae*

4.2.1.1 Behaviour of predominant weeds (m^{-2}) under different treatments

The data on the density and relative density of predominant weed species are given in table 1.

Cyperus rotundus: Among the weed control treatments, the density of *Cyperus rotundus* was maximum in unweeded check (34.8 m^{-2} at 30 DAS and 35.0 m^{-2} at 60 DAS). On the other hand, at 30 DAS it was lower in the crop received I C twice (2.9 m^{-2}) and it was followed by metolachlor at 1.0 kg a.i. ha^{-1} + IC (4.2 m^{-2}) and pendimethalin at 1.0 kg a.i. ha^{-1} ...

IC (4.5 m^{-2}). At 60 DAS, *Cyperus rotundus* was less in the crop applied with metolachlor at 1.0 kg a.i. ha^{-1} + IC (8.8 m^{-2}).

At harvest, lowest density (29.8 m-2) was observed in the plot received metolachlor at 1.0 kg a.i. ha^{-1} + IC as compared to that observed in the crop with other weed control treatments. Higher preponderance of this weed was observed in the crop treated with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC.

Among the nitrogen levels, the weed density increased progressively from 30 DAS to harvest. At harvest, higher weed density was observed in no nitrogen applied crop (48.5 m^{-2}), while lower density was observed in the crop received 90 kg N ha^{-1} (25.4 m- 2). At 30 DAS, higher preponderance was recorded with 60 kg N ha^{-1} (50.0 %), while at harvest with 0 and 30 kg N ha^{-1} levels (50.2 and 50.0 % respectively).

Fimbristylis miliacea: This weed appeared only after 30 DAS in the crop and it was totally controlled throughout the crop period by application of herbicide and it was controlled upto 60 DAS with IC twice.

Among nitrogen levels, at 60 DAS and harvest, higher weed density and preponderance was observed with no nitrogen application (2.7 and 2.5 m^{-2} and 1.4 and 1.3 % respectively).

Cynodon dactylon: Maximum density of 32.4 m^{-2} was observed in unweeded check, while all the weed management treatments effectively reduced *Cynodon dactylon* density (1.4 to 3.1 m^{-2} at 30 DAS). However, there was slight increase in weed population towards harvest. The higher relative density of this weed was observed in the crop applied with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC with 27.4, 20.9 and 19.3 per cent at 30 and 60 DAS and harvest, respectively.

At 30 DAS, among the nitrogen levels, maximum (12.4 m^{-2}) and minimum (5.7 m^{-2}) weed densities were observed in the crop received zero and 60 kg N ha^{-1}. On the other hand, at 60 DAS, the weed density decreased in all nitrogen levels and thereafter increased. Higher preponderance was recorded in the crop applied with 90 kg N ha^{-1} as compared to other levels at all stages of sampling.

Commelina benghalensis : This weed was totally controlled during the entire crop period by application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC, while application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice controlled the weed upto 30 DAS. At 30 DAS, the relative density was higher (3.6 %) in the crop received pendimethalin @ 1.0 kg a.i. ha^{-1} + IC. Among the nitrogen levels, at 30 DAS, maximum weed density was observed in the crop received no nitrogen (0.5 m^{-2}) and at 60 DAS in the crop received 90 kg N ha^{-1} (0.5 m^{-2}). On the other hand, the relative density at 30 and 60 DAS was higher in the crop applied with 60 kg N ha^{-1}.

Dinebra retroflexa : During the crop growth period, the integrated weed management treatments completely controlled this weed. At all stages of sampling relatively higher weed density was observed in the crop received no nitrogen than that of other N levels.

Panicum repens : Application of pre-emergence herbicides followed by intercultivation reduced this weed species totally in the crop as compared

Table 1 : Effect of different weed control treatments and nitrogen levels on the density (no. m^{-2})and preponderance of weed species (%) in soybean

Treatments	*Cyperus rotundus*			*Fimbristylis miliacea*			*Cynodon dactylon*			*Commelina benghalensis*		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Weed control treatments												
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	4.5 (41.7)	13.6 (52.6)	37.6 (62.4)	-	-	-	3.1 (27.4)	5.5 (20.9)	12.0 (19.3)	0.4 (3.6)	0.5 (1.9)	0.1 (0.2)
Fluchloralin 1.0 kg ha-1 fb intercultivation at 25 DAS	6.2 (71.3)	32.3 (70.7)	39.3 (65.1)	-	-	-	1.6 (17.5)	6.2 (13.0)	8.3 (14.2)	-	0.1 (0.1)	0.1 (0.2)
Metolachlor 1.0 kg ha-1 fb intercultivation at 25 DAS	4.2 (56.6)	8.8 (49.1)	29.8 (51.1)	-	-	-	1.4 (19.2)	3.2 (17.1)	10.3 (18.0)	-	-	-
Intercultivation with push-hoe at 20 and 40 DAS	2.9 (19.7)	14.4 (35.6)	31.0 (34.7)	-	-	0.4 (0.6)	3.1 (21.0)	5.3 (10.9)	6.7 (8.4)	-	0.2 (0.3)	-
Unweeded check	34.8 (25.0)	35.0 (19.6)	32.2 (23.1)	-	6.9 (3.7)	6.3 (4.5)	32 4 (22.1)	6.5 (3.6)	3.7 (3.1)	1.1 (0.7)	0.9 (0.5)	0.1 (0.1)
Nitrogen level (kg ha^{-1})												
0	9.3 (39.1)	22.4 (44.3)	48.5 (50.2)	-	2.7 (1.4)	2.5 (1.3)	12.4 (22.7)	4.2 (11.5)	9.7 (12.0)	0.5 (0.7)	0.3 (0.6)	-
30	9.7 (43.9)	23 1 (47.1)	33.2 (50.0)	-	1.1 (0.6)	0.8 (0.7)	8.5 (17.9)	4.5 (13.0)	6.5 (10.4)	0.2 (0.6)	0.3 (0.4)	0.1 (0.2)
60	11.5 (50.0)	16.1 (46.0)	28.8 (45.1)	-	0.8 (0.5)	1.1 (0.9)	5.7 (17.9)	5.1 (12.8)	7.7 (12.7)	0.3 (1.9)	0.3 (0.4)	-
90	11.6 (38.5)	21.8 (44.6)	25.4 (43.5)	-	0.8 (0.4)	1.0 (1.1)	7.2 (28.0)	7.5 (14.9)	8.9 (15.3)	0.2 (0.2)	0.5 (0.8)	0.1 (0.2)

Figures in parentheses denote preponderance of weed species (%)

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to that in IC twice and no weeding. The weed density increased towards harvest in the crop received 30 and 60 kg N ha^{-1} while decreased at harvest in the crop applied with 90 kg N ha^{-1}.

Dactyloctenium aegyptium : This weed appeared at later stages of the crop and the weed management treatments - pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin + @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC effectively eliminated this weed species from crop. The weed density increased towards harvest in the crop in IC done twice and unweeded check. Among the nitrogen levels, the density and relative density were higher in the crop received no nitrogen over other levels at 60 DAS and harvest.

Digitaria sanguinalis : This weed also appeared after 30 DAS in the crop, but was controlled in all the weed management treatments. On the other hand, the weed was observed only at harvest in the crop applied with 90 kg N ha^{-1}. At harvest, the higher weed density (1.3 m^{-2}) and relative density (0.8 %) were observed in the crop applied with no nitrogen.

Parthenium hysterophorus : Among the dicot weeds, this weed species was predominant. The highest weed density was observed in unweeded check at all stages of sampling (34.7, 36.0 and 33.7 plants m^{-2} at 30 and 60 DAS and harvest respectively). The weed management treatments effectively reduced the density of *Parthenium* sp. (0.9 to 2.7 m^{-2} at 30 DAS, 2.0 to 6.5 m^{-2} at 60 DAS and 6.4 to 13.9 m^{-2} at harvest). Among the weed control treatments, the preponderance of weed species was highest in unweeded check and ranged from 20.7 to 26.2 per cent.

At 30 DAS, lower (3.0 m^{-2}) and higher (11.2 m^{-2}) densities were observed in the crop received 60 kg N ha^{-1} and no nitrogen respectively. On the other hand, at 60 DAS and harvest, the weed density was higher in the crop applied with no nitrogen. The weed preponderance was higher in the crop received no nitrogen (20.3 %) and 30 kg N ha^{-1} (20.3%) at 30 DAS and no nitrogen (18.7%) at 60 DAS and 90 kg N ha^{-1} (17.3 %) at harvest.

Digera arvensis : It was another dominant weed observed in the crop. The weed was controlled efficiently upto 60 DAS by the application of herbicides integrated with intercultivation. Higher weed density of 17.2 and 21.3 m^{-2} was recorded in unweeded check at 30 and 60 DAS respectively. Among nitrogen levels, the crop applied with 90 kg N ha^{-1} resulted in maximum density at 30 and 60 DAS, while the weed density declined towards harvest in all nitrogen levels. Higher preponderance of the weed was observed in the crop received 60 kg N ha^{-1} at all stages of sampling.

***Euphorbia* spp.** : *Euphorbia* spp. were totally controlled during the entire crop period with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and with fluchloralin @ 1.0 kg a.i. ha^{-1} + IC upto 30 DAS. Higher weed density and relative density were observed in unweeded crop and that received metolachlor @ 1.0 kg a.i. ha^{-1} + IC respectively at 30 and 60 DAS and harvest. Among the nitrogen levels, the crop received 60 kg N ha^{-1} recorded higher weed density and pre-ponderance at 30 DAS and harvest.

Amaranthus spinosus : Total control of this weed species throughout the crop duration was achieved with integrated weed management. On the other

Table 1 (Cont.)

Treatments	*Dinebra retroflexa*			*Panicum repens*			*Dactyloctenium aegyptium*			*Digitaria sanguinalis*			*Parthenium hysterophorus*		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Weed control treatments															
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	-	-	-	-	-	-	-	-	-	-	-	-	2.0 (17.3)	4.7 (18.0)	8.3 (14.0)
Fluchloralin 1.0 kg ha-1 fb intercultivation at 25 DAS	-	-	-	-	-	-	-	-	-	-	-	-	0.9 (10.9)	6.2 (12.9)	6.4 (11.7)
Metolachlor 1.0 kg ha-1 fb intercultivation at 25 DAS	-	-	-	-	-	-	-	-	-	-	-	-	0.9 (10.8)	2.0 (11.6)	8.0 (13.6)
Intercultivation with push-hoe at 20 and 40 DAS	1.8 (13.0)	4.9 (9.4)	8.7 (9.4)	0.3 (2.3)	9.1 (16.4)	15.5 (17.4)	-	1.5 (3.8)	3.2 (4.1)	-	0.5 (1.0)	1.9 (2.0)	2.7 (16.8)	6.5 (15.2)	13.9 (13.4)
Unweeded check	14.9 (10.4)	34.9 (20.1)	24.8 (18.7)	3.8 (2.0)	19.4 (10.8)	15.6 (9.0)	-	2.3 (1.5)	3.3 (2.5)	-	1.4 (0.9)	0.9 (0.5)	34.7 (23.2)	36.0 (20.7)	33.7 (26.2)
Nitrogen level (kg ha^{-1})															
0	4.1 (3.2)	8.1 (4.8)	8.1 (4.8)	0.1 (0.3)	6.4 (4.9)	9.5 (6.3)	-	1.0 (0.8)	1.1 (0.7)	-	0.5 (0.5)	1.3 (0.8)	11.2 (20.3)	12.3 (18.7)	17.7 (15.0)
30	2.9 (4.0)	7.8 (5.4)	6.9 (6.0)	2.4 (1.1)	7.3 (7.3)	8.3 (6.6)	-	0.7 (0.9)	1.2 (1.1)	-	0.2 (0.8)	0.2 (0.2)	10.5 (20.7)	9.1 (12.8)	13.7 (16.1)
60	4.0 (7.0)	7.6 (6.2)	7.2 (6.7)	0.7 (1.6)	4.1 (4.7)	5.1 (5.7)	-	1.0 (2.0)	1.3 (1.5)	-	0.8 (0.9)	0.3 (0.4)	3.0 (7.4)	11.0 (16.3)	12.6 (14.7)
90	2.3 (4.6)	8.3 (7.3)	4.6 (4.9)	0.1 (0.5)	4.9 (4.8)	1.9 (2 6)	-	0.3 (0.6)	1.5 (2.0)	-	-	0.5 (0.5)	8.3 (14.8)	11.9 (14.9)	12.1 (17.3)

Figures in parentheses denote preponderance of weed species (%)

hand, higher density and pre-ponderance was observed in the crop received 90 kg N ha^{-1} over other levels of nitrogen application at different stages of sampling.

Datura fastuosa : This weed was totally checked during the crop period with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and IC twice. On the other hand, application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC were found effective in controlling the weed upto 30 DAS. The lower weed density and preponderance was observed in the crop applied with 30 kg N ha^{-1}, while it was relatively higher in the crop received no nitrogen at all stages of sampling.

Melilotus indica : Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin + @ 1.0 kg a.i. ha^{-1} IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC controlled this weed upto 60 DAS. The weed density increased towards harvest in all weed control treatments. Among nitrogen levels, the weed density and relative density were higher in the crop applied with 90 kg N ha^{-1} upto 60 DAS and in no nitrogen applied crop at harvest.

4.2.2 Total weed population (m^{-2})

The total weed density was significantly influenced by the weed control treatments, nitrogen levels and their interaction (Table 2).

At 30 DAS, the total weed population was significantly low under all the weed management practices compared to the unweeded check. Application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC resulted in lower density (7.4 m^{-2}) fb fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (8.9 m^{-2}), Pendimethalin

Table 1 (cont.)

Treatments	*Digera arvensis*			*Euphorbia spp.*			*Amaranthus spinosus*			*Datura fastuosa*			*Melilotus indica*		
	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest
Weed control treatments															
Pendimethalin 1.0 kg ha^{-1} fb Intercultivation at 25 DAS	0.9 (7.8)	1.5 (6.1)	2.0 (3.3)	-	-	-	-	-	-	-	-	-	-	-	0.6 (0.9)
Fluchloralin 1.0 kg ha-1 fb Intercultivation at 25 DAS	-	0.6 (1.4)	2.0 (3.2)	-	0.1 (0.2)	1.0 (2.3)	-	-	-	-	0.2 (0.4)	0.3 (0.7)	-	-	1.7 (2.5)
Metolachlor 1.0 kg ha-1 fb intercultivation at 25 DAS	0.9 (12.4)	2.9 (16.2)	5.5 (9.6)	0.1 (1.0)	0.3 (2.1)	0.8 (1.4)	-	-	-	-	0.1 (0.4)	0.5 (0.8)	-	-	2.6 (4.8)
Intercultivation with push-hoe at 20 and 40 DAS	2.7 (19.4)	6.3 (10.8)	4.4 (4.7)	0.1 (0.4)	0.3 (0.7)	0.2 (0.2)	0.1 (0.6)	0.5 (1.0)	0.3 (0.4)	-	-	-	0.6 (3.3)	0.4 (1.0)	3.2 (3.6)
Unweeded check	17.2 (12.0)	21.3 (12.5)	4.1 (4.1)	0.9 (0.7)	0.7 (0.4)	1.0 (0.7)	2.1 (1.7)	3.4 (2.0)	2.5 (2.3)	0.3 (0.2)	0.7 (0.3)	0.3 (0.1)	0.2 (0.1)	0.4 (0.2)	2.4 (1.7)
Nitrogen level (kg ha^{-1})															
0	4.4 (11.1)	6.8 (9.3)	3.5 (4.1)	0.1 (0.3)	0.5 (0.5)	0.3 (0.3)	0.1 (0.1)	0.2 (0.1)	-	0.1 (0.1)	0.2 (0.4)	0.3 (0.4)	-	-	2.9 (3.0)
30	4.7 (10.4)	5.5 (9.3)	2.7 (4.4)	-	0.1 (0.4)	0.1 (0.1)	0.3 (0.2)	0.6 (0.3)	0.1 (0.1)	-	0.2 (0.1)	-	0.1 (0.6)	0.3 (0.2)	1.6 (1.9)
60	3.3 (11.1)	6.4 (11.3)	4.4 (5.9)	0.6 (1.3)	0.4 (0.5)	1.1 (1.9)	0.5 (0.6)	0.7 (0.5)	0.8 (0.7)	0.1 (0.1)	0.2 (0.4)	0.2 (0.4)	-	0.3 (0.8)	1.9 (2.8)
90	5.0 (8.6)	7.2 (7.7)	3.8 (5.5)	0.1 (0.1)	0.3 (0.2)	0.8 (1.4)	0.9 (1.1)	1.5 (1.4)	1.3 (1.4)	0.1 (0.1)	0.1 (0.1)	0.4 (0.5)	0.4 (2.1)	0.6 (2.3)	1.9 (3.0)

Figures in parentheses denote preponderance of weed species (%)

@ 1.0 kg a.i. ha^{-1} + IC (11.1 m^{-2}) and IC twice (14.7 m^{-2}). There was significant reduction in the number of weeds in the crop received 60 kg N ha^{-1} (4.6 m^{-2}) as compared to the crop received other N levels. The weed population was significantly lower with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC at all nitrogen levels (0 to 90 kg N ha^{-1}) as compared to that of unweeded check at no nitrogen level.

At 60 DAS, the crop received metolachlor @ 1.0 kg a.i. ha^{-1} + IC resulted in significantly lowest weed density on the other hand unweeded check recorded highest density (18.2 and 176.0 m^{-2} respectively). Total number of weeds m^{-2} were significantly lowest and were at par in the crop applied with 30 and 60 kg N ha^{-1} (7.2 and 7.0 m^{-2}, respectively). The highest weed population was observed in the crop received no nitrogen and 90 kg N ha^{-1} (68.5 and 67.0 m^{-2}, respectively), and the weed density in these two treatments was at par with each other. The weed density was significantly lowest with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC at all nitrogen levels i.e. from 0 to 90 kg ha^{-1} when compared to weed density observed with unweeded check at no nitrogen applied.

At harvest, the lowest weed density was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC or fluchloralin @ 1.0 kg a.i. ha^{-1} + IC or metolachlor @ 1.0 kg a.i. ha^{-1} + IC, which were on par with each other. The highest weed density was observed in unweeded crop. Among nitrogen levels, the lowest weed density (64.8 m^{-2}) was observed in the crop received 90 kg N ha^{-1} followed by that applied with 60 and 30 kg N ha^{-1} (72.1 and 76.3 m^{-2}, respectively). Fluchloralin applied

Table 2 : Effect of weed control treatments, nitrogen levels and their interactions on total weed density (No. m^{-2}) at different stages of soybean

Treatments	30 DAS						60 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})																		
0	3.3 (10.3)	2.7 (7.0)	3.0 (8.7)	4.4 (18.7)	13.0 (169.3)	5.2 (42.8)	5.1 (25.7)	6.8 (46.3)	4.3 (18.3)	7.5 (55.3)	14.0 (197.0)	7.5 (68.5)	8.3 (68.7)	9.8 (95.0)	7.9 (62.0)	10.9 (118.7)	13.7 (186.7)	10.1 (106.2)
30	3.6 (12.3)	2.7 (7.0)	2.5 (6.0)	3.9 (15.0)	12.5 (157.0)	5.0 (39.4)	4.7 (21.3)	6.7 (44.0)	4.2 (17.7)	7.6 (57.0)	13.3 (175.7)	7.2 (63.1)	7.1 (51.0)	7.8 (60.0)	7.3 (53.3)	9.6 (92.0)	11.2 (125.3)	8.6 (76.3)
60	3.1 (9.3)	3.1 (9.0)	2.7 (6.7)	3.4 (11.0)	10.7 (114.3)	4.6 (30.0)	5.3 (27.7)	6.8 (45.7)	4.2 (18.0)	7.0 (48.7)	12.0 (144.7)	7.0 (56.9)	7.9 (62.0)	6.9 (47.3)	7.7 (58.7)	8.9 (78.0)	10.7 (115.0)	8.4 (72.1)
90	3.6 (12.7)	3.6 (12.7)	3.0 (8.3)	3.8 (14.3)	11.7 (135.7)	5 1 (36.7)	5.4 (29.0)	7.2 (51.7)	4.4 (19.0)	7.0 (48.7)	13.7 (187.0)	7.5 (67.0)	7.8 (61.0)	5.9 (34.0)	7.7 (58.7)	8.2 (67.0)	10.2 (103.7)	7.9 (64.8)
Mean	3.4 (11.1)	3.0 (8.9)	2.7 (7.4)	3.8 (14.7)	11.9 (144.0)	-	5 1 (25.9)	6.8 (46.9)	4.3 (18.2)	7.2 (52.4)	13.2 (176.0)	-	7.8 (60.6)	7.5 (59.0)	7.6 (58.0)	9.3 (88.9)	11.4 (132.6)	-

Data in the parentheses denote the absolute values before square root transformation

	30 DAS S.Ed. ±	30 DAS C.D (0.05)	60 DAS S.Ed. ±	60 DAS C.D (0.05)	Harvest S.Ed. ±	Harvest C.D (0.05)
Weed control treatments	0.1	0.3	0.3	0.7	0.2	0.5
Nitrogen levels	0.1	0.3	0.1	0.3	0.1	0.3
Difference between two nitrogen level means at same level of weed control treatment	0.3	0.6	0.3	0.6	0.3	0.7
Difference between two weed control treatment means at same or different nitrogen levels	0.2	0.5	0.5	1.2	0.4	0.9

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@ 1.0 kg a.i. ha^{-1} + IC at 90 kg N ha^{-1} recorded lowest weed density when compared all other weed control treatments.

4.2.3 Dry matter production of weeds (g m^{-2})

The dry matter production of weeds at 25, 50 and 75 DAS and harvest was significantly influenced by the weed control treatments, nitrogen levels and their interactions (Table 3 and Fig. 3). In general, the dry mater production of weeds increased upto 75 DAS and declined thereafter. Under weed control treatments, the weed dry matter was significantly higher in unweeded crop and at 90 kg N ha^{-1}.

Application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC, pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC significantly reduced the dry matter production of weeds at 25 DAS (11.6, 12.0 and 15.5 g m^{-2} respectively) and were on par with each other. Among the N levels, the lowest dry matter was observed in the crop received no nitrogen (13.6 g m^{-2}), which was followed by that applied with 30 kg N ha^{-1} (18.2 g m^{-2}). The highest weed dry matter was observed with application of 60 and 90 kg N ha^{-1} and the dry matter observed in these treatments was on par with each other. The dry weight of weeds was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC with 30 kg N ha^{-1} as compared to that in metolachlor @ 1.0 kg a.i. ha^{-1} + IC at 60 and 90 kg N ha^{-1}.

Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC significantly reduced the weed dry matter production (23.1 and 23.7 g m^{-2} respectively) at 50 DAS as compared to that of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice treatments (35.4 and 34.2 g m^{-2} respectively). The weed dry matter in latter two treatments was on par with each other. There was significant increase in dry weight of weeds with increase in level of nitrogen from 0 to 30, 60 and 90 kg N ha^{-1}. The dry matter production was significantly lowest on application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC at 30 kg N ha^{-1}, when compared to other weed control treatments.

Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice resulted in significantly lower weed dry matter (86.6, 87.6, 94.7 and 98.3 g m^{-2} respectively) at 75 DAS. The weed dry matter in these treatments was on par with each other. The weed dry matter among different nitrogen levels followed the same trend as that observed at 50 DAS. Dry matter accumulation was significantly lowest with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC at all nitrogen levels (0 to 90 kg N ha^{-1}) as compared to other interaction effects between weed control treatments and nitrogen levels.

At harvest, the dry matter accumulation of weeds under different weed control treatments followed the same pattern as that observed at 75 DAS. With increase in nitrogen levels from 0 to 90 kg N ha^{-1}, there was significant increase in weed dry matter. However, the difference between the crop received 0, 30 and 60 kg N ha^{-1} was not significant. At harvest, all weed control treatments significantly reduced the weed dry matter under all nitrogen levels from 0 to 90 kg N ha^{-1}.

Table 3: Effect of weed control treatments, nitrogen levels and their interactions on dry matter production of weeds (g m^{-2}) at different stages of soybean

Treatments	Weed control treatments																							
	25 DAS						50 DAS						75 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})																								
0	7.5	7.9	8.1	17.6	27.3	13.6	16.5	20.3	17.1	24.7	110.7	37.8	70.0	72.0	73.7	72.1	190.3	95.6	44.5	53.7	45.5	64.3	138.9	69.3
30	12.3	11.1	14.0	18.8	34.9	18.2	21.3	30.5	25.1	29.6	148.7	51.0	89.1	87.0	85.9	95.1	287.0	128.8	41.2	45.1	38.7	50.7	216.6	78.4
60	14.3	24.1	12.5	24.4	37.3	22.5	26.0	43.5	23.6	43.1	161.2	59.4	92.3	94.8	90.1	106.7	373.0	151.3	32.7	33.3	35.6	43.3	320.7	93.1
90	14.3	19.2	11.7	27.5	41.6	22.8	28.7	47.5	29.3	39.6	186.9	66.4	95.2	125.0	101.0	119.3	456.3	179.3	42.4	50.3	40.7	39.1	384.4	111.3
Mean	12.0	15.5	11.6	22.0	35.2		23.1	35.4	23.7	34.2	151.8		86.6	94.7	87.6	98.3	326.6		40.2	45.6	40.1	49.3	265.1	

	25 DAS S.Ed. ±	25 DAS C.D (0.05)	50 DAS S.Ed. ±	50 DAS C.D (0.05)	75 DAS S.Ed. ±	75 DAS C.D (0.05)	Harvest S.Ed. ±	Harvest C.D (0.05)
Weed control treatments	1.9	4.3	2.8	6.5	6.3	14.5	9.4	21.6
Nitrogen levels	1.1	2.3	1.9	3.9	7.2	14.8	6.5	13.2
Difference between two nitrogen level means at same level of weed control treatment	2.6	5.2	4.3	8.8	16.2	33.1	14.5	29.6
Difference between two weed control treatment means at same or different nitrogen levels	3.5	7.4	5.3	11.4	13.6	28.3	17.8	38.0

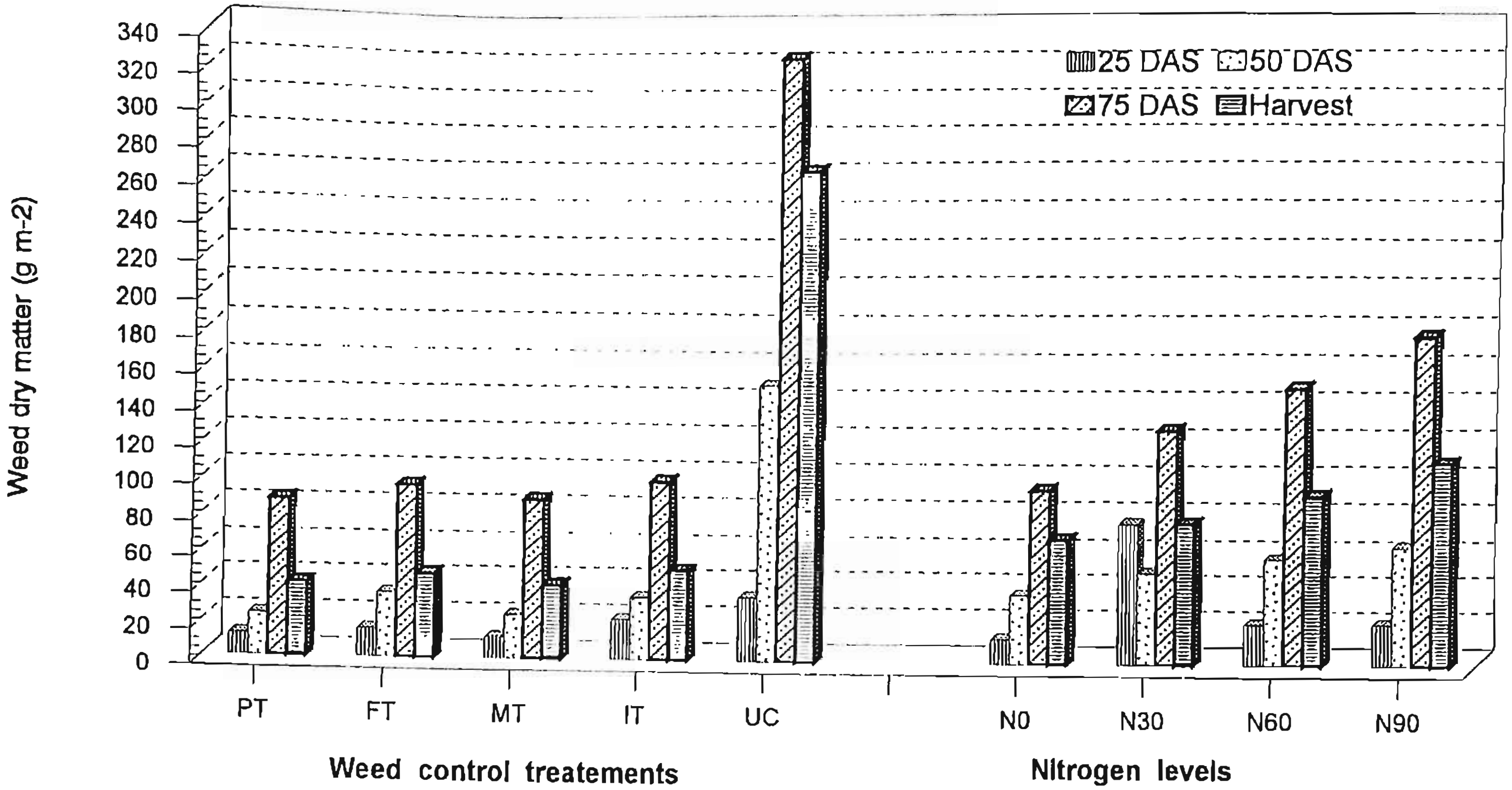

Fig. 3 : Weed dry matter (g m^{-2}) as influenced by weed control treatments and nitrogen levels

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4.2.4 Weed control efficiency (%)

The weed control efficiency (WCE) was significant at 25 DAS and at harvest due to weed management, nitrogen levels and their interaction (Fig. 4).

Maximum weed control efficiency at 25 DAS was observed with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC (67.1 %) which was significantly superior to that of IC twice (36.8 %) and on par with that received pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (65.7 %) and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (57.1 %). Among nitrogen levels, the WCE was significantly higher with no nitrogen application (61.8 %) as compared to 60 and 90 kg N ha^{-1}. The WCE in the former treatment was on par with 30 kg N ha^{-1} (59.0 %) and it was not significant between the latter two treatments. The WCE was significantly higher with application of pendimethalin + IC from 0 to 90 kg N ha^{-1} and was on par with metolachlor @ 1.0 kg a.i. ha^{-1} + IC at all nitrogen levels.

The weed control efficiency was significantly higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at all nitrogen levels applied to the crop, as compared to that observed under other weed control treatments, but remained on par with metolachlor @ 1.0 kg a.i. ha^{-1} + IC when integrated with nitrogen from 0 to 90 kg N ha-1 (Table 4a).

Weed control efficiency at 50 DAS was significantly higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (84.8 %) and it was on par with that received metolachlor @ 1.0 kg a.i. ha^{-1} + IC (84.3 %). The WCE in these treatments was superior to that observed in the plot

Table 4a : Effect of weed control treatments, nitrogen levels and their interactons on weed control efficiency (%) at 25 DAS in soybean

Treatments	Weed contol treatments					
Nitrogen levels (kg ha^{-1})	PT	FT	MT	IT	UC	Mean
0	58.3 (72.1)	57.7 (70.7)	57.3 (70.5)	35.3 (34.1)	-	52.1 (61.8)
30	53.2 (63.8)	55.5 (67.9)	50.7 (59.8)	41.9 (44.7)	-	50.3 (59.0)
60	52.3 (61.8)	36.5 (35.4)	55.1 (66.5)	35.9 (34.5)	-	44.9 (49.5)
90	54.0 (65.3)	47.6 (54.5)	58.7 (71.7)	35.6 (33.9)	-	48.9 (56.3)
Mean	54.6 (65.7)	49.3 (57.1)	55.4 (67.1)	37.1 (36.8)	-	

Data in the parentheses denote the absolute values before angular transformation

	S.Ed±	CD(0.05)
Weed control treatments	3.5	8.1
Nitrogen levels	2.0	4.1
Difference between two nitrogen level means at same level of weed control treatment	4.4	9.1
Difference between two weed control treatment means at same or different nitrogen levels	6.5	14.0

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received fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (77.5 %) and IC twice (77.4 %), which were on par with each other. Nitrogen levels did not significantly influence the weed control efficiency (Table 4b).

The WCE at 75 DAS was significantly higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (71.6 %) as compared to that applied with metolachlor @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice (71.3, 69.4 and 68.5 % respectively), which were at par with each other. Among nitrogen levels, the crop received 90 kg N ha^{-1} resulted in significantly higher WCE (60.6 %) as compared to other levels except that observed with application of 60 kg N ha^{-1} (Table 4b).

At harvest, the WCE among different weed control treatments was not significant (Table 4c). Application of 90 kg N ha^{-1} significantly improved the weed control efficiency (88·7 %) as compared to that observed in 30 kg N ha^{-1} and no nitrogen applied crop. Significantly lowest WCE was observed with no nitrogen application (62·6 %). The higher WCE was observed in all weed control treatments with nitrogen applied at 60 and 90 kg ha^{-1} over no nitrogen and 30 kg N ha^{-1} under the same treatments.

4.2.5 Nutrient uptake by weeds

4.2.5.1 Nitrogen uptake (kg ha^{-1})

The nitrogen uptake increased with the advancement of crop upto 75 DAS and thereafter declined (Table 5 and Fig. 5). The nitrogen uptake by weeds was significantly influenced by the weed control treatments, nitrogen levels and by their interaction. In general the uptake increased progressively

Table 4b : Effect of weed control treatments and nitrogen levels on weed control efficiency (%) at 50 and 75 DAS in soybean

Treatments	50 DAS	75 DAS
Weed control treatments		
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	67.1 (84.8)	58.0 (71.6)
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	61.8 (77.5)	56.6 (69.4)
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	66.7 (84.3)	57.8 (71.3)
Intercultivation with push-hoe at 20 and 40 DAS	61.7 (77.4)	56.0 (68.5)
Unweeded check	-	-
S.Ed±	0.9	0.8
CD(0.05)	2.1	1.9
Nitrogen levels (kg ha-1)		
0	52.2 (65.8)	41.7 (49.6)
30	52.0 (65.5)	44.9 (55.0)
60	50.3 (63.1)	47.7 (59.4)
90	51.4 (64.7)	48.4 (60.6)
S.Ed±	0.7	1.3
CD (0.05)	NS	2.7
W x N	NS	NS

Data on parenthesis denote the absolute values before angular transformation

Table 4c : Effect of weed control treatments, nitrogen levels and their interactions on weed control efficiency (%) at harvest in soybean

Treatments	Weed contol treatments					
	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})						
0	56.1 (68.4)	51.6 (61.5)	55.0 (67.0)	47.2 (53.8)	-	52.4 (62.6)
30	64.1 (81.0)	63.4 (79.2)	65.2 (82.3)	61.5 (76.1)	-	63.5 (79.6)
60	71.3 (89.6)	71.3 (89.6)	70.7 (88.9)	67.9 (85.1)	-	70.3 (88.3)
90	70.6 (88.9)	69.0 (86.8)	71.1 (89.3)	71.4 (89.8)	-	70.5 (88.7)
Mean	65.5 (81.9)	63.8 (79.2)	65 5 (81.8)	61.9 (76.1)	-	

Data in the parentheses denote the absolute values before angular transformation

	S.Ed±	CD(0.05)
Weed control treatments	2 5	5.9
Nitrogen levels	1.4	2.9
Difference between two nitrogen level means at same level of weed control treatment	3.2	6.5
Difference between two weed control treatment means at same or different nitrogen levels	4.7	10.1

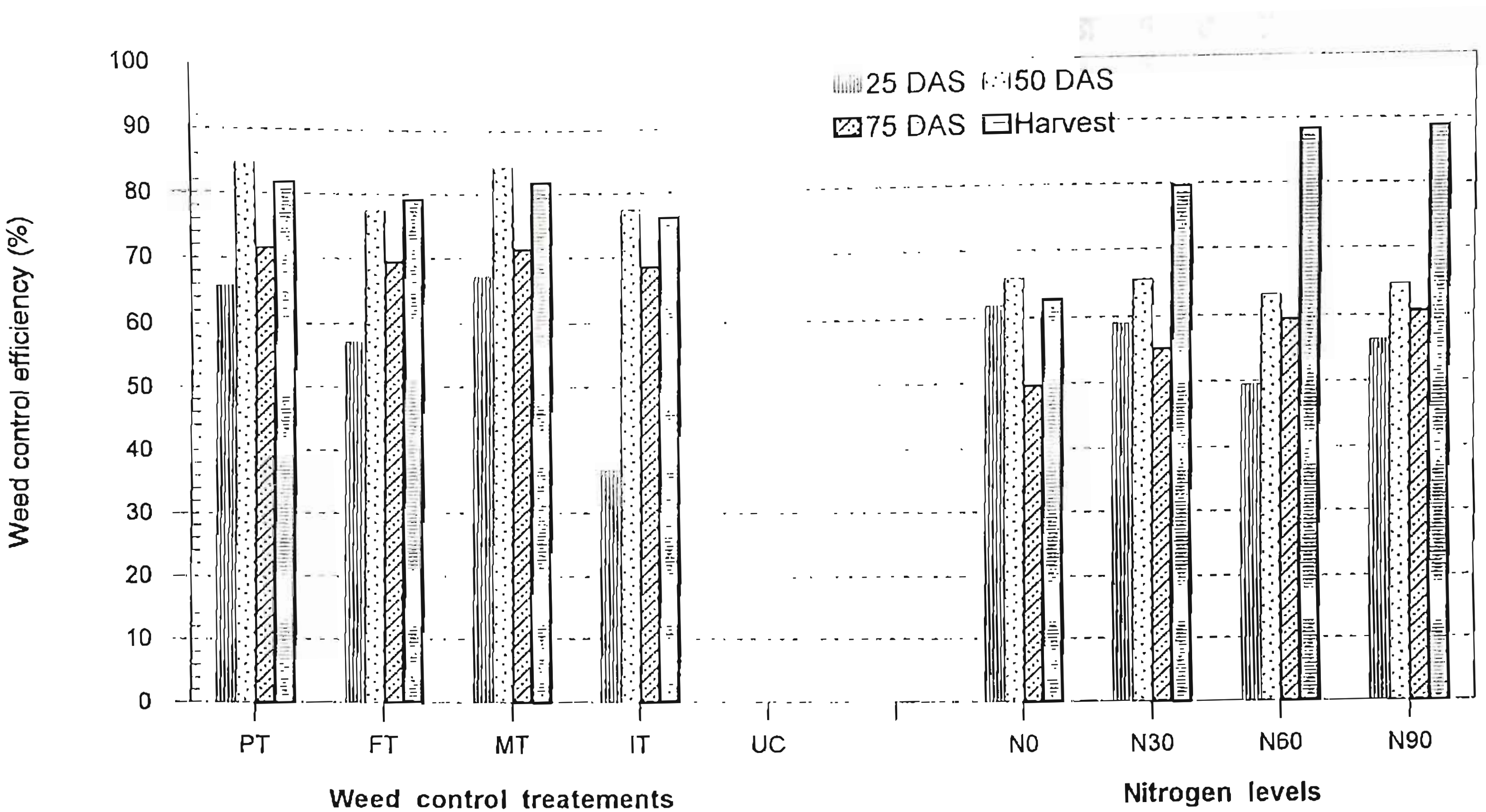

Fig. 4 : Weed control efficiency (%) as influenced by weed control treatments and nitrogen levels

with successive increments in nitrogen levels. In unweeded crop significantly higher N uptake was observed with application of 90 kg N ha^{-1}.

The nitrogen uptake by weeds at 25 DAS was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (2.5 kg ha^{-1}) compared to that received fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (3.4 kg ha^{-1}), IC twice (4.4 kg ha^{-1}) and unweeded check (7.4 kg ha^{-1}). The uptake in these treatments was on par with that applied with metolachlor @ 1.0 kg a.i. ha^{-1} + IC (2.7 kg ha^{-1}). Among the nitrogen levels, significantly lowest uptake of nitrogen was observed with no nitrogen application (2.6 kg ha^{-1}) as compared to that of 30 (3.8 kg ha^{-1}), 60 (4.9 kg ha^{-1}) and 90 (5.0 kg ha^{-1}) kg N ha^{-1}. The uptake in latter two treatments was on par with each other. Among weed control treatments, the uptake of nitrogen by weeds was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC at zero and 30 kg N ha^{-1} over remaining nitrogen levels.

The N uptake by weeds at 50 DAS followed similar trend as that observed at 25 DAS. The uptake of nitrogen by weeds was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC 0 to 60 kg N ha^{-1} as compared to that of unweeded check at 90 kg N ha^{-1}.

The N uptake by weeds at 75 DAS was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (17.2 kg ha^{-1}), metolachlor @ 1.0 kg a.i. ha^{-1} + IC (18.3 kg ha^{-1}) and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (19.9 kg ha^{-1}) compared to IC twice (40.3 kg ha^{-1}) and unweeded check (71.5 kg ha^{-1}). The nitrogen uptake due to N application was similar as that observed at 25 and 50 DAS.

Similar trend in nitrogen uptake by weeds at harvest with different weed management treatments was observed as that at 75 DAS. Among the nitrogen levels, significantly lowest N uptake was recorded with no nitrogen application (12.5 kg ha^{-1}) as compared to that of 60 (15.9 kg ha^{-1}) and 90 (18.9 kg ha^{-1}) kg N ha^{-1}. The N uptake in the former treatment was on par with that observed in 30 kg N ha^{-1} (13.7 kg ha^{-1}). Minimum uptake of nitrogen was recorded with weed management treatments at all levels of nitrogen from 0 to 90 kg ha^{-1} as compared to that of unweeded check.

4.2.5.2 Phosphorus uptake (kg ha^{-1})

The phosphorus uptake by weeds increased with advancement of crop growth upto 75 DAS and declined thereafter (Table 6). Phosphorus uptake by weeds varied significantly with weed control treatments, nitrogen levels and by their interactions.

Application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC, pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC recorded significantly lowest uptake at 25 DAS as compared to IC twice and unweeded crop. The P uptake in the former treatments was on par with each other. Among nitrogen levels, significantly lowest uptake (0.47 kg ha^{-1}) was recorded with no nitrogen application and highest uptake was observed with 90 kg N ha^{-1} (0.85 kg ha^{-1}). The interaction effect of weed control and nitrogen levels resulted in significant reduction in phosphorus uptake with all integrated weed management treatments at no nitrogen application.

Table 5: Effect of weed control treatments, nitrogen levels and their interactions on the uptake of nitrogen by weeds (kg ha^{-1}) at different stages of soybean

Treatments	Weed control treatments																							
	25 DAS						50 DAS						75 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})																								
0	1.6	1.6	1.7	2.7	5.8	2.6	3.5	4.5	3.8	10.9	24.3	9.4	10.5	15.2	15.0	30.5	41.8	22.6	6.6	13.5	12.7	13.2	16.9	12.5
30	2.6	2.5	3.0	4.0	7.4	3.8	4.7	6.8	5.5	13.1	32.7	12.5	18.6	18.1	18.1	40.9	62.1	31.5	9.0	11.3	8.3	14.2	25.9	13.7
60	3.0	5.4	3.0	5.4	7.9	4.9	5.8	9.6	5.2	19.1	35.4	15.0	19.8	20.1	19.1	42.4	82.0	36.6	7.1	8.4	12.0	13.3	38.9	15.9
90	3.0	4.3	3.2	5.8	8.8	5.0	6.5	10.5	6.5	17.5	41.1	16.4	19.9	26.6	21.3	47.4	100.3	43.1	9.3	12.7	11.8	14.2	46.7	18.9
Mean	2.5	3.4	2.7	4.4	7.4		5.1	7.8	5 20	15.1	33.3		17.2	19.9	18.3	40.3	71.5		8.0	11.4	11.2	13.7	32.1	

	S.Ed. ±	C.D (0.05)	S.Ed. ±	C.D (0.05)	S.Ed. ±	C.D (0.05)	S.Ed. ±	C.D (0.05)
Weed control treatments	0.3	0.8	0.7	1.6	1.4	3.3	2.1	4.9
Nitrogen levels	0.3	0.5	0.6	1.1	1.8	3.6	1.2	2.5
Nitrogen levels at same level of weed control treatment	0.5	1.0	1.2	2.5	3.9	8.0	2.8	5.6
Weed control treatments at name or different nitrogen levels	0.6	1.3	1.4	2.9	3.2	6.6	3.9	8.5

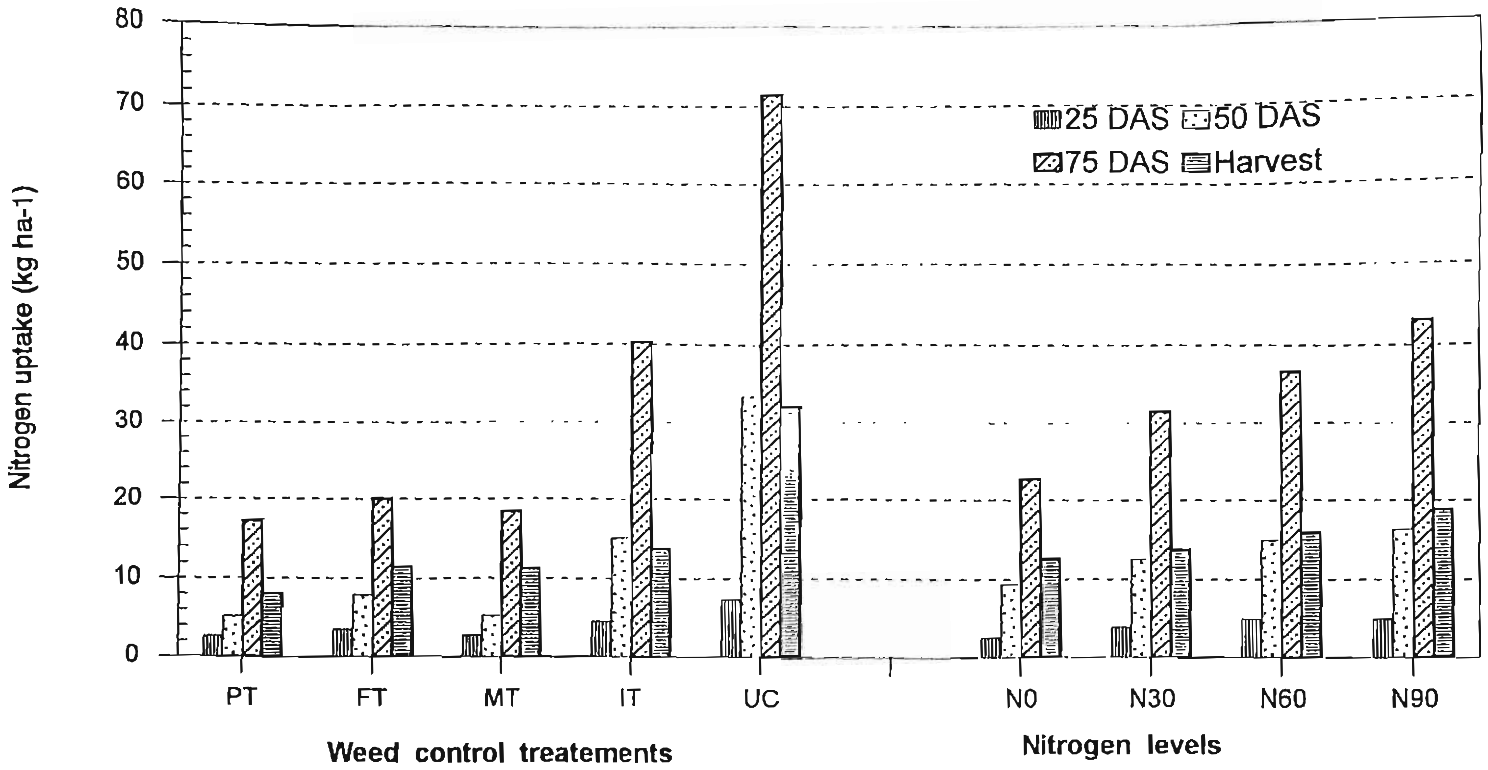

Fig. 5 : Nitrogen uptake by weeds (kg ha^{-1}) as influenced by weed control treatments and nitrogen levels

At 50 DAS, significantly lower phosphorus uptake was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC as compared to that received fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice. On the other hand, significantly higher uptake of phosphorus was observed in unweeded crop (5.25 kg ha^{-1}). The phosphorus uptake increased significantly with successive increase in nitrogen levels from zero to 90 kg N ha^{-1}. The uptake of phosphorus by weeds was lowest under all weed control treatments with no nitrogen application except that with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, which was effective upto 30 kg N ha^{-1}.

At 75 DAS, the phosphorus uptake was significantly lowest in all the herbicide applied treatments and that of IC twice. The uptake of phosphorus by weeds due to nitrogen levels followed the similar trend as that observed at 50 DAS. Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC resulted in lowest uptake of phosphorus at zero nitrogen level over other weed control treatments and nitrogen levels.

At harvest, similar trend in phosphorus uptake by weeds was observed as that of 75 DAS. Among the nitrogen levels, higher phosphorus uptake was observed with application of 60 and 90 kg N ha^{-1}, which were on par with each other and significantly superior to that observed with 30 kg N ha^{-1} and no nitrogen application. Significantly lowest phosphorus uptake by weeds was observed with all weed control treatments at higher nitrogen level of 90 kg N ha^{-1} as compared to that of unweeded check with no nitrogen application.

Table 6: Effect of weed control treatments, nitrogen levels and their interactions on the uptake of phosphorus by weeds (kg ha^{-1}) at different stages of soybean

Treatments	Weed control treatments																							
	25 DAS						50 DAS						75 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})																								
0	0.28	0.22	0.29	0.64	0.93	0.47	0.56	0.68	0.58	0.71	3.82	1.27	1.35	1.05	2.51	2.54	6.74	2.84	1.52	1.78	1.59	1.28	4.59	2.15
30	0.46	0.43	0.51	0.68	1.29	0.67	0.75	1.04	0.86	1.13	5.13	1.78	3.05	3.08	2.88	3.33	9.66	4.40	1.36	1.59	1.29	1.74	7.44	2.68
60	0.53	0.85	0.44	0.89	1.34	0.81	0.91	1.25	0.80	1.51	5.64	2.02	3.08	3.81	2.94	3.52	13.12	5.29	1.11	1.10	1.97	1.43	10.76	3.27
90	0.65	0.72	0.44	0.97	1.50	0.85	0.99	1.66	1.01	1.35	6.42	2.28	3.38	4.07	3.47	4.16	16.10	6.23	1.43	1.12	1.35	1.30	13.21	3.68
Mean	0.48	0.55	0.42	0.79	1.26		0.80	1.16	0.81	1.17	5.25		2.71	3.00	2.95	3.39	11.40		1.35	1.39	1.55	1.44	9.00	

	25 DAS S.Ed. ±	25 DAS C.D (0.05)	50 DAS S.Ed. ±	50 DAS C.D (0.05)	75 DAS S.Ed. ±	75 DAS C.D (0.05)	Harvest S.Ed. ±	Harvest C.D (0.05)
Weed control treatments	0.07	0.16	0.09	0.23	0.23	0.53	0.30	0.70
Nitrogen levels	0.04	0.08	0.06	0.13	0.24	0.49	0.22	0.45
Difference between two nitrogen level means at same level of weed control treatment	0.09	0.18	0.14	0.29	0.53	1.10	0.50	1.02
Difference between two weed control treatment means at same or different nitrogen levels	0.13	0.28	0.18	0.40	0.48	1.01	0.58	1.25

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4.2.5.3 Potassium uptake (kg ha^{-1})

Potassium uptake by weeds increased upto 75 DAS and declined thereafter towards harvest and it was significantly influenced by the weed control treatments, nitrogen levels and by their interactions (Table 7). In general, unweeded check recorded highest potassium uptake at all stages of sampling.

At 25 DAS, the potassium uptake was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (1.8 kg ha^{-1}) as compared to that of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (2.7 kg ha^{-1}), IC twice (2.7 kg ha^{-1}) and unweeded control (6.2 kg ha^{-1}). The potassium uptake in the former treatment was on par with that observed with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC (1.9 kg ha^{-1}). Significantly lower potassium uptake was observed with no nitrogen application as compared to that of N application. The potassium uptake in the crop received 30, 60 and 90 kg N ha^{-1} was on par. The uptake of potassium by weeds was significantly lower with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC upto 30 kg N ha^{-1} over other weed control treatments and nitrogen levels.

Pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC resulted significantly in lowest uptake of potassium (2.9 kg ha^{-1}) at 50 DAS as compared to all other weed management treatments. Significantly higher uptake was observed with unweeded check (25.9 kg ha^{-1}). With increase in nitrogen level from 0 to 90 kg N ha^{-1} there was significant increase in potassium uptake by weeds. The interaction effect of application of pendimethalin

@ 1.0 kg a.i. ha^{-1} + IC from 0 to 60 kg N ha^{-1} significantly decreased potassium uptake as compared to that of application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC 0 to 30 kg N ha^{-1}.

At 75 DAS, significantly low potassium uptake by weeds was observed in the crop received integrated weed management with herbicides, pendimethalin, metolachlor, fluchloralin and IC twice. Highest potassium uptake by weeds was observed in unweeded crop (33.2 kg ha^{-1}). The potassium uptake by weeds was significantly higher at 90 kg N ha^{-1} (20.6 kg ha^{-1}) over that of 30 kg N ha^{-1} (17.7 kg ha^{-1}) and was on par with that of 60 kg N ha^{-1} (19.8 kg ha^{-1}). The integrated weed management treatments resulted in significantly lower removal of potassium by weeds at 90 kg N ha^{-1} compared to that of unweeded check at no nitrogen application.

At harvest, all the weed control treatments resulted in significantly low potassium uptake as compared to that in unweeded crop. Nitrogen levels followed the similar trend as that observed at 75 DAS. The potassium uptake was significantly least with all weed control treatments at 90 kg N ha^{-1} as compared to that of unweeded treatment at zero nitrogen application.

4.3 OBSERVATIONS ON CROP GROWTH

4.3.1 Germination (%)

The crop germination was significantly influenced by the weed control treatments (Table 8), while nitrogen levels and their interaction did not have significant influence. The germination was significantly lower with application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (86.7 %) as compared to that observed in other treatments.

Table 7: Effect of weed control treatments, nitrogen levels and their interactions on the uptake of potassium by weeds (kg ha^{-1}) at different stages of soybean

Treatments	Weed control treatments																							
	25 DAS						50 DAS						75 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})																								
0	1.0	1.4	1.4	1.6	2.7	1.6	1.6	4.0	3.3	2.6	6.5	3.5	8.2	9.7	10.5	12.3	18.7	11.8	6.6	7.3	7.4	7.3	15.14	8.7
30	1.3	3.1	1.7	2.7	7.3	3.2	2.3	6.0	3.2	5.6	27.4	8.9	14.3	17.3	12.7	14.7	29.5	17.7	9.4	7.6	8.4	7.4	26.2	11.8
60	2.0	3.3	2.0	3.3	7.5	3.6	2.6	8.6	5.2	7.1	32.4	11.1	12.6	13.8	12.3	22.2	38.5	19.8	7.0	7.5	8.3	8.8	41.1	14.5
90	3.0	3.3	2.6	3.4	7.3	3.9	5.2	8.6	5 7	8.0	37.6	13.0	14.1	15.2	14.0	13.5	46.4	20.6	9.2	10.7	8.7	7.1	44.9	16.1
Mean	1.8	2.7	1.9	2.7	6.2		2.9	6.8	4.3	5.8	25.9		12.3	13.9	12.3	15.6	33.2		8.0	8.2	8.2	7.6	31.8	

	25 DAS S.Ed. ±	25 DAS C.D (0.05)	50 DAS S.Ed. ±	50 DAS C.D (0.05)	75 DAS S.Ed. ±	75 DAS C.D (0.05)	Harvest S.Ed. ±	Harvest C.D (0.05)
Weed control treatments	0.3	0.8	0.5	1.2	0.8	1.7	1.4	3.3
Nitrogen levels	0.2	0.4	0.3	0.7	0.9	1.8	0.8	1.7
Difference between two nitrogen level means at same level of weed control treatment	0.4	0.9	0.8	1.6	2.0	4.1	1.9	3.8
Difference between two weed control treatment means at same or different nitrogen levels	0.6	1.4	1.0	2.2	1.6	3.4	2.7	5.8

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4.3.2 Phytotoxicity scoring

Pre-plant incorporation of fluchloralin @ 1.0 kg a.i. ha^{-1} showed phytotoxic symptoms on crop at 10 DAS and crop injury score of 3.5 (Table 8). Subsequently, the phytotoxic effect disappeared and the crop resumed normal growth by 30 DAS.

4.3.3 Plant height (cm)

The plant height did not vary significantly among the different weed control treatments at 30 DAS. Among the nitrogen levels, maximum plant height of 20 cm was observed in the crop received 90 kg N ha^{-1}, which was significantly superior to that applied with 0, 30 and 60 kg N ha^{-1}. Significantly lower plant height was recorded in the crop received no nitrogen (17.1 cm) (Table 9a).

At 60 DAS, the plant height was significantly higher in unweeded check (58.9 cm) as compared to that observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (52.5 cm) and metolachlor @ 1.0 kg a.i. ha^{-1} + IC (51.6 cm) and IC twice (49.9 cm). Significantly lowest plant height was observed in the crop applied with fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (47.4 cm). Nitrogen application significantly increased the plant height similar to that observed at 30 DAS. The interaction effect of Weed management and N levels indicated that the plant height observed under unweeded check at 30 kg N ha^{-1} was on par with the plant height obtained with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC and IC twice at 90 kg N ha^{-1} (Table 9b).

Table 8: Effect of weed control treatments and nitrogen levels on germination (%) and phytotoxicity scoring in soybean

Treatments	Germination	Phytotoxicity scoring	
		10 DAS	30 DAS
Weed control treatments			
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	70.9 (89.1)	0	0
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	68.7 (86.7)	3.5	0
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	71.1 (89.4)	0	0
Intercultivation with push-hoe at 20 and 40 DAS	70.8 (89.0)	0	0
Unweeded check	70.9 (89.2)	0	0
S.Ed±	0.6	-	-
CD(0.05)	1.5	-	-
Nitrogen levels (kg ha-1)			
0	70.3 (88.5)	0	0
30	71.1 (89.4)	0	0
60	70.5 (88.6)	0	0
90	70.1 (88.3) -	0	0
S.Ed±	1.0	-	-
CD (0.05)	NS	-	-
W x N	NS	-	-

Data in the parentheses denote the absolute values before angular transformation

Table 9a : Effect of weed control treatments and nitrogen levels on plant height (cm) at 30 DAS in soybean

Treatments	30 DAS
Weed control treatments	
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	19.1
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	18.1
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	18.1
Intercultivation with push-hoe at 20 and 40 DAS	18.8
Unweeded check	19.1
S.Ed±	0.7
CD(0.05)	NS
Nitrogen levels (kg ha-1)	
0	17.1
30	18.4
60	19.1
90	20.0
S.Ed±	0.2
CD (0.05)	0.5
W x N	NS

At harvest, the plant height of the crop among different weed management treatments differed significantly from each other. With increase in levels of nitrogen from 0 to 90 kg ha^{-1}, there was an increase in plant height, which differed significantly from each other. Interaction between weed control treatments and nitrogen levels on plant height was almost similar as that observed at 60 DAS (Table 9b).

4.3.4 Dry matter production (g plant^{-1})

The dry matter production was low at 25 DAS and increased with advancement of crop upto 75 DAS and declined towards harvest in the crop received pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC, while the accumulation continued till harvest in the crop applied with fluchloralin @ 1.0 kg a.i. ha^{-1} + IC, IC twice and unweeded check (Table 10 and Fig. 6). The interaction of weed control treatments and nitrogen levels on crop dry matter production was not significant.

The differences in dry matter production at 25 DAS was not significant between different weed control treatments and nitrogen levels.

The crop dry matter production at 50 DAS was not influenced by the weed management treatments. On the other hand, nitrogen application significantly increased the dry matter as compared to that of no nitrogen application. The dry matter of the crop was on par with each other in the crop received 30, 60 and 90 kg N ha^{-1}.

At 75 DAS, the unweeded control resulted in low dry matter production as compared to that with application of pendimethalin @ 1.0 kg a.i. ha^{-1}

Table 9b : Effect of weed control treatments, nitrogen levels and their interaction on plant height (cm) at 60 DAS and at harvest in soybean

Treatments	Weed control treatments											
	60 DAS						Harvest					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})												
0	38.8	33.6	37.9	37.5	35.1	36.5	41.0	37.3	40.2	40.1	39.0	39.5
30	51.2	47.0	50.1	49.6	60.5	51.6	57.4	54.9	56.2	55.4	65.3	57.8
60	58.1	53.1	57.7	51.7	66.3	57.3	65.6	58.5	63.6	58.6	77.1	64.6
90	62.1	55.9	61.0	60.9	74.0	62.8	69.2	61.1	67.4	66.5	84.3	69.6
Mean	52.5	47.4	51.6	49.9	58.9		58.3	52.9	56.8	55.1	66.4	

	S.Ed. ±	C.D (0.05)	S.Ed. ±	C.D (0.05)
Weed control treatments	0.5	1.3	0.6	1.3
Nitrogen levels	0.3	0.6	0.2	0.4
Nitrogen levels at same level of weed control treatment	0.6	1.3	0.4	0.9
Weed control treatments at same or different nitrogen levels	1.0	2.2	1.0	2.3

+ IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice, which were on par with each other. Among the nitrogen levels, application of 90 kg N ha^{-1} (15.6 g $plant^{-1}$) resulted in significantly higher crop dry matter over that observed with 30 kg N ha^{-1} and no nitrogen and the dry matter in the former was on par with that of 60 kg N ha^{-1} (14.8 g $plant^{-1}$). Significantly lowest dry matter production was recorded with no nitrogen application (9.4 g $plant^{-1}$).

At harvest, the dry matter production between different weed management treatments were not significant. On the other hand, application of 60 kg N ha^{-1} resulted in significantly higher dry matter over that observed with 30 kg N ha^{-1} and no nitrogen application and was on par with that of 90 kg N ha^{-1}.

4.3.5 Post-harvest observations

4.3.5.1 Pods $plant^{-1}$

The number of pods $plant^{-1}$ was significantly influenced with weed management treatments and nitrogen levels, however, there was no interaction of these on pods $plant^{-1}$ (Table 11). Significantly higher pod number $plant^{-1}$ were observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (30.6) as compared to unweeded crop (22.0). The pods $plant^{-1}$ in the crop received IC twice (29.6) and metolachlor @ 1.0 kg a.i. ha^{-1} + IC (28.6) were on par with each other and significantly superior to that of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (26.4). Among the nitrogen levels, the crop received 90 kg N ha^{-1} resulted significantly higher pod number $plant^{-1}$ (31.3) as compared to that of 30 kg N ha^{-1} (25.8) and no nitrogen applied crop

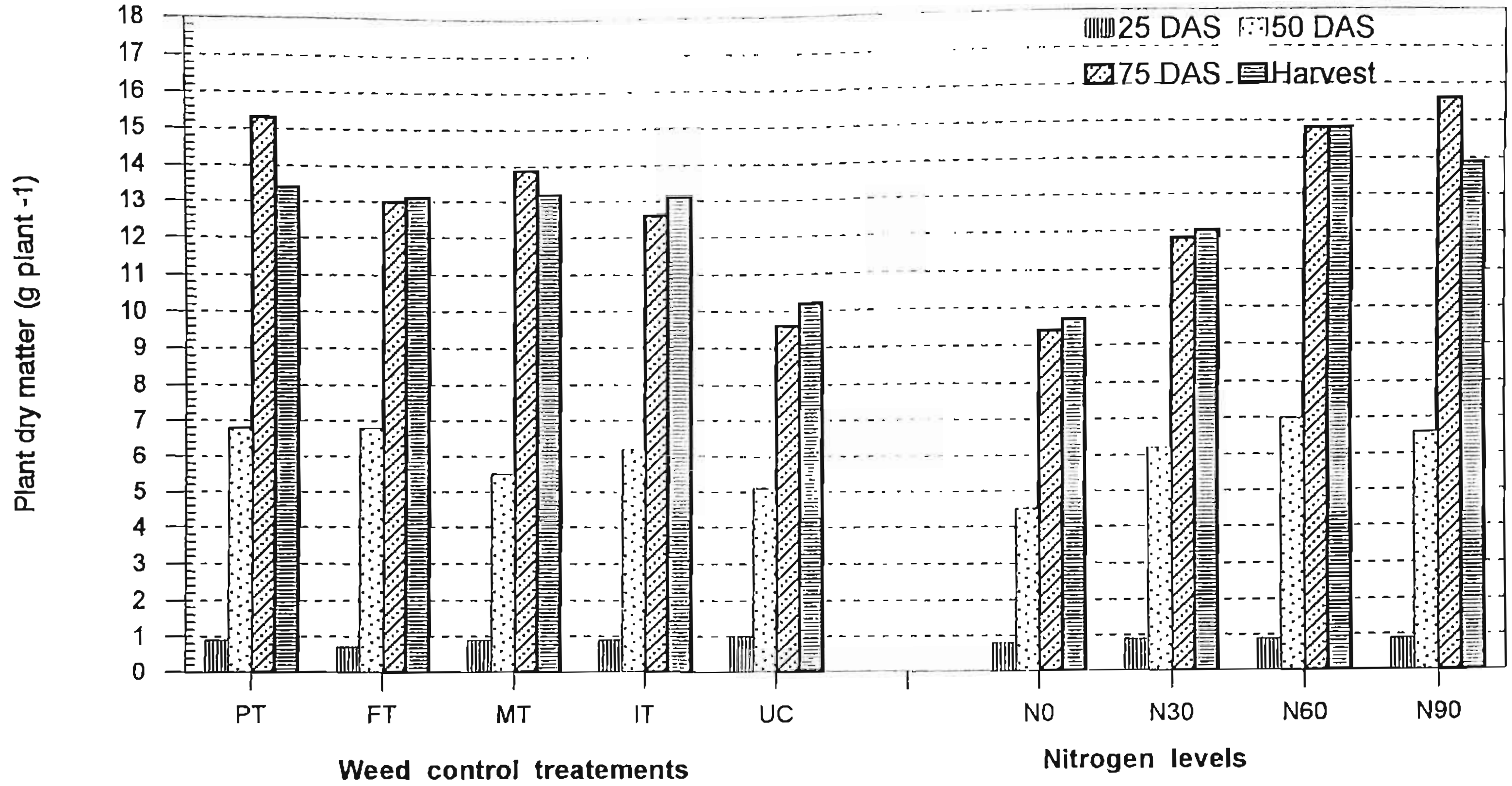

Fig. 6 : Plant dry matter (g plant^{-1}) as influenced by weed control treatments and nitrogen levels

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Table 10 : Effect of weed control treatments and nitrogen levels on dry matter production (g plant^{-1}) of soybean at 25, 50, 75 DAS and at harvest

Treatments	25 DAS	50 DAS	75 DAS	Harvest
Weed control treatments				
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.9	6.8	15.3	13.4
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.7	6.8	13.0	13.1
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.9	5.5	13.9	13.2
Intercultivation with push-hoe at 20 and 40 DAS	0.9	6.2	12.6	13.1
Unweeded check	1.0	5.1	9.6	10.2
S.Ed±	0.1	0.7	1.2	1.0
CD(0.05)	NS	NS	2.8	NS
Nitrogen levels (kg ha^{-1})				
0	0.8	4.5	9.4	9.7
30	0.9	6.2	11.8	12.0
60	0.9	7.0	14.8	14.8
90	0.9	6.6	15.6	13.9
S.Ed±	0.1	0.4	0.7	1.0
CD (0.05)	NS	0.8	1.5	2.1
W x N	NS	NS	NS	NS

(21.5), which were on par with that of 60 kg N ha^{-1} (31.2). Significantly lowest pod number was recorded with no nitrogen applied crop as compared to nitrogen application.

4.3.5.2 Seeds pod^{-1}

Significantly higher seed number pod^{-1} (2.4) was obtained with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC over rest of the weed management treatments, which were on par with each other and significantly superior to that observed in unweeded check (2.1) (Table 11). Nitrogen levels had significant effect on the seed number pod^{-1} and highest number was observed with 60 (2.3) and 90 kg N ha^{-1} (2.3), which were on par with each other and significantly superior to that observed in no nitrogen applied crop. The interaction effect of weed management and nitrogen levels on seed number pod^{-1} was not significant.

4.3.5.3 100-seed weight (g)

The 100-seed weight was not significantly influenced by the weed management treatments, nitrogen levels and their interaction (Table 11).

4.3.5.4 Seed yield (kg ha^{-1})

The effect of weed management and nitrogen levels and interaction between weed management and nitrogen levels on seed yield was found significant (Table 12 and Fig. 7).

Among the weed management treatments, higher seed yield was recorded with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (1086 kg ha^{-1}) followed by IC twice (1033 kg ha^{-1}) and metolachlor application

Table 11 : Effect of weed control treatments and nitrogen levels on pods $plant^{-1}$, Seeds pod^{-1} and 100-seed weight in soybean

Treatments	Pods $plant^{-1}$	Seeds pod^{-1}	100-seed weight (g)
Weed control treatments			
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	30.6	2.4	12.3
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	26.4	2.3	12.4
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	28.6	2.3	12.4
Intercultivation with push-hoe at 20 and 40 DAS	29.6	2.3	12.4
Unweeded check	22.0	2.1	12.3
S.Ed±	0.8	0.03	0.2
CD(0.05)	1.8	0.08	NS
Nitrogen levels (kg ha-1)			
0	21.5	2.1	12.3
30	25.8	2.2	12.4
60	31.2	2.3	12.3
90	31.3	2.3	12.5
S.Ed±	1.2	0.03	0.2
CD (0.05)	2.4	0.08	NS
W x N	NS	NS	NS

@ 1.0 kg a.i. ha^{-1} + IC (1031 kg ha^{-1}), which were on par with each other and significantly superior to that obtained with application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (839 kg ha^{-1}). Significantly lower seed yield was observed in the crop received no weeding (589 kg ha^{-1}) as compared to other weed management treatments.

Among the nitrogen levels, significantly the higher yield was recorded with application of 60 kg N ha^{-1} (1070 kg ha^{-1}), which was on par with that of 90 kg N ha^{-1} (1037 kg ha^{-1}). The yield obtained with no nitrogen application (685 kg ha^{-1}) was significantly lowest as compared to all other N levels. The seed yield observed with 30 kg N ha^{-1} was significantly higher than that observed with no nitrogen application.

The seed yield obtained with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (837 kg ha^{-1}), metolachlor @ 1.0 kg a.i. ha^{-1} + IC (813 kg ha^{-1}) and IC twice (767 kg ha^{-1}) at no nitrogen application was on par with the yield of the crop with no weeding at 90 kg N ha^{-1} (827 kg ha^{-1}). Significantly higher seed yield was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (1324 kg ha^{-1}), which was on par with that observed in the crop received metolachlor @ 1.0 kg a.i. ha^{-1} + IC (1288 kg ha^{-1}) at 60 kg N ha^{-1} and with IC twice (1226 kg ha^{-1}) applied with 90 kg N ha^{-1}.

4.3.5.5 Weed index (W.I %)

Weed index indicates per cent reduction in grain yield due to weed competition. The weed index varied significantly among the weed management

Table 12 : Effect of weed control treatments, nitrogen levels and their interactions on seed yield (kg ha^{-1}) of soybean

Treatments	Weed contol treatments					
	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})						
0	837	668	813	767	339	685
30	1030	778	982	1031	527	870
60	1324	970	1288	1108	661	1070
90	1152	940	1039	1226	827	1037
Mean	1086	839	1031	1033	589	-

	S.Ed±	CD(0.05)
Weed control treatments	29.1	67.2
Nitrogen levels	23.9	48.7
Difference between two nitrogen level means at same level of weed control treatment	53.4	109.0
Difference between two weed control treatment means at same or different nitrogen levels	57.1	120.9

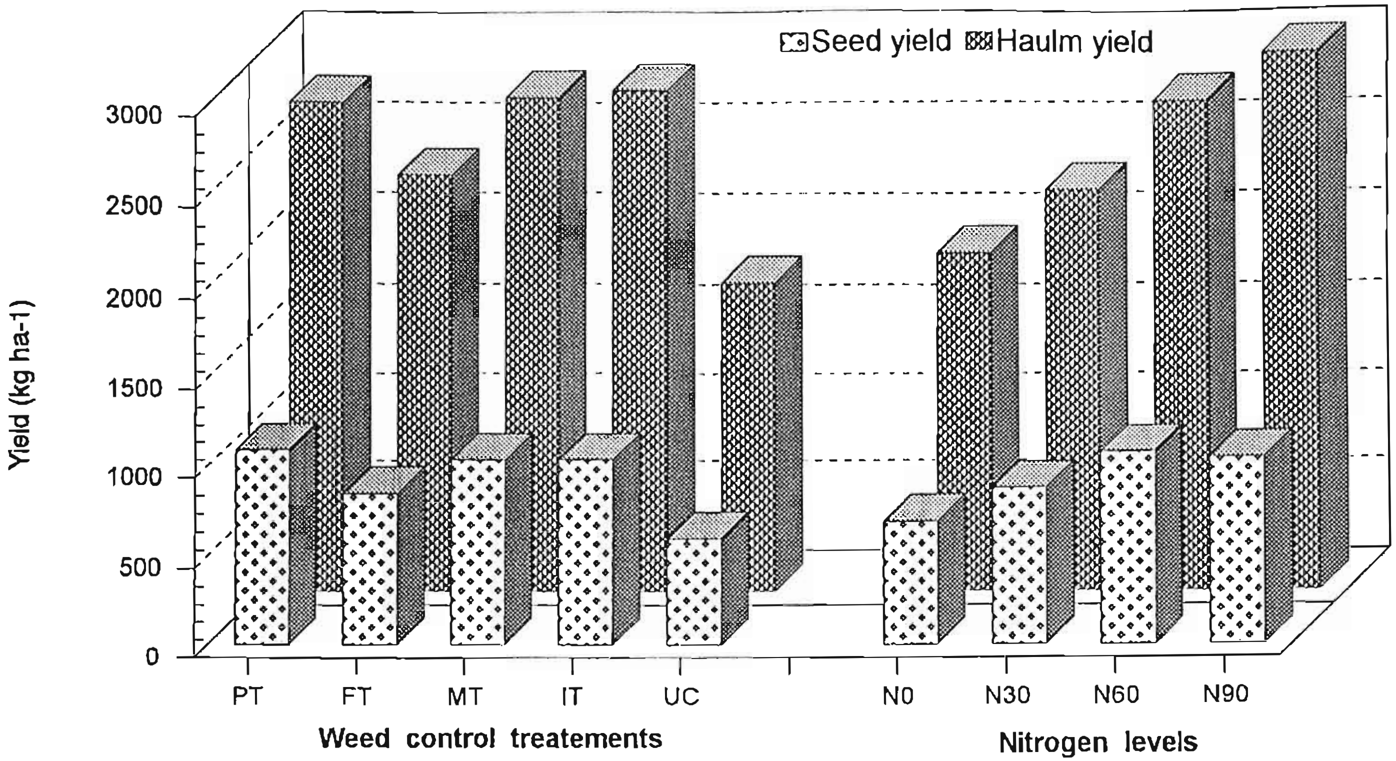

Fig. 7 : Seed and haulm yields (kg ha^{-1}) as influenced by weed control treatments and nitrogen levels

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treatments and it did not differ significantly among the nitrogen levels, while their interaction was significant (Table 13).

Significantly lowest weed index (2.6 %) was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, which was followed by that received metolachlor @ 1.0 kg a.i. ha^{-1} + IC (7.4 %), IC twice (8.0 %) and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (24.3 %). Unweeded control recorded significantly the highest weed index (48.2 %) among the weed management treatments. Significantly lowest (0.5 %) weed index was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at 60 kg N ha^{-1}, while the highest (60.1 %) was recorded in unweeded control at no nitrogen application.

4.3.5.6 Integrated weed management index (IWMI %)

IWMI varied significantly with weed management treatments, nitrogen levels and their interaction (Table 13).

Among weed management treatments, higher IWMI was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (46.6 %), which was on par with that observed in metolachlor @ 1.0 kg a.i. ha^{-1} + IC (43.3 %) and the lowest IWMI value (30.9 %) was observed with application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC. Among the nitrogen levels, significantly highest and lowest IWMI values were observed with application of no nitrogen (55.2 %) and 90 kg N ha^{-1} (20.1 %) respectively. Significantly higher IWMI was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at no nitrogen (59.5 %) and 60 kg N ha^{-1} (50.0 %), which was on par with that received metolachlor @ 1.0 kg a.i. ha^{-1} + IC at no nitrogen

Table 13: Effect of weed control treatments, nitrogen levels and their interactions on weed index (WI) and integrated weed management index (IWMI) in soybean

Treatments	Weed Index (%)						Integrated weed management index (%)					
	Weed contol treatments						Weed control treatments					
	PT	FT	MT	IT	UC	Mean	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})												
0	5.5 (1.4)	22.4 (20.6)	11.4 (4.2)	14.3 (9.5)	50.9 (60.1)	20.9 (19.1)	50 6 (59.5)	43.9 (48.1)	49.8 (58.2)	-	-	48.1 (55.2)
30	7.4 (2.5)	30.9 (26.3)	14.7 (6.9)	10.5 (4.9)	45 0 (50.0)	21.7 (18.1)	44.3 (48.8)	34.4 (32.1)	42.9 (46.4)	-	-	40.5 (42.4)
60	2.2 (0.5)	31.3 (27.0)	7.7 (3.1)	24.1 (16.7)	45.1 (50.2)	22 1 (19.5)	45 0 (50.0)	34.2 (31.7)	44.1 (48.5)	-	-	41.1 (43.4)
90	10.3 (6.4)	28.9 (23.6)	22.8 (15.6)	3.4 (1.0)	34.9 (32.8)	20.1 (15.9)	32.0 (28.1)	20.3 (12.0)	26.8 (20.4)	-	-	26.3 (20.1)
Mean	6.3 (2.6)	28.3 (24.3)	14.1 (7.4)	13.0 (8.0)	43.9 (48.2)		42.9 (46.6)	33.1 (30.9)	40.9 (43.3)	-	-	

Data in the parentheses denote the absolute values

	S.Ed. ±	C.D (0.05)	S.Ed. ±	C.D (0.05)
Weed control treatments	3.2	7.3	1.4	3.3
Nitrogen levels	2.9	NS	1.3	2.7
Difference between two nitrogen level means at same level of weed control treatment	6.5	13.3	3.0	6.1
Difference between two weed control treatment means at same or different nitrogen levels	6.4	13.5	2.9	6.1

level (58.2 %). On the other hand, lowest IWMI was observed with application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC at 90 kg N ha^{-1} (12.0 %).

4.3.5.7 Haulm yield (kg ha^{-1})

Significant differences among the weed management and nitrogen levels on haulm yield was observed but their interaction was not significant (Table 14 and Fig. 7).

Among the weed management treatments, significantly higher haulm yield (2791 kg ha^{-1}) was recorded with IC twice over that received fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (2317 kg ha^{-1}) and no weeding (1734 kg ha^{-1}). The haulm yield in this treatment was on par with that applied with metolachlor @ 1.0 kg a.i. ha^{-1} + IC (2752 kg ha^{-1}) and pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (2719 kg ha^{-1}). Among the nitrogen levels, significantly higher haulm yield was obtained with application of 90 kg N ha^{-1} (2988 kg ha^{-1}) as compared to that of 30 kg N ha^{-1} (2237 kg ha^{-1}) and no nitrogen application (1897 kg ha^{-1}) but was on par with that obtained in the crop received 60 kg N ha^{-1} (2728 kg ha^{-1}).

4.3.5.8 Harvest index (%)

The harvest index significantly differed among the weed management, nitrogen levels and their interactions (Table 15). The harvest index obtained with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (39.9 %) was significantly higher compared to all other treatments. The lowest harvest index (34.3 %) was observed with unweeded check, which was on par to that received fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (36.0 %). Among nitrogen levels, the highest harvest index was observed with application of 30 kg

Table 14 : Effect of weed control treatments and nitrogen levels on Haulm yield of soybean

Treatments	Haulm yield (kg ha^{-1})
Weed control treatments	
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	2719
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	2317
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	2752
Intercultivation with push-hoe at 20 and 40 DAS	2791
Unweeded check	1734
S.Ed±	193
CD(0.05)	446
Nitrogen levels (kg ha^{-1})	
0	1897
30	2237
60	2728
90	2988
S.Ed±	155
CD (0.05)	316
W x N	NS

N ha^{-1} (39.1 %) which was on par with 60 kg N ha^{-1} (38.7 %). The HI in these treatments was significantly superior to that observed in no nitrogen and 90 kg N ha^{-1}. The HI in the latter two treatments was on par with each other. The HI was significantly higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at 60 kg N ha^{-1}, while lowest was observed with unweeded check at no nitrogen application.

4.3.6 Fertilizer nitrogen use efficiency (NUE)

The fertilizer nitrogen use efficiency indicated significant differences among the nitrogen levels, while weed management treatments and their interaction were found to be non-significant (Table 16).

Fertilizer use efficiency was significantly higher with application of 60 kg N ha^{-1} (6.4 kg grain kg N^{-1} ha^{-1}) over that of 90 kg N ha^{-1} (3.9 kg grain kg N^{-1} ha^{-1}) but was on par with that observed with 30 kg N ha^{-1} (6.2 kg grain kg N^{-1} ha^{-1}). Significantly lowest NUE was recorded with application of 90 kg N ha^{-1}.

4.3.7 Nutrient uptake by soybean

4.3.7.1 Nitrogen uptake (kg ha^{-1})

Nitrogen uptake increased with the age of the crop upto harvest in the crop applied with fluchloralin @ 1.0 kg a.i. ha^{-1} + IC, IC twice and unweeded check, while the increase was upto 75 DAS and declined thereafter at harvest in the crop received pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC. Nitrogen uptake was significantly influenced by weed control treatments at 75 DAS, while nitrogen levels

Table 15 : Effect of weed control treatments, nitrogen levels and their interactions on harvest index (%) in soybean

Treatments	Weed contol treatments					
	PT	FT	MT	IT	UC	Mean
Nitrogen levels (kg ha^{-1})						
0	38.7 (39.0)	35.3 (33.5)	37.4 (37.0)	37.4 (37.0)	33.7 (31.0)	36.5 (35.5)
30	39.6 (40.7)	36.1 (34.8)	38.2 (38.3)	39.6 (40.7)	39.8 (41.0)	38.6 (39.1)
60	41.2 (43.4)	39.2 (40.0)	40.5 (42.2)	37.7 (37.4)	33.8 (30.9)	38.4 (38.7)
90	37.2 (36.6)	36.8 (35.9)	34.9 (32.7)	36.0 (34.6)	35.9 (34.4)	36.1 (34.8)
Mean	39.1 (39.9)	36.8 (36.0)	37.7 (37.5)	37.7 (37.4)	35.8 (34.3)	

Data in the parentheses denote the absolute values before angular transformation

	S.Ed±	CD(0.05)
Weed control treatments	0.8	1.9
Nitrogen levels	0.7	1.4
Difference between two nitrogen level means at same level of weed control treatment	1.5	3.1
Difference between two weed control treatment means at same or different nitrogen levels	1.6	3.4

Table 16: **Effect of weed control treatments and nitrogen levels on fertilizer nitrogen use efficiency (FUE) in soybean**

Treatments	FUE (Kg grain kg N^{-1} ha^{-1})
Weed control treatments	
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	6.0
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	3.9
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	5.3
Intercultivation with push-hoe at 20 and 40 DAS	6.5
Unweeded check	5.7
S.Ed±	1.1
CD(0.05)	NS
Nitrogen levels (kg ha-1)	
0	-
30	6.2
60	6.4
90	3.9
S.Ed±	0.6
CD (0.05)	1.2
W x N	NS

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were significant at all stages of sampling. The interaction effect of weed control treatments and nitrogen levels on N uptake by soybean was not significant (Table 17 and Fig. 8).

Nitrogen uptake at 25 DAS did not differ significantly with weed management treatments and it ranged from 10.2 to 13.5 kg ha^{-1}. Among the nitrogen levels, significantly highest nitrogen uptake was observed in the crop applied with 90 kg N ha^{-1} (13.8 kg ha^{-1}), which was significantly superior to that of other levels. Nitrogen uptake in no nitrogen, 30 and 60 kg N ha^{-1} applied crop was 10.8, 12.2 and 12.3 kg ha^{-1} respectively.

The N uptake at 50 DAS showed similar trend as that observed at 25 DAS among different weed management treatments. On the other hand, the N uptake with application of 60 kg N ha^{-1} was significantly superior (64.4 kg ha^{-1}) as compared to that of no nitrogen application and 30 kg N ha^{-1} (43.8 and 50.9 kg ha^{-1} respectively) and was on par with that observed with 90 kg N ha^{-1} application (60.8 kg ha^{-1}).

The N uptake at 75 DAS, in the crop received integrated weed management (Pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice) was on par with each other and significantly superior to that observed with unweeded check. Nitrogen uptake increased significantly with increase in nitrogen levels from 0 to 30, 60 and 90 kg N ha^{-1}.

The N uptake at harvest was significantly higher with 60 kg N ha^{-1} application (113.0 kg ha^{-1}) as compared to 30 kg N ha^{-1} (93.4

Table 17: Effect of weed control treatments and nitrogen levels on Nitrogen uptake (kg ha^{-1}) by soybean crop at 25, 50, 75 DAS and at harvest

Treatments	Nitrogen uptake (kg ha^{-1}) at			
	25 DAS	50 DAS	75 DAS	harvest
Weed control treatments				
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	12.3	61.4	111.7	102.1
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	10.2	61.9	94.9	99.0
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	12.7	49.8	101.7	100.1
Intercultivation with push-hoe at 20 and 40 DAS	12.6	55.6	91.8	99.1
Unweeded check	13.5	46.1	69.4	76.7
S.Ed±	1.3	6.8	8.8	8.1
CD(0.05)	NS	NS	20.3	NS
Nitrogen levels (kg ha-1)				
0	10.8	43.8	68.6	63.8
30	12.2	50.9	85.7	93.4
60	12.3	64.4	105.2	113.0
90	13.8	60.8	116.1	111.5
S.Ed±	0.9	3.8	5.1	7.9
CD (0.05)	1.8	7.7	10.4	16.2
W x N	NS	NS	NS	NS

kg ha^{-1}) and no nitrogen (63.8 kg ha^{-1}) and was on par with that of 90 kg N ha^{-1} (111.5 kg ha^{-1}).

4.3.7.2 Phosphorus uptake (kg ha^{-1})

The phosphorus uptake increased progressively upto 75 DAS and later decreased towards harvest (Table 18). The interaction effect of weed control treatments and nitrogen levels on phosphorus uptake was found to be non-significant at all the stages of sampling.

The phosphorus uptake of soybean at 25 DAS was not significantly influenced by the weed management treatments. Among nitrogen levels, higher uptake was observed with application of 90 kg N ha^{-1} (0.68 kg ha^{-1}) while lowest uptake in the crop received no nitrogen (0.46 kg ha^{-1}). The uptake in the crop applied with 30 and 60 kg N ha^{-1} was on par with that noticed in 90 kg N ha^{-1}.

The phosphorus uptake at 50 DAS did not vary significantly with weed control treatments and the uptake ranged between 1.77 and 2.40 kg ha^{-1}. Application of 30, 60 and 90 kg N ha^{-1} resulted in significantly higher phosphorus uptake (3.19, 3.58 and 2.49 kg ha^{-1} respectively) as compared to no nitrogen application (1.29 kg ha^{-1}) and the uptake in the former treatments was on par with each other.

At 75 DAS, maximum phosphorus uptake was observed with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (3.66 kg ha^{-1}) which was significantly superior to that of unweeded check (2.30 kg ha^{-1}) and was on par with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC (3.33 kg ha^{-1}),

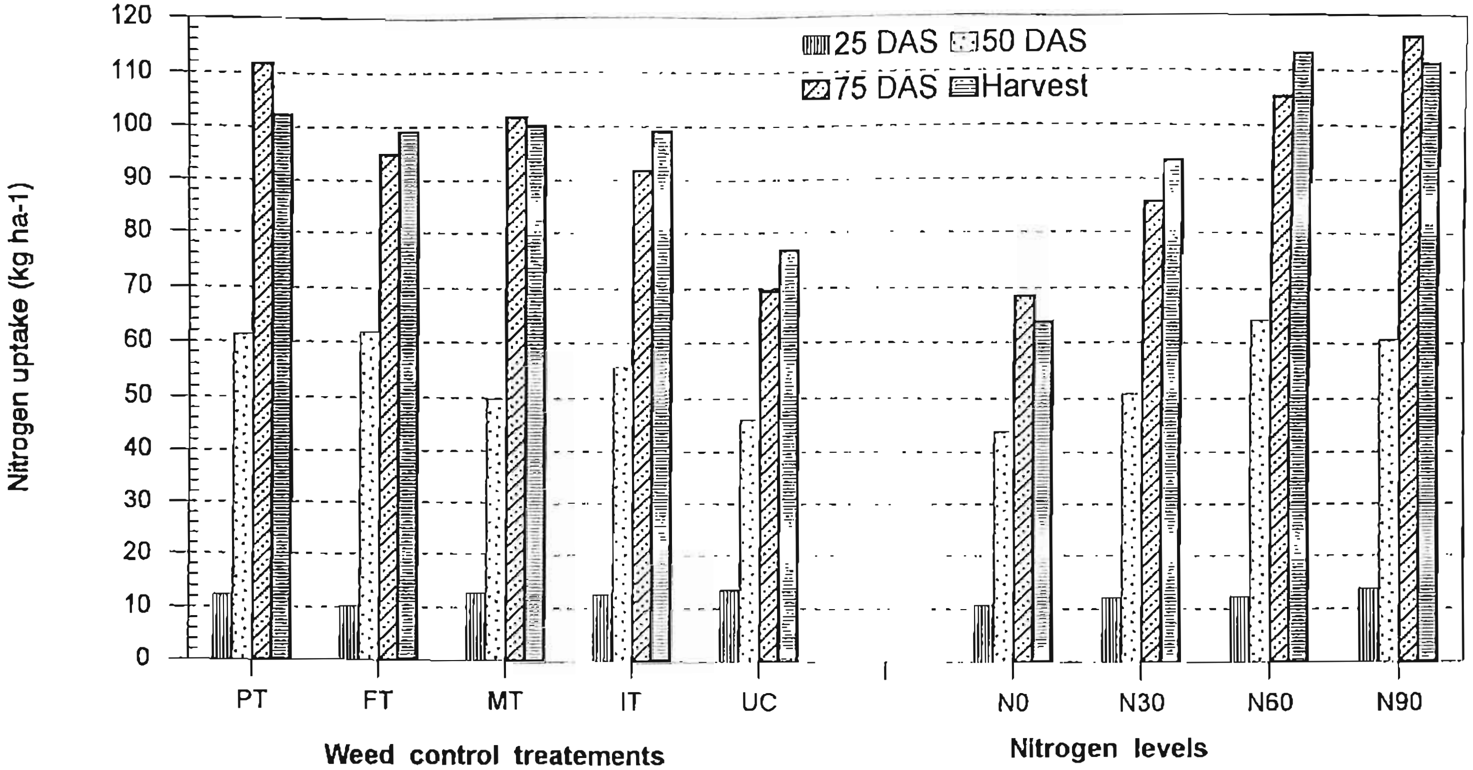

Fig. 8 : Nitrogen uptake by soybean (kg ha^{-1}) as influenced by weed control treatments and nitrogen levels

fluchloralin @ 1.0 kg a.i. ha^{-1} (3.13 kg ha^{-1}) and IC twice (2.98 kg ha^{-1}). Among nitrogen levels, significantly higher phosphorus uptake was observed with 90 kg N ha^{-1} application (3.81 kg ha^{-1}) as compared to 30 kg N ha^{-1} (3.19 kg ha^{-1}) and no nitrogen (1.74 kg ha^{-1}) and was on par with that of 60 kg N ha^{-1} (3.58 kg ha^{-1}).

The phosphorus uptake at harvest was similar to that observed at 25 and 50 DAS in case of weed management treatments and 75 DAS with regard to N application.

4.3.7.3 Potassium uptake (kg ha^{-1})

The potassium uptake increased with the age of the crop upto 75 DAS and thereafter declined towards harvest (Table 19). The interaction of weed control treatments and nitrogen levels did not influence significantly the uptake of potassium by the crop.

The potassium uptake at 25 DAS was not significantly influenced by weed management treatments and nitrogen levels.

The uptake at 50 DAS also showed similar trend as that of 25 DAS with different weed control treatments. On the other hand, the potassium uptake with application of 60 (34.1 kg ha^{-1}), 90 (33.3 kg ha^{-1}) and 30 kg N ha^{-1} (31.0 kg ha^{-1}) was on par with each other but was significantly superior to that received no nitrogen (24.7 kg ha^{-1}).

The potassium uptake at 75 DAS was significantly higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and IC twice

Table 18: Effect of weed control treatments and nitrogen levels on Phosphorus uptake (kg ha^{-1}) by soybean crop at 25, 50, 75 DAS and at harvest.

Treatments	Phosphorus uptake (kg ha^{-1}) at			
	25 DAS	50 DAS	75 DAS	Harvest
Weed control treatments				
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.57	2.40	3.66	1.66
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.48	2.37	3.13	1.62
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	0.60	1.92	3.33	1.61
Intercultivation with push-hoe at 20 and 40 DAS	0.59	2.13	2.98	1.61
Unweeded check	0.66	1.77	2.30	1.22
S.Ed±	0.06	0.25	0.29	0.13
CD(0.05)	NS	NS	0.67	NS
Nitrogen levels (kg ha^{-1})				
0	0.46	1.29	1.74	0.82
30	0.61	2.35	3.19	1.55
60	0.57	2.36	3.58	1.96
90	0.68	2.49	3.81	1.86
S.Ed±	0.04	0.14	0.17	0.12
CD(0.05)	0.08	0.29	0.36	0.25
W x N	NS	NS	NS	NS

(53.5, 48.7, 45.3 and 44.0 kg ha^{-1} respectively) over that of unweeded check (33.8 kg ha^{-1}) and were on par with each other. Nitrogen levels increased the uptake of potassium significantly with successive increase from 0 to 30, 60 and 90 kg ha^{-1}.

The potassium uptake at harvest with different weed management treatments did not vary significantly. Among the nitrogen levels, significantly higher potassium uptake was observed with application of 60 kg N ha^{-1} (37.2 kg ha^{-1}) as compared to that of 30 kg N ha^{-1} (29.7 kg ha^{-1}) and no nitrogen application (18.1 kg ha-1) and was on par with that of 90 kg N ha^{-1} (34.9 kg ha^{-1}). Lowest potassium uptake was observed with no nitrogen application.

4.3.8 Protein content (%)

Seed protein content in soybean was significantly influenced by the weed control treatments and nitrogen levels while their interaction on protein content was not significant (Table 20).

Among the weed control treatments, application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC resulted significantly higher seed protein content (39.7 %) over rest of the weed management treatments except that applied with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC. Significantly minimum protein content was recorded with unweeded check (38.0 %). Among the nitrogen levels, seed protein content increased significantly with successive increase in nitrogen from 0 to 90 kg N ha^{-1}, which ranged between 37.5 and 40.1 per cent.

Table 19: **Effect of weed control treatments and nitrogen levels on Potassium uptake (kg ha^{-1}) by soybean crop at 25, 50, 75 DAS and at harvest.**

Treatments	Potassium uptake (kg ha^{-1}) at			
	25 DAS	50 DAS	75 DAS	Harvest
Weed control treatments				
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	6.3	34.5	53.5	32.1
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	5.3	34.6	45.3	31.2
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	6.7	27.9	48.7	31.2
Intercultivation with push-hoe at 20 and 40 DAS	6.6	31.1	44.0	31.2
Unweeded check	7.0	25.7	33.8	24.1
S.Ed±	0.7	3.7	4.2	2.5
CD(0.05)	NS	NS	9.7	NS
Nitrogen levels (kg ha^{-1})				
0	6.0	24.7	29.1	18.1
30	6.9	31.0	41.6	29.7
60	6.3	34.1	52.1	37.2
90	6.3	33.3	57.5	34.9
S.Ed±	0.5	2.1	2.5	2.4
CD(0.05)	NS	4.2	5.0	5.0
W x N	NS	NS	NS	NS

4.3.9 Oil content (%)

Different weed control treatments, nitrogen levels and their interaction had no significant effect on the seed oil content (Table 20). The per cent oil content ranged from 19.4 to 20.1 between different weed control treatments and from 19.5 to 20.2 under different nitrogen levels.

4.3.10 Residual effect on ragi

The germination of ragi seeds after harvest of soybean indicated that the residues left by the herbicides had significant effect on the seed germination (Table 21). Low germination was observed in the crop grown after application of fluchloralin @ 1.0 kg a.i. ha^{-1} (94.1). On the other hand, the germination of ragi grown after application of herbicides, pendimethalin @ 1.0 kg a.i. ha^{-1} and metolachlor @ 1.0 kg a.i. ha^{-1} was significantly higher (98.7 and 99.2 % respectively) as compared to that observed with former. The germination percentage did not vary due to application of different nitrogen levels.

4.3.11 Net monetary returns (Rs ha^{-1})

The cost of cultivation involving weed control treatments and nitrogen levels is presented in the appendices B and C and their economic analysis is presented in the table 22.

The higher gross returns (Rs. 10,310 ha^{-1}) were obtained with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, IC twice (Rs. 9806 ha^{-1}), metolachlor @ 1.0 kg a.i. ha^{-1} + IC (Rs. 9787 ha^{-1}) and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC (Rs. 7968 ha^{-1}), while the lowest returns were

Table 20 : Effect of weed control treatments and nitrogen levels on seed protein content (%) and oil content (%) of soybean

Treatments	Seed protein content (%)	Seed oil content (%)
Weed control treatments		
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	39.3	19.9
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	38.7	20.1
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	39.7	19.8
Intercultivation with push-hoe at 20 and 40 DAS	38.9	20.1
Unweeded check	38.0	19.4
S.Ed±	0.3	0.4
CD(0.05)	0.6	NS
Nitrogen levels (kg ha-1)		
0	37.5	19.5
30	38.5	20.0
60	39.6	20.2
90	40.1	19.8
S.Ed±	0.3	0.3
CD (0.05)	0.5	NS
W x N	NS	NS

Table 21 : Effect of weed control treatments and nitrogen levels on germination of ragi

Treatments	Germination (%)
Weed control treatments	
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	85.1 (98.7)
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	77.2 (94.1)
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	86.7 (99.2)
Intercultivation with push-hoe at 20 and 40 DAS	89.3 (99.8)
Unweeded check	87.3 (99.3)
S.Ed±	1.5
CD(0.05)	3.4
Nitrogen levels (kg ha-1)	
0	82.1 (96.7)
30	84.2 (97.8)
60	86.6 (99.1)
90	87.7 (99.3)
S.Ed±	1.5
CD (0.05)	NS
W x N	NS

Data in the parentheses denote the absolute values before angular transformation recorded in the crop received no weeding (Rs. 5586 ha^{-1}). Among the nitrogen levels, gross returns were maximum with application of 60 kg N ha^{-1} (Rs. 10,165 ha^{-1}) followed by that of 90 (Rs. 9846 ha^{-1}) and 30 kg N ha^{-1} (Rs. 8255 ha^{-1}). The lowest returns were obtained with the crop where no nitrogen was applied (Rs. 6500 ha^{-1}).

Application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC resulted in maximum net returns (Rs. 4051 ha^{-1}) with higher benefit : cost ratio (0.70), which was closely followed by IC twice (Rs. 3988 ha^{-1} with B:C ratio of 0.68). The lowest net returns were recorded in the crop with unweeded check (Rs. 983 ha^{-1}) with minimum B:C ratio (0.21). Among the nitrogen levels, the maximum net returns were obtained with application of 60 kg N ha^{-1} (Rs. 4010 ha^{-1}) with a higher B:C ratio (0.65). The net returns decreased with application of N beyond 60 kg ha^{-1}. The lowest net returns (Rs. 785 ha^{-1}) and B:C ratio (0.13) were observed with no nitrogen application.

4.3.12 Correlation studies

The influence of yield attributing characters as well as weed management practices on seed yield of soybean was fitted in a linear regression equation (Table 23). Pods $plant^{-1}$, seeds pod^{-1}, 100-seed weight, seed protein content, seed oil content, nitrogen uptake by crop at harvest were found to be positively correlated with seed yield. Dry weight and N uptake by weeds at harvest were negatively correlated with yield.

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Table 22 : Net monetary returns as influencd by different weed control treatments and nitrogen levels in soybean

Treatments	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns (Rs ha^{-1})	Benefit : cost ratio
Weed control treatments				
Pendimethalin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	10310	6570	3740	0.56
Fluchloralin 1.0 kg ha^{-1} fb intercultivation at 25 DAS	7968	5959	2009	0.33
Metolachlor 1.0 kg ha^{-1} fb intercultivation at 25 DAS	9787	5736	4051	0.70
Intercultivation with push-hoe at 20 and 40 DAS	9806	5818	3988	0.68
Unweeded check	5586	4603	983	0.21
Nitrogen levels (kg ha^{-1})				
0	6500	5715	785	0.13
30	8255	5935	2320	0.39
60	10165	6155	4010	0.65
90	9846	6375	3471	0.54

Price of soybean @ Rs 950 q^{-1}

Table 23 : Correlation co-efficient between seed yield and yield components and weed parameters

	r-value	Regression equation y = a+bx
Grain yield vs		
Pods plant^{-1}	0.966**	Y = 9.05 + 0.966 X
Seeds pod^{-1}	0.906**	Y = 1.79 + 0.906 X
100-seed weight (g)	0.345*	Y = 12.24 + 0.345 X
Seed protein content(%)	0.871**	Y = 35.21 + 0.871 X
Seed oil content (%)	0.711**	Y = 18.88 + 0.711 X
N uptake by crop at harvest (kg ha^{-1})	0.870**	Y = 25.68 + 0.870 X
Weed dry weight at harvest (g m^{-2})	-0.627*	Y = 312.69 -0.627 X
N uptake by weeds at harvest (kg ha^{-1})	-0.575*	Y = 35.64 - 0.575 X

** Significant at 1 per cent level

* Significant at 5 per cent level

DISCUSSION

CHAPTER V

DISCUSSION

Soybean being a high protein crop, requires large quantity of nitrogen, though it is capable to meet its major part of 'N' requirement through symbiotic'N' fixation. However 'N' requirement is to be supplemented through external source for early establishment. With the increasing cost of fertilizers and the increase in soybean area under cultivation necessitate the improved crop management particularly the N use efficiency. Weed competition reduces the soybean yields from 35 to 50 per cent (Bhan *et al.* 1972). Herbicides like pendimethalin, fluchloralin and metolachlor were found to be effective in controlling the weeds in soybean and increase its yield (Shekara and Nanjappa, 1993). The integrated weed management approach of adoption of chemical with other mechanical methods found feasible and has been well documented in soybean (Gogoi *et al.*, 1991; Singh *et al.*, 1992; Singh *et al.*, 1994; Chandel *et al.*, 1995 and Balasubramanian and Arumugam, 1996).

However, studies on increasing the nitrogen use efficiency through integrated weed management in soybean are meagre. Hence, the present investigation was planned with a view to increase the nitrogen use efficiency through integrated weed management in soybean. The results obtained in the present investigation are discussed hereunder.

There were no adverse weather conditions during the crop growth period. The optimum mean maximum and minimum temperature and relative humidity coupled with more sunshine hours were observed, favouring better growth and dry matter production of crop.

Fifteen weed species belonging to eight families were observed in the experimental field. Among them two species were sedges, while six species were grasses and the remaining seven species were broad leaved weeds.

Effect of IWM practices

The crop yield is the ultimate desired product of all the growth and yield attributing characters. The treatments, which influence these characters favourably result in higher crop yields. The weed management treatments with application of pendimethalin @ 1.0 kg a.i. ha^{-1} – IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC and IC twice significantly increased the yield by 84, 75 and 75 per cent respectively over that of no weeding. The application of these herbicides and intercultivation effectively controlled the weeds and reduced the weed competition during the critical periods and resulted in higher yields. The former weed management practices significantly reduced the weed density (Table 2), dry matter production (Table 3) and NPK uptake by weeds (Tables 5, 6 and 7) and resulted significantly higher crop dry matter (Table 10), NPK uptake (Tables 17, 18 and 19), pod and seed number (Table 11) with substantial contribution to seed yield. The seed yield had positive and significant correlation with number of pods $plant^{-1}$, seeds pod^{-1} and nitrogen uptake by crop and negative correlation with dry weight and nitrogen uptake by weeds (Table 23). There was significant reduction in total weed population with application of herbicides over that of unweeded check (Table 2) during the crop period. The reduction in total weeds was 95 and 94 per cent respectively with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC at 30 DAS and 89 and 85 per cent with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC and pendimethalin @ 1.0 kg a.i. ha^{-1} + IC respectively at 60 DAS. The density of individual dominant weeds, viz., *Cyperus rotundus*, *Cynodon dactylon parthenium hysterophorus* and *Digera arvensis* was effectively reduced by application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC upto 60 DAS (Table 1) due to the activity of herbicides during the initial stages of crop growth and the intercultivation done at the later date controlled subsequent weed emergence.

All the weed management practices influenced the weed dry matter production at all stages of observation. There was higher dry matter accumulation by weeds in unweeded check at all stages of sampling due to early establishment and profuse growth of weeds in absence of herbicide treatment. Application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC, Pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and fluchloralin @ 1.0 kg a.i. ha^{-1} + IC reduced weed dry weight by 67, 65 and 55 per cent over no weeding at 25 DAS. The per cent reduction in weed dry weight was 84 with both metolachlor and pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at 50 DAS. The IC twice was effective over weeds and was comparable with herbicide treatments at 50 DAS after second intercultivation operation at 40 DAS. Further, WCE in IWM treatments was significant over IC twice at 25 DAS. Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC recorded higher WCE of 66, 85 and

72 per cent at 25, 50 and 75 DAS respectively followed by metolachlor @ 1.0 kg a.i. ha^{-1} + IC.

The uptake of nutrients by weeds results in reduced availability of nutrients to crop with subsequent reduction in growth and yield of crop. Unweeded control recorded highest uptake of nutrients at all stages of crop and competed with soybean. The nutrient uptake was highest (72 kg N, 11 kg P and 33 kg K ha^{-1}) in unweeded control compared to weed management treatments at 75 DAS (Tables 5, 6 and 7). There was significant reduction in nutrient uptake by weeds under all the weed management practices compared to no weeding at all stages of sampling indicating effective control of weed growth resulting in increased uptake by crop contributing for higher yields (Tables 17, 18 and 19).

Application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC registered lower yield among the herbicide treatments, but 43 per cent more than no weeding due to reduction in germination percentage, plant height, crop dry matter and yield components of soybean (Tables 8, 9a, 9b, 10 and 11). Germination percentage is considered as important factor in deciding the optimum plant stand in realising the higher crop yield. The lowest seed germination (86.7 %) was observed with application of fluchloralin @ 1.0 kg a.i. ha^{-1} among the herbicide treatments, which also resulted in initial phytotoxicity on crop, but subsequently disappeared and normal crop growth was observed (Brar *et al.* 1985 and Manjunath *et al.*, 1989).

Yield components are high expressions contributing directly to the crop yield. Significant increase in number of pods $plant^{-1}$ and no. of seeds

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pod^{-1} were observed due to weed management practices over no weeding. This might be due to less weed competition and better crop growth by the synergistic effect of weed management practices. The pod and seed number were highest with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (30.6 and 2.4 respectively) compared to unweeded control (22.0 and 2.1, respectively) (Table 11). In case of weed index, the lower value (2.6 %) was recorded with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, while the higher value was with unweeded control as weeds caused greater reduction in plant dry matter, yield components and seed yield of soybean. The weed management treatments significantly influenced the nutrient uptake by crop at 75 DAS, coinciding with higher dry matter accumulation under weed free environment. Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC resulted in higher uptake of NPK with 61, 46 and 58 per cent respectively over no weeding at 75 DAS (Maurya *et al.*, 1990; Shekara and Nanjappa, 1993; Singh *et al.*, 1994; Arumugam *et al.*, 1995; Pandey *et al.*, 1995; Rao. 1997 and Chhokar *et al.*, 1997). The efficient weed control and greater production of dry matter and uptake of nutrients in the crop received IWM resulted in increased yield attributes and thereby seed yield.

The effect of nitrogen levels

The higher seed yield is attributed to enhancement in plant height and higher crop dry matter, yield components and higher fertility conditions with minimum loss of nutrients by weeds. Among the nitrogen levels applied to the crop, significantly higher seed yield (66 %) was observed with the crop that received 60 kg N ha^{-1} over that of crop received no nitrogen.

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Majumdar and Behera (1991), Naidu and Pillai (1991) and Trivedi and Sharma (1997) observed similar response to nitrogen in soybean.

Weed growth is normally influenced by the N levels and more competition exists for the nitrogen from the weeds to the crop. The total density of weeds was maximum with the crop applied with no nitrogen and 90 kg N ha^{-1} at 30 and 60 DAS (Table 2), which indicates the competitive ability of weeds to crop even at low levels of nitrogen and also under higher nutrient status. Mani (1975) pointed out that the competition for nutrients in general and nitrogen in particular in most of the situations is a serious factor in limiting the crop yields. The increase in dry matter production of weeds was 34, 58 and 87 per cent more with application of 30, 60 and 90 kg N ha^{-1} respectively over no nitrogen application at 75 DAS, where significantly higher dry matter of weeds was recorded. Maximum weed control efficiency was observed with application of 60 and 90 kg N ha^{-1} at harvest, where reduction in weed dry weight was due to smothering effect of crop. The NPK uptake was more at increased levels of nitrogen due to luxurious consumption of nutrients by weeds, which as to the tune of 91, 113 and 73 per cent respectively with 90 kg N ha^{-1} over no nitrogen application.

The crop dry matter accumulation was significant upto 60 kg N ha^{-1} with 57 and 25 per cent increase over no nitrogen and 30 kg N ha^{-1} respectively, where in higher nitrogen availability contributed for more dry matter production (Bishnoi and Ramdutt, 1983; Vanaja, 1993 and Jadhav *et al.*, 1994). Nitrogen application has significant influence on yield components due to adequacy of nutrients to produce more number of reproductive sinks in the crop. Significantly higher pod and seed number were recorded with 60 kg N ha^{-1} over that of 30 kg N ha^{-1} and no nitrogen application, which was in conformity with the reports of Nayak *et al.*, (1989), Khelkar *et al.* (1991) and Dahatonde and Shava (1992). The NPK uptake was significantly higher with successive increase in nitrogen level due to more availability of nitrogen at the root zone of the crop. The increase in yield attributes and dry matter and NPK uptake with application of N fertilizer improved the seed yield of soybean. The seed yield had positive correlation with these parameters (Table 23).

Fertilizer nitrogen use efficiency (NUE) increased upto 60 kg N ha^{-1} and declined thereafter (Table 16). Application of nitrogen at 30 and 60 kg N ha^{-1} had higher NUE of 6.2 and 6.4 kg grain kg N^{-1} ha^{-1} respectively. There was 39 per cent reduction in NUE at 90 kg N ha^{-1} over 60 kg N ha^{-1} as there was increased weed growth and nutrient removal by weeds at 90 kg N ha^{-1}.

Interaction effect of weed control treatments and nitrogen levels

The interaction effect of weed management treatments with nitrogen levels showed that the application of fertilizer with any weed management practice improved the yield significantly over unweeded control. The yield obtained with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC and IC twice at no nitrogen was similar to that of yield obtained with unweeded control at 90 kg N ha^{-1}. Significantly highest seed yield (1324 kg ha^{-1}) was recorded with pendimethalin @ 1.0 kg a.i. ha^{-1} + IC with the application of 60 kg N ha^{-1}, which was on par

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with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC at the same level of nitrogen (1288 kg ha^{-1}) and IC twice at 90 kg N ha^{-1} (1226 kg ha^{-1}). This was due to effective reduction in weed dry matter and also nutrient uptake by weeds and increase in crop dry matter and nutrient uptake and yield attributes with the application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC at 60 kg N ha^{-1}. The interaction effect resulted in significantly higher WCE with all nitrogen levels applied to crop in all herbicide treatments, except the application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC at 25 DAS, while it was effective with the application of 30 to 90 kg N ha^{-1} at harvest, which could be due to higher WCE of herbicides at the initial stages of application with more herbicidal activity and later due to smothering effect of crop canopy at harvest.

Weed management treatments significantly increased the seed protein content over no weeding. Seed protein content increased significantly with increase in nitrogen levels, which could be due to increased availability of key element, nitrogen essential for protein synthesis. Different weed management treatments and nitrogen levels did not vary significantly on the seed oil content. Maurya *et al.* (1990), Singh and Singh (1994) and Jain *et al.*, (1995) reported no marked influenced of herbicide treatments on this qualitative parameter, which is genetically controlled.

Bioassay studies

The biassay studies with ragi revealed lower germination of seed in the plot received fluchloralin @ 1.0 kg a.i. ha^{-1} among the weed management treatments. Ragi was reported to be sensitive to fluchloralin residues upto

0.01 ppm concentration resulting in drastic reduction in germination (AICRP-WC, Annual report, Hyderabad Centre, 1993).

Economics

Economic analysis of this investigation involving various weed management and nitrogen levels revealed that higher net returns were recorded with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC (Rs. 4051 ha^{-1}) resulting in higher B:C ratio (0.70) fb IC twice (Rs. 3988 ha^{-1} with 0.68 B:C ratio). The lower returns with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC (Rs. 3740 ha^{-1}) despite higher gross returns indicate more expenditure incurred on herbicide and vice-versa observed with that of metolachlor @ 1.0 kg a.i. ha^{-1} + IC. Among the nitrogen levels, the maximum net returns (Rs. 4010 ha^{-1}) with higher B:C ratio (0.65) was recorded with application of 60 kg N ha^{-1} and the net returns reduced by 42 and 13 per cent compared to that observed with 30 and 90 kg N ha^{-1} respectively. Similar net returns with IC twice (Chandrakar and Urkurkar, 1993) and Pendimethalin (Poston *et al.*, 1992), Metolachlor (Chandel *et al.*, 1995) and Fluchloralin (Halvenkar *et al.*, 1995) application were reported earlier.

From the above discussion, following conclusions are drawn.

1. The dominant weed flora associated with soybean in the present study comprised of monocots and dicots accounting for 61 and 39 per cent of total weed flora. All the weed management treatments maintained lower weed densities during the early stages of crop growth. The interaction of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC

and metolachlor @ 1.0 kg a.i. ha^{-1} + IC with nitrogen levels was effective at 60 kg N ha^{-1} resulting in lower weed density.

2. Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC effectively reduced the weed dry matter at 60 kg N ha^{-1} during entire crop duration. The weed control efficiency was higher with the above treatments at all nitrogen levels during the initial stages of soybean.

3. The integrated weed management treatments significantly reduced the nutrient uptake by weeds compared to no weeding. Interaction of weed control treatments and nitrogen levels was limited upto 30 kg N ha^{-1} in reducing the nutrient uptake during the initial stages of crop growth and upto 90 kg N ha^{-1} at harvest.

4. Soybean plant height and dry matter production were significantly influenced by application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC. Nitrogen levels had significant effect on plant height upto 90 kg N ha^{-1} and on the dry matter production upto 60 kg N ha^{-1}. The yield components and seed yields were significantly high with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC. The yield was reduced with application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC due to reduction in plant height, dry matter and yield attributes of soybean.

5. The fertilizer use efficiency was maximum with application of nitrogen at 60 kg N ha^{-1} and decreased with further increase in nitrogen.

6. The herbicides except fluchloralin tried under present study were observed to be safe for soybean and also for succeeding crops as evident from ragi bio-assay test. The fluchloralin application exhibited phytotoxcity on the crop with ultimate reduction in crop and yield parameters.

7. The net returns were maximum with herbicide application of metolachlor at 1.0 kg a.i. ha^{-1} fb intercultivation with push-hoe at 25 DAS, resulting in higher B:C ratio. Higher returns were recorded with 60 kg N ha^{-1} application.

Based on the present study, it can be inferred that, application of metolachlor @ 1.0 kg a.i. ha^{-1} fb intercultivation at 25 DAS with 60 kg N ha^{-1} could be more beneficial and economical in soybean crop.

SUMMARY

CHAPTER VI

SUMMARY

A field experiment entitled "Nitrogen use economy through integrated weed management in soybean" was conducted during rabi, 1996-97, at Agricultural College farm, Rajendranagar to develop an integrated weed management strategy to optimize the nitrogen use in soybean. The experiment was laid out in split-plot design with five weed control treatments as main plots (Pendimethalin, fluchloralin and metolachlor each at 1.0 kg a.i. ha^{-1} fb intercultivation, twice intercultivation with push-hoe at 20 and 40 DAS and unweeded check) and four nitrogen levels (0, 30, 60 and 90 kg ha^{-1}) as sub-plots with three replications.

Sedges and grasses were found to be dominant over annual diocot weeds. The density of predominant weeds *Cyperus rotundus*, *Cynodon dactylon*, *parthenium hysterophorus* and *Digera arvensis* was effectively reduced by the herbicide treatments upto 60 DAS. The total weed population was reduced effectively upto 60 DAS to the extent of 89 and 85 per cent with application of metolachlor @ 1.0 kg a.i. ha^{-1} + IC and pendimethalin @ 1.0 kg a.i. ha^{-1} + IC treatments respectively. The total weed density was higher with application of no nitrogen and 90 kg N ha^{-1} during the initial stages of crop growth and later decreased towards harvest under 90kg N ha^{-1} due to smothering effect of crop.

Weed dry matter was significantly higher in unweeded check at all stages of observation compared to weed management treatments. There was increase in dry matter of weeds with successive increase in nitrogen levels

with application of 30, 60 and 90 kg N ha^{-1} (34, 58 and 87 %) over no nitrogen. Uptake of N P K by weeds was minimum with herbicides treatments integrated with intercultivation, while it was maximum in unweeded control. The uptake by weeds increased significantly with progressive increase in nitrogen levels and maximum uptake was observed with 90 kg N ha^{-1}. Weed control efficiency was higher with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC at all stages of sampling over rest of integrated weed management treatments. Significantly higher WCE was observed with no nitrogen and 30 kg N ha^{-1} at 25 DAS, while it was maximum with 60 and 90 kg N ha^{-1} at harvest.

The seed germination of soybean was significantly higher with weed management treatments except application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC which resulted in considerably lower seed germination. The seed germination was not influenced by nitrogen levels. Plant dry matter differed significantly among the weed control treatments at 75 DAS recording 59, 45 and 35 per cent more with application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, fluchloralin @ 1.0 kg a.i. ha^{-1} + IC and metolachlor @ 1.0 kg a.i. ha^{-1} + IC respectively over unweeded check, while among the N levels it was significantly higher with application of 60 kg N (57 and 25 %) over no nitrogen and 30 kg N ha^{-1}. Nutrient uptake by soybean was highest at 75 DAS and declined towards harvest due to senescence of crop. Among the weed management treatments, application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC recorded significantly higher NPK uptake (61, 46 and 58 %) by the crop over unweeded check at 75 DAS, while the NPK uptake increased with increase in nitrogen levels from 0 to 30, 60 and 90 kg N ha^{-1}.

The yield components-number of pods $plant^{-1}$ and seeds pod^{-1} were significantly increased by the weed management treatments over unweeded control, while their increase was significant on nitrogen application upto 60 kg N ha^{-1}. 100-seed weight did not vary significantly among the weed control treatments and nitrogen levels.

Application of pendimethalin @ 1.0 kg a.i. ha^{-1} + IC, metolachlor @ 1.0 kg a.i. ha^{-1} + IC and IC twice increased the yield significantly by 84, 75 and 75 per cent respectively over unweeded control, while application of fluchloralin @ 1.0 kg a.i. ha^{-1} + IC resulted in lower seed yield among the weed management treatments, but was 43 per cent higher over no weeding. Among the nitrogen levels, the crop yield was significantly higher (66 %) with 60 kg N ha^{-1} over no nitrogen application. Nitrogen use efficiency was significantly higher (6.2 and 6.4 kg grain kg N^{-1} ha^{-1}) with application of 30 and 60 kg N ha^{-1} and declined with increase in application of 90 kg N ha^{-1} (3.9 kg grain kg N^{-1} ha^{-1}).

All the weed management treatments significantly increased the seed protein content compared to unweeded control. Among the nitrogen levels, seed protein content increased significantly with increasing levels of nitrogen and maximum content (40.1 %) was observed with 90 kg N ha^{-1}. Seed oil content did not differ significantly with weed management and application of nitrogen.

The interaction of nitrogen fertilizer with all the weed management treatments significantly increased the seed yield over unweeded check. The yield obtained at higher level of nitrogen with unweeded treatment was similar to yield observed with that of lower level of nitrogen under weed management treatments.

Higher net returns (Rs. 4051 ha^{-1}) and B:C ratio (0.70) were recorded with application of metolachlor @ 1.0 kg ai ha-1 + IC fb IC twice (Rs. 3988 ha^{-1} and 0.70 respectively) among the weed control treatments. The net returns were maximum with application of 60 kg N ha^{-1} (Rs. 4010 ha^{-1} with B:C ratio of 0.65).

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The references in the literature cited are arranged as per the revised P.G. Guidelines for thesis presentation, 1981 (as amended upto May, 1993) of Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.

APPENDICES

Appendix A

Weekly meteorological data during crop growth period

Std. week No.	Temperature (^{0}c)		Relative humidity (%)		Rainfall (mm)	Mean sunshine Hrs.	Evapo-ration (mm/day)
	Max	Min	7.30 Hrs	14.00 Hrs			
43	29.6	21.2	88.0	65.0	10.2	5.1	2.6
44	30.4	16.1	81.0	46.0	0.0	9.5	3.6
45	30.0	17.6	88.0	64.0	26.0	8.2	3.1
46	30.4	16.2	77.0	49.0	0.0	9.4	3.6
47	28.7	14.7	84.0	61.0	0.0	6.8	3.2
48	29.0	11.3	77.0	39.0	0.0	9.6	2.9
49	28.3	13.9	76.0	46.0	0.0	6.1	2.6
50	28.2	14.4	80.0	46.0	0.0	6.6	2.8
51	28.5	13.1	70.0	38.0	0.0	7.6	2.4
52	28.3	10.8	85.0	32.0	0.0	8.7	2.4
1	27.3	11.0	83.0	36.0	0.0	9.2	3.1
2	26.8	15.5	86.0	64.0	1.2	6.6	2.8
3	27.3	15.8	85.0	54.0	36.8	7.3	2.1
4	28.8	11.6	81.0	43.0	0.0	9.7	3.2
5	30.9	14.0	79.0	31.0	0.0	10.1	4.2

Appendix B

Cost of different weed control treatments

Sl.No.	Treatment Details		Cost of herbicides (Rs. ha^{-1})	Cost of labour (Rs. ha^{-1})		Total cost of the treatment (Rs. ha^{-1})
	Herbicides (kg ha^{-1})	Intercultivation/ Hand weeding		Herbicide application	Intercultivation	
1.	Pendimethalin @ 1 kg ha^{-1}	Intercultivation at 25 DAS	1650.00	92.00	225.00	1967.00
2.	Fluchloralin @ 1 kg ha^{-1}	Intercultivation at 25 DAS	1039.00	92.00	225.00	1356.00
3.	Metolachlor @ 1 kg ha^{-1}	Intercultivation at 25 DAS	816.00	92.00	225.00	1133.00
4.	Intercultivation with push-hoe	At 20 and 40 DAS	-	-	675.00 + 540.00	1215.00
5.	Unweeded check	-	-	-	-	-

Cost of herbicides

Pendimethalin @ Rs. 495.00 l^{-1}

Fluchloralin @ Rs. 467.50 l-1

Metolachlor @ Rs. 408.00 l^{-1}

Labour charges

For spraying, 2 mandays @ Rs. 45 per manday

One intercultivation, 5 mandays @ Rs. 45 per man day

Fixed cost of knapsack sprayer @ Rs. 2.00

Appendix C

Cost of cultivation of soybean

Sl.No.	ITEM OF EXPENDITURE	Cost (Rs ha^{-1})
1.	Seed bed preparation 2 ploughings, 2 harrowings and one levelling @ Rs. 60 per one cattle pair	300.00
2.	Fertilizers	
	Single super phosphate @ Rs.149 per 50 kg bag	745.00
	and Muriate of potash @ Rs. 205 per 50 kg bag	137.00
	Cost of application for 5 mandays @ Rs.45	225.00
3.	Cost of seed for 50 kgs @ Rs. 18.75 kg^{-1}	937.50
	Cost of sowing 12 mandays @ Rs.45 per manday	540.00
4.	Irrigation @ Rs. 15 per ha cm. and 6 mandays @ Rs. 45 per manday	360.00
5.	Plant protection (including cost of Insecticides and man power for spraying)	264.00
6.	Harvesting : 12 mandays @ Rs.45 per manday	540.00
7.	Threshing and winnowing	225.00
	Cost excluding nitrogen fertilizer	4273.50

Cost of Nitrogen fertilizer		Cost of cultivation excluding nitrogen	Total cost
1. @ 0 :	-	4273.50	4273.50
2. @ 30 :	220.00	4273.50	4493.50
3. @ 60 :	440.00	4273.50	4713.50
4. @ 90 :	660.00	4273.50	4933.50

Price of urea @ Rs. 171 per 50 kg bag.

Appendix D

CALENDER OF FIELD OPERATIONS

24.10.96	Primary and Secondary tillage operations
26.10.96	Layout Bund and Channel formations
27.10.96	Levelling and pre-plant incorporation (FT)
28.10.96	Basal application of NPK Sowing Irrigation
29.10.96	Pre-emergence application of herbicides (PT and MT)
06-11.96	Bio-metric observations and thinning
15.11.96	Plant protection operations
16.11.96	Intercultivation (IT)
17.11.96	Irrigation
21.11.96	Intercultivation (PT, FT and MT) Destructive Sampling
26.11.96	Top dressing of nitrogen Biometric observations
28.11.96	Irrigation
06-12-96	Intercultivation (IT)
12-12-96	Plant protection operations
16-12-96	Destructive sampling
18-12-96	Irrigation
26-12-96	Bio-metric observations
30-12-96	Irrigation
10-01-97	Destructive sampling
15-01-97	Irrigation
02-02-97	Bio-metric observations and Destructive Sampling
03-02-97	Bulk and border rows harvesting
04-02-97	Net plot harvesting
09-02-97	Threshing

146/-