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Research Paper

Efficacy of herbicides on weed parameters and yield of greengram [*Vigna radiata* Wiljeck]

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ABSTRACT

Weed management studies were conducted to find out economically viable and cost-effective application of herbicides on productivity of greengram during *kharif* season of 2020–21 and 2021–22 on sandy loam soils of Rajasthan. The 10-treatments with 4 replications were tested in randomized block design. Herbicide fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha recorded the maximum weed control efficiency and weed dry matter and found at par with sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @187.5 g/ha and propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha applied at 20 DAS. These were significantly superior over weedy check. Improvement in the crop growth, yield attributes and yield were also recorded with above herbicides. Although, hoeing twice at 25 and 40 DAS recorded higher seed yield but low B:C ratio (2.8) as compared to fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha (3.1) and sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha (3.1) and propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS (3.0). Hence, application of herbicides in greengram holds a great promise for timely, cost effective and economic weed management.

Key words: Economics, Greengram, Herbicides, Weed-parameters, Yield attributes

Greengram (*Vigna radiata* L.) have hardiness and resistant to drought, thus it is most widely cultivated in western Rajasthan under harsh climatic conditions. It provides high-quality easily digestible proteins for human (20-25%) and a good source of dietary fibre, starch, minerals and vitamins (Dhakal *et al.,* 2015). India contributes more than 70% of world's greengram production (Greengram Outlook, 2023) with a production of 3.16 million tonnes covering about 1.56 m ha area. Rajasthan is leading and covering 9.97 lakh ha (64% of country) and 26% of total country's greengram production during 2022-23 followed by Karnataka, Madhya Pradesh and Haryana (Indiastat, 2023). Its cultivation is mainly restricted to less fertile/ marginal soil under rainfed conditions which is a major constraint in low productivity. Weeds are the most underestimated form of biotic stress in agriculture and causes significant reduction up to 85% in greengram yield (Mirjha *et al.,* 2013). The management of weeds has been observed as one of the most imperative practices in crop production to ensure the maximum yield and high quality of farm produce. The earlier popular practice of weed management was manually hand weeding which was effective but during peak period of weed infestation, the unavailability of labour, continuous rains and increasing labour wages necessitates the herbicidal application for weed control in greengram and helpful to economize the cost of production (Yadav *et al.,* 2019). A scouting on weed flora in greengram dominating area indicated that grassy weeds contributed more to the total weed population as compared to broad-leaf weeds in hot and humid season due to congenial environment (Singh *et al.,* 2015). The present investigation on sandy loam soils of arid western Rajasthan was carried out to assess the efficacy of herbicide on weeds and productivity of greengram.

MATERIALS AND METHODS

The experiment was carried out at the instructional farm; College of Agriculture Sumerpur situated in the western part of India at 25°09' N latitude and 73°04' E longitude with an elevation of 297.7 m above mean sea level in Rajasthan. The climate is hot and humid receiving an average annual rainfall to the tune of 524.6 mm. The soil of the experimental site was texturally sandy loam, slightly alkaline in *p*H (7.92), low in organic carbon (0.26 %) and available nitrogen (198.7 kg/ha), medium in available

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phosphorus (16.20 kg/ha) and high in available potassium (285.0 kg/ha). Experiment was comprised of 10-treatments, viz. T_1, pendimethalin 30 EC@ 750 g/ha as pre-emergence; T_2, imazethapyr 35% + imazamox 35% WDG @ 60 g/ha at 20 DAS; T_3, fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS; T_4, imazethapyr 10% SL @ 40 g/ha at 20 DAS; T_5, imazethapyr 10% SL @ 60 g/ha at 20 DAS; T_6, sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS, T_7, propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS; and T_8, one hoeing at 25 DAS; T_9, weed free up to 40 DAS and T_{10}, weedy check with 4 replications in a randomized block design. Greengram variety 'GM 4' was sown in July 20th and June 24th during 2020 and 2021, respectively with a seed rate of 15 kg/ha by maintaining rectangular crop geometry of 30 cm × 10 cm between rows and within a row. The crop was fertilized with 40 kg N and 20 kg P_2O_5/ha as basal while herbicides were sprayed with knap-sack sprayer fitted with flat-fan nozzle using spray volume of 500 l/ha as accordance to treatments. The experimental unit i.e., gross plot was 6.0 m × 4.8 m while net plot was 5.0 m × 3.6 m in size. Weed samples were collected randomly from two spots using a quadrant of 0.25 m^2 (0.5 m × 0.5 m) at harvest of crop and were being sun dried for 24 hours followed by oven drying at 65°C till a constant weight was achieved. The final dry weight of broadleaf weeds, grasses and sedges were recorded and expressed in g/m^2.

Weed control efficiency (WCE): It was calculated by using formula given by Mani *et al.* (1973).

$$\text{WCE (\%)} = \frac{\text{Dry matter of weeds in unweeded plot(g)} - \text{Dry matter of weeds in treated plot(g)}}{\text{Dry matter of weeds in unweeded plot (Weedy check)(g)}} \times 100$$

Weed index (WI): It represents the per cent reduction in yield under the particular treatment due to the presence of weeds and assess the efficacy of an herbicide or weed control practice (Gill and Kumar, 1969). Lesser the WI, better is the efficiency of treatment. It is expressed in percentage and was determined with the help of following formula:

$$\text{WI (\%)} = \frac{\text{Yield from weed free plot} - \text{yield from treated plot}}{\text{Yield from weed free plot}} \times 100$$

Herbicide efficiency index (HEI): This index represents the potential of a particular herbicide for controlling the weeds along with their phyto-toxicity effect on the crop (Krishnamurthy *et al.,* 1975).

$$HEI = \frac{\frac{\text{Crop yield from treated plot} - \text{crop yield from weedy check plot}}{\text{Crop yield from weed free plot}} x\ 100}{\frac{\text{weed biomass in treated plot}}{\text{weed biomass in weedy check plot}} x\ 100}$$

Plant height, number of branches and other yield attributes recorded from five plants selected randomly, tagged in each plot. After harvesting and threshing, winnowing and cleaning was done for each net plot and recorded seed yield in kg/plot. Thereafter, it was converted to kg/ha. Similarly fodder yield was calculated. Harvest index was calculated by dividing the economic yield (grain yield) by biological yield and expressed as percentage (Donald and Hamblin, 1976). The total mean monetary return was calculated using minimum support prices declared by Government of India. To realize the economics of treatments under investigation as well as monetary advantages were calculated using prevailing sell prices and computing the cost of cultivation on hectare basis. Benefit cost ratio was calculated treatment wise to ascertain economic viability of the treatments by using following formula. The data recorded for evaluation of treatment was subjected to statistical analysis by applying technique of analysis of variance (Cochran and Cox, 1967).

$$\text{B : C ratio} = \frac{\text{Net return (₹ha}^{-1})}{\text{Total cost of cultivation (₹ ha}^{-1})}$$

RESULTS AND DISCUSSION

Weed flora

The weed density and diversity in greengram was influenced by season, varietal character, agro-ecological conditions and cultural practices. The dominant weed flora observed at experimental site were *Cyperus rotundus, Echinochloa crusgalli*, *Cynodon dactylon, Digitaria sanguinalis, Eleusine indica, Digera arvensis*, *Portulaca oleracea*, *Euphorbia hirta, Euphorbia microphylla, Phyllanthus niruri* etc. Weed dry matter production, weed control efficiency, weed index and herbicide efficiency index were significantly affected with the application of pre and post emergence herbicides as compared to weedy check (Table 1). The minimum weed dry matter (19.1 g/m^2), the maximum weed control efficiency (67.6%), the weed index (7.4%) and the maximum herbicide efficiency index (1.3%) were recorded with the post emergence application of fomesafen 11.1% +fluazifop-p-butyl 11.1% SL @ 220 g/ha and application of sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha followed by propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS and was significantly superior over weedy check and rest of treatments (Table 1). However, the extreme values of above parameters were recorded with weed free but these are not feasible under every circumstance. The herbicide applications at most appropriate stage of plant growth that successfully reduced total weed dry matter, maintained a weed free environment and reduced crop weed competition during early stage (Niranjan *et al.*, 2020). The weed free crop environment up to 40 DAS recorded the maximum weed dry matter reduction and further aggravated by shading effect of crop.

Growth attributes

The data pertaining to growth parameters were pre-

Table 1. Effect of herbicidal weed management on weed parameters and their efficacy in greengram at harvest

Treatment	Weed dry-matter (g/m^2)	Weed control efficiency (%)	Weed index (%)	Herbicide efficiency index (%)
Pendimethalin 30 EC @ 750 g/ha	28.9	51.2	10.7	0.8
Imazethapyr 35% + Imazamox 35% WDG @ 60 g/ha	34.9	41.0	17.5	0.6
Fomesafen 11.1% + Fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS	19.1	67.6	7.4	1.3
Imazethapyr 10% SL @ 40 g/ha at 20 DAS	31.6	46.6	15.7	0.7
Imazethapyr 10% SL @ 60 g/ha at 20 DAS	29.7	49.7	13.4	0.7
Sodium acifluorfen 16.5% + Clodinafop propargyl 8% EC @ 187.5 g /ha at 20 DAS	20.1	66.0	7.6	1.3
Propaquizafop 2.5% + Imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS	23.4	60.6	10.2	1.0
One hoeing at 25 DAS	25.1	57.7	13.4	0.9
Weed free upto 40 DAS	17.0	71.2	0.0	1.7
Weedy check	59.4	0.0	46.9	0.0
SEm±	0.90	1.46	2.04	0.06
CD (P=0.05)	2.56	4.13	5.78	0.16

sented in Table 2. Plant height and number of branches per plant recorded at harvest were found to be affected significantly with the application of herbicides at the most appropriate stage. These values were recorded the maximum with post emergence application of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha (50.6 and 4.25, respectively) and followed by sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha (50.5 cm and 4.20, respectively) and propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha applied at 20 DAS (50.4 cm and 4.20, respectively) as against the weedy check. However, the rest of herbicide treatments were at par to each other in respect of growth parameters.

Yield attributes

Data revealed that yield attributes, viz. mean number of pods/plant, number of seeds/pod and 1000-seed weight were recorded significantly higher with the application of herbicides over the mechanical methods and weedy check (Table 2). The maximum number of pods/plant (20.7), number of seeds/pod (11.7) and 1000-seed weight (46.6g) were recorded with post emergence application of fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha followed by sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @187.5 g/ha and propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS as against the weedy check. The rest of treatments were at par to each other but significantly superior to weedy check. Significantly higher number of yield attributes were mainly due to lower weed dry weight and minimum crop-weed competition during the crop growth period (Chhodavadia *et al.,* 2013). The weed free environment for substantial period diverts the resources demand towards seed. These herbicides were absorbed by root as well as shoot and translocated to site of action and inhibit metabolic process in weeds.

Yield

Data on seed yield, fodder yield and harvest index were significantly influenced by weed control treatments (Table 3). The fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS recorded the maximum seed yield of 11.7 q/ha followed by sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS (11.6 q/ha) while the maximum fodder yield was weighted in propaquizafop 2.5% + imazethapyr 3.75% w/w @ 135 g/ha (17.8 q/ha) followed by fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha (17.6 q/ha) applied as post emergence. However, the treatments sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS recorded the maximum harvest index (40.0%) followed by fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS (39.9%) and both were significantly superior over weedy check. The magnitude of increase in mean seed yield ranged from 55 to 78% with application of herbicides as PRE as well as POST emergence. The weed crop competition under weed management treatments enhanced productivity of crop over weedy environment due to cumulative effect of yield attributes. Further, better weed control associated with decrease in weed population and increase in herbicide efficiency index ultimately reflected in overall yield as compared to weedy check. Also, the better initial growth induced more flower and pod production with timely supply of resources led to a positive

Table 2. Effect of herbicidal weed management on growth and yield attributes of greengram

Treatment	Plant height (cm)			Branches/plant			Pods/plant			Seeds/pod			Test weight (g)		
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled
Pendimethalin 30 EC@ 750 g/ha	51.3	44.9	48.1	4.10	4.10	4.10	21.3	18.9	20.1	11.7	11.5	11.6	47.1	45.2	46.1
Imazethapyr 35% + Imazamox 35 % WDG @ 60 g/ha	52.3	46.0	49.1	4.10	3.95	4.03	18.7	16.4	17.6	10.8	10.6	10.7	44.7	43.9	44.3
Fomesafen11.1% + Fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS	49.7	45.0	47.4	4.35	4.15	4.25	21.1	19.5	20.3	11.7	11.7	11.7	46.2	45.3	45.7
Imazethapyr 10% SL @ 40 g/ha at 20 DAS	50.5	46.0	48.3	4.30	4.05	4.18	20.0	18.1	19.0	10.8	10.6	10.7	43.0	41.9	42.5
Imazethapyr 10% SL @ 60 g/ha at 20 DAS	51.4	46.3	48.8	4.30	3.95	4.13	20.9	18.6	19.7	11.2	11.0	11.1	45.3	44.4	44.9
Sodium acifluorfen 16.5% + Clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS	53.2	47.9	50.5	4.35	4.05	4.20	20.7	18.4	19.5	10.7	10.4	10.5	47.3	45.9	46.6
Propaquizafop 2.5% + Imazethapyr 3.75% w/w @ 135g/ha at 20 DAS	53.2	48.1	50.6	4.30	4.10	4.20	22.1	19.2	20.7	11.6	11.1	11.3	46.2	44.8	45.5
One hoeing at 25 DAS	52.6	48.1	50.3	4.30	3.85	4.08	21.3	19.0	20.1	11.3	10.8	11.1	45.2	44.1	44.6
Weed free upto 40 DAS	55.6	50.1	52.9	4.45	4.20	4.33	23.0	20.2	21.6	12.1	11.8	12.0	48.4	46.4	47.4
Weedy check	45.0	40.7	42.9	3.70	3.60	3.65	15.6	13.9	14.8	9.3	8.9	9.1	44.8	43.9	44.3
SEm±	1.76	1.49	1.00	0.16	0.134	0.09	1.00	0.72	0.53	0.47	0.34	0.25	1.72	0.99	0.86
CD (P=0.05)	5.10	4.33	2.83	0.47	0.390	0.26	2.89	2.09	1.51	1.37	1.00	0.72	4.98	2.89	2.44

source-sink gradient of photosynthates (Yadav *et al.*, 2019, Patel *et al.*, 2021). The maximum grain yield of greengram was in weed free treatment (two hand weeding) is the result of lesser weed infestation and encouraged translocation of photosynthetes from source to sink. Khan *et al.* (2011) and Dubey *et al.* (2018). The broad-spectrum nature of herbicides in experiment affected the establishment of weeds by retarding physiological phenomenon of weeds particularly cell division caused rapid weed suppression and more efficient weed control of dominant annual, broadleaf weeds and sedges (Khairnar *et al.*, 2014).

Economics

The economics of greengram including expenditure incurred on cultivation of crop and return obtained from these were presented in Fig. 1 and Table 3. A perusal of data revealed that the highest mean gross returns (₹92,029/ha) was recorded with hand weeding twice at 25 and 40 DAS and lowest mean gross returns (₹48,852/ha) in weedy check. Among herbicides, the highest mean gross returns (₹84,754/ha) were recorded with application of sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha and fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 days after sowing of the crop as post emergence.

The mean net return and benefit: cost ratio were highest i.e. ₹64,204/ha and 3.1, respectively with sodium acifluorfen 16.5% + clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS followed by fomesafen 11.1% + fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS which was mainly due to lower cost of cultivation (₹20,550/ha and 20,900/ha, respectively) and higher grain yield of crop. This was superior over treatment hand weeding twice at 25 and 40

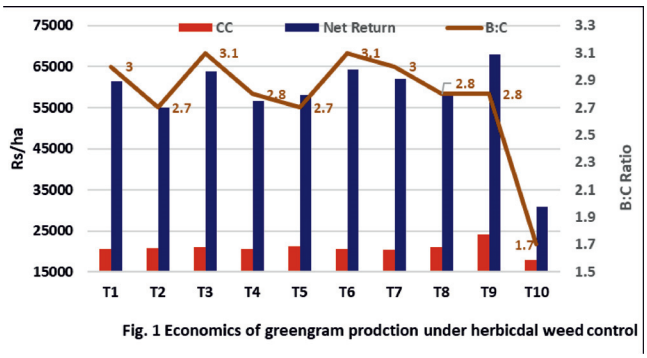

Fig. 1 Economics of greengram prodction under herbicdal weed control

DAS (₹68029/ha and 2.08, respectively) due to higher economic yield but higher cost for manual weeding as against minimum in weedy check (₹30,852/ha and 1.7, respectively). Year to year ups in cost of cultivation, which consequently reflected the benefits were on account of variability in cost of inputs and outputs. Results suggested economic viability and agronomic feasibility of the technology for greengram cultivation and confirmed the findings as reported by Buttar *et al.* (2008) and Chhodavadia *et al.* (2013).

It may be concluded that the application of herbicides at different growth stages is broaden the weed free environment and was a viable option to manage the weeds and enhanced the crop productivity. The new molecules were found superior in respect of already recommended herbicides like pre-emergence application of pendimethalin 30 % EC and post emergence application of imazethapyr 10% SL in diverse growing regions besides traditional practice of hoeing once or twice. Thus, application of either pre-emergence or post emergence herbicides are best practice for achieving efficient and economic weed control besides obtaining higher monetary returns in irrigated green gram considering the current scenario of labour scarcity.

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Table 3. Effect of herbicidal weed management on yield and economics of greengram

Treatment	Seed yield (q/ha)			Fodder yield (q/ha)			Harvest index (%)			Gross returns (× 10^3 ₹/ha)	Cost of cultivation (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
	2020	2021	Pooled	2020	2021	Pooled	2020	2021	Pooled				
Pendimethalin 30 EC @ 750 g/ha	11.8	10.7	11.2	18.75	16.00	17.38	38.61	39.96	39.29	81,844	20,500	61,344	3.0
Imazethapyr 35% + Imazamox 35% WDG @ 60 g/ha	10.8	10.0	10.4	17.75	15.13	16.44	37.84	39.78	38.81	75,660	20,700	54,960	2.7
Fomesafen 11.1% + Fluazifop-p-butyl 11.1% SL @ 220 g/ha at 20 DAS	12.3	11.0	11.7	19.13	16.13	17.63	39.16	40.66	39.91	84,754	20,900	63,854	3.1
Imazethapyr 10% SL @ 40 gm/ha at 20 DAS	11.1	10.1	10.6	18.13	15.25	16.69	38.04	39.81	38.92	77,115	20,500	56,615	2.8
Imazethapyr 10% SL @ 60 gm/ha at 20 DAS	11.5	10.3	10.9	18.05	16.00	17.03	38.90	39.24	39.07	79,298	21,160	58,138	2.7
Sodium acifluorfen 16.5% + Clodinafop propargyl 8% EC @ 187.5 g/ha at 20 DAS	12.4	10.9	11.6	19.00	16.00	17.50	39.62	40.44	40.03	84,754	20,550	64,204	3.1
Propaquizafop 2.5% + Imazethapyr 3.75% w/w @ 135 g/ha at 20 DAS	11.9	10.7	11.3	19.13	16.50	17.81	38.39	39.35	38.87	82,208	20,300	61,908	3.0
One hoeing at 25 DAS	11.6	10.2	10.9	18.50	16.25	17.38	38.59	38.58	38.58	79,298	21,000	58,298	2.8
Weed free upto 40 DAS	13.4	11.9	12.6	19.75	17.25	18.50	40.39	40.75	40.57	92,029	24,000	68,029	2.8
Weedy check	7.1	6.3	6.7	14.13	11.75	12.94	33.32	34.95	34.14	48,852	18,000	30,852	1.7
SEm±	0.37	0.44	0.25	0.840	0.494	0.422	1.314	1.395	0.830				
CD (P=0.05)	1.08	1.28	0.71	2.438	1.433	1.197	3.813	NS	2.353				

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