“Effect of weed management practices on growth & yield of Pigeonpea(*Cajanus cajan* L. Millspaugh] ”

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Title of Thesis	: **"Effect of weed management practices on growth and yield of pigeonpea [*Cajanus cajan* (L.) Millspaugh]"**
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ABSTRACT

Pigeonpea being a *kharif* season crop is highly infested with narrow and broad leaved weeds. Timely weed control is very essential for realization of yield potential of pigeonpea. Due to wider row spacing and initial slow growth of pigeonpea, weeds pose a major problem to its productivity which may lead to its yield reduction up to 80%. Manual and mechanical methods of weed control are quite effective, but they are costly and time consuming. However, due to frequent rains it becomes difficult to do hand weeding at proper time. Under given circumstances farmers needs alternate production system using chemical and cultural weed management that are more efficient, less labour-intensive and offer a quick response enabling farmers to produce more at less costs. In this context the present research work has been carried out.

A field experiment was conducted during *kharif* season of 2012-13 at Bihar Agricultural University, Sabour to find out the cost-effective weed management practices in pigeonpea. Soil of experimental field was sandy loam in texture having pH 7.58, organic carbon 0.40%, and 182, 16.4, 186.3 kg ha^{-1} available N, P and K, respectively. The treatments comprised of twelve weed management options *viz*; T_1 -imazethapyr @ 20g a.i. ha^{-1} at 15 DAS, T_2 -imazethapyr @ 40g a.i.ha^{-1} at 15 DAS, T_3 -imazethapyr @ 60g a.i.ha^{-1} at 15 DAS, T_4 -imazethapyr @ 20g a.i.ha^{-1} at 30 DAS, T_5-imazethapyr @ 40g a.i. ha^{-1} at 30 DAS, T_6-imazethapyr @ 60g a.i.ha^{-1} at 30 DAS, T_7 -pendimethalin @ 750g. a.i. ha^{-1} as PE, T_8-pendimethalin @ 750g. a.i. ha^{-1} as PE + quizalofop-ethyl @ 50g. a.i. ha^{-1} as POE, T_9-pigeonpea + blackgram intercropping, T_{10} -metribuzin @ 250 g. a.i. ha^{-1} as PE, T_{11}-weedy check and T_{12}-weed free. The experiment was laid out in randomized complete block design with three replications.

The results indicated that application of imazethapyr @ 60 g a.i ha^{-1} at 15 DAS recorded significantly lower weed population at all the growth stages of the crop as compared to other treatments. At 60 and 90 DAS, application of imazethapyr @ 60 g a.i ha^{-1} at 15 DAS produced the lowest weed dry biomass (5.04 g m^{-2}) and (4.89 g m^{-2}), respectively. Weedy check recorded significantly higher weed index (40.53 %), than all other treatments under study. While, at 60 days after sowing; higher weed control efficiency (80.38 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS which was found statistically at par with application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (80.16), imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS (78.80 %), imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (78.88 %) and significantly higher than rest of the treatments. The growth and yield attributing characters *viz*; plant height, dry matter accumulation $plant^{-1}$, number of primary and secondary branches $plant^{-1}$, pods $plant^{-1}$, seeds pod^{-1} and seed yield $plant^{-1}$ was higher with application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS which was statistically at par with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS. The treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded higher seed yield of 2526 kg ha^{-1} which was statistically at par with imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (2492.6 kg ha^{-1}) and significantly higher than imazethapyr @ 20g a.i. ha^{-1} at 15 DAS (2129 kg ha^{-1}). However, maximum and minimum seed yield of 2725.0 kg ha^{-1} and 1623.3 kg ha^{-1} was found in weed free and weedy check treatment, respectively. Nutrient depletion due to weeds in different treatments was also affected significantly and lowest values of N P K removal by weeds was noticed in the imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS applied plot. However, maximum net return (Rs 71059) and B: C ratio (2.74) was recorded with application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS followed by application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS. Hence, it may be concluded that application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS considered as the economic viable option of weed control in pigeonpea.

Major advisor	Shruti Suman
(Dr. G. S. Panwar)	M. Sc. (Ag.)

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LIST OF ABBREVIATIONS USED IN THE THESIS

Abbreviation	**Expansion**
N	Nitrogen
P	Phosphorus
K	Potassium
DAS	Days after sowing
ha	Hectare
g	Gram
Kg	Kilogram
m ha	Million hectare
m t	Million tonne
a.i.	Active ingredient
ml	Mililitre
mm	Milimeter
cm	Centimeter
m	Meter
%	Per cent
B C	Benefit cost ratio
NS	Non significant
RH	Relative humidity
S. Em	Standard error mean
C.D.	Critical difference
Fig.	Figure
i.e.	That is

CHAPTER-I

INRODUCTION

“**Effect of weed management practices on growth and yield of pigeonpea [*Cajanus cajan* (L.) Millspaugh]**”

Chapter-I
Introduction

In addition to food security, "nutritional security" has now become an emerging global issue which is haunting the scientific community. Pulse crops are commonly called poor man's meat (Reddy, 2010). By virtue of its high protein content, it can be viewed as a viable option to fight against the nutritional insecurity.

Among the pulse crops, pigeonpea [*Cajanus cajan* (L.) Millspaugh] is a short-lived perennial shrub that is traditionally cultivated as an annual crop in Asia, Africa, Caribbean region and Latin America. It is a good source of protein (20-22%), vitamins (thiamine, riboflavin, niacin & choline), minerals (irons, iodine, calcium, phosphorus, sulphur & potassium). Besides its main use as *dhal* (dehulled split peas), its immature green seeds and pods are also consumed as vegetable. The crushed dry seeds are fed to animals, while green leaves form a quality fodder. The dry stems of pigeonpea are used as fuel wood. Apart from these uses, perennial type pigeonpea is grown on sloppy mountain and bunds for reducing soil erosion (Saxena, 2001). Being a pulse, pigeonpea enriches soil through symbiotic nitrogen fixation; release soil bound phosphorus, recycles the soil nutrients and adds organic matter and other nutrients that make pigeonpea ideal crop for sustainable agriculture (Saxena, 2008). It is having wider adaptability with a good drought tolerant capacity due to its deep tap root system. So, it performs well in semi-arid tropics where moisture availability is less.

Pigeonpea is the fourth important multipurpose legume crop in the world and predominantly cultivated in the developing countries of tropical and sub-tropical environments between 30˚N and 30˚S latitudes. Globally it is grown on an area of 5.32 million hectares (m ha), with an annual production of 4.32 million tonnes and mean productivity of 813.2 kg ha^{-1} (FAO, STAT- 2012) in over 50 countries.

India, being a developing country having a serious issue of imbalanced nutrition. Most of the population of country is poor having limited access to animal protein in their daily diet. According to WHO recommendation, daily pulse consumption should be 80 gram per capita per day whereas availability of pulse is just 36 gram per capita per day which is evidenced by annual import of pulses in our country. In Bihar the contribution of cereals in total protein consumption is more than 73.0% which is not a healthy trend as cereal proteins lack many essential amino acids that are present in the pulses from which only 10.60% of total protein intake come in the diet of rural population. This alarming situation perhaps has arisen due to quest of food security rather than nutritional security.

In this case pigeonpea is a very good option which can supplement a substantial amount of protein in the daily diet of the majority of the Indian population. In India it is grown in an area of 3.86 m ha with the production of 2.65 mt and productivity of 686.5 kg ha^{-1} (FAO STAT, 2012). It is predominantly grown in the states of Maharashtra, Uttar Pradesh, Karnataka, Andhra Pradesh, Bihar and Gujarat.

In Bihar pigeonpea occupies an area of 36,070 ha and contributes 54,650 tonnes in production and 15.15 q ha^{-1} in productivity. Bihar ranked number one in pigeonpea productivity. Hence it can play a major role in meeting India's shortage in pulses. Its demand statistics always outscores the production; and hence regular imports of the order of 400,000 tonnes / year (Sultana *et al*., 2012) from Myanmar and Africa are made to feed the population. Hence it is clear that there is a good scope to increase its productivity up to the global level.

Since the scope of increasing the area of pigeonpea in the country is limited, increasing its productivity is the only viable option through managing various biotic and abiotic factors. There are various factors which limits the pigeonpea productivity *viz*; poor drainage/water stagnation causes loss due to increase incidence of *phytopthora blight*, problem of flower drop during winter season due to low temperature, more area diverted to rice, lack of high yielding disease resistance cultivars, smaller land holding and longer crop maturity, grown on marginal land, pod borer & weed infestation.

Among the various biotic factors limiting pigeonpea production and productivity, weeds are of prime importance. Ahlawat *et al*. (2005) reported that on an average, weed can reduce the yield by 40-64% in pigeonpea. For obtaining high yields, weed control is a must using different strategies as weeds can cause up to 80% reduction in grain yield of pigeonpea (Talnikar *et al*., 2008). Weed infestation causes 40-45 per cent losses in *kharif* season crops in Bihar. In pulses, crop losses due to weeds ranging from 60-70 percent at farmers' field are common and in some conditions crop may be a complete failure. However, during *rabi* season 30-40 % losses in productivity of crops, besides decreasing the quality of the produce with poor resource use efficiency (Annonymus, 2010). This problem gets more intensified due to scarce labour availability. The traditional system of hand weeding is based on the premise of cheap and readily available labour. After inception of MNREGA, labour availability at famers' field is a key issue. Moreover, Bihar is also experiencing a boom in economy resulting in a clear shift in labourers from agriculture to other sectors of economy; therefore the labour availability for farming is becoming a major limiting factor. Under given circumstances farmers need alternate production system using chemical weed management that are more efficient, less labour-intensive and offer a quick response enabling farmers to produce more at less costs.

Pigeonpea due to its slow initial growth is a poor competitor of weed, particularly in *kharif* season where several spells of rain triggers the several flushes of weeds. Again due to its wider row spacing, a fair opportunity is being utilised by weeds to compete with the crops. Its long critical period of crop weed competition of (5 to 8 weeks) compels the farmers to maintain the field weed free. But, in practice this often becomes impossible due to labour shortage and engagement of labour in paddy transplanting.

Herbicide usage for control of weeds in crop lands has been proved successful in many advanced countries and is now gaining importance in Indian agriculture. Also, advanced scientific farming methods demand the adoption of herbicide technology. The chemical weed control measures appear more convenient, less time consuming, less expensive and provide a weed free condition for the early establishment of crop plants. Herbicides must be selective to the crop plants, effective on broad spectrum of weeds, safe to the environment and should not leave any residual toxic effects on succeeding crops. As results of this, numerous herbicides are in the market now and several new ones are being introduced like imazethapyr, quizalofop-ethyl etc. for effective weeds control in soybean and groundnut. But information on their usage, suitability and concentration for effective control of weeds in pigeonpea is scarce in Bihar conditions.

Pigeonpea is generally sown in the month of May-June with rains and wider row spacing is followed and the duration of the crop is about 5 to 6 months. With the onset of rains particularly it faces a stiff competition from most aggressive weeds like *Digera arvensis, Cyperus rotundus* and *Digitaria sanguinalis* (Yadav and Singh, 2009). The crop due to its slow initial growth for 45-60 days offers congenial environment for weeds. Therefore, intercropping with short duration crops like green gram and black gram due to its smothering effect can help in controlling weeds and can be viewed as a supplement to chemical weed control in pigeonpea. Hand weeding though has been found to be very effective in controlling weeds in pigeonpea (Srivastava and Srivastava, 2004), however, labour is not only time consuming but many times it is not available especially during critical crop-weed competition period. Further there is a need for controlling the standing weeds by using post-emergent herbicide also. Hence, integrated method of weed management is considered as best option for controlling weeds in pigeonpea.

Recognising the importance of controlling weeds in enhancing growth and yield up to a considerable extent, the field experiment entitled "Effect of weed management practices on growth and yield of pigeonpea" was conducted during the *kharif* season of 2012-13 at BAU, Sabour farm with the following objectives.

- To study the effect of weed management practices on growth and yield of pigeonpea.
- To study the crop-weed competition in pigeonpea.
- To study the weed dynamics in pigeonpea.
- To estimate the effect of herbicides on profitability of pigeonpea.

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CHAPTER-II

REVIEW OF LITERATURE

Chapter-II

Review of Literature

A resume of work done in India and abroad on weed management practices in pigeonpea which has direct and indirect bearing on the specific objectives investigation is presented in this chapter under following headings:

2.1. Weed flora observed in pigeonpea at different locations.

Vaishya and Khan (1989) found the predominant weed species in the experimental plots like *Cyperus rotundus* (L.), *Fimbristylis dichotoma, Ammania bacifera, Euphorbia hirta, Euphorbia microphylla, Caesulia axillaris, Phyllanthus niruri, Echinochloa colonum, Alternanthera sessilis, Eclipta alba* and *Digitaria ascendens* in sandy loam texture soil at Faizabad, north India.

The important weeds of pigeonpea field at Bhubaneswar (Orissa) in sandy loam soil were *Borreria hispida* (L.), *Celosia argentea* (L.),*Cynodon dactylon* (L.), *Cyperus rotundus* (L.), *Dactyloctenium aegyptium*(Wild.), *Digitaria sanguinalis* (L.) Scop., *Echinochloa colonum* (L.), *Eleusine indica* (L.) Gaetn. and *Phyllanthus niruri* (L.) (Mahapatra *et al.*, 1989).

The dominant weeds found during post rainy season in pigeon pea field were the *Cynodon dactylon* (L.), *Cyperus rotundus,* (L.), *Tridex procumbens* (L.), *Commelina benghalensis* (L.) *and Amaranthus viridis* (L.) in sandy loam soil at Tirupati (Maruthi *et al.,* 1990).

Weed flora that dominated the untreated weedy plots comprised of *Trianthema portulacastrum* (L.), *Amaranthus viridis* (L.), *Digera muricata*(L.Mart.), *Tribulus terestris* (L.), *Echinochloa crussgulli* (L.), *Cynodondactylon* (L.), *Cyperus rotundus* (L.) in clay-loam soil of Gwalior (Varshney,1993).

Singh *et al.* (1994) reported from Mirzapur that the major weed flora in the experimental field were *Eleusine indica, Digitaria ciliaris,Cyperus rotundus, Cyperus iria, Amaranthus viridis, Commelina benghalensis, Eclipta alba* and *Euphorbia hirta* under medium deep ultisols area of Mirzapur (Uttar Pradesh).

Jacob Thomas *et al.* (1994*)* reported from Indian Agricultural Research institute, New Delhi that the most dominating weeds found during rainy season were *Trianthema monogyna* (L.) Forsk and *Eleusine indica* (L.). The other weeds present were *Phyllanthus niruri* (L.), *Tribulus terestris* (L.), *Leucas aspera* and *Commelina benghalensis* among broad leaf and *Cyperus rotundus* L., *Dactylactenium aegypsium* Richter and *Cynodon dactylon* L. Pers among the grassy weeds under sandy loam soil.

Vijaykumar *et al.* (1995) reported that the major weed flora found at RARS, Palem, Andhra Pradesh, during study in sandy loam soil were *Brachiaria distachya* (L.), *Dactylactenium aegyptium* (L.), *Digitaria ciliaris,Cynodon dactylon* (L.), *Desmodium triflorum* (L.), *Leucas aspera* and *Merrimia emerginata.Cyperus rotundus, Cynodon dactylon, Trianthema monogyna and Echinochloa colona* were dominating weed species which infested the experimental field at Gurgaon (Chauhan *et al.*, 1999).

Vyas *et al.* (2003) opined the predominant weeds at Sehore, Madhya Pradesh were *Echinochloa colonum* (L.), *Digitaria sanguinalis* (L.) Scop., *Caesulia axillaris, Cyperus rotundus,* (L.), *Acalypha indica*, *Anotic monthuloni* and *Digera arvensis*. The most predominant weeds found at Meerut (Uttar Pradesh) were *Trianthema monogyna, Echinochloa colonum, Cynodon dactylon* (L.), *Cyperus rotundus* (L.), *Parthenium hysterophorus* and *Digera arvensis* (Vivek *et al.*, 2003.).

Important weed flora recorded at Bulandshahar (Uttar Pradesh) were *Cynodon dactylon* (L.), *Cyperus rotundus* (L.), *Sorghum helpense*, *Boerhavia diffusa*, *Digetaria arvensis* (L.) and *Commelina benghalensis* (L.) (Tomar *et al*., 2004).

The common weed flora in pigeonpea field at MRS Dharwad was *Commelina benghalensis* (L.), *Parthenium hysterophorus*, *Dinebra retroflexa* and *Oldenlandia sp*. The other weeds which were of minor importance were *Cyperus rotundus (L.)*, *Bracharia eruciformis*, *Hibiscus pondureformis* and *Ocimum cannum (*Channappagoudar and Biradar 2007).

The predominant weed flora observed in the experimental area at Gandhi Krishi Vigana Kendra, Bangalore were *Cynodon dactylon,Cyperus comphrenes*, *Digitaria adsceendensiss*, *Polygala perssicurifolia*, *Polygonium plebigium*, *Argimone mexicana*, *Acanthospermum hispidum*, *Commelina benghalensis*, *Borilla prusilla* and *Phosphalum flavidum* (Nagaraju and Mohankumar, 2009).

Yadav and Singh (2009) reported that the predominant weed species in the experimental plots in sandy loam soils at Varanasi were *Echinochloa colona* (L.), *Echinochloa crussgulli* (L.), *Cynodon dactylon* (L.), *Eleusine indica* (L.) *Digitaria sanguinalis* (L.), *Dactylactenium aegyptium* (L.), *Cyperus difformis* (L.), *Cyperus iria* (L.), *Fimbristylis miliaceae* (L.),*Commelina diffusa* L., *Commelina benghalensis* L., *Ageratum conyzoides* L., *Euphorbia hirta* L., *Caesulia axillaris, Celosia argentia* L., *Caesulia axillaris*, *Cleome viscosa*., *Parthenium hysterophorus* L., *Phyllanthus niruri* L., *Eclipta alba* (L.) and *Corchorus acutengulus*.

The major weeds present in the experimental field of PAU, Ludhiana during *Kharif* were (*commelina benghalensis, Trianthema partulacastra* (Itsit), *Eulphorbia hirta, Digitaria* spp. *Dactyloctenium algyptiacum* (Madhana) and *cyperus* spp. (Singh *et al*., 2010).

Important weed flora recorded at Regional Agricultural Research Station, Warangal (A.P) were *Cynotis axillaris, Digera arvensis, Phyllanthus niruri, Euphorbia hirta, Portulaca oleracae, Triantima portulocastrum, Cynodon dactylon, Cyperus rotundus, Parthenium hysterophorus and Commelina benghalensis and Dinebra retroflexa.* (Padmaja *et al.,* 2013).

2.2. Critical period of crop-weed competition in pigeonpea

Singh *et al.* (1980) reported that the yield obtained from two hand weedings at 25 and 50 DAS were at par with those from weed free treatment. Thus, first 45 days were most critical period in pigeonpea crop and control of weeds during this period offered maximum advantage to the crop.

Diaj-Rivera *et al.* (1985) reported that first 30 DAS appeared critical regarding crop-weed competition. Although this period may vary with genotype and time of sowing. Ali and Varshney (1988) reported that under pigeonpea/mungbean intercropping system, the losses caused by uncontrolled weeds in the productivity of pigeonpea and mungbean were on an average 68 and 41 percent in peninsular zone and 36 and 26 percent in north-west plain zone, respectively.

Gurjar *et al.* (1987) reported that low seedling vigour makes weed control measure essential in pigeonpea cultivation during the critical period of first 40-60 DAS, during which weeds utilize plant nutrients and reduce the crop yield considerably. Weed free upto six weeks after sowing (WAS) and there after no weeding gave higher yields of Arhar (Tewari, 1989).

Study by Vaishya and Khan (1989) indicated that the initial 20 to 50 DAS were found to be the most critical period for crop-weed competition in pigeonpea.

Ali (1987) reported that the critical period for weed competition was the first 8-9 weeks in late pigeonpea and the first 6-7 weeks in early pigeonpea when it was grown along with other intercrops.

Varshney (1992) conducted an experiment at Maharajpur, Gwalior revealed that keeping the field weed free up to 30 and 45 DAS resulted in seed yield significantly higher over 15 days weed free period. However, there was no significant variation when fields were kept weed free up to 30 and 60 DAS.

2.3. Effect of weed competition on yield of pigeonpea

Malik *et al.* (1986) reported that the presence of weeds throughout the growing season reduced the potential yield of pigeonpea by 68 %. Weeds compete with pigeonpea for its growth resulting in reduction of pigeonpea yield ranging from 49-68 % (Vaishya and Khan, 1989).

Pigeonpea invited a platform to a wide spectrum of weed flora that set a stiff competition with crop resulting in yield loss varying from 30 to 40% (Kundra and Brar, 1990).

Rao (1995) reported that the weeds are competitive and adaptable to all adverse environments. There is a severe competition between weeds and plants for nutrients, moisture, light and space which leads to a reduction of agricultural produce up to 45%.

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

Depending upon severity of infection, stage of crop-weed competition, nutrient and moisture availability and agro-climatic conditions, the purple nut sedge reduces the crop yield by 10-32 percent. While annual yield loss due to overall weeds in India is 33 percent accounting nearly Rs. 1980 crores. *Kharif* crops like pigeon pea, mungbean, urdbean, upland rice and maize are more susceptible to this sedge than *Rabi* crops. Besides yield loss, it also harbour certain insect, pest which feed on prevailing crop and affect the yield (Singh *et al*., 2005).

Singh and Sekhon (2013) reported that reduction in yield due to weeds in pigeonpea was 55-60% in Ludhiana.

2.4. Effect of pre and post emergence herbicides on weed dynamics in pigeonpea

Jacob Thomas *et al.* (1994) at IARI, New Delhi, found that fluchloralin @ 0.75 kg a.i.ha^{-1} and pendimethalin @ 1.0 kg a.i.ha^{-1} were effective in reducing weed density and growth of weeds and has increased the pigeonpea yield significantly, whereas, fluzifop-p-butyl and haloxyfop-methyl were found slightly phytotoxic to crops.

Singh *et al.* (1994) reported that hand weeding twice at 20 and 40 DAS registered significantly superior in reducing the weed dry matter when compared to the herbicides. Fluchloralin was more effective than pendimethalin in minimizing weed dry weight. Fluchloralin was more effective in controlling annual grassy weeds like *Eleusine indica* and *Digera ciliaris* as well as broad leaf weeds, which were dominant weeds in the experimental field.

Agrawal *et al.* (1995) conducted a field trial at Jabalpur in *Kharif,* 1984-85 to assess the effects on the weed flora of soybean. The treatments comprises of hand weeding 30 and 45 DAP, Pre-plant incorporation of fluchloralin at 1.0 kg/ha as pre-emergence, metribuzin at 0.75 kg and 1.0 kg, metolachlore at 1.0 kg, post-emergence application of acifluarfen at 0.5 kg. Lowest weed densities were recorded with the 2 hand weedings. Among the herbicidal treatments, metribuzin was most effective at reducing weed density in 1984.

Chauhan *et al.* (1995) reported that integration of reduced rate of each herbicide (1.0 kg a.i.ha^{-1}) with one hand weeding at 60 DAS reduced the density and dry matter of weeds than single application of herbicides at higher rates.

Kelly *et al.* (1998) reported that the application of imazethapyr @70 g a.i.ha^{-1} increased lamb quarters (*Chenopodium album* L.) control and common ragweed *(Ambrosia artemisiifolia L.)* dry weight was reduced from 61 to 64 % in the field gaint foxtail (*Setaria faberi* H.) control with imazethapyr applied alone or with diphenyl ether herbicides increased when 28% urea ammonium nitrate was added with nonionic surfactant compared with nonionic surfactant only. A methylated seed oil improved common rag weed (*Ambrosia artemisiifolia* L.) control by imazethapyr @ 70 g a.i.ha^{-1}, while lamb quarters (*Chenopodium album* L.) and velvet leaf (*Abutilon theophrasti* M.) control increased when methylated seed oil was included with 18 g a.i. ha^{-1} imazethapyr compared to non ionic surfactant in the green house.

Bandiwaddar *et al*. (1999) from UAS Dharwad reported that, two inter cultivation + two hand weedings (30 and 45 DAS) recorded lower weed dry weight (2.53 g) compared to other treatments. Among the herbicide treatments alachlor @ 2.0 kg a.i. ha^{-1} recorded lower weed dry weight (2.65g) which was on par with pendimethalin @ 1.0 kg a.i. ha^{-1}(3.19 g) at 40 DAS.

Chauhan *et al.* (1999) found that maximum dry weight of weeds (118.3 g m^{-2}) was recorded in untreated check, where as lower weed dry weight was observed due to hand weeding twice at 20 and 35 DAS as compared with one hand weeding or herbicide applications, because it could not allow weed growth.

Pre-emergence application of pendimethalin @ 1.25 kg a.i. ha^{-1} for control of weeds in pigeonpea was found most effective method of weed control and recorded 22.4% higher grain yield (Anon, 2001).

Kewat and Pandey (2001) reported that metribuzin at 0.5 and 0.75 kg/ha as PE, effectively controlled most of the domoinant weeds, *viz*; *Trianthema portulacastrum*, *Echinochloa colona*, *Digitaria sanguinalis and Digera arvensis.*

Dubey (2002) reported that application of alachlor (10 G and 50EC) @ 2.0 kg a.i. ha^{-1} and pendimethalin (30EC) @ 1.50 kg a.i. ha^{-1} as pre- emergence reduced the population of sedges considerably as compared to anilofos @ 2.5 kg a.i. ha^{-1} and metalachlor 50 EC @ 1.0 kg a.i. ha$^{-1.}$

Khan *et al*. (2003) conducted an experiment to study the efficacy of different herbicides on weeds and their effect on yield and yield components of edible pea (*Pisum sativum* L.) at Malakandher Research Farm, NWFP Agricultural University, Peshawar during 2001-2002 using RCBD. Minimum weeds m^{-2} (30.60) and the weed biomass g m^{-2} (96) were recorded in hand weeded plots followed by 76.80 weeds m^{-2} and 308 g m^{-2} weed biomass in the post emergently treated metribuzin plots. Pod length (9.612 cm), No. of seeds pod^{-1} (6.14) and pod yield (4673 kg ha^{-1}) were the maximum in hand weeded plots, followed by post emergently metribuzin treated plots. Moreover, the maximum, 100 seed weight (43.85g) and shelling percentage (41.56) were also recorded in post-emergently metribuzin treated plots.

Vyas *et al.* (2003) concluded that the two hoeings + one hand weeding recorded minimum number of weeds followed by application of pendimethalin @ 0.75 and 1.0 kg a.i. ha^{-1} both along with one hand weeding. Higher weed control efficiency (85.76%) was obtained with pendimethalin @ 1.0 kg a.i. ha^{-1} + one hand weeding followed by pendimethalin @ 0.75 kg a.i. ha^{-1} + one hand weeding (84.60 %).

Vivek *et al.* (2003) reported that significantly lower population of weeds was noticed in the plots which were free from weeds for 120 DAS followed by the plots which remained weed free up to 90 DAS, whereas significantly higher grain yield and yield attributing characters were obtained in the plots remaining weed free up to harvest.

Tomar *et al*. (2004) reported that the weed density and dry matter were lower and recorded significantly higher grain yield of pigeonpea in pendimethalin applied @ 1.0 kg a.i. ha^{-1} + one hand weeding at 30 DAS followed by fluchloralin at 1.0 kg a.i. ha^{-1} + one hand weeding at 30 DAS as comparison to control and other practices.

Kushwah and Vyas (2006) reported that the lower weed biomass was recorded with application of imazethapyr @ 75 g a.i. ha^{-1} or quizalofop-ethyl @ 50 g a.i. ha^{-1} followed by two hand weedings at 20 and 40 DAS. Post-emergence application of imazethapyr @ 75 g a.i. ha^{-1} reduced the population of *Caesulia axillaris*, *Anatis monthulani* and *Acalypha indica* significantly as compared to all pre and rest of the post-emergence herbicides under investigation. Quizalofop-ethyl 5 EC @ 50 g a.i. ha^{-1} was significantly effective against *Commelina bengalensis* and *Echinochloa colona*. The lowest weed biomass was recorded with two hand weedings at 20 and 40 DAS followed by imazethapyr @ 75 g a.i.ha^{-1} and quizalofop-ethyl 5 EC @ 50 g a.i. ha^{-1}. Two hand weedings (20 and 40 DAS) and imazethapyr at 75 g a.i. ha^{-1} were most appropriate treatments in terms of reduction in total weed density and increase in soybean yield.

Anon (2006a) reported that pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1} followed by one hand weeding at 45 days after sowing was found as effective as that of weed free condition for management of weeds in pigeonpea.

At Research farm of CCS Haryana Agricultural University an experiment was conducted by Malik *et al*. (2006) to evaluate the efficacy of trifluralin and pendimethalin at varying doses alone and in integration with one hoeing or fenoxaprop against weeds of soybean during rainy season of 2004 & 2005. They concluded that among different herbicidal treatments, on an average the three treatments that are trifluralin @ 1500 g ha^{-1}, trifluralin @ 1000 g ha^{-1} fb one hand hoeing at 20 DAS, pendimethalin 1000 g ha^{-1} fb one hand hoeing at 20 DAS provided 80% control of BLW and 71.5% control of grassy weeds. These three treatments being at par with each other produced pods/plant and grain yield statistically similar to weed free.

Sharma and Yadav (2006) conducted an experiment at Crop research centre of G.B.PUAT in the year 2003. The experiment with ten treatments was performed to assess the effect of weed management practices on *kharif* urdbean. They found that all weed control treatments caused significant reduction in dry matter production of weeds in comparison with weedy check. According to them alachlor was more effective against *C. rotundus* while pendimethalin against *T. monogyna*. Pendimethalin (0.75 and 0.5 kg ha^{-1}) was applied in combination with hand weedings at 30 DAS; it caused lower dry matter of *T. monogyna* (3.21 and 5.26 g m^{2}) as compared to pendimethalin alone @ 1.0 kg ha^{-1} *i.e* 7.8 g/m^{2}.

Tuti and Das (2011) reported from IARI, New Delhi that among all the pre-emergence fb-post-emergence metribuzin treatments, metribuzin 0.25 kg ha^{-1}, Pre-emergence fb 0.1 kg ha^{-1} with 400 litres/ha at 20 DAS resulted in the lowest population of *Trianthema partulacastrum* during both years. Pendimethalin 0.75 kg ha^{-1} as PE controlled all grassy weeds at 40 DAS, where as it was the lowest with metribuzin 0.5 kg ha^{-1} as PE at 60 DAS. The treatment of metribuzin 0.5 kg ha^{-1} as PE caused a significant reduction in total weed dry weight resulting in highest WCE 68.6% and 73.9%., respectively at 40 and 60 days after sowing (DAS).

Dhonde *et al.* (2009) conducted an experiment during *kharif* 2003 at Rahuri and revealed that weed intensity and weed dry matter at harvest were significantly less in weed free treatment followed by fluchloralin as pre-planting incorporation (PPI) @ 1.0 kg ha^{-1} plus glyphosate @ 1.0 kg ha^{-1} at 45 DAS were in second order. Weed intensity and weed dry matter were maximum in weedy check treatment (206.57 m^{-2} and 12.22 q ha^{-1} respectively). Dicot weeds were found higher in proportion than monocot weeds.

Meena *et al.* (2011) conducted an experiment to evaluate the efficacy of imazethapyr on weed control and soybean yield. Among herbicidal doses imazethapyr XL 10% SL 150 g ha^{-1} gave higher WCE of grassy (76.9%), broad leaf (67.9%) and sedges (64.6%) as compared to weedy check but remained statistically at par with two hand weeding, imazethapyr (100g ha^{-1}) while, it was significantly superior over lower dose of imazethapyr 50g ha^{-1} and weedy check.

Khot *et al.* (2012a) conducted *a* field experiment during summer season of 2010 to study the weed management in summer blackgram (*Vigna mungo* L.). They found that an application of pendimethalin 1 kg ha^{-1} as pre-emergence + 1HW + IC at 40 DAS was most effective in reducing weed population (*viz*; monocot, dicot and sedges weeds) and resulted in less dry weight of weeds (204 kg ha^{-1}), higher WCE (85.9%), lowest weed index (7.92%) and it was closely followed by oxyfluorfen 0.18 kg ha^{-1} pre-emergence + 1 HW + IC at 40 DAS. Imazethapyr 75g ha^{-1} post-emergence at 40 DAS was less effective against sedges. The lowest dry weight of weed was recorded with the above treatment of pendimethalin but it was statistically at par with oxyfluorfen 0.18 kg/ha pre-emergence + 1 HW + IC at 40 DAS and quizalofop-ethyl 40 g ha^{-1} post emergence at 30 DAS.

The highest weed control efficiency and lowest weed biomass was recorded with two hand weedings at 20 and 40 DAS (95%) followed by imazethapyr @ 25g ha^{-1} at 20 DAS (92%) and PE application of pendimethalin @1.0 kg ha^{-1} (90%) in urdbean. However the other herbicides quizalofop-p-ethyl, fenoxaprop-p-ethyl and chlorimuron-p-ehtyl alone or in combination also registered notable value of WCE in the range of 78.8 to 89.3 %. (Gupta *et al*., 2013).

Padmja *et al*. (2013) conducted an experiment at RARS, Warangal. They concluded that imazethapyr 75 g a.i. ha^{-1} applied at 20 DAS significantly reduced the density and dry weight of both dicot & monocot weeds recorded at 30 DAS compared to weedy check followed by pendimethalin 0.75 kg ha^{-1} as pre-emergence. They found that imazethapyr 75 g a.i. ha^{-1} applied at 20DAS significantly reduced the density and dry weight of both dicot and monocot weeds recorded at 30 DAS compared to weedy check followed by pendimethalin 0.75 kg ha^{-1} as pre-emergence. Higher weed control efficiency was also recorded with hand weeding twice (96.7%) followed by pendimethalin + paraquat at 42 DAS (78.3%).

Yadav *et al.* (2013) conducted a field experiment to explore the feasibility of growing lentil with integration of weed management practices using herbicide, increased plant population and manual weeding at Meerut during 2008-09 and 2009-10. They reported that lowest weeds density (4 m^2) and dry weight (2064 g m^2) was recorded where pendimethalin was applied 0.75 kg ha^{-1} as PE plus one hand weeding, which was statistically on par with pendimethalin 1.0 kg ha^{-1}, whereas, the highest grain yield of 1662 kg ha^{-1} was recorded by pendimethalin 0.75 kg ha^{-1} plus one hand weeding, which was statistically at par with weed free as well as pendimethalin 1.0 kg ha^{-1}.

2.5. Effect of herbicide on growth and yield of pigeonpea

Itnal *et al*. (1993) concluded that application of pendimethalin or alachlor @ 1.0 kg a.i.ha^{-1} followed by one hand weeding at 30 DAS was found effective in controlling weeds and obtained higher yield in groundnut.

Itnal *et al.* (1993) conducted field trials on sandy loam soils in Karnataka to study different method of weed control in pigeonpea. The highest weed control efficiency (73.54%) and pigeonpea yields (1374 kg ha^{-1}) were recorded as compared with untreated control (399 kg ha^{-1}) with pendimethalin 1.0 kg ha^{-1} + manual weeding 30 DAS.

Vivek *et al.* (2003) found that pigeonpea plant height was severely hampered by the presence of weeds. Maximum height (191.9 cm) was observed in weed free and minimum (150.6 cm) in weedy upto harvest. Similarly yield attributes *viz;* branches per plant, number of seeds per pod and test weight were also significantly influenced due to different weed free and weedy periods. Maximum values regarding all above attributes were recorded in plots kept weed free till harvest. The minimum values, however were recorded in weedy upto harvest.

Pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1} was recorded as most efficient in controlling weeds and produced higher grain yield (1057 kg ha^{-1}) as compared to one hand weeding at Kumarganj and Kanpur, however at Varanasi, though the chemical weed control yielded higher than hand weeding but differences were not statistically significant. It was also reported that control of weeds in pigeonpea through pre-emergence application of pendimethalin @ 1.25 kg a.i. ha^{-1} was found most effective method of weed control and recorded 53.5% higher grain yield than unweeded check Anonymous (2005).

Sharma and Yadav (2006) conducted an experiment at Crop research centre of G.B.PUAT in the year 2003 and reported that grain yield recorded in case of pendimethalin @ 0.75 kg ha^{-1} + hand weeding (1869 kg ha^{-1}) and it was at par with weed free (2080 kg ha^{-1}).

Experiment conducted at AICRP centres of Banagalore and Ludhiana indicated that weed control treatments recorded significantly higher grain yield than weedy check. Application of pendimethalin @ 2.5 kg a.i. ha^{-1} as pre-emergence followed by one hand weeding at 45 DAS demonstrated effective weed control and recorded grain yield of 1634 kg ha^{-1} and on par with hand weeding twice at 25 and 50 DAS (Anonymous, 2006).

Kushwaha and Vyas (2006) reported that imazethapyr @ 75 g ha^{-1} enhanced the grain yield by 45.3 % over weedy check. Maximum yield of 2479 kg ha^{-1} was recorded with the treatment involving two hand weedings and remained at par with imazethapyr @ 100 g ha^{-1} (2238 kg ha^{-1}) and significantly superior than weedy check was (1785 kg ha^{-1}).

Studies conducted to check the efficacy of pre and post emergent herbicides on weed control in pigeonpea at Ludhiana and Pantnagar centres of North West plain zone, revealed that pendimethalin (pre-emergence), paraquat and persuit (post-emergence) were applied in different concentrations and their efficacy was compared against manual hand weeding. Pantnagar centre used alachlor also as pre-emergence but did not use persuit as post-emergence. At this centre application of pendimethalin @ 0.75 kg a.i ha^{-1} as pre-emergence and paraquat as post-emergence @ 2.0 kg a.i. ha^{-1} at 6/8 WAS was as effective as that of weed free treatment. At Ludhiana, pendimethalin @ 0.45 kg a.i. ha^{-1} with paraquat @ 2.0 kg a.i. ha^{-1} (6/8 WAS) was equally effective as that of two hand weedings, while, post emergence herbicide persuit was not found equally effective (Anonymous, 2008).

Mallareddy *et al.* (2008) reported that inter cultivation at 25 and 50 DAS recorded significantly higher plant height (111.5 cm), branches $plant^{-1}$ (8.3), pods $plant^{-1}$ (128.2), grain yield (1748 kg ha^{-1}), water use efficiency (14.3 kg ha^{-1} mm), net returns (Rs. 26,968 ha^{-1}), lower weed dry matter (7.8 g m^{-2}) and weed density (5 m^{-2}). Among weed management practices, the performance of imazethapyr was superior to pendimethalin and fenoxaprop-ethyl.

Deore *et al.* (2008) concluded that application of imazethapyr at 200 g a.i. ha^{-1} recorded significantly higher grain yield (27.75 q ha^{-1}) followed by imazethapyr 100 g a.i.ha^{-1} (27.00 q ha^{-1}), chlorimuran ethyl 9.37 g a.i.ha^{-1} (25.00 q ha^{-1}) and fenoxaprop ethyl 67.5 g a.i.ha^{-1} (24.80 q ha^{-1}). The lower seed yield (19.19 q ha^{-1}) was recorded in weedy check.

Singh *et al*. (2008) conducted a field experiment at the research farm of PAU, Ludhiana for three consecutive years to find out effective weed management practices in gram. He found that integration of one hand weeding with either pre plant incorporation of treflan @ 0.50 kg/ha pre-emergence or application of Stomp @ 0.50 kg/ha proved very effective for controlling weeds as indicated by 82 and 86% reduction in final dry matter accumulation by weeds, respectively as compared to the control treatment. Both these integrated treatments increased seed yield of chickpea by 60 and 59 percent over control.

Maximum values of yield attributes were observed in weed free treatment followed by IWM treatments *viz;* pendimethalin PE @ 1.0 plus kg ha^{-1} plus one hand weeding at 45 DAS, two hand weeding at 20 and 45 DAS and pendimethalin PE@ 1.0 kg ha^{-1} plus glyphosate @1.0 kg ha^{-1} at 45 DAS. The seed yield of pigeonpea (22.9 q ha^{-1}) and stick (65.03 q ha^{-1}) was maximum in weed free treatment followed by IWM treatment *viz;* pendimethalin 1.0 kg ha^{-1} plus one hand weeding at 45 DAS. (Dhonde *et al.* (2009).

Yadav and Singh (2009) reported that two hand weedings at 15 and 45 DAS recorded maximum plant height (248.7 cm), number of branches (17.3), pods $plant^{-1}$ (131.5), grain weight $plant^{-1}$ (52.8 g), test weight (12.2 g) and grain yield (2350 kg ha^{-1}) of pigeonpea than other treatments. This treatment was found at par with pendimethalin @ 1.0 kg a.i. ha^{-1} + one hand weeding at 45 DAS in respect of growth and yield attributes of pigeonpea. Significantly higher values of growth, yield attributes and yields of rice and pigeonpea grain equivalent yield were recorded with two hand weedings than other weed management practices.

The trials conducted at Bangalore, Gulbarga, Lam, Warangal, Vamban, Coimbatore and Ludhiana on different weed management practices revealed that weed free plot registered significantly higher grain yield over control in all the locations (Anonymous, 2009). Pre-emergence application of pendimethalin (0.75 kg a.i. ha^{-1}) followed by one hand weeding at 50 DAS gave significantly higher grain yield at Ludhiana (1508 kg ha^{-1}), Vamban (890 kg ha^{-1}) Coimbatore (1058 kg ha^{-1}), Bangalore (1253 kg ha^{-1}) and Lam (1984 kg ha^{-1}) and found on par with early post-emergent application of imazethapyr (75 g a.i. ha^{-1}) at 15-20 DAS followed by paraquat (0.48 kg ha^{-1}) at 6-8 WAS and other herbicide treated plots. Whereas at Warangal pre-emergence application of pendimethalin (0.75 kg ha^{-1}) followed by paraquat (0.48 kg ha^{-1}) at 6 WAS produced significantly higher yield (1818 kg ha^{-1}) and found on par with other herbicide treated plots.

Kaur *et al*. (2009) reported that the highest grain yield (15.10 q ha^{-1}) was recorded by two hand hoeings at 25 DAS and 40 DAS and which was statistically at par with pendimethalin @ 0.75 kg ha^{-1} (14.47 q/ha) in summer mungbean. It was observed that the maximum number of seeds per pod (9.2) in treatment having two hand hoeing followed by two hoeings with wheel hoe (9.1).

Meena *et al.* (2011) also reported that imazethapyr @ 150 g ha^{-1} recorded maximum yield attributes and seed yield (957 kg ha^{-1}) which was similar with imazethapyr @ 100 g ha^{-1} (945 kg ha^{-1}) but these were significantly superior to imazethapyr at 50 g ha^{-1} and weedy check respectively.

Gupta *et al*. (2013) conducted experiments during *Kharif* 2007 and 2009 in Inceptisol to study the effect of different herbicides (pre and post) along with two hand weedings on urdbean. Although the seed yield was highest with two hand weeding at 20 and 40 DAS but the values are found at par with the application of imazethapyr 25g ha^{-1} at 20DAS. Seed and biological yield recorded with imazethapyr (75.2 and 45.7%) and pendimethalin (50.9 and 26.3%) were higher over weedy check.

Field experiments were conducted by Singh and Sekhon (2013) for seven years from 1998 to 2004 at PAU, Ludhiana to find out integrated weed management in pigeonpea. They reported that uncontrolled weeds caused 31.0 to 52.8% reduction in pigeon pea grain yield in different years. The sole application of pendimethalin as pre-emergence at 0.45 or 0.75kg ha^{-1} was less effective in controlling & improving grain yield than the other treatments (two hand weeding, pendimethalin in integration with hand weeding or ridging or both). Among various treatments, the treatment comprises of integration of pendimethalin 0.45 kg ha^{-1} + hand weeding 30 DAS + ridging 50 DAS provided the highest grain yields ranging between 1216 to 1942 kg ha^{-1} of pigeonpea in all years of study.

Padmja *et al.* (2013) conducted an experiment at Regional Agricultural Research station, Warangal during 2008-09 and 2010-11 to evaluate the weed control efficiency of pre and post–emergence herbicide in pigeon pea. Uncontrolled weeds led to 79% loss in the seed yield of pigeonpea. Application of pendimethalin followed by paraquat at 42 DAS registered higher seed yield (1304 kg ha^{-1}) which was at par with that in hand weeding twice at 25 and 50 DAS (1249 kg ha^{-1}).

2.6. Effect of intercropping on weed control and yield

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

Tewari *et al*. (1990) reported that weed free condition in the initial growth stages increased the grain yield by 60.3% in pigeon pea alone and 84.3% in pigeon pea + blackgram intercropping system. Removal of sedges, grass and broad leaved weed brought about increase to the order of 24.2, 16.9 and 20.0 per cent in pigeon pea alone and 41.5, 47.4 and 22.0 per cent in pigeon pea + blackgram, respectively.

An experiment was performed by Rafey and Prasad (1989-1991) at BAU, Ranchi to find out best management practices in pigeon pea + rice intercropping system. They found that the WCE and grain yield of pigeonpea was maximum *i.e.* 82 % and 1495 kg ha^{-1} respectively, in case of T_{10} (Pendimethalin @ 1.0 kg a.i. ha^{-1} as PE + interculturing (30 DAS). Pre-emergence application of pendimethalin @ 1.5 kg a.i. ha^{-1} gave the least weed density *i.e.* 18.0 m^2 at 90 DAS it was and significantly superior to other treatments.

Ali (1991) conducted 30 experiments over several parts of India during 1982-88 and the mean yield data of these experiments revealed that efficient weed management was one of the most important production inputs in pigeonpea cultivation. He found that the relative yield enhancement from weed management were 31 % as against 5 % due to fertilizer use (18-46-0). Weed control combined with fertilizer use exhibited synergistic effects in some conditions. Further studies at Kanpur during 1986-88 revealed that monocot (narrow-leaved) weeds caused greatest potential damage, closely followed by sedges. Dicot weeds are least harmful. A study on the relative efficacy of different herbicides in a pigeonpea/sorghum intercropping system showed that pendimethalin @ 1.5 kg ha^{-1} as pre-emergence spray was the most effective herbicide followed by alachlor @ 2 kg ha^{-1} or 0.75 kg ha^{-1} pendimethalin + one hand-weeding at 30 days after sowing (DAS).

The field experiment conducted at Regional Agricultural Research Station, Palem, Andhra Pradesh, during rainy season revealed that less weed biomass, higher yields of pigeonpea, better weed control efficiency and higher returns were obtained in weed management system involving hand weeding twice (15 and 30 DAS) followed by hand hoeing (30 and 42 DAS). The next best treatments were pendimethalin (1.0 kg a.i.ha^{-1}) and fluchloralin (1.0 kg a.i.ha^{-1}) followed by two hoeings at 30 and 42 DAS in pigeonpea and groundnut intercropping (Vijaykumar *et al.,* 1995).

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

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

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

Shinde *et al.* (2003) opined that application of pendimethalin @ 1.50 kg a.i.ha^{-1} + one hand weeding at 40 DAS in pigeonpea + pearlmillet intercropping system showed better performance with respect of weed control efficiency especially in the weed free treatment (77%) followed by pendimethalin @ 1.50 kg ha^{-1} + one hand weeding at 40 DAS. The result show the above treatment of pendimethalin gave higher grain yield (1880 kg ha^{-1}) and stick yields of pigeonpea as compared to other treatments but at par with weed free treatment (1880 kg ha^{-1}).

Vyas *et al.* (2003) reported that the seed yield of pigeonpea and intercropped soybean was maximum under weed free treatment and it was on par with two hoeings + one hand weeding and pendimethalin @ 0.75 and 1.0 kg a.i. ha^{-1} both supplemented with one hand weeding.

A field experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, Banglore during *Kharif* season of 2004 and 2005 by Nagaraju *et al*. (2009) to study weed management practices in pigeonpea + Soybean intercropping system under rainfed condition. The maximum weed control efficiency

(93.5%) was recorded at 60 DAS with the pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1} + one hand weeding at 50 DAS followed by alachlor at 1.0 kg a.i. ha^{-1} + one hand weeding at 50 DAS.

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

Higher grain yields of both pigeon pea and soybean were obtained by maintaining weed free condition throughout the crop growth period which was followed by pendimethlin at 1.0 kg a.i. ha^{-1} or alachlor at 1.0 kg a.i. ha^{-1} with one hand weeding at 50 DAS.

2.7. Effect of pre and post-emergence herbicides on nutrient uptake by weeds and crop

Vyas *et al.* (2003) found that the N, P and K uptake by weeds was higher under weedy (20.10, 2.02 and 51.62, N, P and K kg ha^{-1}, respectively (sole pigeonpea), followed by weedy (pigeonpea + soybean intercropping). Phosphorus and potassium uptake by weeds in pendimethalin @ 1.0 kg a.i. ha^{-1} +one hand weeding was minimum (0.20 and 4.53 kg ha^{-1}), while nitrogen uptake in two hoeings + one hand weeding was minimum (2.11 kg ha^{-1}).

Yadav and Singh (2009) found that minimum removal of nitrogen by weeds and maximum nitrogen uptake by cropping system in the weed management practices involving two hand weedings at 15 and 45 DAS (5.5 and 150.35 kg ha^{-1}) in pigeonpea which was found at par with pendimethalin @ 1.0 kg a.i. ha^{-1} + one hand weeding at 45 DAS (8.3 and 142.35 kg ha^{-1}).

Kaur *et al.* (2010) performed a experiment at PAU, Ludhiana during 2003 to assess the effect of weed control in Summer mungbean. The experimental result revealed that the maximum nutrient removal by weeds in unweeded control *i.e.* 68.90, 19.29 and 77.17 kg ha^{-1} of N, P & K, respectively. Nutrient uptake recorded was minimum in case of pendimethalin 0.75 kg ha^{-1} *i.e.* 8.70, 3.17 and 11.57 kg ha^{-1} of N, P and K respectively, followed by pendimethalin 0.45 kg ha^{-1}. These results are in line with those of Kundra *et al*. (1991) who reported the highest uptake in unweeded check *i.e.* 79.1, 19.8 & 79.1 kg ha^{-1} N, P and K, respectively.

Tuti and Das (2011) found that weedy check resulted in the highest uptake of N, P and K by weeds in soybean. However all pre-emergence fb post-emergence treatments of metribuzin irrespective of dose, volume, rate and time, proved equally effective in reducing the N, P and K removal by weeds. The results are in conformity with Idapuganti *et al.* (2006).

Khot *et al*. (2012 b), conducted an experiment in 2010 at Junagadh Agricultural University (Gujarat) to study the weed management in blackgram. They found that the weed free treatment recorded significantly the highest uptake of N, P & K by black gram (48.13, 7.45 & 23.92 kg ha^{-1}) and lower N, P & K uptake by weeds which was closely followed by pendimethalin 1 kg ha^{-1} pre-emergence +1 HW + IC at 40 DAS and at par with treatments quizalofop-ethyl 40 g ha^{-1} as post emergence at 30 DAS.

2.8. Economics of pre and post emergence herbicides in pigeonpea.

Dahiya and Rao (1985) reported that maximum net profit (Rs.6169 ha^{-1}) was obtained by maintaining weed free condition. By following hoeing at 25 and 45 DAS Rs. 4225 ha^{-1} was obtained. Next best treatment was nitrofen at 4.0 kg ha^{-1} as a pre-emergence application which gave Rs. 3864 ha^{-1} when compared to unweeded control, which gave Rs. 1676 ha^{-1}.

Goyal *et al.* (1991) conducted experiment on mid late pigeonpea under rainfed conditions and revealed that physical methods of weed control were superior over chemicals. One hand weeding followed by one intercultivation at 30 DAS was found to be efficient and economical. The economics of the different measures revealed that higher gross income (Rs.9926 ha^{-1}) and additional return (Rs.4930 ha^{-1}) along with net return on each rupee was obtained by one hand weeding + one intercultivation at 30 DAS (16.79). Among chemicals, fluchloralin 1.0 kg a.i. ha^{-1}, applied as pre-emergence along with one intercultivation at 60 DAS was found superior in terms of monetary returns over other weedicides tried.

Vijaykumar *et al.* (1995) found that the mean gross and net returns were higher in the treatment of two hand weedings followed by two hand hoeing (Rs. 8491ha^{-1} and 5071 ha^{-1}). The next best treatments were pendimethalin (1.0 kg a.i ha^{-1}) and fluchloralin (1.0 kg a.i ha^{-1}) each followed by two hand hoeings with values of (Rs.7548 and 4258 ha^{-1}) and (Rs.6758 and 3658 ha^{-1} gross and net returns respectively).Control of weeds in pigeonpea through pre-emergence application of pendimethalin @1.25 kg a.i. ha^{-1} was found most effective method of weed control and recorded 27 % higher net returns than unweeded check (Anonymous, 2001).

Shinde *et al.* (2003) reported the economics of pigeonpea + pearlmillet intercropping system under integrated weed management indicated that the pendimethalin at 1.50 kg *a.i.* ha^{-1} + one hand weeding at 40 DAS recorded maximum net returns and B:C ratio as compared to other treatments.

Experiments were conducted at AICRP centres, HAU Hisar and ARS Warangal on pre-emergence application of pendimethalin @1.25 kg a.i. ha^{-1}, for control of weeds in pigeonpea. Hisar centre harvested 44.8 %more grain yield than unweeded check. On the basis of overall mean of 4 demonstrations conducted on weed management this treatment recorded 50.2 % higher grain yield with 24.8% higher net returns (Anonymous, 2004).

Front line demonstrations conducted at Warangal, Berhampur, Rahuri, Hisar and S.K. Nagar with pre-emergence application of pendimethalin @ 1.25 kg a.i. ha^{-1}. Warangal centre recorded 47.6 % higher grain yield than unweeded check with 50.3 % higher net returns, whereas Berhampur centre recorded 70 % higher grain yield with 69% higher net returns (Anonymous, 2005).

Anonymous (2006) reported that pre-emergence application of pendimethalin @1.25 kg a.i. ha^{-1} was found most effective method and registered 25.43 % higher grain yield with 46.1 % higher net returns than unweeded check.

Anonymous (2007) conducted experiment on control of weeds in pigeonpea through application of pendimethalin @ 1.25 kg a.i. ha^{-1} and recorded 19.5% higher grain yield with 19.03 % higher net returns than unweeded check.

Channappagoudar and Biradar (2007) reported that the economic analysis of different weed management practices showed that integrated weed management practices involving metalachlor @ 1.0 kg a.i. ha^{-1} as a pre-emergence application with cultural practices and hand weeding resulted in higher net returns of Rs. 34864 ha^{-1} with maximum B:C ratio of 2.76.

Weed management in pigeonpea through pre-emergence application of pendimethalin @ 1.25 kg a.i. ha^{-1} was found most effective method of weed control and registered 26 % of higher grain yield with 45.6 % net returns than unweeded (Anonymous, 2008).

Among herbicidal treatments, application of imazethapyr at 100g ha^{-1} recorded significantly higher net return (Rs. 14,237 ha^{-1}) and B:C ratio (1.68) followed by imazethapyr at 150 g ha^{-1} over weedy check and imazethapyr at 50 g ha^{-1} in soybean. (Meena *et al.* 2011).

Gupta *et al*. (2013). The highest value of B:C ratio to the tune of 1.08 was observed with imazethapyr @ 25 g ha^{-1} as POE followed by the value of 0.81 in treatment having pendimethalin as PE @ 1.0 kg ha^{-1}.

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CHAPTER-III

MATERIALS AND METHODS

Chapter-III

Materials and Methods

The details of the materials used and methods adopted during the course of investigation have been described in this chapter under the following headings:

3.1. Experimental site

The field experiment was conducted in O1 plot at Crop Research Farm of Bihar Agricultural College, Sabour (Bhagalpur) in *kharif* season of 2012-13. The location of Bhagalpur falls in the Middle Gangetic plain region of Agro-climatic Zone III A. It is situated between 25°50' N latitude and 87°19' E longitude at an altitude of 52.73 meters above mean sea-level.

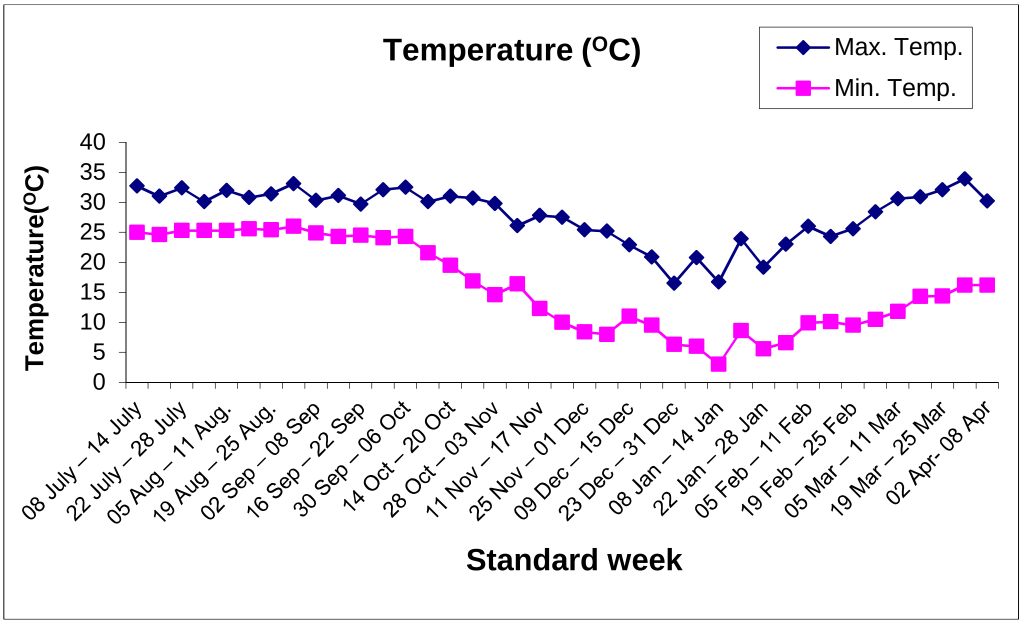
3.2.Climate and weather

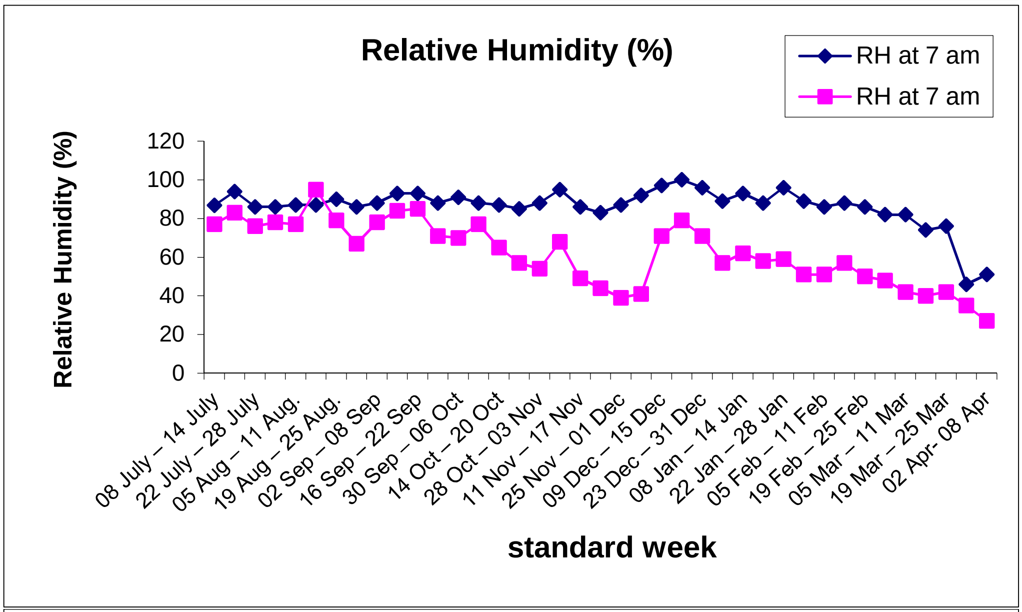
Bhagalpur is located in sub-tropical climate characterized with hot desiccating summer, cold winter and moderate rainfall. May is the hottest month with an average maximum temperature of 35 to 39˚C. January is the coldest month of the year with mean minimum temperature varies from 5 to 10˚C. The average annual rainfall is 1380 mm, precipitating mostly between mid June to mid October. The Bihar Agricultural University, Sabour lies in Agro-climatic zone III A (NARP, Zone of the state) comprising 6 districts *viz*; Bhagalpur, Banka, Munger, Jamui, Lakhisarai and Shekhpura of Bihar are having diverse type of topography and soil classes.

The metrological data recorded during the experimentation period (2012-13) based on observations made at the meteorological observatory of the Bihar Agricultural University, Sabour are depicted in Figure-3.1, and presented in Table-3.1. Weather condition during entire cropping season (July 2012 to March 2013) was normal. Maximum temperature being 38.1˚C was recorded in April at 2 PM. While the lowest temperature recorded in January was 3˚C at 7 AM. The relative humidity ranged from 46 to 100 per cent at 7 AM and 27 to 95 percent at 2 PM during crop period *i.e.* from July, 2012 to April, 2013, respectively.

Table-3.1: Weekly average weather data prevailed during crop period from 8th July 2012 to 8th April 2013.

Stan-dard week	Month/duration	Temperature (^0C)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	7am	2pm	
28	08 July – 14 July	32.7	25.0	86.8	77.0	61.8
29	15 July – 21 July	31.0	24.6	94.0	83.0	161.1
30	22 July – 28 July	32.4	25.3	86.0	76.0	38.0
31	29 July – 04 Aug.	30.1	25.3	86.0	78.0	24.7
32	05 Aug. – 11 Aug.	32.0	25.3	87.0	77.0	33.2
33	12 Aug. – 18 Aug.	30.8	25.6	87.0	95.0	19.2
34	19 Aug. – 25 Aug.	31.4	25.4	90.0	79.0	33.9
35	26 Aug. – 01 Sept.	33.1	26.0	86.0	67.0	33.8
36	02 Sept. – 08 Sept.	30.3	24.9	88.0	78.0	7.8
37	09 Sept. – 15 Sept.	31.1	24.3	93.0	84.0	60.4
38	16 Sept. – 22 Sept.	29.7	24.5	93.0	85.0	33.9
39	23 Sept. – 29 Sept.	32.1	24.1	88.0	71.0	0.0
40	30 Sept. – 06 Oct.	32.5	24.3	91.0	70.0	3.6
41	07 Oct. – 13 Oct.	30.1	21.6	88.0	77.0	37.4
42	14 Oct. – 20 Oct.	31.0	19.5	87.0	65.0	0.0
43	21 Oct. – 27 Oct.	30.7	16.9	85.0	57.0	0.0
44	28 Oct. – 03 Nov.	29.8	14.6	88.0	54.0	0.0
45	04 Nov. – 10 Nov.	26.1	16.4	95.0	68.0	14.8
46	11 Nov. – 17 Nov.	27.8	12.3	86.0	49.0	0.0
47	18 Nov. – 24 Nov.	27.5	10.0	83.0	44.0	0.0
48	25 Nov. – 01 Dec.	25.4	08.4	87.0	39.0	0.0
49	02 Dec. – 08 Dec.	25.2	08.0	92.0	41.0	0.0
50	09 Dec. – 15 Dec.	22.9	11.0	97.0	71.0	0.0
51	16 Dec. – 22 Dec.	20.9	09.5	100.0	79.0	0.0
52	23 Dec. – 31 Dec.	16.5	06.3	96	71	0.0
01	01 Jan. – 07 Jan.	20.8	06.0	89	57	0.0
02	08 Jan. – 14 Jan.	16.7	03.0	93	62	0.0
03	15 Jan. – 21 Jan.	23.9	08.6	88	58	0.0
04	22 Jan. – 28 Jan.	19.2	05.6	96	59	0.0
05	29 Jan. – 04 Feb.	23.0	06.6	89	51	0.0
06	05 Feb. – 11 Feb.	26.0	09.9	86	51	0.0
07	12 Feb. – 18 Feb.	24.3	10.1	88	57	14.6
08	19 Feb. – 25 Feb.	25.6	09.5	86	50	0.0
09	26 Feb. – 04 Mar.	28.4	10.5	82	48	0.0
10	05 Mar. – 11 Mar.	30.6	11.8	82	42	0.0
11	12 Mar. – 18 Mar.	30.9	14.3	74	40	0.0
12	19 Mar – 25 Mar.	32.1	14.4	76	42	0.0
14	26 Mar – 01 Apr.	33.9	16.2	46	35	0.0
15	02 Apr.- 08 Apr.	30.2	16.2	51	27	0.0


Temperature (ºC)
Max. Temp.
Min. Temp.
Temperature(ºC)
0
5
10
15
20
25
30
35
40
08 July – 14 July
22 July – 28 July
05 Aug – 11 Aug.
19 Aug – 25 Aug.
02 Sep – 08 Sep
16 Sep – 22 Sep
30 Sep – 06 Oct
14 Oct – 20 Oct
28 Oct – 03 Nov
11 Nov – 17 Nov
25 Nov – 01 Dec
09 Dec – 15 Dec
23 Dec – 31 Dec
08 Jan – 14 Jan
22 Jan – 28 Jan
05 Feb – 11 Feb
19 Feb – 25 Feb
05 Mar – 11 Mar
19 Mar – 25 Mar
02 Apr- 08 Apr
Standard week


Relative Humidity (%)
RH at 7 am
RH at 7 am
Relative Humidity (%)
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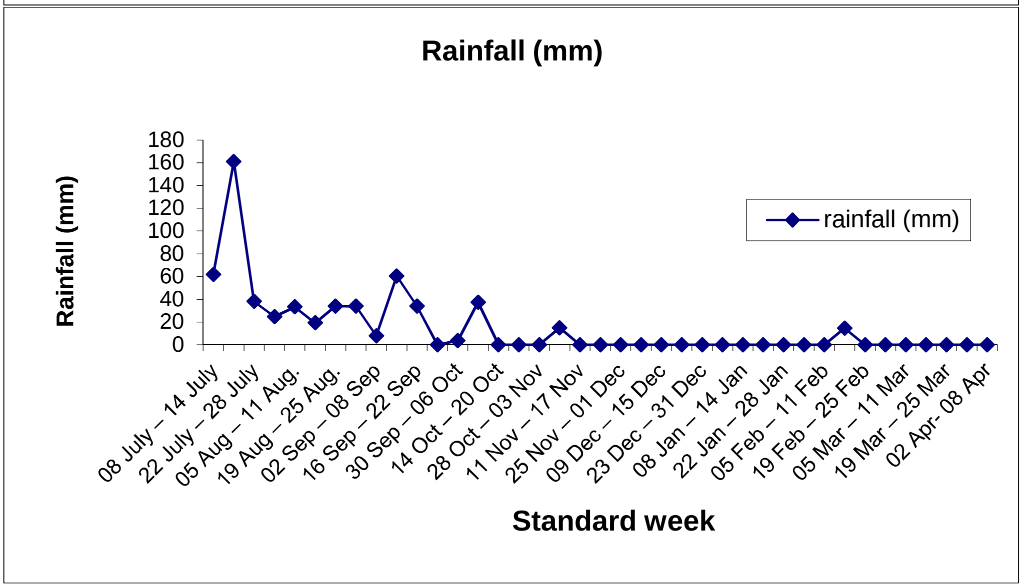
20
40
60
80
100
120
08 July – 14 July
22 July – 28 July
05 Aug – 11 Aug.
19 Aug – 25 Aug.
02 Sep – 08 Sep
16 Sep – 22 Sep
30 Sep – 06 Oct
14 Oct – 20 Oct
28 Oct – 03 Nov
11 Nov – 17 Nov
25 Nov – 01 Dec
09 Dec – 15 Dec
23 Dec – 31 Dec
08 Jan – 14 Jan
22 Jan – 28 Jan
05 Feb – 11 Feb
19 Feb – 25 Feb
05 Mar – 11 Mar
19 Mar – 25 Mar
02 Apr- 08 Apr
standard week


Rainfall (mm)
rainfall (mm)
Rainfall (mm)
0
20
40
60
80
100
120
140
160
180
08 July – 14 July
22 July – 28 July
05 Aug – 11 Aug.
19 Aug – 25 Aug.
02 Sep – 08 Sep
16 Sep – 22 Sep
30 Sep – 06 Oct
14 Oct – 20 Oct
28 Oct – 03 Nov
11 Nov – 17 Nov
25 Nov – 01 Dec
09 Dec – 15 Dec
23 Dec – 31 Dec
08 Jan – 14 Jan
22 Jan – 28 Jan
05 Feb – 11 Feb
19 Feb – 25 Feb
05 Mar – 11 Mar
19 Mar – 25 Mar
02 Apr- 08 Apr
Standard week

3.3. Soil characteristics

A composite soil sample to a depth of 0-15 cm was collected from the experimental field prior to sowing of the crop. The sample was analyzed for its chemical attributes and the values obtained are given in Table-3.2. The experimental soil was sandy loam in texture; low in organic carbon content, low in available nitrogen and medium in available P and K.

Table-3.2: Chemical properties of the experimental soil

S.No	Particulars	Value	Method employed
1	pH (1: 2.5 soil water suspension)	7.58	Glass electrode pH meter (Jackson, 1973)
2	Electrical conductivity	0.16 dSm^{-1}	Electrical conductivity meter (Jackson, 1973)
3	Organic carbon (%)	0.40	Modified Walkley and Black method
4	Available nitrogen (kg/ha)	182 kg ha^{-1}	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
5	Available P_2O_5 (kg/ha)	16.4 kg ha^{-1}	Olsen's method (Olsen *et al.* Jackson, 1973)
6.	Available K_2O (kg/ha)	186.3 kg ha^{-1}	1 N neutral ammonium acetate method (Jackson, 1973)

3.4. Cropping history of the field

The crops grown in the experimental field during previous seasons have been presented in Table-3.3. The experimental crop was preceded by wheat in *rabi* season.

Table-3.3: Cropping history of the experimental field.

Year	Crops taken	
	Kharif	**Rabi**
2008-09	Mungbean	Linseed
2009-10	Fallow	Mustard
2010-11	Pigeonpea	-
2011-12	Fallow	Linseed
2012-13	Pigeonpea*	

3.5. Experimental details

3.5.1. Treatment details

Sl. No.	Treatments	Herbicide	Doses (g a.i.ha^{-1})	Time of application
1.	T_1	Imazethapyr	20	15 DAS
2.	T_2	Imazethapyr	40	15 DAS
3.	T_3	Imazethapyr	60	15 DAS
4.	T_4	Imazethapyr	20	30 DAS
5.	T_5	Imazethapyr	40	30 DAS
6.	T_6	Imazethapyr	60	30 DAS
7.	T_7	Pendimethalin	750	PE
8.	T_8	Pendimethalin fb Quizalofop-ethyl	750 + 50	PE/POE
9.	T_9	Pigeonpea + Blackgram intercropping	-	-
10.	T_{10}	Metribuzin	250	PE
11.	T_{11}	Weedy check		
12.	T_{12}	Weed free		

Note - **PE - Pre-emergence; POE - Post-emergence fb- followed by**

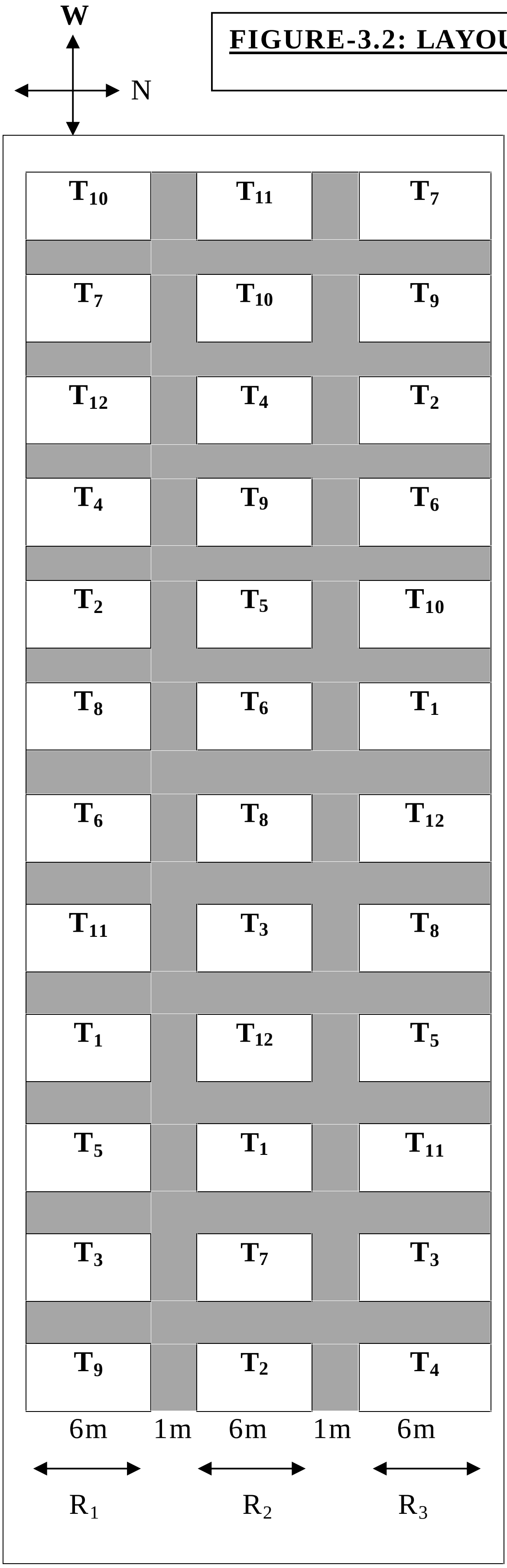
3.5.2. Experimental design and layout

The seeds of pigeonpea variety Pusa-9 were sown at a row to row distance of 67.5 cm and a plant to plant spacing of 30 cm in a Randomised Block Design (RBD) with three replications. The layout is represented by a Figure-3.2 given below.

3.5.3. Variety used

A common variety of Bihar, Pusa-9 was used in experimentation; this variety has been introduced in Bihar during 1995. It has been characterized by indeterminate growth habit and brown seeded having tolerant capacity against sterility mosaic disease and Alternaria blight, non spreading branching habit and easy intercultural operation. It is more preferred by farmers of Bihar in comparison to Bahar. Pusa-9 is more suitable for flood prone areas of Ganagetic basin and widely grown in agro-climatic zone IIIA of Bihar as a *kharif* crop (250-260 days) and September sown crop (200-220 days). Its yield potential is about 20-26 q/ha.

FIGURE-3.2: LAYOUT OF EXPERIMENTAL FIELD



Treatment Details

T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS

T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS

T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS

T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS

T_5-Imazethapyr @ 40g a.i./ha at 30 DAS

T_6-Imazethapyr @ 60g a.i./ha at 30 DAS

T_7 -Pendimethalin @ 750g. a.i./h as PE

T_8-Pendimethalin @ 750g. a.i./ha as PE+ Quizalofop-ethyl @ 50g. a.i./ha as POE

T_9 -Pigeonpea+ blackgram intercropping

T_{10} -Metribuzin @ 250 g. a.i./ha as PE

T_{11} -Weedy check

T_{12} -Weed free

Design: Randomized Block Design (RBD)

Replication: 3

Gross Plot size : 6m x 3.4 m

Net Plot Size : 5.4m x 2.02 m

Spacing: 67.5 cm x 30 cm

Pigeonpea variety: Pusa-9

Blackgram variety: T-9

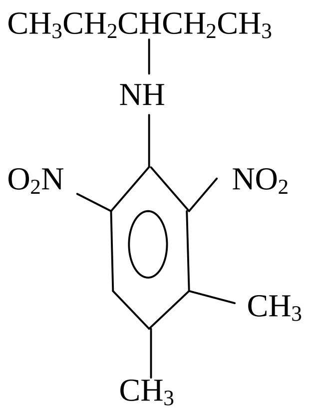
PATH

3.6. Herbicide description

3.6.1. Pendimethalin

Pendimethalin is mostly used as a pre-emergent herbicide for low land rice. Though the main use of pendimethalin is for rice, it has proved useful for other crops as well wheat, maize, sorghum, pearlmillet, chickpea, peas, groundnut, soybean, sunflower, mustard, linseed, jute, cotton and vegetables. Like other dinitroaniline herbicides, pendimethalin binds to tubulin and inhibits the production of microtubules. This disrupts cell division and cell wall formation. Pendimethalin is absorbed by roots and coleoptiles.

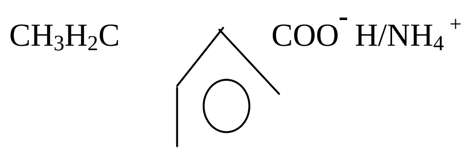
Pendimethalin is strongly absorbed on soil clay and organic matter and is not subject to leaching. In contrast to the case with most other dinitroaniline herbicides, soil microorganisms do not appear to play significant role in degradation of pendimethalin.

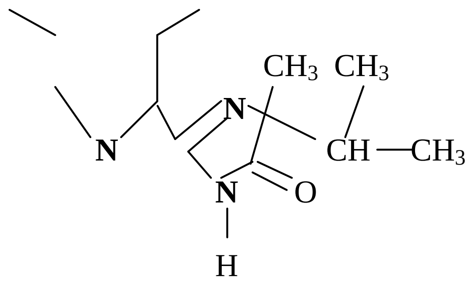


Pendimethalin/penoxalin [N-(1-ethylpropyl)-3,4-dimethyl1-2,6-dinitrobenzenamine]

3.6.2. Imazethapyr

Imazethapyr is a systemic pre-plant incorporated, pre-emergence, or post-emergence applied herbicide. Imazethapyr is mainly used in soybeans; however, it is also used in crops like corn, oil seed rape and vegetables for control of many major annual and perennial grass and broad-leaved weeds. It is absorbed by the roots and foliage, with translocation in the xylem and phloem, and accumulation in the meristematic regions and inhibits branched chain amino acid synthesis (ALS or AHAS.). Hence reduces levels of valine, leucine and isoleucine, leading to disruption of protein and DNA synthesis. Selectivity in soybean and peanuts is attributed to rapid detoxification via hydroxylation and glycosylation.



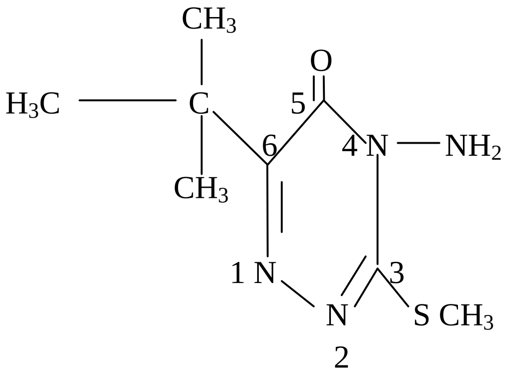


Chemical Name-

[2-{4,5-dihydro-4-methyl1-4-(1-methylethyl)-5-oxo-1-H-imidazo-2-yl}-5-ethyl-3-pyridine carboxylic acid] [Pursuit 30 & 10 EC; Hammer, Pivot]

3.6.3. Metribuzin

Metribuzin is a selective triazinone herbicide that inhibits photosynthesis. It is absorbed by the roots and leaves with acropetal translocation in the xylem. It is used for the control of annual grasses and numerous broadleaf weeds in field and vegetable crops, in turfgrass, and on fallow lands. Metribuzin residues were not found in the soil, grains, and straw following application at 210 and 420 g/ha in wheat crop (Dubey *et al.*, 1998)



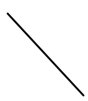
Metribuzin

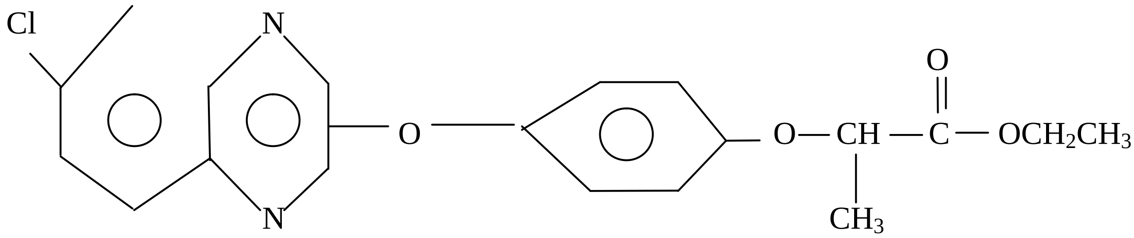
[4-amino-6-(1,1-dimrthylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one]

[Sencor, Lexone, Leguram]

3.6.4. Quizalofop-ethyl

Quizalofop-ethyl 5% EC controls grassy weeds like *Echinochloa sp, Avena sp, Phalaris sp, Cynodon dactylon, Saccharum sp, Sorghum halepense* but control is dose-dependent. For (annual) grasses, 40-50 g ha^{-1} at 3-5 leaf stage while for perennial ones, 65-75 g ha^{-1} at 10-15 cm height of weeds, Quizalofop should be applied. Quizalofop has translocation capacity in plants and is applied at 10-35 DAS of crops like soybean, cotton, brinjal, black gram, cauliflower, cucurbits, potato, onion, jute and sesamum. Weeds turn yellowish within 4-7 days and are killed in 10-20 days. It cannot be used in rice, wheat, maize, sorghum, barley and millets and, therefore, not in soybean intercropped with maize or sorghum.





Chemical name-[Ethyl-2-{4-{(6-Chloro-2-quinoxalinyl) oxy}phenoxy}propionate]

3.7. Cultural operations

The details of pre and post planting operation carried out in experimental field are given in Table - 3.4.

Table- 3.4: Details of pre and post sowing operations in pigeonpea

Particulars	Date	Implement/methods used
Ploughing	05-07-2012	Tractor drawn disc plough
Harrowing	06-07-2012	Tractor drawn harrow
Levelling	07-07-2012	Tractor drawn leveller
Layout	09-07-2012	Manually
Sowing	10-07-2012	Manually
Fertilizer applications		
A) Basal dressing	10-07-2012	Manually
Herbicide application	As per technical progamme	Manually
Hand weeding	25-07-2012	Manually
(Weed free treatment)	10-08-2012	Manually
	22-08-2012	Manually
	10-09-2012	Manually
Irrigation	Nil	
Harvesting	16-04-2013	Manually by sickle
Threshing	25-04-2013	Manually

3.7.1. Seed bed preparation and sowing

The field was prepared by tractor drawn implement with one deep ploughing by soil turning plough and two cross harrowing by disc harrow followed by leveling. In order to create ideal condition for good germination, pre-sowing irrigation was given 10 days before sowing. The seed was treated with bavistin @ 2.5g kg^{-1}. The crop was sown by seed drill on raised bed bund at 67 cm distance made by tractor operated bund maker cum seed drill using 20 kg seed rate per hectare.

3.7.2. Fertilizer application

The crop was fertilized uniformly with the 18 kg N, 46 kg P_2O_5 and 20 K_2O ha^{-1} through DAP and murate of potash, respectively. Whole amount of fertilizers were applied as basal.

3.7.3. Gap filling and thinning

In places where seeds failed to germinate, gap filling was done at 12 days after sowing. When more than one seedling was present in a hill, they were thinned out to maintain one seedling for proper spacing at 20 days after sowing.

3.7.4. Weed free plot maintenance and herbicide application

The weed free plot maintained in such a way that as and when the weed emerge weeding was done. Generally weeding was done about 15 day's intervals. The PE herbicides were applied on next day after sowing in well moist soil, whereas, the POE herbicides were applied on weed foliage by using knapsack sprayer using of 400 litre water ha^{-1} at 15 DAS & 30 DAS as per technical programme.

3.7.5. Plant protection

One spray of profenophos 50 EC @ 1ml $litre^{-1}$ water was used at pod filling stage to control the pod borer infestation.

3.7.6. Harvesting and threshing

The border of experimental plots was marked, harvested and removed from the plot as to distinguish the net plot. The produce of the individual net plot was threshed separately.

3.8. Collection of experimental data

Five plants were randomly selected from the middle rows in the net plot and were tagged for recording observation on plant height, number of branches $plant^{-1}$ (primary & secondary) and yield components. Three plants were selected randomly at each time from the border rows for taking observations on dry matter production.

3.8.1. Growth and development

3.8.1.1. Plant height (cm)

Plant height was measured from the ground level to the tip of growing point and the average of five plants was expressed as plant height in centimetre at 30, 60, 90 and 120 DAS and at harvest.

3.8.1.2. Number of branches $plant^{-1}$

The number of primary branches emerging directly from main stem was counted and the number of branches emerging from each primary branch was counted and the average of the five plants was expressed as number of primary and secondary branches plant^{-1}, respectively.

3.8.1.3. Dry matter production and its distribution (g plant^{-1})

Plant samples for dry matter studies were collected at 60, 90 and 120 days after sowing and at harvest. At each sampling three plants were uprooted at random in each treatment. These samples were first air dried and then oven dried at 65-70^{0}C till a constant weight was obtained. Oven dry weight was recorded and the mean dry matter of whole plant sample was calculated by diving the total dry matter of plant (g plant^{-1}) from three. The total dry matter production plant^{-1} was obtained with the summation of dry weight of all the plant parts and was expressed as g plant^{-1}.

3.8.2. Observation on yield attributes and yield

The plants selected for growth studies were utilized for recording the observations on the following yield components.

3.8.2.1. Number of pods per plant

Fully developed pods were separated from five tagged sample plants in net plot and were counted and the average was taken as the number of pods per plant.

3.8.2.2. Number of seeds per pod

The seeds from 10 representative pods were separated by hand threshing counted and the mean number of seed per pod was calculated by dividing the number of seeds by number of pods.

3.8.2.3. Seed yield per plant (g)

The seeds from the pods of five plants were separated by hand threshing and their mean weight was taken as seed weight per plant and expressed in grams.

3.8.2.4. 100 seed weight (g)

Seed samples from the produce of each treatment were taken at random and 100 seeds from these samples were counted and weighed and expressed in grams.

3.8.2.5. Plant stand at harvest (Number ha^{-1})

Total number of plants from net plot size was counted and it was converted into hectare basis.

3.8.2.6. Seed yield (kg ha^{-1})

Pods from each net plot according to the treatment were threshed, cleaned and the seed weight was recorded and yield per hectare was computed and expressed in kg ha^{-1}.

3.8.2.7. Stalk yield (kg ha^{-1})

Plants from the net plot after threshing were dried and their weight was recorded. From this stalk yield per hectare was calculated and expressed in kg ha^{-1}.

3.8.2.8. Biomass yield (kg ha^{-1})

Above ground plant parts harvested from net plot area including the grain and stover were carefully bundled, tagged and taken to the threshing floor separately. The individual bundle was weighed after complete drying in the sun before threshing and weighed and the biological yield per plot was then converted in to kg ha^{-1}.

3.8.2.9. Harvest index (%)

Harvest index was estimated as per the formula suggested by Donald (1962).

$$HI = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.9. Weed observations

3.9.1. Weed density (Number m^{-2})

The number of weeds were counted from an area of 0.25 m^2 (quadrant size) randomly selected and converted to per square meter (m^{-2}) basis. Later the original values were transformed to square root values ($\sqrt{X+0.5}$) and subjected to statistical analysis.

3.9.2. Weed dry weight (g m^{-2})

The weeds present within the quadrant area were uprooted, and transferred to brown covers. After air drying, the weeds were dried in the hot air oven at 65-70˚C till the constant weights obtained and the original data were subjected to square root transformation ($\sqrt{X + 0.5}$) and analysed statistically.

3.9.3. Weed control efficiency (%)

Weed control efficiency was calculated on dry weight basis by adopting the formula given by Mani *et al.* (1976).

$$WCE = \frac{\text{Dry matter of weeds in weedy check} - \text{Dry matter of weeds in treated plot}}{\text{Dry matter of weeds in weedy check}} \times 100$$

3.9.4. Weed Index/ Weed competition index

Weed index is reduction in yield due to weed infestation. It is calculated by using the formula given by Gill and Kumar (1969).

$$WI = \frac{X - Y}{X} \times 100$$

Where,

X- Yield of weed free plot

Y-Yield of treated plot

3.10. Chemical analysis of soil, plant and weed samples

3.10.1. Soil nutrient analysis

Composite soil samples were drawn from 0 to 15 cm depth from the experimental site before sowing and from each plot after harvest of crop. The soil samples were analysed for available nitrogen (Subbiah and Asija, 1956), phosphorus (Olsen *et al.*, 1954) and potassium (Jackson, 1973) by using standard methods.

3.10.2. Nutrient uptake by crops and weeds

Pigeonpea plant and weed samples collected from each plot at the time of harvest and at 60 DAS respectively were dried and then ground separately in a willey mill to pass through a 40 mesh sieve. The ground material was collected in butter paper covers and later used for chemical analysis. Total nitrogen content in the seed and stalk samples of plant and whole plant sample of weeds, was estimated through digestion followed by distillation by Kel-Plus unit using the method of (Nelson and Sommers, 1980) and expressed in per cent. For analysis of phosphorus and potassium, all plant samples were digested with tri-acid mixture (HNO_3:$HCLO_4$:H_2SO_4 at 10:4:1).

Phosphorus content in samples was determined by vanadomolybdophosphoric yellow color method by using spectro photometer at 470 nm (Piper, 1966). Potassium content in plant samples was determined by flame photometry (Piper, 1966) and was expressed in percentage.

Nitrogen, phosphorus and potassium uptake for crops and weeds was calculated for each treatment using the formula :

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

3.11. Economics

3.11.1. Total cost of cultivation

The prices of inputs prevailed during experimentation were considered for working out the cost of cultivation.

3.11.2. Gross return

Gross returns (Rs./ha) were calculated based on the pigeonpea yield (grain and straw) and the market price of the produce at the time of marketing. The labour wages, cost of inputs and outputs are furnished in appendix-I.

3.11.3 Net returns

The net return per hectare was calculated by deducting the cost of cultivation per hectare from gross return per hectare.

3.11.4 Benefit cost ratio

The Benefit cost ratio was worked out as follows.

$$\text{Benefit cost ratio} = \frac{\text{Net return (Rs. ha}^{-1}\text{)}}{\text{Total Cost of Cultivation (Rs. ha}^{-1}\text{)}}$$

3.12. Statistical analysis and interpretation of data

3.12.1 Statistical analysis

The data were subjected to analysis of variance techniques (ANOVA) for randomized block design as prescribed by Cochran and Cox (1963**).** Critical difference of different treatments at 5% level of probability were calculated wherever F test will be significant.

3.12.2. Standard error of mean

Standard error of mean was calculated by using the formula:

$$Standard\ \ error\ of\ \ \ mean = \frac{\sqrt{EMSS}}{r}$$

Where,

SEm ± = Standard error of mean

EMSS= Error mean sum of square

r = Number of replications on which the observation is based

3.12.3. Critical difference

The critical difference at 5 per cent level of probability will be worked out to compare treatments means wherever 'F' test was significant.

$$Critical\ difference = \text{S Em} \pm \times \sqrt{2} \times t \text{ (at error degree of freedom)}$$

3.12.4. Coefficient of Variation (%)

Coefficient of variation, the standard deviation expressed as percentage of mean, will be computed as follows:

$$C.V.(\%) = \frac{\sqrt{EMSS}}{Mean} \text{ X } 100$$

Where,

C.V. (%) = Coefficient of variation

EMSS= Error mean sum of square

Mean = Grand mean

Analysis of Variance (ANOVA)

Source of variation	***Degree of Freedom***
Replication	2
Treatments	11
Error	22
Total	35

3.12.5. Transformation of data

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

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CHAPTER-IV

EXPERIMENTAL FINDINGS

Chapter-IV

Experimental Findings

The results obtained during the course of investigation are presented in this chapter. Illustrations have also been incorporated for better and easy understanding about important parameters.

4.1. Studies on crop

4.1.1. Plant height (cm)

The data presented in Table-4.1 indicate that the height of pigeonpea plants increased with advancement in crop age and reached maximum at maturity, irrespective of treatments.

Crop grown under weed free condition had tallest plants at 60, 90, 120 days and at harvest. Among the weed control treatments, T_{10} (Metribuzin @ 250 g a.i. ha^{-1} as PE) attained lowest plant height of 19.6 cm at 30 DAS. Whereas, T_9 (pigeonpea + urdbean intercropping) recorded significantly lower plant height at 90 DAS, 120 DAS and at harvest. Among the herbicidal treatments, application of imazethapyr @ 40 g a.i. ha^{-1} at 15 days after sowing had the tallest plants at 60, 90, 120 DAS and at harvest. At harvest, among the herbicidal options plant height did not differ significantly. However, maximum (210.2 cm and 261.7 cm) and minimum (171.1 cm and 216.7) plant heights were recorded in weed free and weedy check, respectively at 120 DAS and at harvest.

4.1.2. Dry matter accumulation (g $plant^{-1}$)

Periodic dry matter accumulation per plant (g $plant^{-1}$) owing to different weed management practices was significant at various stages of crop growth.

Dry matter accumulation per plant exhibited an increasing trend with advancement in crop growth irrespective of the treatment (Table- 4.2). The rate of dry matter accumulation was slow during initial stage. Practicing any of the weed control measure resulted in significant increase in dry matter accumulation per plant in comparison with weedy check. The highest values were recorded under weed free

Table-4.1: Plant height of pigeonpea as influenced by weed management practices at different stages of crop growth

Treatments	Plant height (cm)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	26.4	77.7	106.7	195.6	254.7
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	24.0	90.3	130.3	209.5	259.0
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	23.2	88.6	128.4	204.6	257.8
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	29.2	87.8	117.4	200.1	257.2
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	26.7	83.8	106.3	189.5	248.1
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	27.7	85.5	112.7	184.6	242.5
T_7 -Pendimethalin @ 750g. a.i./ha as PE	21.3	73.1	100.9	177.5	236.2
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	21.1	77.4	98.0	186.0	251.0
T_9 -Pigeonpea+ blackgram intercropping	22.6	78.4	91.0	171.3	233.7
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	19.6	78.2	93.5	183.8	238.8
T_{11} -Weedy check	23.6	71.1	102.7	171.1	216.7
T_{12} -Weed free	27.7	94.3	136.3	210.2	261.7
SEm±	0.71	3.10	4.43	6.34	8.24
CD at 5%	2.10	9.09	12.99	18.59	24.18

Table-4.2: Dry matter accumulation per plant of pigeonpea as influenced by weed management practices at different stages of crop growth

Treatments	Dry matter accumulation (g/plant)			
	60 DAS	90 DAS	120 DAS	At harvest
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	4.95	23.39	83.78	154.06
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	6.77	32.90	124.57	218.93
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	6.25	32.05	115.60	206.50
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	5.55	22.10	98.50	170.07
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	5.69	29.80	101.77	185.90
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	6.48	28.30	111.63	194.33
T_7 -Pendimethalin @ 750g. a.i./ha as PE	5.29	22.33	98.80	174.73
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	5.34	22.55	103.03	178.10
T_9 -Pigeonpea+ blackgram intercropping	6.06	21.87	86.63	146.73
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	6.23	23.92	89.77	150.00
T_{11} -Weedy check	4.73	19.80	80.34	124.83
T_{12} -Weed free	8.95	33.99	148.44	220.67
SEm±	0.42	1.93	4.25	8.00
CD at 5%	1.24	5.66	12.47	23.47

conditions and none of the herbicidal treatment could prove as effective as weed free condition, at all growth stages.

Among the various weed control treatments, significantly higher dry matter accumulation per plant was recorded in treatment T_2 (6.77 g) than T_1 (4.95 g) and T_{11} (4.73 g) at 60 DAS; while it was statistically at par with treatments T_3 (6.25 g), T_4 (5.55 g), T_5 (5.69 g), T_6 (6.48 g), T_9 (6.06 g) and T_{10} (6.23 g). At 90 DAS, the maximum dry matter accumulation was recorded under treatment T_2 (32.90 g) which was significantly superior over rest of the treatments except T_3 (32.05 g), T_5 (29.80 g) and T_6 (28.30 g) among the herbicidal options. At 120 DAS, the maximum dry matter accumulation per plant was obtained under treatment T_2 (124.5 g) which was statistically at par with T_3 (115.6 g), T_6 (111.6 g) and significantly higher than rest of the treatments except weed free treatment. Similarly, at harvest, among different herbicidal treatments, maximum increase in dry matter per plant was observed with T_2 (218.9 g) which was in statistical parity with T_3 (206.5 g).

However, among all treatments; T_{12} (weed free) recorded maximum dry matter accumulation at all growth stages.

4.1.3. No. of primary & secondary branches

The data pertaining to the number of primary and secondary branches per plant at harvest as influenced by different weed management practices are presented in Table-4.3.

4.1.3.1. No. of primary branches plant^{-1}

At harvest, the maximum number of primary branches (14.6) was obtained in T_2 which was statistically at par with T_3 (14.5), T_6 (14.0) and T_5 (13.9) and significantly higher than rest of the treatments. However, significantly higher number of primary branches (14.8) plant^{-1} was recorded in weed free treatment than T_4 and T_{11} and at par with rest of the treatments. The number of primary branches in each treatment was significantly higher than weedy check (9.8).

4.1.3.2. No. of secondary branches plant^{-1}

Number of secondary branches per plant at harvest differed significantly due to different weed management practices.

Table-4.3: No. of primary and secondary branches at harvest as influenced by different weed management practices

Treatments	Number of primary branches plant^{-1} at harvest	Number of secondary branches plant^{-1} at harvest
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	12.6	23.0
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	14.6	27.1
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	14.5	26.0
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	12.0	21.0
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	13.9	24.4
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	14.0	25.6
T_7 -Pendimethalin @ 750g. a.i./ha as PE	12.6	20.2
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	12.4	23.1
T_9 -Pigeonpea+ blackgram intercropping	13.0	21.4
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	14.2	22.4
T_{11} -Weedy check	9.8	16.9
T_{12} -Weed free	14.8	27.8
SEm±	0.89	1.89
CD at 5%	2.63	5.56

DAS = Days after sowing

Among the various treatments, higher number (27.1) of secondary branches was recorded with the treatment T_2 (imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS) which was significantly higher than T_4 (21.0), T_7 (20.2), T_9 (21.4) and statistically at par with T_1 (23.0), T_3 (26.0), T_5 (24.4), T_6 (25.6), T_8 (23.1) and T_{10} (22.4). Maximum number of secondary branches (27.8) was noticed in weed free treatments. All the weed control treatments recorded significantly higher number of secondary branches per plant at harvest in comparison with weedy check treatment having lowest (16.9) secondary branches per plant .

4.2. Effect of weed management practices on yield attributes of pigeonpea.

Crop yield is directly related with yield attributing characters like number of pods per plant, seeds per pod, 100 seed weight etc. The data pertaining to yield attributes is presented in Table-4.4.

4.2.1. Plant stand at harvest (No. ha^{-1})

Plant stand in different treatments did not differ significantly as influenced by different weed management practices. However, maximum (45227) and minimum number (41865) of plant stand at harvest ha^{-1} was recorded in weed free and weedy check treatment, respectively.

4.2.2. No. of pods $plant^{-1}$

The number of pods $plant^{-1}$ differed significantly among different treatments. Among the twelve treatments, significantly higher number (165.3) of pods $plant^{-1}$ was recorded with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) which was statistically at par with T_3 (162.8), T_5 (158.0) and T_6 (163.0); while it was significantly higher than rest of treatments except weed free treatment. All the treatments excluding the treatment of metribuzin @ 250 g a.i. ha^{-1} as PE recorded significantly higher number of pods $plant^{-1}$ than weedy check (127.0). However, maximum number of pods $plant^{-1}$ (170.5) was recorded in weed free treatment.

4.2.3. Number of seeds pod^{-1}

The number of seeds pod^{-1} differed significantly due to different weed management practices.

Table-4.4: Yield attributes of pigeonpea as influenced by weed management practices

Treatments	Plant stand at harvest (No./ha)	Number of pods plant^{-1}	Number of seeds pod^{-1}	Grain yield plant^{-1}(g)	100 Seed weight (g)
T_1-Imazethapyr @ 20g a.i./ha at 15 DAS	44310	141.6	3.2	50.5	12.43
T_2-Imazethapyr @ 40g a.i./ha at 15 DAS	44612	165.3	3.6	59.2	12.67
T_3- Imazethapyr @ 60g a.i./ha at 15 DAS	44614	162.8	3.5	58.2	12.60
T_4- Imazethapyr @ 20g a.i./ha at 30 DAS	44616	143.5	3.3	46.5	12.07
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	44921	158.0	3.5	55.5	12.03
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	43363	163.0	3.5	46.4	11.93
T_7 -Pendimethalin @ 750g. a.i./h as PE	44310	153.3	3.5	46.4	11.90
T_8-Pendimethalin @ 750g. a.i./ha as PE+ Quizalofop-ethyl @ 50g. a.i./ha as POE	43699	147.0	3.5	50.5	11.97
T_9 -Pigeonpea+ blackgram intercropping	41560	146.3	3.5	49.2	12.33
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	38809	136.0	3.4	49.8	12.03
T_{11} -Weedy check	41865	127.0	3.1	37.4	12.13
T_{12} -Weed free	45227	170.5	3.7	63.2	12.73
SEm±	1403	4.07	0.08	1.60	0.30
CD at 5%	NS	11.95	0.23	4.69	NS

DAS = Days after sowing

Among the different herbicidal treatments, application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (3.6) recorded significantly higher number of seeds which was statistically at par with T_3 (3.5), T_5 (3.5), T_6 (3.5), T_7 (3.5), T_8 (3.5) and T_9 (3.5); while significantly higher than T_1 (3.2), T_4 (3.3) and T_{11} (3.1). However, maximum (3.7) and minimum (3.1) number of seeds pod^{-1} was recorded in weed free and weedy check, respectively.

4.2.4. Grain yield $plant^{-1}$

Significantly higher grain yield (59.2 g $plant^{-1}$) was recorded with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) which was found at par with the treatments T_3, imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (58.2 g $plant^{-1}$). Significantly lower grain yield $plant^{-1}$ was recorded in T_1 and T_8 (50.5 g $plant^{-1}$), T_4 (46.5), T_6 & T_7 (46.4), T_9 (49.2) and T_{10} (49.8). However, maximum (63.2 g $plant^{-1}$) and minimum (37.4 g $plant^{-1}$) grain yield per plant was recorded with weed free (T_{12}) and weedy check (T_{11}) treatments, respectively.

4.2.5. 100 seed weight

The hundred seed weight did not differ significantly due to different weed management practices. However, the maximum (12.73 g) hundred seed weight was recorded with weed free treatment followed by T_2 (12.67 g) and T_3 (12.60).

4.3. Effect of weed management practices on yield parameters

The data pertaining to yield parameters as influenced by different weed management practices are presented in Table-4.5.

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

Seed yield (kg ha^{-1}) differed significantly by adopting different weed management practices. The treatment T_2 (imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS) recorded significantly higher seed yield of 2526 kg ha^{-1} than T_1 (2129.0 kg ha^{-1}), T_4 (1982.0 kg ha^{-1}), T_7 (2065.0 kg ha^{-1}), T_8 (2210.0 kg ha^{-1}), T_9 (2124.0 kg ha^{-1}) and T_{10} (2130.0 kg ha^{-1}) and was statistically at par with T_3 (2492.6 kg ha^{-1}), T_5 (2383.0 kg ha^{-1}) & T_6 (2425.0 kg ha^{-1}). Maximum and minimum seed yield of 2725.0 kg ha^{-1} and 1623.3 kg ha^{-1} was found in weed free and weedy check treatment, respectively. Each

Table-4.5: Yield and harvest index of pigeonpea as influenced by weed management practices.

Treatments	Seed yield (kg/ha)	Stalk yield (kg/ha)	Biomass yield (kg/ha)	Harvest index (%)
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	2129.0	7338.6	9467.67	22.5
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	2526.0	8589.3	11115.3	22.7
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	2492.6	8457.0	10949.6	22.7
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	1982.0	6735.0	8717.0	22.7
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	2383.0	8100.3	10483.3	22.7
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	2425.0	8245.0	10670.0	22.7
T_7 -Pendimethalin @ 750g. a.i./ha as PE	2065.0	7018.0	9083.0	22.7
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	2210.0	7514.0	9724.0	22.7
T_9 -Pigeonpea+ blackgram intercropping	2124.0	7219.00	9343.0	22.7
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	2130.0	7274.6	9404.6	22.6
T_{11} -Weedy check	1623.3	5850.3	7473.6	21.7
T_{12} -Weed free	2725.0	9264.0	11989.0	22.7
SEm±	94.9	297.9	382.1	0.42
CD at 5%	278.4	873.7	1120.7	NS

DAS = Days after sowing

treatment recorded significantly higher seed yield (kg ha^{-1}) in comparison with weedy check.

4.3.2. Stalk yield (kg ha^{-1})

. The treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher stalk yield of 8589.3 kg ha^{-1} which was significantly higher than T_1 (7338.6 kg ha^{-1}), T_4 (6735.0 kg ha^{-1}), T_7 (7018.0 kg ha^{-1}), T_8 (7514.0 kg ha^{-1}), T_9 (7219.0 kg ha^{-1}) and T_{10} (7274.6 kg ha^{-1}) and statistically at par with T_3 (8457.0 kg ha^{-1}), T_5 (8100.3 kg ha^{-1}) & T_6 (8245.0 kg ha^{-1}). Maximum and minimum stalk yield of 9264.0 kg ha^{-1} and 5850.3 kg ha^{-1} was found in weed free and weedy check treatment, respectively. However, each weed control treatment recorded significantly higher stalk yield than weedy check.

4.3.3. Biomass yield (kg ha^{-1})

Biomass yield (kg ha^{-1}) at harvest as influenced by different weed management practices differed significantly. The treatment T_2 (imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS) recorded significantly higher biomass yield of 11115.3 kg ha^{-1} than T_1 (9467.6 kg ha^{-1}), T_4 (8717.0 kg ha^{-1}), T_7 (9083.0 kg ha^{-1}), T_8 (9724.0 kg ha^{-1}), T_9 (9343.0 kg ha^{-1}) and T_{10} (9404.6 kg ha^{-1}) which was statistically at par with T_3 (10949.6 kg ha^{-1}), T_5 (10483.3 kg ha^{-1}) & T_6 (10670.0 kg ha^{-1}). Maximum and minimum biomass yield of 11989.0 kg ha^{-1} and 7473.6 kg ha^{-1} was found in weed free and weedy check treatment, respectively. However adoption of all weed control measures led to significantly higher biomass yield than weedy check.

4.3.4. Harvest index (%)

Harvest index, the ratio of economic yield to biological yield, varied significantly under weed control measures led to better diversion of photosynthates towards seed and thereby high harvest index. The value of harvest index (%) did not differ significantly due to different weed management practices. However, maximum and minimum harvest index of 22.7% and 21.7 % was recorded in weed free and weedy check, respectively.

4.4. Weed flora observed in experimental field

The major weed flora observed in the experimental field of pigeonpea included grassy weeds like, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Echinochloa colona*, *Echinochloa crussgulli*, *Eleusine indica and Digitaria sanguinalis.* Sedges like

Cyperus rotundus, *Cyperus iria*, *Cyperus difformis* and broad leaved weeds like *Ageratum conyzoides*, *Digera arvensis*, *Physallis minima*, *Trianthema portulacastrum*, *Boerrhivia diffusa*, *Euphorbia hirta*, *Phyllanthus niruri* and *Bidens biternata.*

Major weeds of the experimental plot in weedy check

Common name	Scientific name	Family	Types of weeds
Grasses			
Bermuda grass	*Cynodon dactylon (L.) Pers.*	Poaceae	Perennial
Crow foot grass	*Dactyloctenium aegyptium (L.) Link Wild*	Poaceae	Annual
Jungle rice / Small barnyard grass	*Echinochloa colonum (L.) Link*	Poaceae	Annual
Barnyard grass	*Echinochloa crusgali (L.) Beauv.*	Poaceae	Annual
Goose grass	*Eleusine indica (L.) Gaertn.*	Poaceae	Annual
Tropoedo grass	*Panicum repens (L.)*	Poaceae	Annual
Broad leaved			
False Amarnath	*Digera arvensis L.*	Amaranthaceae	Annual
Pig weed	*Amaranthus viridis L.*	Amaranthaceae	Annual
Day flower	*Commelila benghalensis (L.)*	Commelianaceae	Annual
Cock’s comb	*Celosia argentea L.*	Amaranthaceae	Annual
Bari Dudhi	*Euphorbia hirta*	Euphorbiaceae	Annual
Hajardana	*Phyllanthus niruri L.*	Euphorbiaceae	Annual
Floss flower	*Ageratum conyzoides L.*	Asteraceae	Annual
Sedges			
Purple nut sedge	*Cyperus rotundus L.*	Cyperceae	Perennial
Flat sedges	*Cyperus iria*	Cyperceae	Annual

4.5. Effect of weed management practices on weed population

The results of the weed population in terms of grassy weeds, BLWs, sedges and total weed density per m^2 as influenced by different weed control treatments recorded at 30, 60 and 90 days after sowing are presented in Table-4.6 to 4.9, respectively.

4.5.1. Grassy weed population (No. m^{-2})

The data pertaining to the population of grass weeds recorded at 30, 60 & 90 DAS as influenced by different weed management practices are presented in Table-4.6. Weed control treatment significantly reduced grassy weed density recorded at different crop growth stages.

In general, weed density declined from 30 DAS to 60 DAS except in pendimethalin at 0.75 kg a.i. ha^{-1}, pendimethalin at 0.75 kg a.i. ha^{-1} fb quizalofop-ethyl @ 50 g a.i. ha^{-1}, pigeonpea + blackgram intercropping and metribuzin @ 250 g a.i. ha^{-1} treated plots. All the weed control measure led to significant reduction in grassy weed population at 60 and 90 days stages as compared to weedy check. Among the herbicidal treatments, at 60 DAS significantly lower weed count per m^2 was recorded with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (3.20) which was statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (3.35) and significantly higher as compared to rest of the treatments except treatment T_1 *i.e.* imazethapyr @ 20 g a.i. ha^{-1} at 15 DAS (3.30).

At 90 days stage, application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded significantly lower grassy weed density (2.40) than T_7, T_8, T_9 and T_{10} treatments. Whereas, it was statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (3.63), imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS (3.61), imazethapyr @ 60 g.ai ha^{-1} at 30 DAS (3.71), imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS (3.74) and imazethapyr @ 20 g a.i. ha^{-1} at 15 DAS (3.91). However, each treatment recorded significantly lower grassy weed population than weedy check.

4.5.2. Broad leaved weed population (No. m^{-2})

A perusal of data on population of broad leaved weeds revealed that all the weed control measure led to significant reduction in its count at 60 and 90 DAS in comparison with weedy check (Table-4.7).

Among the herbicidal treatments the lowest population of BLW at 60 DAS was recorded with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (3.14) which was statistically at par with application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (3.24), and significantly lower over T_8, T_9 and T_{10}. Application of all doses of imazethapyr at 15 DAS recorded lower BLW count as compared to applied at 30 DAS. Pigeonpea + blackgram intercropping system prove their superiority over application of pendimethalin alone and metribuzin @ 250 g a.i. ha^{-1} at 60 DAS in terms of control of broad leaved weeds.

At 90 days stage, perusal of data indicated that imazethapyr @ 60 g a.i. ha^{-1} at 15 days (T_3) recorded lower BLW population than pendimethalin alone (T_7),

Table-4.6: Weed density (m^{-2}) of grassy weeds as influenced by weed management practices

Treatments	Grassy weed density(m^{-2})		
	30 DAS	**60 DAS**	**90 DAS**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	2.63 (6.44)	3.30 (11.01)	3.91 (14.77)
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	2.52 (6.03)	3.35 (10.92)	3.02 (8.89)
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	2.14 (4.34)	3.20 (9.87)	2.40 (5.36)
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	6.90 (47.60)	4.82 (22.82)	3.61 (13.76)
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	6.82 (46.34)	4.59 (20.58)	3.74 (13.58)
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	6.95 (48.23)	4.58 (20.51)	3.71 (13.51)
T_7 -Pendimethalin @ 750g. a.i./ha as PE	5.05 (25.69)	5.26 (27.93)	4.79 (23.52)
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	4.67 (21.63)	5.06 (25.83)	4.21 (17.92)
T_9 -Pigeonpea+ blackgram intercropping	4.25 (17.64)	5.41 (29.47)	4.71 (22.33)
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	3.91 (15.40)	5.46 (29.40)	4.73 (22.19)
T_{11} -Weedy check	6.66 (44.17)	7.34 (53.41)	7.00 (48.58)
T_{12} -Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.40	0.32	0.37
CD at 5%	1.18	0.95	1.08

Figure in parenthesis indicate the original value.

DAS = Days after sowing

pendimethalin + quizalofop-ethyl (T_8) and weedy check. However, application of lower dose 40 g a.i. ha^{-1} imazethapyr (T_2) recorded significantly lower weed density of BLW as compared to T_4, T_7 and T_8.

4.5.3. Population of sedge weeds (No. m^{-2})

The population of sedge weeds presented in Table-4.8 revealed that population of sedges differed significantly due to different weed control treatments at all growth stages.

At 60 days stage, among the different herbicidal treatments, application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded statistically lower population of sedges (3.34) as compared to imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS (5.14), pendimethalin alone (5.52), pendimethalin + quizalofop (5.39), pigeonpea + blackgram (6.04), and metribuzin @ 250 g. ai ha^{-1} (5.55) and at par with T_1, T_2, T_5, and T_6.

At 90 days stage, crop grown with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded lowest sedge density (2.38) which was statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (2.76), imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (2.76) and significantly lower density over rest of the treatments. Application of higher dose of imazethapyr proves their superiority to control sedge weeds over lower doses at both stages.

4.4.5. Total weed density (No. m^{-2})

It is evident from the Table-4.9 that total weed density differed significantly due to weed management practices at all growth stages.

Among the different weed control treatments, application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (T_3) recorded statistically lower density of total weeds than rest of the treatments except imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) at 60 as well as 90 days after sowing. Early post emergence application of imazethapyr proves their superiority over post emergence application of imazethapyr treatments at all stages of crop growth. Crop grown with intercropping system recorded significantly lower weed density as compared to weedy check. However, all the weed control measures reduced the total weed density significantly over weedy check at all stages of crop growth. Sequential application of pendimethalin 750 g a.i. ha^{-1} fb quizalofop-ethyl 50 g a.i. ha^{-1} performed better in controlling total weed density than pendimethalin alone and metribuzin @ 250 g a.i. ha^{-1}.

Table-4.7: Weed density (m^{-2}) of broad leaved weeds as influenced by weed management practices

Treatments	BLW weed density (m^{-2})		
	30 DAS	**60 DAS**	**90 DAS**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	2.50 (5.75)	3.41 (11.27)	3.04 (8.82)
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	2.58 (6.37)	3.24 (10.08)	2.63 (6.65)
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	2.39 (5.25)	3.14 (9.38)	2.54 (6.02)
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	5.91 (34.79)	4.01 (15.61)	3.83 (14.21)
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	6.27 (38.78)	3.46 (11.81)	3.17 (9.59)
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	5.94 (34.86)	3.42 (11.78)	3.10 (9.10)
T_7 -Pendimethalin @ 750g. a.i./ha as PE	4.16 (16.94)	5.09 (25.48)	4.34 (18.34)
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	4.69 (21.91)	4.13 (18.30)	4.22 (17.36)
T_9 -Pigeonpea+ blackgram intercropping	3.70 (13.44)	4.75 (22.05)	3.55 (13.34)
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	4.76 (22.40)	4.87 (23.45)	3.48 (12.72)
T_{11} -Weedy check	6.41 (40.88)	7.30 (53.48)	6.56 (42.77)
T_{12} -Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.30	0.40	0.36
CD at 5%	0.88	1.19	1.06

Figure in parenthesis indicate the original value.

DAS = Days after sowing

Table-4.8: Weed density (m^{-2}) of sedges as influenced by weed management practices

Treatments	Sedges (m^{-2})		
	30 DAS	**60 DAS**	**90 DAS**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	3.08 (9.17)	3.89 (14.84)	3.46 (11.62)
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	3.01 (8.96)	3.42 (11.27)	2.89 (7.91)
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	2.92 (8.05)	3.34 (10.85)	2.38 (5.22)
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	6.51 (42.14)	5.14 (25.97)	3.86 (16.22)
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	5.33 (32.21)	4.27 (17.85)	3.38 (11.06)
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	4.90 (26.76)	3.66 (13.09)	2.76 (7.21)
T_7 -Pendimethalin @ 750g. a.i./ha as PE	4.96 (24.43)	5.52 (30.03)	4.86 (23.17)
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	4.74 (22.40)	5.39 (28.84)	4.74 (22.12)
T_9 -Pigeonpea+ blackgram intercropping	5.34 (38.50)	6.04 (36.05)	5.34 (28.07)
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	5.13 (26.53)	5.55 (30.38)	5.13 (25.83)
T_{11} -Weedy check	6.80 (49.42)	5.82 (37.42)	6.80 (45.78)
T_{12} -Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.62	0.48	0.33
CD at 5%	1.84	1.42	0.99

Figure in parenthesis indicate the original value.
DAS = Days after sowing

4.5. Effect of weed management practices on total weed dry weight (g m^{-2})

Observations on weed dry biomass were taken at 30, 60 and 90 DAS in pigeonpea crop. The data on weed dry weight as affected by different treatments have been summarized and presented in Table-4.10.

A perusal of data revealed that weed dry weight differed significantly at all the stages of growth due to various weed control treatments. Weedy check plot recorded highest weed dry weight at all the three crop growth stages, *i.e.*, 30, 60 and 90 DAS.

At 30 DAS of growth, T_3 recorded the lowest weed dry biomass (1.88 g m^{-2}) and it, was significantly superior to rest of the treatments except T_2 (1.97 g m^{-2}) and T_1 (2.21 g m^{-2}). The treatments T_9 (2.70 g m^{-2}), T_7 (3.21 g m^{-2}), T_8 (2.95 g m^{-2}) and T_{10} (3.09 g m^{-2}) were statistically at par with each other and significantly superior over weedy check (5.11 g m^{-2}).

At 60 DAS, T_3 produced the lowest weed dry biomass (5.04 g m^{-2}) and was almost similar to T_2 (5.06 g m^{-2}). However, T_6 (5.23 g m^{-2}), T_4 (5.33 g m^{-2}), T_5 (5.22 g m^{-2}), were statistically at par with each other and significantly reduced weed dry biomass in comparison to rest of the weed control treatments.

At 90 DAS of growth, the treatment T_3 recorded the lowest weed dry biomass (4.89 g m^{-2}) and was almost similar to T_2 (5.09 g m^{-2}), T_5 (5.45 g m^{-2}) and T_6 (5.31 g m^{-2}) and statistically at par with each other and significantly lower to T_7 (7.08 g m^{-2}), T_8 (6.44 g m^{-2}) and T_{10} (8.96 g m^{-2}). However, all control measure proves their superiority over weedy check in terms of weed dry matter at all stages of crop growth.

Table-4.9: Total Weed density (m^{-2}) at different stages as influenced by weed management practices.

Treatments	Total Weed density(m^{-2})		
	30 DAS	**60 DAS**	**90 DAS**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	4.82 (22.82)	6.34 (39.76)	5.97 (35.21)
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	4.60 (21.35)	5.72 (32.27)	4.88 (23.45)
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	4.23 (17.64)	5.52 (30.1)	4.56 (20.44)
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	11.14 (124.53)	8.06 (64.40)	7.47 (55.37)
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	10.84 (117.33)	7.31 (52.99)	5.88 (34.23)
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	10.41 (109.85)	6.90 (47.32)	5.49 (29.82)
T_7 -Pendimethalin @ 750g. a.i./ha as PE	8.22 (67.06)	9.22 (84.56)	8.07 (65.03)
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	8.15 (65.94)	8.98 (80.15)	7.60 (57.40)
T_9 -Pigeonpea+ blackgram intercropping	8.35 (69.58)	9.36 (87.57)	7.97 (63.74)
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	8.02 (64.03)	9.15 (83.23)	7.80 (60.73)
T_{11} -Weedy check	11.62 (134.47)	11.98 (144.30)	11.72 (137.13)
T_{12} -Weed free	0.71 (0)	0.71 (0)	0.71 (0)
SEm±	0.49	0.29	0.38
CD at 5%	1.44	0.87	1.13

Figure in parenthesis indicate the original value.

DAS = Days after sowing

Table-4.10: Weed dry weight (g m^{-2}) at different growth stages influenced by weed management practices.

Treatments	Weed dry weight (g m^{-2})		
	30 DAS	**60 DAS**	**90 DAS**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	2.21 (4.4)	6.09 (36.6)	6.32 (39.53)
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	1.97 (3.4)	5.06 (25.2)	5.09 (25.8)
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	1.88 (3.1)	5.04 (24.9)	4.89 (23.53)
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	4.79 (22.6)	5.33 (28)	5.95 (34.97)
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	5.07 (25.2)	5.22 (26.8)	5.45 (29.20)
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	4.84 (22.9)	5.23 (26.9)	5.31 (27.90)
T_7 -Pendimethalin @ 750g. a.i./ha as PE	3.21 (9.9)	5.67 (31.7)	7.08 (49.77)
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	2.95 (8.2)	5.36 (28.3)	6.44 (41.03)
T_9 -Pigeonpea+ blackgram intercropping	2.70 (6.8)	7.61 (57.5)	7.20 (51.33)
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	3.09 (9.1)	6.96 (48)	8.96 (79.87)
T_{11} -Weedy check	5.11 (25.6)	11.29 (127.0)	11.95 (142.27)
T_{12} -Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm±	0.12	0.08	0.20
CD at 5%	0.37	0.24	0.60

Figure in parenthesis indicate the original value

DAS = Days after sowing

4.6. Effect of weed management practices on weed control efficiency (%) and weed index

The data pertaining to weed control efficiency at 60 and 90 days after sowing are presented in Table-4.11.

4.6.1. Weed control efficiency (%)

At 60 days after sowing weed control efficiency differed significantly due to different weed management practices. Higher weed control efficiency (80.38 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (T_3) which was found statistically at par with T_2 (80.16), T_5 (78.80%) & T_6 (78.88%) while significantly higher than rest of treatments. Whereas, significantly lower weed control efficiency was noticed in imazethapyr @ 20 g a.i. ha^{-1} at 15 DAS as well as 30 DAS (71.17 and 77.94 %). Among the pre-emergence herbicides, pendimethalin applied @ 750 g a.i. ha^{-1} recorded significantly higher weed control efficiency (75.03 %) than metribuzin @ 250 g a.i. ha^{-1} (62.20 %). The maximum and minimum weed control efficiency of 100% and 0 % was noticed in weed free treatment and weedy check, respectively.

At 90 days after sowing, significantly higher weed control efficiency (83.36 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (T_3) which was on par with the treatments of T_2 (80.52), T_5 (79.49) & T_6 (80.48) and significantly higher than T_1 (72.25) & T_4 (75.27). Whereas significantly lower weed control efficiency of 65.03, 71.08 & 43.93 % was noticed in T_7, T_8 and $T_{10,}$ respectively. However, each treatment recorded significantly higher weed control efficiency than weedy check.

4.6.2. Weed Index (%)

The data pertaining to weed index differed significantly due to different weed control treatments (Table-4.11). Among the herbicidal treatments significantly lower weed index (7.25%) was recorded in imazethapyr @ 40 g a.i. ha^{-1} at 15 days after sowing (T_2) than T_1 (21.84%) & T_4 (27.21%) and statistically at par with T_3 (8.59%), T_5 (12.50%) & T_6 (11.20%). However, T_2 recorded significantly lower weed index than rest of treatments. Weedy check recorded significantly higher weed index (40.53 %), than all other treatments under study.

Table-4.11 : Weed Control efficiency (%) at various growth stages as influenced by weed management practices

Treatments	Weed control efficiency (%)		Weed Index (%)
	60 DAS	90 DAS	
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	71.17	72.25	21.84
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	80.16	80.52	7.25
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	80.38	83.36	8.59
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	77.94	75.27	27.21
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	78.80	79.49	12.50
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	78.88	80.48	11.20
T_7 -Pendimethalin @ 750g. a.i./ha as PE	75.03	65.03	24.21
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	77.72	71.08	18.68
T_9 -Pigeonpea+ blackgram intercropping	54.72	63.93	22.13
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	62.20	43.93	21.88
T_{11} -Weedy check	0.00	0.00	40.53
T_{12} -Weed free	100.00	100.00	0.00
SEm±	0.69	1.60	3.49
CD at 5%	2.03	4.70	10.23

DAS = Days after sowing

4.7. Effect of weed management practices on nutrient uptake by weeds and crop

4.7.1. Nutrient uptake (kg) by weeds

The data pertaining to N, P and K uptake by weeds as influenced by different weed control treatments have been summarized and presented in Table-4.12 at 60 & 90 days after sowing.

A perusal of data revealed that weedy check plot recorded the highest value of nutrient uptake by weeds while the lowest value was obtained under the higher dose of imazethapyr @ 60 g a.i. ha^{-1} either 15 and 30 days stage at 60 and 90 DAS.

4.7.2. Nitrogen uptake by weeds (kg ha^{-1})

The nitrogen uptake by weeds varied significantly due to various weed control treatments. Significantly higher value of N depletion by weeds was obtained under weedy check (34.63 kg ha^{-1}) than all the treatments; while among the herbicidal treatments ,lowest value was obtained with T_3 (7.07 kg ha^{-1}) at 60 DAS. The treatment T_2 (7.53 kg ha^{-1}), T_5 (7.60 kg ha^{-1}), T_4 (7.83 kg ha^{-1}) and T_8 (7.93 kg ha^{-1}) were at par with each other. Adoption of intercropping of pigeonpea with blackgram also deleted lower value of nitrogen over weedy check at 60 DAS.

At 90 DAS, similarly, application of imazethapyr @ 60 g. a.i. ha^{-1} at 15 DAS (7.77 kg ha^{-1}) recorded significantly lower value of nitrogen uptake by weeds than T_1, T_8 and T_{10} and statistically at par with application of imazethapyr @ 40 g. a.i. ha^{-1} at 15 DAS (8.17 kg ha^{-1}), T_4 (9.83 kg ha^{-1}), T_5 (8.13 kg ha^{-1}) and T_6 (7.93) kg ha^{-1}.

Table-4.12: Nutrient uptake by weeds at 60 & 90 DAS as influenced by weed management practices

Treatments	Nutrient uptake (kg/ha) at 60 DAS			Nutrient uptake (kg/ha) at 90 DAS		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	10.23	2.53	9.52	11.07	2.73	10.28
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	7.53	1.86	6.99	8.17	2.01	7.60
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	7.07	1.65	6.50	7.77	1.99	7.58
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	7.83	1.99	7.28	9.83	2.41	9.09
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	7.60	1.94	6.97	8.13	1.65	6.12
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	8.13	1.76	7.05	6.93	1.93	7.20
T_7 -Pendimethalin @ 750g. a.i./ha as PE	8.87	2.60	12.18	13.93	3.60	13.27
T_8-Pendimethalin @ 750g. a.i./ha as PE + quizalofop-ethyl @ 50g. a.i./ha as POE	7.93	1.95	11.09	11.50	2.83	11.09
T_9 -Pigeonpea+ blackgram intercropping	16.10	3.97	13.88	14.40	3.54	13.88
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	13.43	5.53	17.67	22.37	5.53	20.87
T_{11} -Weedy check	34.63	8.70	36.01	39.83	9.42	37.34
T_{12} -Weed free	0	0	0	0.00	0.00	0.00
SEm±	0.26	0.22	1.12	0.75	0.17	0.64
CD at 5%	0.76	0.66	3.30	2.20	0.50	1.89

DAS = Days after sowing

4.7.3. Phosphorus uptake by weeds (kg ha^{-1})

The phosphorus uptake by weeds (kg ha^{-1}) was significant due to different weed control treatments. The highest value of P depletion by weeds was obtained under weedy check (8.70 kg ha^{-1}), which was significantly higher over various weed control treatments. The lowest value of P depletion by weeds was recorded by T_3 (1.65 kg ha^{-1}) and it was statistically at par with T_4 (1.99 kg ha^{-1}), T_5 (1.94 kg ha^{-1}), T_6 (1.76 kg ha^{-1}) and T_8 (1.95 kg ha^{-1}) and significantly lower as compared to T_1 (2.53 kg ha^{-1}), T_7 (2.60 kg ha^{-1}), T_9 (3.97 kg ha^{-1}), T_{10} (5.53 kg ha^{-1}) and weedy check (8.70 kg ha^{-1}) at 60 days stage.

At 90 day stage, the uptake of P by weeds was minimum in T_3 (1.99 kg ha^{-1}) while, maximum in weedy check (9.42 kg ha^{-1}). Adoption of weed control option led to significant reduction in P uptake by weeds over weedy check. Application of imazethapyr @ 40 g a.i. ha^{-1} and 60 g a.i. ha^{-1} applied at 15 DAS and 30 DAS recorded lower values of P uptake over other weed control treatments.

4.7.4. Potassium uptake by weeds (kg ha^{-1})

The data pertaining to K depletion by weeds differed significantly due to weed control treatments. The lowest value of K depletion by weeds was obtained under T_3 (6.50 kg ha^{-1}), which was statistically at par with T_2 (6.99 kg ha^{-1}), T_6 (7.05 kg ha^{-1}), T_4 (7.28 kg ha^{-1}) and T_5 (6.97 kg ha^{-1}). The result revealed that various weed control treatment depleted significantly lower amount of phosphorus (kg ha^{-1}) in comparison with weedy check (36.01 kg ha^{-1}) at 60 days after sowing.

At 90 day stage, the uptake of potassium by weeds was maximum in weedy check (37.34 kg ha^{-1}) while, minimum in T_3 (7.58 kg ha^{-1}). Adoption of weed control option led to significant reduction in potassium uptake by weeds over weedy check. Application of imazethapyr @ 40 g a.i. ha^{-1} and 60 g a.i. ha^{-1}; either applied at 15 DAS or 30 DAS recorded lower values of potassium uptake over other weed control treatments. Among the herbicidal treatment excluding imazethapyr; T_8 recorded significantly lower potassium removal than T_7 and T_{10} (metribuzin @ 250 g a.i. ha^{-1} as pre-emergence).

4.8. Nutrient uptake by seed, stalk and crop at harvest

A perusal of data related with nutrient uptake by seed, stalk and crop is presented in table- 4.13, 4.14 & 4.15, respectively.

4.8.1. Nutrient uptake by seed at harvest

The highest uptake of 92.12, 16.61 & 16.82 kg ha^{-1} of N, P & K was recorded in weed free treatment. Among the various treatments, treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) recorded higher uptake 83.69, 14.20 & 14.30 kg ha^{-1} of N, P & K which was statistically at par with higher dose of imazethapyr *i.e.* 60 g a.i. ha^{-1} applied at 15 DAS having 81.11, 13.09 & 13.35 kg ha^{-1} of N, P & K uptake and T_5 in which 76.33, 12.33 & 12.73 kg ha^{-1} of N, P & K uptake was recorded; significantly higher than rest of treatments. However N, P & K uptake in each treatment was significantly higher than weedy check. The lowest uptake of 51.07, 8.15 & 8.58 kg ha^{-1} of N, P & K respectively was recorded in weedy check.

4.8.2. Nutrient uptake by stalk

Maximum and minimum uptake of 62.29, 11.77 & 88.15 and 31.81, 6.44 & 43.74 kg ha^{-1} of N, P & K was recorded in weed free and weedy check respectively. The higher uptake of P & K was obtained in T_2 (10.84 and 71.32 kg ha^{-1}) which was statistically at par with T_3 having uptake of 10.49 & 68.15 kg ha^{-1}. Whereas N uptake in T_2 (55.92 kg ha^{-1}) was significantly higher than T_3 (46.81 kg ha^{-1}). The treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher uptake of nitrogen, phosphorus and potassium (55.92, 10.84 & 71.32 kg ha^{-1}) than T_4 (38.66, 8.00 & 51.68 kg ha^{-1}), respectively; while P uptake of 10.84 kg ha^{-1} was statistically at par with higher dose of imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (10.18 kg ha^{-1}). The potassium uptake of 71.32 kg ha^{-1} in T_2 was significantly higher than T_5 (61.40 kg ha^{-1}); the same was found statistically at par with T_3 (68.15 kg ha^{-1}). The nitrogen and potassium uptake in T_2 was 55.92 & 71.32 kg ha^{-1} significantly higher than T_6 (48.19 & 60.85 kg ha^{-1}). The nutrient (N, P & K) uptake in weed free was significantly higher than rest of treatments.

Table-4.13: Nutrient uptake (N, P &K) by seed at harvest as influenced by weed management practices

Treatments	Nutrient uptake by seed (Kg/ha)		
	N uptake	**P uptake**	**K uptake**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	66.48	11.73	11.22
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	83.69	14.20	14.30
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	81.11	13.09	13.35
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	62.31	10.12	9.77
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	76.33	12.33	12.73
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	79.06	13.18	10.98
T_7 -Pendimethalin @ 750g. a.i./ha as PE	65.10	11.48	10.95
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	70.55	11.42	12.85
T_9 -Pigeonpea+ blackgram intercropping	66.80	11.57	11.30
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	69.25	11.07	11.29
T_{11} -Weedy check	51.07	8.15	8.58
T_{12} -Weed free	92.12	16.61	16.82
SEm±	3.23	0.76	0.65
CD at 5%	9.49	2.25	1.91

DAS = Days after sowing

Table-4.14: Nutrient uptake (N, P &K) by stalk at harvest as influenced by weed management practices

Treatments	Nutrient uptake by stalk (Kg/ha)		
	N uptake	**P uptake**	**K uptake**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	40.18	8.86	54.33
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	55.92	10.84	71.32
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	46.81	10.49	68.15
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	38.66	8.00	51.68
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	48.97	9.87	61.40
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	48.19	10.18	60.85
T_7 -Pendimethalin @ 750g. a.i./ha as PE	43.34	8.40	57.56
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	46.87	9.16	62.29
T_9 -Pigeonpea+ blackgram intercropping	45.30	8.63	63.34
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	44.69	8.40	59.49
T_{11} -Weedy check	31.81	6.44	43.74
T_{12} -Weed free	62.29	11.77	88.15
SEm±	2.46	0.45	3.06
CD at 5%	7.24	1.34	8.98

DAS = Days after sowing

Table-4.15: Nutrient uptake (N, P &K) by crop (seed + stalk) at harvest as influenced by weed management practices

Treatments	Nutrient uptake by crop (Kg/ha)		
	N uptake	**P uptake**	**K uptake**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	106.67	20.59	65.56
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	139.61	25.04	85.62
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	127.92	23.58	81.50
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	100.97	18.13	61.45
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	125.31	22.21	74.12
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	127.24	23.37	71.83
T_7 -Pendimethalin @ 750g. a.i./ha as PE	108.44	19.89	68.51
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	117.42	20.58	75.14
T_9 -Pigeonpea+ blackgram intercropping	112.09	20.20	74.64
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	113.94	19.47	70.79
T_{11} -Weedy check	82.88	14.59	52.32
T_{12} -Weed free	154.41	28.38	104.97
SEm±	5.31	1.09	3.55
CD at 5%	15.58	3.20	10.42

DAS = Days after sowing

4.8.3. Total Nutrient uptake by crop

The treatment of imazethapyr applied @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher uptake 139.61, 25.04 & 85.62 of N, P & K kg ha^{-1} than T_4 (100.97, 18.13 & 61.45 kg ha^{-1}) and statistically at par with T_3 (127.92, 23.58 & 81.50 kg ha^{-1}) of N, P & K, respectively. There was no significant difference observed in T_5 & T_6. The treatment T_2 recorded significantly higher uptake of N, P & K uptake than rest of the treatments. However, maximum (154.41, 28.38 & 104.97 kg ha^{-1}) and minimum (82.88, 14.59 & 52.32 kg ha^{-1}) uptake N, P & K were recorded in weed free treatment and weedy check respectively.

4.9. Soil Chemical properties after harvest

The data pertaining to soil chemical properties is presented in Table-4.16. Soil sample after harvest was taken from each plot and analysed. Soil p^H did not differ significantly due to adoption of different weed management practices. However, the highest pH (7.46) was obtained in weed free and lowest (7.26) in weedy check. There was slight decrease in pH occur from the initial value of pH (7.58). Electricity conductivity did not differ significantly due to different weed management practices.

Among the various weed control treatments, available nitrogen was maximum (182.83 kg ha^{-1}) in intercropping of pigeonpea with blackgram (T_9) and significantly superior over rest of the treatments except imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (172.20 kg ha^{-1}), imazethapyr @ 60 g a.i./ha at 15 DAS(168.10 kg ha^{-1}), imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS(180.37 kg ha^{-1}) and imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS (168.40 kg ha^{-1}).

Available P_2O_5 was also highest (17.73 kg ha^{-1}) in intercropping of pigeonpea with blackgram which was statistically at par with T_1 (17.02 kg ha^{-1}), T_3 (16.15 kg ha^{-1}) and significantly higher than rest of the treatments.

The available K_2O was highest (244.35 kg ha^{-1}) in imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS. However, many of the herbicidal treatments were statistically at par with each other.

Table-4.16: Soil chemical properties after harvest as influenced by weed management practices.

Treatments	Soil chemical properties				
	pH	**EC**	**Avail N**	**Avail P_2O_5**	**Avail K_2O**
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	7.41	0.24	166.20	17.02	210.50
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	7.39	0.25	172.20	12.74	200.62
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	7.45	0.23	168.10	16.15	198.44
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	7.40	0.24	180.37	11.89	244.35
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	7.30	0.23	168.40	14.30	189.98
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	7.28	0.27	160.60	14.55	190.72
T_7 -Pendimethalin @ 750g. a.i./ha as PE	7.34	0.24	166.30	14.40	206.91
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	7.32	0.22	165.53	14.58	201.91
T_9 -Pigeonpea+ blackgram intercropping	7.30	0.26	182.83	17.73	220.46
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	7.31	0.23	164.80	12.78	217.52
T_{11} -Weedy check	7.26	0.23	151.03	15.92	176.85
T_{12} -Weed free	7.46	0.22	166.60	16.35	208.72
SEm±	0.07	0.01	5.41	0.92	17.33
CD at 5%	0.20	0.04	15.88	2.70	50.85

DAS = Days after sowing

4.10. Economics

The data pertaining to the cost of cultivation, gross returns, net returns and B:C ratio as influenced by different weed control treatments are presented in Table-4.17

4.10.1. Cost of cultivation

The cost of cultivation differed due to different weed management practices. Higher cost of cultivation was involved in weed free plot (Rs. 40000 ha^{-1}) followed by pigeonpea + blackgram intercropping Rs. 29650 ha^{-1}. Weedy check recorded the minimum cost (Rs. 25000 ha^{-1}) of cultivation. The next best treatments with respect to lower cost of cultivation were noticed with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS as well as at 30 DAS (Rs. 25940 ha^{-1}). Among the pre-emergence herbicides, lower cost (Rs. 25943 ha^{-1}) of cultivation was involved in metribuzin @ 250 g a.i. ha^{-1} followed by pendimethalin @ 750 g a.i. ha^{-1} (Rs. 26425 ha^{-1}).

4.10.2. Gross returns

A perusal of data revealed that the gross returns differed due to different weed management practices. Higher gross returns (Rs. 104639 ha^{-1}) were recorded with weed free plot and lower gross returns were obtained in weedy check (Rs. 62667 ha^{-1}). Among the herbicidal treatments, post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS gave significantly higher gross return (Rs. 96999 ha^{-1}) than T_1 (Rs. 81853 ha^{-1}), T_4 (Rs.76105 ha^{-1}) and statistically at par with T_3 (Rs. 95700 ha^{-1}), T_5 (Rs. 91505 ha^{-1}), T_6 (Rs. 93120 ha^{-1}).

4.10.3. Net returns and B : C ratio

The net returns differed among different weed management practices. Higher net returns (Rs. 71059 and Rs. 69440 ha^{-1}) with higher benefit cost ratio (2.74 and 2.64) were recorded with post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS and imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS, respectively. The above described treatments of imazethapyr was statistically at par with T_5 and T_6 (Rs. 65565 and 66860 ha^{-1}) in terms of net return and B:C ratio of 2.53 & 2.55; whereas significantly higher than the rest of the treatments.

Table-4.17: Economics of pigeonpea as influenced by weed management practices

Treatments	Total cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net Return (Rs./ha)	B:C ratio
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	25620	81853.6	56233.6	2.19
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	25940	96999.3	71059.3	2.74
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	26260	95700.3	69440.3	2.64
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	25620	76105.0	50485.0	1.97
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	25940	91505.3	65565.3	2.53
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	26260	93120.0	66860.0	2.55
T_7 -Pendimethalin @ 750g. a.i./ha as PE	26425	79293.0	52868.0	2.00
T_8-Pendimethalin @ 750g. a.i./ha as PE + Quizalofop-ethyl @ 50g. a.i./ha as POE	28125	84864.0	56739.0	2.02
T_9 -Pigeonpea+ blackgram intercropping	29650	81559.0	51909.0	1.75
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	25943	81824.6	55881.7	2.15
T_{11} -Weedy check	25000	62667.0	37667.0	1.51
T_{12} -Weed free	40000	104639.0	64639.0	1.61
SEm±	-	3580.7	3580.7	0.13
CD at 5%	-	10501.93	10501.9	0.39

DAS = Days after sowing

CHAPTER-V

DISCUSSION

Chapter-V

Discussion

The results of the field experiment entitled **"Effect of weed management practices on growth & yield of pigeonpea [*Cajanus cajan* (L.) Millspaugh]"** conducted in pulse section of Bihar Agricultural University, Sabour are discussed under the following headings.

5.1 Effect of weed management properties on crop growth and yield

5.2 Effect of weed control treatments on weed dynamics

5.3 Effect of weed control treatments on nutrient uptake

5.4 Effect of weed management practices on economics

5.1 Effect of weed management properties on crop growth and yield

5.1.1 Effect on crop growth

Plant height differed significantly with various weed control treatments. Higher plant height was recorded in weed free plot (27.7 cm to 261.7 cm) since no weeds were allowed to grow throughout the crop growth period which enabled zero crop-weed competition for resources throughout the crop growth period (Fig-5.1). Weedy check recorded the lower plant height (23.60 cm to 216.70 cm). The main reason was due to the presence of more number of broad leaved, grassy and sedges weeds associated with the crop which exhibited severe competition throughout the crop growth. Weed competition has the effect of progressively decreasing the plant height in pigeonpea (Singh *et al*., 1994 and Nagaraju and Mohankumar, 2009). The main reason attributed to this was increased competition for nutrients, light and space between the pigeonpea and weeds especially in the initial stages. The crop weed competition varied with various treatments, based on intensity of weeds. The higher weed competition was noticed in the treatment of weedy check. Among the herbicidal treatments the maximum plant height (24.0 cm to 259.0 cm) was recorded with post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS, which was statistically at par with imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (23.20 cm to 257.8 cm). It was owing to less number of weeds. Further, the competition between crop and weeds was also reduced as a result of which the plant height was higher. Comparatively lower plant height was recorded in T_3 (imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS) at initial stage of crop growth. This might be due to the application of its higher dose caused some phytotoxic effect on plants; however it recovered gradually with time.

The dry matter production per plant differed significantly with different treatments (Fig.-5.2). At all the stages of crop growth, weedy check recorded significantly lower crop dry matter accumulation (4.73 g to 124.83 g $plant^{-1}$). This might be attributed to severe competition of weeds with crop for growth factors which restricted the development of the crop. While, highest dry matter production per plant at different growth stages was observed in weed free plot (8.95 g to 220.67 g $plant^{-1}$) as no weeds were allowed to grow throughout the crop growth period. As a result, the crop exhibited luxuriant growth and produced more number of branches and reproductive parts like flowers, green pods which in turn produced more dry matter accumulation per plant. Vivek *et al.* (2003) was of the opinion that weed free maintenance for initial 60 days of crop growth resulted in significant reduction in the dry matter accumulation of total weeds which in other words, means that this favoured for higher dry accumulation in the crop. Among the herbicidal treatments the higher total dry matter production was recorded with post-emergence application imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (6.77 g to 218.93 g $plant^{-1}$) which was statistically at par with imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (6.25 g to 206.50 g $plant^{-1}$). Higher dry matter accumulation per plant was observed in these treatments due to effective control of weeds after imposing the treatments at the early stages of crop growth. As a result, the crop had put forth luxuriant growth and produced more number of branches, and reproductive parts like flowers, green pods which in turn produced more dry matter accumulation per plant. The treatments of pre-emergence herbicides produced lower dry matter accumulation per plant that was 5.29 g $plant^{-1}$ to 174.73 g $plant^{-1}$ in pendimethalin @ 750 g a.i. ha^{-1}. This may be attributed due to less control of weed in this treatment. The herbicidal effect gradually decreases with time in case of pendimethalin which finally resulted in less control of weeds which germinate at different intervals with onset of rain.

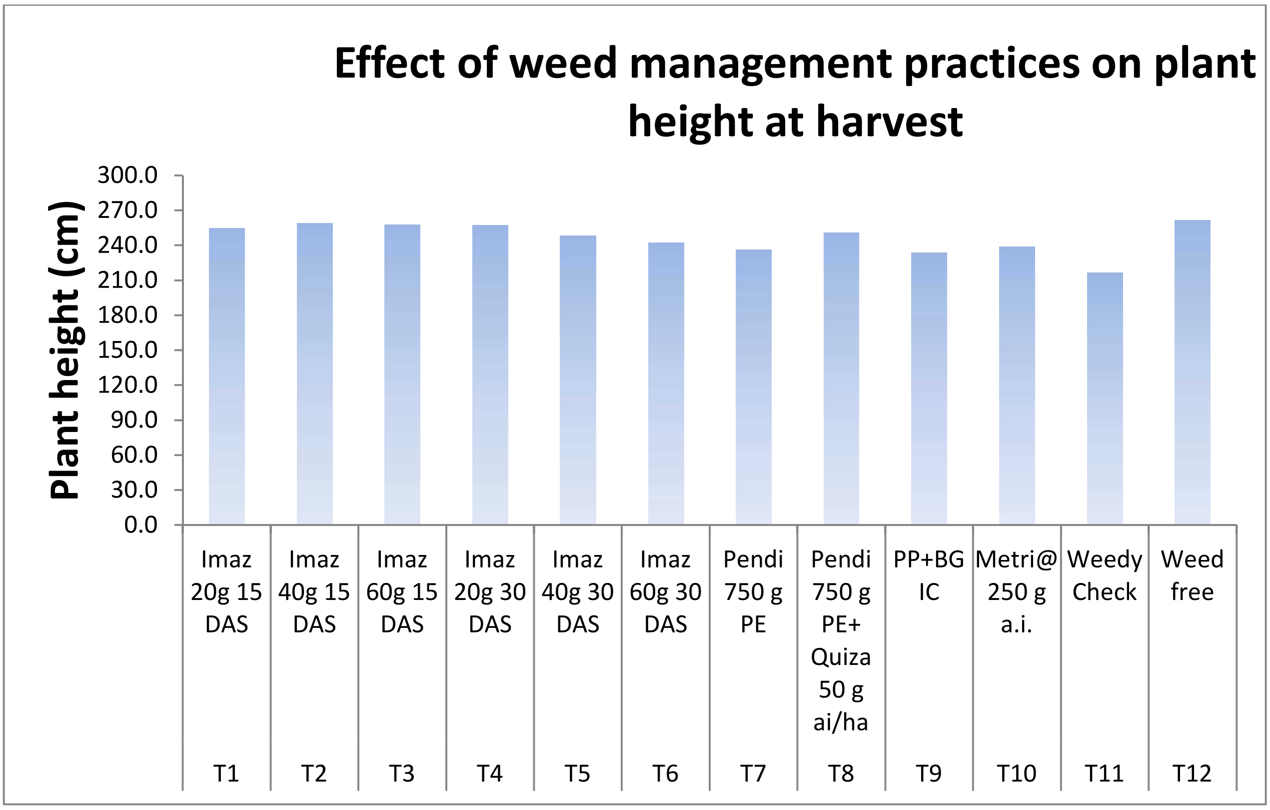


Fig. 5.1: Effect of weed management practices on plant height at harvest

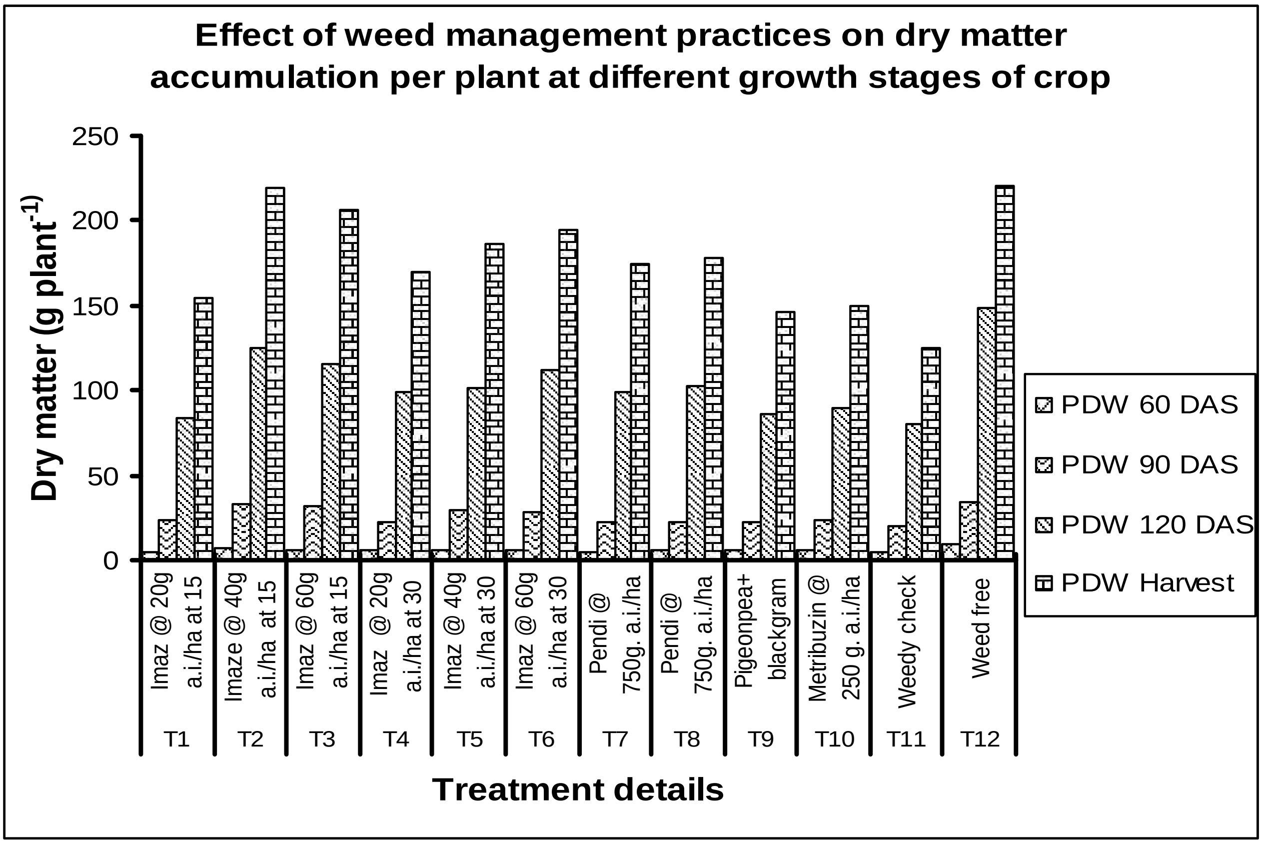


Fig. 5.2: Effect of weed management practices on dry matter accumulation (g plant^{-1})

5.1.2 Effect on yield components

The various yield components were significantly influenced by different weed control treatments. Weed free plot recorded maximum number of pods plant^{-1} (170.5), higher grain yield plant^{-1} (63.2 g) and higher hundred seed weight (12.73 g). The higher yield components in weed free plot was mainly due to the complete elimination of weeds throughout the crop growth, which enabled the better plant growth along with more primary and secondary branches and leaf area, which resulted in higher yield attributing parameters. Whereas these yield components were adversely affected in weedy check. This is due to heavy weed infestation and more crop-weed competition. Among the herbicidal treatments, higher number of pods plant^{-1} (165.3), higher number of seeds pod^{-1} (3.6) and grain yield plant^{-1} (59.2) was observed in post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS. The higher yield attributes were obtained in T_2 may be due to higher weed control efficiency. Gupta *et al.* (2013) also reported higher weed control efficiency (92%) in imazethapyr @ 25 g ha^{-1} at 20 DAS.

5.1.3 Effect on seed and stalk yield of pigeonpea

Seed yield differed significantly owing to different weed control treatments (Fig.-5.3). Significantly higher seed yield was recorded in weed free plot (2725 kg ha^{-1}). The higher yield in weed free plot was mainly due to the complete elimination of weeds throughout the crop growth which enabled minimum competition and causing better plant growth along with more primary and secondary branches. Higher seed yield was also due to higher nutrient uptake (154.41, 28.38 and 104.97 kg N, P and K ha^{-1}, respectively) by pigeonpea that resulted in higher seed yield. Among the herbicidal treatments post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded higher seed yield and was on par with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS and 30 DAS, imazethapyr @ 40 g a.i ha^{-1} at 30 DAS (2526 and 2492.6, 2425.0 & 2383.0 kg ha^{-1}, respectively). The higher yields in these treatments could be attributed to higher dry matter accumulation per plant, plant height, higher nutrient uptake and selective nature of herbicide during early growth stage of the crop. Further higher yield was also due to higher weed control efficiency and minimized crop-weed competition during crop growth. Thus crop plants might have used available resources effectively throughout the crop growth stages resulting in higher seed yield. These results are in close conformation with the findings of Padmaja *et al.* (2013) who reported that application of imazethapyr recorded higher yield attributes and yield which was due to lower weed density and weed dry weight. Application of herbicides controlled the weeds effectively and made available nutrients to crop and consequently resulted in higher yield (Channappagoudar and Biradar 2007 and Vyas *et al.,* 2003). While, weedy check recorded lower yield due to heavy weed infestation and more crop weed competition throughout the crop growth resulting in low nutrient uptake by crop, while weeds removed more quantity of nutrients throughout the crop growth period. This shows that the reduction in yield was apparently due to reduction in growth and yield components caused by weed infestation.

Stalk yield also differed significantly due to different weed management practices (Fig.-5.4). Significantly higher stalk yield was recorded in weed free plot (9264 kg ha^{-1}). The increased stalk yield in weed free treatment was mainly due to complete elimination of weeds throughout the crop growth which enabled better crop growth with more and larger primary and secondary branches $plant^{-1}$, resulting in higher stem dry matter accumulation, which ultimately led to higher stalk yield. Among the herbicidal treatments post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded higher stalk yield (8589.3 kg ha^{-1}), which was at par with post-emergence application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (8457 kg ha^{-1}) as well as imazethapyr @ 40 g a.i./ha at 30 DAS (8100.3 kg ha^{-1}) and imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (8245 kg ha^{-1}) and significantly higher than rest of treatments. The increased stalk yield in these treatments could be attributed to better plant growth, as evidenced by increased primary and secondary branches which made the plants to utilize the resources more efficiently resulting in higher dry matter production of the crop. The lower stalk yield was recorded in weedy check (5850.3 kg ha^{-1}). The lower stalk yield in this treatment was mainly because of severe infestation of weeds, which were competing for the available resources. Singh and Sekhon (2013) also reported that reduction in grain yield in different years due to weeds in pigeon pea to the tune of 31-52.8 % at Ludhiana.

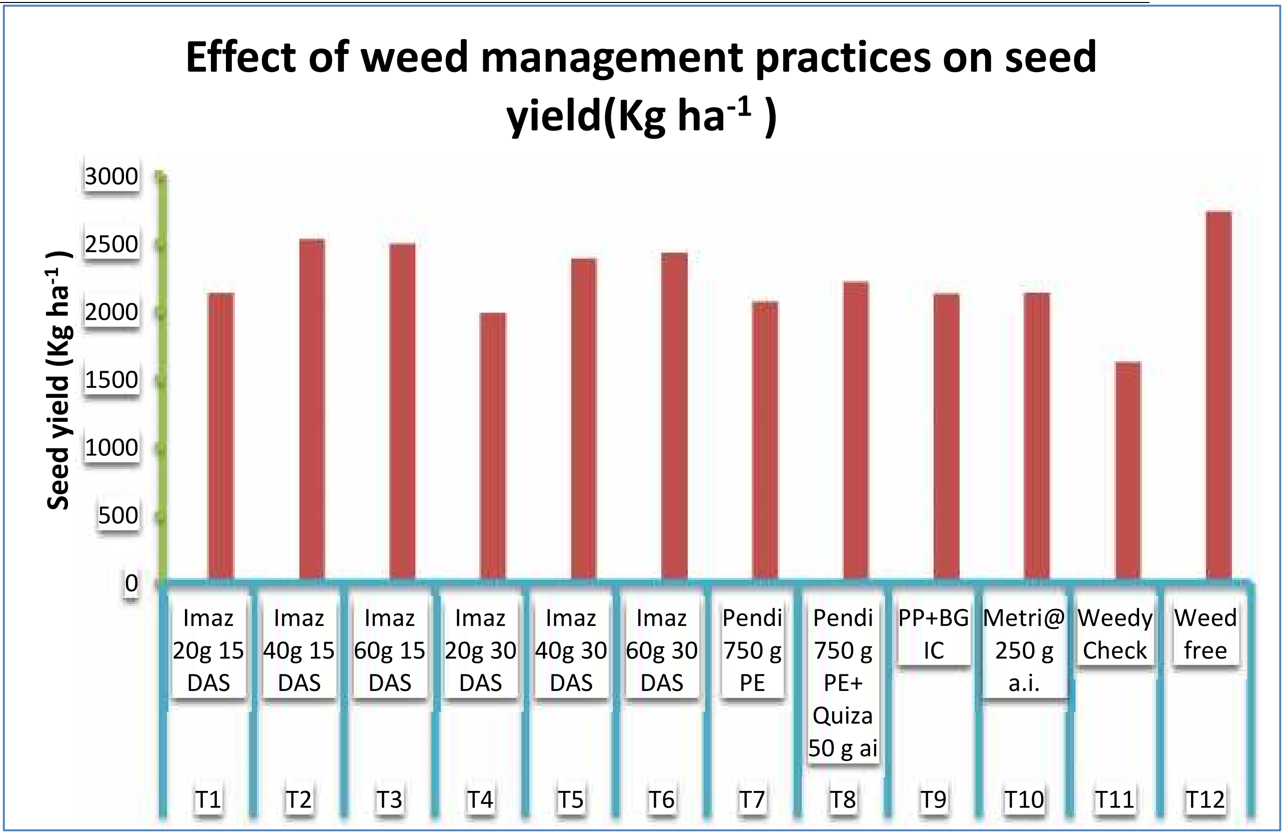


Fig. 5.3: Effect of weed management practices on seed yield (kg ha^{-1})

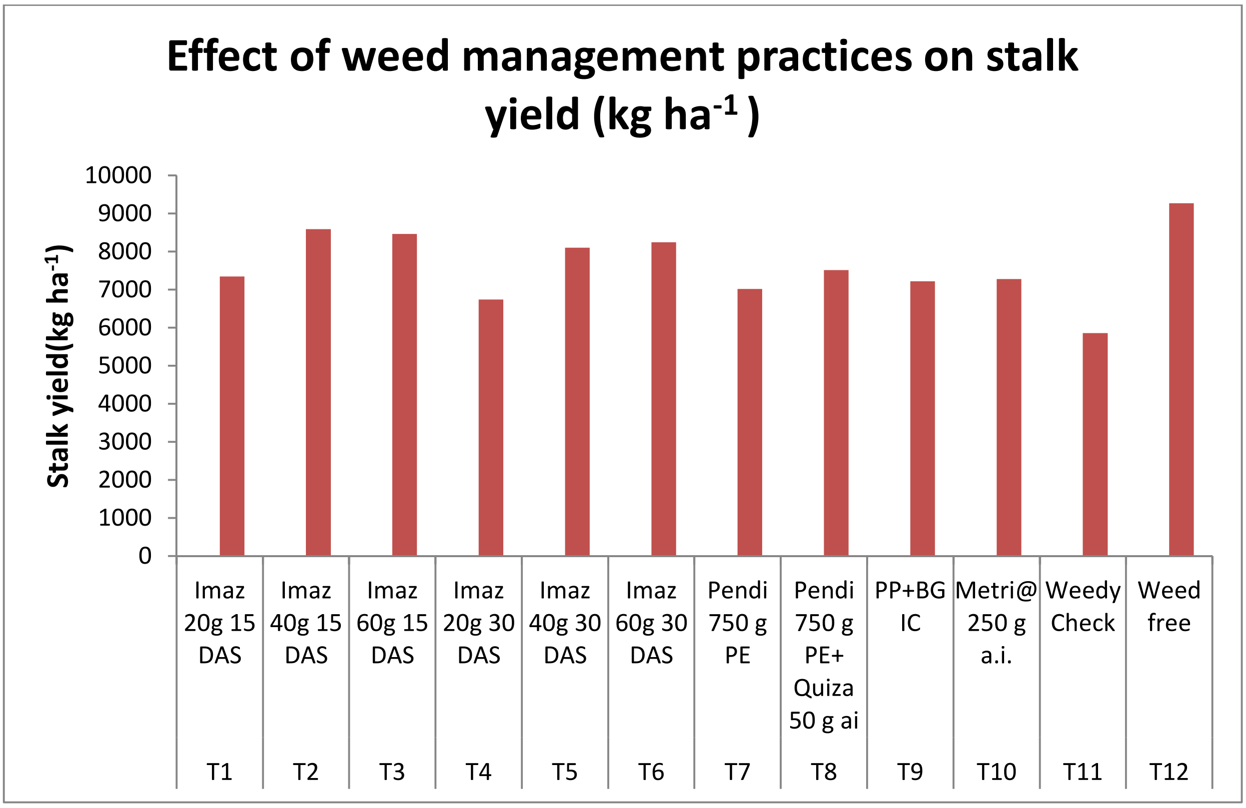


Fig. 5.4: Effect of weed management practices on stalk yield (kg ha^{-1})

5.2. Effect of weed management practices on weed dynamics

Weed population (grasses, broad leaved, sedges and total) at different stages of crop growth (*viz;* 30, 60, 90 DAS) differed significantly (Fig. 5.5, 5.6 and 5.7) among the various weed management practices.

Weed density declined from 30 DAS to 60 DAS except in pendimethalin @ 0.75 kg a.i. ha^{-1} as PE, pendimethalin @ 0.75 kg a.i. ha^{-1} as PE fb quizalofop-ethyl @ 50 g a.i. ha^{-1} pigeonpea and blackgram intercropping and metribuzin @ 250 g a.i. ha^{-1} as pre-emergence. The treatment of pendimethalin did not show decline in weed population because weed come in different flushes. Quizalofop-ethyl mostly control grassy weed that's why it did not perform better in controlling overall weed density. Among the herbicidal treatments, imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded lowest weed density followed by imazethapyr @ 40 g a.i. ha^{-1} at 60 days after sowing. These two treatments caused reduction in weed population due to effective control of weed at early stage of crop growth and also due to its residual impact in soil. Reddy *et al*. (2008) and Ram *et al*. (2012) also reported the prominent effect of imazethapyr in pigeonpea and rajmash, respectively. Imazethapyr effectively controls the germinated weeds either by direct killing or suppression.

Generally, at all the stages (30, 60 & 90 DAS) the higher grassy weed population (44.17 to 53.41 per m^2) was observed in weedy check due to unchecked weed growth throughout the crop growth period (Fig.-5.5). Dhonde *et al*. (2009) also reported the maximum weed in weedy check plot at each growth stages in pigeonpea. The mode of action of Imazethapyr inhibit ALS or AHAS enzymes responsible for the synthesis of three branches chain amino acids such as leusine, isoleusine and valine.

The lowest weed population of BLW observed in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS which was on par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS. This might be due to its broad spectrum control. These treatment of imazethapyr resulted in more reduction of weed in comparison with pre-emergence application of pendimethalin and metribuzin. Pendimethalin control the weed for 30 days. As pigeonpea is a long duration crop the weed come in different flushes. The residual effect of pendimethalin and metribuzin does not remain in soil for long time.

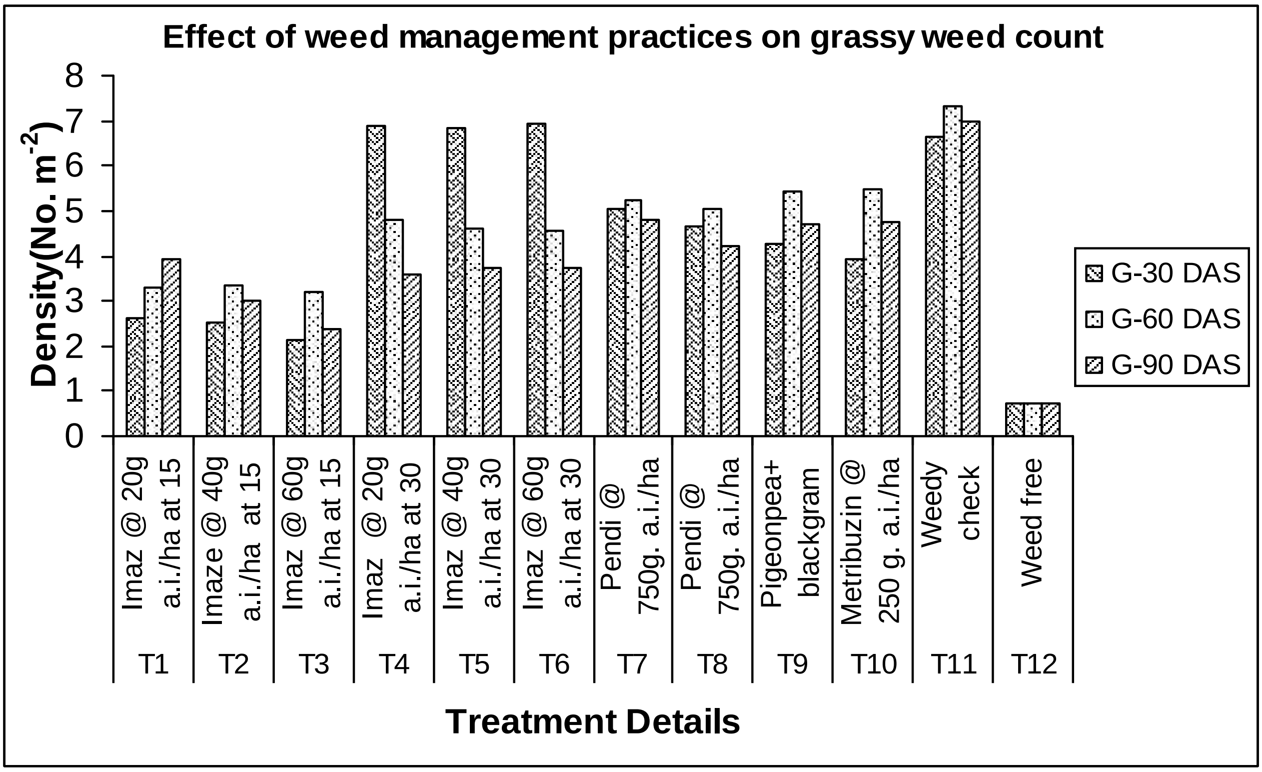


Fig. 5.5: Effect of weed management practices on periodic count of grassy weed

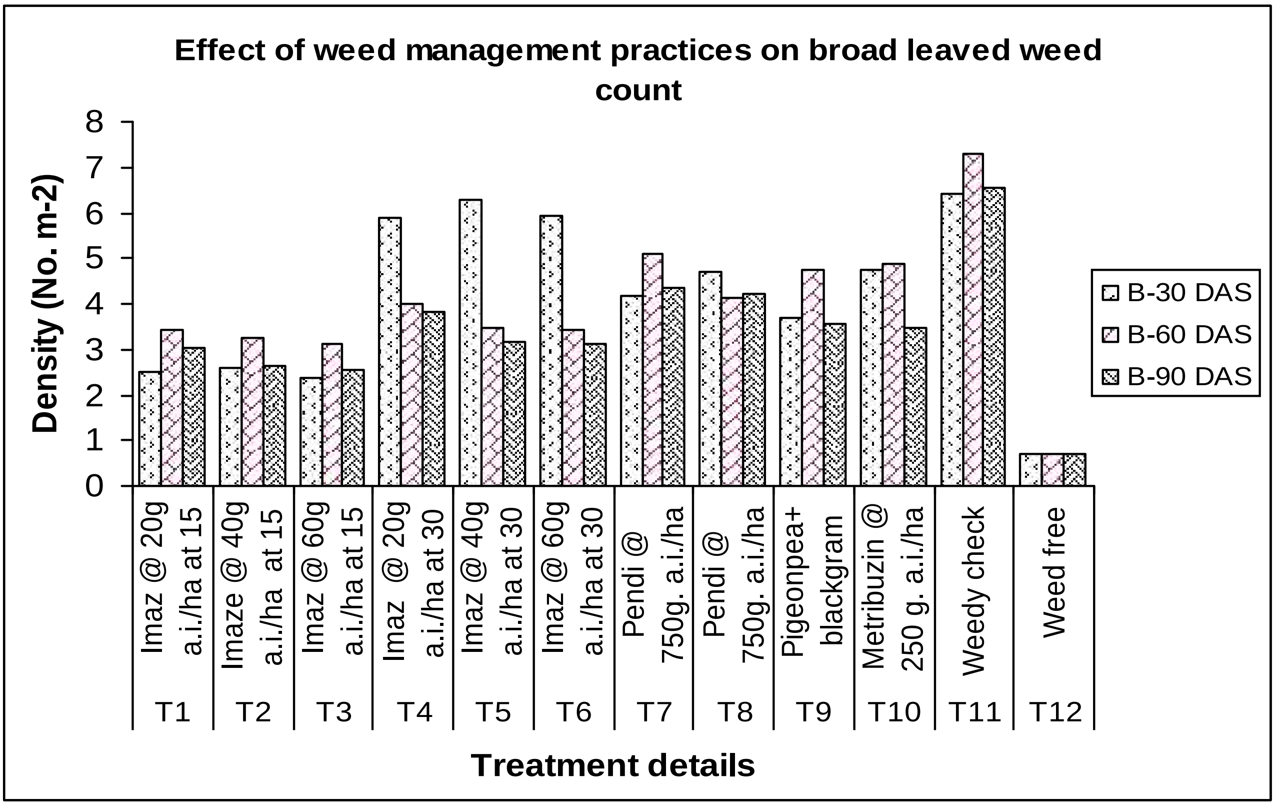
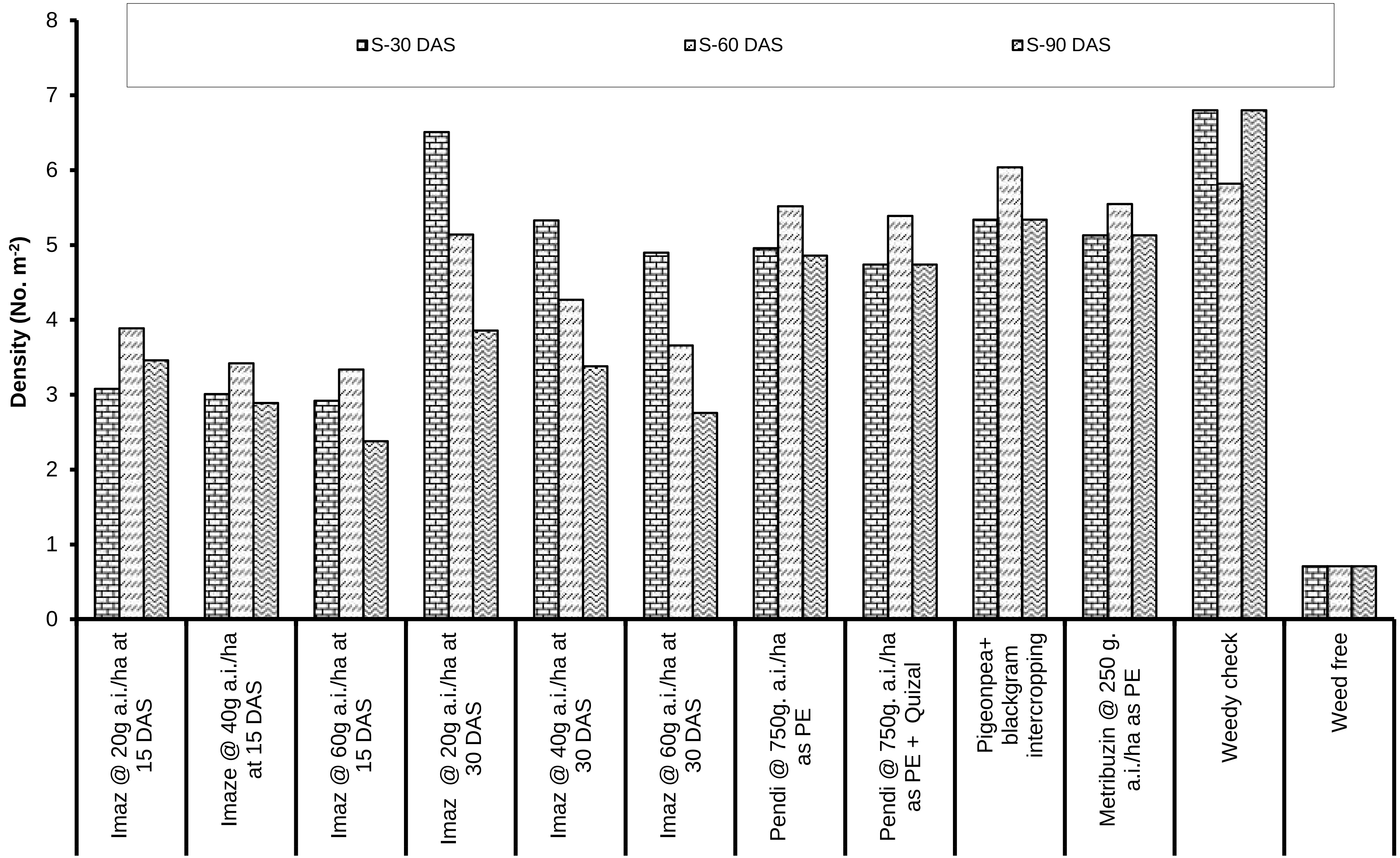


Fig. 5.6: Effect of weed management practices on periodic count of BLW

Fig.- 5.7: Effect of weed management practices on periodic count of sedges



Digera arvensis is a major broad leaved weed, which is usually not controlled by pre-emergence application of pendimethalin. Similarly, the weed population of sedges differed significantly due to different weed management practices. Imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS caused significant reduction in sedges. This might be due to its persistence and long half life period. Total weed population also control effectively with application of imazethapyr as compared to another herbicidal treatment. All the weed control treatments resulted in significant reduction in weed population as compared to weedy check at different growth stages. The maximum weed control efficiency (80.38 %) and (83.36 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (T_3) at 60 and 90 DAS (Fig.-5.8), respectively; as this treatment recoded lowest weed population and weed dry weight (Fig.-5.9). Reddy *et al*. (2008) also reported similar findings due to effective weed control at early stage.

5.3 Effect of weed control treatments on nutrient uptake

The total nutrient uptake by species in mixed vegetation is related to its share in the total effective root length. Below ground competition for soil elements is modelled in an analogy with competition for light. The fraction of nutrient ions that is taken up by a species is related to its share in the root system (Anonymous, 1996). Weeds are vigorous growers and they demand large amounts of plant nutrients. In fact it is common observation that weeds grow tremendously in most of the fertile soils. Obviously, since plant nutrient content of the soil is frequently a limiting factor for crop growth, removal of the competition for such nutrients will make more of them available to the growing crop (Anonymous, 1996).

The uptake of N, P and K by weeds at 60 and 90 DAS differed significantly due to different weed control treatments. In weedy check, weeds removed significantly higher nitrogen, phosphorus and potassium (34.63, 8.70 and 36.01 kg N, P and K ha^{-1} and 39.83, 9.42, 37.34 kg N, P and K ha^{-1}) at 60 and 90 DAS, respectively. While, uptake by the crop were minimum at both stage. The main reason for this kind of behaviour was that the weeds in weedy check were not controlled effectively there by increased the number of weeds per unit area leading to their higher dry weight and enabled them to absorb more nutrients. Similarly Vyas *et al.* (2003) reported the maximum uptake of nitrogen phosphorus and potassium by weeds under weedy check conditions. Among the herbicidal treatments lower uptake of nitrogen, phosphorus and potassium (7.07, 1.65 and 6.50 kg N, P and K ha^{-1}, respectively) by weeds was observed in early post-emergence application of imazethapyr @ 60 g a.i. ha^{-1} applied at 15 DAS,

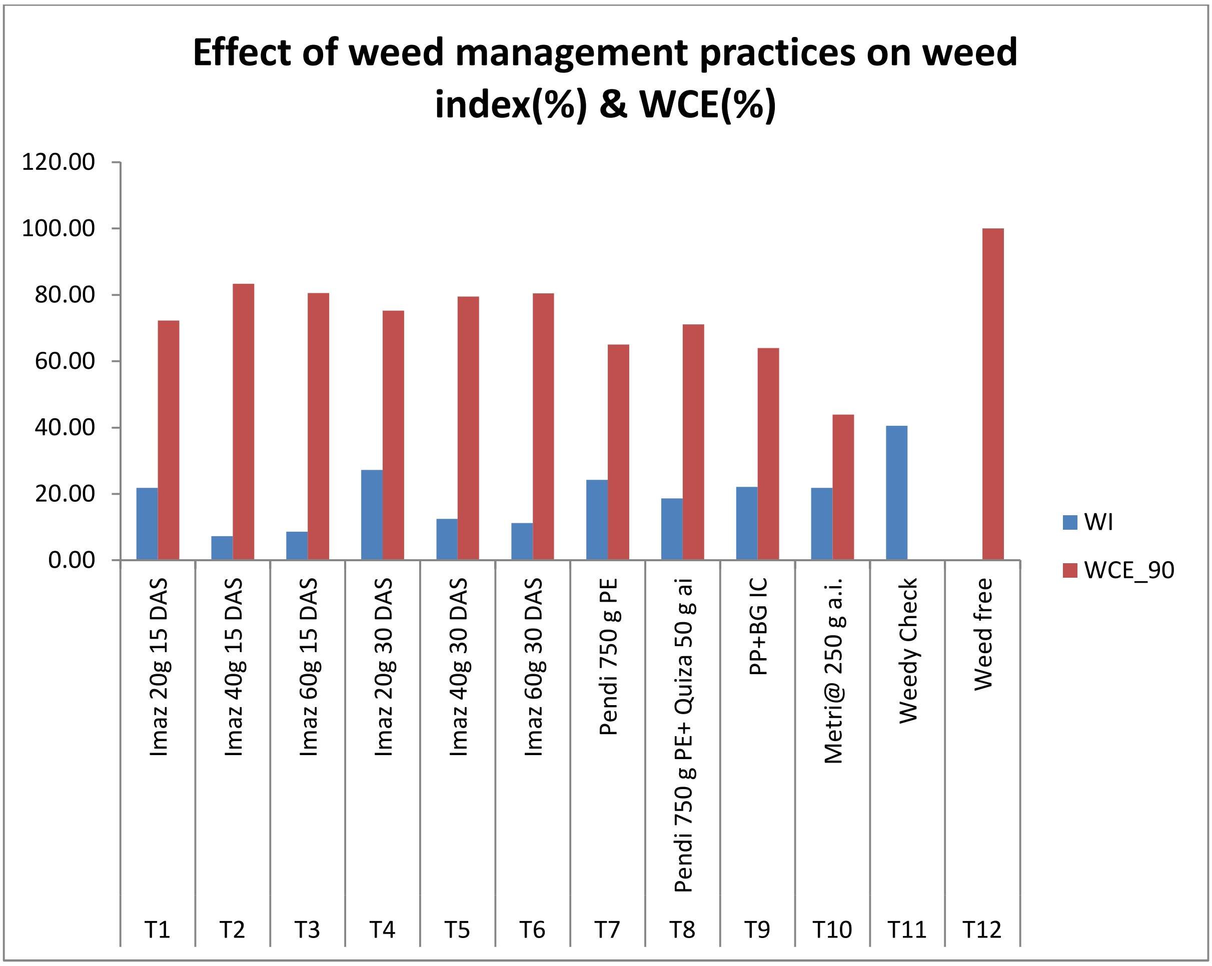


Fig. -5.8: Effect of weed management practices on periodic count of BLW

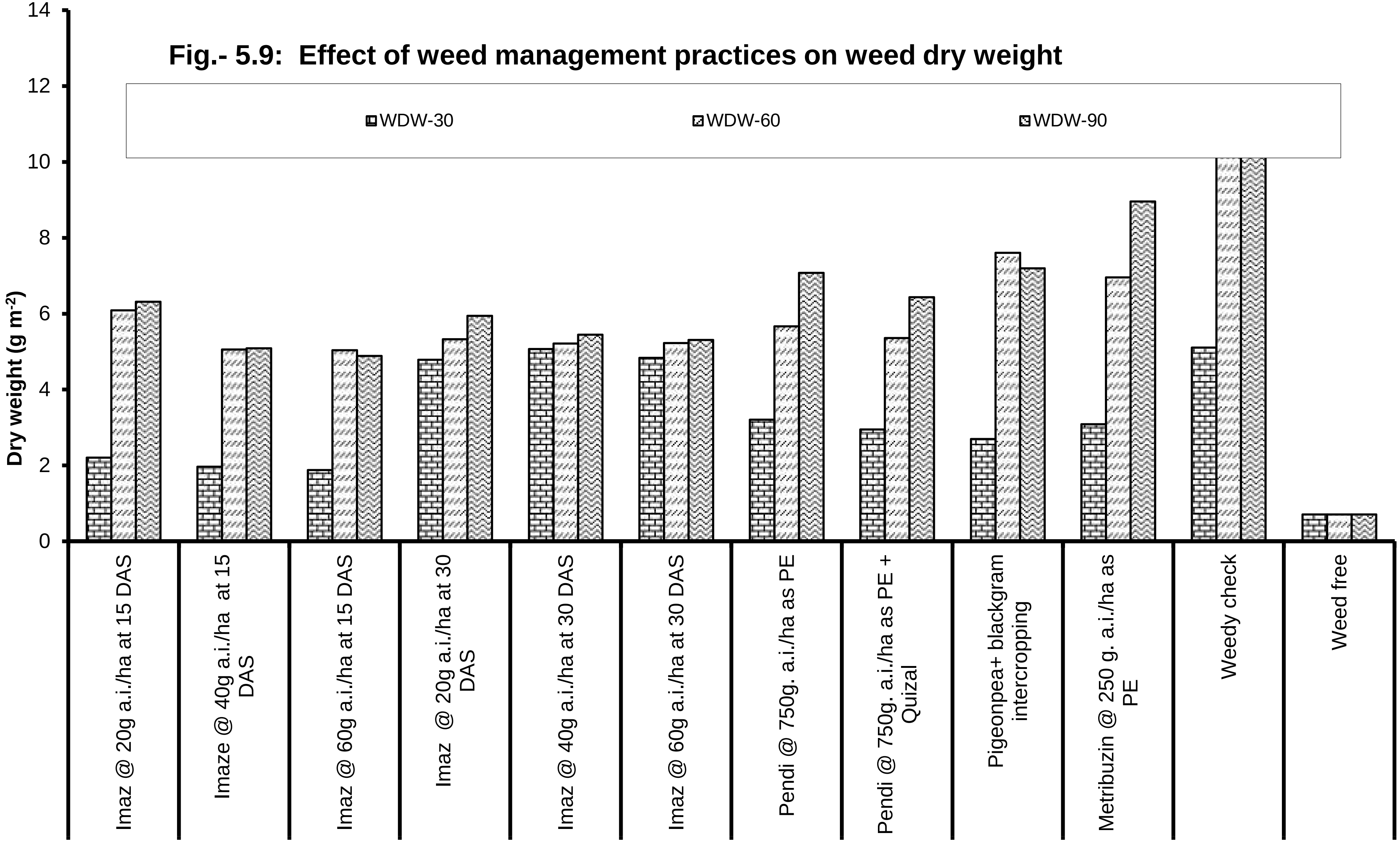


Fig.- 5.9: Effect of weed management practices on weed dry weight
WDW-30
WDW-60
WDW-90
Dry weight (g m-2)
14
12
10
8
6
4
2
0
Imaz @ 20g a.i./ha at 15 DAS
Imaze @ 40g a.i./ha at 15 DAS
Imaz @ 60g a.i./ha at 15 DAS
Imaz @ 20g a.i./ha at 30 DAS
Imaz @ 40g a.i./ha at 30 DAS
Imaz @ 60g a.i./ha at 30 DAS
Pendi @ 750g. a.i./ha as PE
Pendi @ 750g. a.i./ha as PE + Quizal
Pigeonpea+ blackgram intercropping
Metribuzin @ 250 g. a.i./ha as PE
Weedy check
Weed free

the next best treatments with respect to less nutrient (7.53, 1.86 and 6.99 kg N, P and K ha^{-1}, respectively) uptake by weeds at 60 DAS was imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS. The less nutrient removal by weeds at 60 DAS in these treatments was mainly due to better control of weeds during initial stages of crop growth period by post-emergence spray of imazethapyr and long residual effect of herbicide inhibit the germination of new weeds leading to less weed dry matter in these treatments.

The uptake of N, P and K by the pigeonpea crop decreased with increase in weed population and increased with decrease in weed competition. Pigeonpea crop removed the highest plant nutrients (154.41, 28.38 and 104.97 kg N, P and K ha^{-1}, respectively) under weed free plot and the minimum uptake (82.88, 14.59 and 52.32 kg N, P and K ha^{-1}, respectively) was with weedy check (Fig.-5.10). Similar observations were also made by Yadav and Singh (2009) where in the maximum N uptake by crop (150.29 kg ha^{-1}) was recorded in weed free check and the lower N uptake by crop (90.3 kg ha^{-1}) was in weedy check. Among the herbicidal treatments, imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS and imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded significantly higher uptake of nutrients (139.61, 25.04, 85.62 and 127.92, 23.58, 81.50 kg N, P and K ha^{-1}, respectively) by crop compared to all other herbicidal treatments. The post-emergence application of imazethapyr applied @ 40 g & 60 g a.i. ha^{-1} at 15 DAS checked the weed population and weed growth hence reduced the competition for nutrients which finally lead to higher uptake of nutrients.

5.4 Effect of weed management practices on economics

Cost of cultivation varied due to different weed management practices. However, in weed free plot the cost of cultivation was maximum and minimum in weedy check. Higher gross return (Rs. 104639 ha^{-1}) was recorded with weed free plot. Among the different herbicidal treatments, imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (Rs. 96999 ha^{-1}), followed by imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (Rs. 95700 ha^{-1}) gave higher gross return. The higher gross returns were mainly attributed by higher seed yield, obtained due to higher weed control efficiency. The lower gross returns (Rs.62667 ha^{-1}) was recorded with weedy check, which was mainly owing to less seed yield (1623.3 kg ha^{-1}), obtained due to uncontrolled weeds throughout the crop growth. Significantly higher net returns (Rs.71059.3 and Rs.69440.3 ha^{-1}) with higher benefit cost ratio (2.74 and 2.64) were recorded with post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} and imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS, respectively (Fig.-5.11). This was mainly due to higher gross returns along with lesser cost of cultivation, particularly less weed

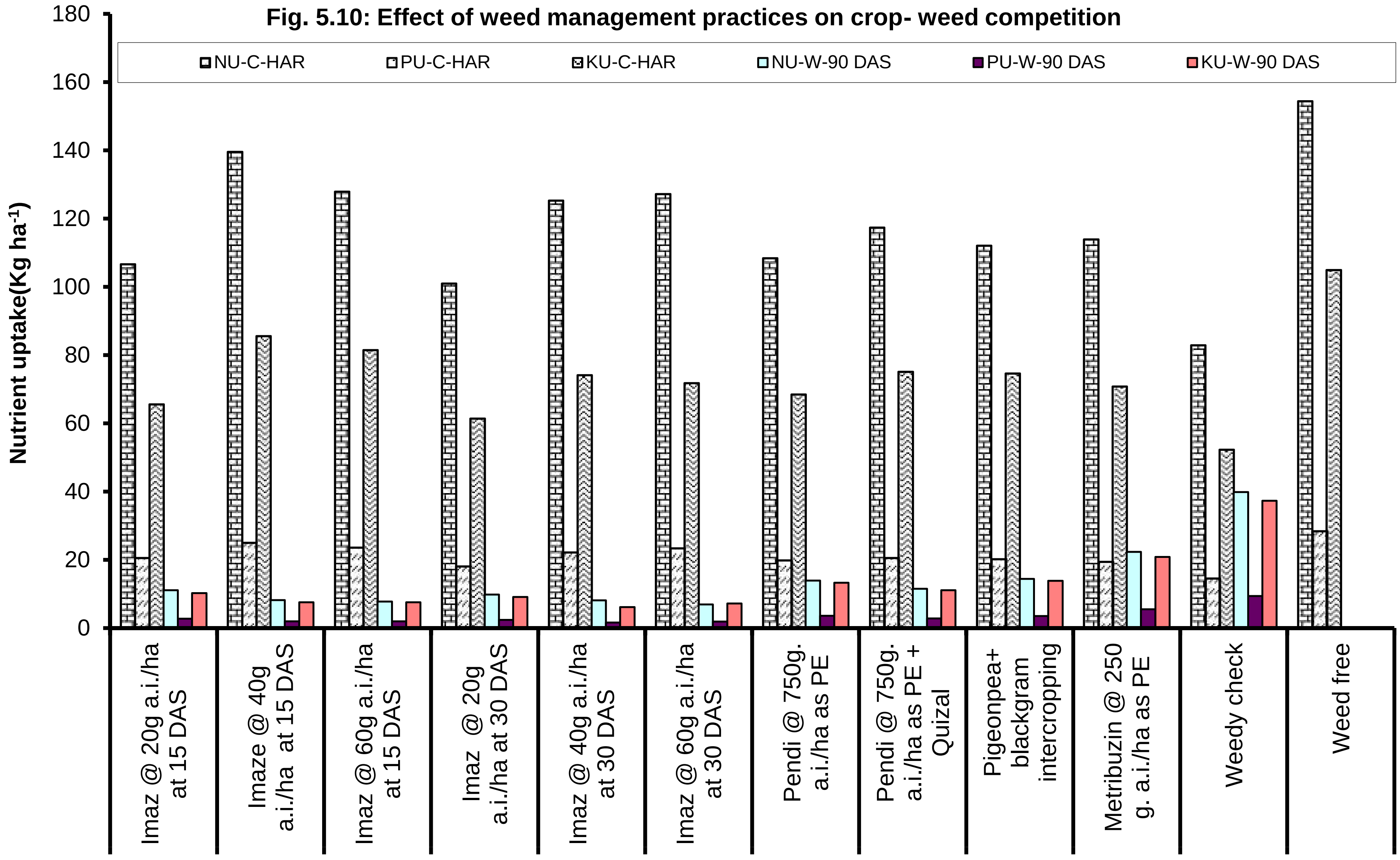


Fig. 5.10: Effect of weed management practices on crop- weed competition
NU-C-HAR
PU-C-HAR
KU-C-HAR
NU-W-90 DAS
PU-W-90 DAS
KU-W-90 DAS
Nutrient uptake(Kg ha-1)
180
160
140
120
100
80
60
40
20
0
Imaz @ 20g a.i./ha at 15 DAS
Imaze @ 40g a.i./ha at 15 DAS
Imaz @ 60g a.i./ha at 15 DAS
Imaz @ 20g a.i./ha at 30 DAS
Imaz @ 40g a.i./ha at 30 DAS
Imaz @ 60g a.i./ha at 30 DAS
Pendi @ 750g. a.i./ha as PE
Pendi @ 750g. a.i./ha as PE + Quizal
Pigeonpea+ blackgram intercropping
Metribuzin @ 250 g. a.i./ha as PE
Weedy check
Weed free

management cost. Significantly lower net returns were recorded with weedy check, application of imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS and intercropping of pigeonpea + blackgram intercropping of Rs. 37667 ha^{-1}, Rs.50485 ha^{-1} and Rs.51909 ha^{-1} respectively. This was mainly due to low seed yield and more cost of cultivation. Padmaja *et al.* (2013) observed similar results with least net return and B:C ratio under weedy check.

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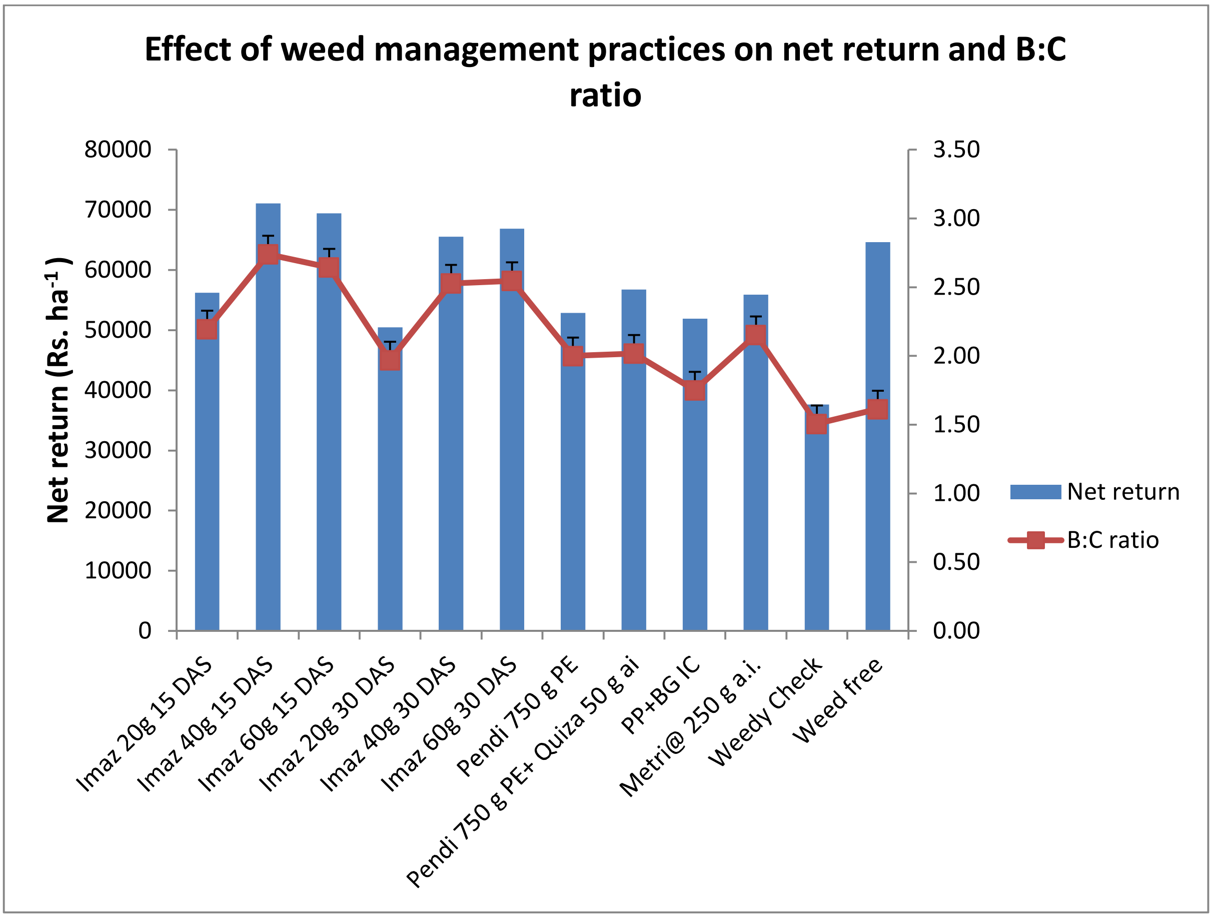

Fig 5.11: Effect of weed management practices on net return & B:C ratio

CHAPTER-VI

SUMMARY & CONCLUSION

Chapter-VI

Summary and Conclusion

A field experiment entitled **"Effect of weed management practices on growth & yield of pigeonpea [*Cajanus cajan* (L.) Millspaugh]"** was conducted during *kharif* season of 2012-13 at Bihar Agricultural University, Sabour to find out the cost-effective management practices with special focus to fine tuning the dose and time of application of herbicide and to study its impact on growth and yield of pigeonpea.

The experiment was laid out in Randomized Complete Block Design with three replications. The weed control treatments were: T_1 -Imazethapyr @ 20g a.i. ha^{-1} at 15 DAS, T_2 -Imazethapyr @ 40g a.i. ha^{-1} at 15 DAS, T_3 -Imazethapyr @ 60g a.i. ha^{-1} at 15 DAS, T_4-Imazethapyr @ 20g a.i. ha^{-1} at 30 DAS, T_5-Imazethapyr @ 40g a.i. ha^{-1} at 30 DAS, T_6-Imazethapyr @ 60g a.i. ha^{-1} at 30 DAS, T_7 -Pendimethalin @ 750g a.i. ha^{-1} as PE, T_8-Pendimethalin @ 750g a.i. ha^{-1} as PE + Quizalofop-ethyl @ 50g a.i. ha^{-1} as POE, T_9 - Pigeonpea + blackgram intercropping, T_{10} -Metribuzin @ 250 g a.i. ha^{-1} as PE, T_{11} -Weedy check and T_{12} -Weed free.

The salient features of the results are summarized in this chapter.

- Different weed control treatments influenced the growth of pigeonpea significantly. Crop grown under weed free condition had tallest plants height at 60, 90, 120 days and at harvest. Application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS had the tallest plant height at 60, 90 and 120 DAS among the herbicidal treatments, which was statistically at par with imazethapyr @ 60 g a.i. ha^{-1} applied at 15 DAS. At harvest, the plant height recorded was non-significant among the herbicidal treatments.

- Adoption of any of the weed control measure resulted in significant increase in dry matter accumulation per plant in comparison with weedy check. At 60 days of crop growth, the maximum dry matter was accumulated in treatment T_2 (6.77 g) which was statistically at par with treatments T_3 (6.25 g) and T_4 (5.55 g), T_5 (5.69 g), T_6 (6.48 g), T_9 (6.06 g) and T_{10} (6.23 g), whereas, it was significantly higher than T_1 (4.95 g) and T_{11} (4.73 g) treatments. At 90 DAS, the maximum dry matter accumulation was recorded under treatment T_2 (32.90 g) which was significantly superior over rest of the treatments except T_3 (32.05 g), T_5 (29.80 g) and T_6 (28.30 g) among the herbicidal treatments. However, at each growth stage weed free condition recorded highest dry matter accumulation per plant.

- The maximum number of primary branches (14.6) was obtained in T_2 which was statistically at par with T_3 (14.5), T_6 (14.0) and T_5 (13.9) and significantly higher than rest of the treatments. Similarly, higher number of secondary branches (27.1) was recorded with the treatment T_2 (imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS) which was significantly higher than T_4 (21.0), T_7 (20.2), T_9 (21.4) and statistically at par with T_1 (23.0), T_3 (26.0), T_5 (24.4), T_6 (25.6), T_8 (23.1) and T_{10} (22.4). Maximum number of secondary branches (27.8) was noticed in weed free treatments. All the weed control treatments recorded significantly higher number of secondary branches per plant at harvest in comparison with weedy check treatment having lowest (16.9) secondary branches per plant .

- The higher number of pods $plant^{-1}$ (165.3) was recorded with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS, which was statistically at par with T_3 (162.8), T_5 (158.0) and T_6 (163.0) and significantly higher than rest of treatments except weed free treatment. All the treatments excluding the treatment of metribuzin @ 250 g a.i. ha^{-1} as PE recorded significantly higher number of pods $plant^{-1}$ than weedy check (127.0). However, maximum number of pods $plant^{-1}$ (170.5) was recorded in weed free treatment.

- Application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) recorded significantly higher number of seeds pod^{-1} (3.6), than T_1 (3.2), T_4 (3.3) and T_{11} (3.1). While T_2 showed statistical parity with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (3.5). However, maximum (3.7) and minimum (3.1) number of seeds pod^{-1} was recorded in weed free and weedy check, respectively.

- Significantly higher seed yield $plant^{-1}$ (59.2 g) was recorded with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) which was found at par with the treatment of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (58.2 g).

- Hundred seed weight did not differ significantly due to different weed management practices. However, the maximum hundred seed weight (12.73 g) was recorded with weed free treatment followed by T_2 (12.67 g) and T_3 (12.60).

- Application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) recorded significantly higher seed yield of 2526 kg ha^{-1} than T_1 (2129.0 kg ha^{-1}), T_4 (1982.0 kg ha^{-1}), T_7 (2065.0 kg ha^{-1}), T_8 (2210.0 kg ha^{-1}), T_9 (2124.0 kg ha^{-1}) and T_{10} (2130.0 kg ha^{-1}) and it was statistically at par with T_3 (2492.6 kg ha^{-1}), T_5 (2383.0 kg ha^{-1}) & T_6 (2425.0 kg ha^{-1}). However, maximum and minimum seed yield of 2725.0 kg ha^{-1} and 1623.3 kg ha^{-1} was found in weed free and weedy check treatment, respectively.

- Maximum and minimum stalk yield of 9264.0 kg ha^{-1} and 5850.3 kg ha^{-1} was found in weed free and weedy check treatment, respectively. The treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher stalk yield of 8589.3 kg ha^{-1} which was significantly higher than T_1 (7338.6 kg ha^{-1}), T_4 (6735.0 kg ha^{-1}), T_7 (7018.0 kg ha^{-1}), T_8 (7514.0 kg ha^{-1}), T_9 (7219.0 kg ha^{-1}) and T_{10} (7274.6 kg ha^{-1}) and statistically at par with T_3 (8457.0 kg ha^{-1}), T_5 (8100.3 kg ha^{-1}) and T_6 (8245.0 kg ha^{-1}).

- The major weed flora observed in the experimental field of pigeonpea included grassy weeds like, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Echinochloa colona*, *Echinochloa crussgulli*, *Eleusine indica and Digitaria sanguinalis.* Sedges like *Cyperus rotundus*, *Cyperus iria*, *Cyperus difformis* and broad leaved weeds like, *Ageratum conyzoides*, *Digera arvensis*, *Physallis minima*, *Trianthema portulacastrum*, *Boerrhivia diffusa*, *Euphorbia hirta*, *Phyllanthus niruri* and *Bidens biternata.*

- All the weed control measure led to significant reduction in grassy weed population at 60 and 90 DAS as compared to weedy check. Among the herbicidal treatments, significantly lower grassy weed density was recorded with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS which was statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS. However, each herbicidal treatment reduced the grassy weed density as compared to weedy check.

- Pigeonpea + blackgram intercropping system prove their superiority over application of pendimethalin alone and metribuzin @ 250 g a.i. ha^{-1} at 60 DAS in terms of control of broad leaved weeds. Among the herbicidal treatments the lowest population of BLW at 60 DAS was recorded with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 days (T_3) followed by application of imazethapyr @ 40 g a.i. ha^{-1} at 15 days (T_2) and significantly lower over T_8, T_9, T_{10} and T_{11}. At 90 days stage, perusal of data indicated that imazethapyr @ 60 g a.i. ha^{-1} at 15 days (T_3)

registered lower BLW population than pendimethalin alone (T_7), pendimethalin + quizalofop-ethyl (T_8) and weedy check.

- Among the different weed control treatments, application of imazethapyr @ 60 g a.i. ha^{-1} recorded statistically lower population of sedges as compared to imazethapyr @ 20 g a.i. ha^{-1} at 60 DAS (T_4), pendimethalin alone (T_7), pendimethalin + quizalofop (T_8), pigeonpea + blackgram (T_9), metribuzin @ 250 g a.i. ha^{-1} (T_{10}) and at par with T_1, T_3, T_5, and T_6 at 60 DAS. Similarly, at 90 days stage, crop grown with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 days (T_3) followed by imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (T_6), imazethapyr @ 40 g a.i. ha^{-1} at 15 days (T_2), imazethapyr @ 20 g a.i. ha^{-1} at 15 days (T_1) and significantly lower density of sedges over rest of the treatment at 90 days stage.

- Application of imazethapyr @ 60 g a.i. ha^{-1} at 15 days stage (T_3) recorded significantly lower density of total weeds followed by imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (T_2) and significantly higher over rest of the treatment at 60 and 90 days stages. Early post emergence application of imazethapyr proves their superiority over post emergence application of imazethapyr treatments at all stages of crop growth. Crop grown with intercropping system recorded significantly lower weed density as compared to weedy check.

- At 30 DAS of growth, T_3 recorded the lowest weed dry biomass (1.88 g m^{-2}) and it, was significantly superior to rest of the treatments except T_2 (1.97 g m^{-2}). The treatments T_9 (2.70 g m^{-2}), T_7 (3.21 g m^{-2}), T_8 (2.95 g m^{-2}) and T_{10} (3.09 g m^{-2}) were statistically at par with each other and significantly superior over weedy check (5.11 g m^{-2}). At 60 and 90 DAS, T_3 also produced the lowest weed dry biomass (5.04 g m^{-2}) and (4.89) was almost similar to T_2 (5.06 g m^{-2}) and (5.09 g m^{-2}), respectively. However, all control measure proves their superiority over weedy check in terms of weed dry matter at all stages of crop growth.

- Significantly higher value of N depletion by weeds was obtained under weedy check (34.63 kg ha^{-1}) than rest of the treatments, while the lowest value was obtained with T_3 (7.07 kg ha^{-1}) at 60 DAS. The treatment T_2 (7.53 kg ha^{-1}), T_5 (7.60 kg ha^{-1}), T_4 (7.83 kg ha^{-1}), T_8 (7.93 kg ha^{-1}), were at par with each other and significantly lowest values of nitrogen were depleted as compared to rest of the treatment. Similarly, at 90 DAS, application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (7.77 kg ha^{-1}) was obtained significantly lower value of nitrogen uptake by weeds followed by application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (8.17 kg ha^{-1}), T_4 (9.83 kg ha^{-1}), T_5 (8.13 kg ha^{-1}) and T_6 (7.93 kg ha^{-1}).

- The highest value of P depletion by weeds was obtained under weedy check (8.70 kg ha^{-1}), which was significantly higher over various weed control treatments. The lowest value of P depletion by weeds was recorded by T_3 (1.66 kg ha^{-1}) and it was almost similar to T_4 (1.99 kg ha^{-1}), T_5 (1.94 kg ha^{-1}), T_6 (1.76 kg ha^{-1}) and T_8 (1.95 kg ha^{-1}), while it was significantly lower as compared to T_1 (2.53 kg ha^{-1}), T_7 (2.60 kg ha^{-1}), T_9 (3.97 kg ha^{-1}), T_{10} (5.53 kg ha^{-1}) and weedy check (8.70 kg ha^{-1}) at 60 days stage. At 90 day stage, the uptake of P by weeds was minimum in T_3 (1.99 kg ha^{-1}) while, maximum in weedy check (9.42 kg ha^{-1}).

- Application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS recorded the lowest K-depletion (6.50 kg ha^{-1}), which was statistically at par with T_2 (6.99 kg ha^{-1}), T_6 (7.05 kg ha^{-1}), T_4 (7.28 kg ha^{-1}) and T_5 (9.97 kg ha^{-1}). The highest value of K-depletion by weeds was obtained under weedy check (29.68 kg ha^{-1}) and was significantly higher over various weed control treatments at 60 days stage. At 90 day stage, the uptake of potassium by weeds was maximum in weedy check (37.34 kg ha^{-1}) while, minimum in T_3 (7.56 kg ha^{-1}).

- Among the herbicidal treatments significantly lower weed index (7.25%) than T_1 (21.84%) and T_4 (27.21%) was recorded in imazethapyr @ 40 g a.i. ha^{-1} at 15 days after sowing and statistically at par with T_3 (8.59%), T_5 (12.50%) and T_6 (11.20%). However, T_2 recorded significantly lower weed index than rest of treatments. Weedy check recorded significantly higher weed index (40.53 %), than all other treatments under study.

- At 60 DAS, higher weed control efficiency (80.38 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (T_3) which was found statistically at par with T_2 (80.16), T_5 (78.80%) & T_6 (78.88%) while significantly higher than rest of treatments. Whereas, significantly lower weed control efficiency was noticed in imazethapyr @ 20 g a.i. ha^{-1} at 15 DAS as well as 30 DAS (71.17 and 77.94 %). At 90 days after sowing, significantly higher weed control efficiency (83.36 %) was noticed in imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (T_3) which was on par with the treatments of T_2 (80.52), T_5 (79.49) and T_6 (80.48) and significantly higher than T_1 (72.25) & T_4 (75.27).

- Lowest cost of cultivation was involved in weedy check (Rs. 25000 ha^{-1}). While, it was maximum in weed free plot (Rs. 40000 ha^{-1}) followed by pigeonpea + blackgram intercropping (Rs. 29650 ha^{-1}). The next best treatments with respect to lower cost of cultivation was noticed in imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS as well as at 30 DAS (Rs. 25940 ha^{-1}).

- Higher gross returns (Rs. 104639 ha^{-1}) was recorded with weed free plot and lower gross returns were obtained in weedy check (Rs. 62667 ha^{-1}). Among the herbicidal treatments, post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher gross return (Rs. 96999 ha^{-1}) than T_1 (Rs. 81853 ha^{-1}), T_4 (Rs. 76105 ha^{-1}) and statistically at par with T_3 (Rs. 95700 ha^{-1}), T_5 (Rs. 91505 ha^{-1}), T_6 (Rs. 93120 ha^{-1}) .

- Higher net returns (Rs. 71059 and Rs. 69440 ha^{-1}) with higher benefit cost ratio (2.74 and 2.64) were recorded with post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS and imazethapyr @ 60 g a.i. ha^{-1}, respectively at 15 DAS which was statistically at par with T_5 and T_6 (Rs. 65565 and 66860 ha^{-1}) in terms of net return and B:C ratio of 2.53 & 2.55, whereas it was significantly higher than the rest of the treatments.

- Among the various treatments, treatment of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher uptake 83.69, 14.20 & 14.30 kg ha^{-1} of N, P & K which was statistically at par with higher dose of imazethapyr *i.e.* 60 g a.i. ha^{-1} applied at 15 DAS having 81.11, 13.09 & 13.35 kg ha^{-1} of N, P & K uptake and T_5 in which 76.33, 12.33 & 12.73 kg ha^{-1} of N, P & K uptake was recorded. Nutrient uptake in T_2 was significantly higher than rest of treatments. However N, P & K uptake in each treatment was significantly higher than weedy check.

- Maximum and minimum uptake of 62.29, 11.77 & 88.15 and 31.81, 6.44 & 43.74 kg ha^{-1} of N, P & K was recorded in weed free and weedy check respectively. The higher uptake of P & K was obtained in T_2 10.84 and 71.32 kg ha^{-1} which was statistically at par with T_3 having uptake of 10.49 & 68.15 kg ha^{-1}, whereas N uptake in T_2 (55.92 kg ha^{-1}) was significantly higher than T_3 (46.81 kg ha^{-1}). The treatment of imazethapyr @ 40 g a.i. ha^{-1} recorded significantly higher uptake of nutrient (55.92, 10.84 & 71.32 kg ha^{-1}) than T_4 (38.66, 8.00 & 51.68 kg ha^{-1}) whereas P uptake of 10.84 kg ha^{-1} was statistically at par with higher dose of imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (10.18 kg ha^{-1}).

- The treatment of imazethapyr applied @ 40 g a.i. ha^{-1} at 15 DAS recorded significantly higher uptake 139.6, 25.04 & 85.62 of N, P & K in kg ha^{-1} by crop than T_4 (100.97, 18.13 & 61.45 kg ha^{-1}) and statistically at par with T_3 (127.92, 23.58 & 81.50 kg ha^{-1}) of N, P & K, respectively. The treatment T_2 recorded significantly higher uptake of N, P & K by crop than rest of the treatments. However, the significantly higher uptake of 154.41, 28.38 & 104.97 kg and lower uptake of N, P & K of 82.88, 14.59 & 52.32 kg ha^{-1} in weed free treatment and weedy check respectively.

- Available nitrogen was maximum (182.83 kg ha^{-1}) in intercropping of pigeonpea with blackgram which was statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (172.20 kg ha^{-1}), imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (168.10 kg ha^{-1}), imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS (180.37 kg ha^{-1}) and imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS (168.40 kg ha^{-1}). Available P_2O_5 was also highest (17.73 kg ha^{-1}) in intercropping of pigeonpea with blackgram which was statistically at par with T_1 (17.02 kg ha^{-1}) and T_3 (16.15 kg ha^{-1}). The available K_2O was higher (244.35 kg ha^{-1}) in imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS. However many of the treatments were statistically at par with each other.

CONCLUSION

Based on the results of the present investigation entitled “effect of weed management practices on growth and yield of pigeonpea”, the following inferences can be drawn:

1. Among the herbicidal treatments significantly higher plant height, dry matter accumulation and yield attributing characters were recorded in POE application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS, which was at par with imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS.

2. Seed yield recorded was higher due to adoption of each weed control treatments in comparison with weedy check due to effective control of weed. The percent increase in seed yield of pigeonpea in T_2 (imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS) were 18.6, 27.4, 6.0, 4.16, 18.2, 14.2, 18.9, 18.5 and 55.6 over treatments T_1 (imazethapyr @ 20 g a.i. ha^{-1} at 15 DAS), T_4 (imazethapyr @ 20 g a.i. ha^{-1} at 30 DAS), T_5 (imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS), T_6 (imazethapyr @ 60

g a.i. ha^{-1} at 30 DAS),T_7 (pendimethalin @ 750 g a.i. ha^{-1}), T_8 (pendimethalin @ 750 g a.i. ha^{-1} fb quizalofop-ethyl @ 50 g a.i. ha^{-1}, T_9 (pigeonpea+ blackgram intercropping), T_{10} (metribuzin @ 250 g a.i. ha^{-1} as PE) and T_{11} (weedy check), respectively. However, weed free condition recorded highest seed yield of 2725 kg ha^{-1}.

3. Uncontrolled growth of weeds led to 40.53% reduction in pigeonpea yield in comparison with weed free condition. Among the herbicidal treatments significantly lower weed index (7.25%) was recorded in application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS, which was statistically at par with application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (8.59%), imazethapyr @40 g a.i. ha^{-1} at 30 DAS (12.50%) and imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (11.20%). However, at 60 DAS higher weed control efficiency was recorded in imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (80.38), which was found statistically at par with imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS (80.16), imazethapyr @ 40 g a.i. ha^{-1} at 30 DAS (78.80 %) & imazethapyr @ 60 g a.i. ha^{-1} at 30 DAS (78.88 %). Similarly, significantly lower amount of N, P and K uptake by weeds was recorded in application of imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS which showed statistical parity with application of imazethapyr @ 40 g a.i. ha^{-1} at 15 days after sowing.

4. The highest net returns of Rs. 71059 ha^{-1} and benefit cost ratio of 2.74 was recorded with post-emergence application of imazethapyr @ 40 g a.i. ha^{-1} at 15 DAS, which was statistically at par with imazethapyr @ 60 g a.i. ha^{-1} at 15 DAS (Rs. 65565 ha^{-1} and 2.53).

As per the result obtained due to various weed control treatments, it is concluded that lower dose (40 g a.i. ha^{-1}) of imazethapyr applied as early post-emergence (15 DAS) proved most economical for controlling weeds in pigeonpea. Since the results are based on one-year experimentation, no definite recommendation can be made and it should be further validated to check its wider applicability under different climatic conditions.

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APPENDICES

Appendix: I Common cost of cultivation of pigeonpea (□ /ha)

	Particulars	**Quantity**	**Rate**	**Amount (in □)**
1.	Field preparation (One ploughing by cultivator, twice disc harrowing and one ploughing by cultivator followed by planking		□ 450 /hr	3000/-
2.	Seed and sowing			
	Cost of seed	20 kg	□ 80 /kg	1600/-
	Seed treatment (Chemical & manpower)			200/-
	Furrow and ridge making Manual seeding	8 labour	□ 150 /day/labour	1000/ 1200/-
3	Irrigation			0/-
		Nil	-	0/-
4.	Fertilizer application 20:50:0 :: NPK kg/ha			
	DAP	100 kg	□ 26 /kg	2600/-
	Labour used for fertilizer application	1 man days	□ 150 /day/labour	150/-
5.	Plant protection measures (Chemical+ manpower)			1000/-
6.	Harvesting Threshing, winnowing, cleaning	40 man days	□ 150 /day/labour	6000/-
7.	Drying & bagging(Cost of bag+ man days)			1000/-
8.	Rental value of land for crop season		□ 4000 /ha	4000/-
	Total cost			21750/-
	Interest on working capital @ 12.0 % per year Miscellaneous			2610.00 640.00
	Grand total			**25000.00**

Appendix: II.

Cost of cultivation in different weed control treatments (Rs. ha^{-1})

Treatments	Input	Quantity used	Cost of herbicide (Rs.)	Cost of man days (Rs.)	Total cost (Rs.)
T_1 -Imazethapyr @ 20g a.i./ha at 15 DAS	Pursuit	200 ml	320	300	620
T_2 -Imazethapyr @ 40g a.i./ha at 15 DAS	Pursuit	400 ml	640	300	940
T_3 -Imazethapyr @ 60g a.i./ha at 15 DAS	Pursuit	600 ml	960	300	1260
T_4 -Imazethapyr @ 20g a.i./ha at 30 DAS	Pursuit	200 ml	320	300	620
T_5-Imazethapyr @ 40g a.i./ha at 30 DAS	Pursuit	400 ml	640	300	940
T_6-Imazethapyr @ 60g a.i./ha at 30 DAS	Pursuit	600 ml	960	300	1260
T_7 -Pendimethalin @ 750g. a.i./ha as PE	Stomp	2497.5ml	1125	300	1425
T_8-Pendimethalin @ 750g. a.i./ha as PE+ Quizalofop-ethyl @ 50g. a.i./ha as POE	Stomp & Tergasuper	2497.5ml+ 1000 ml	2525	600	3125
T_9 -Pigeonpea+ blackgram intercropping	Seed & sowing Manpower involved in harvesting,threshing, cleaning	15 kg seed @ 60 Rs. 10 mandays for harvesting & 15 for threshing and cleaning @ 150 Rs/labour/day	No herbicide	900+1500 +2250	4650
T_{10} -Metribuzin @ 250 g. a.i./ha as PE	Sencor	357g	643	300	943
T_{11} -Weedy check	Nil			0	0
T_{12} -Weed free	Man days (100)			15000	15000