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Effect of Herbicides and their Combination on Growth, Yield and Economics of Summer Greengram

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ABSTRACT

A field study regarding the effect and efficacy of herbicides and their combinations on weed and crop growth, crop yield and crop economics of summer green gram was conducted at Lovely Professional University, Phagwara, Punjab during summer season of 2021-22 in sandy loam soil. Least weed count was recorded with regularly hand weeded (weed free) plot followed by the treatment which was weeded at 20 days and 40 days after sowing (DAS). Under herbicidal treatments, pendimethalin (stomp) 1 kg a.i. ha^{-1} along with hand weeding (HW) @ 20^{th} day resulted in lowest weed density also imazethapyr (pursuit) 75 g a.i. ha^{-1}in combination with quizalofop (turga super) 50 g a.i. ha^{-1}showed statistically similar results. Regular hand weeding (weed free) showed the maximum plant height (66.71cm), which was comparable with pendimethalin (stomp) 1 kg a.i. ha^{-1} + hand weeding (HW) @ 20^{th}day (64.37cm) and imazethapyr (pursuit) 75 g a.i. ha^{-1} + quizalofop-ethyl (turga super)50 g a.i. ha^{-1} (63.67cm). Highest seed yield was obtained under regular hand weeding (weed free) (1.18 t/ha) this result was on par with hand weeding (HW) @ 20^{th} and 40^{th}day after sowing(DAS) (1.17 t/ha) which was also comparable to pendimethalin (stomp)1 kg a.i ha^{-1} + hand weeding @ 20 days after sowing (1.12 t/ha) and imazethapyr (pursuit) 75 g a.i ha^{-1} + quizalofop-ethyl (turga super) 50 g a.i ha^{-1} (1.10 t/ha). Highest Benefit cost ratio (1.58) obtained with the application of imazethapyr (pursuit) 75 g a.i ha^{-1}along with quizalofop-ethyl (turga super) 50 g a.i ha^{-1}.

Key words: *Green gram, Imazethapyr, Hand weeding, Herbicides, Weed indices, Weed management*

Introduction

In India, Green gram (*Vigna radiate* L. Wilczek) is the fourth important legume crop produced after bengal gram (Chickpea), pigeonpea (arhar) and blackgram (Singh and Singh, 2020). Green gramis rich source of proteins (25%) (Walia *et al*., 2011), apart from that, sprouts contain ascorbic acid, rhiboflavin and thiamine (Das, 2013).

Since it is a short duration crop, it is purposefully used in cropping system which provide an extra income to the farmers. In north India, this crop is raised in both *kharif* and summer and in south and south west part it is grown as *rabi* season crop. In the country, moongbean is grown in4606.95 M (million) ha area with an annual produce of 2447.63 M(million) tonnes, while in Punjab it is produced in an area of 22.84 M (million) ha with an yearly production of 20.16 M (million) tonnes (Anonymous, 2021).

Having this much potential the crop is unable to yield it to its fullest because of certain biotic and abiotic factors. Amongst the biotic factors, weed is one of the restricting factors for green gram production as weeds act as major competitor for vital nutritional elements like N,P,K, water, space, light and thus

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reducig the potential yield (Singh and Singh 2020). Therefore effective measures must be taken in order to control weed population in fields so as to reduce yield loss. In Punjab under irrigated areas the yield loss due to weed ranges from 31-58% (Buttar *et al.*,2006; Kaur *et al*., 2009; Singh *et al*., 2014; Kaur *et al*., 2016). While Punia *et al*. (2004) reported grain yield reduction of a range from 23.5- 45.8%.

Since manual weeding is found to be labour intensive, time taking and costly affair, therefore alternative ways such as spraying of pre and post emergent herbicide is required for controlling weed population (Singh *et al*., 2017 and Chaudhary *et al*., 2020). Initial 15-30 days after sowing (DAS) are contemplated as the crucial period for crop - weed competition and a yield reduction of 25-50% is expected during this period, if field is not kept weed free (Walia, 2014). So there is a need to explore herbicidal control of weed in moong bean. Keeping this objective in view, the present experiment has been designed. In this experiment different herbicides and their combinations based on time of application are selected and their effectiveness on weed control, yield and growth has been studied.

Materials and Methods

Experimental field location

The studypertaining to efficacy of herbicides on weed control in green gram was carried out in summer *(Zaid*) season, in the year 2021-22 at agronomy field of Lovely Professional University, Phagwara, Punjab. The experimental site was at an elevation of 234 metre above MSL (mean sea leve)l and located in a latitude of 31.25° North and longitude 75.77° East. This place represents central agro-climatic zone of Punjab. The overall area of the experimental field was 626.04 m^2 with uniform topography. Field soil's Physico-chemical propertieswere analysed before the conduct of the experiment. The soil was found to be sandy loam with pH 7.23 Available nitrogen (125.44 kg ha^{-1}) and phosphorus (17.67 kg ha^{-1}) were found to be low in the soil, while potassium availability (168.54 kg ha^{-1}) found to be in optimum range.

Treatment details

TMB 37 variety of summer green gram was sown @ 30 kg ha^{-1} by maintaining a spacing of 22.5 x 5cm. Ten treatments were laid out in a randomised block design (RBD). The treatment includes pendimethalin - pre emergence (PE)@ 1kg a.i ha^{-1}, pendimethalin - pre emergene (PE) @ 1kg a.i ha^{-1} + 1 hand weeding (HW) @ 20 DAS, quizalofop-p ethyl- post emergence (PoE) @ 50g a.i ha^{-1}, imazethapyr- post emergence (PoE) @ 75g a.i ha^{-1}, pendimethalin- pre emergence (PE) 1kga.i ha^{-1} + quizalofop- post emergence (PoE) @ 50g a.i ha^{-1}, pendimethalin- pre emergence (PE) 1kg a.i ha^{-1} + imazethapyr- post emergence (PoE) 75g a.i ha^{-1}, imazethapyr- post emergence (PoE) @ 75g a.i ha^{-1} + quizalofop - post emergence (PoE) @ 50g a.i ha^{-1}, two hand weeding (HW) at 20 and 40 days after sowing (DAS), unweeded/control, regularly hand weeded (weed free) plot, in gross plot area of 5cm x 3 cm, which was replicated thrice. Knapsack sprayer having flat fan nozzle (20ml)was used to spray respective herbicides. Hand weeding was performed as mentioned using *khurpi*.

Sowing and crop management

After the harvest of previous crop, the land was thoroughly ploughed twice with the help of disc plough, followed by repeated harrowing. The land was, and then levelled using a plank to bring the soil to fine tilth. The seeds of variety TMB-37 (PAU recommended) were sown by maintaining spacing of 22.5cm x 5 cm on 18th April 2022. During the time of sowing, recommended doses of fertilizers (N: P: K- 12.5:40:0 kg ha^{-1}) were applied. Urea and single super phosphate (SSP) were applied as the source of nitrogen, phosphorus respectively. Total five irrigations were provided covering the critical stagesof irrigation, pre flowering and pod formation. Except of weeding operations all the other crop handling practices were followed in accordance to the recommendation of PAU (Punjab Agricultural University) package of practice -2021-22. The crop was harvested on 6th July 2022.

Observations on crop and weeds

Weed indices

Weed index (WI)

It indicatesdecline in crop yield due to weed competition, as compared to regularly hand weeded (weedfree) plots.

$$\text{Weed index (WI)} = \frac{A - B}{B}$$

A= yield from hand weeded (weed free) plot

B = yield from treatment applied plot

Least the weed index, most efficient the herbicide in controlling weeds.

Weed control efficiency (WCE) %

This determines the decline in dry mass of weeds when treated with herbicide, compared to un-weeded plot. Higher WCE, better is herbicidal treatment.

$$WCE\ (\%) = \frac{C - D \times 100}{D}$$

C= dry matter (DM) of weeds in un-weeded plot
D = dry matter (DM) of weeds in treated plots
Herbicide efficiency index (HEI) %

$$HEI = \frac{(E - F) \times G \times 100}{F \times H \times 100}$$

E= Yield in treated plot
F= yield inun-weeded/ control plot
G= weed weight in un-weeded/ control plot
H= weed weight in treated plot

Results and Discussion

Weed Flora

During the entire conduct of the study, a complex weed flora has been identified and were broadly classified as broad leaved weeds, narrow leaves weeds/grasses and sedges. Among the weeds identified broad leaved weeds were, *Amaranthus viridis, Trianthema portulacastrum, Sinapis arvensis*, *Digera arvensis Parthenium hysterophorus* and *Euphorbia hirta*. *Cyperus rodundus* among sedges. Narrow leaved weeds were *poa annua, Echinochloa crusgalli, Dactyloctenium aegyptium* and *Digitaria sanguinalis*.

Weed density

All the weed management practices controlled the weeds significantly when compared to the control plot (unweeded). During the first 15-20 DAS the plots treated with pendimethalin (PE) @ 1kg a.i ha^{-1}(T_1, T_2, T_5, T_6), effectively controlled the weeds by preventing its emergence and thus providing protection during the initial critical days of crop-weed competition. Pendimethalin (PE) @ 1 kg a.i ha^{-1} (T_1) recorded lower density of both narrow (2.3) and broad leaved weeds (2.3) during the first 15 DAS. The total number of weeds recorded were (4.49) against the control plot which recorded (8.03) during the first 15 DAS. Whereas regularly hand weeded plot (T_{10}) recorded lowest count of narrow (0.9), broad leaved weeds (0.7) and sedges (0.9) during 15 DAS. At 30th day observation, post emergence (PoE) spray of quizalofop-p ethyl @ 50g a.i ha^{-1} (T_3) and imazethapyr @ 75 g a.i ha^{-1} (T_4) effectively suppressed the later flush of weeds. However it was observed that quizalofop-p ethyl (PoE) @ 50 g a.i ha^{-1}, was more efficient in managing narrow leaved weeds (3.0) than broad leaved weeds (4.8) whereas imazethapyr (PoE) @ 75 g a.i ha^{-1} controlled both narrow leaved (2.5) and broad leaved (3.1) weeds. The sequential application of quizalofop-p ethyl (PoE) @ 50g a.i ha^{-1} after pendimethalin (PE) @ 1 kg a.i ha^{-1} (T_5) and imazethapyr (PoE) @ 75 kg a.i ha^{-1} after pendimethalin @ 1 kg a.i ha^{-1} (T_6) effectively controlled weed at both 15 DAS and 30 DAS owing to the fact that pendimethalin prevented growth of weeds and protected field during the initial days, while the weeds which emerged later were managed by the application of post emergence (PoE) herbicide, at 30 DAS, pendimethalin (PE) 1kg a.i ha^{-1} +quizalofop (PoE) @ 50g a.i ha^{-1} recorded a total of 4.98 weeds m^{-2}, while pendimethalin (PE) 1kg a.i ha^{-1} + Imazethapyr (PoE) 75g a.i ha^{-1} recorded 4.49 total weeds m^{-2}. It was observed during the experiment that, combinational application of imazethapyr (PoE) @ 75g a.i ha^{-1} and quizalofop-p ethyl (PoE) @ 50g a.i ha^{-1} was more efficient in controlling later emerged grasses (2.0) and broad leaved weeds (2.3). At harvest, regularly hand weeded plot (weed free) remained superior by maintaining the lowest number of all types of weeds (1.18) this was followed by hand weeding (HW) at 20 and 40 days after sowing (DAS) (3.48). Under the herbicide treatments, pendimethalin (PE) @ 1kg a.i ha^{-1}along with hand weeding (HW) @ 20 days after sowing (DAS) was observed to be most effective by maintaining lesser number of weeds (5.93). It may be attributed to the fact that hand weeding @ 20 DAS removed all types of weeds (grasses, sedges and broad leaved weeds). Also it was noted that, combinational application of imazethapyr (PoE) 75g a.i ha^{-1} in combination with quizalofop (PoE) 50g a.i ha^{-1} maintained similar kind of weed density (6.15) as former treatment. The highest weed density (9.8 at harvest) at every stage of crop growth was obtained under unweeded/control plot which was followed by Pendimethalin (PE) @ 1kg a.i ha^{-1} (7.99 at harvest) (all figures are represented in Table 1). Alike observations were reported by Poornima *et al*. (2018) and Ramesh (2016).

Growth parameters

At harvest, the maximum plant height (66.71cm),

Table 1. Weed density at 15, 30 DAS and at harvest. (**Note:** the numbers in parentheses are original values, which is transformed to x + 0.5

Treatments	WEED COUNT											
	15 DAS				30 DAS				At Harvest			
	Broad	Grasses	Sedges	Total	Broad	Grasses	Sedges	Total	Broad	Grasses	Sedges	Total
Pendimethalin (PE)@ 1000g ha^{-1}	(5.0)	(4.7)	(10.0)	(19.7)	(9.0)	(8.0)	(11.3)	(28.3)	(26.0)	(24.0)	(13.3)	(63.3)
	2.3	2.3	3.2	4.49	3.1	2.9	3.4	5.37	26.5	4.9	3.7	7.99
Pendimethalin + 1 HW @ 20 DAS	(5.0)	(5.3)	(10.0)	(20.3)	(0.3)	(0.7)	(1.3)	(2.3)	(11.3)	(11.0)	(12.3)	(34.7)
	2.3	2.4	3.2	4.55	0.9	1.1	1.3	1.66	11.8	3.4	3.6	5.93
Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	(19.0)	(22.3)	(15.0)	(56.3)	(22.3)	(8.3)	(13.0)	(43.7)	(28.3)	(14.0)	(15.0)	(57.3)
	4.4	4.8	3.9	7.54	4.8	3.0	3.7	6.65	28.8	3.8	3.9	7.60
Imazethapyr @ 75g ha^{-1}	(19.7)	(21.7)	(16.7)	(58.0)	(9.3)	(6.0)	(13.0)	(28.3)	(16.3)	(13.0)	(12.7)	(42.0)
	4.5	4.7	4.1	7.65	3.1	2.5	3.7	5.37	16.8	3.7	3.6	6.52
Pendimethalin (PE) 1000g ha^{-1} +	(6.3)	(4.0)	(9.3)	(19.7)	(9.3)	(5.7)	(9.3)	(24.3)	(21.7)	(14.7)	(14.7)	(51.0)
Quizalofop (PoE) @ 50g ha^{-1}	2.6	2.1	3.1	4.49	3.1	2.5	3.1	4.98	22.2	3.9	3.9	7.18
Pendimethalin (PE) 1000 g ha^{-1} +	(4.7)	(5.3)	(9.7)	(19.7)	(5.3)	(4.0)	(10.3)	(19.7)	(17.0)	(13.0)	(12.0)	(42.0)
Imazethapyr (PoE) 75 g ha^{-1}	2.3	2.4	3.2	4.49	2.4	2.1	3.3	4.49	17.5	3.7	3.5	6.52
Imazethapyr (PoE) @ 75g ha^{-1} +	(19.7)	(22.0)	(17.3)	(59.0)	(5.0)	(3.7)	(9.3)	(18.0)	(13.0)	(12.0)	(12.3)	(37.3)
Quizalofop (PoE) @ 50g ha^{-1}	4.5	4.7	4.2	7.71	2.3	2.0	3.1	4.22	13.5	3.5	3.6	6.15
2 HW (20 & 40 DAS)	(18.7)	(21.7)	(14.7)	(55.0)	(2.3)	(2.7)	(2.3)	(7.3)	(3.7)	(4.3)	(3.7)	(11.7)
	4.4	4.7	3.9	7.45	1.7	1.8	1.7	2.79	4.2	2.2	2.0	3.48
Unweeded / Control	(23.0)	(24.0)	(17.0)	(64.0)	(36.3)	(42.0)	(25.0)	(103.3)	(35.7)	(31.7)	(24.3)	(91.7)
	4.8	4.9	4.2	8.03	6.1	6.5	5.0	10.35	36.2	5.7	5.0	9.59
Weed free – regular hand weeding	(0.0)	(0.3)	(0.3)	(0.7)	(0.0)	(0.0)	(0.3)	(0.3)	(0.3)	(0.7)	(0.3)	1.3
as and when required	0.7	0.9	0.9	1.05	0.7	0.7	0.9	0.88	0.8	1.0	0.9	1.18
S.EM	0.9	0.7	0.8	1.313	0.7	0.4	0.8	1.398	1.3	0.7	0.8	0.199
C.D	2.6	2.1	2.5	3.902	2.1	1.3	2.3	4.155	4.0	2.1	2.3	0.591
C.V	12.3	9.3	12.2	6.11	12.2	9.5	13.8	8.70	13.4	8.7	11.3	5.55

plant dry matter (31.89g plant^{-1}) and number of branches (5.94) were recorded under totally weed free plot which was regularly hand weeded as and when required. This was closely followed by hand weeded treatment(HW) at 20 and 40 days after sowing (DAS) (T_8). The findings were in line with Singh and Yadav (2015). Under various treatments with herbicides, application of pendimethalin (PE) @ 1kg a.i ha^{-1} + hand weeding (HW) at 20 DAS (T_2) and post- emergence spray of imazethapyr (75g a.i ha^{-1}) + quizalofop-p ethyl (50g a.i ha^{-1}) (T_7) significantly recorded higher values of plant height (64.37 cm) (63.67cm), plant dry matter (28.59 g plant^{-1}) (28.41 g plant^{-1}), number of branches (5.72) (5.57) respectively, while the highest LAI (5.04) under the herbicidal treatments was recorded with the imazethapyr (PoE) @ 75g a.i ha^{-1} + quizalofop-p ethyl (PoE) 50g a.i ha^{-1}. This could be due to the combined effect of early post emergence herbicides which controlled weeds efficiently at the critical phase of crop growth, thus reducing the competition for resources among crop and weeds (Poornima *et al*. 2018).Under the growth parameters, lowest values of plant height (57.09 cm), plant dry matter (17.43 g plant^{-1}), number of branches (4.11) at harvest and LAI (3.08) at 60 DAS were recorded in control (unweeded) plot, which was on par with pre-emergence spray of pendimethalin @ 1kg a.i ha^{-1} (Table 2).

Yield parameters

Significantly maximum no. of

pods per plant (31.33), no. of seeds per pod (9.33) and thousand seed weight (32.89g) were recorded under regular hand weeded plot, there was less competition observed between crop and weed, since the plot was kept weed free during the entire period of crop growth. This was statistically inferior to two hand weeding (HW) at 20th and 40thday. Among the herbicidal treatments, pendimethalin @ 1kg a.i ha^{-1}+ HW @ 20 DAS produced highest number of pods (27.00), seeds(7.67) and 1000 seed weight (27.87g). This was precisely followed by combinational application of early post emergence herbicide imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop- p ethyl (PoE) 50g a.i ha^{-1}. This combinational application recoded (27.00) number of pods, (7.33) number of seeds and (30.05g) 1000 seed weight (Table 3) and was statistically comparable to pendimethalin + HW at 20 DAS. The lowest no. of pods per plant (20.00), no. of seeds per pod (4.33) and thousand seed weight (25.87g) were obtained under unweeded plot (control) which was followed by pendimethalin (PE) @ 1kg ha^{-1}.

Maximum grain yield (1.18 t/ha) and stover yield (2.13t/ha) were resulted from fully hand weeded plot and was on par with hand weeded plot(HW) at 20 and 40 DAS (1.17, 2.11t/ha grain and straw yield respectively). Alike findings obtained by Tamang *et al.* (2015). Under the herbicide application, pendimethalin (PE) @ 1kg a.i ha^{-1} + HW at 20 DAS showed significant grain (1.12 t/ha) and stover yield (2.02 t/ha) and was comparable to hand weeded plot. Jinger *et al.* (2015) reported similar kind of results. The combinational application of quizalofop–p ethyl (PoE) @ 50g a.i ha^{-1} + imazethapyr (PoE) @

Table 2. Effect of pre and post emergence herbicides on plant growth parameters (at harvest).

Treatment	Plant height (cm)	Plant dry weight (g/ plant)	Number of branches per plant	LAI at 60 DAS
T_1 Pendimethalin (PE) 1 kg ha^{-1}	58.55	18.50	4.23	3.52
T_2 Pendimethalin + 1 HW @ 20 DAS	64.37	28.59	5.72	4.45
T_3 Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	61.77	20.77	4.63	3.68
T_4 Imazethapyr @ 75g ha^{-1}	63.04	24.24	4.80	4.31
T_5 Pendimethalin (PE) 1000g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	62.97	23.82	4.73	3.62
T_6 Pendimethalin (PE) 1000 g ha^{-1} + Imazethapyr (PoE) 75 g ha^{-1}	63.24	27.00	5.50	3.89
T_7 Imazethapyr (PoE) @ 75g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	63.67	28.41	5.57	5.04
T_8 2 HW (20 & 40 DAS)	65.33	29.06	5.87	4.76
T_9 Unweeded / Control	57.09	17.43	4.11	3.08
T_{10} Weed free – regular hand weeding as and when required	66.71	31.89	5.94	5.44
S.EM	1.528	1.325	0.186	0.347
C.D	4.541	3.936	0.553	1.030

Table 3. Effect of pre and post emergence herbicides on yield attributing characters.

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	1000 seed weight (g)
T_1 Pendimethalin (PE) 1 kg ha^{-1}	21.00	4.67	27.16
T_2 Pendimethalin + 1 HW @ 20 DAS	27.33	7.67	31.16
T_3 Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	22.33	5.00	27.87
T_4 Imazethapyr @ 75g ha^{-1}	24.33	5.33	28.90
T_5 Pendimethalin (PE) 1000g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	23.00	5.67	28.31
T_6 Pendimethalin (PE) 1000 g ha^{-1} + Imazethapyr (PoE) 75 g ha^{-1}	25.00	6.00	29.93
T_7 Imazethapyr (PoE) @ 75g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	27.00	7.33	30.05
T_8 2 HW (20 & 40 DAS)	28.67	8.67	32.12
T_9 Unweeded / Control	20.00	4.33	25.87
T_{10} Weed free – regular hand weeding as and when required	31.33	9.33	32.89
S.EM	0.860	0.470	0.868
C.D	2.555	1.397	2.578

75g a.i ha^{-1} also showed significant grain and seed yield (1.10, 2.00 t/ha) repectively and was statistically similar to hand weeded plot. Ali *et al.* (2011) also reported similar findings. Whereas, pre and post- emergence herbicide's combinational spray were significantly at par and resulted in 1.03 t/haof seed yield and 1.90 t/ha of straw yield under pendimethain (PE) @ 1kg a.i ha^{-1} + imazethapyr (PoE) @ 75g a.i ha^{-1} plot, while 1.03 t/haseed yield and 1.83 t/hastraw yield under pendimethalin (PE) @ 1kg a.i ha^{-1} + quizalofop (PoE) @ 50g a.i ha^{-1}. This could be attributed to the fact that, pendimethalin efficiently controlled the emergence of weeds atearly growth phaseof the crop while post- emergence herbicides (imazethapyr and quizalofop) controlled later flush of weeds (Jinger *et al.*, 2015). The lowest grain (0.75 t/ha) and stover yield (1.34 t/ha) recorded under unweeded plot, closely followed by pendimethalin (PE) @ 1kg a.i ha^{-1} (0.78, 1.36 respectively) (Table 4).

Weed indices

The data show that, minimum weed index (5.65%), obtained with application of pendimethalin @ 1kg a.i ha^{-1} + hand weeding (HW) at 20 days after sowing (DAS). This was on parwith the application of imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop @ 50g a.i ha^{-1} (7.10%). Lower the weed index better efficient is the treatment. While in case of Weed control efficiency (WCE), higher WCE, better the herbicide in controlling the weed population. According to this, among the herbicidal treatments, combination of imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop-p ethyl (PoE) @ 50g a.i ha^{-1} resulted in higher (62.12%) WCE

Table 4. Effect of pre and post emergence herbicides on grain, straw yield

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1 Pendimethalin (PE) 1 kg ha^{-1}	0.78	1.36	2.15	36.42
T_2 Pendimethalin + 1 HW @ 20 DAS	1.12	2.02	3.14	35.61
T_3 Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	1.01	1.62	2.62	38.49
T_4 Imazethapyr @ 75g ha^{-1}	1.03	1.83	2.86	35.93
T_5 Pendimethalin (PE) 1000g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	0.91	1.83	2.74	33.27
T_6 Pendimethalin (PE) 1000 g ha^{-1} + Imazethapyr (PoE) 75 g ha^{-1}	1.03	1.90	2.93	35.17
T_7 Imazethapyr (PoE) @ 75g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	1.10	2.00	3.10	35.48
T_8 2 HW (20 & 40 DAS)	1.17	2.11	3.28	35.64
T_9 Unweeded / Control	0.75	1.34	2.09	35.91
T_{10} Weed free – regular hand weeding as and when required	1.18	2.13	3.32	35.73
S.EM	0.035	0.058	0.057	-
C.D	0.105	0.172	0.168	3.895

Table 5. Effect of pre and post emergence herbicides on weed indices

Treatment	Weed Index (WI)(%)	Weed control efficiency (WCE)(%)	Herbicide efficiency index (HEI)
T_1 Pendimethalin (PE) 1 kg ha^{-1}	33.74	24.08	0.09
T_2 Pendimethalin + 1 HW @ 20 DAS	5.65	61.32	1.27
T_3 Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	15.15	28.04	0.47
T_4 Imazethapyr @ 75g ha^{-1}	13.41	45.33	0.68
T_5 Pendimethalin (PE) 1000g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	23.09	37.84	0.36
T_6 Pendimethalin (PE) 1000 g ha^{-1} + Imazethapyr (PoE) 75 g ha^{-1}	13.17	50.64	0.76
T_7 Imazethapyr (PoE) @ 75g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	7.10	62.12	1.23
T_8 2 HW (20 & 40 DAS)	1.33	95.36	12.11
T_9 Unweeded / Control	36.57	0.00	0.00
T_{10} Weed free – regular hand weeding as and when required	0.00	99.76	0.00
S.EM	2.957	2.448	0.381
C.D	8.786	7.274	1.132

Table 6. Effect of pre and post emergence herbicide on economics of greengram,

Treatments	Gross Return (Rs ha^{-1})	Net Return (Rs ha^{-1})	B:C Ratio
T_1 Pendimethalin (PE) 1 kg ha^{-1}	62897.40	6679.91	1.12
T_2 Pendimethalin + 1 HW @ 20 DAS	89711.55	25844.07	1.40
T_3 Quizalofop-p ethyl (PoE) @ 50g ha^{-1}	80392.10	24531.61	1.44
T_4 Imazethapyr @ 75g ha^{-1}	82341.56	26472.41	1.47
T_5 Pendimethalin (PE) 1000g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	73387.31	16404.83	1.29
T_6 Pendimethalin (PE) 1000 g ha^{-1} + Imazethapyr (PoE) 75 g ha^{-1}	82643.28	25652.12	1.45
T_7 Imazethapyr (PoE) @ 75g ha^{-1} + Quizalofop (PoE) @ 50g ha^{-1}	88330.30	32410.14	1.58
T_8 2 HW (20 & 40 DAS)	93827.00	23431.51	1.33
T_9 Unweeded/Control	60276.40	5180.91	1.09
T_{10} Weed free – regular hand weeding as and when required	95082.88	17037.39	1.22

this was closely followed by pendimethalin 1kg ha^{-1} + HW @ 20 DAS (61.32%). Ramesh, 2018 also reported similar findings. Whereas in case of Herbicide efficiency index (HEI) both pendimethalin (PE) 1kg a.i ha^{-1} + hand weeding (HW) @ 20 DAS (1.27%) and quizalofop (PoE) 50g a.i ha^{-1} + imazethapyr (PoE) 75g a.i ha^{-1} (1.23%) obtained similar observations (Table 5).

Economics

The highest gross return (95082.88 Rs ha^{-1}) was obtained in regularly hand weeded plot since it was kept weed free all the time, which resulted in greater yield and thus maximum gross return. While the lowest was recorded (60276.40 Rs ha^{-1}) under unweeded plot. Maximum net return (32410.14 Rs ha^{-1}) obtained with imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop (PoE) 50g a.i ha^{-1} owing to the fact that in hand weeded plot labours were engaged throughout the crop period and expenses related to that were high when compared to herbicidal application. The lowest net return (5180.91 Rs ha^{-1}) obtained in unweeded plot owing to low yield and this was on par with pendimethalin (PE) 1kg a.i ha^{-1} (6679.91 Rs ha^{-1}). In case of B:C ratio, imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop (PoE) 50g a.i ha^{-1}(T_7)resulted in maximum B:C ratio (1.58) and lowest (1.09) recoded under unweeded plot. Regularly hand weeded plot have a B:C ratio of (1.22), which is low when compared to the maximum value. This could be due to fact that, hand weeding is not an economically wise option for maximizing return and benefits. Also it is labour intensive and time taking process. Whereas the application of herbicides is more economically feasible, time saving procedure (Table 6).

Conclusion

It can be summarised that, all the treatments were effective in suppressing weeds and producing better yield when compared to unweeded plot or control. Even though regular hand weeding as and when required, resulted in better yield but the economic data suggest that it is not a feasible option to be followed. Whereas imazethapyr (PoE) 75g a.i ha^{-1} + quizalofop (PoE) 50g a.i ha^{-1} found to be more economical and it is statically similar to regularly weeded plot in all the growth and yield parameters.

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