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Optimization of Integrated Weed Management Practices for Sustainable Production of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] in Arid Regions

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ABSTRACT

Clusterbean [Cyamopsis tetragonoloba (L.) Taub.] is an important drought-tolerant legume crop widely cultivated in the arid and semi-arid regions of India, particularly Rajasthan. Effective weed management is essential for enhancing its productivity under rainfed conditions. A field experiment entitled "Optimization of Integrated Weed Management Practices for Sustainable Production of Clusterbean in Arid Regions" was conducted during Kharif 2025 at the Research Farm, Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan. The experiment was laid out in a Randomized Block Design with sixteen weed management treatments replicated thrice. Treatments comprised pre-emergence application of pendimethalin, post-emergence application of imazethapyr and imazethapyr + imazamox at different doses, either alone or integrated with hand weeding, along with weedy check and weed-free treatments. Results revealed that weed management practices significantly improved crop growth, yield attributes, and yield over the weedy check. The weed-free treatment recorded the highest plant height (115.1 cm), dry matter accumulation (170.6 g m^{-1} row length), pods $plant^{-1}$ (40.3), seeds pod^{-1} (3.73), seed yield (1486 kg ha^{-1}), straw yield (4141 kg ha^{-1}), and biological yield (5626 kg ha^{-1}). Among herbicidal treatments, pendimethalin @ 0.75 kg ha^{-1} alone or integrated with one hand weeding at 30 DAS performed comparably to the weed-free treatment. Weed infestation substantially reduced growth and yield, with the weedy check producing only 767 kg ha^{-1} seed yield. The study concluded that integrated weed management involving pendimethalin @ 0.75 kg ha^{-1}, either alone or combined with hand weeding, is an effective and sustainable strategy for improving clusterbean productivity in arid regions.

Keywords: *Clusterbean, integrated weed management, pendimethalin, imazethapyr, imazamox, hand weeding.*

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INTRODUCTION

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.], commonly known as guar, is an important leguminous crop cultivated extensively in the arid and semi-arid regions of India. The crop is highly drought tolerant due to its deep taproot system and ability to withstand moisture stress, making it well suited for dryland and rainfed farming conditions. Clusterbean is a multipurpose crop valued for its tender pods used as vegetables, nutritious fodder, green manure, and most importantly for guar gum extracted from its seeds. Guar gum is a commercially important industrial product widely utilized in food processing, pharmaceuticals, textiles, paper, cosmetics, and petroleum industries. In addition, clusterbean contributes to soil fertility through biological nitrogen fixation and serves as an excellent source of protein-rich livestock feed.

India is the largest producer and exporter of clusterbean, accounting for nearly 80–85 per cent of global production. Rajasthan is the leading clusterbean-growing state, contributing the major share of national production. Despite its economic importance, the productivity of clusterbean remains low, mainly due to cultivation under rainfed conditions and various biotic constraints.

Among these constraints, weed infestation is one of the most serious factors limiting crop productivity. Weeds compete with the crop for nutrients, moisture, light, and space during the critical early growth stages, causing substantial yield losses. Although hand weeding is effective, labour scarcity and rising costs necessitate alternative approaches. Therefore, integrated weed management involving pre- and post-emergence herbicides along with cultural practices has emerged as an effective strategy to improve weed control, enhance crop productivity, and increase economic returns in clusterbean cultivation.

MATERIALS AND METHODS

A field experiment entitled "Optimization of Integrated Weed Management Practices for Sustainable Production of Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] in Arid Regions" was conducted during the Kharif season of 2025 at the Research Farm, Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan. The experimental site is located in the semi-arid region of Rajasthan and is characterized by hot summers, low rainfall, and high evaporative demand. During the crop growing period, a total rainfall of 202.7 mm was received in 17 rainy days, with average maximum and minimum temperatures of 36.4°C and 22.8°C, respectively.

The soil of the experimental field was loamy sand in texture, slightly alkaline in reaction (pH 8.23), low in organic carbon (0.09%) and available nitrogen (78.1 kg ha^{-1}), while medium in available phosphorus (22.1 kg ha^{-1}) and potassium (210.0 kg ha^{-1}). The experiment was laid out in a Randomized Block Design (RBD) comprising sixteen weed management treatments replicated three times. The treatments included pre-emergence application of pendimethalin, post-emergence application of imazethapyr and imazethapyr + imazamox at different doses, either alone or in combination with hand weeding, along with weedy check and weed-free treatments.

Clusterbean variety RGC-1066 was sown on 18 July 2025 using a seed rate of 20 kg ha^{-1} at a spacing of 30 cm × 10 cm. The gross and net plot sizes were 13.5 m^2 and 6.3 m^2, respectively. A basal dose of 20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} was applied through urea and DAP. Pendimethalin was applied immediately after sowing as a pre-emergence treatment, whereas imazethapyr and imazethapyr + imazamox were sprayed at 25 days after sowing using a knapsack sprayer with 500 L water ha^{-1}. Hand weeding was carried out according to the treatment schedule.

Data on weed density, weed dry matter accumulation, weed control efficiency, plant stand, plant height, number of branches, dry matter accumulation, nodulation, yield attributes, seed yield, straw yield, biological yield, harvest index, chlorophyll content, gum content, nutrient uptake, and economics were

recorded using standard procedures. The collected data were subjected to analysis of variance (ANOVA) following Fisher's method for Randomized Block Design, and treatment means were compared using the critical difference (CD) test at the 5 per cent level of significance.

RESULTS

A critical examination of data indicates that all the weed control treatments significantly affected the plant height at 60 DAS as well as at harvest compared to weedy check but not at 30 DAS. The maximum plant height at 60 DAS was recorded under weed free treatment (99.0 cm) but it was found statistically at par with pendimethalin 0.75 kg ha^{-1} alone (97.0 cm) and pendimethalin 0.75 kg ha^{-1} +hand weeding at 30 DAS (96.8 cm). The minimum plant height (61.8 cm) was recorded under weedy check.

Data further indicate that the maximum plant height at harvest was recorded under weed free treatment (115.1 cm) but it was found statistically at par with pendimethalin 0.75 kg ha^{-1} alone (112.8 cm) and pendimethalin 0.75 kg ha^{-1}+ hand weeding at 30 DAS (112.6 cm) and minimum (71.4 cm) was recorded under weedy check. The increase in plant height with weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1}+ hand weeding at 30 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazethapyr+ imazamox 80 g ha^{-1}+ hand weeding at 40 DAS were 61.30, 58.07, 57.79, 22.73 and 33.10 per cent, respectively over weedy check.

Branches $plant^{-1}$

An assessment of data reveals that all the weed control treatments brought about non-significant effect on the number of branches $plant^{-1}$. The average number of branches $plant^{-1}$ was 1.10.

Table: Effect of weed control measures on plant stand 20 DAS, at harvest and branches $plant^{-1}$ in clusterbean

Treatments	Plant stand per metre row length		Branches ($plant^{-1}$) At harvest
	20 DAS	At harvest	
Weedy check(W_1)	11.1	10.3	1.2
Weed free(W_2)	10.4	10.2	1.3
Pendimethalin 0.75 kg ha^{-1} PE(W_3)	10.2	10.1	1.3
W_3 + HW 30 DAS(W_4)	12.9	10.2	1.2
Imazethapyr 40 g ha^{-1} 25 DAS(W_5)	10.1	10.0	1.1
Imazethapyr 50 g ha^{-1} 25 DAS(W_6)	10.2	10.1	1.2
Imazethapyr 60 g ha^{-1} 25 DAS(W_7)	10.3	10.2	1.3
W_5 + HW 40 DAS(W_8)	13.3	10.2	1.2
W_6 + HW 40 DAS(W_9)	10.1	10.0	1.1
W_7 + HW 40 DAS(W_{10})	10.2	10.1	1.3
Imazethapyr+Imazamox 40 g ha^{-1} 25 DAS(W_{11})	10.3	10.2	1.1
Imazethapyr+Imazamox 60 g ha^{-1} 25 DAS(W_{12})	10.7	10.2	1.3
Imazethapyr+Imazamox 80 g ha^{-1} 25 DAS(W_{13})	10.3	10.1	1.1
W_{11} + HW 40 DAS(W_{14})	10.6	10.2	1.2
W_{12} + HW 40 DAS(W_{15})	10.7	10.0	1.2
W_{13} + HW 40 DAS(W_{16})	10.4	10.3	1.2
SEm±	1.21	0.66	0.17
CD (P=0.05)	NS	NS	NS

HW= Hand weeding DAS=Day after sowing

Table: Effect of weed control measures on plant height 30 DAS, 60 DAS and at harvest in clusterbean

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
Weedy check(W_1)	19.9	61.9	71.4
Weed free(W_2)	20.2	99.1	115.1
Pendimethalin 0.75 kg ha^{-1} PE(W_3)	20.6	96.9	112.6
W_3 + HW 30 DAS(W_4)	25.9	97.1	112.8
Imazethapyr 40 g ha^{-1} 25 DAS(W_5)	16.8	73.7	85.2
Imazethapyr 50 g ha^{-1} 25 DAS(W_6)	20.2	74.0	85.7
Imazethapyr 60 g ha^{-1} 25 DAS(W_7)	20.5	74.4	86.1
W_5 + HW 40 DAS(W_8)	26.2	74.9	86.7
W_6 + HW 40 DAS(W_9)	19.1	75.3	87.2
W_7 + HW 40 DAS(W_{10})	19.3	75.7	87.6
Imazethapyr+Imazamox 40 g ha^{-1} 25 DAS(W_{11})	19.5	80.7	93.5
Imazethapyr+Imazamox 60 g ha^{-1} 25 DAS(W_{12})	19.1	81.1	94.0
Imazethapyr+Imazamox 80 g ha^{-1} 25 DAS(W_{13})	19.6	81.5	94.5
W_{11} + HW 40 DAS(W_{14})	20.7	81.1	93.9
W_{12} + HW 40 DAS(W_{15})	19.9	81.5	94.4
W_{13} + HW 40 DAS(W_{16})	20.8	81.9	95.0
SEm±	2.99	5.49	6.46
CD (P=0.05)	NS	15.87	18.67

Dry weight of nodules $plant^{-1}$

An assessment of data (Table 4.8) reveals that all the weed control treatments brought about non-significant effect on dry weight of nodules $plant^{-1}$**.** Data further reveal that the dry weight of nodules $plant^{-1}$ at 50 DAS was recorded highest 28.2 mg g^{-1} and lowest 27.4 mg g^{-1} with weed free treatment and weedy check, respectively.

Dry matter accumulation

Dry matter accumulation at 30 DAS

An assessment of data (Table 4.8) elucidates that all the weed control treatments caused non-significant effect on plant dry matter (g m^{-1} row length) over weedy check. Data further reveal that the maximum dry matter accumulation at 30 DAS was 15.7 g m^{-1} row length and minimum was 9.4 g m^{-1} row length were recorded with imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS and weedy check, respectively .

Dry matter accumulation at 60 DAS

A perusal of data indicates that all the weed control treatments significantly increased dry matter accumulation of clusterbean compared to weedy check (62.9 g m^{-1} row length). The highest plant dry matter (98.8 g m^{-1} row length) was recorded under weed free treatment but it was found statistically at par with pendimethalin 0.75 kg ha^{-1} alone (96.2 g m^{-1} row length) and pendimethalin 0.75 kg ha^{-1} +hand weeding at 30 DAS (97.3 g m^{-1} row length).

Data further reveal that among herbicides, the performance of pendimethalin 0.75 kg ha^{-1} alone and pendimethalin 0.75 kg ha^{-1} +hand weeding at 30 DAS were found significantly superior in increasing dry matter accumulation of clusterbean over each dose of imazethapyr and imazethapyr+imazamox. Integration of each herbicide with one hand weeding recorded effective increase in plant

dry matter compared to their application alone. The increase in plant dry matter with weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS and imazethapyr+imazamox 80 g ha^{-1}+ hand weeding at 40 DAS were 57.17, 53.03, 54.79 and 28.67 per cent, respectively over weedy check.

Dry matter accumulation at harvest

A critical examination of data reveals that all the weed control treatments significantly increased dry matter accumulation of clusterbean compared to weedy check (89.5 g m^{-1} row length). Data show that the highest plant dry matter (170.6 g m^{-1} row length) was recorded under weed free treatment but it was found statistically at par with all other treatments except weedy check.

Data further show that among herbicides, the performance of pendimethalin 0.75 kg ha^{-1} was found superior in enhancing dry matter accumulation of clusterbean closely followed by each dose of imazethapyr and imazethapyr+imazamox. Integration of each herbicide with one hand weeding also recorded increase in plant dry matter accumulation compared to their application alone. The increase in plant dry matter with weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS, imazethapyr 40 g ha^{-1}, imazethapyr 50 g ha^{-1}, imazethapyr 60 g ha^{-1}, imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS, imazethapyr 50 g ha^{-1}+ hand weeding at 40 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand weeding at 40 DAS were 90.51, 86.03, 83.36, 66.92, 72.52, 71.73, 74.97, 73.74, 75.08, 74.078, 71.51, 73.85, 76.53, 80.78 and 80.34 per cent, respectively over weedy check.

Table: Effect of weed control measures on crop dry matter accumulation and dry weight of nodules in clusterbean

Treatments	Dry matter accumulation (g) per metre row length			Dry weight of nodules at 50 DAS (mg $plant^{-1}$)
	30 DAS	60 DAS	At harvest	
Weedy check(W_1)	9.4	62.9	89.6	27.4
Weed free(W_2)	9.9	98.8	170.6	28.2
Pendimethalin 0.75 kg ha^{-1} PE(W_3)	10.9	97.3	164.2	28.0
W_3 + HW 30 DAS(W_4)	13.8	96.2	167.4	28.0
Imazethapyr 40 g ha^{-1} 25 DAS(W_5)	10.5	72.6	149.4	27.0
Imazethapyr 50 g ha^{-1} 25 DAS(W_6)	11.2	73.0	154.5	27.1
Imazethapyr 60 g ha^{-1} 25 DAS(W_7)	12.1	73.4	153.7	27.3
W_5 + HW 40 DAS(W_8)	15.7	73.9	156.6	27.5
W_6 + HW 40 DAS(W_9)	12.0	74.3	155.5	27.6
W_7 + HW 40 DAS(W_{10})	12.7	74.7	157.6	27.8
Imazethapyr+Imazamox 40 g ha^{-1} 25 DAS(W_{11})	13.4	79.7	155.9	28.0
Imazethapyr+Imazamox 60 g ha^{-1} 25 DAS(W_{12})	13.5	80.1	153.4	27.5
Imazethapyr+Imazamox 80 g ha^{-1} 25 DAS(W_{13})	11.8	80.5	155.6	27.7
W_{11} + HW 40 DAS(W_{14})	13.5	80.1	158.1	27.5
W_{12} + HW 40 DAS(W_{15})	13.4	80.5	161.8	27.6
W_{13} + HW 40 DAS(W_{16})	14.5	80.9	161.5	27.4
SEm±	1.54	5.43	10.38	2.15
CD (P=0.05)	NS	15.70	29.98	NS

HW= Hand weeding DAS=Day after sowing

Yield attributes and Yield

Pods plant^{-1}

An appraisal of data reflects that all weed control treatments significantly increased number of pods plant^{-1} over weedy check (28.7). The number of pods plant^{-1} was found statistically at par with all other remaining treatments except weedy check.

Data further reveal that among the all weed control treatments the trend of increase in number of pods plant^{-1} with weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS, imazethapyr 40 g ha^{-1}, imazethapyr 50 g ha^{-1},imazethapyr 60 g ha^{-1}, imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS, imazethapyr 50 g ha^{-1}+ hand weeding at 40 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand weeding at 40 DAS were recorded 40.07, 32.41, 34.85, 27.88, 34.85, 35.19, 37.64, 38.68, 36.24, 37.29, 39.38, 34.86, 36.24, 39.38 and 35.89 per cent, respectively compared to weedy check.

Seeds pod^{-1}

A critical examination of data reveals that all the weed control treatments significantly increased number of seeds pod^{-1} over weedy check (2.65). Weed free treatment recorded highest number of seeds pod^{-1} (3.77) which was found statistically at par with all remaining treatments except weedy check.

Table: Effect of weed control measures on yield attributes in clusterbean

Treatments	Pods plant^{-1}	Seeds pod^{-1}	Test weight (g)
Weedy check(W_1)	28.8	2.66	30.9
Weed free(W_2)	40.3	3.73	31.9
Pendimethalin 0.75 kg ha^{-1} PE(W_3)	38.1	3.68	31.3
W_3 + HW 30 DAS(W_4)	38.8	3.69	31.0
Imazethapyr 40 g ha^{-1} 25 DAS(W_5)	36.8	3.48	31.7
Imazethapyr 50 g ha^{-1} 25 DAS(W_6)	38.8	3.38	30.9
Imazethapyr 60 g ha^{-1} 25 DAS(W_7)	38.9	3.34	31.5
W_5 + HW 40 DAS(W_8)	39.6	3.39	30.9
W_6 + HW 40 DAS(W_9)	39.9	3.43	31.4
W_7 + HW 40 DAS(W_{10})	39.2	3.51	30.8
Imazethapyr+Imazamox 40 g ha^{-1} 25 DAS(W_{11})	39.5	3.38	30.9
Imazethapyr+Imazamox 60 g ha^{-1} 25 DAS(W_{12})	40.1	3.35	31.0
Imazethapyr+Imazamox 80 g ha^{-1} 25 DAS(W_{13})	38.8	3.38	31.5
W_{11} + HW 40 DAS(W_{14})	39.2	3.54	30.9
W_{12} + HW 40 DAS(W_{15})	40.1	3.55	31.0
W_{13} + HW 40 DAS(W_{16})	39.1	3.53	31.2
SEm±	1.83	0.06	1.59
CD (P=0.05)	5.30	0.17	NS

HW= Hand weeding DAS=Day after sowing

Data further indicate that among the herbicides the trend of increase in number of seeds pod^{-1} under weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS, imazethapyr 40 g ha^{-1}, imazethapyr 50 g ha^{-1}, imazethapyr 60 g ha^{-1}, imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS, imazethapyr 50 g ha^{-1}+ hand weeding at 40 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand

weeding at 40 DAS were 42.27, 38.87, 40.38, 30.94, 27.17, 24.91, 27.55, 29.06, 32.08, 27.17, 26.04, 27.55, 33.59, 33.97 and 32.84 per cent, respectively compared to weedy check.

Test weight

An assessment of data elucidates that all the weed control treatments caused non-significant effect on test weight over weedy check. Data further reveal that the maximum test weight was 31.9 g with weed free treatment and minimum was 30.9 g with weedy check.

Seed yield

An examination of data indicates that all the weed control treatments significantly increase seed yield of clusterbean over weedy check (767 kg ha^{-1}). The highest seed yield (1486 kg ha^{-1}) was recorded with weed free treatment which was found statistically at par with all other treatments except weedy check. Among all weed control treatments, the performance of pendimethalin 0.75 kg ha-1 alone and pendimethalin 0.75 kg ha-1+ hand weeding at 30 DAS was found higher in seed yield closely followed by application of imazethapyr 40, 50, 60 g ha-1, imazethapyr 40, 50, 60 g ha-1 integrated with one hand weeding, imazethapyr+imazamox 40, 60, 80 g ha-1 and imazethapyr+imazamox 40, 60, 80 g ha-1 integrated with one hand weeding. Integration of each herbicide with one hand weeding also effectively increased the seed yield compared to herbicides applied alone. The increase in seed yield due to weed free treatment, pendimethalin 0.75 kg ha-1 alone, pendimethalin 0.75 kg ha-1 + hand weeding at 30 DAS, imazethapyr 40 g ha-1, imazethapyr 50 g ha-1, imazethapyr 60 g ha-1, imazethapyr 40 g ha-1 + hand weeding at 40 DAS, imazethapyr 50 g ha-1+ hand weeding at 40 DAS, imazethapyr 60 g ha-1+ hand weeding at 40 DAS, imazamox+imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand weeding at 40 DAS were 93.63, 88.41, 87.74, 72.08, 73.21, 73.80, 78.39, 79.81, 80.87, 76.28, 76.71, 77.07, 82.82, 83.62 and 84.64 per cent, respectively over weedy check.

Straw yield

A perusal of data shows that all the weed control treatments significantly increase in straw yield of clusterbean over weedy check (2184 kg ha^{-1}). The highest straw yield (4141 kg ha^{-1}) was recorded with weed free treatment which was found statistically at par with all other treatments except weedy check.

Among all weed control treatments, the performance of pendimethalin 0.75 kg ha^{-1} alone and pendimethalin 0.75 kg ha^{-1}+ hand weeding at 30 DAS was found higher in straw yield closely followed by application of imazethapyr 40, 50, 60 g ha^{-1}, imazethapyr 40, 50, 60 g ha^{-1} integrated with one hand weeding, imazethapyr+imazamox 40, 60, 80 g ha^{-1} and imazethapyr+imazamox 40, 60, 80 g ha^{-1} integrated with one hand weeding. Integration of each herbicide with one hand weeding also effectively increased the straw yield compared to herbicides applied alone. The increase in straw yield due to weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS, imazethapyr 40 g ha^{-1}, imazethapyr 50 g ha^{-1}, imazethapyr 60 g ha^{-1}, imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS, imazethapyr 50 g ha^{-1}+ hand weeding at 40 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand weeding at 40 DAS were 89.67, 86.46, 82.01, 65.14, 72.31, 71.12, 73.84, 71.68, 74.46, 73.56, 69.57, 72.56, 74.55, 79.85 and 79.00 per cent, respectively over weedy check.

Biological yield

A reference to data presented in table indicates that all the weed control treatments significantly increase in biological yield of clusterbean over weedy check (2951 kg ha^{-1}). The highest biological yield (5626 kg ha^{-1}) was

recorded with weed free treatment which was found statistically at par with all other treatments except weedy check.

Among all weed control treatments, the performance of pendimethalin 0.75 kg ha^{-1} alone and pendimethalin 0.75 kg ha^{-1}+ hand weeding at 30 DAS was found higher in biological yield closely followed by application of imazethapyr 40, 50, 60 g ha^{-1}, imazethapyr 40, 50, 60 g ha^{-1} integrated with one hand weeding, imazethapyr+imazamox 40, 60, 80 g ha^{-1} and imazethapyr+imazamox 40, 60, 80 g ha^{-1} integrated with one hand weeding. Integration of each herbicide with one hand weeding also effectively increased the biological yield compared to herbicides applied alone. The increase in biological yield due to weed free treatment, pendimethalin 0.75 kg ha^{-1} alone, pendimethalin 0.75 kg ha^{-1} + hand weeding at 30 DAS, imazethapyr 40 g ha^{-1}, imazethapyr 50 g ha^{-1}, imazethapyr 60 g ha^{-1}, imazethapyr 40 g ha^{-1} + hand weeding at 40 DAS, imazethapyr 50 g ha^{-1}+ hand weeding at 40 DAS, imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS, imazamox+ imazethapyr 40 g ha^{-1}, imazamox+imazethapyr 60 g ha^{-1}, imazamox+ imazethapyr 80 g ha^{-1}, imazamox+imazethapyr 40 g ha^{-1}+ hand weeding at 40 DAS, imazamox+imazethapyr 60 g ha^{-1}+ hand weeding at 40 DAS and imazamox+imazethapyr 80 g ha^{-1}+ hand weeding at 40 DAS were 90.70, 86.96, 83.50, 66.94, 72.55, 71.82, 75.02, 73.79, 76.12, 74.26, 71.43, 73.73, 76.70, 80.83 and 80.47 per cent, respectively over weedy check.

DISCUSSION

The yield attributing characters *viz*., pods $plant^{-1}$ and seeds pod^{-1} were significantly improved under various weed control treatments as compared to weedy check (Table 4.9 and Fig 4.3) and the effect was more pronounced with weed free treatment closely followed by rest of the weed control treatments. This was attributed to minimum infestation of weeds (Table 4.1, 4.2, 4.3 and 4.4) together with lesser competition for other growth resources i.e. light, space, water, nutrients. Thus, reduced crop-weed competition resulted into overall improvement in crop growth as reflected by plant height and dry matter accumulation (Table 4.7 and 4.8) consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. The results corroborate with the findings of Singh et al. (1994), Kumar et al. (2003) and Singh et al. (2006).

It is evident from the results (Table 4.9, 4.10 and Fig. 4.3) that superiority of weed free treatment over all weed control methods significantly enhanced yield components *viz.*, pods $plant^{-1}$ and seed $pods^{-1}$ with concomitant increased in seed, straw and biological yield. The extents of increase in seed, straw and biological yield of clusterbean were by 93.62, 89.66 and 90.69 per cent under weed free treatment respectively compared to weedy check.

It is an established fact that least crop-weed competition during critical phase of crop growth exerts an important regulation function on complex process of yield formation due to better availability of water, space and nutrients to the crop plant. It also helps in improving aeration and nutrient uptake by plant resulting in higher metabolic activity (Lalitha Bai & Sinha, 1993). In preceding section it was, well emphasized that reduced crop-weed competition under weed free treatment as well as other herbicides, markedly influenced 'source' by virtue of higher photosynthetic and metabolic activity which in turn improved growth of crop and consequently yield components. The adverse effect of weed competition under present investigation is clearly reflected under weedy check, wherein dense population of weed reduced crop growth *viz.*, dry matter accumulation compared to weed free treatment as well as other treatments. This ultimately reduced yield components i.e., pods $plant^{-1}$ and seeds $pods^{-1}$ compared to other weed control methods. Nutrient stress caused by weeds might have also affected the seed bearing capacity of each pod. Not only this, but even normally stable component like test weight was also adversely affected by weeds under weedy check (Table

4.9, 4.10 and Fig 4.3). Thus, the weeds were able to adversely affect vegetative as well as reproductive parts of crop plant ultimately crop yield.

The reduced crop-weed competition caused significant increase in growth characters and yield ultimately led to higher seed yield of clusterbean. The significant improvement in seed yield as a result of weed free treatment, imazethapyr @ 40, 50, 60 g ha^{-1}, imazethapyr+ imazamox @ 40, 60 and 80 g ha^{-1}alone and also followed by one hand weeding at 40 DAS could be ascribed to the fact that yield of crop depends on several yield components which are interrelated. Under present investigation existence of high positive correlation between pods $plant^{-1}$ and seeds pod^{-1} (r=0.930 and 0.939, respectively) on seed yield also validate the aforesaid statement. Similarly, total weed dry weight at harvest was also negatively correlated with seed yield (r= -0.977) (Table 4.19). Under weedy situation, at early crop growth stage a greater part of nutrients present in soil are depleted by weeds for their growth. The crop plant thus, faced stress of nutrients which ultimately affected their growth, development and yield. The observed relationship was also reported by Bhadoria et al. (2000), Raskar and Bhoi (2002), Sumachandrika et al. (2003) and Upadhayay et al. (2013).

Alike seed yield, straw yield also significantly increased under various treatments of weed management during the experimentation over weedy check. Increase in straw yield might be due to the direct influence of various weed management treatments on the suppression of weeds. Thus, crop-weed competition resulted into increased plant height, dry matter accumulation and nutrient uptake (Table 4.7, 4.8, and Fig.4.1,4.4). The results corroborate with the findings of Kumar *et al.* (2003), Mishra and Chandrabhanu (2006) and Tiwari et al. (2014).

Biological yield is a function of seed and straw yield. Thus, significant increase in biological yield with various weed management treatments could be ascribed to the increased seed and straw yield (Table 4.10).

An another herbicide, pendimethalin which proved efficient for controlling weeds was found marginally superior to imazethapyr and imazethapyr+imazamox in terms of seed, straw and biological yield (Table 4.10). This seems to be on account of its activity due to continuous retention of moisture in soil by rainfall during beginning of crop season (Table 3.1) because it was applied as surface application instead of incorporation. The results corroborate with the findings of Sumachandrika et al. (2003), Guriqbal (2005) and Yadav et al. (2011).

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