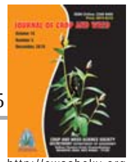
Journal of Crop and Weed, 16(2): 52-59 (2020)

ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Evolving agronomic and economically viable weed management methods for maximizing the weed control *vis-à-vis* the productivity of irrigated green gram (*Vigna radiata* L.)

M. SENTHIVELU, [1]D. KUMARESAN AND P. JAYAMANI

Department of Pulses, [1]Centre for Plant Breeding and Genetics
Tamil Nadu Agricultural University, Coimbatore- 641003, Tamil Nadu

Received : 05.11.2019 ; Revised : 21.07.2020 ; Accepted : 10.08.2020

DOI : https://doi.org/10.22271/09746315.2020.v16.i2.1314

ABSTRACT

To evolve agronomic and economically viable weed management methods for maximum weed control efficiency vis-à-vis the higher productivity of irrigated upland greengram, field experiments were conducted during the consecutive years of kharif 2015 and 2016 at Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore. The field experiments were laid out in Randomized Complete Block Design (RCBD) and replicated thrice with following weed control and weedy check treatments viz., T_1-Pendimethalin 30EC @1.0kg a.i. ha^{-1}at 3 DAS,T_2-Pendimethalin + Imazethapyr (ready-mix) 32EC @ 1.0kg a.i. ha^{-1}at 3 DAS, T_3- T_1 + Quizalofop-ethyl 5EC @ 50g a.i. ha^{-1}at 15-20 DAS, T_4- T_2 + Quizalofop-ethyl 5EC @50g a.i. ha^{-1}at 15-20 DAS, T_5- T_1 + Imazethapyr 10SL @40g a.i. ha^{-1}at 15-20 DAS, T_6- T_1 + Hand weeding at 30 DAS, T_7- T_2 + Hand weeding at30 DAS, T_8 - Hand weeding at 20 and 40 DAS and T_9 - Weedy check. Among the various weed control methods attempted under field experiments, the least weed count of 4.11 Nos. m^{-2}and weed dry weight of 36.5kg ha^{-1} at harvest stage was recorded in hand weeding twice at 20 and 40 DAS, and it was on par with the weed control methods of pendimethalin + imazethapyr (ready-mix) 32EC @ 1.0kg a.i. ha^{-1}at 3 DAS + hand weeding at 30 DAS followed by pendimethalin @1.0 kg ha^{-1}+ hand weeding at 30 DAS and significantly lesser than all the other weed control treatments.The maximum efficiency of weed control (87%) at harvest stage and consequently the higher grain yield (1247 kg ha^{-1}) and gross return (₹ 60783 ha^{-1}) was recorded in hand weeding twice at 20 and 40 DAS, whereas the higher net return (₹31202 ha^{-1}) and benefit: cost ratio (2.13) was accounted in integrated weed control practice of pendimethalin + imazethapyr (ready-mix) @ 1.0kg a.i. ha^{-1} +hand weeding at 30 DAS, and it was on par with hand weeding twiceat 20 and 40 DAS, and pendimethalin @1.0kgha^{-1}+ hand weeding at 30 DAS. It was concluded from the two years of experimental results that, weed control methods comprising of application of either pendimethalin + imazethapyr (ready-mix) 32EC @ 1.0kg ha^{-1}or pendimethalin 30EC @1.0kg a.i. ha^{-1}at 3 DAS followed by hand weeding at 30 DAS was the efficient and economically viable weed management practice for irrigated upland greengram. It was also concluded that under non-availability of labour for adopting hand weeding practice, pre-emergence application of pendimethalin + imazethapyr (ready-mix) 32EC @ 1.0kg ha^{-1} at 3 DAS followed by early post-emergence application of quizalofop-ethyl 50g ha^{-1} at 15-20 DAS could be adopted as an alternate weed control methods for maximizing the productivity of irrigated greengram.

Keywords: Green gram productivity, hand weeding, integrated weed management, irrigated upland, pre and early post-emergence herbicide

Grain legumes referred as 'pulses'are second most important category of food grain cropsand itremains as main source of dietary protein of majority of Indian population, hence it is widely known as "rich man's vegetable" and "poor man's meat". However, the per capita availability of pulses has come down from 61g day^{-1} in 1951-52 to 33g day^{-1} in 2014-'15. India always remains as the global leader in pulses production, consumption and as well as biggest importer to meet the demand of the ever increasing populace requirement. In India, pulses are cultivated in an area of 28.83 million hectare with a production of 23.94 million tonnes and the average productivity of 830 kg ha^{-1}. Among the major grain legumes, greengram/mungbeanis a third important pulse crops in the order of chickpea, pigeonpea and urdbean, and it is primarily cultivated in an area of 4.07 million hectare with a production of 1.90 million tonnes with an average productivity of 467 kg ha^{-1} (Singh *et al.*, 2015). Due to its short duration, early and synchronized maturity characteristics, greengram plays a pivotal role in intensive and multiple crop production activities *viz.*, catch cropping, mixed cropping, intercropping *etc*. However, yield potential of the greengram remains dismal and very low owing to several abiotic and biotic stress during the cropping period as well as poor and uncared crop management practice. Weed infestation and its intensity at critical stages of the crop growth period is a very important biotic limitation in irrigated upland greengram cultivation and has been found to reduce 50-80 per cent yield under irrigated dry as well as in rainfed ecosystems (Nagender *et al.*, 2016; Raj *et al.*, 2012; Khaliq *et al.*, 2002). Due to its diversity nature and competitive ability, weeds are foremost menace to

Email: senthivelu.m@tnau.ac.in

agricultural crop cultivation in general and pulses cultivation in specific and the unchecked weed infestation and its intensity out-compete greengram crop for natural resources utilization and thus severe yield reduction, poor grain quality and depletion of available soil nutrients (Chhodavadi *et al*., 2013).

In Indian agriculture weeds are generally and traditionally controlled by hand weeding and hoeing methods which are more effective but not most efficient in-terms of economic aspects. Because this method is a labour intensive, physically cumbersome and economically expensive management methods under labour crunch and peak labour demand situation of the cropping period. With the inventions of spectrum of new generation selective herbicides, the choices and options for controlling/managing the weed infestation at critical crop growth stage and maximizing the productivity of greengram has been witnessed tremendous utility of the herbicides in the recent years. Despite the availability of several selective herbicides, which could be applied as either before the germination of weeds (pre-emergence) or after the germination of the weeds (post-emergence) or sequential application of pre-emergence and early post emergence or combined with manual weeding/hoeing for effective and efficient weed management in greengram, data pertaining its field application efficiency and their effect on yield attributing parameters thereby grain yieldand economics of greengram is lacking under irrigated upland ecosystems. With this background and lacunae in research aspects, the present field experiments were executed with an objective of evolving agronomicand economically viable weed management methodsfor maximizing the weed control vis-à-vis the productivity of irrigated greengram under upland ecosystem.

MATERIALS AND METHODS

Field experiments under irrigated upland condition were investigated for evolving agronomic and economically viable weed management methods for maximizing the weed control vis-à-vis the productivity of irrigated greengram under upland ecosystem during *kharif* season of 2015 and 2016 at experimental farm of Millet Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu State situated in Southern Agro-Climatic Zone of India and Western Agro-Climatic Zone of Tamil Nadu State at a latitude of 11º00′00′′ N and longitude of 77º00′00′′ E with an altitude of 426.72 m above mean sea level. The farm of the experimental site extends over an area of 78.4 ha with Alfisol (red soil) as major soil type. The soil of experimental field was sandy loam type (15.0 % coarse sand, 30.5 % fine sand, 35.8 % silt and 18.7 % clay) in texture and classified as Typic Ustivertept belonging to Periya Nayakkan Palayam (P. N. Palayam) series and had 8.1 pH (1:2 soil : water), 0.44 dS m^{-1}, EC, 0.38 per cent organic carbon (chromic acid wet oxidation method), 239.0 kg ha^{-1} available nitrogen (by Alkaline permanganate method), 10.4 kg ha^{-1} available phosphorus (Olsen method^{-}) and 475.0 kg ha^{-1} of 1 N neutral ammonium-acetate-extractable potassium (by flame photometry) with bulk density of 1.45 Mg per m^3. Thirty years average annual rainfall of the experimental site is 685 mm received in 38 rainy days and distributed at 209.4 mm (31.25 %) and 305.4 mm (45.58 %), respectively during south-west monsoon period (June-September) and north-east monsoon (October-December). The mean maximum and minimum temperature are 32.12 ºC and 21.51 ºC, respectively. The relative humidity of the forenoon varied from 61 to 91 per cent whereas afternoon it ranged between 14 and 68 per cent. Wind velocity was 5.8 km hr^{-1}, the mean daily sunshine was 7.4 hr day^{-1} with mean solar radiation of 400 Cal. cm^{-2} day^{-1} and pan evaporation of 5.4 mm day^{-1}.

The field experiments were executed in Randomized Complete Block Design (RCBD) and replicated thrice with following weed control and weedy check treatments *viz*., T_1- Pendimethalin 30EC @ 1.0kg a.i. ha^{-1} at 3 DAS,T_2- Pendimethalin + Imazethapyr (ready-mix) 32EC @ 1.0kg a.i. ha^{-1} at 3 DAS, T_3- T_1 + Quizalofop-ethyl 5EC @ 50g a.i. ha^{-1}at 15-20 DAS, T_4- T_2 + Quizalofop-ethyl 5EC @50g a.i. ha^{-1}at 15-20 DAS, T_5- T_1 + Imazethapyr 10SL @40g a.i. ha^{-1}at 15-20 DAS, T_6- T_1 + Hand weeding at 30 DAS, T_7- T_2 + Hand weeding at30 DAS, T_8 - Hand weeding at 20 and 40 DAS and T_9 - Weedy check. To establish the experimental crop, chemically and biologically treated seeds of greengram CO 8 variety was sown at 30cm x 10cm spacing and basally fertilized with 25: 50: 25kg of $NP_2O_5K_2O$ ha^{-1} through the source of urea, single super phosphate and muriate of potash fertilizer respectively. Standard procedures were adopted for recording the data on weed density, weed dry weight, weed control efficiency, and various yield attributes and grain yield of greengram. Weed parameters like density and it dry matter was recorded by collecting the weed samples from one square metre area using a quadrate with a surface area of 0.25m^2 in each experimental unit. Weed control efficiency of the various weed control methods adopted in the field experiment were calculated from the weed dry matter values and expressed in percentage. Yield attributing parameters of greengram *viz*., number of pods $plant^{-1}$, seeds pod^{-1} and 100 seed weight were estimated by randomly selecting 5 plants from each experimental

Table 1: Effect of herbicidal and integrated weed management methods on weed density under irrigated upland greengram

Treatments	Weed density (Nos.m-2)								
	20 DAS			40 DAS			At harvest		
	Kharif 2015	*Kharif* 2016	Pooled Mean	*Kharif* 2015	*Kharif* 2016	Pooled Mean	*Kharif* 2015	*Kharif* 2016	Pooled Mean
T1	4.90 (24.0)	4.36 (19.0)	4.64 (21.5)	6.30 (39.7)	5.84 (34.0)	6.07 (36.9)	7.44 (55.3)	6.79 (46.0)	7.12 (50.7)
T2	4.09 (16.7)	3.92 (15.3)	4.01 (16.0)	6.06 (36.7)	5.10 (26.0)	5.61 (31.4)	6.95 (48.3)	6.19 (38.3)	6.58 (43.3)
T3	4.81 (23.1)	4.51 (20.3)	4.66 (21.7)	5.60 (31.3)	5.32 (28.3)	5.46 (29.8)	6.46 (41.7)	5.75 (33.0)	6.12 (37.4)
T4	4.13 (17.0)	3.97 (15.7)	4.06 (16.4)	5.13 (26.3)	4.93 (24.3)	5.03 (25.3)	5.66 (32.0)	5.27 (27.7)	5.47 (29.9)
T5	4.73 (22.3)	4.40 (19.3)	4.57 (20.8)	5.10 (26.0)	5.00 (25.0)	5.05 (25.5)	6.22 (38.7)	5.72 (32.7)	5.98 (35.7)
T6	4.71 (22.1)	4.66 (21.7)	4.69 (21.9)	4.73 (22.3)	4.33 (18.7)	4.53 (20.5)	5.17 (26.7)	4.70 (22.0)	4.94 (24.4)
T7	4.13 (17.0)	4.09 (16.7)	4.12 (16.9)	4.25 (18.0)	4.04 (16.3)	4.15 (17.2)	4.70 (22.0)	4.33 (18.7)	4.52 (20.4)
T8	6.81 (46.3)	6.35 (40.3)	6.58 (43.3)	5.00 (25.0)	4.40 (19.3)	4.72 (22.2)	4.33 (18.7)	3.88 (15.0)	4.11 (16.9)
T9	7.14 (51.0)	6.66 (44.3)	6.91 (47.7)	8.70 (75.7)	8.08 (65.3)	8.40 (70.5)	10.44 (109.0)	10.12 (102.3)	10.28 (105.7)
SEm (±)	**0.37**	**0.47**	**0.42**	**0.52**	**0.38**	**0.45**	**0.45**	**0.41**	**0.43**
LSD (0.05)	**0.79**	**0.99**	**0.89**	**1.10**	**0.80**	**0.95**	**0.96**	**0.87**	**0.92**

** - Figures in parenthesis are originally observed values subjected to √(x+0.05) transformation*

treatment plot as well as replication and averaged. For assessing the grain and haulm yield of greengram, the border rows in each plot were harvested first and then the plants in the net plots were harvested separately. Grains of the test crop were separated through manual threshing and cleaning and then cleaned seeds were dried and the yield was recorded at 12 per cent moisture level and expressed in kg ha^{-1}. After threshing the matured pod, the haulm/stalk left in the net plot area were sun dried for three days and then dry weight of haulm/stalk of each treatment and replication was computed and expressed in kg ha^{-1}. Significance of the difference observed in weed parameters, yield attributes, grain and haulm yield, and economics ofthe greengram under different chemical, integrated weed management and manual hand weeding/hoeingmethodswere tested and compared using Analysis of Variance (ANOVA) and Homogeneity test as suggested by Gomez and Gomez (1984).Data on weed count were subjected to square root ("(x+0.5)) transformation to make analysis of variance more valid as suggested by Chandel (1984).Wherever the treatments difference were found significant, the critical differences were worked out at 5 *per cent* probability and values were furnished.

RESULTS AND DISCUSSION

Weeds by their virtue of complexity, adaptive flexibility, rapid growth and development behavoiur, it predominate the crop habitat and thus possess competitive advantage for utilization of all the natural resources than cultivated crop. Among the weed species found and recorded in the experimental plot, 75 per cent of the weeds belongs to broad leaved category, 13 per cent of the weeds belongs to grasses group and the remaining 8 per cent of the weeds belong to sedges types.The dominant and major weed flora pertaining to broad leaved category were *Amaranthus viridis, Boerhavia diffusa, Boerhavia erecta, Cleome viscosa, Commelina benghalensis, Corchorus fascicularis, Corchorus olitorius*, *Digera arvensis*, *Euphorbia hirta*, *Euphorbia microphylla, Parthenium hysterophorus, Phyllanthus niruri*, *Phyllanthusmader aspatensis, Trianthema portulacastrum*, grassy types were *Chloris barbata,Cynodan dactylon, Echinochloa colonum, Echinochloa crusgalli* and *Panicum repens* and sedges weed types were *Cyperus rotundus* and *Cyperus difformis.*

Table 2: Influence of chemical and integrated weed management methods on weed dry weight and weed control efficiency under irrigated greengram

Treatments	Weed dry weight (kg ha^{-1})									Weed control efficiency (%)								
	20 DAS			40 DAS			At harvest			20 DAS			40 DAS			At harvest		
	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean
T_1	43.7	36.7	40.2	77.5	60.6	69.1	144.4	124.6	134.5	65.0	66.8	65.9	59.1	64.5	61.8	49.6	54.3	52.0
T_2	30.3	25.5	27.9	57.7	44.0	50.9	120.7	92.5	106.6	75.7	76.9	76.3	69.6	74.2	71.9	57.9	66.0	62.0
T_3	44.4	38.5	41.5	47.2	39.1	43.2	86.6	66.3	76.5	64.4	65.2	64.8	75.1	77.1	76.1	69.8	75.7	72.8
T_4	31.6	26.0	28.8	40.4	33.9	37.2	76.0	61.0	68.5	74.7	76.5	75.6	78.7	80.1	79.4	73.5	77.6	75.6
T_5	43.9	37.3	40.6	44.9	36.5	40.7	82.2	64.9	73.6	64.8	66.3	65.6	76.3	78.6	77.5	71.3	76.2	73.8
T_6	41.6	38.5	40.1	30.3	22.7	26.5	53.3	42.8	48.1	66.7	65.2	66.0	84.0	86.7	85.4	81.4	84.3	82.9
T_7	30.3	27.2	28.8	25.9	19.3	22.6	46.9	36.7	41.8	75.7	75.4	75.6	86.3	88.7	87.5	83.6	86.5	85.1
T_8	119.5	105.8	112.7	36.0	25.8	30.9	40.5	32.5	36.5	4.2	4.3	4.3	81.0	84.9	83.0	85.9	88.1	87.0
T_9	124.8	110.6	117.7	189.7	170.5	180.1	286.6	272.4	279.5	-	-	-	-	-	-	-	-	-
SEm (±)	**2.9**	**4.7**	**3.8**	**4.8**	**4.0**	**4.4**	**13.1**	**11.5**	**12.3**	**2.0**	**4.0**	**3.00**	**2.0**	**1.7**	**1.85**	**3.2**	**2.6**	**2.90**
LSD (0.05)	**6.1**	**9.9**	**8.0**	**10.2**	**8.4**	**9.3**	**27.8**	**24.5**	**26.2**	**4.3**	**8.5**	**6.40**	**4.2**	**3.6**	**3.90**	**6.8**	**5.5**	**6.15**

Table 3: Yield attributes and yield of irrigated greengram as influenced by chemical and integrated weed management methods

Treatments	Pods plant-1 (Nos.)			Seeds pod^{-1} (Nos.)			Test weight (g)			Grain yield (kg ha^{-1})			Haulm yield (Kg ha^{-1})			Harvest Index		
	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean	2015	2016	Pooled Mean
T1	27.6	30.8	29.2	8.6	8.9	8.8	3.55	3.58	3.57	650	710	680	1254	1426	1340	0.342	0.332	0.337
T2	33.5	36.6	35.1	9.0	9.3	9.2	3.60	3.62	3.61	717	828	773	1344	1573	1459	0.348	0.345	0.347
T3	37.2	40.9	39.1	9.2	9.6	9.4	3.64	3.66	3.65	820	900	860	1463	1585	1524	0.359	0.362	0.361
T4	43.7	47.6	45.7	9.5	9.7	9.6	3.72	3.73	3.73	946	975	961	1596	1624	1610	0.372	0.375	0.374
T5	38.7	43.3	41.0	9.4	9.9	9.7	3.69	3.70	3.70	865	905	885	1474	1549	1512	0.370	0.369	0.370
T6	47.2	56.6	51.9	9.7	10.0	9.9	3.73	3.75	3.74	1115	1125	1120	1683	1718	1701	0.391	0.396	0.394
T7	52.5	59.0	55.8	10.3	10.5	10.4	3.78	3.79	3.79	1196	1220	1208	1816	1839	1828	0.397	0.399	0.398
T8	57.4	64.8	61.1	10.5	10.6	10.6	3.82	3.84	3.83	1234	1259	1247	1841	1848	1845	0.401	0.405	0.403
T9	13.5	15.4	14.5	7.2	7.0	7.1	3.48	3.48	3.48	415	447	431	993	1030	1012	0.295	0.303	0.299
SEm (±)	**3.1**	**2.6**	**2.9**	**0.7**	**0.6**	**0.7**	**0.30**	**0.30**	**0.30**	**59**	**62**	**61**	**105**	**112**	**109**	**0.006**	**0.006**	**0.006**
LSD(0.05)	**5.6**	**6.5**	**6.1**	**1.5**	**1.3**	**1.40**	**NS**	**NS**	**NS**	**126**	**132**	**129**	**222**	**238**	**230**	**0.013**	**0.013**	**0.013**

Table 4: Economics of chemical and integrated weed management methods in irrigated green gram

Treatments	Total variable cost (Rs. ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B: C ratio		
	2015	**2016**	**Pooled Mean**	**2015**	**2016**	**Pooled Mean**	**2015**	**2016**	**Pooled Mean**	**2015**	**2016**	**Pooled Mean**
T_1	21710	22138	21924	30875	35500	33188	9167	13362	11265	1.42	1.60	1.51
T_2	22590	23020	22805	34058	41400	37729	11468	18380	14924	1.51	1.80	1.66
T_3	23900	24350	24125	38950	45000	41975	15050	20650	17850	1.63	1.85	1.74
T_4	24785	25232	25009	44935	48750	46843	20153	23518	21836	1.81	1.93	1.87
T_5	23170	23618	23394	41088	45250	43169	17919	21632	19776	1.77	1.92	1.85
T_6	26455	27138	26797	51253	56250	53752	24794	29112	26953	1.94	2.07	2.01
T_7	27340	28020	27680	56763	61000	58882	29423	32980	31202	2.08	2.18	2.13
T_8	29415	30323	29869	58615	62950	60783	29202	32627	30915	1.99	2.08	2.04
T_9	17250	17723	17487	19713	22350	21032	2459	4627	3543	1.14	1.26	1.20
SEm (±)	-	-	-	**2813**	**3122**	**2968**	**2813**	**3122**	**2968**	**0.11**	**0.12**	**0.12**
LSD (0.05)	-	-	-	**5962**	**6619**	**6291**	**5962**	**6619**	**6291**	**0.24**	**0.26**	**0.25**

Weed diversity and its density, dry weight and control efficiency in irrigated upland greengram crop system varied significantly under different chemical, integrated weed management and hand weeding/hoeing methods at the observed time of 20 and 40 DAS and at harvest stage (Table 1 and 2). At 20 DAS, minimum weed count of 4.01Nos m^{-2}, weed dry weight of 27.9kg ha^{-1} and maximum weed control efficiency of 76.3% was recorded in pre-emergence application of pendimethalin + imazethapyr 32EC (ready-mix)@ 1.0kg a.i. ha^{-1} at 3 DAS (T_2), which was significantly minimum in terms of weed count and dry weight, whereas maximum in terms of weed control efficiency than hand weeding practice at 20 and 40 DAS (T_8) and weedy check (T_9) and was on par with the treatments which are having application of pre- emergence herbicide either pendimethalin 30EC @ 1.0kg a.i. ha^{-1}(T_1, T_3, T_5 and T_6) or pendimethalin +imazethapyr 32EC (ready-mix) @ 1.0kg a.i.ha^{-1} at 3 DAS (T_4 and T_8). Whereas at 40 DAS and at harvest stages, application of early post emergence herbicide and hand hoeing/weeding integrated with pre-emergence herbicide application altered the weed density, dry weight and control efficiency. At 40 DAS, integrated weed management methods comprising of pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1} at 3 DAS followed by hand weeding at 30 DAS (T_7) registered minimum weed count of 4.15Nos. m^{-2}, dry weight of 22.6kg ha^{-1} and maximum weed control efficiency of 87.5 per cent, and it was on par with pendimethalin 30EC @1.0 kg a.i. ha^{-1} at 3 DAS followed by hand weeding at 30 DAS (T_6) and hand weeding at 20 and 40 DAS (T_8) and it was significantly lower relevant to weed count and its dry weight and significantly higher relevant to weed control efficiency than application of pre-emergence herbicide alone (T_1 and T_2) and sequential application of pre-emergence and early post emergence herbicide at 3 and 15 -20 DAS respectively (T_3, T_4 and T_5). At harvest stage of the crop, least weed count (4.11Nos m^{-2}), weed dry weight (36.5kg ha^{-1}) and the highest weed control efficiency (87.0%) was recorded in the weed control treatment of hand weeding twice at 20 and 40 DAS (T_8) and was on par with integrated weed management methods through either pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1} at 3 DAS + hand weeding at 30 DAS (T_7) or pendimethalin 30EC @ 1.0kg a.i. ha^{-1} at 3 DAS + hand weeding at 30 DAS (T_7) and it was significantly lower in terms of weed count and its dry weight andsignificantly higher in terms of weed control efficiency than application pre-emergence herbicide alone ($T_1$and T_2), sequential application of pre-emergence and post emergence herbicide (T_3, T_4 and T_5) and weedy check (T_9). Irrespective of the stages of the crop growth, weedy check/unweeded control plot registered maximum weed count of 6.91, 8.40 and 10.28 Nos. m^{-2}, weedy dry weight of 117.7, 180.1 and 279.5kg ha^{-1} at 20 and 40 DAS, and at harvest stages respectively and all the weed control methods attempted in this field experiments recorded significantly less weed count and dry matter production of weeds than the unweeded control and thereby higher weed control efficiency. Similar findings were also reported in the earlier research investigated by Kaur *et al*. (2010), Raj *et al*. (2012), and Chhodavadia *et al*. (2013). The minimum weed count and its dry weight, and the maximum weed control efficiency in hand weeding twice at 20 and 40 DAS and integrated weed management approach comprising of chemical and physical/mechanical methods were due to efficient, effective and maximum control of broad-spectrum of weed species *viz*., broad leaved weeds, grasses and sedges and its density during the most critical period of crop-weed competition and by smothering effect of well developed crop at later stage of the cropping period. The highest weed control efficiency in integrated weed management methods exhibit the magnitude and intensity of effective control and efficient reduction of weed density and its dry weight over weedy check as well as weed control by application of either pre-emergence herbicide alone or sequential application of pre-emergence and early post emergence herbicides at 3 and 15-20 DAS respectively.

Perusal of the data pertaining to yield attributes and yield of greengram presented in table 3, indicated that adoption of various weed management methods through pre-emergence herbicide alone (T_1 and T_2), sequential application of pre-emergence and early post emergence herbicide at 3 DAS and 15-20 DAS (T_3, T_4 and T_5) and integrated weed management (T_6 and T_7) and hand weeding twice at 20 and 40 DAS (T_8) significantly influenced the yield attributing parameters of greengram *viz*., pod $plant^{-1}$ and seeds pod^{-1}, there by enhancement in grain and haulm yield and thus harvest index of the greengram. However no significant difference was observed in test weight of the greengram as influenced by the different weed control methods investigated in the field experiments.

Among the various weed control methods attempted in the present study, practicing hand hoeing/weeding twice at 20 and 40 DAS (T_8) significantly registered higher pods $plant^{-1}$ (61.1Nos.), seed pod^{-1} (10.6Nos.), grain yield (1247kg ha^{-1}), haulm yield (1845kg ha^{-1}) and harvest index (0.403) than weedy check (T_9), pre-emergence application of pendimethalin 30EC @ 1.0kg a.i. ha^{-1}(T_1), pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1}(T_2),sequential application of pendimethalin 30EC @ 1.0kg a.i. ha^{-1}at 3 DAS followed by quizalofop-ethyl 5EC @ 50g a.i. ha^{-1} at 15-20 DAS (T_3), pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1}+quizalofop-ethyl 5EC @ 50g a.i. ha^{-1} at 15-20 DAS (T_4), pendimethalin 30EC @ 1.0kg a.i. ha^{-1}at 3 DAS +imazethapyr 10SL @40g a.i. ha^{-1}at 15-20 DAS (T_5). However integrated weed management methods comprising of pendimethalin 30EC @ 1.0kg a.i. ha^{-1} at 3 DAS followed by hand weeding at 30 DAS ((T_6) and pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1}+ hand weeding at 30 DAS (T_7) recorded on par value of number pods $plant^{-1}$ (51. 9 and 55.8Nos.), seed pod^{-1} (9.9 and 10.4 Nos.), grain yield (1120 and 1208 kg ha^{-1}), haulm yield (1701 and 1828 kg ha^{-1}) and harvest index (0.394 and 0.398) respectively. Further, hand weeding twice at 20 and 40 DAS, pendimethalin 30EC @ 1.0kg a.i. ha^{-1}at 3 DAS + hand weeding at 30 DAS, and pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0 kg a.i. ha^{-1}+ hand weeding at 30 DAS recorded 65.4%, 64.3% and 61.5% higher grain yield, 45.1%, 44.6% and 40.5% higher haulm yield respectively than weed check (T_9). Higher yield attributing characters of greengram and thereby higher grain and haulm yield might be due to effective control of all kind of weeds *viz*., grasses, sedges and broad leaved at critical crop growth and development stage of the greengram. Effective control of weed diversity, density and its growth and thereby reducing the crop-weed competition at critical stages of the greengram enabled efficient utilization of the natural resources like space, sunlight, carbon di-oxide, soil moisture and soil nutrients, which in turn enhanced and maintained the optimum level of source-sink relationships which responsible for higher grain yield and haulm yield and thereby harvest index of irrigated greengram. The finding of the experiments was in accordance and conformity with the earlier findings reported by Chhodavadia *et al*. (2014), Komal *et al*. (2015), Sobhana, *et al*. (2018) and Jaidka *et al*. (2018). The lower grain yield of 431 kg ha^{-1} and haulm yield of 1012 kg ha^{-1} recorded under weedy check/ unweeded control treatments clearly indicated the higher order and intensive crop-weed competition for utilization of different natural resources and it emphasized the importance of effective and efficient weed control methods at crucial period of the irrigated upland greengram either by chemical method or physical method or integrated approach. Yield losses of similar degree and magnitude due to the severe crop-weed competition have been reported by Rathi *et al*. (2008), Kaur *et al*. (2010) and Ali *et al*. (2011).

Data relevant to economics *viz*., gross return, net return and benefit: cost ratio of the various chemical weed control and integrated weed management methods investigated in irrigated upland greengram (Table 4) exhibited significant difference during both the years of field experimentation conducted during *Kharif*, 2015 and 2016. Among the different weed control treatments tried, hand weeding twice at 20 and 40 DAS (T_8) significantly registered maximum gross returns of ₹ 60783 ha^{-1}than weedy check (T_9-₹ 21032 ha^{-1}), application of pre-emergenceherbicide alone (T_1 and T_2) and sequential application of pre and early post emergence herbicides at 3 and 15-20 DAS respectively (T_3, T_4 and T_5), however it recorded on par values of gross return under integrated weed control treatments involving either pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1} followed by hand weeding at 30 DAS (T_7-₹ 58882 ha^{-1}) or pendimethalin 30EC @ 1.0kg a.i. ha^{-1} at 3 DAS + hand weeding at 30 DAS (T_6-₹53752 ha^{-1}). In terms of net return and benefit: cost ratio, pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1} followed by hand weeding at 30 DAS (T_7) significantly accounted higher values of ₹ 31202 ha^{-1} and 2.13 respectively than weedy check (T_9), application of either pre-emergence herbicide alone (T_1 and T_2) or combination of pre-emergence and early post emergence herbicides at 3 and 15-20 DAS respectively (T_3, T_4 and T_5), but it recorded on par values of net return and benefit: cost ratio with hand weeding twice at 20 and 40 DAS (T_9) and integrated application of pendimethalin + imazethapyr 32EC (ready-mix) @ 1.0kg a.i. ha^{-1} followed by hand weeding at 30 DAS (T_7). This higher monetary return and benefit: cost ratio in hand weeding twice and integrated weed management approaches obviously due to effective and timely control of broad-spectrum of weeds in greengram crop system, which facilitated crop-weed competition free as well as amenable crop cultivation environment for better growth and development thus lead to realization of higher greengram grain yield than under weedy check and chemical weed control method alone. Moreover, integrated weed management methods need less labourr equirement than hand weeding twice and thereby lower variable cost for weeding operation. This experimental results manifest the core and very importance of integrated weed control/management methods in modern intensive cropping systems under labour scarcity conditions (Chhodavadi *et al*., 2013; Paudel *et al*., 2017; Meena *et al*., 2018)

It was concluded that from the results of the present field experiments that integrated weed control/ management methods having the combination of pre-emergence application of pendimethalin+imazethapyr (ready mix) 32 EC @ 1.0kg ha^{-1} at 3 DAS followed by hand weeding at 30 DAS (or) pre-emergence application of pendimethalin 30 EC @ 1.0kg ha^{-1} at 3 DAS followed by hand weeding at 30 DASis the most effective and efficient, high productive and economically viable weed management methods for irrigated upland greengram crop system. In acute labour scarcity condition/peak labour demand situation, sequential application of pendimethalin+imazethapyr (ready mix) 32 EC @ 1.0kg ha^{-1} at3 DAS as pre-emergence herbicide followed by quizalofop-ethyl @ 50g ha^{-1} at 15-20 DAS as early post emergence herbicide could be explored as an alternate weed management methods for augmenting and maximizing the productivity of irrigated upland greengram.

REFERENCES

Ali, S., Patel, J., Desai, L. and Singh, J. 2011. Effect of herbicides on weeds and yield of rainy season greengram (*Vigna radiata*. L. Wilczek). *Legume Res.*, **34 (4)**: 300-303.

Chandel, S. R. S. 1984. Analysis of variance. A Hand Book of Agricultural Statistics, 7th edition, pp. 358-359.

Chhodavadia, S., Sagarka, B. and Gohil, B. 2014. Integrated management for improved weed suppression in summer green gram (*Vigna radiata* L. Wilczek). *Bioscan*, **9 (2)**: 1577- 1580.

Chhodavadia, S. K., Mathukiya, R.K. and Dobariya, V. K. 2013. Pre and post-emergence herbicides for integrated weed management in summer greengram. *Indian J. Weed Sci.*,**45(2)**: 137-139.

Gomez, K.A. and Gomez, A. A. 1984. Statistical procedure for agricultural research, Willey Inter - Science Publications, New York. pp: 680.

Jaidka, M. and Sharma, M. 2018. Post-emergence chemical weed control in *kharif* green gram (*Vigna radiata*). *J. Krishi Vigyan,* 7 (Special Issue) : 129-134.

Kaur, G., Brar, H. S. and Singh, G. 2010. Effect of weed management on weeds, nutrient uptake, nodulation, growth and yield of summer mungbean (*Vignaradiata*). *Indian J. Weed Sci.*,**42** (1 & 2) : 114 - 119.

Khaliq, A., Aslam, Z. and Cheema, Z. A. 2002. Efficacy of different weed management strategies in mungbean (*Vignaradiata* L.). *Int. J. Agri. Biol.*, **4 (2)**: 237-239.

Komal, S. and Yadav, R. 2015. Effect of weed management on growth, yield and nutrient uptake of greengram. *Indian J. Weed Sci.*, **47(2)**: 206 - 210.

Meena, H., Meena, P.K.P., Nagar, K.C., Kumhar, B.L. and Meena, B. S. 2018. Comparative efficacy of herbicides for weed management in soybean (*Glycine max* L.). *Chem. Sci. Rev. Lett.*, **7 (25)**: 170-174.

Nagender, T., Srinivas, A., Leela Rani, P., Ram Prakash, T. and Narender, J. 2016. Production and economics of green gram (*Vigna radiata* L. Wilczek.) under various weed management strategies. *Progressive Res.*, **11 (1)**: 453-456.

Panse, V.G. and Sukhatme, P.V. 1978. Statistical methods for agriculture workers. Indian Council of Agriculture Research, New Delhi. pp. 152.

Paudel, P., Singh, R.S., Pandey, I.P. and Prasad, S.S. 2017. Effect of different weed management practice on weed dynamic, yield and economics of soybean production. *Azarian J. Agric.* **4 (2)**: 54-59.

Raj, V.C., Patel, D.D., Thanki, J.D. and Arvadia, M. K. 2012. Effect of integrated weed management on weed control and productivity of green gram (*Vigna radiata*). *Bioinfolet,* **9 (3)**: 392-396.

Rathi, P. K., Rathi, J.P.S., Singh, O.P. and Baiswar, R. 2008. Production and economics of greengram under various row spacing in relation to weed control methods. *Plant Archives*, **8(1)**:471-479.

Singh, A. K., Singh, S.S., Prakash, V., Kumar, S. and Dwivedi, S. K. 2015. "Pulses production in India: present status, bottleneck and way forward". *J. Agri. Search*., **2 (2)**:75-83.

Sobhana, E., Velayutham, A. and Sujithra, P. 2018. Effect of pre and early postemergence herbicides on the growth and yield of rainfed greengram. *International J. Adv. Agric. Sci. Tech.,* **5 (7)**: 52 - 60.