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Phenological Behaviour, Weed Dynamics and Productivity of Green Gram Influenced by Weed Control Treatments

Rajni Punia, S.S. Punia, Sudesh Devi*, Virender Singh Hooda, Navish Kumar Kamboj and Sanjay Kumar Thakral

Chaudhary Charan Singh Haryana Agricultural University, Hisar- 125004, Haryana, India

**Corresponding author*

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A field experiment was conducted at Research farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar, during *Kharif* season of 2013 to evaluate different weed control treatments on weed dynamics, phenology, heat unit requirement and productivity of green gram. The experimental field was infested with both types of weeds. RM of imazethapyr + imazamox (RM) at 80 g/ha applied at 3-4 leaf stage recorded highest value of WCI (80.68), CRI, GDD, HTU, PTU, calendar days, HUE, HeUE, PUE and seed yield (398 kg/acre) and lowest value of total weed population , weed index (13) over other herbicidal treatments. Two (hand) hoeings employed at 20 and 40 DAS gave statistically at par results with weed free treatment followed by one (hand) hoeing. Post-emergence application of RM imazethapyr + imazamox (RM) at 60-80 g/ha exhibited 74-80% control of weeds and showed higher crop growth. In sight of results, two hoeings at 20 and 40 DAS or post emergence application of imazethapyr + imazamox at 80 g ha^{-1} or imazethapyr alone at 70 g ha^{-1} should be adopted for the control of weeds in green gram.

Introduction

Green gram (*Vigna radiata* (L.) Wilczek) is a short duration pulse crop grown in India since ancient times and it is also known as mungbean, golden gram, chop soybean, etc. It is a self-pollinated annual crop belonging to leguminosae family due to this; it is capable of meeting its nitrogen requirements own from the atmospheric nitrogen through biological nitrogen fixation in association with rhizobium present in root nodules (Upadhayay *et al.*, 1999). Weed management is an important factor for improving the productivity of green gram as weeds compete for different resources like nutrients, water, light and space with crop during early growth period. In green gram, Yield losses due to weeds have been estimated about 30-50% (Kumar *et al.*, 2004).

It is grown as rainfed or irrigated conditions in wider rows, cultural and mechanical weed control can be practiced. But it is not always feasible due to high cost, non-availability of labours at appropriate time, prevailing weather conditions (continuous moisture), and long window of weed emergence in the growing season. So, chemical method of weed management offers good scope for harvesting a good crop of green gram. The most commonly and effective herbicides for controlling weeds in green gram are trifluralin, linuron and acetachlor (Malik *et al*., 2000) and pendimethalin, alachlor and fluchloralin (Mishra and Singh, 1993). Now a day, herbicide resistance is becoming the major cause of yield losses in crops. Therefore, effective weed management requires an integrated approach using both chemical and non-chemical approaches. The number of market entry of herbicides with new mode of action has reduced. For effective management of complex weed flora, there is need to use mixture of existing herbicides (Devi *et al*., 2017a), which should have a wide spectrum of weed control without crop injury and residual effect on succeeding sensitive crops and can enhance the productivity of crop (Devi *et al*., 2017b).

Every (crop) plant has a definite temperature requirement for attaining certain phonological stages. A change in optimum temperature during different phonological stages of a crop adversely affects the initiation and duration of different phenophases and finally economic yield of any crop. It is therefore indispensable to harvest knowledge of exact duration of phenophases in a particular environment and their association with yield attributes for achieving high yields (Kumar *et al*., 2009). Influence of temperature on phenology and yield of crop plant can be studied under field condition through accumulated heat unit system (Haider *et al*., 2003; Pandey *et al*., 2010). To keep this in view, the present study was conducted to assess the effects of different weed control treatments on weed dynamics and productivity of green gram.

Materials and Methods

A field experiment was conducted during *Kharif* season 2013 at Agronomy farm, CCS HAU, Hisar, having an elevation of 215.2 meters above mean sea level with latitude of 29^0 10' in the North and longitude of 75^0 46'in the East in sub-tropical zone. The soil of the experimental site was sandy-loam in texture, having pH 8, electrical conductivity 0.30 dS/m, medium in organic carbon (0.6%), medium in available nitrogen (320 kg/ha), medium in available phosphorus (17 kg/ha), and rich in available potassium (307 kg/ha). The detail of treatments of experiment and mean weekly meteorological data is given in Table 1 and Figure 1, respectively. The experiment was laid out in randomized block design with three replications. The sowing of greengram MH-421 was done on 22 June, 2013 and other practices were followed as per package of practices given by CCS HAU, Hisar. The weed population was recorded with quadrates measuring 0.25 m^2 area randomly at three places in each plot. The data on weed population was subjected to square-root transformation before statistical analysis. Weed dry weight, weed population and crop yield in treated and weedy check plots were used in calculation of weed control index (Misra and Tosh, 1979) and weed index (Gill and Vijaykumar, 1969). Crop resistance index (CRI) was calculated by following formula:

$$CRI = (CDMT \div CDMC) \times (WDMC \div WDMT)$$

Where, CDMT- crop dry matter in treated plots (g/m^2), CDMC- crop dry matter in control plot (g/m^2), WDMC- weed dry matter in control plot (g/m^2), WDMT- weed dry matter in treated plots (g/m^2).

Total accumulated agrometeorological indices *viz*., GDD (growing degree days), HTU (Helio-thermal unit), PTU (Photothermal unit), HUE (Heat use efficiency), HUE (Helio-thermal use efficiency) and PUE (Photothermal use efficiency) were computed by using daily meteorological data the date of occurrence of different phonological events *viz*., vegetative stage, 50% flowering stage, 50% poding stage and maturity were recorded when 75 percentage of the plants in each replicated reached the respective stages. GDD determine using base temperature of 10°C for green gram.

$$\text{GDD } (^{\circ}\text{C day}) = \frac{Tmax + Tmin}{2} - Tbase$$

Where,

Tmax- Daily maximum temperature (°C), Tmin- Daily minimum temperature (°C), Tbase- Base temperature of 10°C

$$HTU\ (^{\circ}\text{C day hour}) = GDD\ x\ Actual\ sunshine\ hours$$

$$PTU\ (^{\circ}\text{C day hour}) = GDD\ x\ Daylength$$

$$\text{HUE (kg/ha/oC day)} = Seed\ yield/biological\ yield\ (kg/ha) \div GDD\ (^{\circ}\text{C day})$$

$$\text{HeUE (kg/ha/oC day hour)} = Seed\ yield/biological\ yield\ (kg/ha) \div HTU\ (^{\circ}\text{C day hour})$$

$$\text{PUE (kg/ha/oC day hour)} = Seed\ yield/biological\ yield\ (kg/ha) \div PTU\ (^{\circ}\text{C day hour})$$

The data related to all parameters was subjected to one-way ANOVA by using online package for statistical analysis.

Results and Discussion

Weed studies

The experimental field was infested with many grassy as well as broad leaved weeds like *Echinocloa colona*, *Cyperus rotundus, Dactylocteinum aegyptium, Corchorus olitorius, Celosia argentia, Trianthema portulacastrum*, and *Digera arvensis*. Similar type of weed flora was reported by various researchers in green gram (Dungarwal *et al.*, 2003; Singh *et al.*, 2003)

Total weed population (TWP): All weed control treatments significantly influenced the weeds population in comparison to weedy check (Table 2). Significantly higher weed population was recorded in weedy check plots and lower under one (hand) hoeing and two (hand) hoeing. Among herbicidal treatments, alone application of imazethapyr at different doses failed to control weeds effectively and recorded higher weed population than pre-mix of imazethapyr with pendimethalin and imazamox at different doses. In case of alone application of imazethapyr at different doses, higher dose of 70 g/ha showed the lower value of weed population over lower doses of 50 & 60 g/ha. Whereas, in case of pre-mix application, ready mix (RM) of imazethapyr + imazamox at 80 g/ha resulted in better control of weeds and recorded significantly lower total weed population. The RM application of imazethapyr + imazamox gave the better results over RM application of imazethapyr + pendimethalin at different doses in green gram. Pre-emergence application of pendimethalin was statistically at par with pre-emergence application of RM of imazethapyr + pendimethalin at 800 and 900 g/ha (Table 2).

Weed control index (WCI): Significantly higher value of WCI was recorded under weed free plot followed by one (hand) hoeing and two (hand) hoeing (Table 2). Among herbicidal treatments, significantly higher value of WCI was recorded under RM of imazethapyr + imazamox at 80 g/ha followed by RM of imazethapyr + imazamox at 70 g/ha, then by RM of imazethapyr + pendimethalin 1000 g/ha and pendimethalin at 1000 g/ha. This may be due to better control of weeds by RM of imazethapyr + imazamox. The RM application of imazethapyr + imazamox at different doses gave higher value of WCI over RM application of imazethapyr + pendimethalin at different doses.

Weed index (WI): Significantly lower value of WI was reported under two (hand) hoeing followed by one (hand) hoeing at 20 DAS. As the doses of RM of imazethapyr + imazamox increase from 50 g/ha to 80 g/ha, WI value decreased significantly (Table 2). The value of WI also decreased as the doses of RM of imazethapyr + pendimethalin increased from 800 g/ha to 1000 g/ha.

Pre-emergence application of pendimethalin recorded the higher value of WI over other herbicidal treatments, but, maximum value of WI was recorded under weedy check due to lower yield in weedy check. Veeraputhiran (2009) reported lesser weed population, higher WCI and lower weed index under hand weeding twice and 30 x 10 cm spacing followed by mechanical weeding in both green gram and black gram.

Crop Studies

Crop growth rate (CGR): At 30 DAS, the higher value of CGR was observed under weed free and RM of imazethapyr + pendimethalin at 1000 g/ha followed by RM of imazethapyr + pendimethalin at 900 g/ha and then by pre-emergence application of pendimethalin (Table 2).

At 60 DAS, significantly higher value of CGR was observed under two (hand) hoeing; which was at par with one (hand) hoeing, weed free, RM of imazethapyr + pendimethalin at 900 & 1000 g/ha and pendimethalin 1000 g/ha.

Lowest value of CGR was observed under alone application of imazethapyr at 50 g/ha. At harvest, highest value of CGR was recorded under alone application of imazethapyr at 50 g/ha and lowest under weedy check and pendimethalin at 1000 g/ha (Table 2).

Crop resistance index (CRI): At 30 DAS, the significantly higher value of crop resistance index was recorded under two (hand) hoeing followed by one hoeing. At 30 and 60 DAS, among herbicidal treatments, RM application of imazethapyr + imazamox at 80 g/ha showed significantly the higher value of CRI over other treatments, followed by lower doses of this combination.

Crop seed and biological yields: all weed control treatments significantly increased the seed and straw yields over weedy check (Table 2. Weed free treatment by virtue of providing a favourable environment recorded maximum seed and straw yields (457.20 & 1638 kg/acre, respectively); which was significantly higher over all other treatments.

Among herbicide treatments imazethapyr + imazamox (RM) at 80 g/ha applied at 3-4 leaf stage recorded maximum seed and straw yield (398 & 1349 kg/acre, respectively) which was significantly higher than all herbicide treatments and 51% higher yield than pre emergence application of pendimethalin at 1000 g/ha. Post-emergence application of imazethapyr at 70 g/ha at 3-4 leaf stage also increase the seed yield (366 kg/acre) significantly which was at par with the imazethapyr + imazamox (RM) at 70 g/ha (Table 2).

Among all the weed control treatments lowest seed yield (196.80 kg/acre) was recorded with pendimethalin at 1000 g ha^{-1}. Seed yield was significantly increased in two hoeing (431 kg/acre) in comparison to all treatments except weed free. The maximum straw yield was recorded in weed free treatment followed by one (hand) hoeing given at 20 DAS and two (hand) hoeings employed at 20 and 40 DAS (1555.60 and 1570.40 kg/acre). Among herbicidal treatments, RM of imazethapyr + imazamox at 60 g/ha applied at 3-4 leaf stage recorded maximum straw yield (1349.60 kg ha^{-1}) (Table 2). Vikas *et al.* (2013) reported that highest seed yield was recorded with two HW (hand weeding) at 20 and 40 DAS in urdbean.

Table.1 Details of treatments of experiment in green gram

S. No.	Treatment		Dose (g/ha)	Application time
1.	T1	Pendimethalin	1000	PRE
2.	T2	Imazethapyr	50	3-4 leaf stage
3.	T3	Imazethapyr	60	3-4 leaf stage
4.	T4	Imazethapyr	70	3-4 leaf stage
5.	T5	Imazethapyr +pendimethalin (RM)	800	PRE
6.	T6	Imazethapyr +pendimethalin (RM)	900	PRE
7.	T7	Imazethapyr +pendimethalin (RM)	1000	PRE
8.	T8	Imazethapyr + imazamox(RM)	50	3-4 leaf stage
9.	T9	Imazethapyr + imazamox(RM)	60	3-4 leaf stage
10.	T10	Imazethapyr + imazamox(RM)	70	3-4 leaf stage
11.	T11	Imazethapyr + imazamox(RM)	80	3-4 leaf stage
12.	T12	One hand hoeing		20 DAS
13.	T13	Two hand hoeing	-	20 & 40 DAS
14.	T14	Weedy check	-	-
15.	T15	Weed free	-	-

Table.2 Effect of weed management treatments on different indices, seed, straw and biological yields in greengram

Treatments	Total Weed Population (No./m^2)	Weed Control Index	Weed Index	Crop Growth Rate (g/m^2/day)			Crop Resistance Index		Seed Yield (kg/acre)	Biological Yield (kg/acre)
				30 DAS	60 DAS	At Harvest	30 DAS	60 DAS		
T1	10.0(99.0)	70.50	57.0	0.22	0.68	0.29	5.68	2.67	196.80	977.60
T2	12.4(152.6)	47.26	36.9	0.17	0.30	0.84	2.38	2.15	288.40	1185.20
T3	11.9(139.6)	55.09	26.8	0.16	0.44	0.66	2.62	3.13	334.80	1288.80
T4	11.6(133.9)	56.40	20.0	0.15	0.48	0.76	2.52	3.64	366.00	1303.60
T5	9.9(98.0)	60.56	50.6	0.21	0.53	0.39	2.98	2.23	226.00	1007.60
T6	8.8(75.6)	61.10	49.3	0.23	0.68	0.23	2.63	3.03	232.00	1081.60
T7	6.9(46.6)	71.27	31.8	0.26	0.69	0.31	3.22	3.31	312.00	1200.00
T8	10.4(106.3)	59.79	33.2	0.16	0.47	0.78	3.50	2.62	305.60	1170.40
T9	7.8(59.4)	74.41	25.7	0.16	0.58	0.73	6.06	4.08	339.60	1306.80
T10	5.9(33.7)	76.24	23.0	0.14	0.65	0.69	7.37	4.73	352.00	1318.40
T11	5.3(27.0)	80.68	13.0	0.12	0.70	0.64	9.97	6.34	398.00	1349.60
T12	3.2(10.0)	93.99	11.4	0.16	0.75	0.20	19.98	6.12	405.20	1555.60
T13	2.6(5.6)	94.26	5.7	0.16	0.80	0.41	21.33	23.22	431.20	1570.40
T14	13.4(177.3)	0.00	74.6	0.13	0.46	0.29	1.00	1.00	116.00	616.40
T15	1.0(0.0)	100	0.0	0.26	0.73	0.44	0.00	0.00	457.20	1638.40
SE(m)	0.22	0.35	0.09	0.02	0.04	0.03	0.15	0.08	4.80	46.40
CD at 5%	0.66	1.07	0.27	0.06	0.13	0.10	0.46	0.26	14.40	134.80

Table.3 Effect of weed management treatments on agrometeorological indices in greengram

Treatments	Sowing to Vegetative Stage				Sowing to 50% Flowering Stage				Sowing to 50% Poding Stage			
	Days	GDD	HTU	PTU	Days	GDD	HTU	PTU	Days	GDD	HTU	PTU
T1	39.00	842.10	5608.61	11649.17	50.67	1074.52	6847.19	14769.40	63.67	1323.63	8530.88	18037.53
T2	35.33	764.67	5049.58	10605.33	47.33	1010.18	6624.36	13911.93	60.33	1257.47	8140.50	17177.77
T3	35.67	772.03	5103.28	10797.80	47.67	1016.62	6653.31	13997.87	60.67	1264.08	8179.54	17264.03
T4	37.33	807.52	5366.53	11180.03	49.33	1048.78	6798.06	14427.00	62.33	1297.17	8374.73	17694.27
T5	39.00	842.10	5608.61	11649.17	51.00	1080.72	6924.55	14851.67	64.00	1330.25	8569.92	18123.07
T6	39.33	849.02	5657.03	11742.97	51.33	1087.15	6920.16	14937.17	64.33	1336.87	8608.96	18208.83
T7	39.67	855.93	5705.44	11836.63	51.67	1093.35	6997.52	15019.43	64.67	1343.48	8648.00	18294.37
T8	38.67	835.18	5560.19	11555.50	50.67	1074.52	6847.19	14769.40	63.67	1323.63	8530.88	18037.53
T9	39.33	849.02	5657.03	11742.97	51.33	1087.15	6920.16	14937.17	64.33	1336.87	8608.96	18208.83
T10	40.00	862.85	5753.86	11930.13	52.00	1099.55	7041.54	15101.53	65.00	1349.92	8711.69	18377.37
T11	40.33	869.77	5802.28	12023.80	52.33	1105.75	7118.89	15183.80	65.33	1356.53	8750.73	18462.90
T12	41.33	890.52	5947.53	12304.17	53.33	1124.35	7250.95	15429.97	66.33	1375.83	8941.80	18711.77
T13	41.67	897.43	5995.94	12304.17	53.67	1130.55	7294.97	15511.93	66.67	1382.27	9005.49	18794.63
T14	35.33	764.67	5049.58	10605.33	45.67	978.02	6479.61	13481.70	58.67	1224.38	7945.31	16745.60
T15	41.67	897.43	5995.94	12397.53	53.67	1130.55	7294.97	15511.93	66.67	1382.27	9005.49	18794.63
SE(m)	0.41	8.50	59.92	110.81	0.38	7.11	53.83	94.42	0.38	7.42	53.35	96.01
CD at 5%	1.18	24.75	174.47	322.65	1.10	20.70	156.73	274.93	1.10	21.59	155.35	279.57

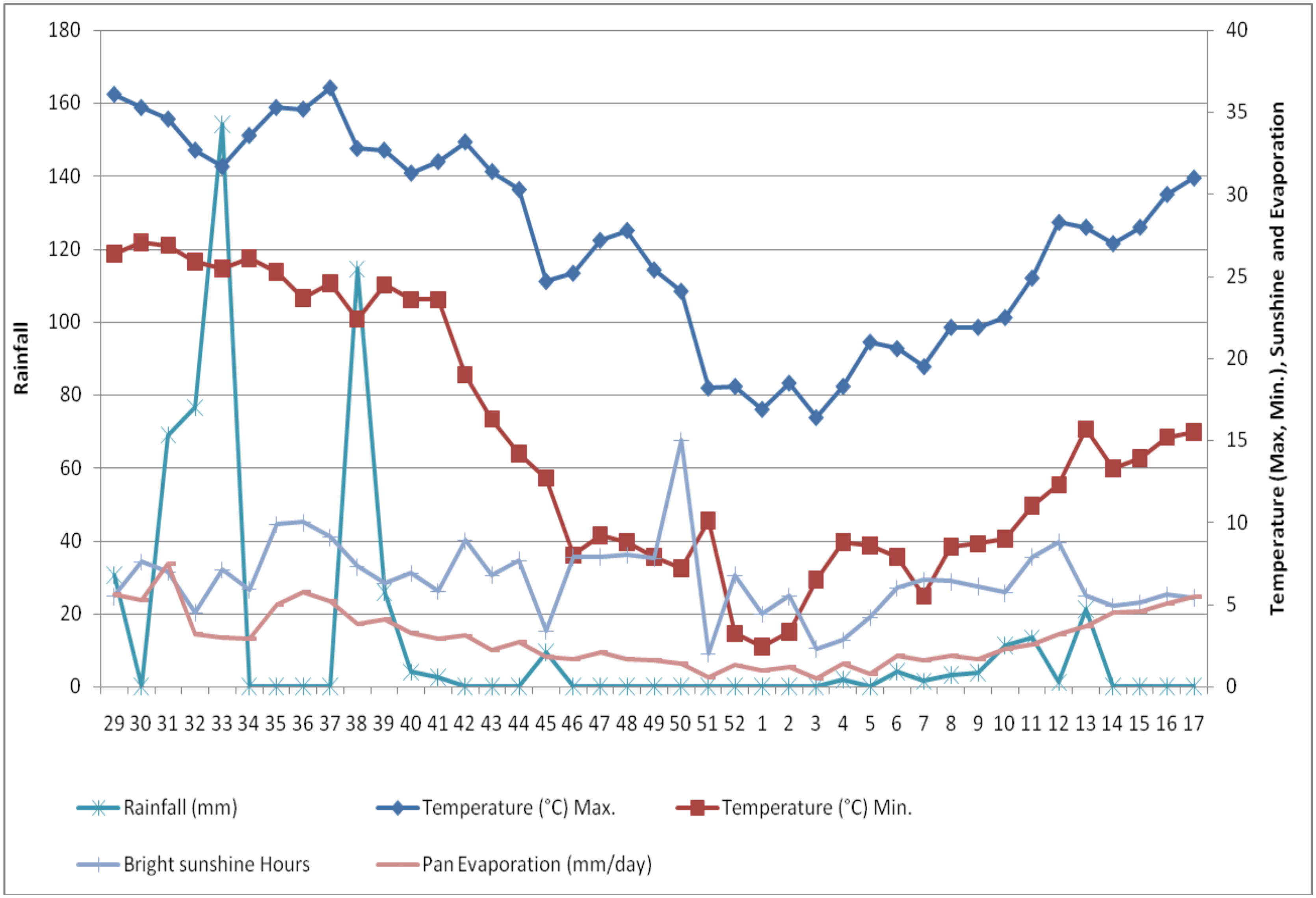
GDD: growing degree days, HTU: helio-thermal Units, PTU: photothermal units

Table.4 Effect of weed management treatments on agrometeorological indices and efficiency indices in greengram

Treatments	Sowing to Physiological Maturity Stage				HUE		HeUE		PUE	
	Days	GDD	HTU	PTU	SY Based	BY Based	SY Based	BY Based	SY Based	BY Based
T1	86.67	1758.35	12780.70	23763.17	0.28	1.39	0.04	0.19	0.02	0.10
T2	83.33	1689.85	12196.37	22941.07	0.43	1.75	0.06	0.24	0.03	0.13
T3	83.67	1696.70	12258.73	23026.03	0.49	1.90	0.07	0.26	0.04	0.14
T4	85.33	1730.95	12570.43	23449.70	0.53	1.88	0.07	0.26	0.04	0.14
T5	87.00	1764.22	12823.53	23835.20	0.32	1.42	0.04	0.20	0.02	0.11
T6	87.33	1771.07	12866.33	23907.43	0.33	1.53	0.05	0.21	0.02	0.11
T7	87.33	1776.93	12909.17	23979.47	0.44	1.69	0.06	0.23	0.03	0.13
T8	86.67	1758.35	12780.70	23763.17	0.44	1.66	0.06	0.23	0.03	0.12
T9	87.33	1771.07	12866.33	23907.43	0.48	1.84	0.07	0.25	0.04	0.14
T10	88.00	1782.80	12952.00	24051.33	0.49	1.85	0.07	0.25	0.04	0.14
T11	88.33	1788.67	12994.83	24123.37	0.56	1.89	0.08	0.26	0.04	0.14
T12	89.33	1806.27	13123.33	24338.87	0.56	2.15	0.08	0.30	0.04	0.16
T13	89.67	1812.13	13166.17	24410.63	0.60	2.17	0.08	0.30	0.04	0.16
T14	81.67	1655.60	11884.67	22515.33	0.18	0.93	0.02	0.13	0.01	0.07
T15	89.67	1812.13	13166.17	24410.63	0.63	2.26	0.09	0.31	0.05	0.17
SE(m)±	0.40	7.09	53.48	84.25	0.002	0.01	0.001	0.001	0.002	0.001
CD at 5%	1.17	20.65	155.74	245.32	0.01	0.02	0.001	0.003	0.006	0.003

SY: seed yield, BY: biological yield, HUE: heat use efficiency, HeUE: Helio thermal use efficiency, PUE: photothermal use efficiency

Fig.1 Mean weekly meteorological data from June, 2013 to April, 2014



Agrometeorological indices of greengram

Calendar day's requirement for different phenophases development: The day's requirement of phenophases development of green gram was significantly influenced by weed management treatments and is given in tables 3 and 4. Minimum days to attain different phonological stages (vegetative stage, 50 % flowering stage, 50 % poding stage and maturity) were taken by weedy check. This happening may be related to intensity of stress cause by weeds for resources like water, nutrient, space etc.; which forced the plant to complete the life cycle as soon as possible to leave its progeny in any case. Maximum days were taken by weed free treatment. Among herbicidal treatments, application of imazethapyr at different doses at 3-4 leaf stage attained the maturity earlier over other RM herbicides (Tables 3 and 4).

Growing degree days (GDD): GDD required for different phenophases varied with weed control treatments. GDD were found to be significant at all the phenological stages (Tables 3 and 4). Significantly higher GDD at different phenological stages were accumulated under weed free and two (hand) hoeing employed at 20 & 40 DAS. These treatments were at par with one (hand) hoeing. Among different herbicidal treatments, RM of imazethapyr + imazamox at 80 g/ha accumulated the highest GDD (heat units) at different phenological stages of green gram. Alone application of imazethapyr @ 50 g/ha at 3-4 leaf stage accumulated lowest GDD; which was at par with weedy check. This difference may be due to more or less days taken at different phenological stages by different weed control treatments.

Helio thermal units (HTU): HTU required for different phenophases varied with weed control treatments. HTU were found to be significant at all the phenological stages (Tables 3 and 4). Significantly higher HTU at different phenological stages were recorded under weed free and two (hand) hoeing; these treatments were at par with one (hand) hoeing. Among different herbicidal treatments, RM of imazethapyr + imazamox at 80 g/ha attained the maximum value of HTU at different phenological stages of green gram and minimum under alone application of imazethapyr at 50 g/ha. Weedy check consumed the lower HTU over other treatments (Tables 3 and 4). This may be due to less days taken by weedy check at different phenological stages due to more competition between weed and crop plant for resources.

Photo thermal units (PTU): PTU were found significant at all the phenological stages of green gram due to weed control treatments (Tables 3 and 4). Significantly higher PTU at different phenological stages were recorded under weed free and two (hand) hoeing. These treatments were at par with one (hand) hoeing. Among different herbicidal treatments, RM of imazethapyr + imazamox at 80 g/ha used the maximum value of PTU at different phenological stages of green gram and minimum under alone application of imazethapyr at 50 g/ha. This may be due to more days taken at different phenological stages. Weedy check used the lower PTU to complete the different stages over other treatments.

Heat, helio and photo thermal use efficiencies (HUE, HeUE, and PUE): the maximum values of HUE, HeUE, and PUE based on seed and biological yields were recorded under weed free and minimum under weedy check (Table 4). Among herbicidal treatments, RM of imazethapyr + imazamox at 80 g/ha gave the significantly higher value of HUE, HeUE, and PUE based on seed and biological yields and significantly lower under pendimethalin @ 1000 g/ha. This may be due to difference in seed & biological yields (Table 2) and GDD, HTU &PTU (Table 4).

All weed control treatments proved effective in respect of weed control in green gram and gave significantly higher grain yield over weedy check. The application of RM of imazethapyr +imazamox @ 80 g/ha at 3-4 leaf stage gave the better control of weeds over other herbicidal treatments, this was at par with one and two (hand) hoeing. RM of imazethapyr +imazamox @ 80 g/ha gave the higher seed and biological yields and took the highest calendar days, growing degree days, helio-thermal units and photothermal units from sowing to physiological maturity, heat use efficiency , helio-thermal use efficiency and photothermal use efficiency . In sight of results of this study, post emergence application of RM of imazethapyr +imazamox @ 80 g/ha at 3-4 leaf stage should be adopted in labour scarcity situation, otherwise, two (hand) hoeings at 20 & 40 DAS or should be adopted for the control of weeds in green gram.

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