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Influence of Tillage, Herbicide and Planting Delay on Nutrient Status and Yield of Cluster Bean as Replacement Crop Following Pearl Millet Stand Failure

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ABSTRACT

Background: Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.], with vernacular name of Guar, is annual, economically important and drought-hardy legume (Mondal and Gera, 2020) salinity tolerant grown under semiarid and subtropical regions. It is cultivated under both irrigated and rainfed condition in India (Rathod *et al.* 2020). India is its major producer, accounting for 80% of world's total production (Meena *et al*., 2018). Cluster bean is grown in India on 5.60 Mha and produces of 2.82 million tonnes with a low national average yield of merely 504 kg/ha (Anonymous, 2019).

Methods: The experiments were conducted at the Agronomy Farm, College of Agriculture, SK Rajasthan Agricultural University (SKRAU), Bikaner during *kharif* seasons of 2018 and 2019. The Farm is situated on Bikaner - Sriganganagar road situated at 28°4′21″ NL latitude and 73°20′17″ EL longitude with an altitude of 234.7 meters above the mean sea level. The experiment was laid out in strip plot design in three factors with 32 treatments comprising four tillage, two herbicide and four planting delay treatments. Statistical analysis by using STAR (R-Packages 1.5 STAR 2.0.) (Statistical Tool for Agricultural Research), software developed by Department of Plant Breeding Genetics and Biotechnology, IRRI (International Rice Research Institute), Manila, Phillipines.

Result: The disc plough (T_2), control (H_0) and early planting P_1 (July 10) significantly increased N, P, K, total nutrient uptake and partial nutrient balance (PBN) than other treatments. All the interactions were found significant in nutrient of cluster bean. The seed and straw yield of cluster bean was found significantly higher in disc plough (T_2), control (H_0) and early planting P_1 (July 10) compared to other treatments of pooled basis. The interactions were found significant between tillage × herbicide × planting delay in yield of cluster bean.

Key words: Cluster bean, Herbicide, NER, Nutrient, Planting delay, PNB, Tillage, Yield.

INTRODUCTION

Cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.], with vernacular name of Guar, is an annual, economically important and drought-hardy legume (Mondal and Gera, 2020) salinity tolerant grown under semiarid and subtropical regions. It is cultivated under both irrigated and rainfed condition in India (Rathod *et al*. 2020). India is its major producer, accounting for 80% of world's total production (Meena *et al*., 2018). Cluster bean is grown in India on 5.60 M.ha. and produces of 2.82 million tonnes with a low national average yield of merely 504 kg/ha (Anonymous, 2019). In spite of being widely adapted crop in India, its productivity is very low. There is now tremendous pressure on growers to use nutrient management approach to increase productivity and sustain soil health (Dhakal *et al*. 2016; Kumar *et al*. 2020). Guar increases N and organic matter content of soil by fixing atmospheric nitrogen and adding plant residues, respectively (Kalyani, 2012). Crop residues are major source of livestock feed and constitute about 40-60% of total dry matter intake in livestock. At present, India faces a net deficit of 10.9% dry crop residues. The demand of dry fodder will reach to 631 million tonnes by the year 2050 and at the current level of growth in forage resources, there will be 13.2% deficit in dry fodder in the year 2050 by Choudhary *et al.,* (2019).

Atrazine residues may affect the production of these *Kharif* crops as a replacement crop, after stand failure of pearl millet. The residual effect of atrazine could be minimized by using better inputs, proper production technology, delaying planting of replacement crops and adoption of appropriate tillage methods. Out of these tillage and delaying planting of replacement crops can be effective tools in reducing residual effect of herbicides by dilution as well as degradation (Soltani *et al*. 2011). Several tillage

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implements performe different types of tillage such as disc plough, harrow and cultivators but performance in reducing the residual effect of herbicides is different depending on soil types. Braswell *et al*. (2015) reported that soybean response to cotton herbicides was noted primarily with the three-week replant delay and greater response was noted with fluometuron. Soybean planted three week after diuron and fluometuron application was injured 1 to 15% and 6 to 33%, respectively, depending upon location. Various delay planting performance in mitigate the residual effect of herbicides is different depending on soil types.

The tillage, herbicide and planting delay enhanced yield and could results in increased N, P and K content and partial nutrient balance (PBN) in the seed and straw. Therefore, the objective of this article was to assess the interactions of tillage × herbicide × planting delay on nutrient status and yield of cluster bean as replacement crops following pearl millet stand failure in light textured soils.

MATERIALS AND METHODS

An attempt was made to study the response of cluster bean to various tillage operations, herbicide and planting delay. The experiments were conducted at the Agronomy Farm, College of Agriculture, SK Rajasthan Agricultural University (SKRAU), Bikaner during *kharif* seasons of 2018 and 2019. The farm is situated on Bikaner-Sriganganagar road situated at 28°4′21″ NL latitude and 73°20′17″ EL longitude with an altitude of 234.7 meters above the mean sea level. Mean weekly meteorological data during *Kharif* 2018 and 2019 including maximum (°C) and minimum temperature (°C) range during crop growing period from 31.1°C to 41.8°C and 9.9°C to 29.9°C in 2018 and 25.5°C to 42.3°C and 12.8°C to 30.5°C in 2019, respectively. The total rainfall during crop growing period was 287.4 mm with 14 rainy days in 2018 and 246.0 mm with 15 rainy days in 2019. The soil was sandy loam with pH 8.39, available N 124.25 kg/ha (Subbiah and Asija, 1956), P 28.25 kg/ha (Olsen *et al*., 1954), K 259 kg/ha (Metson, 1956) and 0.16% organic carbon (Walkley and Black, 1947). The gross and net plot size were used 20.25 m^2 and 12.60 m^2. Package and practices of crop was done using spacing (30 cm), seed rate (24 kg ha^{-1}) and variety (RGC 1066). Recommended dose of fertilizers 20: 32 kg /ha (N_2:P_2O_5) were applied as basal dose at the time of sowing. The crop was irrigated to canal water with 3 post sowing irrigations were applied during 2018 and 2019 as per the requirement of crop using sprinkler irrigation method. Seed treatment was done using Agromycin (250 ppm kg $seed^{-1}$) in both the years. Two sprays of Imidacloprid (30.5% SC) @ 3 ml in 10 liter water in standing crop was done to control the white fly and Jassid in 2019. The nitrogen, phosphorus and potassium content in plants samples was determined in seed, straw and further uptake was calculated as per standard laboratory procedures.

$$\text{NER- kg/kg} = \frac{\text{Biological yield}}{\text{Nutrient uptake}}$$

$$\text{PBN- kg/kg} = \frac{\text{Nutrient uptake by biological yield}}{\text{Total nutrient applied}}$$

Lal and Saini (2016)

The experiment was laid out in strip plot design in three factors with 32 treatments comprising four tillage, two herbicide and four planting delay treatments. Statistical analysis by using STAR (R-Packages 1.5 STAR 2.0.) (Statistical Tool for Agricultural Research), software developed by Department of Plant Breeding Genetics and Biotechnology, IRRI (International Rice Research Institute), Manila, Phillipines.

RESULTS AND DISCUSSION

N, P, K content

A perusal of data presented in the Table 1 indicates that various tillage operations, herbicide and planting delay were statistically at par in the nitrogen, phosphorus and potassium content in seed and straw of pooled basis.

N, P, K uptake

Interaction of Herbicide and Tillage (Nitrogen, Phosphorus and Potassium)

The interaction between herbicide and tillage method were found significant in both years (Table 2 a, d, g). Cluster bean seed, straw and total uptake was significantly decreased in all the tillage operation in atrazine treated plots (H1) as compared to control (H0), however, difference in decrease uptake was minimized in T2 (disc plough) and T4 (disc harrow) compared to T1 (no tillage) and T3 (cultivator) in pooled basis. The results also confirmed with the findings of Rathore *et al*. (2014); Kumar (2016) who reported among similar effect of tillage on nutrient uptake among different tillage in cluster bean.

Interaction of Herbicide and Planting delay (Nitrogen, Phosphorus and Potassium)

A herbicide by replant delay interaction was significantly noted with seed, straw and total uptake (Table 2 b, e, h). Pearl millet herbicide, atrazine significantly reduced the seed, straw and total nitrogen uptake of cluster bean as a replacement crop at P1 (10 days delay) and P2 (20 days delay) level of planting delay compared to control (H0) in pooled basis. However, planting delay of P3 (30 days delay) and P4 (40 days delay) were at par when H0 (control) and H1 (Atrazine application). When planting treatments were compared in H0, then P1 (10 July sowing) recorded significantly highest uptake. Further, seed, straw and total uptake significantly deceased as the planting delay time increased in H0 (control) treatment. However, in atrazine treated plots (H1), P1 and P2 planting delay treatments were statistically at par with each other.

Yield

Tillage

The scrutiny of the data presented in the Table 1 on cluster bean clearly exhibited that the seed yield (1406 kg ha^{-1}) in T2 (disc plough) was significantly superior to T4 (disc harrow),

Table 1: Effect of tillage, herbicide and planting delay on nitrogen, phosphorus and potassium content, nutrient efficiency ratio (NER) and yield of cluster bean as a replacement crop (mean 2 years).

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		NER (Kg Kg^{-1})			Yield (kg ha^{-1})	
A. Tillage	Seed	Straw	Seed	Straw	Seed	Straw	N	P	K	Seed	Straw
T1 - No tillage	3.21	1.10	0.37	0.15	0.75	1.22	31.42	272.4	142.90	997	2976
T2 - Tillage with disk plough with planking	3.33	1.15	0.38	0.16	0.80	1.31	30.76	263.9	125.6	1406	3805
T3 - Tillage with cultivator with planking	3.23	1.10	0.37	0.16	0.78	1.21	30.98	271.0	130.6	1022	3021
T4 - Tillage with harrow with planking	3.31	1.13	0.37	0.16	0.79	1.22	30.50	276.7	128.9	1271	3629
S.Em.±	0.05	0.02	0.01	0.00	0.02	0.02	0.53	5.0	5.0	23	71
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	70	220
B. Herbicide											
H0 - Control	3.30	1.14	0.38	0.16	0.79	1.23	30.82	267.2	130.4	1279	3662
H1 - Atrazine 0.5 kg ha^{-1}	3.23	1.10	0.37	0.15	0.77	1.25	31.01	274.8	133.6	1069	3053
S.Em.±	0.04	0.01	0.00	0.00	0.01	0.02	0.45	3.6	2.0	13	46
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	37	130
C. Planting delay											
P1 - 10 days after herbicide application	3.28	1.13	0.38	0.16	0.80	1.23	31.47	263.6	131.8	1512	4051
P2 - 20 days after herbicide application	3.28	1.12	0.37	0.16	0.80	1.20	30.54	267.5	127.6	1257	3581
P3 - 30 days after herbicide application	3.27	1.11	0.37	0.16	0.77	1.21	30.58	268.8	133.0	1068	3184
P4 - 40 days after herbicide application	3.25	1.11	0.36	0.15	0.76	1.31	31.06	284.1	135.6	859	2614
S.Em.±	0.06	0.02	0.01	0.00	0.01	0.03	0.73	5.0	3.5	29	82
C.D.(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	90	254

T3 (cultivator) and T1 (no tillage) while T3 and T1 tillage operations were found to be statistically at par each other, but T4 was significantly higher than T3 and T1 tillage operations. On the basis of pooled data, the seed yield was decreasing to the tune of 9.60%, 27.31% and 29.08% in T4, T3 and T1 tillage operations, respectively, compared to disc plough treatments. In case of straw yield in T2 (3805 kg ha^{-1}) and T4 (3629 kg ha^{-1}) was statistically at par with each other, but significantly better than T3 (cultivator) and T1 (no tillage), while T3 and T1 were statistically at par to each other during 2018 and 2019. The straw yield was significantly reduced under T3 and T1 tillage practices to the tune of 20.60% and 21.78%, respectively, compared to the T2 treatment on the basis of pooled data. The results also confirmed with the findings of Sharp *et al*., (1982). The results corroborate with the similar effect of tillage on atrazine persistence in the soil and soybean injury. Atrazine applied at 2.24 kg ha^{-1} resulted in decreased biomass and yield as much as 49 and 42%, respectively under the chisel and no-tillage systems compared with moldboard plowing by Soltani *et al*., (2011).

Herbicide

The yield (Table 1) of cluster bean was significantly lower owing to atrazine residue during crop growing season. On the basis of pooled data, the seed and straw yield was decreasing to the tune of 16.41% and 16.63% in H1 (atrazine) treatments compared to H0 (control) treatment. These results are in agreement with the findings of Soltani *et al*., (2011) and Braswell *et al*., (2015). Mobility of Initially atrazine loss in the soil was slow (up to 20 days), but sharp reductions had occurred by 30 days (60-63 and 50-57%) (Saikia *et al*., 2000).

Table 1(a): Interaction of tillage and herbicide on yield (kg ha^{-1}) of cluster bean as a replacement crop.

Planting delay	Tillage (Mean 2 years)									
	Seed					Straw				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	1147	1488	1144	1339	1279	3383	3955	3528	3782	3662
H1	846	1324	900	1203	1069	2568	3654	2515	3477	3053
Mean	997	1406	1022	1271		2976	3805	3021	3629	
H × T (H at same level of T)			S.Em.±		23			71		
			C.D.(p=0.05)		70			220		
H × T (T at same level of H)			S.Em.±		15			48		
			C.D.(p=0.05)		44			143		

Table 1(b): Interaction of planting delay and herbicide on yield (kg ha^{-1}) of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)									
	Seed					Straw				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	1849	1323	1082	863	1279	4932	3691	3253	2772	3662
H1	1174	1191	1054	854	1069	3170	3471	3116	2455	3053
Mean	1512	1257	1068	859		4051	3581	3184	2614	
H × P (H at same level of P)			S.Em.±		23			71		
			C.D.(p=0.05)		70			220		
H × P (P at same level of H)			S.Em.±		17			53		
			C.D.(p=0.05)		52			157		

Table 1(c): Interaction of tillage and planting delay on yield (kg ha^{-1}) of cluster bean as a replacement crop.

Planting delay	Tillage (Mean 2 years)									
	Seed					Straw				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
P1	1105	2008	1211	1724	1512	3210	5012	3460	4523	4051
P2	1163	1427	1095	1344	1257	3070	4142	3307	3806	3581
P3	960	1217	968	1127	1068	3051	3455	2918	3314	3184
P4	759	973	814	890	859	2571	2609	2400	2875	2614
Mean	997	1406	1022	1271		2976	3805	3021	3629	
P × T (P at same level of T)			S.Em.±		23			71		
			C.D.(p=0.05)		70			220		
P × T (T at same level of P)			S.Em.±		26			77		
			C.D.(p=0.05)		77			228		

Planting delay

The seed and straw yield was significantly influenced by the planting delay and data presented in Table 1, revealed that the P4 (August 9) planting delay significantly the decreased straw yield compared to the P1 (July 10) on the basis of pooled data plainly exhibited the significant decreased in the seed and straw yield under P2, P3 and P4 planting to the tune of 16.86% and 11.60%, 29.36% and 21.40% and 43.18% and 35.47%, respectively, compared to the P1 planting. All the treatments of planting delay were significant among themselves. The results are in close proximity with the findings of Meena *et al*., (2018) and also our results are similar to those of Taneja *et al*., (1995) reported that sowing of cluster bean on 10 July gave the highest seed yield of 2.17 t ha^{-1}, whereas, sowing on 30 July gave the lowest yield (1.26 t ha^{-1}).

Interaction of herbicide and tillage (Yield)

The interactions between herbicide and tillage operations were found significant in pooled basis (Table 2a). Cluster bean seed and straw yield was significantly decreased in all the tillage operation in atrazine treated plots (H1) as compared to control (H0), however, difference in decreased yield was minimized in T2 (11.02% and 7.61% reduction) and T4 (10.15% and 8.06% reduction) compared to T1 (26.24% and 24.09% reduction) and T3 (21.32% and 28.71% reduction) in pooled basis.

Interaction of herbicide and planting delay (yield)

A herbicide by replant delay interaction was noted with seed yield (Table 2b). Pearl millet herbicide, atrazine significantly reduced the seed and straw yield of cluster bean as a replacement crop at P1 (10 days delay) and P2 (20 days delay) level of planting delay compared to control (H0) but, planting of P3 (30 days delay) and P4 (40 days delay) were statistically at par in H0 (control) and H1 (Atrazine application) treatments. The data further showed that when planting delay treatments were compared in H0 then, P1 (10 July sowing) recorded significantly the highest seed yield. Further, seed yield significantly deceased as the planting delay time increased in H0 (control) treatment however, in atrazine treated plots (H1), P1 and P2 planting delay treatments were statically at par with each other.

Interaction of planting delay and tillage (Yield)

The interaction between planting delay and tillage operations were found significant in pooled basis (Table 1c). It was observed that significantly higher seed and straw yield of cluster bean was obtained in P1 (July 10) planting in T2 (disc plough) tillage operation however, this advantage was significantly diminished in all other tillage operations in P2 planting delay.

Nutrient efficiency ratio (NER - Kg Kg^{-1})

It is the total biomass produced per unit of nutrient uptake. A critical examination of data (Table 1) reveals that different tillage operations were statistically at par in the nitrogen and potassium but highest in No tillage (T1) and cultivator (T3) compared to disc plough and disc harrow. Phosphorus under different treatment were no significant variation but highest in disc harrow (T4) and no tillage (T1) than other treatment. The nitrogen, phosphorus and potassium nutrient efficiency ratio were higher in atrazine residue (H1) and planting delay (P4) than other treatment of pooled basis.

Interaction of herbicide and tillage (Partial nutrient balance - nitrogen and phosphorus)

The interaction between herbicide and tillage method were found significant on pooled basis (Table 3a, d). Cluster bean seed, straw and total uptake was significantly decreased in all the tillage operation in atrazine treated plots (H1) as compared to control (H0), however, difference in decrease uptake was minimized in T2 (disc plough) and T4 (disc harrow) compared to T1 (no tillage) and T3 (cultivator) in pooled basis.

Interaction of herbicide and planting delay (Partial nutrient balance - nitrogen and phosphorus)

A herbicide by replant delay interaction was significantly noted with seed, straw and total partial nutrient balance (Table 3b, e). Pearl millet herbicide, atrazine significantly reduced the seed, straw and total nutrient balance of cluster bean as a replacement crop at P1 (10 days delay) and P2 (20 days delay) level of planting delay compared to control (H0) in pooled basis. However, planting delay of P3 (30 days delay) and P4 (40 days delay) were at par when H0 (control) and H1 (Atrazine application). When planting treatments were

Table 2(a): Interaction of herbicide and tillage on nitrogen uptake (kg ha^{-1}) in straw and total uptake of cluster bean as a replacement crop

Herbicide	Tillage (mean 2 years)									
	Straw					Total uptake				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	110.2	133.0	115.3	126.5	121.3	147.6	183.2	152.7	171.2	163.7
H1	81.25	119.9	80.40	114.3	98.9	108.0	163.4	109.2	154.0	133.7
Mean	95.76	126.4	97.86	120.4		127.8	173.3	131.0	162.6	
H × T (H at same level of T)			S.Em.±		2.20			2.8		
			C.D. (p=0.05)		6.77			8.6		
H × T (T at same level of H)			S.Em.±		1.96			2.4		
			C.D. (p=0.05)		5.69			7.0		

Table 2(b): Interaction of herbicide and planting delay on nitrogen uptake (kg ha^{-1}) in seed, straw and total uptake of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)														
	Seed					Straw					Total uptake				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	61.99	43.90	35.56	28.28	42.43	164.9	122.5	106.8	90.79	121.3	226.9	166.4	142.4	119.1	163.7
H1	37.86	38.75	34.42	27.66	34.67	102.2	112.9	101.7	79.12	98.98	140.0	151.7	136.1	106.8	133.7
Mean	49.93	41.32	34.99	27.97		133.6	117.7	104.3	84.96		183.5	159.0	139.3	112.9	
H × P (H at same level of P)			S.Em.±		1.09			2.20					2.8		
			C.D. (p=0.05)		3.35			6.77					8.6		
H × P (P at same level of H)			S.Em.±		0.75			1.96					2.4		
			C.D. (p=0.05)		2.22			5.69					7.0		

Table 2(c): Interaction of herbicide and tillage on phosphorus uptake (kg ha^{-1}) in straw and total uptake of cluster bean as a replacement crop.

Herbicide	Tillage (Mean 2 years)									
	Straw					Total uptake				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	12.66	15.22	13.17	14.42	13.87	16.96	20.97	17.45	19.53	18.73
H1	9.42	13.95	9.27	12.98	11.41	12.52	19.01	12.59	17.47	15.40
Mean	11.04	14.59	11.22	13.70		14.74	19.99	15.02	18.50	
H × T (H at same level of T)	S.Em.±			0.30				0.36		
	C.D. (p=0.05)			0.91				1.11		
H × T (T at same level of H)	S.Em.±			0.21				0.24		
	C.D. (p=0.05)			0.61				0.70		

Table 2(d) Interaction of herbicide and planting delay on phosphorus uptake (kg ha^{-1}) in seed, straw and total uptake of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)														
	Seed					Straw					Total uptake				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	7.16	5.04	4.06	3.17	4.86	19.07	14.04	12.22	10.14	13.87	26.23	19.08	16.28	13.31	18.73
H1	4.48	4.44	3.93	3.12	3.99	12.11	12.91	11.63	8.97	11.41	16.59	17.35	15.56	12.09	15.40
Mean	5.82	4.74	4.00	3.15		15.59	13.47	11.92	9.55		21.41	18.21	15.92	12.70	
H × P (H at same level of P)			S.Em.±		0.11			0.30					0.36		
			C.D. (p=0.05)		0.35			0.91					1.11		
H × P (P at same level of H)			S.Em.±		0.07			0.24					0.25		
			C.D. (p=0.05)		0.22			0.72					0.75		

Table 2(e): Interaction effect of herbicide and tillage on potassium uptake (kg ha^{-1}) in straw and total uptake of cluster bean as a replacement crop.

Herbicide	Tillage (Mean 2 years)									
	Straw					Total uptake				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	26.04	31.85	27.71	30.73	29.08	34.85	43.91	36.74	41.58	39.27
H1	19.13	29.49	19.43	27.17	23.80	25.54	40.18	26.41	36.52	32.16
Mean	22.58	30.67	23.57	28.95		30.20	42.05	31.57	39.05	
H × T (H at same level of T)	S.Em.±		0.84					1.05		
	C.D. (p=0.05)		2.57					3.22		
H × T (T at same level of H)	S.Em.±		0.52					0.61		
	C.D. (p=0.05)		1.55					1.85		

Table 2(f): Interaction of herbicide and planting delay on potassium uptake (kg ha^{-1}) in seed, straw and total uptake of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)														
	Seed					Straw					Total uptake				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	15.08	10.59	8.53	6.56	10.19	40.36	29.61	25.48	20.87	29.08	55.44	40.19	34.01	27.43	39.27
H1	9.41	9.53	8.01	6.49	8.36	25.10	27.66	23.69	18.77	23.80	34.50	37.19	31.70	25.26	32.16
Mean	12.24	10.06	8.27	6.52		32.73	28.63	24.59	19.82		44.97	38.69	32.86	26.35	
H × P (H at same level of P)			S.Em.±		0.30			0.84					1.05		
			C.D. (p=0.05)		0.91			2.57					3.22		
H × P (P at same level of H)			S.Em.±		0.15			0.54					0.58		
			C.D. (p=0.05)		0.46			1.62					1.74		

Table 3(a): Interaction of tillage and herbicide on straw and total nitrogen partial nutrient balance (PNB) of cluster bean as a replacement crop.

Herbicide	Tillage (Mean 2 years)									
	Straw (Kg Kg^{-1})					Total PNB (Kg Kg^{-1})				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	5.51	6.65	5.77	6.32	6.06	7.38	9.16	7.64	8.56	8.19
H1	4.06	6.00	4.02	5.72	4.95	5.40	8.17	5.46	7.70	6.68
Mean	4.79	6.32	4.89	6.02		6.39	8.67	6.55	8.13	
H × T (H at same level of T)	S.Em.±			0.11				0.14		
	C.D. (p=0.05)			0.34				0.43		
H × T (T at same level of H)	S.Em.±			0.10				0.12		
	C.D. (p=0.05)			0.28				0.35		

Table 3(b): Interaction of herbicide and planting delay on seed, straw and total nitrogen partial nutrient balance (PNB) of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)														
	Seed (Kg Kg^{-1})					Straw (Kg Kg^{-1})					Total uptake (Kg Kg^{-1})				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	3.10	2.19	1.78	1.41	2.12	8.25	6.12	5.34	4.54	6.06	11.35	8.32	7.12	5.95	8.19
H1	1.89	1.94	1.72	1.38	1.73	5.11	5.65	5.09	3.96	4.95	7.00	7.58	6.81	5.34	6.68
Mean	2.50	2.07	1.75	1.40		6.68	5.89	5.21	4.25		9.17	7.95	6.96	5.65	
H × P (H at same level of P)	S.Em.±			0.05				0.11					0.14		
	C.D. (p=0.05)			0.17				0.34					0.43		
H × P (P at same level of H)	S.Em.±			0.04				0.12					0.14		
	C.D. (p=0.05)			0.11				0.36					0.41		

Table 3(c): Interaction of tillage and herbicide on straw and total phosphorus partial nutrient balance (PNB) of cluster bean as a replacement crop.

Herbicide	Tillage (Mean 2 years)									
	Straw (Kg Kg^{-1})					Total PNB (Kg Kg^{-1})				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
H0	0.40	0.48	0.41	0.45	0.43	0.53	0.66	0.55	0.61	0.59
H1	0.29	0.44	0.29	0.41	0.36	0.39	0.59	0.39	0.55	0.48
Mean	0.34	0.46	0.35	0.43		0.46	0.62	0.47	0.58	
H × T (H at same level of T)	S.Em.±			0.01				0.01		
	C.D. (p=0.05)			0.03				0.03		
H × T (T at same level of H)	S.Em.±			0.01				0.01		
	C.D. (p=0.05)			0.02				0.02		

Table 3(d): Interaction of herbicide and planting delay on seed, straw and total phosphorus partial nutrient balance (PNB) of cluster bean as a replacement crop.

Herbicide	Planting delay (Mean 2 years)														
	Seed (Kg Kg^{-1})					Straw (Kg Kg^{-1})					Total uptake (Kg Kg^{-1})				
	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean
H0	0.22	0.16	0.13	0.10	0.15	0.60	0.44	0.38	0.32	0.43	0.82	0.60	0.51	0.42	0.59
H1	0.14	0.14	0.12	0.10	0.12	0.38	0.40	0.36	0.28	0.36	0.52	0.54	0.49	0.38	0.48
Mean	0.18	0.15	0.12	0.10		0.49	0.42	0.37	0.30		0.67	0.57	0.50	0.40	
H × P (H at same level of P)			S.Em.±		0.004			0.01					0.01		
			C.D. (p=0.05)		0.011			0.03					0.03		
H × P (P at same level of H)			S.Em.±		0.002			0.01					0.01		
			C.D. (p=0.05)		0.007			0.02					0.02		

compared in H0, then P1 (10 July sowing) recorded significantly highest nutrient balance. Further, seed, straw and total nutrient balance significantly deceased as the planting delay time increased in H0 (control) treatment. However, in atrazine treated plots (H1), P1 and P2 planting delay treatments were statistically at par with each other.

CONCLUSION

Disc plough tillage (T2), control (H0) and (July 10) planting delay significantly increased the seed and straw yield, nutrient uptake, partial nutrient balance in nitrogen and phosphorus of cluster bean as replacement crop compared to other tillage treatments.

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