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EFFECT OF WEED MANAGEMENT PRACTICES UNDER VARYING IRRIGATION LEVELS ON CLUSTER BEAN PRODUCTIVITY AND RESIDUAL EFFECT ON SUCCEEDING MUSTARD CROP

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SUMMARY

Cluster bean (*Cyamopsis tetragonoloba* L.) is grown under both rainfed and irrigated conditions in Haryana and weeds pose serious threat to its production under both the conditions. Owing to increasing labour cost, there is need for chemical weed management, but, there is no chemical recommendation for weed management in cluster bean in Haryana. So, a field experiment was conducted during *kharif* season of 2018 and 2019 at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar, India in a semi-arid climate. The experiment was laid out in split-plot design having three replications, with three irrigation levels *viz*., no post-sown irrigation, one irrigation and two irrigations in main plots, while five weed management practices *viz*., pendimethalin 1.0 kg/ha as PRE, imazethapyr 70 g/ha as PRE, imazethapyr 70 g/ha at 21 DAS, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS and farmers' practice (2 hand weedings at 3 and 5 WAS) in sub-plots. The cluster bean crop was infested with *Cyperus rotundus*, *Convolvulus arvensis*, *Digera arvensis* and *Echinochloa colona*. The dry weight of weeds at 60 DAS and at harvest increased with the increasing irrigation levels. Among the weed management practices, two hand weedings at 3 and 5 WAS, produced minimum weed dry weight at 30 DAS, 60 DAS and harvest, while, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS was found most effective in controlling the weeds among the chemical methods. During both the years, maximum seed yield of cluster bean was produced by irrigating the crop with two irrigations (1036 and 726 kg/ha), which was statistically at par with one irrigation (1009 and 682 kg/ha, during 2018 and 2019, respectively). Two hand weedings at 3 and 5 WAS, was found superior to chemical weed control treatments in producing seed yield (1121 and 754 kg/ha during 2018 and 2019, respectively). However, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS produced highest seed yield (968 and 674 kg/ha, during 2018 and 2019, respectively), which was statistically similar to imazethapyr 70 g/ha PRE (932 and 654 kg/ha, during 2018 and 2019, respectively) and both of them were superior to imazethapyr 70 g/ha at 21 DAS and pendimethalin 1.0 kg/ha as PRE. The bacterial and PSB count at harvest of cluster bean crop increased with increase in irrigation levels and bacterial population was lower with soil application of herbicides (either pendimethalin or imazethapyr) as compared to foliar application of herbicides and 2 HW treatments, however, PSB population was not affected by weed management practices. Maximum herbicide residue at harvest of the cluster bean crop was found in imazethapyr 70 g/ha at 21 DAS and followed by imazethapyr 70 g/ha PRE and imazethapyr + imazamox (RM) 70 g/ha at 20 DAS. Reduction in the germination, growth and yield of mustard was observed due to residual effect of the chemicals applied in cluster bean during both years of study, maximum being with imazethapyr 70 g/ha at 21 DAS followed by imazethapyr 70 g/ha PRE and imazethapyr + imazamox (RM) 70 g/ha at 21 DAS.

Key words: Cluster bean, mustard, irrigation, weed management, herbicide residue

Cluster bean [*Cyamopsis tetragonaloba* (L.) Taub], commonly known as guar, is a *kharif* pulse crop of arid and semi-arid regions (Bhatt *et al.*, 2017) and it is considered as one of the most drought tolerant deep-rooted and annual legume in India. The crop is grown for feed, fodder, green manure (as soil fertility enhancer), guar gum and vegetable purpose. It is an industrial crop also, as its seeds are the source of high quality galactomannan gum and its guar meal is rich in protein (40-45%) which is used as animal feed (Panchta *et al*., 2016). The gum and the water-soluble resin extracted from the seeds are also used in other industries, including paper manufacturing, cosmetics, mining and oil drilling (Wong and Parmar *et al*., 1997). Its production in India is subject to high year to-year fluctuations because of variability in intensity and pattern of monsoon rainfall. India is the largest producer of cluster bean and accounts for about 80 per cent of its global production followed by 15% in Pakistan. In India, the crop is mainly grown in the dry habitats of Rajasthan, Haryana, Gujarat and Punjab and to a limited extent in Uttar Pradesh and Madhya Pradesh. In India, the total area under cluster bean was 31.4 lakh ha with a production of 15.19 lakh tonnes guar seed and a productivity of 484.0 kg/ha during 2018-19 (Anonymous, 2021). Traditionally, it has been grown as rainfed crops, hence the information pertaining to effects of irrigation on growth, yield and water productivity of cluster bean is inadequate. However, during recent it has been grown as an irrigated crop in arid and semi-arid regions (Sammauria *et al*., 2009). In Haryana, it is generally cultivated as rainy season (*kharif*) crop (Satpal *et al*., 2020). There are many constraints for lower yield of cluster bean, but weed infestation is one of the main constraints (Yadav *et al*. 1993) as cluster bean is a poor competitor with weeds and suffers heavily in the early growth stage due to favourable environment for weeds to thrive. Various other factors like type of irrigation, cropping pattern, weed control measures and environment also have a significant influence on the intensity and infestation of weeds (Saavedra *et al.*, 1990).

The pre-emergence (PRE) herbicides like pendimethalin were found effective in controlling the weeds during early stages, but late flushes and escaped/ regenerated weeds in later stages, also hamper the crop yield to certain extent (Meena *et al.*, 2022). This warrants the use of post-emergence (POE) herbicides for weed control. Imazethapyr applied in cluster bean has been observed to show adverse effect on the succeeding crop of mustard in the light soils of South-West Haryana, where cluster bean is a major crop. Many farmers are resorting to lower use rates of imazethapyr for fear of phytotoxicity in sequential mustard crop. Lower use rates of imazethapyr may kill some weeds of cluster bean notably *D. arvensis*, but in the long run there could be issues of lower use rates stimulating herbicide resistance. Also, imazethapyr+ imazamox (RM) is showing lower residual effects but it is not effective for some hardy weeds.

The knowledge about role of microbial degradation, chemical hydrolysis, photo-degradation and effect of temperature, moisture *etc*. on dissipation of imazethapyr and imazamox is essential before predicting the persistence of the herbicide in a particular condition. This becomes more important under the situations prevailing in Haryana where soil pH is high, organic matter is low, rainfall is less, temperature is high and soil moisture is generally low.

The information regarding effects of irrigation and weed management practices on weed flora, yield and water productivity of cluster bean, microbial population and residual effect on succeeding mustard is scanty. Keeping these points in view, it was considered to carry out field experiments on the effect of irrigation and weed management practices in cluster bean and their residual effect on succeeding mustard crop.

MATERIALS AND METHODS

A field experiment was conducted at Research Farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar, India to study the effect of irrigation and weed management practices in cluster bean (*Cyamopsis tetragonoloba* L.) during *kharif* 2018 and 2019 and their carryover effect on succeeding mustard [*Brassica juncea* (L.) Czernj. & Coss.] crop in *rabi* season, 2018-19 and 2019-20. The experimental location is situated at 29°10' N latitude and 75°46' E longitude at an elevation of 215.2 m above mean sea level in a semi-arid climate. The soil of experimental field was sandy loam (60.30% sand, 28.35% silt and 11.35% clay) in texture, low in organic carbon (0.43%), and N (151.5 kg/ha), medium in P (15.8 kg/ ha), and sufficient in K (319 kg/ha).The experimental design was a split-plot design having three replications, the main plots were randomly assigned to the irrigation treatments:

I_1 = No post-sown irrigation (check treatment) as control
I_2 = One post-sown irrigation at 30-35 DAS
I_3 = Two post-sown irrigation at 30-35 and 60-65 DAS

Sub-plots were randomly allocated to weed control treatments (Table 1). Cluster bean variety HG 2-20 was sown in the first week of July during both the years with seed-cum-fertilizer drill at a spacing of 45cm × 10cm in a plot size of 5.0 m × 4.5m by using

15.0 kg/ha seed rate after treating with streptocycline during both years of study. Recommended dose of fertilizers (40 kg P_2O_5 and 20 kg N/ha through SSP and Urea) was applied at sowing. Application of PRE and POE herbicides in different treatments were done by using flat fan nozzle mounted on a backpack sprayer with a spray discharge of 500 L/ha for PRE herbicides and 300 L/ha for POE herbicides. All other agriculture practices for growing cluster bean crop were performed as per University package of practices. The rainfall received was 347.5 & 28.6 mm during *kharif* and *rabi* seasons of 2018-19 and 278.7 & 113.2 mm, respectively, during 2019-20.

Visual weed control was quantified visually at 30 and 60 DAS (days after sowing) on 0-100 scale, where 0 = no weed control and 100 = complete weed control. Observations on weed dry weight were recorded by removing the weeds at soil surface through randomly placing a quadrant (0.25 m^2) in each plot at 30, 60 and 90 DAS and thereafter, dry weight of those removed weeds was recorded after drying the weeds in the sun and later in an oven at 70ºC upto 72 h. The crop was harvested in second week of October during both years of study.

Observations on the population of total bacteria and phosphate solubilizing bacteria (PSB) were recorded after the harvest of the cluster bean crop and mean data of two years is depicted in figure1(a, b & c). Soil samples were collected from three places in each plot near the root zone at a depth of up to 15 cm. Then, the samples were mixed well to get composite samples/plots. About 100 g of soil was taken from each composite sample per plot. All soil samples were stored at – 4°C deep freezer until further processing. Soil samples were analyzed to enumerate total bacteria and PSB using the serial dilution technique and the pour plate method (Parshad *et al.*, 2021). To ensure that microorganisms attached to soil particles or present in aggregates were separated and suspended uniformly in the water, ten grams of each soil sample were added to 90 mm of sterile water blank, and the mixture was shaken on a rotary shaker for approximately fifteen minutes. A newly sterile pipette was used every time a serial dilution was made. Then, 0.01 ml of appropriate dilutions were spread on specific media in triplicate. The plates were then incubated at 28±1°C for about 48 hours. After incubation, the colonies of microorganisms appearing on agar plates were counted following standard methods (Pramer and Schmidt, 1964). Nutrient agar media was used for total bacteria, while Pikovskaya's (PKV) agar media was used for PSB.

Method for analysis of residues of pendimethalin, imazethapyr and imazamox was validated by performing recovery experiments at 0.003 and 0.01 µg/g fortification levels in soil. The method validation and quality control procedures for pesticide residues in food and feed were as per by European Union- document No. SANCO 2000. Analytical grade standard of pendimethalin, imazethapyr and imazamox (Sigma-Aldrich), HPLC grade Acetonitrile (Merck), G.R. grade acetonitrile (Merck); HPLC-grade water (Merck), ammonium carbonate, sodium chloride, dichloromethane were used. The liquid chromatograph of WATERS used for the analysis was equipped with millimium-32 software, waters 515 HPLC pump, photodiode array detector PDA 996 and X Terra™ Reverse Phase (RP) C_{18} column. The calibration curve was plotted at different concentrations of working standard solutions. Results of the fortified, field samples and laboratory samples were quantified on peak area basis by calibration method. Full scan chromatogram and mass spectrum of imazethapyr and imazamox were generated only for 2018.

After the harvest of cluster bean crop, without disturbing the soil and layout (under zero tillage conditions), the mustard crop (Var. RH 725) was sown on third week of October during both the years to

TABLE 1
Common, chemical names, chemical group, mode of action rate and time of application of the herbicides.

Treatment/Active ingredient	Chemical group	Mode of action	Rate (g a.i./ha)	Time of application
T_1 = Pendimethalin	Dinitroaniline	Inhibition of VLCF (very long chain fatty acids)	1000	Just after sowing as PRE
T_2 = Imazethapyr	Imidazolinone	Inhibitor of branched chain amino acid synthesis (ALS or AHAS)	70	Just after sowing as PRE
T_3 = Imazethapyr	Imidazolinone	-do-	70	21 DAS
T_4 = Imazethapyr+imazamox	Imidazolinone Imidazolinone	-do-	70	21 DAS
T_5 = Farmers'practice (2 HW)	-	-	-	3 and 5 WAS

study the residual effect of different herbicides applied in cluster bean under different irrigation levels. Emerged weeds at sowing were killed by nonselective and non-residual herbicide (glyphosate) prior to planting the mustard crop. The crop was harvested on third week of March during both the years. Data on number of plants per meter row length, plant height, and yield were recorded to measure the residual effect of herbicides applied in cluster bean under different irrigation levels on succeeding mustard crop. The data with zero value were subjected to square root transformation. The data were subjected to analysis of variance and significant differences among treatments were tested by calculating CD at 5% level of significance differences evaluated by using ANOVA.

RESULTS AND DISCUSSION

Effect on weed flora

Major weeds infesting the cluster bean crop were *Cyperus rotundus*, *Convolvulus arvensis*, *Digera arvensis* and *Echinochloa colona*. Other minor weeds such as *Trianthema portulacastrum*, *Celosia argentea*, *Phyllanthus niruri, Physalis minima*, and *Cynodon dactylon* were not present uniformly in all the plots. The visual weed control at 30 DAS remained similar under all irrigation treatments because no post sown irrigation was applied upto 30 DAS (Table 2). However, visual weed control at 60 DAS decreased with increase in irrigation levels and lower visual weed control was observed in one and two post sown irrigation treatments as compared with no post sown irrigation. Availability of greater soil moisture might help the weeds to have more germination and take better growth in those plots with one or two post sown irrigation. Similarly, the dry weight of weeds at 30 DAS remained similar under all irrigation treatments because no post sown irrigation was applied upto 30 DAS. But, the dry weight of weeds at 60 DAS was significantly lower under no post sown irrigation treatment as compared with one or two irrigation levels, in which dry weight of weeds remained similar. This was due to less water availability to the plants in no post sown irrigation treatment as compared with one or two irrigation treatments. Similar dry weight of weeds under one and two post sown irrigation treatments was due to the fact that only one post sown irrigation was applied to both treatments upto 60 DAS. Furthermore, the dry weight of weeds at 90 DAS increased with the increasing levels of irrigation. The dry weight of weeds at 90 DAS remained significantly lower under no post sown irrigation treatment as compared with one or two irrigation levels, in which dry weight of weeds remained at par with each other (Table 2). Khaffagy *et al.* (2022) also observed that increased irrigation levels led to increased dry weights of accompanying weeds in soybean crop. Moreover, there was a significant reduction in weed dry weight with reduced irrigation level, which may be due to the fact that higher irrigation level can encourage weeds to emerge early and provide better growth conditions (Chowdhury *et al.* 2017). The decrease in the dry weight of total weeds could be due to the reduction in weed growth as an adaptive strategy in response to water deficit (Gonçalves *et al.* 2018). These results are consistent with El-Metwally *et al.* (2020). This reduction in the dry weight of weeds may be attributed to the inhibitory effect of treatments on the growth stages and development of associated weeds. These results are consistent with El-Metwally *et al.* (2020) and Chowdhury *et al.* (2017).

The visual weed control at 30 DAS remained higher under 2 HW (at 3 and 5 WAS) and imazethapyr 70 g/ha PRE as compared with other weed control treatments. This was due to better effect of HW at 21 DAS and effect of PRE herbicide upto 30 DAS, while POE herbicides applied at 21 DAS showed their effects even upto later stages. At 60 DAS, higher visual weed control was observed under 2 HW (at 3 and 5 WAS) and imazethapyr + imazamox (RM) 70 g/ha at 21 DAS treatments as compared with other weed control treatments, which might be due to the fact that PRE herbicides might not be effective upto 60 DAS. Among the weed management practices, two hand weedings at 3 and 5 WAS, produced minimum weed dry weight at 30, 60 DAS and 90 DAS, while, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS, was most effective in controlling the weeds among the chemical methods at all stages during both the years of study.

Effect on cluster bean

During both the years of study, the yield attributing characters like number of pods/plant, number of seeds/pod, and 1000 seed weight of cluster bean crop were observed significantly lower under the treatment with no post sown irrigation as compared with one and two post sown irrigation treatments, in which these parameters remained at par with each other (Table 3). This was due to less

TABLE 2

Effect of irrigation levels and weed management on visual weed control and weed dry weight in cluster bean crop

Treatments	Visual control (%)		Weed dry weight (g/m^2)*		
	30 DAS	60 DAS	30 DAS	60 DAS	90 DAS
Irrigation levels					
I_0 = No post-sown irrigation	74	77	4.4 (20.2)	7.4 (59.4)	9.6 (100.3)
I_1 = One irrigation at 30-35 DAS	74	64	4.3 (20.6)	9.2 (87.1)	11.2 (131.0)
I_2 = Two irrigations (30-35 DAS & 65-70 DAS)	74	63	4.6 (22.1)	9.2 (88.2)	12.4 (161.6)
CD (p=0.05)	-	-	NS	0.8	1.4
Weed Management					
T_1 = Pendimethalin 1.0 kg/ha as PRE	70	50	6.0 (35.7)	11.5 (130.9)	15.5 (240.0)
T_2 = Imazethapyr 70 g/ha PRE	90	60	4.7 (21.4)	7.5 (55.7)	9.9 (98.7)
T_3 = Imazethapyr 70 g/ha at 21 DAS	60	70	4.9 (24.1)	9.4 (88.4)	12.4 (154.3)
T_4 = Imazethapyr + imazamox (RM) 70 g/ha at 21 DAS	60	80	3.6 (14.7)	7.5 (61.3)	9.9 (100.9)
T_5 = Farmers practice (2 hand weedings at 3 and 5 WAS)	90	80	3.1 (9.0)	7.2 (54.9)	7.7 (61.1)
CD (p=0.05)	-	-	0.9	0.9	1.1

*Original data were subjected to square root transformation and presented in parentheses.

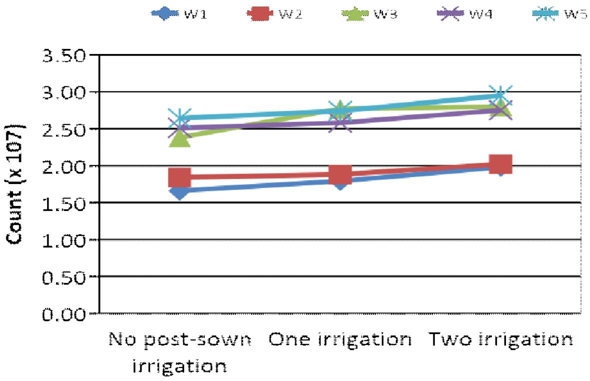
TABLE 3

Effect of irrigation levels and weed management practices on yield parameters and seed yield of cluster bean

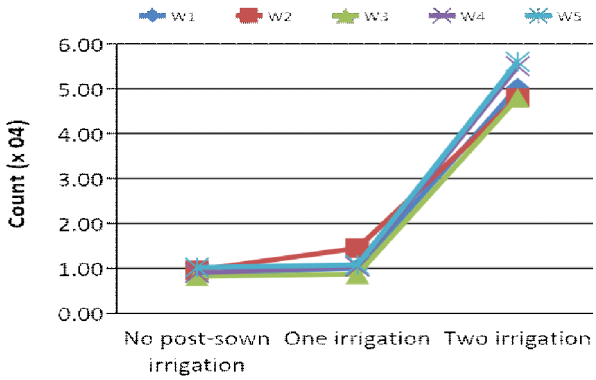
Treatments	No. of pods/plant		Seeds/pod		1000-seed wt. (g)		Seed yield (kg/ha)	
	18-19	19-20	18-19	19-20	18-19	19-20	18-19	19-20
Irrigation levels								
I_0 = No post-sown irrigation	39.57	21.45	5.43	5.22	20.91	19.08	719	536
I_1 = One irrigation at 30-35 DAS	42.61	25.40	6.86	6.24	24.39	22.58	1009	682
I_2 = Two irrigations (30-35 DAS & 65-70 DAS)	43.97	26.64	7.06	6.66	25.43	23.03	1036	726
CD (p=0.05)	1.74	2.17	0.34	0.46	0.79	0.66	72	56
Weed Management								
T_1 = Pendimethalin 1.0 kg/ha as PRE	36.49	22.00	5.93	5.51	23.09	21.08	771	568
T_2 = Imazethapyr 70 g/ha PRE	43.33	25.18	6.57	6.17	23.48	21.47	932	654
T_3 = Imazethapyr 70g/ha at 21 DAS	38.19	22.82	6.09	5.69	23.29	21.27	814	591
T_4 = Imazethapyr+imazamox (RM) 70 g/ha at 21 DAS	43.13	25.10	6.55	6.14	23.87	21.86	968	674
T_5 = Farmers practice (2 hand weedings at 3 and 5 WAS)	49.12	27.89	7.10	6.70	24.16	22.15	1121	754
CD (p=0.05)	2.13	1.95	0.30	0.54	0.70	0.55	72	46

water availability to the plants in no post sown irrigation treatment as compared with one or two irrigation treatments, whereas, availability of greater soil moisture in plots with one or two post sown irrigation might help the crop plants to utilize all available growth promoting factors in a better way for their better growth and development. Similarly, maximum seed yield (1036 & 726 kg/ha) was produced by irrigating the cluster bean crop with two irrigations, however, it was statistically at par with one irrigation (1009 & 682 kg/ha) treatment, but significantly higher than no post sown irrigation (719 and 536 kg/ha) treatment during 2018 and 2019, respectively.

These results may be attributed to less irrigation water, the rate of soil water absorption by plants becomes less than the rate of evapo-transpiration, consequently leading to reduced photosynthesis, decreased seed filling, and decreased seed yield may occur (Morsy and Tantawy, 2018). The application of sufficient irrigation levels with necessary nutrients provides the better conditions for processes of cell division and enlargement as well as for meristematic activity (Abdelaal *et al.*, 2020).



Bacterial Count
Fig. 1 (a)



PSB Count
Fig. 1 (b)

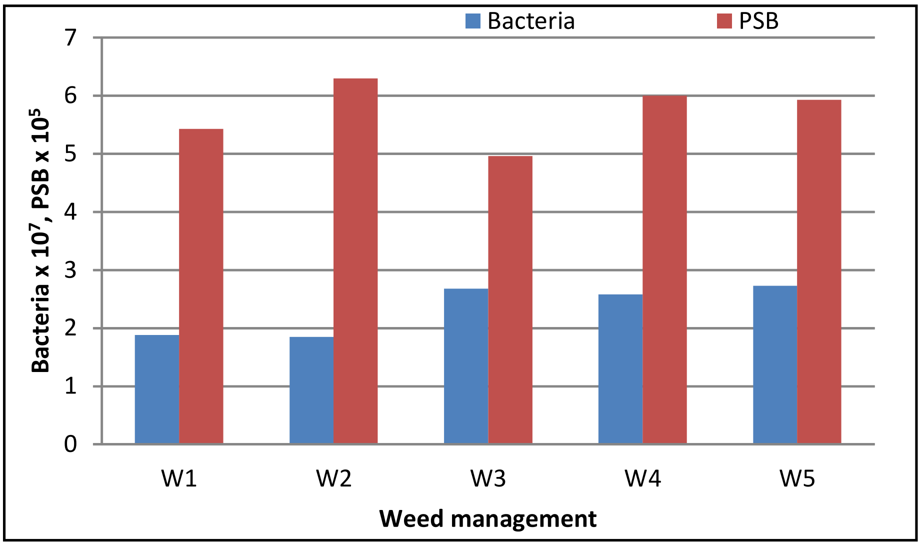


Fig. 1 (b)

Fig. 1 (a-c): Effect of on irrigation levels and weed control practices on population of total bacteria and PSB at harvest of cluster bean.

TABLE 4
Herbicide residues* (µg/g) in soil at harvest of cluster bean (2018)

Weed Management practices	Residues* (µg/g) in soil at harvest		
	No post-sown irrigation	One irrigation	Two irrigations
T_1	0.013	BDL	BDL
T_2	0.034	0.024	0.011
T_3	0.042	0.032	0.016
T_4	0.026	0.016	0.009
T_5	ND	ND	ND

*Average of three replicates.
Limit of detection (LOD)- imazethapyr and imazamox = 0.005 µg/g; pendimethalin = 0.001 µg/g, Limit of quantification (LOQ)- imazethapyr and imazamox = 0.01 µg/g; pendimethalin = 0.005 µg/g, BDL = below detectable limit (imazethapyr and imazamox = 0.005 µg/g; pendimethalin = 0.001 µg/g), ND- Not detected.

Khaffagy *et al.* (2022) and Sinha *et al.* (2022) also observed similar results in soybean crop and Deva and Kolhe (2016) in chick pea.

The seed yield of cluster bean in the treatment with 2 HW (at 3 and 5 WAS) remained significantly higher (1121 & 754 kg/ha) than all other chemical weed control treatments during 2018 and 2019, respectively. The reason for higher seed yield in the treatment with 2 HW (at 3 and 5 WAS) might be due to the fact that HW helped to control weeds effectively and also created better environment in soil for root growth, which in turn resulted in higher nutrient absorption leading to greater crop growth and yield. Among the chemical methods, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS produced highest seed yield (968 & 674 kg/ha), which remained statistically similar to imazethapyr 70 g/ha PRE (932

& 654 kg/ha) and both of them were superior to imazethapyr 70 g/ha at 21 DAS and pendimethalin 1.0 kg/ha as PRE during 2018 and 2019, respectively.

The control of total weeds during the crucial period for the crop growth stages gave the highest values of crop yield and increased seed yield. There was a significant effect of weed management practices on growth characteristics and yield of cluster bean in the both seasons. All herbicide and HW treatments were effective on weeds and led to a significant decrease in their dry weight, while increasing the seed yield of cluster bean compared to the control (untreated check). The untreated check produced the lowest yield of cluster bean, due to the heavy infestation of weeds, which grow faster and suppress crop growth, thus causing a reduction in yield (El-Metwally *et al*., 2017). Such treatments combined with optimal irrigation constitute promising weed control treatments to promote cluster bean yield and can play an important role where labour is too expensive and time is a constraint. These results corroborate the findings of El-Metwally *et al*. (2017) and Khaffagy *et al.* (2022) in soybean and Rana *et al.* (2019) and Deva and Kolhe (2016) in chick pea.

Effect on microbial count

The bacterial count (Fig. 1) at harvest of the cluster bean crop increased with an increase in irrigation levels, irrespective of weed control treatments. This might be due the fact that availability of greater soil moisture in plots with one or two post sown irrigation might help the crop plants to utilize all available growth promoting factors in a better way for their better root growth. Higher quantity of root exudates would have been released from those plants which had better root growth and these root exudates were used as a source of food by the soil microbes resulting into greater microbial population. Singh and Singh (2020) also reported that higher number of irrigations in summer mungbean also have moderating effect on soil microclimate resulting in higher bacterial population. Notably, compared to foliar herbicide application and two-hand weeding treatments, the bacterial count was lower when soil application of herbicides (pendimethalin or imazethapyr) was done.

This phenomenon could be attributed to the increased absorption of herbicides by the plants, subsequently leading to degradation through their metabolic pathways, thereby reducing the quantity available for residue. On the other hand, sprayed herbicides might have attached themselves to soil particles and increased the amount available for residue, which would have led to a decrease in the microbial population. Singh and Singh (2020) observed that 35 days following the sowing of the green gram crop, imazethapyr treatments had inhibitory effects on the bacterial population in the rhizosphere.

Similarly, the population of phosphate-solubilizing bacteria at harvest increased with irrigation levels, regardless of weed control treatments. The fact that the population of phosphate-solubilizing bacteria at harvest appeared to be minimally affected by the weed control treatments (Fig. 1) revealed the

TABLE 5

Residual effect of irrigation levels and weed management applied in cluster bean on succeeding mustard crop

Treatment	No. of plants/m.r.l. at 20 DAS		Plant height (cm)		Seed yield (kg/ha)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Irrigation levels						
I_1	12.8	13.3	200.6	210.5	1507	1636
I_2	14.4	15.1	209.4	219.6	1827	2030
I_3	15.8	16.7	218.7	229.4	1895	2037
CD (p=0.05)	1.6	2.0	7.4	13.3	123	183
Weed Management treatment						
T_1	15.6	16.4	215.1	225.6	1851	1990
T_2	12.9	13.4	206.5	216.7	1642	1801
T_3	12.5	13.0	200.1	209.9	1572	1683
T_4	14.5	15.3	209.8	220.1	1747	1939
T_5	16.1	17.0	216.3	227.0	1902	2093
CD (p=0.05)	1.6	2.4	8.9	10.5	149	157

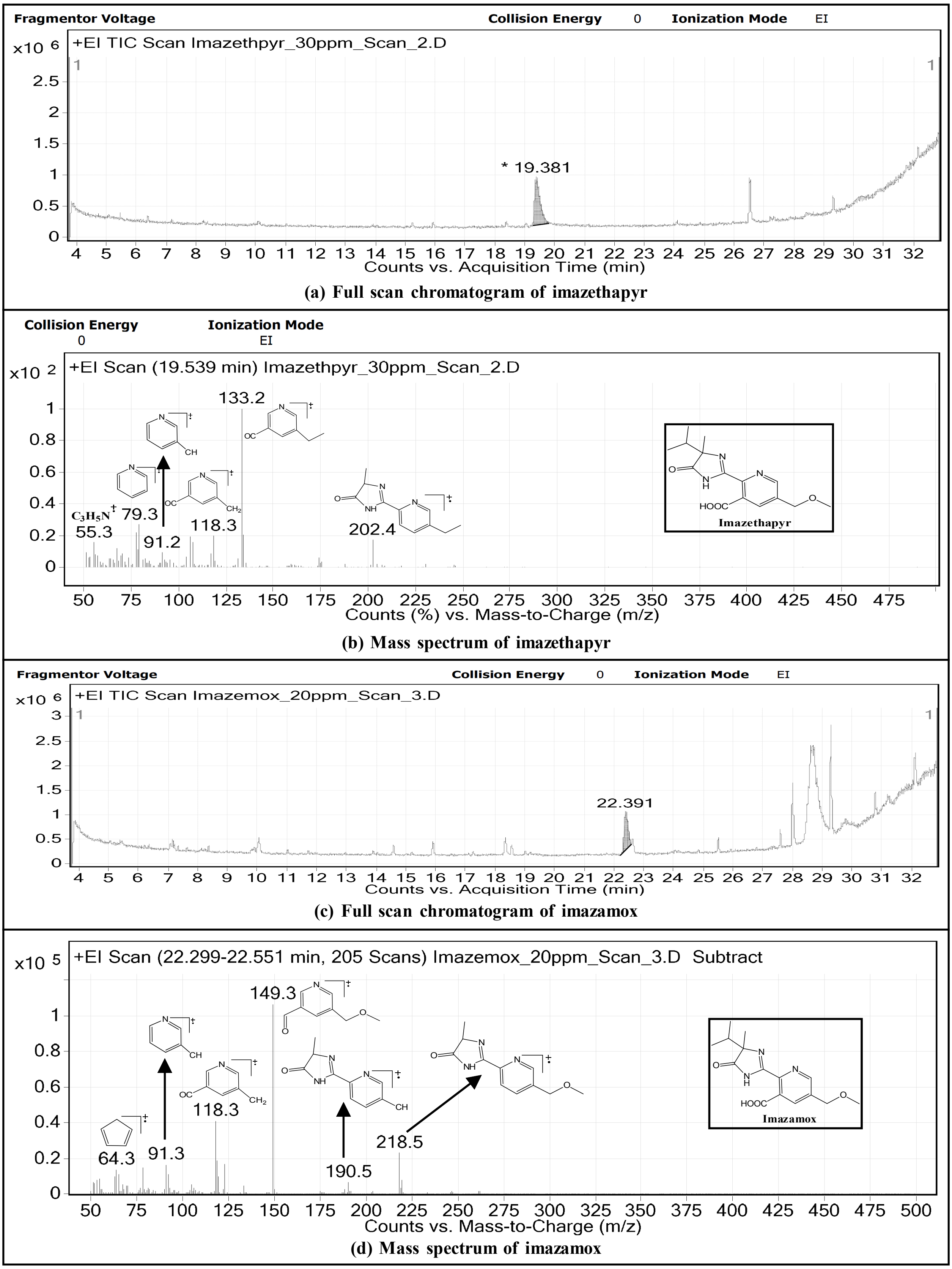


Fig. 2. (a) Full scan chromatogram of imazethapyr,(b) Mass spectrum of imazethapyr (c) Full scan chromatogram of imazamox(d) Mass spectrum of imazamox.

TABLE 6

Residual effect of herbicides applied in cluster bean under varying irrigation levels on seed yield (kg/ha) of succeeding mustard

Weed management treatment	Irrigation levels (2018-19)				Irrigation levels (2019-20)			
	No irrigation	One irrigation	Two irrigation	Mean	No irrigation	One irrigation	Two irrigation	Mean
T_1	1800	1853	1900	1851	1846	2057	2065	1990
T_2	1287	1770	1870	1642	1433	1951	2018	1801
T_3	1080	1760	1877	1572	1203	1892	1953	1683
T_4	1520	1830	1890	1747	1693	2135	1990	1939
T_5	1847	1920	1940	1902	2004	2114	2161	2093
Mean	1507	1827	1895		1636	2030	2037	
CD (p=0.05)	Irrigation levels: 123				Irrigation levels: 183			
	Weed management :149				Weed management :157			
	Weed mgt at same level of irrigation: 270				Weed mgt at same level of irrigation:295			
	Irrigation at same level of weed mgt: 260				Irrigation at same level of weed mgt: 301			

remarkably resilient nature of these microbes. This could be explained by a variety of microbial adaptation strategies used to offset the harmful effects of herbicides, such as bio-degradation (Yang and Lee, 2008) and enzymatic hydrolysis (Herman *et al*., 2005).

Herbicide residue

Method for analysis of pendimethalin, imazethapyr and imazamox was validated by performing recovery experiments at 0.003 and 0.01 µg/g fortification levels in soil. The recovery was found greater than 80% and considered satisfactory for sample analysis as per the Method Validation and Quality Control Procedures for Pesticide Residues in Food and Feed by European Union- document no. SANCO 2000. Maximum herbicide residue at harvest of the cluster bean crop was found in imazethapyr 70 g/ha at 21 DAS and followed by imazethapyr 70 g/ha PRE and imazethapyr + imazamox (RM) 70 g/ha at 20 DAS (Table 4 & Fig. 2). The herbicide residue decreased with increase in irrigation levels in cluster bean.

Residual effect on succeeding mustard crop

Reduction in the germination, growth and yield of mustard was observed due to residual effect of the chemicals applied in cluster beanduring both years of study (Table 5). Maximum effect was observed with imazethapyr 70 g/ha at 21 DAS followed by imazethapyr 70 g/ha PRE and imazethapyr + imazamox (RM) 70 g/ha at 21 DAS. Similarly, Loux *et al.* (1989) reported that imazethapyr caused injury to crop after 5 months of application in silt loam soil. Greenland (2003) also reported that residual of imazethapyr delayed tomato maturity. In Australia, persistence of imazethapyr was reported for more than 3 years. Its persistence was more infuenced by soil type rather than soil pH. In clay soils, 10% of applied imazethapyr persisted up to 24 months but in sandy soil it took 5 months for degradation of 90% of imazethapyr (Hollaway *et al.*, 2006). Shaner and Hornford (2005) reported that imazamox and imazethapyr applied early POE, did not have residual activity. Imazamox dissipates more rapidly than imazethapyr in the soil. The most important factors affecting the soil activity of the imidazolinones were soil organic matter, pH, moisture and temperature. During both years, the residual effect of imazethapyr in succeeding mustard crop decreased with increase in irrigation levels in cluster bean which increased yield of mustard crop (Table 6). Similarly, Ayeni and Bradley (1998) observed that as the rainfall amount increased, imazethapyr bioactivity declined significantly in loamy sand and sandy loam soil. Persistence of imazethapyr herbicide has been found to decrease with increased temperature as minimum persistence was recorded between 35 and 45°C and degradation enhanced when soil moisture increased from 15% to 75% of field capacity (Singh et al. 2010 and Flint and Witt, 1997). Similarly, herbicide residues found below 7.5 cm were greater in the clay loam soil than in silt loam soil.

CONCLUSION

Cluster bean productivity increased with increased irrigation levels during both years of study, however, problem of weeds also increased under greater irrigations. Two HW (at 3 and 5 WAS) were found superior to chemical weed control treatments in producing higher seed yield of cluster been during both years. Among the chemical methods, imazethapyr + imazamox (RM) 70 g/ha at 21 DAS produced highest seed yield which was statistically similar to imazethapyr 70 g/ha as PRE. Crop growth and yield of succeeding mustard crop was adversely affected due to residual effect of the chemicals applied in cluster bean. Maximum effect was observed with imazethapyr 70 g/ha at 21 DAS followed by imazethapyr 70 g/ha PRE and imazethapyr + imazamox (RM) 70 g/ha at 21 DAS during both years and these effects decreased with increase in irrigation levels in cluster bean.

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