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Efficacy of pre- and post-emergence herbicides in rainy season greengram (*Vigna radiata*)

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ABSTRACT

A field study was conducted during *kharif* season of 2011 and 2012 to assess the efficacy of post-emergence application of Imazethapyr alone or in combination with pre-emergence herbicide Pendimethalin. Treatments comprised four doses of Imazethapyr (40, 60, 80 and 100 g/ha) alone and combination with Pendimethalin @ 1.25 kg/ha and Pendimethalin @ 1.25 kg/ha + manual weeding. The study reveals that the yield loss due to weed competition in *kharif* season greengram [*Vigna radiata* (L.) Wilczek] was to the tune of 62%. Weed control efficiency was highest in Pendimethalin @ 1.25 kg/ha + Imazethapyr @ 100 g/ha as pre- and post-emergence combination. Similar trend was also observed in plant biomass, nodulation and yield attributes. Grain yield (839 kg/ha), net return (₹ 16 060/ha) and B: C ratio (1.77) were also highest in Pendimethalin @ 1.25 kg/ha + Imazethapyr @ 100 g/ha. Thus, pre-emergence application of Pendimethalin @ 1.25 kg/ha followed by post-emergence application of Imazethapyr @ 100 g/ha at 25 days after sowing may be recommended for effective weed management in *kharif* season greengram.

Key words: Greengram, Imazethapyr, Pendimethalin, Post-emergence herbicide, Weed control efficiency.

In India, greengram [*Vigna radiata* (L.) Wilczek] is mainly cultivated during rainy (*kharif*) season (69% of total greengram area). The higher crop-weed competition is the primary reason for the poor productivity of rainy season greengram (410 kg/ha) in contrast to rabi/summer season greengram (620 kg/ha) (Kumar 2010). The loss of greengram yield due to weeds ranges from 60- 80% across the different agro-climatic conditions (Dungarwal *et al*. 2003, Brij Nandan *et al*. 2011). In recent past, lot of efforts have been made to find out an economical weed control techniques in pulses.

Timely control of weeds is essential for higher yield of greengram. The critical period of weed management in greengram is 3-7 weeks after sowing (Senanayake and Pathirana 1987, Utomo 1988/1989). Pendimethalin ($C_{13}H_{19}N_3O_4$) is an herbicide of aniline group used as pre-emergence to control initial flush of weeds in most of pulses including rainy season mungbean. It controls initial flush of annual grasses and some of the broadleaf weeds (Khaliq *et al*. 2002, Singh 2011). Pendimethalin inhibits cell division and cell elongation in susceptible plants. However, sole application of Pendimethalin is not sufficient to control the diverse group of weed flora (mainly broadleaf weeds) in *kharif* season greengram crop. Further, the effectiveness of Pendimethalin as pre-emergence also neutralized due to rains in *kharif* season. Therefore, Pendimethalin along with a manual weeding at 25-30 days after sowing (DAS) are usually recommended (Khaliq *et al*. 2002, Singh 2011, Akter *et al*. 2013). Manual weeding is effective in weed control, but it is uneconomical due to higher labour cost (Cheema *et al*. 2003, Chand *et al*. 2004). Due to higher cost and non-availability of farm labours on time, it becomes an urgent need to sort out an efficient broad spectrum post-emergence herbicide for rainy season greengram crop to maximize productivity and replace manual weeding (Kumar 2010). Kundu *et al*. (2011) recommended Quizalofop-ethyl @ 50 g/ha at 15 DAS + manual weeding at 30 DAS in mungbean. Similarly, post-emergence application of Imazethapyr is being recommended in soybean (Meena *et al*. 2011, Jadhav and Gadade 2012). Imazethapyr ($C_{15}H_{19}N_3O_3$) belongs to the chemical group of imidazolinone herbicides, which is one of the most promising classes of commercial herbicides, and its mechanism of action is the inhibition of branched-chain amino acid biosynthesis. In the initial screening trials at Kanpur during 2009-2010, it has shown promising results in rainy season pulses like pigeonpea, greengram and blackgram (Kumar 2010). However, no systematic study was conducted to see the efficacy of post-emergence application of Imazethapyr in rainy season greengram. Therefore, the present study was conducted to assess the field efficacy of post-emergence application of

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Imazethapyr alone and in combination with pre-emergence application of Pendimethalin in rainy season greengram.

MATERIALS AND METHODS

A field experiment was conducted during rainy season of 2011 and 2012 at New Research Farm of ICAR-Indian Institute of Pulses Research, Kanpur, India (26°27' N, 80°14' E and 152.4 m above MSL). Weekly rainfall pattern during crop growing season was recorded from meteorological station located at the Institute. The soil characteristics of the experimental site before start of the study are given in Table 1. The soil of experimental site comes under the taxonomical class Typic Usrtochrept with sandy loam texture. The climate is tropical sub-humid, receives annual rainfall of 722 mm and mean annual maximum and minimum temperature is 33.0 and 20.0°C, respectively.

Treatments comprised four different doses of post-emergence (POE) application of Imazethapyr (40, 60, 80 and 100 g/ha) alone, and in combination with pre-emergence (PE) application of Pendimethalin @ 1.25 kg/ha and Pendimethalin @ 1.25 kg/ha (PE) + manual weeding at 25-30 days after sowing (DAS). Thus, treatments are - T1: Imazethapyr @ 40 g/ha (POE); T2: Imazethapyr @ 60 g/ha (POE); T3: Imazethapyr @ 80 g/ha (POE); T4: Imazethapyr @ 100 g/ha (POE); T5: Pendimethalin @1.25 kg/ha (PE) + Imazethapyr @ 40 g/ha (POE); T6: Pendimethalin @1.25 kg/ha (PE) + Imazethapyr @ 60 g/ha (POE); T7: Pendimethalin @1.25 kg/ha (PE) + Imazethapyr @ 80 g/ha (POE); T8: Pendimethalin @1.25 kg/ha (PE) + Imazethapyr @ 100 g/ha (POE); T9: Pendimethalin @1.25 kg/ha (PE) and T10: Pendimethalin @ 1.25 kg/ha (PE) + manual weeding at 25-30 DAS (recommended practice). Weedy and weed free plots were also maintained to work out the weed control indices and yield loss due to weeds. The experiment was laid out in randomized block design (RBD) with three replications. Greengram variety Samrat was used for the study which matured in 60 days. Greengram was sown 20-22 July in both the years. Plant to plant distance was maintained ~10 cm in a row spacing of 30 cm. Recommended dose of fertilizer 20:60:40:20 kg NPKS/ha was applied through urea, diammonium phosphate, muriate of potash and agricultural grade sulphur at the time of field preparation. Optimum soil moisture was ensured at the time of sowing for proper germination and to attain desired plant stand per unit area. Pendimethalin was applied as pre-emergence within 24 hr of sowing and Imazethapyr was applied at 24-25 DAS. Since greengram was grown during rainy season and soil moisture was sufficient to complete its life cycle, no irrigation was applied to the crop. Plant protection measures were followed uniformly in all treatments as per recommendation for the region.

Table 1 Initial soil physico-chemical properties (0-15 cm)

Properties	Values
Texture	Sandy clay loam
Bulk density (g/cm)	1.42
pH (1:2.5 soil : water)	7.4
CEC [cmol (p^+)/kg]	13.5
EC (dS/m)	0.14
Soil organic C (%)	0.43
Available N (kg/ha)	242
Olsen- P (kg/ha)	11.3
Available K (kg/ha)	173

An iron square of size 0.25 m^2 was used to record observation on weed numbers and weed dry weight through random sampling in each plot before (23 DAS) and after (40 DAS) application of post-emergence herbicide Imazethapyr. Weeds of each sample were counted species wise and the data of total number of weeds was subjected to square root transformation ($\sqrt{X} + 0.5$) before statistical analysis. For dry weight, species wise weed samples of each treatment were dried in the sun and then in an oven at 70°C for 72 hr. For plant observations, five random plants from each plot were selected at 25 and 40 DAS to record observation on nodulation and plant growth parameters. Similarly, five random plant samples from each treatment were collected from each plot at the time of harvest for recording observations on plant growth and yield attributing characters.

Many indices are used to assess the effectiveness of weed management practices. Weed control efficiency (WCE), one of the commonly used indices can be defined as the percentage reduction in weed population due to applied weed management practice over control. It can be worked out by using weed population present in control (weedy check) and treatment plot (Mani *et al*. 1973).

$$WCE = \frac{WPC - WPT}{WPC} \times 100 \quad \text{-Eq. 1}$$

where, WPC: Weed population (number/m) in control plot, WPT: Weed population (number/m) in treatment plot.

Weed population sometimes do not give better picture of weed controlled under weed management treatment. Therefore, it is advisable to use weed control index (WCI) in place of WCE. It can be worked out by using same formula replacing weed population in treatment by weed dry weight (Mishra and Tosh 1979).

$$WCE = \frac{WDC - WDT}{WDC} \times 100 \quad \text{-Eq. 2}$$

where, WDC: Weed dry matter/m in control plot, WDT: Weed dry matter/m in treatment plot.

Weed index (WI) is based on crop yield. It can be defined as the percent reduction in yield due to the presence of weeds in comparison to weed free treatment. It can be calculated as follows:

$$WI = \frac{YF - YT}{YF} \times 100 \quad \text{-Eq. 3}$$

where, YF: Grain yield from minimum weed competition plot, i.e. weed free plot, YT: Grain yield from treatment plot.

The economics of treatments was computed on the basis of prevailing market price of inputs and outputs in Indian rupees (Approx. 62 rupees = 1 US$) for each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizer and seed. The cost of labour incurred in performing different operations was also included. Net return (NR) was calculated as:

Net return= Gross return – Cost of cultivation -Eq. 4

Each sample was analyzed in triplicate and the values were then averaged. Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following SPSS software based programme, and the treatment means were compared at P≤0.05 level of probability using t-test and calculating LSD values.

RESULTS AND DISCUSSION

The major weeds present at the experiment site were *Cyperus rotundus, Cyprus iria, Digera arvensis, Phyllanthus niruri* and *Commelina benghalensis*. The diversity and dominance of weeds followed a similar pattern during both the years. *Cyperus* sp. was the most dominant weed with relative density of 64% followed by *Digera arvensis* (15%). However, relative dry weight was highest for *Digera arvensis* (39%) followed by *Cyperus* sp. (30%)**.** The higher relative dry weight of *Digera arvensis* was due to higher dry biomass per plant than other weeds.

Weed destiny and weed dry weight

Weed density at 23 and 40 DAS was highest in *Cyperus rotundus* followed by *Digera arvensis* and *Commelina benghalensis* (Table 2). In case of only Pendimethalin application (T9), density of *Digera arvensis* and *Phyllanthus niruri* increased at 40 DAS in comparison to 23 DAS, however, decreased in *Cyperus*. The application of Imazethapyr @ 100 g/ha (T4 and T8) drastically reduced the density of all the major weeds. The weed density after application of Imazethapyr @ 100 g/ha was mainly governed by *Cyperus* population. In parallel to the weed density, the weed dry weight at 40 DAS in Pendimethalin application was highest in *Digera arvensis* followed by *Commelina benghalensis*. The dry weight increased for all weeds at 40 DAS in comparison to 23 DAS and the maximum increase in dry weight was recorded in *Digera arvensis* (436%), which contributed significantly to total weed dry weight. Whereas, decrease in weed dry weight was observed in most of the weeds after application of Imazethapyr @ 100 g/ha. Imazethapyr was found most effective against *Digera arvensis* even at lower dose of 40 g/ha. Thus, *Digera arvensis* was totally controlled with post-emergence application of Imazethapyr at all doses. Yellowing of the leaves and stunted growth in *Cyperus* was observed with application of Imazethapyr @ 100 g/ha. In the present study, only partial control of *Cyperus* was achieved with Imazethapyr application thus contributed higher density and dry weight

Table 2 Density and dry weight of weeds under different weed management practices during 2012

Treatment	Weed density (number/m)								Weed dry weight (g/m)							
	Cyperus sp.		*Digera arvensis*		*Commelina benghalensis*		*Phyllanthis niruri*		*Cyperus* sp.		*Digera arvensis*		*Commelina benghalensis*		*Phyllanthis niruri*	
	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS	23 DAS	40 DAS
T1	327	259	38	0	47	53	52	32	15.5	24.4	25.1	0.0	15.9	25.4	2.0	4.3
T2	284	301	49	0	28	19	40	35	11.5	26.2	24.4	0.0	16.0	10.8	2.0	2.6
T3	252	245	48	0	49	29	19	7	10.1	18.5	35.4	0.0	29.2	26.2	1.0	0.5
T4	481	287	93	0	35	20	56	9	18.1	24.3	18.2	0.0	8.8	20.7	1.4	1.3
T5	320	263	43	0	47	24	43	49	13.4	27.5	28.5	0.0	16.8	16.9	1.3	3.8
T6	167	216	53	0	20	28	40	34	6.6	28.1	15.5	0.0	11.6	20.2	1.8	3.3
T7	117	168	64	0	23	13	32	13	6.8	24.3	26.0	0.0	8.4	10.5	1.4	2.5
T8	253	165	41	0	25	7	24	11	13.5	22.1	16.6	0.0	17.3	8.1	1.1	3.6
T9	188	160	44	81	13	21	31	40	11.6	17.5	15.1	80.6	6.7	33.2	1.8	3.2
T10	120	100	43	0	16	9	53	15	4.0	11.6	8.9	0.0	6.8	1.3	0.5	0.8
CD (P=0.05)	80	89	18		8	6	10	11	4.0	4.9	6.7		5.6	5.6	0.5	0.8

of this weed at 40 DAS in all the treatments.

Weed control indices

Weed control efficiency (WCE) was worked out on the basis of weed density. Weed control efficiency was highest in T8 (68.6%) followed by T10 (63.5%) and lowest in T1 (2.1%). Weed control index (WCI) followed a similar trend with highest value in T8 (84.3%) followed by T10 (82.5%) (Table 3). Generally, during rainy season manual weeding become difficult and weeds are removed by cutting from soil surface by hand tools like *khurpi* or sickle due to wet soil. Thus, fast regeneration of weeds after weeding reduced the efficiency of manual weeding. However, herbicide (Imazethapyr) treatments effectively control the weeds and also prevents the weeds to regenerate. Thus, higher values of WCE and WCI were observed in treatment T8 and T10. Weed index means percent reduction in yield due to presence of weeds. Thus, more weeds mean more crop-weed competition and more reduction in grain yield of greengram. Thus, lowest value of weed index (2.6%) was recorded in T8 followed by T7 (6.2%), whereas highest value in T9 (60.2%). Similar findings were also reported by Singh (2011).

Nodulation and plant growth

In the present study, nodules number and dry weight after application of Imazethapyr were declined in most cases except T8. Where, an enhancement in nodules number and nodules dry weight was observed in T10. The improvement in nodules number and nodules dry weight under T8 was 16% and 18.7% (Table 4). The decline in nodules number and nodules dry matter were mainly due to poor weed control which resulted in higher crop-weed competition and poor plant growth (Raman and Krishnamoorthy 2005 Chattha *et al*. 2007). It appears from the study that nodulation in

Table 3 Nodulation and weed control efficiency index under different weed management practices at 40 days after sowing (pooled mean of two years)

Treatment	Weed density (Number/m)	Weed dry weight (g/m^2)	WCE (%)	WCI (%)	WI (%)
T1	18.4(320)	85.4	3.2	54.1	36.9
T2	17.4(291)	66.3	13.2	64.1	29.7
T3	15.4(223)	54.8	29.7	69.0	20.3
T4	14.3(190)	52.1	44.6	69.7	13.7
T5	19.7(263)	44.1	21.7	75.5	28.9
T6	15.9(236)	45.3	28.2	74.7	18.9
T7	12.4(141)	38.8	54.2	79.0	6.2
T8	10.8(106)	27.5	68.6	84.3	2.6
T9	17.8(301)	185.1	27.9	6.8	60.2
T10	11.3(116)	38.5	63.5	82.5	7.0
CD (P=0.05)	3.0	23.1			

*WCE: Weed control efficiency; WCI: Weed control index; WI: Weed index.

Table 4 Effect of weed management practices on nodulation and plant growth parameters of rainy season greengram (pooled mean of two years)

Treatment	Nodules number (/plant)		Nodules dry weight (g/plant)		Plant height (cm)			Above ground plant biomass (g/plant)			Root biomass (g plant)		
	25 DAS	40 DAS	25 DAS	40 DAS	25 DAS	40 DAS	Harvest	25 DAS	40 DAS	Harvest	25 DAS	40 DAS	Harvest
T1	27. 8	22.6	0.028	0.023	20.7	51.5	50.4	1.49	7.60	12.30	0.22	0.35	0.57
T2	30.6	24.5	0.042	0.028	21.0	47.1	46.0	1.62	7.89	13.42	0.27	0.37	0.57
T3	17.8	17.2	0.021	0.020	20.4	46.4	46.8	1.34	7.97	15.08	0.27	0.37	0.59
T4	22.6	18.3	0.031	0.022	19.7	44.9	45.0	1.41	8.15	13.96	0.27	0.38	0.60
T5	24.3	24.9	0.028	0.023	18.7	45.4	47.6	1.37	8.42	14.19	0.22	0.36	0.61
T6	25.8	26.7	0.037	0.023	16.3	45.7	45.4	1.29	9.55	13.54	0.25	0.43	0.58
T7	21.4	23.5	0.034	0.030	17.3	47.8	47.2	1.07	9.40	14.57	0.20	0.49	0.60
T8	24.8	28.8	0.032	0.038	16.8	47.0	45.5	1.35	9.77	15.21	0.20	0.52	0.64
T9	23.2	15.7	0.025	0.018	20.6	50.7	51.1	1.38	7.59	13.32	0.24	0.43	0.59
T10	19.0	22.9	0.027	0.029	18.1	47.6	46.7	1.56	8.18	16.63	0.20	0.37	0.58
CD (P=0.05)	5.8	3.2	0.008	0.006	1.9	3.2	3.6	0.10	1.20	1.46	0.06	0.08	NS

*DAS: Days after sowing; NS: Non-significant

greengram remained unaffected due to chemical action of Imazethapyr.

Crop-weed competition mainly affected the plant height, i.e. higher competition between crop and weeds leads to taller and thinner plants. Therefore, at 25 DAS comparatively taller mungbean plants were observed in treatments without pre-emergence application of Pendimethalin (T1-T4). At 40 DAS and at harvest, taller plants (51.5 and 51.1 cm) were observed in T1 and T9, respectively.

The above ground plant biomass at 25 DAS was higher in treatments with Pendimethalin followed by manual weeding or Imazethapyr. Similarly, at 40 DAS and harvest, higher above ground plant biomass was recorded in treatments with Imazethapyr and manual weeding. This might be due to poor crop-weed competition in treatments applied with post-emergence herbicide Imazethapyr and manual weeding. Thus, highest per above ground plant biomass was observed in T8 and T10 at 40 DAS and at harvest, respectively. Similar to above ground plant biomass, root biomass at 25 DAS was higher in treatments without Pendimethalin; however, at 40 DAS and at harvest a reverse trend was noticed. The highest value of root biomass at 40 DAS (0.52 g/plant) and at harvest (0.64 g/plant) was recorded in T8 and lowest in Imazethapyr @ 40 g/ha (0.35 and 0.57 g/plant, respectively). Poor crop-weed competition and better availability of resources to greengram plants in treatments T8 and T10 might be the reason for higher above ground plant biomass and root biomass.

Yield attributes and yield

Number of pods per plant, 1000 seed weight and harvest index were considerably influenced due to weed management practices (Table 5). Significantly highest pod number/plant (41.5), 1000 seed weight (26.2 g) and harvest index (29.8%) were recorded in T8 followed by T10 and the lowest value in T9. Poor crop-weed competition and better growth and development of crop plants under post-emergence application of Imazethapyr @ 100 g/ha and manual weeding might be the reason for higher values of yield attributes in greengram. Similar findings were also reported by Awan *et al*. (2009) and Madukwe *et al*. (2012).

The highest greengram seed yield was recorded in T7 (786 kg/ha) and T10 (919 kg/ha) during 2011 and 2012, respectively and lowest under pre-emergence application of T9 (335 and 348 kg/ha during 2011 and 2012, respectively).

Table 5 Yield attributes, yield and economics of greengram under different weed management practices

Treatment	Pods/plant	Seeds/pod	1000 seed weight (g)	Harvest index (%)	Yield (kg/ha)			Gross return (₹/ha)	Net returns (₹/ha)	B:C ratio
					2011	2012	Mean			
T1	21.0	10.9	23.5	16.9	569	507	538	23 672	6 022	1.34
T2	27.7	9.5	22.1	21.6	555	657	606	26 664	8 614	1.48
T3	31.1	9.5	24.5	21.6	688	676	682	30 008	11 558	1.63
T4	30.6	10.4	24.9	26.7	724	757	741	32 604	13 754	1.73
T5	32.1	9.5	25.7	23.7	523	709	616	27 104	7 454	1.38
T6	34.3	9.8	23.5	24.8	653	743	698	30 712	10 662	1.53
T7	38.3	10.8	22.7	27.1	786	823	805	35 420	14 970	1.73
T8	41.5	9.3	26.2	29.8	780	897	839	36 916	16 066	1.77
T9	19.9	10.5	24.0	16.0	335	348	342	15 048	-3 302	0.82
T10	37.0	10.8	24.5	28.2	691	919	805	35 420	11 670	1.49
CD (P=0.05)	5.3	NS	2.1	3.7	142	131				

* NS: Non-significant

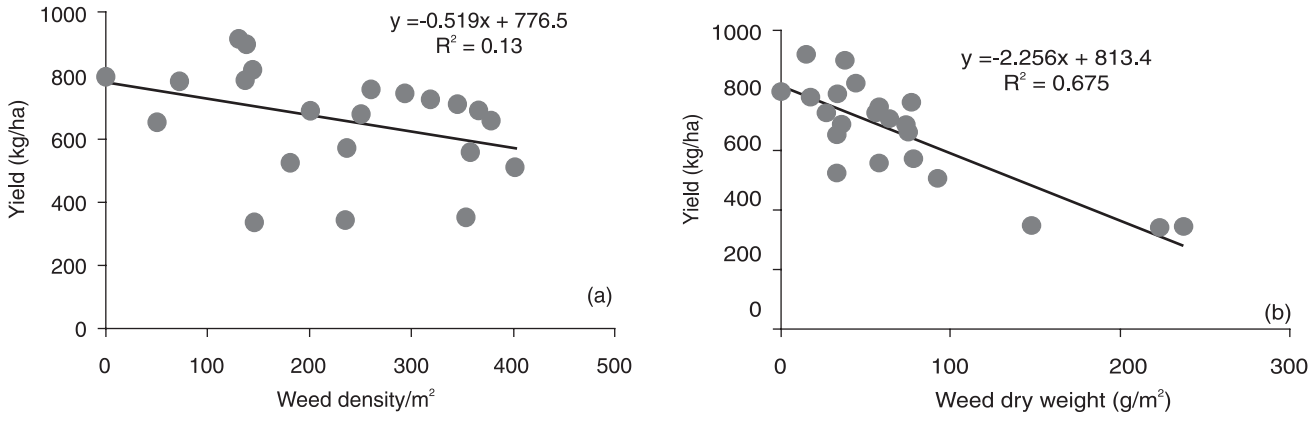

Fig 1. Relationship between weed density (a) and weed dry weight (b) and greengram yield

Based on two years yield data, highest mean grain yield of greengram (839 kg/ha) was recorded in T8; however, the lowest under T9 (342 kg/ha). Better plant and root growth, higher yield attributes and less crop-weed competition might be the reasons behind the higher mean grain yield of greengram under T8 and T10. Increase in grain yield due to efficient weed management practices was also reported by Singh *et al*. (1991), Chand *et al*. (2004), Singh (2011) and Akter *et al*. (2013). It is also evident from Fig 1 (a and b) that greengram seed yield is negatively correlated with weed density and the weed dry weight. It is also clear that weed dry weight had negative impact (R^2 = 0.6757) on grain yield than weed density (R^2 = 0.13).

Economics

Higher seed yield under T8 and T10 resulted in higher gross return (Table 5). The highest gross return was recorded in T8 (₹ 36 916/ha) followed by T10 (₹ 35 420/ha) and T7 (₹ 35 420/ha). However, highest net return was recorded in T8 (₹ 16 060/ha) followed by T7 (₹ 14 970/ha). Higher cost of manual weeding leads to high cost of production which resulted in less net profit in case of T10 (₹ 11 670/ha). A similar trend was also recorded in B: C ratio with highest value in T8 (1.77) followed by T7 (1.73). The highest net return T8 was mainly due to better weed control at low investment and higher yield (Kumar *et al.* 2010, Prakash *et al*. 2006, Singh 2011).

Heavy infestation of diverse group of weeds is normally observed during rainy season in pulse crops. In present investigation, maximum weed control efficiency, greengram seed yield and net returns were recorded in treatment T8 and T10. Thus, from above study Pendimethalin @ 1.25 kg/ha (PE) + Imazethapyr @ 100 g/ha (POE) may be recommended for effective weed management in rainy season greengram. Application of post-emergence Imazethapyr @ 100 g/ha may also help to solve the problem of non-availability of farm labours for weeding operation on time and at affordable price.

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