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Biological and economic feasibility of different weed control options in cluster bean (*Cyamopsis tetragonoloba*) in South West Rajasthan

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Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.] is cultivated on about 3.32 million ha area with an annual production of about 1.26 million tonnes. Cluster bean is dominantly grown in rainfed production systems of arid and semi-arid tracts (SATs) of Rajasthan experiencing frequent and variable droughts and variety of other production constraints. Guar is a popular crop in SATs due to its low input and management demands as well as its diversified use (vegetables, green fodder, green manure, seeds and industrial gum). Presence of galactomannan (gum) in its endosperm is around 30-35% of seed weight. However, the productivity of guar is quite low owing to its cultivation on marginal and sub marginal soils, lack of optimum fertilizer use and follow up of recommended package of practices (insects and pest control, use of *Rhizobium* culture etc), high weed infestation etc. Amongst other agronomic factors known to augment guar productivity, appropriate weed control is the most important and inadequate weed management stands to be a major production constraint (severe competition by mixed weed flora) that deprives growers from harnessing the full production potential of guar cultivars. Weeds may reduce the guar productivity up to 53.7% (Saxena *et al.* 2004). Although weeds pose variable inter-specific competition throughout the entire crop period but initial one month period is particularly critical (Kumar *et al.* 1996). Hand weeding at 15-30 days after sowing (DAS) is a traditional and effective weed control practice in cluster bean. Pre-emergence use of pendimethalin and alachlor (Gurjar *et al*. 2001 and Chauhan *et al.* 2002) is only recommended chemical weed control option in cluster bean in Rajasthan. However, if use of these pre-emergence herbicides is skipped by farmers due to one or other reasons, no recommendation on post emergence herbicide is available. Further, cross and multiple weed resistance to herbicides is increasingly being reported from across the globe and no option of herbicide rotation to pendimethalin and alachlor is available in cluster bean in SATs of Rajasthan.

The current chemical weed control studies in India on imazethapyr, quizalfop-ethyl, pendimethalin and alachlor have mainly been concentrated on pulses and groundnut. These studies primarily focus on relative weed control over unweeded check, doses and time of application of these herbicides, their relative weed control efficiency and effect on crop yield and monetory benefits. Imazethapyr has been reported to outperform pendimethalin (Reshkar and Bhoi 2002 in soybean; Sasikala *et al.* 2007 in groundnut) and quizalofop-ethyl (Dixit and Varshney 2007 in soybean) while quizalofop-ethyl has also been reported to outperform imazethapyr (Tiwari 2002 in soybean). However, independent chemical weed control studies involving all these four herbicides as well as their performance with manual weeding in clusterbean are quit meager in India in general and in SATs of Rajasthan in particular. Therefore in this backdrop a study involving independent as well as integrated options of manual and chemical weed control was planned in South West Rajasthan in cluster bean considering instances of cross and multiple resistance and broadening the chemical weed control options for farmers with ultimate objective of sustained higher productivity and monetory gains to growers.

Selective post emergence herbicides like imazethapyr and quizalofop-ethyl were assessed with selective pre emergence herbicides like pendimethalin and alachlor independently as well as in combination with manual weeding at 40 days after sowing (DAS) in clusterbean in randomized block design with three replications during *kharif* 2010-11 at Research Farm of Agronomy Department at Maharana Pratap University of Agriculture & Technology, Udaipur, Rajasthan

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located at $24^0 35'$ N latitude and $74^0 42'$ E longitude at an altitude of 582.17 meter above mean sea level. The experiment comprised 12 treatments (T_1: T_7: quizalofop-ethyl 60 g/ha at 20 DAS, T_8: T_7 + hand weeding at 40 DAS, T_9: pendimethalin 1.0 kg/ha as pre emergence application, T_{10}: T_9 + hand weeding at 40 DAS, T_{11}: alachlor 2.0 kg/ha as pre emergence application and T_{12}: T_{11} + hand weeding at 40 DAS). Soil of the experimental site was clay loam in texture (sand: 36.0%, silt: 28.9% and clay: 35.1%), medium in available N (285.0 kg/ha), low in available P (20.42 kg/ha), high in available K (230.90 kg/ha), medium in organic carbon content (0.78 %) and slightly alkaline in reaction (pH 8.1). Total rainfall received during the entire crop period of cluster bean crop was 638 mm. Clusterbean Cv. RGC 936 (80-90 days) was sown on 22 July 2010 at 30 × 10 cm spacing using a seed rate of 18 kg/ha after treatment with Thirum @ 2 g/kg of seed and with *Rhizobium* and phosphorus solubulizing bacteria. A plant population of 3.33 lakhs was uniformly maintained in all treatments after thinning at 15 DAS. The crop was raised as rainfed applying recommended fertilizers and plant protection measures. The herbicide treatments imposed as per the treatment specifications while hand weeding was applied at 40 DAS in relevant treatments. Weed density was worked out after counting number of weeds in one meter square area while yield, yield contributing characters and dry matter accumulation were recorded at/ after crop harvest on 25.10.2010. The economics was worked out on prevailing market rates of crop produce and inputs used along with actual cost on different operation.

Weed free check (T_2) recorded significantly higher cluster bean seed yield than various sole or integrated options of weed control (manual and chemical) however, variations were statistically at par with two hand weedings at 20 and 40 DAS (T_4) and use of imazethapyr 100 g/ha at 20 DAS + hand weeding at 40 DAS, i e T_6 (Table 1). Significantly, higher cluster bean seed yield under T_2 and statistically at par variations with T_4 and T_6 is well supported by significantly higher performance of growth and yield characters (plant height, branches/plant, dry matter accumulation/plant, pods/plant, weight of seeds/pod and test weight) under T_2 and statistically at par variations with T_4 and T_6 in respects of these growth and yield characters. Besides, T_2 also recorded

Table1 Effect of weed control on weed density, weed index and growth of clusterbean

Treatment	Weed density (m^2)	Weed index (%)	Plant height (cm)	Branches/ plant	Dry matter accumulation (g/plant)
Weedy check (T_1)	16.27* (264.33)	71.78	81.67	6.33	14.50
Weed free check (T_2)	0.71 (0.00)	0.00	121.00	14.67	26.60
One HW 40 DAS (T_3)	6.81 (46.00)	31.80	96.67	10.67	17.00
Two HW 20 and 40 DAS (T_4)	4.06 (16.33)	6.57	113.00	13.00	25.60
Imazethapyr 100 g/ha 20 DAS (T_5)	5.46 (29.33)	27.59	105.33	10.67	20.67
T_5 + HW 40 DAS (T_6)	4.40 (19.00)	6.93	109.67	13.00	25.17
Quizalofop-ethyl 60 g/ha 20 DAS (T_7) |	13.43 (180.00)	33.81	103.33	10.33	18.33
T_7 + HW 40 DAS (T_8)	6.65 (44.00)	20.08	106.67	12.00	23.33
Pendimethalin 1.0 kg/ha PE (T_9)	8.92 (79.00)	32.94	99.67	10.33	17.53
T_9 + HW 40 DAS (T_{10})	5.79 (33.33)	20.54	102.33	12.00	20.93
Alachlor 2.0 kg/ha PE (T_{11})	10.07 (101.00)	32.00	100.67	9.67	19.67
T_{11} + HW 40 DAS (T_{12})	6.37 (40.33)	20.77	104.33	11.00	21.50
CD (P=0.05)	0.81		16.78	2.20	3.54

DAS, Days after sowing; Figures in parenthesis are original values; * Transformed values $\sqrt{(X + 0.5)}$

significantly higher number of seeds/pod than all other chemical or manual weed control options evaluated in the study which further go in the favour of the highest seed yield under T_2. Although use of imazethapyr @ 100 g/ha at 20 DAS (T_5) as well as use of quizalifop-ethyl @ 60 g/ha at 20 DAS + hand weeding at 40 DAS (T_8) recorded plant height statistically at par with T_2, T_4 and T_6 but performance of T_5 and T_8 in respect of yield attributes and seed yield was statistically much inferior. Further increase in plant height is also associated with solar energy response under higher plant density which was relevant under both T_5 and T_8 treatments up to 20 DAS that may lead to increase in plant height under these treatments in a short duration leguminous cluster bean crop.

Number of weeds per m^2 (weed density) was significantly reduced under weed control options of T_2, T_4 and T_6 than weedy check (T_1). The weed index was also reduced by 71.77, 65.21 and 64.85% under T_2, T_4 and T_6 than weedy check, respectively. This confirms to the better use of growth resources by cluster bean plants on account of lower crop-weed interface in T_2, T_4 and T_6 treatments that resulted in significantly higher grain yield, net returns and benefit cost ratio (Table 1). The result of this study is supported by several reports that reiterate that effectiveness in weed control by different manual/chemical options during critical weed crop interface occupies an important place (Rashkar and Bhoi 2002, Kushwah and Vyas 2005). The highest grain yield under weed free check have also been reported by several authors including Bhadoria *et al.* (2000). Higher seed yield and better performance of growth and yield characters under hand weeding than chemical control of weeds have also been reported by many workers including Sammauria (1995), Shaikh *et al.* (2002), Rajput and Kushwah (2004) etc.

It is notable that mere use of either pre emergence herbicides like pendimethalin (T_9) and alachlor (T_{11}) or post emergence herbicides like imazethapyr (T_5) and quizalofop ethyl (T_7) recorded statistically at par seed yield of cluster bean indicating no superiority over each other particularly with regards to productivity of cluster bean. However, when these chemical weed control options were integrated with hand weeding at 40 DAS, they recorded significant variations in the seed yield of cluster bean. The additional cluster bean grain yield produced due to combining hand weeding with different herbicides was 380.67, 253.66, 232.33 and 205.33 kg/ha under imazethapyr (T_5), quizalofop ethyl (T_7), pendimethalin (T_9) and alachlor (T_{11}), respectively. The significant variations in cluster bean seed yield on account of combining different herbicides with hand weeding at 40 DAS reveals weed-crop competition up to 40 days and more and may be attributed to differences in mode of action of herbicides (imazethapyr: inhibition of aceto lacto synthetase; quizalofop ethyl: aceto Co A carboxylase inhibition; pendimethalin: inhibition in cell division and elongation and alachlor: inhibition in GA 3 induced alfa amylase production in seeds), variations in metabolism period of herbicides and variations in extent of killing and suppression of weeds over the time scale covering the entire cluster bean crop period by virtue of herbicide residues and persistent in soil and plant systems.

Table2 Effect of weed control on yield attributes, yield and economics of cluster bean

Treatment	Pods/ plant	No. of seeds/ pod	Weight of seeds/pod (g)	Weight of 1000 seeds (g)	Seed yield (kg/ha)	Harvest index (%)	Net returns (₹/ha)	B/C ratio
Weedy check (T_1)	14.33	5.00	0.12	25.63	518.33	26.13	2 688.97	0.35
Weed free check (T_2)	34.00	9.67	0.26	33.23	1 840.00	30.57	21 485.01	1.58
One HW 40 DAS (T_3)	21.67	6.67	0.18	27.27	1 258.78	28.94	14 187.73	1.40
Two HW 20 and 40 DAS (T_4)	31.00	8.67	0.24	32.62	1 720.00	29.48	21 188.75	1.78
Imazethapyr 100 g/ha 20 DAS (T_5)	25.00	7.11	0.21	31.53	1 330.00	30.35	15 972.35	1.68
T_5 + HW 40 DAS (T_6)	29.67	8.33	0.23	32.42	1 710.67	29.97	21 770.74	1.98
Quizalofop-ethyl 60 g/ha 20 DAS (T_7)	23.00	6.81	0.20	28.87	1 216.67	31.43	13 328.51	1.37
T_7 + HW 40 DAS (T_8)	24.00	7.21	0.21	30.27	1 470.33	29.93	16 983.55	1.52
Pendimethalin 1.0 kg/ha PE (T_9)	23.00	6.82	0.20	28.33	1 230.00	28.94	14 423.43	1.55
T_9 + HW 40 DAS (T_{10})	25.00	7.20	0.21	29.50	1 462.33	30.08	17 167.55	1.59
Alachlor 2.0 kg/ha PE (T_{11})	23.67	6.91	0.20	30.77	1 250.50	29.90	14 991.15	1.67
T_{11} + HW 40 DAS (T_{12})	26.33	7.13	0.21	31.10	1 455.83	29.88	17 403.43	1.66
CD (P=0.05)	4.15	0.36	0.03	1.19	230.50	NS	3 862.22	0.39

SUMMARY

Among different weed control options, post emergence application of imazethapyr @ 100 g/ha at 20 DAS or quizalofop ethyl @ 60 g/ha at 20 DAS + hand weeding at 40 DAS recorded statistically at par variations with weed free check. These integrated weed options recorded significantly higher cluster bean yield, growth and yield characters and monetory gains to farmers than sole application of pre emergence herbicides or their combination with hand weeding at 40 DAS by recording significantly lower weed density and weed index. Thus, these integrated weed options open gate of herbicide rotation for pre emergence herbicides like pendimethaline and alachlor and can be more profitability used until cross or multiple resistance cases are not observed in cluster bean crop in Rajasthan.

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