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Evaluation of different herbicides for weed management in chickpea (*Cicer arietinum* L.)

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Abstract
The present research work in entitled "Response of gram (*Cicer arietinum* L.) to different herbicides under south Gujarat condition" was carried out during *rabi* season of 2016-2017 at the College Farm, Navsari Agricultural University, Navsari. The soil was found slightly alkaline (pH 7.8) in nature with normal electric conductivity (0.36 dS/m). The experiment comprising of ten weed management treatments were conducted in a randomized block design with three replications. To find out suitable herbicides for the management of weeds in chickpea. Results indicated that weed control treatments significantly reduced dry weight of weeds in chickpea. The weed free up to harvest treatment and the pre-emergence herbicidal treatments involving pendimethalin 0.75 kg/ha supplemented with post- emergence application of Fenoxaprop-p-ethyl 37.2 g/ha at 20 DAS were also found lowest weed population and highest mean seed (1775 kg/ha) and stover (2917 kg/ha) yields. Significantly higher values of growth characters and yield attributes *viz*., plant height, number of branches per plant, number of pods per plant, number of root nodules per plant and seed weight per plant were recorded in these treatments. Weed Management practices on quality parameters, nutrient uptake by crop. The result indicated that significantly maximum protein content (20.52%) and protein yield (364 kg/ha) as well as uptake of nutrient by seed N (59.70 kg/ha), P_2O_5 (13.10 kg/ha) and K_2O (16.20 kg/ha) were recorded by treatment weed free up to harvest (H.W. 20, 40 and 60 DAS) as compared to unweeded (control), respectively.

Keywords: Chickpea, chemical control, herbicide, weed management, pre-emergence, post- emergence, weed population, WCI, WI, growth, yield

1. Introduction
Chickpea is the major pulse crop in India. The cultivated area of chickpea in India has been constantly increasing though, the productivity has not substantially increased during this period (Samriti *et al.* 2020) [13]. It is a well-known fact that productivity of chickpea is affected by various biotic and abiotic factors. Poor weed management is one of the factors of the reduction in chickpea productivity (Rathod *et al.* 2017) [11] and affects its productivity adversely. Chickpea is a poor weed competitor due to its slow initial growth rate, on the contrary, weeds grow fast and compete with crop for nutrients, space, and water (Chaudhary *et al.* 2005, Rao, 2000) [3, 9], hence, reduced chickpea yield up to 70–80%. The initial 30- 60 days of the crop growth period are very important for crop weed competition in chickpea (Kumar and Singh 2010) [5].

The predominant methods of weed control are hand weeding and interculturing in gram which found more effective but unavailability of labour at the time of weeding resulting in sever weed infestation which make mechanical weeding ineffective, tedious and costly. Under such circumstances, chemical control of weeds may be the viable and cost effective alternative for this crop. Effective herbicide at appropriate rate may prove as an effective weed control method and replace conventional methods of weed control. Post emergent application need great care with respect to stage of growth and air temperature to avoid phytotoxicity. So, if weed growth is minimized during the period of crop weed competition, crop yield will be equivalent to that of weed free crop. Therefore, it is an essential to control weeds by any means during crop weed competition. Thus, weeds are a serious constraint in increasing production and easy harvesting of gram. Gram is a poor competitor to weeds because of slow growth rate and limited leaf area develop at early stage of crop growth. Yield losses due to weed competition vary considerably depending on the level of weed infestation and weed species prevailing in the field. Although manual weeding is effective in weed control, it is uneconomical due to higher costs (Kumar *et al.* 2010) [5]. Use of post-emergence herbicides in combination with pre-emergence may be one of tools for broad-spectrum weed control.

2. Materials and Methods

A field study was carried out at the College Farm, Navsari Agricultural University, Navsari during *rabi* season of 2016-2017. The soil of the experimental field was clayey in texture and showed low, medium and high rating for available nitrogen (219.52 kg/ha) phosphorus (30.91 kg/ha) and potassium (319.00 kg/ha), respectively. The soil was found slightly alkaline (pH 7.8) in nature with normal electric conductivity (0.36 dS/m). Ten treatment of weed management practices *viz.*, T_1: Pendimethalin 0.75 kg/ha as pre-emergence, T_2:Pendimethalin 0.75 kg/ha as pre -emergence + 1 H.W at 20 DAS, T_3:Pendimethalin 0.75 kg/ha as pre -emergence + Imazethapyr 16.5 g/ha at 20 DAS as post-emergence, T_4:Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post- emergence, T_5:Pendimethalin 0.75 kg/ha as pre-emergence + Propaquizafop 0.75 kg/ha at 20 DAS as post-emergence, T_6:Pendimethalin 0.75 kg/ha as pre- emergence + (Propaquizafop 2.5% + Imazethapyr 3.75% 0.57 kg/ha) at 20 DAS as post- emergence, T_7: Pendimethalin 0.75 kg/ha as pre- emergence + Quizalofop-p-ethyl 40 g/ha at 20 DAS as post- emergence, T_8: Pendimethalin 0.75 kg/ha as pre-emergence + Fenoxaprop-p-ethyl 37.2 g/ha at 20 DAS as post –emergence, T_9: Weed free, T_{10}: Uncontrol (weedy check) were evaluated in randomized block design with three replications. The herbicides were applied as post emergence depending upon the treatment. The plot size was 3 × 3 and net plot size was 2.4 × 2.8 m. Observations were recorded at harvest on different characters and mean values were subjected to statistical analysis. The efficacy of various treatments was done by a comparative assessment of growth, yield, root nodulation, weed dry weight, weed control efficiency. Chickpea varieties were sown a row spacing of 30 cm during third week of October. The crop was fertilized with recommend dose of 20-50-00 NPK kg/ha.

3. Results and Discussion

Table 1: Effect of different herbicides on growth parameters of chickpea

Tr. No.	Plant population per net plot area		Plant height (cm)			Number of branches per plant	
	At 20 DAS	At harvest	30 DAS	60 DAS	At harvest	60 DAS	At harvest
T_1	176.0	163.0	21.2	37.7	50.3	7.8	9.1
T_2	174.0	165.3	21.4	41.2	52.8	8.3	9.3
T_3	176.6	88.0	14.6	29.5	45.8	5.8	7.3
T_4	176.6	57.3	15.3	23.0	39.3	4.6	6.2
T_5	172.6	111.3	15.6	28.0	46.4	6.9	7.6
T_6	175.3	112.6	14.6	28.6	47.7	7.2	8.4
T_7	176.6	166.6	20.7	41.2	56.0	8.4	9.4
T_8	177.3	170.0	23.3	41.8	56.5	8.3	9.2
T_9	174.6	172.3	23.6	43.6	57.8	8.6	9.9
T_{10}	175.6	141.0	20.8	32.3	46.5	5.9	6.6
S.Em. ±	7.96	5.81	0.76	1.25	1.83	0.28	0.34
C.D at 5%	NS	17.25	2.25	3.71	5.45	0.82	1.01

3.1 Growth parameters

3.1.1 Plant populations

An examination of data given in Table 1 revealed that initial plant population was not affected due to different weed management treatments but final plant population was recorded significantly higher under treatment T_9. Because of phyto-toxic effect of chemical on gram plant under treatment T_4, final population was significantly reduced.

3.1.2 Plant height

Significantly, higher plant height at 30, 60 DAS and at harvest was recorded under weed free treatment (T_9) which was found statistically at par with treatment T_8, T_7 and T_2. Significantly lower plant height at 60 DAS and at harvest was recorded under treatment (T_4) being at par with treatment T_5, T_6 and T_3 for plant height at 60 DAS as reported in Table 1. This might be due to effective weed control reduced the crop-weed competition facilitate the crop for the better availability of moisture, nutrient, light and space. The lowest plant height in unweeded control might be due to more competition between crop and weeds for moisture, nutrient, light and space. The results are in conformity with the results obtained by Singh *et al.* (2004) [15], Kachhadiya *et al.* (2009) [4] and Kumar *et al.* (2010) [5] for gram.

3.1.3 Number of branches

It was observed from data presented in Table 1 showed that significantly higher number of branches per plant at 60 DAS and at harvest was recorded under treatment T_9 (weed free) which was found statistically at par with treatment T_7, T_2, T_8 and T_1. Significantly lower number of branches per plant at 60 DAS and at harvest was registered under the treatment T_4 [Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post-emergence] which was remained at par with treatment T_{10} for number of branches per plant at harvest. This might be due to effective control of weeds by use of pre and post emergence weedicide facilitated the crop to utilize more nutrients and water for better growth and development. Similar results were also reported by Singh *et al.* (2008) [1] and Kacchadiya *et al.* (2009) [4] for gram.

Table 2: Effect of different herbicides on weed population, weed control efficiency, weed index and dry weight of weeds in chickpea

Tr. no.	Weed population at 20 DAS (m^2)		Weed population at 40 DAS(m^2)		Weed population at 60 DAS (m^2)		Weed population at harvest (m^2)		WCE (%)	WI (%)	Dry weight of weeds at harvest (kg/ha)
	M	D	M	D	M	D	M	D			
T_1	5.37 (28.33)	3.76 (13.67)	5.43 (29.00)	3.85 (14.33)	5.87 (34.00)	4.67 (21.33)	5.93 (34.67)	4.74 (22.00)	31.64	31.94	14.26 (203.0)
T_2	5.74 (32.67)	3.85 (14.33)	1.86 (3.00)	1.68 (2.33)	4.22 (17.33)	4.41 (19.00)	4.30 (18.00)	4.10 (16.67)	55.21	10.30	11.25 (133.00)
T_3	4.71 (21.67)	3.72 (13.33)	4.30 (18.00)	3.58 (12.33)	2.20 (4.33)	1.86 (3.00)	1.76 (2.67)	2.04 (3.67)	94.64	29.57	4.02 (16.67)
T_4	5.81 (33.33)	3.66 (13.00)	3.29 (10.33)	3.02 (8.66)	1.68 (2.33)	1.95 (3.33)	1.34 (1.33)	2.04 (3.67)	95.62	66.36	3.67 (13.63)
T_5	6.12 (37.00)	3.48 (11.67)	4.91 (23.67)	3.63 (12.67)	1.68 (2.33)	1.86 (3.00)	1.34 (1.33)	2.11 (4.00)	94.94	24.90	4.03 (15.73)
T_6	6.10 (36.67)	3.80 (14.00)	4.52 (20.00)	3.63 (12.67)	1.56 (2.00)	2.73 (7.00)	1.22 (1.00)	2.04 (3.67)	96.29	21.01	3.38 (11.00)
T_7	4.74 (22.00)	4.18 (17.00)	3.39 (11.00)	3.34 (10.67)	1.68 (2.33)	4.45 (19.33)	1.56 (2.00)	4.21 (17.33)	86.86	9.24	6.28 (39.00)
T_8	4.64 (21.00)	4.02 (15.67)	3.53 (12.00)	3.88 (14.00)	2.04 (3.67)	4.30 (18.00)	2.11 (4.00)	4.13 (16.67)	83.83	7.71	6.94 (48.00)
T_9	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	100.00	-	0.71 (0.00)
T_{10}	6.79 (45.67)	5.21 (26.67)	6.84 (46.30)	5.49 (29.67)	6.84 (46.30)	5.57 (30.60)	6.84 (46.40)	5.62 (31.10)	-	54.92	17.25 (297.00)
S.Em. ±	0.13	0.09	0.11	0.10	0.10	0.10	0.12	0.11	-	-	0.15
C.D at 5%	0.38	0.27	0.34	0.30	0.29	0.31	0.37	0.33	-	-	0.45

Note: Data in parenthesis indicate original value and transformed value of same are outside,
M: Number of monocot, D: Number of dicot, WCE: Weed control efficiency, WI: Weed index

3.2 Weed parameters

3.2.1 Weed populations

It was evident from data presented in Table 2 that treatment T_9 was weed free condition, treatment T_8 and T_5 recorded significantly lower number of monocot and dicot weeds per m^2 area, respectively over other treatments at 20 DAS. Treatment T_2 recorded significantly lower number of monocot and dicot weeds per m^2 area at 40 DAS. Whereas, treatment T_6 and T_3 recorded significantly lower number of monocot and dicot weeds per m^2 area than rest of the treatments at 60 DAS and treatment T_6 and T_4 recorded significantly lower number of monocot and dicot weeds per m^2 area than rest of the treatments at harvest. The highest number of monocot and dicot weeds per m^2 area at 20, 40, 60 DAS and at harvest were recorded under unweeded treatment (T_{10}). This might be due to effective weed control in respective treatments either manual or herbicidal or both resulted in remarkable reduction in weed population. The findings are confined with those reported by Patel *et al*. (2006) [8] and Chandrakar *et al*. (2015) [2] in gram crop.

3.2.2 Dry weight of weeds

Perusal of data presented in Table 2 that highest dry weight of weeds was recorded under treatment T_{10} (unweeded control).Whereas treatment T_4 [Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post- emergence] and treatment T_6 [Pendimethalin 0.75 kg/ha as pre- emergence + (Propaquizafop 2.5% + Imazethapyr 3.75% 0.57 kg/ha) at 20 DAS as post- emergence] were resulted in significantly lower dry weight of weeds at 60 DAS and at harvest, respectively. The remarkable minimum dry weight recorded under these treatment (T_9 and T_4) mainly due to the lowest weed counts and because of better weed control and better growth of crop in term of a greater number of branches per plant which did not allow weeds to grow vigorously due to its smothering effect. Similar results were also reported by Chandrakar *et al*. (2015) [2] in gram.

3.2.3 Weed control efficiency and weed index

A perusal of data summarized in Table 2 revealed that higher weed control efficiency was observed under treatment T_9 which was closely followed by treatment T_6 and T_4. This might be due to better control of weeds through application of pre and post emergence chemical weedicide resulted in remarkable reduction in weed population and ultimately less dry weights of weeds resulting in better weed control efficiency under these treatments i.e. T_9, T_6 and T_4. These results are confirmed by those reported by Buttar *et al*. (2008) [1] and Kachhadiya *et al*. (2009) [4]. Treatment T_8 (Pendimethalin 0.75 kg/ha as pre- emergence + Fenoxaprop-p-ethyl 37.2 g/ha at 20 DAS as post –emergence) and T_7 (Pendimethalin 0.75 kg/ha as pre- emergence + Quizalofop-p-ethyl 40 g/ha at 20 DAS as post- emergence) found more effective with lower weed index of 7.71 and 9.24%, respectively. Treatment T_4 recorded higher weed index (66.36%) which was followed by treatment T_{10} (unweeded control). This might be due to effective weed control achieved under these treatments curtailed the crop-weed competition provide better condition for crop growth, that reduced the yield losses due to weed. Almost similar results were reported by Singh *et al*. (2003) [14], Kachhadiya *et al*. (2009) [4] and Sanjeev *et al*. (2015) [12] in gram.

Table 3: Effect of different herbicides on yield, yield attributes and economics of chickpea

Tr. No.	No. of pods per plant	Seed yield per plant (g)	Seed index (g)	Yield (kg/ha)		Harvest index (%)	B:C ratio
				Seed	Stover		
T_1	49.2	11.56	19.59	1208	2000	37.6	1.93
T_2	54.5	12.85	19.15	1592	3208	33.1	2.45
T_3	45.9	10.72	19.19	1250	2250	35.7	1.85
T_4	31.3	6.38	18.87	597	1342	30.6	0.38
T_5	45.0	10.91	19.26	1333	2192	37.8	1.71
T_6	47.2	11.05	19.66	1402	2490	35.6	2.00
T_7	53.8	12.84	20.61	1611	2916	35.5	2.40
T_8	54.6	13.37	19.78	1638	2925	35.8	2.88
T_9	55.5	13.65	20.19	1775	2917	37.8	2.13
T_{10}	35.9	8.62	19.22	800	1800	30.7	1.20
S.Em. ±	1.71	0.54	0.77	70.54	175.05	1.67	-
C.D at 5%	5.08	1.61	NS	209.59	520.11	NS	-

3.3 Yield attributes and yield

3.3.1 Yield attributes

It was observed from data presented in Table 3 that significantly higher number of pods per plant (55.53) and seed yield per plant (13.65 g) were recorded under treatment T_9 (weed free) which was remained at par with treatment T_8, T_7 and T_2. Whereas, significantly lower value of these characters was recorded under the treatment T_4 [Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post- emergence] being at par with treatment T_{10} (unweeded control) for pods per plant. This might be due to significant reduction in crop weed competition due to effective control of weeds under these treatments reflected in better growth and development of the crop in term of higher plant height and number of branches per plant ultimately resulted in higher yield attributes. Moreover, higher uptake of nutrient provided better condition for higher growth and development of crop which resulted in maximum number of pods per plant and pods yield per plant. The results are in close association with the findings of Patel *et al.* (2006) [8], Rathi *et al.* (2007) [10] and Mudalagiriyappa *et al.* (2013) [7] in gram.

3.3.2 Yield

The statistical analysis of the data presented in Table 3 revealed that significantly higher seed yield (1775 kg/ha) was recorded under treatment T_9 (weed free) which was remained at par with treatment T_8 (1638kg/ha), T_7 (1611 kg/ha) and T_2 (1592 kg/ha). Whereas, treatment T_4 [Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post- emergence] being at par with treatment T_{10} (unweeded control) noted significantly lower seed yield of gram. Significantly higher stover yield (3208 kg/ha) was recorded under treatment T_2 (Pendimethalin 0.75 kg/ha as pre -emergence + 1 H.W. at 20 DAS) which was remained at par with treatments T_8 (2925 kg/ha), T_9 (2917 kg/ha) and T_7 (2916 kg/ha). Significantly lower stover yield (1342 kg/ha) was recorded under treatment T_4. This might be due to effective control of weeds in terms of reduced weed population and dry weight of weeds, which facilitated the crop to utilize more nutrients and moisture for better growth and development measured in terms of various growth attributing characters such as plant height, number of branches per plant and yield attributing characters like number of pods per plant and yield per plant. All these parameters showed cumulatively positive and significant influence on seed and stover yields of gram. These findings are in close agreement with those reported by Patel *et al.* (2006) [8], Sanjeev *et al.* (2015) [12] and Chandrakar *et al.* (2015) [2] for gram.

3.3.4 Economics

Treatment T_8 secured higher B: C ratio of 2.88 followed by treatment T_2 (Pendimethalin 0.75 kg/ha as pre -emergence + 1 H.W at 20 DAS). Whereas treatment T_4 [Pendimethalin 0.75 kg/ha as pre -emergence + (Imazethapyr 35% + Imazamox 35% 20 g/ha) at 20 DAS as post- emergence] registered the lowest B: C ratio of 0.38 as reported in Table 3. Higher gross returns along with the lower cost of cultivation under these treatments (T_9, T_8 and T_7) might be responsible for higher net return and B: C ratio. These finding are in close vicinity those reported by Kacchadiya *et al.* (2009) [4].

4. Conclusion

In view of the result obtain from the investigation it can be concluded that to achieve profitable yield from gram, gram crop should kept weed free throughout crop growth period by hand weeding at 20, 40 and 60 DAS. Under scarcity of labour, apply pendimethalin 0.75 kg/ha as pre emergence couple with either Fenoxaprop-p-ethyl 37.2 g/ha as post emergence or Quizalofop-p-ethyl 40 g/ha as post emergence or hand weeding at 20 DAS.

5. Author's contributions

This work was carried out in collaboration among all authors. Author LK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LK and VMP managed the analyses of the study. Authors MKR and BMB managed the literature, wrote the final draft of the manuscript and completion of publication. All authors read and approved the final manuscript.

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