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STUDY ON WEED MANAGEMENT PRACTICES IN *KHARIF* GREENGRAM (*VIGNA RADIATA* L.) UNDER LOAMY SAND IN NORTH GUJARAT, INDIA

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ABSTRACT

A field experiment with the objectives to understand the effect of weed management practices on *kharif* greengram (*Vigna radiata* L.). The predominant weed flora observed in the experimental field were *Cyperus rotundus* L., *Bulbostylis barbata* Rottb. among sedges, *Cynodon dactylon* L., *Dactyloctenium aegyptium* L., *Digitaria sanguinalis* L. among grasses, *Amaranthus viridis* L., *Corchorus tridens* L., *Boerhavia erecta* L., *Tribulus terrestris* L., *Digera arvensis* L., *Leucas aspera* L among broad leaf weeds. Weed free treatment recorded significantly higher seed and stover yield (1545 and 3316 kg/ha, respectively). Further, imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS registered significantly higher seed and stover yield (1330 and 2905 kg/ha, respectively) and found at par with stale seedbed *fb* interculture and hand weeding at 40 DAS (1286 and 2828 kg/ha, respectively) as compared to unweeded check (491 and 1297 kg/ha, respectively) owing to the effective suppression of grasses, sedges, broad leaf and total weeds at 50 DAS and at harvest. Due to better yields obtaines, weed free treatment recorded higher output energy, net energy returns, energy use efficiency, energy productivity and lower specific energy (64161 MJ/ha, 56723 MJ/ha, 8.63, 0.208 Kg/MJ and 4.82 MJ/kg, respectively) which was followed by imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS (55866 MJ/ha, 49118 MJ/ha, 8.28, 0.197 Kg/MJ and 5.07 MJ/kg, respectively) and stale seedbed *fb* interculture and hand weeding at 40 DAS (54249 MJ/ha, 46829 MJ/ha, 7.31, 0.173 Kg/MJ and 5.77 MJ/kg, respectively). Wherein, unweeded check recorded lower input energy, output energy, net energy returns, energy use efficiency, energy productivity and higher specific energy (6341 MJ/ha, 23430 MJ/ha, 17089 MJ/ha, 3.70, 0.077 Kg/MJ and 12.92 MJ/kg, respectively).

Key words : Energrtics, Soil solarization, Stale seedbed, Weeds, Yield.

Introduction

Greengram [*Vigna radiata* (L.) Wilczek] also known as moong bean is one of the important pulse crop of India, belonging to the family *Leguminosae* and subfamily *Papilionaceae.* It has been reported that greengram has been cultivated in India since ancient times. Greengram is a fairly good source of some dietary minerals. The total minerals content in greengram is to the tune of 3.5 percent. Greengram seeds contain 22-28% protein, 60-65% carbohydrates, 1.0-1.5% fat, 3.5-4.5% fibre and 4.5-5.5% ash (Anonymous, 2019). Among the array of biotic and abiotic factors, weed infestation emerges as the primary biotic factor contributing to the reduced productivity of greengram in India. The potential yield loss in greengram due to weed has been estimated in the range of 10-45 % (Rao and Chauhan, 2014). The critical period of crop-weed competition in greengram has been pinpointed as occurring from 15 to 30 days after sowing, with weed presence beyond this period resulting in significant losses in greengram yield (Mandal *et al.*, 2006). Competition with the weeds led to 30 to 80% grain yield reduction in greengram during summer and *kharif* seasons, while 70-80% during *rabi* season (Algotar *et al.*, 2015). Use of herbicides in conjunction with cultural practices or other practices would make complete control of weeds and will be acceptable by the poor farmer (Ayansina *et al.*, 2003). Application of different straw mulches, soil solarization and stale seedbed have been found efficient in managing weeds. Hence, development of an integrated weed management is economically viable as well as ecologically safe for effective weed control and enhances the productivity of greengram.

Materials and Methods

The field experiment was conducted on Plot No. C-6 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat) to study on weed management practices in *kharif* greengram (*Vigna radiata* L.) under loamy sand in North Gujarat conditions. The soil of experimental field was loamy sand in texture with low in organic carbon (0.25 %) and available nitrogen (148.0 kg/ha), medium in available phosphorus (38.6 kg/ha) and available potassium (252.4 kg/ha) having pH value of 7.45. The experiment was laid out in Randomized Block Design with three replications. The treatments comprised of ten methods of weed management *viz.*, T_1: Soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, T_2: Soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, T_3: Soil solarization *fb* interculture and hand weeding at 40 DAS, T_4: Stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, T_5: Stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, T_6: Stale seedbed *fb* interculture and hand weeding at 40 DAS, T_7: Imazethapyr 100 ml/ha as PoE at 15 DAS, T_8: Imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS, T_9: Weed free, T_{10}: Unweeded check. Greengram variety 'GM 4' was sown on 18th July, 2023 and fertilized with 20-40-00 kg N-P_2O_5-K_2O/ha. The crop was grown with recommended package of practices for south Gujarat Agro-climatic Zone and was harvested on 09th October, 2023. Chlorophyll content index (CCI) was measured by using MC-100 at 25 and 50 DAS from the previously tagged five plants leaves from the each net plot. At 25 and 50 DAS, PSII quantum yield was measured by using LI-600 from the previously tagged five plants leaves from the each net plot. The net energy returns, energy use efficiency, energy productivity, and specific energy were calculated using the following formulas (Alipour *et al.*, 2012). The different formulas used for the calculations of various eneregtics calculations are as under

Net energy returns (MJ/ha) = Output energy (MJ/ha) – input energy (MJ/ha)

$$\text{Energy use efficiency} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Seed yield (kg/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Specific energy (MJ/kg)} = \frac{\text{Input energy (MJ/ha)}}{\text{Seed yield (kg/ha)}}$$

Results and Discussion

Effect on weed parameters

The primary weed species observed in the experimental field at different growth stages included: *Cyperus rotundus* L., *Bulbostylis barbata* Rottb. among sedges, *Cynodon dactylon* L., *Dactyloctenium aegyptium* L., *Digitaria sanguinalis* L. among grasses and *Amaranthus viridis, Corchorus tridens* L., *Boerhavia erecta* L., *Tribulus terrestris* L., *Digera arvensis* L., *Leucas aspera* L. among broad leaf weeds. At each stage (25, 50 DAS and at harvest), the dominant species were *Cyperus rotundus* L. among the sedges, *Cynodon dactylon* L. among the grasses, and *Boerhavia erecta* L. among the broadleaf weeds.

Different weed management practices, significantly influenced weed density at different stages (Tables 1 and 2). At 25 DAS, among different weed management practices, weed free treatment recorded significantly lower density of sedges, grasses, broad leaf and total weeds (Table 1). However, stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS also recorded significantly lower density of sedges, grasses, broad leaf and total weeds next to weed free treatment which was found on par with stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, imazethapyr 100 ml/ha as PoE at 15 DAS, imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS, soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS. Whereas, unweeded check has recorded significantly higher density of sedges, grasses, broad leaf and total weeds. The significantly lower weed density witnessed in the weed free treatment is attributed to successful uprooting and removal of weeds through physical and mechanical techniques which ultimately resulted in lower sedges, grasses, broad leaf and total weeds. Further, significantly lower category wise and total weed density observed at 25 DAS in stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS and stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS treatments is ascribed to the exhaustion of the ready to germinate weed present in top soil layer through stale seedbed action followed by further germination prevention of weed seed by castor shell/ mustard straw mulch materials. Wherein, the lower density of sedges, grasses, broad leaf and total weeds noticed under soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS and soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS treatments is because of killing of weed seed by high temperature generated in soil layer due to polythene mulching on soil and subsequently germination prevention by castor shell/ mustard straw mulch materials. The lower density of sedges, grasses, broad leaf and total weeds under imazethapyr 100 ml/ha as PoE at 15 DAS and imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS is ascribed for the selective action of imazethapyr on broad leaf weeds, grasses and sedges. These findings were also supported by Jain *et al.* (2022) who revealed from two years pooled data that broad leaf weeds, grasses, sedges and total weeds were completely controlled by stale seedbed + plastic mulch up to harvest of the crop and weed free check up to 60 DAS in maize. Chavan *et al.* (2020) also observed significantly lower biomass of monocot, dicot and total weeds under weed free treatment followed by soil solarization for 30 days with 25 µ polythene mulch during summer + one hand weeding in a two year experiment. Kumar *et al.* (2014) revealed that higher dose of imazethapyr (100 g/ha) was found effective in controlling sedge *C. rotundus* in greengram. Similar findings were also reported by Meena *et al.* (2011) in soybean. Whereas, significantly higher weed density found under unweeded check was due to no any weed control action which created unrestricted growth conditions for the sedges, grasses, broad leaf and total weeds which resulted in elevated values of density of all the category of weeds. These findings were also supported by Duary *et al*. (2016), Raut *et al.* (2018) and Ali *et al*. (2011).

The density of weeds at 50 DAS (Table 1) and at harvest (Table 2) as influenced by weed management practices depicted that weed free treatment has significantly lowered density of sedges, grasses broad leaf and total weeds. Subsequently, imazethapyr 100 ml/ ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS recorded significantly lower density of sedges, grasses, broad leaf and total weeds which was found on par with stale seedbed *fb* interculture and hand weeding at 40 DAS. However, highest density of sedges, grasses, broad leaf and total weeds were observed under unweeded check. Imazathapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS witnessed reduced weed population because of removal of weeds by chemical and physical efforts *i.e.*, imazethapyr might have selectively killed broad leaf, grasses and sedges by inhibiting aceto lactate synthase enzyme in these weed plants and interculturing and hand weeding killed all the weeds by mechanical force which drastically made reduction in density of category wise weeds like sedges, grasses, broad leaf and total weeds. The similar results were also noticed by Leva *et al.* (2018) and Joshi *et al.* (2020). Stale seedbed *fb* interculture and hand weeding at 40 DAS also reported lower weed density due to integration of stale seedbed with interculturing and hand weeding. In stale seedbed, all the category of weed seeds were killed well before their emergence from soil due to the proper seed bed and irrigation provided. Further, whatever the later emerged weeds were also killed by interculturing and hand weeding action. The similar outcomes were also expressed by Jain *et al.* (2022) and Chavan *et al.* (2020). The noticeably higher density of sedges, grasses, broad leaf weeds, and total weed population in the unweeded check treatment is evidently due to the lack of weed management throughout the crop growth period. Consequently, this has resulted in uncontrolled and rapid growth in both weed density and biomass. Kumar *et al.* (2020) observed that the unweeded check treatment in greengram resulted in a significantly higher density of weeds and greater weed dry weight, indicating lower weed control efficiency. Further, these findings were also supported by Kalhapure *et al*. (2013), Mavarkar *et al.* (2015) and Meena *et al.* (2018).

Effect on growth parameters

Various weed management practices, significantly influenced the growth and yield parameters of greengram (Tables 3, 4 and 5). The data indicated that the different treatments used in this experiment did not exert significant effect on plant population at harvest. The dry matter accumulation per plant at harvest revealed that among the different treatments, weed free reported significantly higher dry matter accumulation per plant at harvest. Further, following weed free treatment significantly higher dry matter accumulation per plant was noticed under imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS which was statistically on par with stale seedbed *fb* interculture and hand weeding at 40 DAS. Whereas, unweeded check found sticked to significantly lower dry matter accumulation per plant. Thus, as the dry weight of weeds at 50 DAS and at harvest were reduced, there was increment in the dry matter production per plant which ultimately enhanced seed yield through source sink relationship. Singh *et al.* (2015) also proved that weed free treatment recorded

Table 1 : Effect of different weed management practices on category wise weed density at 25 DAS and 50 DAS in greengram.

Treatments	Weed density at 25 DAS (No./m^2)				Weed density at 50 DAS (No./m^2)			
	Sedges	Grasses	Broad leaf weeds	Total	Sedges	Grasses	Broad leaf weeds	Total
T_1: Soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	2.41c (5.33)	3.30c (10.67)	3.44c (11.33)	5.26c (27.33)	5.75b (32.67)	7.10b (50.00)	7.17b (51.33)	11.58b (134.00)
T_2: Soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS	2.55c (6.00)	3.42c (11.33)	3.53c (12.00)	5.45c (29.33)	5.84b (34.00)	7.14b (50.67)	7.20b (52.00)	11.67b (136.67)
T_3: Soil solarization *fb* interculture and hand weeding at 40 DAS	4.06b (16.00)	4.89b (24.00)	5.17b (26.67)	8.15b (66.67)	4.36c (18.67)	5.76c (32.67)	5.80c (33.33)	9.23c (84.67)
T_4: Stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	2.12c (4.00)	2.53c (6.00)	2.78c (7.33)	4.21c (17.33)	4.22c (17.33)	5.61c (31.33)	5.70c (32.00)	8.99c (80.67)
T_5: Stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS	2.26c (4.67)	2.64c (6.67)	2.92c (8.00)	4.44c (19.33)	4.30c (18.00)	5.70c (32.00)	5.76c (32.67)	9.12c (82.67)
T_6: Stale seedbed *fb* interculture and hand weeding at 40 DAS	3.88b (14.67)	4.81b (22.67)	4.94b (24.00)	7.85b (61.33)	2.97d (8.67)	4.22d (17.33)	4.33d (18.67)	6.68d (44.67)
T_7: Imazethapyr 100 ml/ha as PoE at 15 DAS	2.64c (6.67)	3.05c (9.33)	3.00c (8.67)	4.96c (24.67)	5.92b (34.67)	7.38b (54.00)	7.27b (52.67)	11.91b (141.33)
T_8: Imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS	2.68c (7.33)	3.20c (10.00)	3.12c (9.33)	5.15c (26.67)	2.90d (8.00)	3.86d (15.33)	3.34d (10.67)	5.84d (34.00)
T_9: Weed free	0.71d (0.00)	0.71d (0.00)	0.71d (0.00)	0.71d (0.00)	0.71e (0.00)	0.71e (0.00)	0.71e (0.00)	0.71e (0.00)
T_{10}: Unweeded check	5.32a (28.00)	6.31a (39.33)	6.60a (44.00)	10.54a (111.33)	7.21a (52.00)	8.79a (77.33)	8.89a (78.67)	14.41a (208.00)
S.Em. ±	0.26	0.32	0.31	0.41	0.30	0.33	0.34	0.42
C.V.%	15.65	16.13	15.07	12.51	11.70	10.17	10.58	8.16

Figures in parentheses are original values and figures outside the parentheses are $\sqrt{x+0.5}$ transformed values
Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance

Table 2 : Effect of different weed management practices on category wise weed density at harvest in greengram.

Treatments	Weed density (No./m²)				Plant population	Dry matter accumulation (g/plant)	Number of nodules per plant	Fresh weight of nodules (mg/plant)
	Sedges	Grasses	Broad leaf weeds	Total				
T_1: Soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	5.21b (26.67)	5.87b (34.00)	6.08b (36.67)	9.87b (97.33)	9.67	14.98	14.43	264.1
T_2: Soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS	5.31b (28.00)	5.92b (34.67)	6.12b (37.33)	10.02b (100.00)	9.00	14.62	14.02	254.4
T_3: Soil solarization *fb* interculture and hand weeding at 40 DAS	3.98c (15.33)	4.59c (20.67)	4.78c (22.67)	7.69c (58.67)	9.33	17.98	14.99	269.6
T_4: Stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	3.78c (14.00)	4.44c (19.33)	4.66c (21.33)	7.41c (54.67)	9.50	18.38	15.62	279.3
T_5: Stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS	3.89c (14.67)	4.51c (20.00)	4.73c (22.00)	7.54c (56.67)	9.33	18.12	15.32	274.4
T_6: Stale seedbed *fb* interculture and hand weeding at 40 DAS	2.35d (5.33)	3.03d (9.33)	3.26d (10.67)	4.98d (25.33)	9.67	21.08	15.87	282.6
T_7: Imazathapyr 100 ml/ha as PoE at 15 DAS	5.39b (28.67)	6.35b (40.00)	6.26b (38.67)	10.38b (107.33)	10.00	13.03	10.51	174.1
T_8: Imazathapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS	2.26d (4.67)	2.85d (8.67)	2.39d (5.33)	4.28d (18.67)	10.17	21.34	13.21	234.8
T_9: Weed free	0.71e (0.00)	0.71e (0.00)	0.71e (0.00)	0.71e (0.00)	10.33	24.11	18.64	373.3
T_{10}: Unweeded check 242.2		6.67a (44.67)	7.62a (58.00)	7.72a (59.33)	12.72a (162.00)	9.17	9.59	13.81
S.Em. ±	0.30	0.31	0.29	0.37	0.64	0.87	0.90	16.3
C.D. at 5%					NS	2.59	2.68	48.4
C.V.%	13.13	11.77	10.76	8.55	11.61	8.73	10.67	10.66

Figures in parentheses are original values and figures outside the parentheses are $\sqrt{x+0.5}$ transformed values.
Treatment means with the letter(s) in common are not significant by DNMRT at 5% level of significance.

Table 3 : Effect of weed management practices on yield parameters and energetic of greengram.

Treatments	Number of pods per plant	Length of pod (cm)	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Input energy (MJ/ha)	Output energy (MJ/ha)	Net energy returns (MJ/ha)	Energy use efficiency	Energy productivity (Kg/MJ)	Specific energy (MJ/kg)
T_1	14.70	6.14	34.59	822	2030	28.88	122823	37453	-85370	0.30	0.007	149.51
T_2	14.51	6.09	34.25	786	1943	28.75	91573	35844	-55729	0.39	0.009	116.53
T_3	18.56	6.52	33.89	1030	2408	29.98	29164	45249	16085	1.55	0.035	28.31
T_4	20.39	7.09	35.05	1080	2458	30.50	101079	46602	-54477	0.46	0.011	93.61
T_5	19.33	6.33	35.61	1048	2415	30.27	69829	45602	-24226	0.65	0.015	66.60
T_6	24.37	6.57	35.11	1286	2828	31.22	7420	54249	46829	7.31	0.173	5.77
T_7	13.97	6.10	32.79	761	1894	28.59	6626	34857	28231	5.26	0.115	8.71
T_8	25.33	7.75	35.42	1330	2905	31.41	6748	55866	49118	8.28	0.197	5.07
T_9	29.76	8.35	36.47	1545	3316	31.67	7438	64161	56723	8.63	0.208	4.82
T_{10}	10.31	5.90	33.77	491	1297	27.78	6341	23430	17089	3.70	0.077	12.92
S.Em. ±	1.16	0.65	1.24	66.32	123.07	0.91	NA	NA	NA	NA	NA	NA
C.D. at 5%	3.45	NS	NS	197.03	365.66	NS						
C.V.%	10.52	16.80	6.20	11.29	9.07	5.29						

Note: T_1: Soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, T_2: Soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, T_3: Soil solarization *fb* interculture and hand weeding at 40 DAS, T_4: Stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, T_5: Stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, T_6: Stale seedbed *fb* interculture and hand weeding at 40 DAS, T_7: Imazethapyr 100 ml/ha as PoE at 15 DAS, T_8: Imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS, T_9: Weed free, T_{10}: Unweeded check.

significantly taller plants and higher dry matter production. Reduced crop-weed competition resulted into overall improvement in crop growth as reflected by higher plant height and dry matter accumulation consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. Similar outcomes were also expressed by the earlier researchers *viz.*, Malik *et al.* (2005) and Gelot *et al.* (2017). The higher dry matter accumulation might be due to lower crop-weed competition in treatments applied with post-emergence herbicide imazethapyr and manual weeding as the imazethapyr herbicide application has witnessed substantial reduction in broad leaf, sedges and grass weeds density at initial stage (25 DAS) and further killing of standing weeds by interculture and hand weeding physical action. Hence, this treatment proved effective in relatively higher dry matter accumulation per plant due to perfect removal of weeds resulting in lower crop-weed completion and higher dry matter accumulation. Similar findings were proved by Duary *et al.* (2016), Singh *et al.* (2021) and Patel *et al.* (2022). Subsequently higher dry matter production registered under stale seedbed *fb* interculture and hand weeding at 40 DAS was assigned to integration of stale seedbed with interculture and hand weeding which removed all the kinds of weed flora effectively resulting in higher weed control efficiency as witnessed by significantly lower category wise and total weed density and dry weight due to combined effect of vanishing all the germinated weeds by stale seedbed action and subsequent removing of emerged weeds by interculture and hand weeding. The interculture and hand weeding activity also provided proper soil aeration which resulted higher dry matter accumulation and better crop growth. Among various treatments unweeded check recorded significantly lower dry matter accumulation per plant which

Table 4 : Effect of weed management practices on soil fertility status after harvest of greengram.

Treatments	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
T_1: Soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	7.29	0.14	0.29	157.00	44.10	260.11
T_2: Soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS	7.26	0.15	0.26	153.40	41.33	255.67
T_3: Soil solarization *fb* interculture and hand weeding at 40 DAS	7.02	0.14	0.25	149.00	34.33	241.27
T_4: Stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS	7.19	0.16	0.28	156.00	43.52	258.47
T_5: Stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS	7.29	0.14	0.27	152.04	40.37	253.20
T_6: Stale seedbed *fb* interculture and hand weeding at 40 DAS	7.38	0.14	0.23	148.33	34.33	240.35
T_7: Imazethapyr 100 ml/ha as PoE at 15 DAS	7.17	0.15	0.24	150.00	36.03	243.03
T_8: Imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS	7.33	0.14	0.22	147.00	33.73	238.33
T_9: Weed free	7.26	0.13	0.21	146.84	32.87	237.00
T_{10}: Unweeded check		7.14	0.14	0.24	149.33	35.70 242.37
S.Em±	0.32	0.01	0.02	7.22	2.76	11.98
C.D. at 5%	NS	NS	NS	NS	NS	NS
C.V.%	7.63	7.47	11.30	8.29	12.71	8.40

might be due to severe competition for various resources, which made the crop plant inefficient to take up sufficient moisture, nutrients and ultimately dry matter accumulation was adversely affected due to less production and supply of photosynthates. Similar findings were observed by Tamang *et al.* (2015), Singh *et al.* (2015), Kumar and Hiremath (2018).

Among various weed management practices, weed free treatment registered significantly highest number of nodules and fresh weight of nodules. Further, stale seedbed *fb* interculture and hand weeding at 40 DAS recorded significantly higher number of nodules and fresh weight of nodules that was statistically at par with stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, soil solarization *fb* interculture and hand weeding at 40 DAS, solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, unweeded check and imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS. Whereas, imazethapyr 100 ml/ ha as PoE at 15 DAS recorded significantly lower number of nodules per plant. Comparatively, weed free treatment recorded significantly highest number of nodules and fresh weight of nodules mainly because of proper soil aeration and lowering crop weed competition through hand weeding, which might have increased the soil microflora and consequently, root nodulation activities. The findings were also supported by Chaudhary *et al.* (2018) and Goud *et al*. (2016). Stale seedbed *fb* interculture and hand weeding at 40 DAS, stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, soil solarization *fb* interculture and hand weeding at 40 DAS, soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, unweeded check and imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS found significantly higher number of nodules and fresh weight of nodules may be due to favourable soil conditions and creates reduced weed densities and weed dry weight which reduce crop weed competition for moisture, nutrients, space and light. Further, the application of mulched materials also might have inceased microbial activity in soil which may also be responsible for higher root nodule number and fresh weight. Tehria *et al*. (2015) also reported that in pea, nodule count was found to be the highest in stale seedbed compared to herbicide treatment. The findings were similar to Sinchana and Raj (2020). Datta *et al.* (2017) observed that mulch applied plots reported higher nodule number as compared to herbicides treated plots. Patel *et al.* (2022) also proved that interculturing *fb* hand weeding at 20 and 40 DAS registered significantly higher nodule dry weight. The significantly lower number of nodules and fresh weight of nodules per plant observed under the treatment with imazethapyr at 100 ml/ha as PoE at 15 DAS was primarily due to the post-emergence application of the herbicide just before flowering (at 45 DAS), which may hampered nodulation activity in soil.

At 25 DAS, significantly higher chlorophyll content index was recorded under weed free treatment. Further, stale seedbed *fb* interculture and hand weeding at 40 DAS recorded significantly higher chlorophyll content index that was statistically at par with stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, soil solarization *fb* interculture and hand weeding at 40 DAS, soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, unweeded check and imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS. Whereas, imazethapyr 100 ml/ha as PoE at 15 DAS witnessed significantly lower chlorophyll content index. The analysis of data reported at 50 DAS revealed that, among the different treatments weed free treatment registered significantly higher chlorophyll content index which was found statistically on par with imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS and stale seedbed *fb* interculture and hand weeding at 40 DAS. Whereas, significantly poor chlorophyll content index was reported under unweeded check which was statistically on par with imazethapyr 100 ml/ha as PoE at 15 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS and soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS.

The higher value of chlorophyll content index observed in the weed-free treatment is likely because of no competition for light between the crop and weeds, which significantly impacted chlorophyll development in plants. Similarly, significantly higher chloropyll content index values observed under imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS and stale seedbed *fb* interculture and hand weeding at 40 DAS was might be addressed to lower crop-weed competition for light and nitrogen due to efficient weed control in these treatments as evidenced by higher weed control efficiency values. Conversely, the lowest value was recorded in the unweeded check, probably because the weed flora shaded the crop plants, obstructing light penetration into the crop canopy and ultimately reduced chlorophyll content. Similar results were also obtained by Kaur and Kaur (2019) and Das *et al.* (2023). The maximum total chlorophyll content was recorded in the stale seedbed *fb* plastic mulch at sowing which was statistically at par with soil solarization *fb* plastic mulch at sowing over weedy check (Subha *et al*., 2021). However, at 25 and 50 DAS, the different weed control treatments did not affect the PSII quantum yield significantly.

Effect on yield parameters

Among different weed management practices, weed free treatment recorded significantly highest number of pods per plant at harvest, which have resulted in significantly higher seed and stover yield. Further, next to weed free treatment imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS registered significantly higher number of pods per plant and led to significantly higher seed and stover yield and found at par with stale seedbed *fb* interculture and hand weeding at 40 DAS. Whereas, significantly lower number of pods per plantseed yield and stover yield at harvest were recorded under unweeded check. However, the length of pod and test weight were not significantly differed due to weed management treatments effects.

The relationship between growth, yield parameters and yield were evident from significantly strong positive correlation coefficient between total dry matter production

Table 5 : Correlation and regression equations for various dependent and independent parameters of greengram.

S. no.	Independent variable (x)	Dependent variable (y)	Correlation coefficient (r)	Regression equation y	R^2
1	Total weed density at 25 DAS (No./m^2)	Total weed dry weight at 25 DAS (g/m^2)	0.9983**	y=1.26+0.56x	0.9966
2	Total weed density at 50 DAS (No./m^2)	Total weed dry weight at 50 DAS (g/m^2)	0.9989**	y=-3.73+0.65x	0.9979
3	Total weed density at harvest (No./m^2)	Total weed dry weight at harvest (g/m^2)	0.9992**	y=-0.86+0.64x	0.9984
9	Dry matter accumulation /plant at harvest (g/plant)	Seed yield	0.9944**	y=-229.05+71.98x	0.9889
10	No. of nodules per plant		0.6368*	y=-384.76+95.79x	0.4056
11	Fresh weight of nodules per plant		0.6530*	y=-76.87+4.13x	0.4264
12	No. of pods per plant		0.9949**	y=25.25+51.91x	0.9899
14	Stover yield (kg/ha)		0.9982**	y=-242.71+0.54x	0.9964
17	Dry matter accumulation /plant at harvest (g/plant)	Stover yield	0.9960**	y=25.96+134.15x	0.9920
18	No. of nodules per plant		0.6284*	y=-225.64+175.88x	0.3949
19	Fresh weight of nodules per plant		0.6466*	y=332.72+7.61x	0.4181
20	No. of pods per plant		0.9874**	y=516.75+95.85x	0.9750
22	No. of pods per plant	Pod yield per plant	0.9923**	y=3.98+0.70x	0.9846

** = Significant at 1% * = Significant at 5%, DMA- Dry matter accumulation.

per plant, number of pods per plant and stover yield per plant (0.9944**, 0.9949** and 0.9982*, respectively) with the seed yield of greengram. The increase in the number of pods per plant and pod yield per plant with the application of stale seedbed *fb* interculture and hand weeding at 40 DAS was due to better control of weeds, including sedges, grasses, and broad leaf weeds before the sowing of crop by stale seed bed and after the sowing by interculture and hand weeding at 40 DAS. This effective weed management reduced competition from weeds for growth resources, leading to enhanced crop growth and resource utilization. Consequently, the efficient production, partitioning and translocation of photosynthates resulted in higher seed and stover yields of greengram. Thus, the treatments that effectively eliminated weeds through imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS and stale seedbed *fb* interculture and hand weeding at 40 DAS resulted in significantly higher yield attributes, seed yield, and stover yield. This was due to the physical action of hand weeding and interculturing and the herbicidal modes of action as well as stale seedbed. Imazethapyr integrated with hand weeding at 30 DAS resulted in significantly higher seed yield over other treatments (Patel *et al.*, 2016b). Jain *et al.* (2022) also proved that the two years pooled mean data indicated that stale seedbed + hoeing once manually at 20 DAS + straw mulch (5 t/ha) at 30 DAS gave maximum grain yield of maize. Conversely, the unweeded check plot showed a significantly lower number of pods per plant and pod yield per plant, resulting in reduced overall seed and stover yields. This decline was due to the extensive and vigorous growth of weeds compared to all other weed control treatments due to no weed control action made. Consequently, this lead to lower weed control efficiency. These findings are in agreement with those of Kushwah and Vyas (2006), Singh *et al.* (2010), Kundu *et al.* (2011b), Meena *et al.* (2011), Goud *et al.* (2014), Choudhary *et al.* (2016), Raut *et al.* (2018) and Kumar and Hiremath. (2018).

Effect on energetics

Different weed management practices influenced the various energy parameters of greengram cultivation (Table 3). Among various treatments, input energy was found higher under soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS followed by stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/

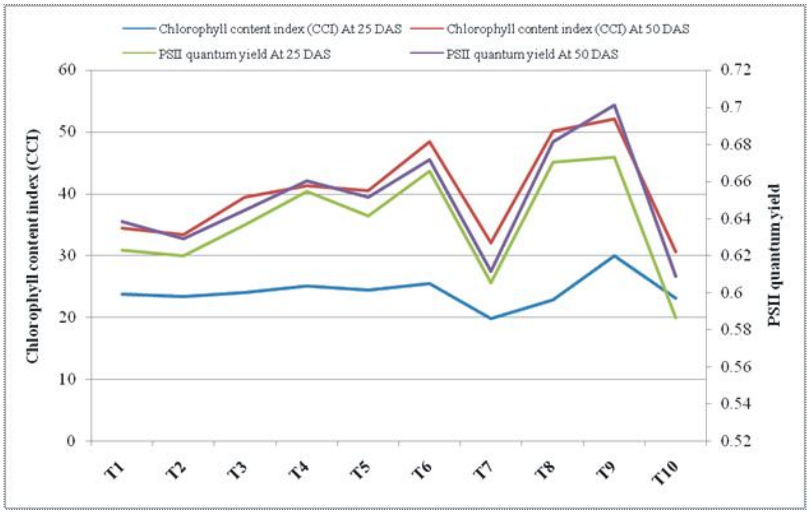

Fig. 1 : Effect of weed management practices on chlorophyll content index (CCI) and PSII quantum yield in greengram.

ha at 10 DAS, stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS, soil solarization *fb* interculture and hand weeding at 40 DAS and weed free treatment. Whereas, unweeded check witnessed lower input energy. Whereas, among various weed management practices, weed free treatment recorded higher output energy, net energy returns, energy use efficiency, energy productivity and lower specific energy which was followed by imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS and stale seedbed *fb* interculture and hand weeding at 40 DAS. Wherein, unweeded check recorded lower input energy, output energy, net energy returns, energy use efficiency, energy productivity and higher specific energy.

The higher input energy witnessed under soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, stale seedbed *fb* mustard straw mulch @ 5 t/ha, soil solarization *fb* interculture and hand weeding at 40 DAS and weed free treatment due to higher dose of different mulches, polythene sheet and energy required for labours in stale seedbed. Wherein, under weed free treatment higher input energy witnessed was owing to maximum energy required as the more number of manual labours were used for hand weeding and inturculturing operations. However, comparatively lower energies recorded under other herbicidal treatments are ascribed to difference in dosage of herbicides. Nevertheless, lower energy input under unweeded check revealed the direct impact of no any energy used for weed control operations.Whereas, elevated vales of output energy, net energy returns, energy use efficiency, energy productivity and lower specific energy registered under T_9: weed free, T_8: imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS, and T_6: stale seedbed *fb* interculture and hand weeding at 40 DAS were reasoned to their significantly higher seed and stover yields (1545 and 3316 kg/ha in T_9; 1330 and 2905 kg/ha in T_8; 1286 and 2828 kg/ha in T_6). These higher yields were further attributed to better crop growth conditions due to effective control of weeds and resultant improved growth, yield parameters and yields. These less crop-weed competition and favourable growing environments have led to more energy returns per unit of energy input used, hence was reflected in terms of higher net energy returns, energy use efficiency, energy productivity and lower specific energy. Wherein, lower net energy returns, energy use efficiency, energy productivity and higher specific energy seen under soil solarization *fb* castor shell mulch @ 7.5 t/ha at 10 DAS, soil solarization *fb* mustard straw mulch @ 5 t/ha at 10 DAS, stale seedbed *fb* castor shell mulch @ 7.5 t/ha at 10 DAS and stale seedbed *fb* mustard straw mulch @ 5 t/ha at 10 DAS were due to higher input energy required for soil solarization, stale seedbed and different mulches. Additionally, lower output energy, net energy returns, energy use efficiency, energy productivity and higher specific energy recorded under unweeded check due to magnificent yield loss caused by different weeds which encompassed in terms of lower seed and stover yields (490.97 and 1297.04 kg/ha, respectively). Lal *et al.* (2016) at Jabalpur reported minimum energy ratio, higher energy intensiveness/ intensity, lowest energy profitability, net energy return (production), maximum specific energy, and lowest human energy profitability in unweeded ckeck. These findings are further proponented by Nagarjun *et al.* (2019), Kumar *et al.* (2021) and Malhi *et al.* (2021).

Effect on soil fertility status

The mean data on soil pH, EC, OC (%), available N, P_2O_5 and K_2O are given in Table 4. The analysis of data concluded that soil pH, EC, OC (%), available N, P_2O_5 and K_2O did not showed significant variation among different weed management treatments.

Conclusion

Based on results of one year field experiment, it is concluded that either imazethapyr 100 ml/ha as PoE at 15 DAS + interculture *fb* hand weeding at 40 DAS or stale seedbed *fb* interculture and hand weeding at 40 DAS is suggested for effective control of weeds and achieving higher yield and net returns in *kharif* greengram.

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