STANDARDIZATION OF DOSES OF POST EMERGENCE HERBICIDES IN GARDEN PEA (*Pisum sativum* var. *hortense*)

THESIS

By

MANU NAG

Submitted to

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PALAMPUR-176 062 (H.P.) INDIA

IN

Partial fulfilment of the requirements for the degree

OF

MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)

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Affectionately

dedicated

to my

Parents

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CERTIFICATE I

This is to certify that the thesis entitled **"Standardization of doses of post emergence herbicides in Garden Pea (*Pisum sativum* var. *hortense*) "** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Agronomy** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Mr. Manu Nag (Admission No. A-2005-30-08)** son of **Sh. Ram Pal Nag** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place: Palampur
Dated: the 10 December, 2007

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Chairman,
Advisory Committee

CERTIFICATE II

This is to certify that the thesis entitled **"Standardization of doses of post emergence herbicides in Garden Pea (*Pisum sativum* var. *hortense*) "** submitted by **Mr. Manu Nag (Admission No. A-2005-30-08)** son of **Sh. Ram Pal Nag** to the Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Agronomy**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Needless to say, all omissions and errors are mine.

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(Manu Nag)

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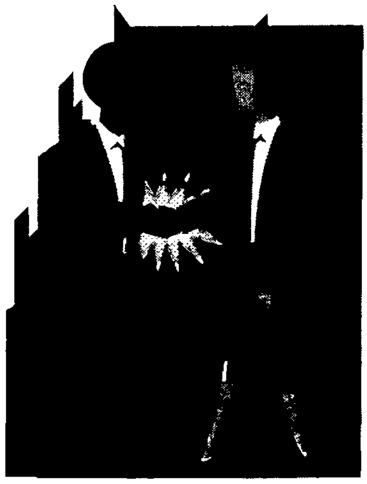


INTRODUCTION

Chapter I

INTRODUCTION

The garden pea (*Pisum sativum* var. *hortense*) is one of the most important cool season crops. In India, it is cultivated on an area of 1.55 million hectares with production of 4.0 million tonnes (Anonymous, 2005a). It is commercially grown as a winter season crop in Northern plains of India. In Himachal Pradesh, it is a leading cash crop in mid and high hills, grown over an area of 14,789 hectares with an annual production of 1,54,043 metric tonnes (Anonymous, 2004a).

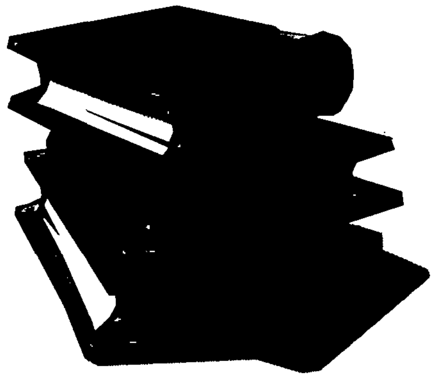
Pea has great potential both for seeds as a pulse (field pea) and pods as vegetable (garden pea). However, weeds continue to be a major threat to the productivity of pea. Since, this crop has slow growth in initial stages, severe weed infestation reduces the yield drastically. Problems owing to weeds are further aggravated due to frequent irrigation and high fertility which provides congenial conditions for their growth and development. Weeds have been reported to cause 81 per cent loss in yield (Singh *et al.,* 1996). Such a huge loss in yield is the manifestation of competition for nutrients, moisture, light and space as well as harbouring of injurious insect-pests and diseases. The critical period for crop-weed competition in pea varies from 40-60 days after sowing (Bhyan *et al.,* 2004). In the later stages, a good crop itself smothers weeds.

Weeds can be controlled by manual, mechanical and chemical methods. Manual weeding is effective but it is cumbersome, time consuming and uneconomical. On the other hand, mechanical means generally lead to root injury

(Casarini *et al.,* 1996). In this context, the use of herbicides is the better alternative. Various pre-plant and pre-emergence herbicides have been tested under different agro-climatic conditions of Himachal Pradesh and recommended for control of weeds in pea (Singh *et al.,* 1996). However, the information on post-emergence herbicides to control weeds is very scanty. Many a times, the extension workers and farmers of the state demand information on post-emergence herbicides especially when due to one or the other reason they fail to apply pre-emergence herbicides.

Recently, new post-emergence herbicides *viz.*, imazethapyr and quizalofop have been introduced. However, their doses are to be standardized for effective control of weeds in pea crop under varied agro-ecological situations. Therefore, keeping the foregoing need in view, present study entitled "Standardization of doses of post emergence herbicides in Garden Pea (*Pisum sativum* var. *hortense*)" was conducted under mid-hill conditions of Himachal Pradesh with the following objectives:

- To study the relative efficacy of post-emergence herbicides to control weeds and their effect on growth and yield of pea,
- to standardize the dose and time of application of post-emergence herbicides for effective control of weeds, and
- to find out the relative economics of different weed control treatments.



REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

The information relevant to various aspects pertaining to the present investigation has been reviewed and presented in this chapter. There is very less information about application of post-emergence herbicides for control of weeds in pea. Therefore, the literature on use of post-emergent herbicides (used in the present study) on other crops have also been considered under the following heads:

2.1 Losses caused by weeds

2.2 Crop-weed competition

2.3 Weed control methods

2.3.1 Manual and mechanical

2.3.2 Chemical

2.4 Economics

2.1 Losses caused by weeds

The weeds interfere and reduce the efficiency, add to the agricultural operations, brings down the yield and markedly lower down the land value. Hence, it is not surprising that the losses caused by weeds are encountered universally and crop yields are adversely affected. Crop yields are lowered because weeds compete with the crop plants for water, nutrients, light and space. They also harbour insect-pests and diseases of crop plants. While reviewing a good amount of literature, Alkamper (1976) concluded that weeds usually absorb nutrients faster and in relatively large amounts than crops and therefore, derive greater benefit.

Weeds are serious problem in pea crop because it is generally sown on roughly prepared seed beds after harvesting (Gautam and Singh, 1971). Presence of weeds throughout the growing season reduce pea yield by 20-50 per cent as compared to weed free plots (Sandhu *et al.,* 1978). Randhawa *et al.* (1980) reported that weeds caused 20-25 per cent losses in yield of pea when compared with weed free. Bhalla and Sarangtham (1982) reported that weeds caused 24 per cent reduction in pod yield of pea. At Karnal, Rathi *et al.* (1986) documented 24.3-32.2 per cent losses in crop yield due to uncontrolled weed growth. Singh *et al.* (1984) reported 50.8 per cent reduction in green pod yield of pea due to unchecked weed growth. In Australia, Lemerle *et al.* (2006) documented as high as 70-80 per cent yield losses due to infestation of weeds at a planting density of 10 plants/m^2.

It can be concluded from the above literature that weeds cause 20-80 per cent losses in seed yield of pea.

2.2 Crop-weed competition

Competition between crop plants and weeds is probably the most important single factor limiting the yield and quality. Weeds compete with crop plants for nutrients, moisture, light, carbon dioxide and space. Since, this crop has slow growth in early stages, severe weed infestation reduces the yield drastically. Further, the irrigated conditions encourage growth of weeds. The critical period of crop-weed competition is the period in the life cycle of the crop during which there is maximum loss in seed yield due to competition by weeds.

In general, the competition is more severe in early stages than at later stages. After the critical period is over, attempts to keep the field weed free throughout the growth period of the crop will entail unnecessary additional expenditure without proportionate return in the yield. Bhyan *et al.* (2004) found that critical period for crop-weed competition was between 40-60 days after sowing during which weed infestation greatly affect pea yield. However, under mid hill conditions of Himachal Pradesh, Singh and Angiras (2002) reported first 30 to 60 DAS as the critical period of crop-weed competition.

From the above literature, it can be concluded that weeds pose a serious competition with pea crop in the early stage resulting in considerable yield losses. The critical period of crop-weed competition varies from 30 to 60 DAS.

2.3 Weed control methods

2.3.1 Manual and mechanical

Manual methods of weed control are the most widely used methods in developing and under-developed countries of the world. Singh and Nepalia (1994) reported that hand weeding was quite effective in controlling weeds in pea crop. Vaishya *et al.* (1999) reported that hand weeding twice at 20 & 40 days after sowing had highest weed control efficiency (86%). Similarly at Peshawar in Pakistan, Khan *et al.* (2003) recorded lowest weed biomass with hand weeding. Rajeev *et al.* (2006) reported that hand weeding twice was as good as season long weed control in pea for yield.

Sandhu *et al.* (1978) reported that hand weeding twice controlled weeds effectively and increased the yield significantly. Rathi *et al.* (1986) reported that hand weeding twice done at 3 & 6 weeks after sowing gave season long weed control and consistently higher pea yield. Gogoi *et al.* (1991) also documented highest yield in the manually weeded plot. In semi arid Mediterranean climate of

North Jordan, Tawaha *et al.* (2001) reported highest seed yield of pea with weeding twice at 30 & 60 DAS. However, Vishnoi *et al.* (1983) obtained highest green pea pod yield with hand weeding thrice. Rana *et al.* (2007) reported that hand weeding twice at 25-50 DAS was as effective as pendimethalin 1.2 kg/ha in reducing dry weight of weeds and influencing seed yield of pea.

However, in pea manual and mechanical weed control is difficult, time consuming and cumbersome. Casarini *et al.* (1966) reported considerable reduction in pea yield because of root injury due to mechanical weed control. Gupta and Singh (1968) opined that hoeing in absence of weeds did not improve pea growth and yield. It is reported by Singh and Chaudhary (1974) that one hand weeding one month after sowing reduced pea yield by 40.9 per cent over chemical weed control. Mani *et al.* (1976) found that mechanical weed control either with bullock drawn or hand operated implements proved less effective as these operations brought to the surface new weed seeds which germinate and proved harmful to the crop.

2.3.2 Chemical

2.3.2.1 Pendimethalin (Stomp)

Pendimethalin is a selective pre-plant or pre-emergence soil applied herbicide. It inhibits cell division probably by interaction with micro tubular system. Pendimethalin generally kills grassy weeds and was less effective on broad-leaved weeds (Walia, 2003).

Kundra and Gill (1990) reported that pre-emergence application of pendimethalin at 0.75 & 1.0 kg/ha gave good control of weeds and significantly higher seed yield of pea in silty loam soils of Ludhiana. Similar results were also reported by Kumar *et al.* (1990). Leela (1993) reported that pendimethalin at 0.5 &

1.0 kg/ha provided complete control of weeds associated with pea crop. Similarly, Rana (2002) reported most effective weed control with pendimethalin (1.0 kg/ha). Chadda *et al.* (2004) found that pendimethalin 1.5 kg/ha was most effective treatment under Spiti valley conditions of Himachal Pradesh. Ausklins (1997) reported that pendimethalin was more effective in increasing seed yield of pea. Prakash *et al.* (2000) reported higher number of pods per plant, plant height, pod length, seeds per pod and shelling percentage with pendimethalin. Rana *et al.* (2007) reported that pendimethalin (1.25 kg/ha) resulted in significantly higher plants height, number of pods per plant, shelling percentage and pod yield under Lahaul valley conditions of Himachal Pradesh. At Palampur, Singh and Angiras (2004) reported that pendimethalin 1.5 kg/ha significantly reduced the weed dry matter accumulation and resulted in highest green pod yield. At Jabalpur, Mishra and Bhan (1997) reported that pendimethalin 1.0 kg/ha was as effective as hand weeding in controlling weeds in pea. Banga *et al.* (1998) found that pre-emergence pendimethalin 1.0 kg/ha supplemented with one hoeing at 40 days after sowing was most effective for the control of *Melilotus alba* and *Chenopodium album*.

However, Vaishya *et al.* (1999) reported that pendimethalin 1.0 kg/ha was inferior to hand weeding (20 & 40 DAS) in reducing weed density and dry weight. Ciuberkis (1998) found pendimethalin 1.2 kg/ha less effective in controlling weeds. Similarly, in Lithuania pendimethalin was less effective against weeds (Ausklins and Dovydaitis, 1998). Nelson and Giles (1989) found that on silty loam soils, pre-emergence application of pendimethalin (1.7 kg/ha) didn't adequately control *Amaranthus retroflexus, Setaria spp.* and *Avena spp.* Similarly, in Pakistan, pendimethalin 1.25 kg/ha (pre-emergence) did not control *Cyperus rotundus* and

Cynodon dactylon (Hussain *et al.*, 1990). Haar *et al.* (2001) also found that pendimethalin (2.2 kg/ha) didn't control *Avena spp.* in California.

2.3.2.2 Imazethapyr (Pursuit)

Imazethapyr is an imidazole compound used as a selective herbicide. It controls weeds by reducing the levels of three branched-chain aliphatic amino acids, isoleucine, leucine and valine through the inhibition of accetohydroxy synthase which in turn leads to interference in DNA syntheses and cell growth.

Gonzalez *et al.* (1996) observed that imazethapyr is a selective herbicide in legumes and has direct effect on root initiation rather than on development. Vencil *et al.* (1990) obtained 80 per cent control of *Chenopodium album* with post-emergence application of imazethapyr at 36-38 g/ha. Rubiales *et al.* (2003) observed that pre and post-emergence application of imazethapyr in late sown wheat reduced *Orobanche crenata* infestation and increased yield. Doberzanski *et al.* (1991) observed highly effective weed control in garden pea with imazethapyr. Skrzypczak *et al.* (1994) obtained greatest weed control efficiency with pre or post-emergence imazethapyr. Balesta *et al.* (1994) found that post-emergence application of imazethapyr 0.5-0.75 kg/ha gave 80-90% control of the major weeds in pea. Similarly, Fraser *et al.* (2003) reported that imazethapyr at recommended rate was quite effective against weeds in pea. Sikkema *et al.* (2005) found that post-emergence application of imazethapyr at 30 g/ha maintained high level of weed control in garden pea.

Knott and Eke (1989) reported that imazethapyr 0.05 kg/ha + pendimethalin 1.0 kg/ha as pre-emergence or early post-emergence application showed activity against wide range of broad-leaved weeds including *Galium* *aparine* and volunteer rape in pea and beans (*Vicia faba*). Hanson and Thill (2001) obtained good control of weeds in pea with imazethapyr + pendimethalin.

2.3.2.3 Quizalofop (Targa super)

Quizalofop belongs to aryloxyphenoxypropionic group of herbicides. It is used to control annual grassy weeds in various vegetable crops including garden pea. The compound is absorbed from the leaf surface and is moved throughout the plant. It inhibits synthesis of acetyl-CoA-carboxylase which is required for fatty acid synthesis. It deprives the plant of a key intermediate (malonyl CoA) essential to both lipid and flavanoid (gibberelin, abscicic acid, caretenoid etc.) biosyntheses and lead to phytotoxic effects. This herbicide generally kills *Phalaris minor, Avena fatua* and *Lolium temulentum*.

Bertilson (1987) reported that quizalofop is a post-emergence herbicide for control of grasses in broad-leaved crops. It gave better control of *Agropyron repens* than sethoxydim in peas and spring oilseeds. Admaczewski *et al.* (1987) found that post-emergence application of quizalofop-ethyl controlled *Agropyron repens* and *Avena fatua* effectively in pea. Hallgren (1988) recorded 90 per cent control of volunteer cereals with quizalofop-p (UBI 4874) and pre-mergence application at 30-90 g/ha effectively controlled 23 annual grass weeds. Quizalofop-ethyl kills monocotyledonous weeds in dicotyledonous crops (Korosmezei and Nazy, 1994). Chambers *et al.* (1995) in Australia, observed that quizalofop-p-ethyl at 12 g/ha gave greater than 98 per cent control of volunteer cereals and 44 to 83.7 per cent of rye grass. Quizalofop p-ethyl gave good control of grassy weeds in pastures (Raux *et al.*, 1995). In Bulgaria, Radeva (1995) found that quizalofop-ethyl reduced weediness by 59.5 to 70.5%. Vallin (1999) in France reported that quizalofop (Targa-D+) gave best results when applied at 2-3 leaf stage. In South

Central and Southern zone of Chile, lower dose of quizalofop gave poor control of *Avena* and *Lolium spp.* and the former was found resistant (Espinoza and Zapata, 2000). Admaczewski *et al.* (2001) reported that post-emergence application of quizalofop-p-tefuryl (Pantera 40 EC) at 4-8 leaf stage gave an excellent control of *Elymus repens* in pea-spring cereal crop rotation in Poland.

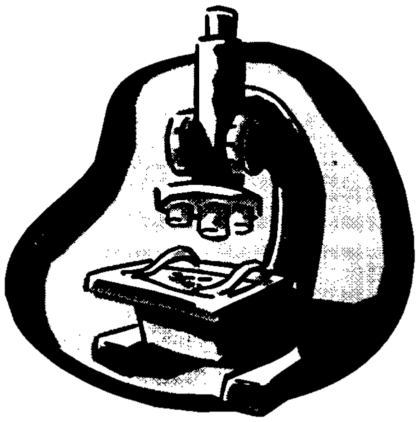
2.3.2.4 Isoproturon (Millron)

It belongs to urea group (*i.e.* phenyl urea herbicide). It generally kills broad-leaved and grassy weeds. It inhibits photosynthetic electron transport in photosystem-II. This leads to production of powerful oxidants which damages membranes, pigments and causes rapid destruction of cells (Walia, 2003).

Saimbhi *et al.* (1990) in sandy loam soils of Haryana found that isoproturon 0.98 kg/ha gave good control of weeds and increased the yield. At Ludhiana, Sekhon *et al.* (1993) observed that in sandy loam soil, isoproturon 0.94 kg/ha (pre-emergence) effectively decreased weed dry weight in rainy season pulses. However, at Palampur, post-emergence application of isoproturon 1.5 kg/ha didn't give effective control of *Lolium temulentum* and *Vicia sativa* (Anonymous, 2004b and 2005b). Chauhan *et al.* (1998) from Karnal reported just 44 per cent control of *Phalaris minor* with isoproturon at 1.0 kg/ha. Similarly, in Pakistan, isoproturon was moderately effective in controlling grassy weeds and very weak on *Avena spp.* (Khan *et al.*, 2002). It has also been reported that isoproturon application at 1.5 kg/ha exhibited phytotoxic effect on winter grain legumes (Anonymous, 2001).

2.4 Economic studies

The economics of any treatment decides its feasibility. Ahlawat *et al.* (1981) recorded relatively higher net returns in pea with chemical weed control over hand weeding. Similarly, Leela (1993) also found herbicidal treatments more economical over hand weeding twice. But, contrary to these findings, Kumar *et al.* (1990) from Hissar reported that hand weeding twice gave higher net returns than chemical control of weeds. Under Sangla valley conditions of Himachal Pradesh, pendimethalin 1.5 kg/ha resulted in significantly higher net returns (Rana, 2002) Singh and Angiras (2005) recorded significantly highest net returns and benefit: cost ratio with pendimethalin 1.5 kg/ha under mid-hill conditions of Himachal Pradesh. Similar were the findings of Rana *et al.* (2007) who reported higher benefit: cost ratio for pendimethalin than for hand weeding. Kundra and Gill (1990) found that manual and chemical weed control gave higher cash returns over unweeded.



MATERIALS AND METHODS

Chapter III

MATERIALS AND METHODS

The present experiment was conducted at the experimental farm of Department of Agronomy, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalya, Palampur (H.P.) during *Rabi* 2005-06. The details of the materials used and methods employed in the experiment are being presented in this chapter.

3.1 Experimental site

3.1.1 Location

The research farm is situated at $32^0\ 6'$ N latitude, $76^0\ 3'$ E longitude and 1290.8 m altitude. The area represents the mid hill zone of Himachal Pradesh. The soils of this area belong to the order 'Alfisol' and are acidic in reaction.

3.1.2 Climate and weather conditions

Agro-climatically, Palampur represents the sub-temperate humid zone of Himachal Pradesh. It is endowed with mild summers and cool winters along with high rainfall during monsoon. The annual average precipitation of Palampur is about 2500 mm. The weather data for the period of experimentation have been presented in Fig. 3.1 and appended in Appendix-I. A cursory glance at Fig. 3.1 and meteorological data presented in Appendix-I reveals that the weekly maximum and minimum temperatures during the period of investigation ranged from 15.5 to 24.2 ^{0}C and 4.5 to 13.9 ^{0}C, respectively. The mean relative humidity varied from 39.2 (47 and 49th standard weeks) to 63.9 per cent (5th standard week). The crop in its life cycle experienced 206.5 mm of total rainfall, out of which 45.4 per cent was received from flowering to last picking. The data on

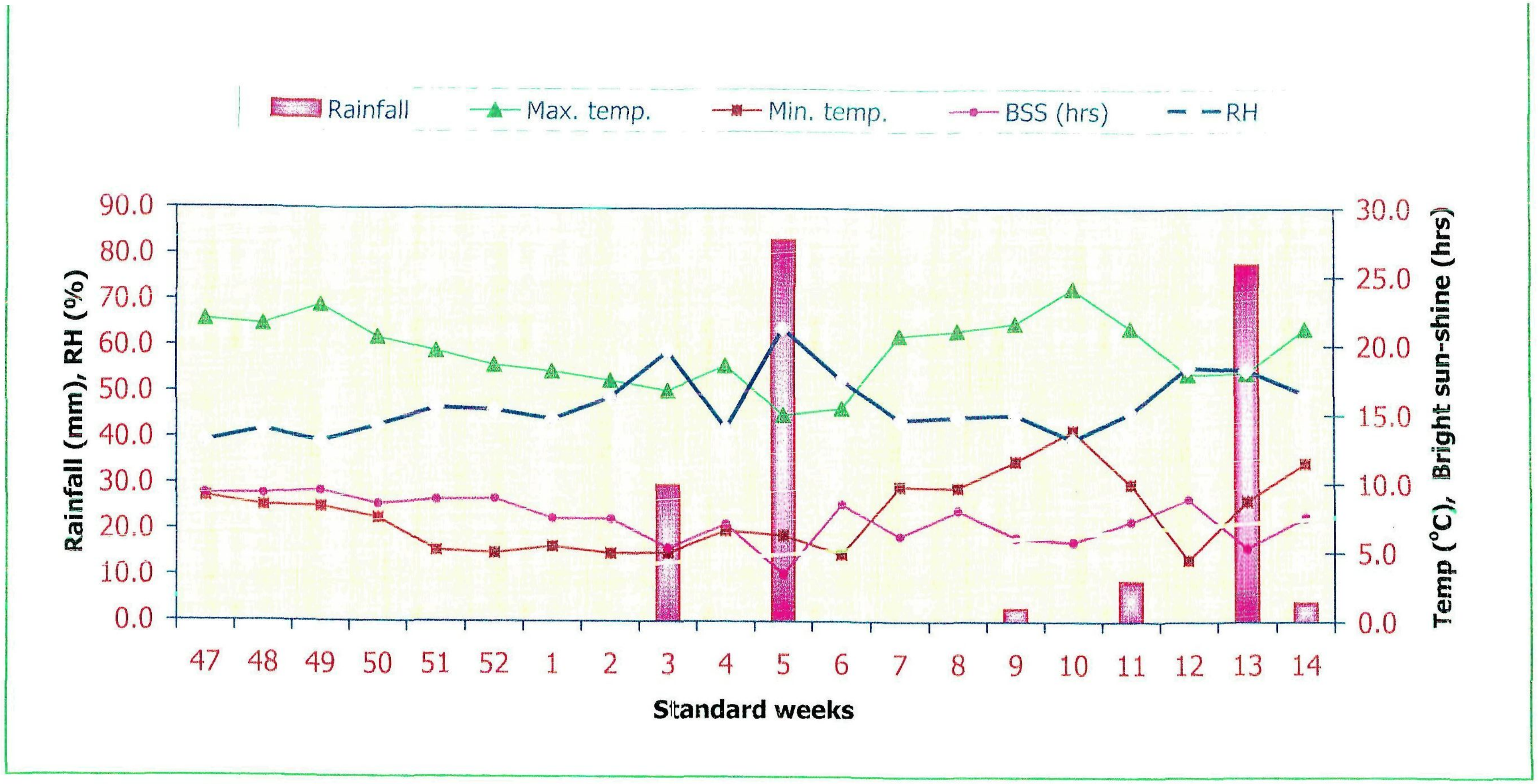


Fig. 3.1 Mean weekly meteorological data 2005-2006 (*Rabi*)

duration of sunshine hours showed that the highest weekly average number of bright sunshine hours of 9.5 was in 49th standard week of 2005 and lowest of 3.4 hours was in 5th standard week of 2006. The crop experienced 1041.1 hours of bright sunshine in its life cycle.

3.2 Cropping history

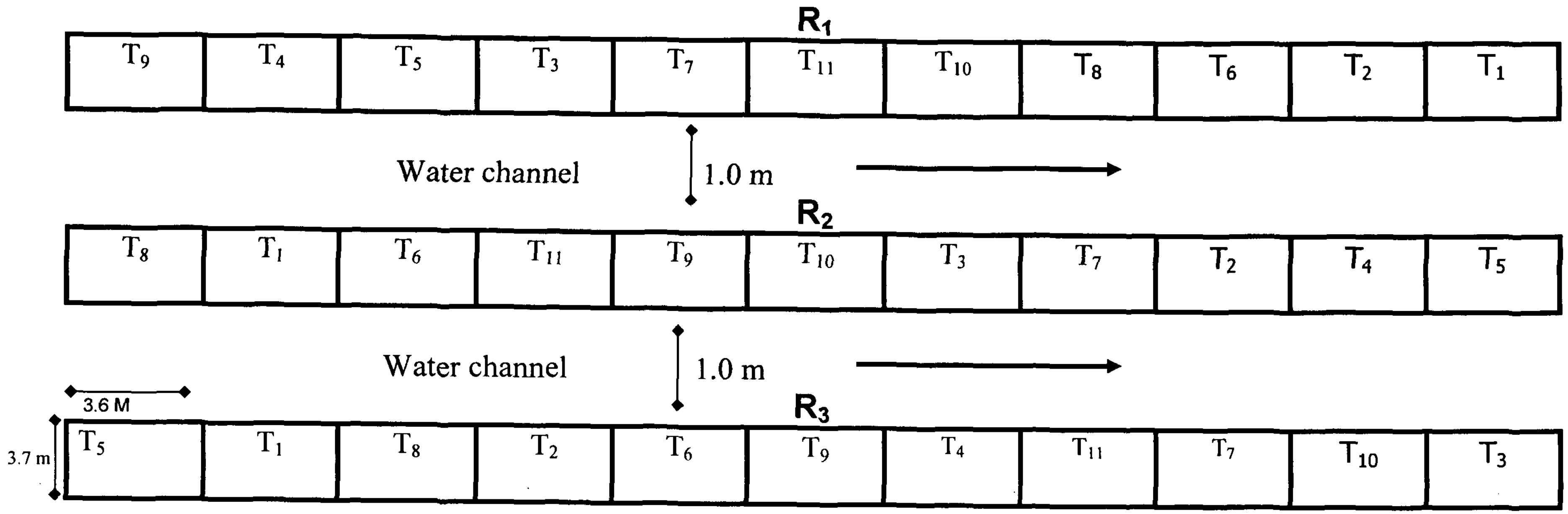
The field in which the present investigation undertaken, was under okra-wheat cropping sequence in the preceding years.

3.3 Details of experiment

Three post-emergence herbicides *viz.*, imazethapyr at 100 & 150 g/ha (20 & 40 DAS), quizalofop at 25 & 37.5 g/ha (20 DAS), isoproturon at 1.0 & 1.25 kg/ha (40 DAS) were compared to pre-emergence application of pendimethalin at 1.50 kg/ha, hand weeding twice and weedy check in Randomized Block Design (RBD) with three replications. The layout plan of the experiment has been shown in Fig. 3.2.

The detail of treatments is given here as under:

S. No.	Treatment	Dose (g/ha)	Time of application (DAS)
1.	Imazethapyr	100	20
2.	Imazethapyr	150	20
3.	Imazethapyr	100	40
4.	Imazethapyr	150	40
5.	Quizalofop	25	20
6.	Quizalofop	37.5	20
7.	Isoproturon	1000	40
8.	Isoproturon	1250	40
9.	Pendimethalin	1500	1
10.	Hand weeding	-	30 & 60
11.	Weedy check	-	-



Gross plot size 3.6 m X 3.7 m = 13.32 m^2
Net plot size 2.4 m X 2.7 m = 6.48 m^2
Design Randomized Block Design
Spacing 30 cm X 10 cm

S. No.	Treatments:	
T_1	Imazethapyr	100 g/ha (20 DAS)
T_2	Imazethapyr	150 g/ha (20 DAS)
T_3	Imazethapyr	100 g/ha (40 DAS)
T_4	Imazethapyr	150 g/ha (40 DAS)
T_5	Quizalofop	25 g/ha (20 DAS)
T_6	Quizalofop	37.5 g/ha (20 DAS)
T_7	Isoproturon	1000 g/ha (40 DAS)
T_8	Isoproturon	1250 g/ha (40 DAS)
T_9	Pendimethalin	1500 g/ha (1 DAS)
T_{10}	Hand weeding	(30 & 60 DAS)
T_{11}	Weedy check	-

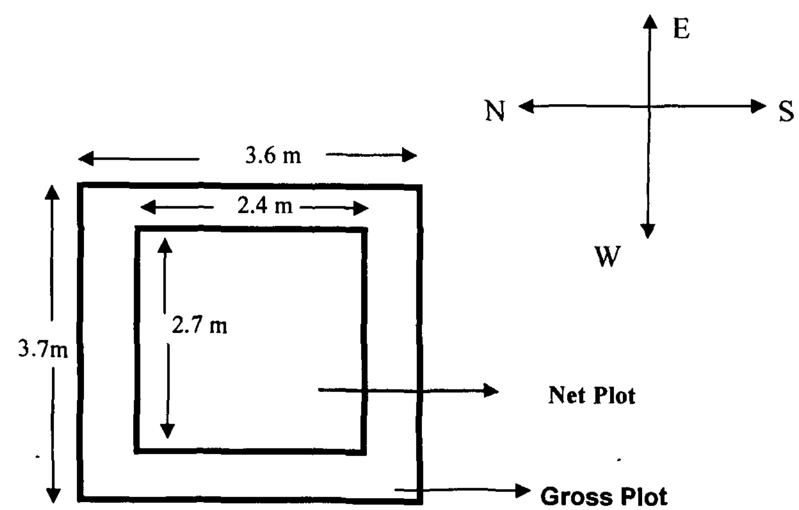


Fig. 3.2 Layout plan

The detail of herbicides used in the present investigation has been given in Table 3.1 and the mode of action of these herbicides has been given in Appendix-XV.

Table 3.1 Detail of herbicides used in the experiment

S. No.	Common name	Trade name	Chemical name	Conc.	Formulation
1.	Imazethapyr	Pursuit	5-ethyl-2[(RS)-4-isopropyl-4 methyl-oxo-2- imidazolin-2-yl] nicotinic acid	10	EC
2.	Quizalofop	Targa super	(RS)-2-[4-(6-chloroquinoxalin-2-yloxy) phenoxy] propionic acid	5	EC
3.	Isoproturon	Millron	3-(4-isopropyl phenyl) -1, 1-dimethyl urea	75	WP
4.	Pendimethalin	Stomp	N-(1-ethylpropyl)-3,4-imethyl-2,6-dinitrobenzene amine	30	EC

3.4 Physico-chemical properties of soil

Before the sowing of pea crop, a composite soil sample (0-15 cm) was collected from the experimental field. The sample was air dried, ground and passed through 2 mm sieve. The sample was analysed for major physical and chemical properties as per the standard procedure (Table 3.2). It is evident from the data that soil of the experimental site was silty clay loam in texture, acidic in reaction and medium in organic carbon, available nitrogen, phosphorus and potassium.

Table 3.2 Physico-chemical properties of soil (0-15 cm) before sowing

Soil characteristics	Value	Method of analysis
A Physical		
Sand (%)	20.1	
Silt (%)	49.6	International pipette method (Piper, 1966)
Clay (%)	30.0	
Textural class	Silty clay loam	
B Chemical		
pH	5.5	Glass electrode pH meter (Jackson, 1967)
Organic carbon (%)	0.69	Walkley and Black's rapid titration method (Piper,1966)
Available N (kg/ha)	361	Alkaline permanganate method (Subbiah and Asija ,1956)
Available P (kg/ha)	20	Olsen's method (Olsen *et al.,* 1954)
Available K (kg/ha)	262	Neutral normal ammonium acetate extraction method (A.O.A.C., 1970)

3.5 Details of field operations

The date on which the particular field operation was carried out has been shown in Table 3.3. The brief description of the major field operations has been given here as under:

3.5.1 Field preparation and layout

The field was ploughed with tractor drawn mould board plough. It was followed by harrowing and planking.

Table 3.3 Details of field operations

S. No.	Name of operation	Date
1.	Primary tillage	26-10-05
2.	Application of FYM	01-11-05
3.	Layout	11-11-05
4.	Pre-sowing irrigation	13-11-05
5.	Application of fertilizer	19-11-05
6.	Sowing of pea crop	19-11-05
7.	Spray of pendimethalin	20-11-05
8.	Spray of imazethapyr	09-12-05
9.	Spray of quizalofop	09-12-05
10.	Hand weeding	19-12-05
11.	Irrigation	23-12-05
12.	Spray of imazethapyr	29-12-05
13.	Spray of isoproturon	29-12-05
14.	Hand weeding	18-01-06
15.	Irrigation	23-01-06
16.	Irrigation	21-02-06
17.	First picking	15-03-06
18.	Second picking	20-03-06
19.	Third picking	25-03-06
20.	Fourth picking	30-03-06
21	Harvesting of haulms	03-04-06

3.5.2 Layout

The plots of size 3.6 m x 3.7 m = 13.32 m^2 were laid out by making bunds with sufficient provision of irrigation channels and path as per layout plan (Fig. 3.2).

3.5.3 Manures and fertilizer application

Well rotten FYM at 8 t/ha (wet weight basis) was applied before harrowing and planking. Application of nitrogen 46 kg/ha, phosphorus 60 kg/ha and potassium 60 kg/ha was made through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. The fertilizers were applied as basal by band placement in the furrow bottoms ensuring that they did not come in direct contact with seeds.

3.5.4 Seed and sowing

The seeds of variety 'Palam Priya' were sown at 75 kg/ha on November 19, 2005. Before sowing, the seeds were treated with bavistin at 2.5 g/kg of seed. The seeds were sown at a row to row spacing of 30 cm and seed to seed spacing of 10 cm.

3.5.5 Herbicides spray

Pre-emergent herbicide was sprayed as per treatment with help of Knapsack sprayer having flat fan nozzle using 600 litres of water per hectare. Application of post-emergent herbicides was made using hollow cone nozzle.

3.5.6 Gap filling

To maintain the desired plant population, gap filling was also carried out.

3.5.7 Pickings and harvesting

Green pods were picked manually. In all, four pickings were taken. The haulms were harvested with sickles.

3.6 Details of observations recorded

The details of various observations recorded in the present investigation have been presented in this section under following sub heads:

3.6.1 Weed studies

3.6.1.1 Weed count

A 50 cm x 50 cm quadrate was placed randomly at two spots in each net plot. The spots were earmarked with the help of pegs. Species-wise weed count at 30 days interval starting from 60 DAS onwards was recorded from the earmarked spots. The weed number so obtained was converted into number per square metre by multiplying with a factor 2.

3.6.1.2 Dry weight

A quadrate of 50 cm x 50 cm was thrown at random at two sites between two boarder rows in each plot at monthly interval starting from 60 days after sowing. Weeds encompassed in the quadrates were clipped from the ground level and species-wise dry weight was recorded after oven drying at 75 ^{0}C. The total weed dry weight from the two spots was multiplied with factor 2 to express it in gram per square metre.

3.6.1.3 Weed control efficiency

Weed control efficiency of different treatments was calculated at maximum weed dry matter accumulation stage as per the formula (Walia, 2003) given below:

$$\text{Weed control efficiency (\%)} = \frac{W_c - W_t}{W_c} \times 100$$

Where,

W_c - Weed dry weight in weedy check plot, and

W_t - Weed dry weight in treated plot

3.6.1.4 Phytotoxicity rating

The phytotoxicity rating was made by three persons without knowing the layout plan of the experiment. First observation was made at 15 days after herbicide application and the subsequent observations were made at 30 days interval. The phytotoxicity rating was done using 0-10 scale, where, 0 means no toxicity and 10 means complete kill of the crop.

3.6.2 Crop studies

3.6.2.1 Emergence count

In the net plot area, one metre row length was earmarked using pegs. The emergence of crop was keenly observed starting from emergence of few plants till the plant count was constant. The final observation of emergence count per metre row length was multiplied with factor 3.33 to get number of plants per square metre.

3.6.2.2 Days to emergence

The date on which the emergence count was constant, was noted and number of days taken to complete emergence were calculated from date of sowing.

3.6.2.3 Plant height

Five plants were randomly selected from net plot area and were tagged. Height of these plants from the ground level to the tip of the top most leaf was recorded at 30 days interval starting from 60 days after sowing. Average of five plants was expressed as mean plant height in centimeters.

3.6.2.4 Dry matter accumulation

On both sides of each plot, the second row from the boarder was demarcated as sampling row. Pea plants were clipped close to the ground level from half metre row length at monthly interval from 60 days after sowing onwards. The sample was oven dried at 75 ^{0}C till constant weight. The weight so obtained was multiplied with factor 3.33 to express as gram per square metre.

3.6.2.5 Relative growth rate (RGR)

The relative growth rate from 120 DAS to harvest was worked out by using the formula outlined by Reddy and Shankra (1992).

$$\text{Relative growth rate (CGR)} = \frac{\text{Log e } W_2 - \text{Log e } W_1}{t_2 - t_1}$$

Where,

W_1 = Initial dry weight of plants

W_2 = Final dry weight

t_1 & t_2 = Time interval

3.6.2.6 Crop growth rate (CGR)

The crop growth rate from 120 DAS to harvest was worked out by using the formula outlined by Reddy and Shankra (1992).

$$\text{Crop growth rate (CGR)} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_1 = Initial dry weight of plants

W_2 = Final dry weight

t_1 & t_2 = Time interval

3.6.2.7 Count and dry weight of root nodules per plant

In each plot, five plants were randomly selected and uprooted from sampling row at pre (90 DAS) and post-flowering (120 DAS) stages of the crop growth. Roots were separated from plant and washed to remove the nodules. The value obtained after counting was divided by five to obtain number of nodules per plant. The nodules were oven dried at 75 ^{0}C. The total weight was divided by 5 to express the nodules dry weight per plant.

3.6.2.8 Days to flowering

Sixteen plants were randomly selected from the net plot area and were keenly observed for flowering. When 12 out of 16 plants flowered (at least one flower on each plant), the date was noted and days taken to 75 per cent flowering were calculated from the sowing date.

3.6.2.9 Days to first picking

Days from sowing to the date on which first picking was done were expressed as days taken to first picking.

3.6.2.10 Days to last picking

Days from sowing to the date on which last picking was done were expressed as days taken to last picking.

3.6.2.11 Final plant population

The number of plants was recorded from one metre row length at two sites marked randomly in each plot at last picking. The plant number so counted was averaged and converted into number of plants per square metre by multiplying with factor 3.33.

3.6.2.12 Number of pods per plant

In each plot, the pods borne by the randomly selected five plants were counted at each picking. The average number of pods per plant was obtained by dividing the total number of pods by five.

3.6.2.13 Pod length

The length of ten randomly selected pods at each picking from net plot in each treatment was averaged. The pod length was expressed in centimeters.

3.6.2.14 Number of seeds per pod

From the produce of each net plot, ten pods were randomly selected at each picking. Then the pods were hand shelled. The mean number of seeds per pod were obtained by dividing the total number of seeds by 40.

3.6.2.15 Shelling percentage

Shelling percentage was worked out as per the formula outlined below:

$$\text{Shelling percentage (\%)} = \frac{\text{Seeds weight (g)}}{\text{Green pod weight (g)}} \times 100$$

3.6.2.16 100-seed weight

A composite seed sample from net plot produce of second picking was taken. The hundred fresh seeds were counted with seed counter. Their weight was recorded in grams.

3.6.2.17 Pod yield (q/ha)

The net plot yield obtained in four pickings was totaled to obtain pod yield per plot (kg/plot). Green pod yield in q/ha was obtained by multiplying the plot yield with factor 15.43.

3.6.2.18 Haulms yield (q/ha)

The net plot haulms yield at last harvest was weighed in kilograms. The haulms yield in q/ha was obtained by multiplying the plot haulms yield with factor 15.43.

3.6.3 Chemical studies

3.6.3.1 Total soluble solids (TSS)

Fresh seeds of garden pea were crushed with the help of pastel and mortar. The sap was extracted with the help of muslin cloth. A drop of sap was placed on the glass stage of hand refrectometer. The concentration of sap was read on the graduated scale, which was seen through eye piece to obtain TSS percentage in pods ("Erma hand refrectometer method", A.O.A.C., 1970).

3.6.3.2 Ascorbic acid (mg/100 g of fresh weight)

Fresh pea seeds from the produce of second picking were subjected to the analysis of ascorbic acid content following "2, 6–dichlorophenol–indophenol visual titration method". The ascorbic acid content was expressed as mg/100 g of fresh weight (Ranganna, 1979).

3.6.3.3 Protein content in seed (%)

The nitrogen content in seeds from the produce of net plot was determined by the "Alkaline potassium permanganate method"and value was multiplied with a factor 6.25 to get protein content in seeds (Ranganna, 1979).

3.6.4 Economic studies

3.6.4.1 Cost of cultivation (Rs/ha)

Cost of cultivation was calculated by adding all costs involved in each operation/input. The details of prevailing market prices and components of cost of cultivation have been given in Appendix-II.

3.6.4.2 Gross returns (Rs/ha)

The treatment-wise pod and haulms yields were multiplied with their respective gate/market prices (the gate price is one which is obtained by selling the produce at the farm itself or that fixed by the university). The gross returns were obtained by adding returns from pod yield (Rs.10/kg) and haulms yield (Rs.100/q).

3.6.4.3 Net returns (Rs/ha)

The treatment-wise net returns were obtained by subtracting the cost of cultivation from the gross returns of the respective treatment.

3.6.4.4 B: C ratio

The B: C ratio (net return per rupee invested) was calculated as per the formula outlined below:

$$\text{Net returns per rupee invested} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

3.6.5 Statistical analysis

The data obtained were subjected to analysis of variance as outlined by Gomez and Gomez (1984). Suitable transformation of data was done wherever required. The weed count data were analyzed after subjecting to square root ($\sqrt{x+1.0}$) transformation. The treatment means were compared by using transformed means. The actual means have been given in parentheses. The critical difference (CD) was calculated at 5 per cent level of significance.

EXPERIMENTAL RESULTS

Chapter IV

EXPERIMENTAL RESULTS

The results emanating from the present investigation have been described in this chapter under the following three broad headings:

4.1 Weed studies

4.2 Crop studies

4.3 Economic studies

4.1 Weed studies

4.1.1 Distribution of weed flora

The per cent invasion by different weeds at maximum weed population stage *i.e.* at 90 DAS has been shown in Table 4.1.

Table 4.1 Species-wise proportion of weeds in experimental area

Weed species	Population (m^{-2})	Percentage
Phalaris minor	122.7	43.2
Vicia sativa	74.7	26.3
Avena fatua	65.3	23.0
Others	21.3	7.5
Total	284.0	100

The perusal of the data reveals that *Phalaris minor, Vicia sativa* and *Avena fatua* were the dominant weeds constituting 43.2, 26.3 and 23.0 per cent, respectively, of the total weed flora. *Lolium temulentum, Stellaria media* and *Coronopus didymus* showed their little infestation but as a whole constituted 7.5 per cent of the total weed flora.

Table 4.2 Effect of treatments on species-wise and total weed count (number/m^2) at 90 DAS (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	*Phalaris minor*	*Avena fatua*	*Vicia sativa*	Others	Total
Imazethapyr	100	20	7.00 (48.0)	4.72 (21.3)	5.22 (26.7)	2.69 (6.7)	10.15 (102.7)
Imazethapyr	150	20	6.40 (40.0)	4.28 (17.3)	4.37 (18.7)	2.49 (5.3)	9.11 (82.7)
Imazethapyr	100	40	3.90 (14.7)	3.90 (14.7)	2.75 (6.7)	1.00 (0.0)	6.08 (36.0)
Imazethapyr	150	40	3.58 (12.0)	3.73 (13.3)	2.49 (5.3)	1.00 (0.0)	5.56 (30.7)
Quizalofop	25	20	7.55 (56.0)	5.86 (33.3)	8.55 (73.3)	2.75 (6.7)	13.06 (170.7)
Quizalofop	37.5	20	3.75 (13.3)	3.73 (13.3)	7.92 (62.7)	2.49 (5.3)	9.70 (94.7)
Isoproturon	1000	40	6.80 (45.3)	5.08 (25.3)	5.38 (28.0)	2.24 (4.0)	10.21 (104.0)
Isoproturon	1250	40	6.60 (42.7)	4.99 (24.0)	5.11 (25.3)	2.24 (4.0)	9.91 (97.3)
Pendimethalin	1500	1	5.68 (32.0)	7.63 (57.3)	5.96 (34.7)	2.24 (4.0)	11.41 (129.3)
Hand weeding	-	30 & 60	2.49 (5.3)	2.95 (8.0)	1.82 (2.7)	1.00 (0.0)	4.04 (16.0)
Weedy check	-	-	11.12 (122.7)	8.14 (65.3)	8.70 (74.7)	4.57 (20.0)	16.88 (284.0)
CD (P=0.05)			0.80	0.88	0.77	0.51	0.81

Values given in parentheses are the means of original values

4.1.2 Weed count

A cursory glance at the data in Table 4.2 and Appendices-III-VII reveals that the population of *Phalaris minor* and *Avena fatua* and all weeds together was highest at 90 DAS and thereafter there was a gradual decrease. The population of

Vicia sativa and other weeds was highest at 60 DAS. Thereafter, there was gradual decline with the advancement in crop growth stage. In this section, the treatment effects were explained only at 90 DAS, since the behaviour of the treatments was almost identical at all the stages of observation. Also, hand weeding twice treatment was completed just at 60 DAS. However, the data on the count of different weed species at the remaining stages of observation have been appended in the Appendices-III-VII.

4.1.2.1 *Phalaris minor* (Canary grass/Gulli danda)

All the weed management treatments were significantly superior to weedy check in reducing the population of *Phalaris minor* (Table 4.2). Imazethapyr at 100 & 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha (20 DAS) being statistically similar were the superior herbicidal treatments in reducing the count of *Phalaris minor*. Imazethapyr at 150 g/ha (20 DAS) was as effective as the standard pre-emergent herbicidal check pendimethalin at 1.5 kg/ha. Hand weeding twice resulted in significantly lowest population of *Phalaris minor*.

4.1.2.2 *Avena fatua* (Wild oat)

All the weed control treatments brought about significant variation in the count of *Avena fatua* (Table 4.2). Hand weeding twice resulted in significantly lower count of *Avena fatua*. However, imazethapyr at 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha (20 DAS) were statistically alike with hand weeding twice. But these herbicidal treatments were also statistically at par with imazethapyr at 150 g/ha (20 DAS) & at 100 g/ha (40 DAS). The remaining post-emergent herbicidal treatments also significantly reduced the count of *Avena fatua* over the standard pre-emergent herbicidal check. But, pre-emergent check pendimethalin at 1.5 kg/ha did not influence the count of *Avena fatua* significantly as compared to the weedy check.

4.1.2.3 *Vicia sativa*

A critical perusal of the data (Table 4.2) depicts that hand weeding twice remaining at par with imazethapyr at 150 g/ha (40 DAS) resulted in significantly lower population of *Vicia sativa.* However, imazethapyr at 150 g/ha (40 DAS) was statistically similar with imazethapyr at 100 g/ha (40 DAS). The other superior herbicidal treatments in reducing the population of *Vicia sativa* over the standard check pendimethalin were imazethapyr at 100 & 150 g/ha (20 DAS) and isoproturon at 1.25 kg/ha. Quizalofop at lower rate *i.e.* at 25 g/ha did not differ significantly from weedy check.

4.1.2.4 Other weeds

All weed control treatments were significantly superior to weedy check in reducing the count of other weeds (Table 4.2). Hand weeding twice and imazethapyr at 100 & 150 g/ha (40 DAS) remaining statistically at par, were superior to other treatments. The remaining treatments (isoproturon and quizalofop at both rates and imazethapyr at 100 & 150 g/ha at 20 DAS) were equal to pre-emergence pendimethalin in influencing the population of other weeds.

4.1.2.5 Total weeds

All weed control treatments were significantly superior to weedy check in reducing total weed population (Table 4.2). Amongst different herbicidal treatments, imazethapyr at 100 & 150 g/ha (40 DAS) was the best. However, except quizalofop at 25 g/ha, all the remaining post-emergent herbicides at higher rate were superior to their respective lower doses in influencing total weed population. Hand weeding twice resulted in significantly lowest total weed population.

4.1.3 Weed dry weight

Species-wise and total weed dry weight was recorded at 60, 90, 120 and at harvest. Total weed dry weight increased at increasing rate upto 90 DAS and then increased at decreasing rate upto 120 DAS. There was then decrease in weed dry weight after 120 DAS. The data on species-wise and total weed dry weight at maximum weed dry weight stage (120 DAS) have been summarized in Table 4.3. The data pertaining to rest of stages have been given in Appendices VIII-XII.

4.1.3.1 *Phalaris minor*

A cursory view at the data (Table 4.3) depicts that all weed control treatments were significantly superior to weedy check in reducing the dry weight of *Phalaris minor.* Imazethapyr at 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha remaining statistically alike with imazethapyr at 100 g/ha (40 DAS), significantly reduced the dry weight of *Phalaris minor.* Imazethapyr at 100 g/ha (40 DAS) was statistically at par with hand weeding, isoproturon at 1.0 & 1.25 kg/ha (40 DAS) and imazethapyr at 150 g/ha (20 DAS). The lower doses of imazethapyr and quizalofop at 20 DAS could not significantly reduce the dry weight of *Phalaris minor* over the standard herbicidal check.

4.1.3.2 *Avena fatua*

All weed control treatments were significantly superior to weedy check in reducing *Avena fatua* dry weight. Imazethapyr at 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha (20 DAS) remaining at par with imazethapyr at 100 g/ha (40 DAS) resulted in significantly lower dry weight of *Avena fatua.* However, imazethapyr at

100 g/ha (40 DAS) was statistically alike with both the doses of isoproturon, quizalofop (25 g/ha) and hand weeding twice. Pendimethalin at 1.5 kg/ha (pre-emergence) was least effective in reducing the dry weight of *Avena fatua*.

4.1.3.3 *Vicia sativa*

A cursory glance at the data (Table 4.3) shows that imazethapyr at 150 g/ha (40 DAS) being at par with imazethapyr at 100 g/ha (40 DAS) and hand weeding twice significantly reduced *Vicia sativa* dry weight as compared to rest of the treatments. However, hand weeding twice and imazethapyr at 100 g/ha were not significantly different from the standard herbicidal check (Pendimethalin). Isoproturon (40 DAS) and imazethapyr (20 DAS) at both rates significantly reduced *Vicia sativa* dry weight over weedy check. However, quizalofop at lower rate was statistically similar with weedy check.

4.1.3.4 Other weeds

All weed control treatments were significantly superior to weedy check in reducing the dry weight of other weeds (Table 4.3). Application of imazethapyr at 100 & 150 g/ha (40 DAS) and hand weeding twice were the most effective treatments. Pendimethalin at 1.5 kg/ha (pre-emergence) was next superior treatment. Isoproturon at 1.0 & 1.25 kg/ha (40 DAS) and imazethapyr at 100 & 150 g/ha (20 DAS) were statistically at par with each other. Quizalofop at 25 g/ha (20 DAS) was least effective against other weeds.

4.1.3.5 Total dry matter accumulation

All weed control treatments were significantly superior to weedy check in curtailing total weed dry weight (Table 4.3). Significantly lower total weed dry weight was obtained with imazethapyr at 150 g/ha (40 DAS). This was followed by imazethapyr at 100 g/ha (40 DAS) and hand weeding twice. Quizalofop at 37.5

Table 4.3 Effect of treatments on species-wise and total dry matter accumulation (g/m^2) at 120 DAS (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	*Phalaris minor*	*Avena fatua*	*Vicia sativa*	Others*	Total
Imazethapyr	100	20	18.0	16.5	16.7	4.35 (17.9)	69.1
Imazethapyr	150	20	15.7	15.9	16.0	4.32 (17.7)	65.2
Imazethapyr	100	40	13.7	14.7	7.7	1.00 (0.0)	36.1
Imazethapyr	150	40	11.5	12.0	5.8	1.00 (0.0)	29.3
Quizalofop	25	20	22.0	16.4	25.1	4.75 (21.6)	85.1
Quizalofop	37.5	20	11.5	12.4	22.9	3.67 (12.5)	59.3
Isoproturon	1000	40	16.5	16.5	17.3	4.34 (17.9)	68.2
Isoproturon	1250	40	15.9	16.1	17.0	4.32 (17.7)	66.8
Pendimethalin	1500	1	20.1	32.2	9.6	3.18 (9.1)	71.1
Hand weeding	-	30 & 60	15.7	15.5	6.9	1.00 (0.0)	38.2
Weedy check	-	-	49.6	35.9	27.1	5.62 (30.7)	143.3
CD (P=0.05)			3.34	3.08	3.01	0.21	5.84

*Values given in parentheses are the means of original values

g/ha (20 DAS) was followed by imazethapyr at 100 g/ha (20 DAS). In addition to the above mentioned weed control treatments, the other superior treatment in reducing total dry weight was pendimethalin. But pendimethalin at 1.5 kg/ha (pre-emergence) was at par with isoproturon at 1.0 & 1.25 kg/ha and imazethapyr at 100 g/ha (20 DAS).

4.1.4 Weed control efficiency

The data on species-wise and total weed control efficiency as affected by various treatments have been presented in Table 4.4.

4.1.4.1 *Phalaris minor*

In general, *Phalaris minor* control efficiency, increased with increase in dose. The control efficiency ranged from 55.7 to 77.1 per cent owing to different treatments under study. The highest *Phalaris minor* control efficiency (77.1%) was obtained following imazethapyr at 150 g/ha. This was followed by quizalofop at 37.5 g/ha (76.9%), imazethapyr 100 g/ha applied at 40 DAS (72.4%), imazethapyr 150 g/ha at 20 DAS (68.6%) and hand weeding twice (68.2%).

4.1.4.2 *Avena fatua*

Weed control efficiency of *Avena fatua* ranged from 10.3 per cent with pendimethalin to 66.6 per cent with imazethapyr 150 g/ha (40 DAS). The latter treatment imazethapyr at 150 g/ha (40 DAS) was closely followed by quizalofop at 37.5 g/ha (65.5%), imazethapyr at 100 g/ha at 40 DAS (59.1%), hand weeding twice (56.1%) and imazethapyr at 150 g/ha applied at 20 DAS (56.6%).

4.1.4.3 *Vicia sativa*

Imazethapyr at 150 g/ha (40 DAS) had the highest *Vicia sativa* control efficiency of 79 per cent. This was followed by hand weeding twice (75.9%) and imazethapyr at 100 g/ha applied at 40 DAS (71.8%). Quizalofop at 25 & 37.5 g/ha (20 DAS) were not effective against *Vicia sativa* as control efficiency was just 5.9 and 14.9 per cent, respectively.

Table 4.4 Effect of treatments on weed control efficiency (%) at maximum weed dry weight stage (120 DAS)

Treatment	Dose (g/ha)	Time of application (DAS)	*Phalaris minor*	*Avena fatua*	*Vicia sativa*	Others	Total
Imazethapyr	100	20	63.3	53.8	38.6	41.0	51.7
Imazethapyr	150	20	68.6	55.6	41.4	42.0	54.6
Imazethapyr	100	40	72.4	59.1	71.8	100.0	74.9
Imazethapyr	150	40	77.1	66.6	78.9	100.0	79.7
Quizalofop	25	20	55.7	53.5	5.9	29.1	40.5
Quizalofop	37.5	20	76.9	65.5	14.9	59.0	58.7
Isoproturon	1000	40	66.8	53.8	36.7	41.4	52.5
Isoproturon	1250	40	68.0	54.9	37.8	41.8	53.5
Pendimethalin	1500	1	59.2	10.3	64.7	70.3	50.4
Hand weeding	-	30 & 60	68.2	56.5	75.9	100.0	73.5
Weedy check	-	-	-	-	-	-	-

4.1.4.4 Other weeds

The perusal of the data in Table 4.4 reveals that hand weeding twice and imazethapyr at 100 & 150 g/ha (40 DAS) had hundred per cent control efficiency for other weeds. These were followed by pendimethalin at 1.5 kg/ha and quizalofop at 37.5 g/ha having control efficiencies of 70.3 and 59.0 per cent, respectively. Quizalofop at 25 g/ha resulted in lowest control efficiency of 29.1 per cent.

4.1.4.5 Total weed control efficiency

Total weed control efficiency due to different treatments ranged from 40.5 to 79.7 per cent. Imazethapyr at 150 g/ha (40 DAS) resulted in highest total weed control efficiency of 79.7 per cent. This was followed by imazethapyr at 100 g/ha at 40 DAS (74.9%) and hand weeding twice (73.5%). Quizalofop at 25 g/ha gave lowest total weed control efficiency (40.5%).

4.2 Crop studies

The data with regard to different aspects of growth, development, yield attributes as well as pod and haulms yields of pea crop have been discussed in this section under different headings.

4.2.1 Growth studies

4.2.1.1 Emergence count

The data on emergence count have been given in Table 4.5. The perusal of the data reveals that the emergence of pea was not significantly influenced by different weed control treatments.

4.2.1.2 Plant height

Plant height recorded at 60, 90 and 120 DAS has been given in Appendix-XIII. The plant height increased with sigmoidal pattern with a grand growth stage between 60 to 120 DAS. The data on height at harvest presented in Table 4.5 reveal that imazethapyr at 150 g/ha (40 DAS) being statistically at par with its lower dose at 100 g/ha (40 DAS), quizalofop at 25 & 37.5 g/ha (20 DAS) and pendimethalin at 1.5 kg/ha (pre-emergence) resulted in significantly taller plants over rest of the treatments except imazethapyr at 100 g/ha (20 DAS). The remaining treatments also significantly increased the plant height over weedy check.

Table 4.5 Effect of treatments on emergence count, plant height, dry matter accumulation, CGR (120 DAS to harvest) and RGR (120 DAS to harvest) of pea crop

Treatment	Dose (g/ha)	Time of application (DAS)	Emergence count (no./m^2)	Plant height (cm)	Plant Dry matter (g/m^2)	CGR (g/m^2/day)	RGR (g/g/day)
Imazethapyr	100	20	27.7	61.5	341.6	4.56	0.0187
Imazethapyr	150	20	27.7	63.4	359.8	4.69	0.0178
Imazethapyr	100	40	29.0	65.0	394.1	6.29	0.0229
Imazethapyr	150	40	29.0	66.7	407.6	6.54	0.0231
Quizalofop	25	20	27.7	63.9	194.8	2.23	0.0131
Quizalofop	37.5	20	29.0	64.1	391.0	6.25	0.0231
Isoproturon	1000	40	27.7	63.1	329.3	4.22	0.0177
Isoproturon	1250	40	29.0	63.1	339.7	4.90	0.0204
Pendimethalin	1500	1	29.0	64.0	331.5	4.23	0.0175
Hand weeding	-	30 & 60	29.0	65.4	404.9	6.39	0.0228
Weedy check	-	-	27.7	59.1	182.8	1.91	0.0171
CD (P=0.05)			NS	3.12	57.02	1.47	0.0044

4.2.1.3 Plant dry matter accumulation

The plant dry matter recorded at 60, 90 and 120 DAS has been given in Appendix-XIV. The data on plant dry matter accumulation upto harvest have been presented in Table 4.5. A cursory glance at the data depicts that the plant dry weight increased consistently with advancement in crop growth with maximum rate at 90 to 120 DAS. Imazethapyr at 150 g/ha (40 DAS) and hand weeding twice remaining statistically at par with imazethapyr at 100 g/ha (40 DAS), imazethapyr at 150 g/ha (20 DAS) and quizalofop at 37.5 g/ha (20 DAS) resulted in significantly higher plant dry matter accumulation as compared to other treatments. Isoproturon (40 DAS) and imazethapyr (20 DAS) at both rates were comparable to pendimethalin at 1.5 kg/ha (pre-emergence). However, quizalofop at 25 g/ha (40 DAS) did not increase plant dry matter accumulation significantly over the weedy check.

4.2.1.4 Crop growth rate (CGR)

Crop growth rate worked out from 120 DAS to harvest has been given in Table 4.5. Significantly higher crop growth rate was realized in the treatment imazethapyr 150 g/ha (40 DAS). However, this was statistically at par with the crop growth rate obtained under imazethapyr 100 g/ha (40 DAS), quizalofop 37.5 g/ha (20 DAS) and hand weeding twice treatments.

4.2.1.5 Relative growth rate (RGR)

Relative growth rate obtained from 120 DAS to harvest has been given in Table 4.5. Significantly higher relative growth rate was in the treatment imazethapyr 150 g/ha (40 DAS). However, imazethapyr 150 g/ha (40 DAS) was statistically at par with imazethapyr 100 g/ha (40 DAS), imazethapyr 100 g/ha (20 DAS), quizalofop 37.5 g/ha (20 DAS), isoproturon 1.25 g/ha (40 DAS) and hand weeding twice in influencing the relative growth rate.

4.2.1.6 Nodules/plant

The data on nodules number at pre (90 DAS) and post-flowering (120 DAS) stage have been presented in Table 4.6. A close examination of the data infers that imazethapyr at 100 & 150 g/ha and quizalofop at 37.5 g/ha (20

DAS) being statistically alike with hand weeding twice resulted in significantly higher number of nodules over rest of the treatments at pre-flowering stage. However, imazethapyr at 150 g/ha (40 DAS) remaining at par with hand weeding twice, gave significantly higher number of nodules over rest of the treatments at post-flowering stage. Quizalofop at 25 g/ha both at pre and post-flowering stage and imazethapyr (20 DAS) at both rates at pre-flowering stage were as good as the herbicidal check pendimethalin at 1.5 kg/ha. However, all weed control treatments were superior to weedy check both at pre and post-flowering stage in influencing nodules/plant.

4.2.1.7 Nodules dry weight/plant

Dry weight of nodules varied significantly due to different weed control treatments (Table 4.6). All weed control treatments were superior to weedy check in influencing nodules dry weight. Imazethapyr at 150 g/ha (40 DAS) resulted in highest nodules dry weight at post-flowering stage. However, it was statistically at par with its lower dose at 100 g/ha (40 DAS) at pre-flowering stage. The higher dose of quizalofop and imazethapyr at 20 DAS was superior to their respective lower dose both at pre and post-flowering stages. Quizalofop at 25 g/ha (20 DAS) both at pre and post-flowering stages was as effective as pendimethalin. However, isoproturon at both the rates was least effective amongst all treatments at both the stages of observations.

Table 4.6 Effect of treatments on root nodules (number/plant) and its dry weight per plant (mg)

Treatment	Dose (g/ha)	Time of application (DAS)	Root nodules			
			Count		Weight	
			Pre-flowering	Post-flowering	Pre-flowering	Post-flowering
Imazethapyr	100	20	45.0	27.7	40.0	22.6
Imazethapyr	150	20	46.1	33.0	42.8	27.7
Imazethapyr	100	40	49.0	35.4	46.8	30.3
Imazethapyr	150	40	49.7	36.8	48.2	31.2
Quizalofop	25	20	45.4	31.3	39.4	26.6
Quizalofop	37.5	20	48.3	35.0	45.8	30.0
Isoproturon	1000	40	42.1	26.7	36.5	21.5
Isoproturon	1250	40	41.9	26.6	36.0	21.4
Pendimethalin	1500	1	44.6	30.9	39.2	26.0
Hand weeding	-	30 & 60	48.0	36.0	44.5	30.3
Weedy check	-	-	33.6	24.7	33.0	19.9
CD (P=0.05)			2.07	1.09	1.48	0.88

4.2.2 Phytotoxicity

The data on phytotoxicity rating have been given in Table 4.7. The data indicate slight phytotoxicity due to the application of isoproturon at 1.25 kg/ha. However, plants recovered by 120 DAS. No phytotoxicity was observed in other herbicidal treatments.

Table 4.7 Effect of treatments on phytotoxicity rating

Treatment	Dose (g/ha)	Time of application (DAS)	Time of observation (DAS)		
			55	85	115
Imazethapyr	100	20	0	0	0
Imazethapyr	150	20	0	0	0
Imazethapyr	100	40	0	0	0
Imazethapyr	150	40	0	0	0
Quizalofop	25	20	0	0	0
Quizalofop	37.5	20	0	0	0
Isoproturon	1000	40	0	0	0
Isoproturon	1250	40	4.0	2.25	0.00
Pendimethalin	1500	1	0	0	0
Hand weeding	-	30 & 60	0	0	0
Weedy check	-	-	0	0	0

4.2.3 Development studies

Data on number of days for attainment of various development stages *viz.*, 75 per cent flowering and days taken to first and last picking have been presented in Table 4.8. A cursory glance at the data inferred that the effect of treatments on days taken to 75 per cent flowering and first and last picking was not significant.

Table 4.8 Effect of treatments on development studies

Treatment	Dose (g/ha)	Time of application (DAS)	Days to		
			75% flowering	first picking	last picking
Imazethapyr	100	20	95.3	116.0	130.0
Imazethapyr	150	20	95.7	116.7	130.7
Imazethapyr	100	40	95.7	116.7	131.0
Imazethapyr	150	40	95.7	116.7	131.0
Quizalofop	25	20	95.3	116.0	130.0
Quizalofop	37.5	20	95.7	116.7	131.0
Isoproturon	1000	40	95.3	116.3	130.3
Isoproturon	1250	40	95.3	116.3	130.3
Pendimethalin	1500	1	95.3	116.0	130.0
Hand weeding	-	30 & 60	95.7	116.7	131.0
Weedy check	-	-	95.0	116.0	130.0
CD (P=0.05)			NS	NS	NS

4.2.4 Yield attributes

The data on effect of different treatments on yield attributes of pea crop have been presented in Table 4.9.

4.2.4.1 Plant population

Number of plants per square metre was not affected significantly due to different treatments (Table 4.9).

Table 4.9 Effect of treatments on yield attributes

Treatment	Dose (g/ha)	Time of application (DAS)	Plant population (no/m^2)	Pods per plant (no.)	Pod length (cm)	Seeds per pod (no.)	Shelling percentage	100-seed weight (g)
Imazethapyr	100	20	26.0	12.0	5.1	5.1	59.9	33.1
Imazethapyr	150	20	26.0	12.7	6.2	5.3	62.3	35.2
Imazethapyr	100	40	26.0	13.3	6.8	6.0	64.2	35.8
Imazethapyr	150	40	26.0	13.3	7.0	6.1	64.5	36.3
Quizalofop	25	20	25.0	12.0	4.8	4.9	56.8	23.3
Quizalofop	37.5	20	26.0	13.1	6.6	6.0	63.6	34.1
Isoproturon	1000	40	25.7	12.3	5.7	5.3	61.5	32.7
Isoproturon	1250	40	25.7	12.4	5.7	5.1	61.8	32.9
Pendimethalin	1500	1	26.0	11.8	5.6	5.0	61.9	33.5
Hand weeding	-	30 & 60	26.7	13.2	6.3	5.7	63.6	34.7
Weedy check	-	-	25.0	10.7	4.8	4.5	57.8	22.1
CD (P=0.05)			NS	1.46	0.64	0.77	4.39	3.07

4.2.4.2 Pods per plant

Weed control treatments significantly influenced the number of pods per plant (Table 4.9). Imazethapyr at 100 & 150 g/ha (40 DAS) being statistically at par with imazethapyr at 100 & 150 g/ha (20 DAS), hand weeding twice, quizalofop at 25 & 37.5 g/ha and isoproturon at 1.0 & 1.25 kg/ha resulted in significantly higher pods per plant as compared to weedy check. However, imazethapyr 100 g/ha (20 DAS), quizalofop 25 g/ha (20 DAS) as well as pendimethalin at 1.5 kg/ha did not increase pods per plant significantly over weedy check.

4.2.4.3 Pod length

Pod length was significantly influenced by weed control treatments (Table 4.9). Imazethapyr at 150 g/ha (40 DAS) produced longer pods. However, it was statistically similar with its lower dose at 100 g/ha and quizalofop at 37.5 g/ha (20 DAS). The next superior treatment was hand weeding twice which was at par with imazethapyr at 150 g/ha (20 DAS), imazethapyr at 100 g/ha (40 DAS), quizalofop at 37.5 g/ha (20 DAS) and isoproturon at 1.0 & 1.25 kg/ha (40 DAS). Quizalofop at 25 g/ha and imazethapyr at 100 g/ha (20 DAS) did not significantly increase pod length over the weedy check.

4.2.4.4 Seeds per pod

Weed control treatments significantly affected the number of seeds per pod (Table 4.9). Significantly higher seeds per pod were obtained with imazethapyr at 150 g/ha (40 DAS). However, it was statistically alike with imazethapyr at 100 g/ha (40 DAS), hand weeding twice and quizalofop at 37.5 g/ha. Imazethapyr at 100 g/ha (20 DAS), quizalofop at 25 g/ha (20 DAS), isoproturon at 1.25 kg/ha and pendimethalin at 1.5 kg/ha did not record any significant improvement in number of seeds per pod over the weedy check.

4.2.4.5 Shelling percentage

Weed control treatments brought about significant variation in shelling percentage (Table 4.9). Imazethapyr at 100 & 150 g/ha (40 DAS), 150 g/ha (20 DAS), quizalofop at 37.5 g/ha (20 DAS) and hand weeding twice resulted in significantly higher shelling percentage over weedy check.

4.2.4.6 100-seed weight

Weed control treatments significantly influenced 100-seed weight. Significantly higher 100-seed weight was recorded with imazethapyr at 150 g/ha (40 DAS). However, it was statistically at par with its lower dose applied at same time, imazethapyr at 150 g/ha (20 DAS), hand weeding twice, quizalofop at 37.5 g/ha and pendimethalin at 1.5 kg/ha. All other treatments except quizalofop at 25 g/ha were also superior to weedy check in influencing 100-seed weight.

4.2.5 Yield

4.2.5.1 Green pod yield

Weed control treatments brought about significant variation in green pod yield (Table 4.10). All weed control treatments were significantly superior to weedy check in influencing green pod yield. An examination of the data inferred that each of the herbicide at higher rate was superior to its lower rate in influencing green pod yield. Significantly highest green pod yield was obtained with imazethapyr at 150 g/ha (40 DAS). Hand weeding twice and imazethapyr at 100 g/ha (40 DAS) being statistically similar with each other were the next superior treatments in influencing green pod yield. All the post-

Table 4.10 Effect of treatments on green pod and haulms yields of pea

Treatment	Dose (g/ha)	Time of application (DAS)	Green pod yield (q/ha)	Haulms yield (q/ha)
Imazethapyr	100	20	56.9	17.1
Imazethapyr	150	20	60.6	18.5
Imazethapyr	100	40	69.2	18.6
Imazethapyr	150	40	72.0	19.9
Quizalofop	25	20	43.0	17.5
Quizalofop	37.5	20	66.0	18.2
Isoproturon	1000	40	58.1	16.3
Isoproturon	1250	40	59.9	17.1
Pendimethalin	1500	1	50.1	16.6
Hand weeding	-	30 & 60	69.2	18.4
Weedy check	-	-	31.1	15.2
CD (P=0.05)			1.31	1.81

emergent herbicidal treatments except quizalofop at 25 g/ha were superior to standard pre-emergent herbicidal check in influencing pea pod yield. Weeds in unweeded check reduced pea pod yield by 56.8 per cent over the best post-emergent herbicidal treatment.

4.2.5.2 Haulms yield

Weed control treatments significantly influenced haulms yield (Table 4.10). Significantly higher haulms yield was obtained with imazethapyr at 150 g/ha (40 DAS). However, it behaved statistically alike to imazethapyr at 150 g/ha (20 DAS) and at 100 g/ha (40 DAS), hand weeding twice and quizalofop at 37.5 g/ha (20 DAS). Among other treatments, pendimethalin at 1.50 kg/ha and isoproturon at 1.0* kg/ha did not significantly affect haulms yield over weedy check. Unchecked weed growth reduced the haulms yield to the extent of 23.6 per cent as compared to best treatment *i.e.* imazethapyr 150 g/ha (40 DAS).

4.2.6 Quality parameters

Data on various quality parameters *viz.*, ascorbic acid, total soluble solids and protein content in seeds of pea have been presented in Table 4.11. The effect of treatments on ascorbic acid, total soluble solids and protein content was not significant.

Table 4.11 Effect of treatments on quality parameters

Treatment	Dose (g/ha)	Time of application (DAS)	Ascorbic acid (mg/100g)	Total soluble solids (TSS %)	Protein content in seed (%)
Imazethapyr	100	20	21.0	16.2	21.0
Imazethapyr	150	20	21.2	16.4	21.1
Imazethapyr	100	40	21.1	16.3	21.2
Imazethapyr	150	40	21.1	16.3	21.1
Quizalofop	25	20	20.8	16.0	20.8
Quizalofop	37.5	20	21.2	16.4	21.1
Isoproturon	1000	40	20.9	16.1	20.9
Isoproturon	1250	40	20.7	15.9	21.0
Pendimethalin	1500	1	20.7	15.9	20.9
Hand weeding	-	30 & 60	21.3	16.5	20.9
Weedy check	-	-	20.5	15.7	20.7
CD (P=0.05)			NS	NS	NS

4.3 Economic studies

The constant and variable expenses incurred on various operations and inputs have been given in Appendix-II. The estimate on gross returns (Rs/ha), net returns (Rs/ha) and B: C ratio as affected due to different treatments has been summarized in Table 4.12. The gross returns was obtained by selling pods at Rs. 10/kg and haulms at Rs. 100/q.

Table 4.12 Effect of treatments on economic studies

Treatment	Dose (g/ha)	Time of application (DAS)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit: cost ratio
Imazethapyr	100	20	58610	33137	1.30
Imazethapyr	150	20	62450	36427	1.40
Imazethapyr	100	40	71060	45587	1.79
Imazethapyr	150	40	73990	47967	1.84
Quizalofop	25	20	44750	19677	0.78
Quizalofop	37.5	20	67820	42397	1.67
Isoproturon	1000	40	59730	34945	1.41
Isoproturon	1250	40	61610	36722	1.48
Pendimethalin	1500	1	51760	25387	0.96
Hand weeding	-	30 & 60	71040	42537	1.49
Weedy check	-	-	32620	8217	0.34

4.3.1 Gross returns (Rs/ha)

All treatments were superior to weedy check in influencing gross returns (Table 4.12). Imazethapyr at 150 g/ha (40 DAS) gave highest gross returns (Rs

73,990/ha). This was followed by imazethapyr at 100 g/ha (40 DAS) and hand weeding twice. It is pertinent to highlight that all the post-emergent herbicidal treatments except quizalofop at 25 g/ha were superior to the pre-emergent standard check pendimethalin at 1.5 kg/ha. It is also to mention that higher dose of the herbicides under study was slightly superior to its lower one in influencing the gross returns.

4.3.2 Net returns

All weed control treatments were superior to weedy check in influencing net returns (Table 4.12). Imazethapyr at 150 g/ha (40 DAS) gave highest net returns of Rs 47,967/ha. This treatment was followed by imazethapyr at 100 g/ha (40 DAS) with net returns of Rs. 45,587/ha and hand weeding of Rs 42,537/ha. All post-emergent herbicidal treatments except quizalofop at 25 g/ha were superior to pendimethalin at 1.5 kg/ha (pre-emergence) in influencing net returns. In general each post-emergent herbicide at higher dose was superior to its lower one in influencing net returns.

4.3.3 B: C ratio

All weed control treatments were superior to weedy check in influencing benefit: cost ratio (Table 4.12). It is evident from the Table that imazethapyr at 150 g/ha (40 DAS) gave highest benefit: cost ratio (1.84). This was followed by imazethapyr at 100 g/ha (40 DAS) (1.79), quizalofop at 37.5 g/ha (20 DAS) (1.67) and hand weeding twice (1.49). Isoproturon 1.0 & 1.25 kg/ha (40 DAS) with benefit: cost ratio of 1.41 & 1.48 was slightly better than imazethapyr at 100 & 150 g/ha (20 DAS) with 1.30 & 1.40, respectively. However, in general all post-emergent herbicides except quizalofop at 25 g/ha were superior to the standard check (pre-emergence pendimethalin at 1.5 kg/ha).

DISCUSSION

Chapter V

DISCUSSION

In this chapter an attempt has been made to establish the cause and effect relationship of experimental findings described in the previous chapter justifying by giving the possible scientific explanation and supporting references based on the available evidences. The effect of different weed control treatments has been discussed under the following heads:

5.1 Weather conditions

5.2 Weed studies

5.3 Crop studies

5.4 Economic studies

5.1 Effect of weather on crop performance

The performance of any crop depends on the interaction of two main factors namely genetic and enviornmental. The enviornment plays a significant role in influencing the growth, development and yield. Among the various enviornmental factors, day length and temperature are the principal limiting factors. Pea crop requires a cool growing season. Moderate temperature is essential throughout the growing season for good growth. Mean weekly meteorological data during the period of experimentation (Appendix-I and Fig 3.1) reveal that the mean weekly maximum and minimum temperature during the crop season ranged from 15.5 ^{0}C to 24.2 ^{0}C and 4.5 ^{0}C to 13.9 ^{0}C, respectively. A temperature of 22 ^{0}C is favourable for good germination (Singh, 1999). However, the air temperature at this stage was below optimum resulting in poor growth of the crop inspite of satisfactory germination of the crop. The optimum monthly temperature for growth is 13-18 ^{0}C. High temperature at flowering is injurious. At the time of flowering and pod formation, the temperature was high which adversely affected these phenophases. There was slight desiccation of flowers due to high temperature. High photorespiration decreased the storage of dry matter in pod. *Pea requires irrigations at critical stages of the growth viz., grand growth,* flowering and pod filling (Singh, 1999). The total rainfall was 206.5 mm during whole growing period. The rainfall was not sufficient to accomplish the water requirement of the crop. As such the crop was given supplemented irrigations at critical stages of crop growth *viz.,* pre-sowing, seedling establishment, grand growth and flowering stages. Relative humidity was found to be low at critical stages of the growth which favours desiccation of floral organs (Singh, 1999).

5.2 Weed studies

5.2.1 Weed dominance

The data on distribution of weed species presented in Table 4.1 & Fig. 5.1 indicated that the major grassy weeds of the experimental field were *Phalaris minor* and *Avena fatua*. These weeds constituted 66.2 per cent of the total weed flora. *Vicia sativa* was the dominant broad-leaved weed constituting 26.3 per cent of the total weed flora. The other notable weeds *Lolium temulentum, Coronopus didymus* and *Stellaria media* as a whole constituted 7.5 per cent of the total weed flora. The association and severe yield

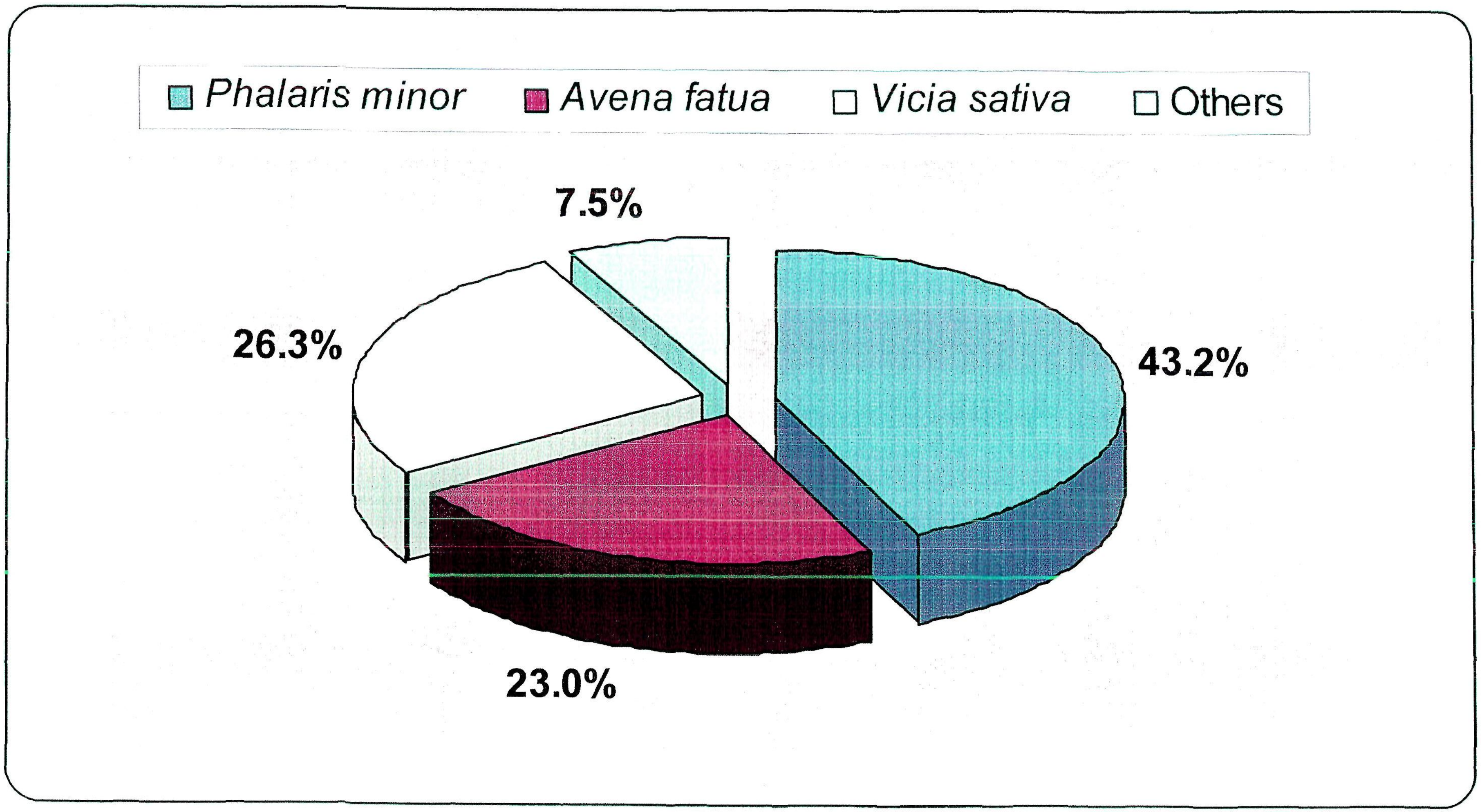


Fig 5.1 Composition of weeds

reduction owing to *Phalaris minor, Avena fatua* and *Lolium temulentum* in pea have been documented by Singh *et al.* (1996).

5.2.2 Effect of treatments on weeds

A cursory glance at Table 4.2 and Appendices-III-VII indicated that the maximum population of *Vicia sativa* and other weeds was at 60 DAS, whereas the population of grassy weeds and thereby of total weeds was maximum at 90 DAS. Thereafter, it declined at decreasing rate. The decrease could be attributed to mortality of some of the weeds which might be due to smothering with development of crop canopy. On the other hand, the dry matter accumulation by both grassy and broad-leaved weeds increased at the increasing rate upto 120 DAS; thereafter it declined due to advancement towards senescence stage (Table 4.3 and Appendices-VIII-XII). With few exceptions weed control treatments significantly decreased the population and dry matter of weeds over unweeded check. Significantly lower population of *Phalaris minor, Avena fatua, Vicia sativa,* other weeds and total weeds and dry matter of *Vicia sativa* and other weeds was obtained with hand weeding twice. Sandhu *et al.* (1978) also reported superiority of hand weeding twice in decreasing the intensity and dry weight of weeds due to removal of the first and second weed flushes. However, hand weeding twice was at par with imazethapyr at 100 & 150 g/ha (40 DAS) for controlling *Vicia sativa* and other weeds. Imazethapyr at 150 g/ha (40 DAS) being statistically at par with its lower dose (40 DAS), significantly reduced the weed dry matter of *Phalaris minor* and *Avena fatua* over rest of the treatments. Effective control of weeds with imazethapyr in pea has also been reported by Fraser (2003). Significantly lowest total weed dry matter was obtained with imazethapyr at 150 g/ha (40 DAS). The higher efficacy of imazethapyr at 150 g/ha in reducing the total weed dry matter accumulation could be due to the effective control of all weed species, thus, resulting in highest weed control efficiency of 79.7 per cent. These results are in direct confirmation with those of Balesta *et al.* (1994) who also found excellent control of weeds with imazethapyr. In general, early post-emergence application (20 DAS) of imazethapyr was less effective against all weed species which gave weed control efficiency of 51.7 per cent at 100 g/ha and 54.6 per cent at 150 g/ha. The superior performance of imazethapyr at 40 DAS could be probably due to higher absorption of herbicide through more foliage of weeds of first and second flushes as compared to its application at 20 DAS. Quizalofop at 37.5 g/ha at 20 DAS and isoproturon at 1.25 kg/ha were statistically at par in reducing the count and dry matter of all the weeds except *Vicia sativa.* Increase in dose of quizalofop and isoproturon decreased the population and dry matter of weeds significantly, thereby increasing weed control efficiencies. The superiority of isoproturon in controlling weeds in pea has also been reported by Khan *et al.* (2002). Application of quizalofop at 25 g/ha (20 DAS) was least effective herbicidal treatment in suppressing the weeds as the weed control efficiency was lowest (40.5%). Pre-emergence application of pendimethalin 1.5 kg/ha reduced the population and dry matter of all weeds except *Avena fatua* having weed control efficiency of 50.4 per cent. Nelson and Giles (1989) and Haar *et al.* (2001) also reported poor control of *Avena fatua* with the application of pendimethalin.

5.3 Crop studies

The progressive plant height and dry matter accumulation of pea crop presented in Table 4.5 and Appendices-XIII-XIV indicate that different treatments influenced both the parameters significantly at each observation. The plant height followed a sigmoidal growth pattern in all the treatments with a grand growth period between 60 to 120 DAS. There was consistent increase in dry matter accumulation with the advancement in crop growth in each of the treatments with a maximum rate of increase between 90 to 120 DAS. Reduced crop weed competition due to effective control of weeds by various treatments resulted in better utilization of growth factors by the crop and these resulted in its better growth and development. Enhanced growth of weeds caused intense competition with the crop for growth factors and resulted in significantly lower plant height and dry matter accumulation by pea (Table 4.5). Singh and Angiras (2002) also reported significant decrease in plant height and dry matter production due to unchecked weed growth in peas. The higher weed control efficiency (79.7%) with imazethapyr at 150 g/ha (40 DAS) reduced crop weed competition and helped in significant increase in the rate of growth of the crop. Skrzypczak *et al.* (1994) reported similar results with imazethapyr at 150 g/ha (40 DAS). This can be ascribed to the effective control of weeds leading the favorable enviornment for growth and photosynthetic activity of the crop. However, it was also statistically at par with imazethapyr at 100 g/ha (40 DAS) and at 150 g/ha (20 DAS), hand weeding twice and quizalofop at 37.5 g/ha (20 DAS) in increasing plant height, nodulation and dry matter of pea. The phasic development of the pea crop was not significantly affected by weed control treatments (Table 4.8).

Imazethapyr 100 & 150 g/ha (40 DAS), quizalofop 37.5 g/ha (20 DAS) and hand weeding twice resulted in significantly higher CGR and RGR over rest of the treatments. All the yield contributing characters *viz.,* number of pods per plant, number of seeds per pod, pod length, shelling percentage and 100-seed weight significantly increased due to imazethapyr at 100 & 150 g/ha (40 DAS) and at 150 g/ha (20 DAS), hand weeding twice, quizalofop 37.5 g/ha and isoproturon 1.25 kg/ha over weedy check. However, pendimethalin 1.5 kg/ha was as effective as the above treatments in influencing the shelling percentage and 100-seed weight. Improvement in yield contributing characters due to these treatments may be attributed to significantly lower weed dry matter and weed population. Rana *et al.* (2007) also reported significantly higher yield contributing characters of peas with effective weed control.

A critical perusal of the data in the Table 4.9 & Fig. 5.2 clearly showed that effective control of weeds owing to different treatments significantly increased the pea pod and haulms yields over weedy check. Imazethapyr at 150 g/ha (40 DAS) resulted in significantly higher pod and haulms yields which were 56.8 and 23.6 per cent higher over weedy check. However, imazethapyr at 100 g/ha (40 DAS) & at 150 g/ha (20 DAS) and hand weeding twice and quizalofop at 37.5 g/ha (20 DAS) were statistically at par with imazethapyr at 150 g/ha (40 DAS) in influencing the haulms yield of pea. Imazethapyr 100 g/ha (40 DAS) and hand weeding twice being statistically alike were next superior treatments in influencing pod yield of pea.

The quality characters *viz.,* ascorbic acid, total soluble solids and protein content were not affected significantly due to different weed control treatments. Isoproturon at 1.25 kg/ha exhibited phytotoxic effects on crop. However, toxicity was slight (4.0 at 55 DAS & 2.25 at 85 DAS) and crop recovered by 120 DAS. Phytotoxic effects of isoproturon at 1.5 kg/ha on winter grain legumes have also been documented (Anonymous, 2001).

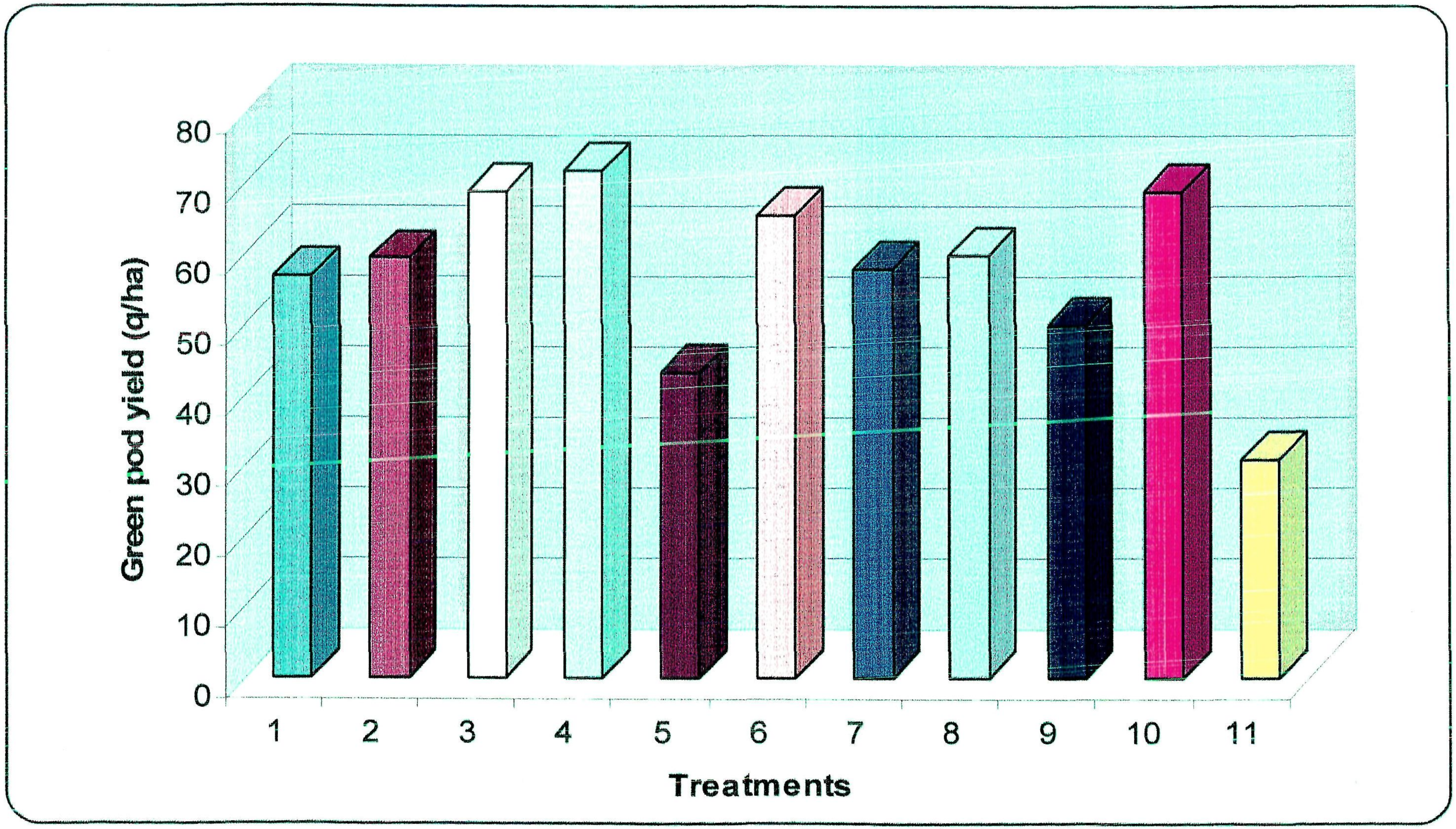


Fig 5.2 **Effect of different treatments on pod yield of pea**

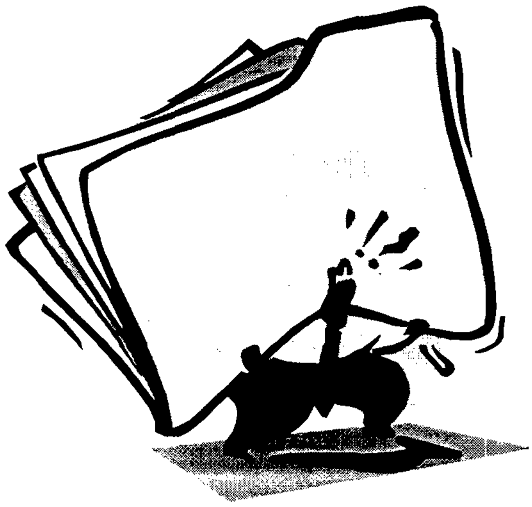
5.4 Economic Studies

The acceptance of any technology depends upon its feasibility. The treatments which do not produce remunerative returns are not acceptable to farming community. With an idea to evaluate various weed control treatments in terms of economic returns, the green pod yield was converted into monetary terms *viz.,* gross and net returns.

The economics of various treatments have been presented in Table 4.12. The cost of cultivation was highest in hand weeding twice followed by pre-emergence application of pendimethalin 1.5 kg/ha (Appendix-II). All the treatments were superior to weedy check in influencing gross returns. Imazethapyr at 150 g/ha (40 DAS) gave highest gross returns (Rs. 73,990/ha) because of higher green pods and haulms yields. All the post-emergent herbicides except quizalofop at 25 g/ha (20 DAS) recorded higher gross returns over pre-emergent standard check pendimethalin at 1.5 kg/ha. The higher doses of herbicides were more economical than the lower ones due to better weed control and higher yields. All the treatments gave higher cash returns than weedy check. Similar were the findings of Ahlawat *et al.* (1981).

Imazethapyr at 150 g/ha (40 DAS) gave highest net returns (Rs. 47,967/ha) followed by imazethapyr 100 g/ha at 40 DAS (Rs 45,587/ha) and hand weeding twice (Rs. 42,537/ha). This was owed to higher green pod and haulms yield due to better weed control in these treatments.

All the treatments resulted in higher B: C ratio (Table 4.12) over the weedy check. This might be due to lower cost of cultivation and higher pod as well as haulms yields.



SUMMARY
&
CONCLUSION

Chapter VI

SUMMARY AND CONCLUSION

Grassy weeds are the major threat to the productivity of pea. Therefore, the control of grassy weeds is important for realizing higher yields. Pre-emergence application of pendimethalin is recommended for this crop. But this herbicide has limited period of application and once the period is over, the manual weeding or application of post-emergence herbicides are the only options left with the farmers. Moreover, non-availability of labour and high wages makes the manual weeding cumbersome and uneconomical. Therefore, in order to find a better solution, the present investigation was undertaken with the following objectives:

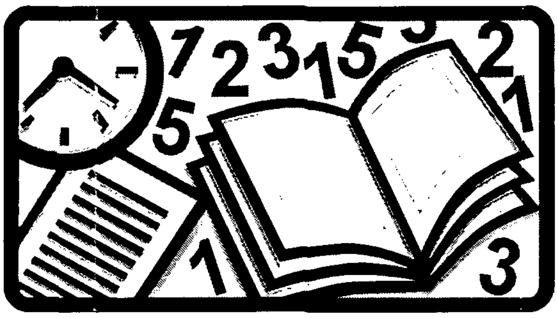
- To study the relative efficacy of post-emergence herbicides to control weeds and their effect on growth and yield of pea,
- to standardize the dose and time of application of post-emergence herbicides for effective control of weeds, and
- to find out the relative economics of different weed control treatments.

To achieve the above objectives, 11 treatments *viz.,* imazethapyr 100 & 150 g/ha at 20 & 40 DAS, quizalofop 25 & 37.5 g/ha at 20 DAS, isoproturon 1.0 & 1.25 kg/ha at 40 DAS and pendimethalin 1.5 kg/ha (pre-emergence), hand weeding twice and unweeded check were tested in Randomized Block Design with three replications. The variety "Palam Priya" was sown on November 19, 2005 and harvested on April 3, 2006.

The major weed flora of the experimental field was constituted of *Phalaris minor, Vicia sativa, Avena fatua* which constituted 43.2, 26.3 and 23 per cent, respectively of the total weed flora. All the treatments were superior to weedy check in decreasing the population and dry weight of total weeds. The post-emergence application of all the herbicides (except quizalofop 25 g/ha at 20 DAS) and hand weeding twice recorded significantly lower population and dry matter of weeds over pre-emergence treatment of pendimethalin at 1.5 kg/ha. Higher doses of all the post-emergence herbicides were superior to their lower doses. Significantly lowest population and dry matter accumulation of all the weed species was obtained with imazethapyr at 150 g/ha applied at 40 DAS, with total weed control efficiency of 79.7 per cent. Imazethapyr at 150 g/ha at 40 DAS resulted in significantly higher plant height, dry matter accumulation and root nodulation. However, this was statistically at par with imazethapyr at 100 g/ha (40 DAS) and at 150 g/ha (20 DAS), quizalofop at 37.5 g/ha and hand weeding twice in influencing nodulation. The pods per plant, pod length, seeds per pod, shelling percentage and 100-seed weight were significantly increased with imazethapyr at 100 & 150 g/ha (40 DAS) and at 150 g/ha (20 DAS), quizalofop 37.5 g/ha and hand weeding twice over all other treatments. Significantly highest pod yield (72 q/ha), net returns (Rs 47,967) and B: C ratio (1.84) were recorded with imazethapyr 150 g/ha (40 DAS). The next superior treatment was imazethapyr 100 g/ha at 40 DAS.

Conclusion

Imazethapyr at 150 g/ha (40 DAS) was the most effective treatment in controlling weeds and increasing green pod and haulms yield with net returns of Rs.47,967 and B: C ratio of 1.84.



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APPENDICES

Appendix – I

Mean weekly meteorological data for experimental period *Rabi* 2005-06 recorded at Palampur, during 2005-2006

Standard week	Maximum Temperature (°C)	Minimum Temperature (°C)	Mean Temperature (°C)	RH (%)	Rainfall (mm)	BSS (hrs)
47 (19-25 Nov.)	21.9	9.0	15.5	39.2	0.0	9.3
48 (26-2 Dec.)	21.6	8.4	15.0	41.8	0.0	9.2
49 (3-9 Dec.)	23.0	8.3	15.7	39.2	0.0	9.5
50 (10-16 Dec).	20.7	7.5	14.1	42.7	0.0	8.5
51 (17-23 Dec.)	19.7	5.2	12.4	46.6	0.0	8.8
52 (24-31Dec.)	18.6	5.0	11.8	46.1	0.0	8.9
1 (1-7 Jan.)	18.2	5.5	11.8	44.1	0.0	7.5
2 (8-14 Jan).	17.5	4.9	11.2	48.9	0.0	7.4
3 (15-21 Jan).	16.8	5.0	10.9	58.9	29.7	5.3
4 (22-28 Jan.)	18.6	6.6	12.6	42.1	0.0	7.1
5 (29-4 Feb.)	15.5	6.3	10.6	63.9	83.1	3.4
6 (5-11 Feb.)	15.5	4.9	10.2	52.6	0.0	8.5
7 (12-18 Feb.)	20.8	9.8	15.3	44.0	0.0	6.2
8 (19-25 Feb.)	21.1	9.7	15.4	44.6	0.0	8.0
9 (26-4 Mar.)	21.7	11.6	16.7	45.1	2.8	6.1
10 (5-11 Mar.)	24.2	13.9	19.1	39.7	0.0	5.8
11 (12-18 Mar.)	21.3	10.0	15.7	45.6	8.8	7.3
12 (19-25 Mar.)	18.0	4.5	11.3	55.5	0.0	8.9
13 (26-1 Apr.)	18.1	8.8	13.4	54.9	77.9	5.4
14 (2-8 Apr.)	21.3	11.5	16.4	49.6	4.2	7.6

Appendix-II

Economics of different treatments

S. No.	Common cost of cultivation / Particulars	Quantity (no./ha)	Units	Rate (Rs/unit)	Amount (Rs/ha)
1	Pre-sowing irrigation	10	Hour	70	700
	labour	2	Mandays	70	140
2	Preparatory tillage two ploughing & one harrowing	12	Tractor hours	240	2880
3	Cost of seeds	75	kg/ha	60	4500
4	Seed treatment with bavistin	187.5	g/kg	0.61	114
5	Sowing	15	Mandays	70	1050
6	Manures and fertilizers				
a	FYM	8	t/ha	42	3360
b	FYM incorporation	5	Mandays	70	350
c	Urea 46% N	100	kg/ha	4.83	483
d	SSP 16% P_2O_5	375	kg/ha	3.8	1425
e	MOP 60% K_2O	100	kg/ha	4.46	446
f	Fertilizers application	0.5	Mandays	70	35
7	After care operations				
a	Irrigations	30	*hours*	*70*	*2100*
b	Labour	6	mandays	70	420
c	Pickings	80	mandays	70	5600
8	Straw harvesting.	10	mandays	70	700
	Total				24303

Variable expenses

S.No.	Treatment	Dose g/ha	a.i. (%)	Commercial product (kg/ha)	Labour (mandays)	Rate of chemical (Rs/Litre)	Cost of weed control* (Rs)	Total cost (Fixed + variable Rs/ha)
1	T_1 Imazethapyr	100	10	1	1	1100	1170	25473
2	T_2 Imazethapyr	150	10	1.5	1	1100	1720	26023
3	T_3 Imazethapyr	100	10	1	1	1100	1170	25473
4	T_4 Imazethapyr	150	10	1.5	1	1100	1720	26023
5	T_5 Quizalofop	25	5	0.5	1	1400	770	25073
6	T_6 Quizalofop	37.5	5	0.75	1	1400	1120	25423
7	T_7 Isoproturon	1000	75	1.33	1	310	482	24785
8	T_8 Isoproturon	1250	75	1.66	1	310	584	24888
9	T_9 Pendimethalin	1500	30	5	1	400		26373
10	T_{10} Hand weeding	-	-	-	60		4200	28503
11	T_{11} Weedy check	-	-		-	-	-	24303

*Including cost of spray Rs. 70/ha

Appendix – III

Effect of weed control treatments on progressive count (number/m²) of *Phalaris minor* (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	6.60 (42.7)	7.00 (48.0)	6.80 (45.3)	6.40 (40.0)
Imazethapyr	150	20	6.08 (36.0)	6.40 (40.0)	6.18 (37.3)	5.68 (32.0)
Imazethapyr	100	40	3.58 (12.0)	3.90 (14.7)	3.20 (9.3)	2.69 (6.7)
Imazethapyr	150	40	3.32 (10.7)	3.58 (12.0)	2.95 (8.0)	2.49 (5.3)
Quizalofop	25	20	7.16 (50.7)	7.55 (56.0)	6.90 (46.7)	6.76 (45.3)
Quizalofop	37.5	20	3.32 (10.7)	3.75 (13.3)	3.20 (9.3)	2.69 (6.7)
Isoproturon	1000	40	6.48 (41.3)	6.80 (45.3)	6.40 (40.0)	5.97 (34.7)
Isoproturon	1250	40	6.29 (38.7)	6.60 (42.7)	6.29 (38.7)	5.74 (32.0)
Pendimethalin	1500	1	4.90 (24.0)	5.68 (32.0)	5.62 (30.7)	5.24 (26.7)
Hand weeding	-	30 & 60	2.24 (4.0)	2.49 (5.3)	2.24 (4.0)	2.24 (4.0)
Weedy check	-	-	9.74 (94.7)	11.12 (122.7)	9.81 (96.0)	9.04 (81.3)
CD (P=0.05)			0.78	0.80	0.78	0.75

Values given in the parentheses are the means of original values

Appendix — IV

Effect of weed control treatments on progressive count (number/m^2) of *Avena fatua* (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	4.24 (17.3)	4.72 (21.3)	4.10 (16.0)	3.58 (12.0)
Imazethapyr	150	20	3.73 (13.3)	4.28 (17.3)	3.58 (12.0)	2.95 (8.0)
Imazethapyr	100	40	3.49 (12.0)	3.90 (14.7)	3.20 (9.3)	2.75 (6.7)
Imazethapyr	150	40	3.58 (12.0)	3.73 (13.3)	2.95 (8.0)	2.49 (5.3)
Quizalofop	25	20	5.11 (25.3)	5.86 (33.3)	4.64 (21.3)	4.10 (16.0)
Quizalofop	37.5	20	3.47 (12.0)	3.73 (13.3)	3.20 (9.3)	2.69 (6.7)
Isoproturon	1000	40	4.64 921.3)	5.08 (25.3)	4.10 (16.0)	3.37 (10.7)
Isoproturon	1250	40	4.84 (22.7)	4.99 (24.0)	4.10 (16.0)	3.37 (10.7)
Pendimethalin	1500	1	7.07 (49.3)	7.63 (57.3)	7.07 (49.3)	6.39 (40.0)
Hand weeding	-	30 & 60	2.49 (5.3)	2.95 (8.0)	2.49 (5.3)	2.24 (4.0)
Weedy check	-	-	7.53 (56.0)	8.14 (65.3)	7.59 (57.3)	6.97 (48.0)
CD (P=0.05)			0.86	0.88	0.84	0.77

Values given in the parentheses are the means of original values

Appendix — V

Effect of weed control treatments on progressive count of (number/m^2) *Vicia sativa* (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	5.74 (32.0)	5.22 (26.7)	4.57 (20.0)	4.10 (16.0)
Imazethapyr	150	20	4.96 (24.0)	4.37 (18.7)	3.58 (12.0)	2.95 (8.0)
Imazethapyr	100	40	2.95 (8.0)	2.75 (6.7)	2.49 (5.3)	2.24 (4.0)
Imazethapyr	150	40	2.75 (6.7)	2.49 (5.3)	2.24 (4.0)	2.24 (4.0)
Quizalofop	25	20	8.54 (72.0)	8.55 (73.3)	8.46 (70.7)	7.98 (62.7)
Quizalofop	37.5	20	7.91 (62.7)	7.92 (62.7)	7.89 (61.3)	7.37 (53.3)
Isoproturon	1000	40	6.04 (36.0)	5.38 (28.0)	4.72 (21.3)	4.10 (16.0)
Isoproturon	1250	40	5.58 (30.7)	5.11 (25.3)	4.40 (18.7)	3.58 (12.0)
Pendimethalin	1500	1	6.67 (44.0)	5.96 (34.7)	5.36 (28.0)	4.84 (22.7)
Hand weeding	-	30 & 60	1.82 (2.7)	1.82 (2.7)	1.82 (2.7)	1.41 (1.3)
Weedy check	-	-	8.77 (76.0)	8.70 (74.7)	8.45 (70.7)	8.06 (64.0)
CD (P=0.05)			0.84	0.77	0.75	0.67

Values given in the parentheses are the means of original values

Appendix – VI

Effect of weed control treatments on progressive count (number/m^2) of other weed species (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	2.95 (8.0)	2.69 (6.7)	2.69 (6.7)	2.49 (5.3)
Imazethapyr	150	20	2.95 (8.0)	2.69 (6.7)	2.49 (5.3)	2.24 (4.0)
Imazethapyr	100	40	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Imazethapyr	150	40	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Quizalofop	25	20	3.90 (14.7)	2.95 (8.0)	2.75 (6.7)	2.49 (5.3)
Quizalofop	37.5	20	2.95 (8.0)	2.49 (5.3)	2.49 (5.3)	2.24 (4.0)
Isoproturon	1000	40	3.73 (13.3)	2.49 (5.3)	2.24 (4.0)	2.24 (4.0)
Isoproturon	1250	40	3.73 (13.3)	2.49 (5.3)	2.24 (4.0)	2.24 (4.0)
Pendimethalin	1500	1	2.95 (8.0)	2.49 (5.3)	2.24 (4.0)	2.24 (4.0)
Hand weeding	-	30 & 60	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Weedy check	-	-	4.86 (22.7)	4.70 (21.3)	4.57 (20.0)	4.40 (18.7)
CD (P=0.05)			0.61	0.54	0.51	0.45

Values given in the parentheses are the means of original values

Appendix — VII

Effect of weed control treatments on progressive count (number/m^2) of total weeds species (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	10.04 (100.0)	10.15 (102.7)	9.41 (88.0)	8.62 (73.3)
Imazethapyr	150	20	9.02 (81.3)	9.11 (82.7)	8.20 (66.7)	7.25 (52.0)
Imazethapyr	100	40	5.64 (32.0)	6.08 (36.0)	4.97 (24.0)	4.24 (17.3)
Imazethapyr	150	40	5.42 (29.3)	5.56 (30.7)	4.58 (20.0)	3.93 (14.7)
Quizalofop	25	20	12.76 (162.7)	13.06 (170.7)	12.09 (145.3)	11.40 (129.3)
Quizalofop	37.5	20	9.58 (93.3)	9.70 (94.7)	9.29 (85.3)	8.46 (70.7)
Isoproturon	1000	40	10.54 (112.0)	10.21 (104.0)	9.07 (81.3)	8.14 (65.3)
Isoproturon	1250	40	10.29 (105.3)	9.91 (97.3)	8.83 (77.3)	7.71 (58.7)
Pendimethalin	1500	1	11.18 (125.3)	11.41 (129.3)	10.63 (112.0)	9.70 (93.3)
Hand weeding	-	30 & 60	3.58 (12.0)	4.04 (16.0)	3.58 (12.0)	3.20 (9.3)
Weedy check	-	-	15.81 (249.3)	16.88 (284.0)	15.62 (244.0)	14.59 (212.0)
CD (P=0.05)			0.86	0.81	0.73	0.71

Values given in the parentheses are the means of original values

Appendix — VIII

Effect of weed control treatments on progressive dry matter accumulation of *Phalaris minor* (g/m²)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	7.8	12.7	18.0	13.5
Imazethapyr	150	20	5.9	10.7	15.7	10.7
Imazethapyr	100	40	6.4	9.8	13.7	9.2
Imazethapyr	150	40	4.7	8.7	11.5	8.9
Quizalofop	25	20	10.7	16.0	22.0	22.6
Quizalofop	37.5	20	4.7	7.4	11.5	10.3
Isoproturon	1000	40	6.7	11.6	16.5	10.3
Isoproturon	1250	40	6.3	11.1	15.9	11.1
Pendimethalin	1500	1	13.3	18.5	20.1	17.2
Hand weeding	-	30 & 60	3.7	13.7	15.7	9.8
Weedy check	-	-	32.5	43.9	49.6	36.1
CD (P=0.05)			3.17	3.27	3.34	3.13

Appendix — IX

Effect of weed control treatments on progressive dry matter accumulation of *Avena fatua* (g/m²)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	6.0	13.2	16.5	11.5
Imazethapyr	150	20	5.0	12.3	15.9	9.4
Imazethapyr	100	40	4.0	11.0	14.7	7.8
Imazethapyr	150	40	2.9	8.1	12.0	6.5
Quizalofop	25	20	7.7	15.2	16.4	18.8
Quizalofop	37.5	20	3.2	9.0	12.4	7.5
Isoproturon	1000	40	5.6	13.0	16.5	10.2
Isoproturon	1250	40	5.2	12.4	16.1	9.6
Pendimethalin	1500	1	13.6	26.3	32.2	22.7
Hand weeding	-	30 & 60	2.7	11.1	15.5	9.3
Weedy check	-	-	15.3	27.8	35.9	27.8
CD (P=0.05)			2.81	2.93	3.08	2.89

Appendix – X

Effect of weed control treatments on progressive dry matter accumulation of *Vicia sativa* (g/m^2)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	6.0	10.7	16.7	9.9
Imazethapyr	150	20	5.7	9.7	16.0	7.8
Imazethapyr	100	40	2.6	5.8	7.7	5.3
Imazethapyr	150	40	1.8	4.3	5.8	4.0
Quizalofop	25	20	12.1	23.2	25.1	20.7
Quizalofop	37.5	20	10.5	21.4	22.9	18.5
Isoproturon	1000	40	8.6	14.6	17.3	12.1
Isoproturon	1250	40	8.4	14.2	17.0	11.1
Pendimethalin	1500	1	6.3	8.5	9.6	8.8
Hand weeding	-	30 & 60	1.5	6.3	6.9	2.7
Weedy check	-	-	12.4	23.3	27.1	21.1
CD (P=0.05)			2.69	2.92	3.01	2.75

Appendix — XI

Effect of weed control treatments on progressive dry matter accumulation of other weed species (g/m^2) (data transformed to $\sqrt{x+1}$ transformation)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	2.24 (4.1)	3.82 (13.6)	4.35 (17.9)	3.78 (13.4)
Imazethapyr	150	20	2.11 (3.5)	3.76 (13.2)	4.32 (17.7)	3.75 (13.1)
Imazethapyr	100	40	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Imazethapyr	150	40	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Quizalofop	25	20	2.69 (6.3)	4.13 (16.1)	4.75 (21.6)	4.23 (16.9)
Quizalofop	37.5	20	1.92 (2.7)	3.32 (10.1)	3.67 (12.5)	3.47 (11.0)
Isoproturon	1000	40	2.14 (3.7)	3.69 (12.7)	4.34 (17.9)	3.87 (14.0)
Isoproturon	1250	40	2.10 (3.4)	3.67 (12.5)	4.32 (17.7)	3.79 (13.4)
Pendimethalin	1500	1	2.49 (5.3)	2.78 (6.8)	3.18 (9.1)	3.01 (8.1)
Hand weeding	-	30 & 60	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)
Weedy check	-	-	1.00 (8.1)	4.80 (22.0)	5.62 (30.7)	5.10 (25.1)
CD (P=0.05)			0.32	0.27	0.21	0.25

Values given in the parentheses are the means of original values

Appendix – XII

Effect of weed control treatments on progressive dry matter accumulation of total weed species (g/m^2)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	23.8	50.2	69.1	36.8
Imazethapyr	150	20	20.0	45.9	65.2	31.6
Imazethapyr	100	40	12.9	26.7	36.1	14.5
Imazethapyr	150	40	9.3	21.1	29.3	12.9
Quizalofop	25	20	36.8	70.5	85.1	60.1
Quizalofop	37.5	20	21.1	47.9	59.3	39.9
Isoproturon	1000	40	24.5	51.9	68.2	36.4
Isoproturon	1250	40	23.3	50.2	66.8	35.5
Pendimethalin	1500	1	38.5	60.0	71.1	34.1
Hand weeding	-	30 & 60	7.9	31.1	38.2	12.5
Weedy check	-	-	68.4	116.9	143.3	82.3
CD (P=0.05)			6.88	4.92	5.84	4.29

Appendix – XIII

Effect of weed control treatments on plant height (cm)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	12.9	34.8	60.5	61.5
Imazethapyr	150	20	13.1	39.7	62.4	63.4
Imazethapyr	100	40	14.2	42.8	64.0	65.0
Imazethapyr	150	40	14.0	45.6	65.7	66.7
Quizalofop	25	20	11.9	35.8	63.0	63.9
Quizalofop	37.5	20	13.7	40.9	63.1	64.1
Isoproturon	1000	40	12.2	37.3	62.3	63.1
Isoproturon	1250	40	12.1	36.6	62.2	63.1
Pendimethalin	1500	1	11.6	36.2	62.6	64.0
Hand weeding	-	30 & 60	14.0	42.8	64.4	65.4
Weedy check	-	-	9.3	33.6	58.1	59.1
CD (P=0.05)			1.33	3.85	3.32	3.12

Appendix – XIV

Effect of weed control treatments on plant dry matter accumulation (g/m^2)

Treatment	Dose (g/ha)	Time of application (DAS)	60 DAS	90 DAS	120 DAS	At harvest
Imazethapyr	100	20	82.6	137.7	250.4	341.6
Imazethapyr	150	20	88.6	140.4	266.0	359.8
Imazethapyr	100	40	93.1	146.7	268.2	394.1
Imazethapyr	150	40	105.0	150.7	276.7	407.6
Quizalofop	25	20	77.4	133.0	156.5	194.8
Quizalofop	37.5	20	90.0	143.5	266.0	391.0
Isoproturon	1000	40	83.0	138.9	241.6	329.3
Isoproturon	1250	40	79.2	135.6	245.0	339.7
Pendimethalin	1500	1	83.8	137.4	247.0	331.5
Hand weeding	-	30 & 60	95.1	149.7	277.1	404.9
Weedy check	-	-	74.9	125.4	132.2	182.8
CD (P=0.05)			13.55	20.52	31.58	57.02

Appendix – XV

Mode of Action

Pendimethalin (Stomp)

Pendimethalin is a selective pre-plant or pre-emergence soil applied herbicide. It inhibits cell division probably by interaction with micro tubular system. Pendimethalin generally kills grassy weeds and was less effective on broad-leaved weeds.

Imazethapyr (Pursuit)

Imazethapyr is an imidazole compound used as a selective herbicide. It controls weeds by reducing the levels of three branched-chain aliphatic amino acids, isoleucine, leucine and valine through the inhibition of of accetohydroxy synthase which in turn leads to interference in DNA syntheses and cell growth.

Quizalofop (Targa super)

Quizalofop belongs to aryloxyphenoxypropionic group of herbicides. It is used to control annual grassy weeds in various vegetable crops including garden pea. The compound is absorbed from the leaf surface and is moved throughout the plant. It inhibits synthesis of acetyl-CoA-carboxylase which is required for fatty acid synthesis. It deprive the plant of a key intermediate (malonyl CoA) essential to both lipid and flavanoid (gibberelin, abscicic acid, caretenoid etc.) biosyntheses and lead to phytotoxic effects. This herbicide generally kills *Phalaris minor, Avena fatua* and *Lolium temulentum*.

Isoproturon (Millron)

It belongs to urea group (i.e. phenyl urea herbicide). It generally kills broad-leaved and grassy weeds. It inhibits photosynthetic electron transport in photosystem-II. This leads to production of powerful oxidants which damages membranes, pigments and causes rapid destruction of cell.

Appendix – XVI

Analysis of variance

Source of variation	Number	Degree of freedom
Replication (r)	3	r-1 = 2
Treatment (t)	11	t-1 = 10
Error		(r-1) (t-1) = 20
Total		32
CD (P = 0.05)		

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Name of the student	:	Manu Nag
Admission No.	:	A-2005-30-08
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ABSTRACT

To find out the effective dose and time of application of post-emergent herbicides for weed control in pea, the present investigation was carried out during *Rabi* 2005-06 at the experimental farm of Department of Agronomy. Eleven treatments *viz.,* imazethapyr 100 & 150 g/ha at 20 & 40 DAS, quizalofop 25 & 37.5 g/ha at 20 DAS, isoproturon 1.0 & 1.25 kg/ha at 40 DAS and pendimethalin 1.5 kg/ha (pre-emergence), hand weeding twice and unweeded check were tested in Randomized Block Design with three replications. The soil of experimental site was silty clay loam in texture and acidic in reaction with pH 5.5. The variety "Palam Priya" was sown on November 19, 2005 and harvested on April 3, 2006.

The major weed flora was constituted of *Phalaris minor, Vicia sativa, and Avena fatua* (43.2, 26.3 and 23 per cent), respectively. All the weed control treatments significantly decreased the population and dry matter of total weeds over weedy check. Post-emergence application of all the herbicides (except quizalofop 25 g/ha at 20 DAS) and hand weeding twice recorded significantly the lowest population and dry matter of weeds over pre-emergence pendimethalin 1.5 kg/ha. Higher doses of all the post-emergent herbicides were superior to their lower doses. Significantly lower population and dry matter accumulation of all the weeds species was obtained with imazethapyr 150 g/ha applied at 40 DAS, with weed control efficiency of 79.7 per cent. Imazethapyr 150 g/ha at 40 DAS resulted in significantly higher plant height, dry matter accumulation, crop growth rate, relative growth rate and root nodulation. Pods per plant, pod length, seeds per pod, shelling percentage and 100 seed weight increased significantly with imazethapyr at 100 & 150 g/ha (40 DAS) and at 150 g/ha (20 DAS), quizalofop 37.5 g/ha and hand weeding twice over other treatments. Significantly highest pod yield was recorded with imazethapyr 150 g/ha (40 DAS). Imazethapyr 150 g/ha at 40 DAS gave highest net returns (Rs 47,967/ha) and B: C ratio (1.84) followed by imazethapyr 100 g/ha (40 DAS).

Manu Nag

Signature of the student

Signature of Major Advisor

Countersigned
Head of Department