EFFECT OF PRECEDING WINTER CROPS AND RESIDUE MANAGEMENT ON GROWTH PERFORMANCE, WEED, NUTRIENT UPTAKE AND ECONOMICS OF CLUSTERBEAN *(Cyamopsis tetragonoloba* L. Taub.] UNDER ZERO-TILL SEMI-ARID CONDITION

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ABSTRACT

Field experiments under zero-till rainfed ecosystem were conducted during 2010-11 and 2011-12 at Indian Agricultural Research Institutive New Delhi for identifying the agronomic performance, weed dynamics, nutrient uptake and profitability of clusterbean based cropping systems (clusterbean-wheat, clusterbean-mustard and clusterbean-chickpea) as influenced by three residue management practices (no residue, crop residues and *Leucaena* twigs) applied to both summer and winter seasonal crops. Randomized Complete Block Design with four replications were used to conduct the trials. Significantly higher green-pod yield of clusterbean (10.08 t ha^{-1} and 6.70 t ha^{-1}) was recorded with the application of *Leucaena* twigs, followed by crop residue mulching and the least with no-residue application in 2010 and 2011, respectively. Wheat and chickpea as preceding crops produced significantly higher clusterbean green-pod yield (6.54 t ha^{-1} and 6.43 t ha^{-1}) than mustard (5.18 t ha^{-1}). The yield attributes *viz.* pod-clusters and weight of pods per plant showed significant variation. Significantly higher dry matter yield (299.9 g m^{-2}) of *Cyperus iria* was recorded with mustard residues followed by chickpea (253.1 g m^{-2}) and wheat (194.0 g m^{-2}) residues. The nutrient uptake showed the same trend as that of dry pod and stalks yields and resulted significant influence due to residue management and preceding crops. Economic analysis exhibited the highest returns and net returns per Rupee invested under wheat with *Leucaena* twigs followed by chickpea with *Leucaena* twigs. Clusterbean after wheat and chickpea with *Leucaena* twigs was high yielding and profitable for rainfed areas under zero-till semi-arid condition.

Key words: Clusterbean, Preceding winter-season crops, Residue management, Zero-till rainfed

INTRODUCTION

Clusterbean or guar [*Cyamopsis tetragonoloba* (L.) Taub.] is a drought-tolerant, drought-hardy and multipurpose legume mainly grown in arid and semi-arid regions of India, Pakistan and Africa (Chamola and Hasija, 1984). India produces about 40% of world guar seeds and is grown in almost 25.30 lakh ha area with the productivity of 3.37 t ha^{-1} (Anonymous, 2006). Growing legumes like clusterbean during rainy-season followed by cultivating long-duration, drought-hardy winter-season crops like wheat, chickpea and mustard as subsistence and cash crops on the preserved soil moisture is the popular cultivation practice under semi-arid dryland areas. Clusterbean has been identified as the most remunerative and useful crop preferably in wheat–based cropping system (Reddy *et al.,* 1981). Clusterbean-mustard system was found more remunerative (IRs 20,304/ ha) than clusterbean-wheat (IRs 18,662 ha^{-1}) at Hisar (Saxena *et al.,* 1997), however, clusterbean-wheat gave high net returns (IRs 27,089 ha^{-1}) with maximum water-use efficiency at Gwalior (Singh *et al.,* 1998). The average productivity of both of those rainy- and winter-season crops are only half as that of irrigated ecosystem (Faroda *et al.,* 2007), where conservation tillage practices (zero-tillage + mulching +

crop diversification) could be a useful practice for ensuring sustainable production in rainfed areas (Saxena, 2012).

Growing succulent legumes like *Leucaena* as alley cropping around the periphery of bunds is common practice in India (Dhyani *et al.,* 2009). Indeed, there are several evidences of remarkable crop yield increase in rainfed cropping systems through the maintenance of appropriate vegetative cover under no-till conditions. Application of *Leucaena leucocephala* mulch in standing crops helps in conservation and carryover of soil moisture for proper growth and development of crops (Sharma *et al.,* 2010, 2011). Application of conservation agriculture practices with residue retention has been found successful in maintaining sustainability in yield of various crops in Mexico and north-western India (Sayre *et al.,* 2005; Gupta *et al.,* 2010). *In-situ* use of residues of rainy-season crops to winter-season crops and winter-season crop residues to rainy-season crops could be used as low-cost input because of their easy access from the seasonal harvest. Therefore, adoption of resource-conserving technologies involving zero-tillage and vegetative residues management is the presently felt need as 'low-input agriculture' to improve productivity, resource-use efficiency and achieve sustainability of rainfed ecosystem. The present investigation was aimed to understand the various effects of residue management practices and preceding winter crops on the growth performance, weed dynamics, nutrient uptake and profitability of the clusterbean based systems under semi-arid zero-till rainfed conditions.

MATERIALS AND METHODS

Zero-till rainfed field experiments were conducted during 2010-11 and 2011-12 at New Indian Agriculture Research Institute (IARI), Pusa, New Delhi for evaluating the agronomic performance and economics of clusterbean as affected by three residue management practices viz. no-residue, crop residues and *Leucaena* twigs applied to both clusterbean and winter-seasonal crops viz. wheat, chickpea and mustard. Clusterbean during monsoon and preceding winter-season crops, both were grown under zero-tillage following other recommended practices under rainfed conditions. The experiment was laid out in Randomized Block Design with four replications. The daily meteorological data showed that there was high rainfall (954 mm) in 2010, while it was 30.61% less than that of 2010 in 2011 (662 mm) and 10.42% less than that of average of 10 years (739 mm). The soil of the experimental field was sandy-loam in texture, with 147.2 kg ha^{-1} alkaline $KMnO_4$ - oxidizable N, 17.0 kg ha^{-1} $NaHCO_3$ - extractable P, 225.1 kg ha^{-1} 1 N NH_4OAc- exchangeable K, 0.40% organic C with 7.5 pH of soil reaction. The moisture content at 1/3 and 15 atmospheric tensions was 18.8 and 6.5%, respectively, with bulk density 1.55 (Mg m^{-3}) of surface soil layer (0-15 cm).

'Pusa Navabahar' cv. of clusterbean was sown by happy-seeder under zero-till field, prepared after Laser Land Leveler (LLL) in 2009 with the inter and intra spacing of 40 cm and 5 cm maintaining ± 50 plants m^{-2} on 12 July, 2010, and 16 June, 2011. Crop was grown with 20:40:20 kg NPK ha^{-1}. Diammonium phosphate was applied in crop-rows with happy seeder, while Urea and Muriate of Potash were broadcasted just before sowing. Pendimethalin @ 0.50 kg a.i. ha^{-1} applied only in 2010. In 2011, crop was heavily infested with weeds especially *Cyperus iria* and, therefore hand weeding was done after counting and taking dry matter yield m^{-2} at maximum vegetative stage. The crop was affected with Streak Mosaic Virus in 2011 and hence, foliar spray of endosulphan was followed twice at 40 and 60 days. Green pods at marketable maturity were harvested by hand picking in two flushes during first- second weeks of October in 2010, and third week of September in 2011.

Growth parameters viz. plant height, LAI and dry matter, were taken from 30 DAS up to harvest. The weed number and dry biomass in clusterbean were taken from 0.25 m^2 at the maximum vegetative phase of the crop. The yield attributes like plant population m^{-2} at maturity was counted from the fixed 1 m row inserted with pegs from beginning of measuring growth parameters, while pod-clusters plant^{-1} and total pods plant^{-1} were counted from randomly selected five plants plot^{-1}. The green-pod and stalk yields, and harvest index were recorded from the net plot of 25 m^2 in 2010 and from 10 m^2 areas in 2011. The concentration of N, P and K in dry-pod and stalk was analyzed as per the standard method (Prasad *et al.,* 2006), and the uptake values were calculated on the basis of their dry matter yield at harvest. Economic analysis was done, and expressed as cost of cultivation, gross and net returns, and net returns/ Rs invested. The biometric data on ancillary and yield parameters were analyzed by standard statistical techniques and regression analysis for major yield attributes and green-pod yield was done (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth parameters

Growth parameters viz. plant height, LAI and dry matter accumulation of clusterbean as influenced by residue management and previous winter-season crops is presented in Table 1 and 2. All growth parameters increased with the advancement of their growth stages. The shortest plant height and the lowest LAI were resulted at 30 DAS, and were considerably more in 2011 than in 2010 due to hindered growth during initial stage. Excess rainfall just after planting of clusterbean resulting in water stagnation on soil surface upto 2 months in 2010. Higher dry matter yield was also achieved with advancement of crop age, which might be due to greater availability of brighter sunshine hours with comparatively less rainfall during post developmental stages of clusterbean during 2010.

Table 1. Effect of crop residues and *Leucaena* twigs on growth parameters of clusterbean in 2010

Treatment	Plant height (cm)			LAI		Dry matter (g m^{-2})	
	30 DAS	60 DAS	At maturity	30 DAS	60 DAS	30 DAS	60 DAS
No residue	18.9	67.5	112.1	0.45	1.97	165.8	397.0
Crop residues	15.5	66.3	113.0	0.54	2.17	183.6	469.8
Leucaena twigs	19.6	75.4	118.4	0.62	2.51	215.2	549.2
SEm±	0.90	2.04	3.65	0.045	0.086	4.77	14.6
CD (P=0.05)	3.11	7.06	NS	NS	0.298	16.5	50.5

The initial weather conditions during sowing and thereafter up to one month of growth in 2011 was quite favorable, which led to enhance the plant height, LAI and dry matter production. *Leucaena* twigs exerted the highest influence on growth parameters than crops residue in both years. The effect of preceding winter-season crops on growth parameters of clusterbean was significant on LAI and dry matter production in 2011. Crop residues and *Leucaena* twigs mulching resulted statistically at par result on dry matter yield at 60 DAS, but the other growth parameters like LAI at 60 DAS was significantly higher with *Leucaena* twigs and that might be due to its quick decomposition. Crop residue maintained more moisture to supply to the crop from their effective root-zone due to decreasing runoff, improving infiltration and checking evaporation loss and more absorbance of rainfall amounts (Narain and Singh, 1997).

Table 2 Effect of crop residues and *Leucaena* twigs on growth parameters of clusterbean after winter-season crops in 2011

Treatment	Plant height (cm)			LAI		Dry matter (g m^{-2})	
	30 DAS	60 DAS	At maturity	30 DAS	60 DAS	30 DAS	60 DAS
Preceding crops (A)							
Wheat (W)	24.0	77.3	110.6	0.48	2.91	164.0	402.8
Chickpea (CP)	25.1	76.0	108.7	0.40	2.19	176.9	366.6
Mustard (M)	25.6	76.1	106.8	0.58	2.25	199.9	436.9
SEm±	0.61	0.60	1.22	0.021	0.093	5.15	13.4
CD (P=0.05)	NS	NS	NS	0.061	0.262	15.0	39.1
Residues management (B)							
No residues (NR)	23.3	69.0	96.7	0.39	1.98	113.4	311.0
Crop residues (CR)	26.6	79.9	113.4	0.63	2.37	233.5	449.9
Leucaena twigs (LT)	24.8	80.5	115.9	0.44	3.00	193.9	445.4
SEm±	0.61	0.60	1.22	0.021	0.093	5.15	13.4
CD (P=0.05)	1.78	1.75	3.56	0.061	0.262	15.0	39.1
Interaction (A x B)							
W – NR	22.2	70.2	93.2	0.38	2.06	90.0	295.3
W – CR	26.2	79.7	117.6	0.64	3.09	228.6	447.6
W – LT	23.6	81.9	120.9	0.43	3.58	173.4	465.6
CP – NR	23.6	67.5	96.9	0.33	1.88	101.8	271.1
CP – CR	26.8	80.3	113.0	0.50	2.34	227.8	415.0
CP – LT	24.8	80.2	116.3	0.36	2.34	201.2	413.8
M – NR	24.1	69.4	100.1	0.45	1.53	148.4	366.6
M – CR	26.8	79.7	109.7	0.75	2.14	244.2	487.1
M – LT	26.0	79.3	110.7	0.53	3.08	207.2	456.9
SEm±	1.06	1.04	2.11	0.034	0.155	8.92	23.2
CD (P=0.05)	NS	NS	6.16	NS	0.454	NS	NS

Raising clusterbean after wheat followed by mustard and chickpea with crop residues and *Leucaena* twigs mulching recorded significantly higher plant height at maturity, and higher LAI at 60 DAS and that might be because of combined effect of mulching on improving moisture and nutrient availability and to enhance crop performance through direct nutritional contributions (Kumar *et al.,* 1992).

Weed population and dry weight

The number and dry weight of *Cyperus iria* and dry weight of other weed species rather than *Cyperus iria* in 2011 presented in Table 3 stated that preceding winter-season crops and residues management have significant influence in number and dry weight of *Cyperus iria* in clusterbean. Significantly higher number (1352 m^{-2}) and dry matter yield (212.1 g m^{-2}) of *Cyperus iria* was recorded after mustard followed by chickpea and wheat as preceding crops. The same trend was followed to dry weight of other weed species. Mustard and chickpea as previous crops left extra residues from their litter falls and made the soil more friable, fertile and suitable for holding moisture for the long and therefore recorded high infestation of weeds. Wheat on the other hand did not add fertility in surface soil by which, *Cyperus iria* population and their dry weight both were significantly less. In general, the mulching materials suppressed the weed species, but in this trial, the residues management has increased both the crop growth and fertility status in the soil.

Table 3 Effect of crop residue *and Leucaena* twigs on weed population and their dry matter yield at maximum vegetative stage of clusterbean after winter-season crops in 2011

Treatment	*Cyperus* (plants m^{-2})	Dry weight of *Cyperus* (g m^{-2})	Dry weight of other weed species (g m^{-2})
Preceding crops (A)			
Wheat (W)	1190	144.6	58.9
Chickpea (CP)	1244	158.9	66.4
Mustard (M)	1352	212.1	75.8
SEm±	31.8	5.62	1.98
CD (P=0.05)	92.7	16.4	5.79
Residues management (B)			
No residues (NR)	935	125.6	64.3
Crop residues (CR)	1740	249.0	65.7
Leucaena twigs (LT)	1110	141.1	71.1
SEm±	31.8	5.62	1.98
CD (P=0.05)	92.7	16.4	NS
Interaction (A x B)			
W – NR	812	102.3	57.0
W – CR	1694	194.0	59.0
W – LT	1063	137.4	60.7
CP – NR	950	112.5	67.3
CP – CR	1717	253.1	65.7
CP – LT	1066	111.2	66.3
M – NR	1044	162.0	68.7
M – CR	1809	299.9	72.3
M – LT	1202	174.5	86.3
SEm±	55.0	9.74	3.44
CD (P=0.05)	NS	28.4	NS

The interaction effect of preceding crops and residue management practices showed significant variation only on dry weight of *Cyperus iria* in clusterbean and recorded the maximum dry weight (299.9 g m^{-2}) after mustard with crop residues, followed by chickpea (253.1 g m^{-2}), and the lowest (194 g m^{-2}) under wheat with crop residues over the *Lecuaena* and no-residues mulching. There was 53.7% reduction in seed yield of clusterbean in Jodhpur, Rajasthan by keeping the crop weed-free for the initial 30 and 40 days also reduced the weed dry weight by 63.4 and 75%, respectively and concluded that clusterbean required an initial 40 days weed-free period for better seed yield and maximum net returns (Saxena *et al.,* 2004). But, the finding of our experiment was inverse of the earlier findings. Shifting of *Cyperus iria* was overlooked. Decline in crop yield has mostly been attributed to allelopathic effects and these problems have been observed both in monocultures, multiple-cropping systems and agro-forestry and found the yield reductions of crops up to 24% due to continuous cultivation of pearlmillet, compared with its rotation with clusterbean in an arid-region (Saxena *et al*., 1999).

Yield attributes and yield

Regression and correlation analysis of major yield attributes (x) of clusterbean with green-pod yield (y) as affected by residues management and preceding winter-season crops is presented Figure 1 and 2. Regression analysis between yields and major yield attributes of clusterbean showed highly significant positive correlation of green-pod yield with plant stands m^{-2} at maturity and weight of green pods $plant^{-1}$ in 2011. Number of pods $plant^{-1}$ in 2011 and plant population m^{-2}, at maturity, number of pods $plant^{-1}$ and weight of green pods $plant^{-1}$ in 2010 showed significant correlation with green-pods yield of clusterbean (Figure 1).

Green-pod, stover and biological yields of clusterbean as affected by residues management and preceding winter-season crops is presented in Figure 2. Both green-pod and biological yield showed significant variation due to residue management in 2010. Effect of preceding crop was found significant in deserving higher green-pod, stover and biological yields in 2011. Chickpea and wheat as preceding crops recorded significantly higher green-pod yield and the lowest after mustard, however, significantly higher stover and biological yield was recorded after mustard followed by chickpea and wheat. Under mustard plot, due to infestation of streak mosaic virus and heavy infestation of weeds, the translocation of resources did not fairly expressed in sink.

The effect of residues management practices on yield performance of clusterban was found significant and *Leucaena* twigs showed statistically at par results with crop residues on green-pod, stover and biological yields in 2011 as contrast to significantly higher influence over crop residues and no-residue mulching in 2010. Crop residues having high C:N ratio took more time to decompose, which in the first season did not add soil fertility, but it helped positively in absorbing more amounts of moisture either from rainfall or dew. Higher yield under *Leucaena* twigs over crop residues and no-residue in 2010 might be due to addition of N through *Leucaena* twigs. Rapid decomposition of *Leucaena* twigs increased quick release of nutrients, thereby increase in growth and yield attributes and resulted higher yield performance.

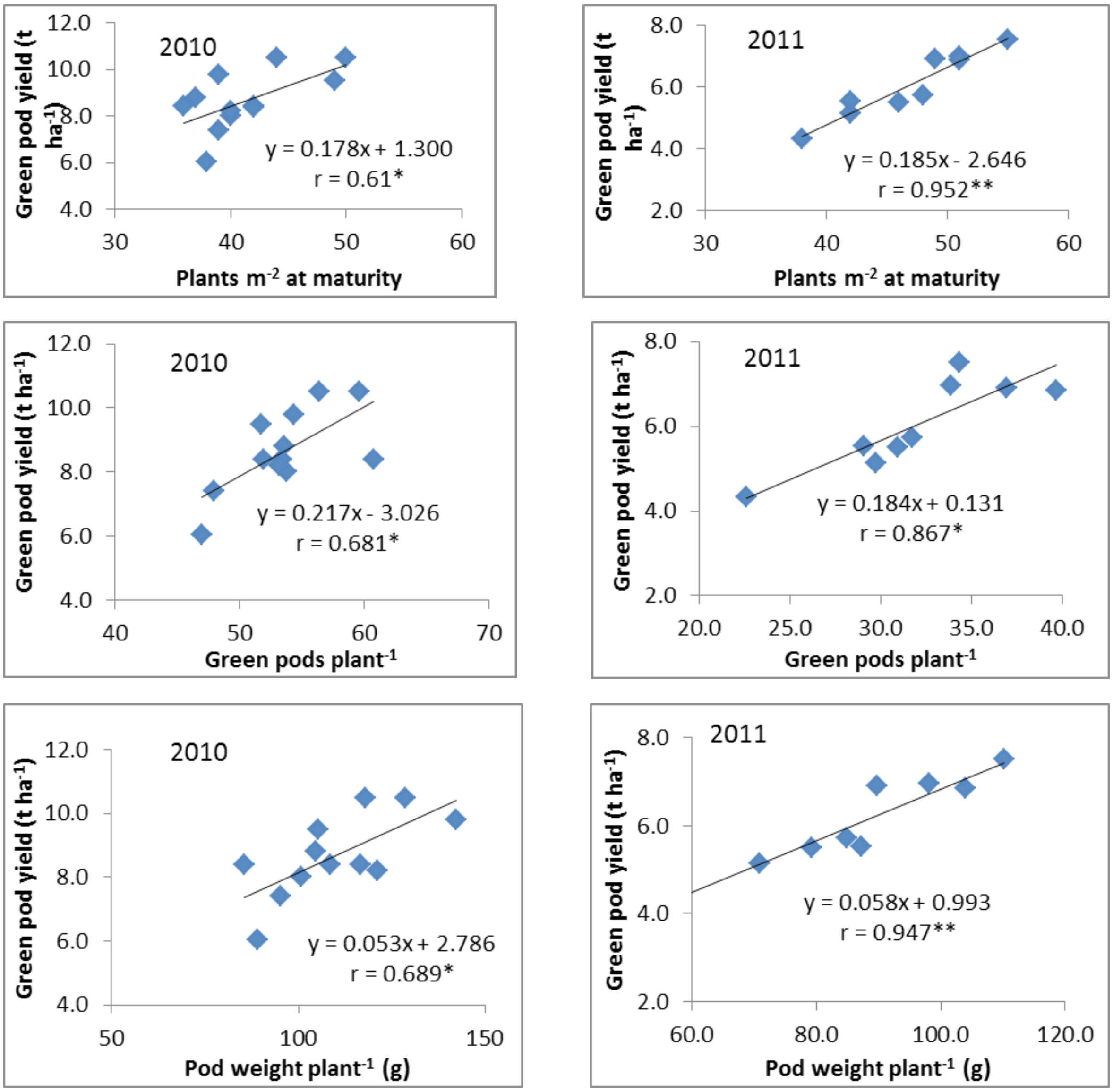

Figure 1: Regression and correlation of clusterbean green-pod yield (y) with yield attributes (x)

Interaction effect of preceding crops and residues management exerted significant variations only on stover and biological yields, and harvest index of clusterbean in 2011. This indicated that translocation of metabolites to sink was not enough in residues and previous legumes crops. Proportionate distribution of rainfall and better availability of sunshine hours at reproductive stages of clusterbean with weed and disease free conditions during the cropping season in general and more availability of nutrients under *Leucaena* twigs residues management treatment achieved higher yield performance in 2010. Rathore *et al.* (1996) reported that appropriate plating in clusterbean would be on II or III weeks of July for getting higher yield under semi-arid conditions of Rajsthan. Clusterbean-mustard system was found to be high yielding at Hisar (Saxena *et al.,* 1997) than other mustard based system.

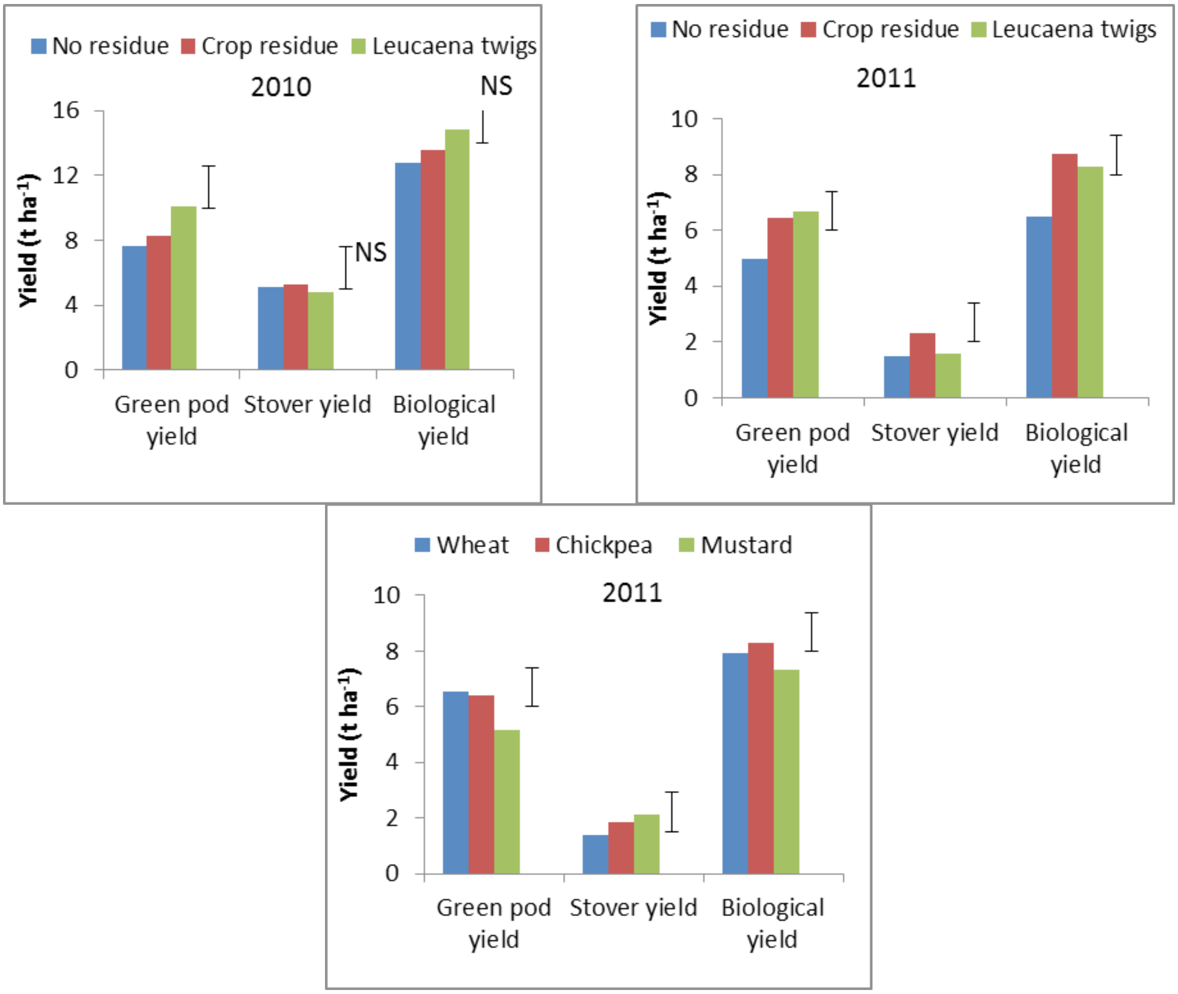

Figure 2: Yield performance of clusterbean as influenced by residue management and preceding winter-season crops

Nutrient uptake

The NPK uptake (kg ha^{-1}) taken by clusterbean is shown in Table 4 and 5. The same statistical pattern on dry weight of green-pod and stover yield was also found on total NPK-uptake in general. The effect of residues management on total uptake of NPK and P uptake by dry green-pod was found significant in 2010. However, it remained significant in total uptake and uptake in dry green-pod and stover in 2011. *Leucaena* twigs recorded significantly higher total NPK and P uptake in dry green-pod over crop residues and control in 2010, while it remained statistically at par with crop residues in 2011. Chickpea as preceding crop followed by mustard showed significant variation on N and P uptake in dry green-pod, stover yield and in total uptake, while K uptake was higher after mustard, but statistically at par with chickpea. Legumes as preceding crop recorded significantly higher yield, therefore recorded higher NPK uptake. Similarly, crop residues showed significant variation in NPK uptake over control in 2010, and almost same response was recorded with *Leucaena* residues in 2011. Higher total uptake of NPK might be due to higher dry matter production in crop residues and *Leucaena* twigs and the minimum with control.

Table 4: Effect of crop residues *and Leucaena* twigs on nutrient uptake (kg ha^{-1}) in clusterbean in 2010

Treatment	N			P			K		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
No residues	65.1	53.7	118.9	8.21	6.01	14.2	16.1	45.6	61.7
Crop residues	70.0	64.6	134.6	8.74	7.13	15.9	17.8	53.1	70.9
Leucaena twigs	87.1	67.2	154.3	11.28	7.26	18.5	20.6	56.2	76.8
SEm±	5.62	4.62	4.07	0.60	0.53	0.44	1.19	2.83	2.16
CD (P=0.05)	NS	NS	14.07	2.09	NS	1.53	NS	NS	7.48

Table 5: Effect of crop residues and *Leucaena* twigs on nutrient uptake (kg ha^{-1}) in clusterbean after winter-season crops in 2011

Treatment	N			P			K		
	Pod	Stover	Total	Pod	Stover	Total	Pod	Stover	Total
Preceding crops (A)									
Wheat (W)	60.2	39.4	99.6	7.19	4.27	11.5	14.2	36.2	50.5
Chickpea (CP)	59.3	57.8	117.1	7.06	6.01	13.1	14.1	52.0	66.1
Mustard (M)	48.5	59.9	108.4	5.40	6.51	11.9	11.4	55.1	66.5
SEm±	1.26	1.76	1.97	0.22	0.22	0.28	0.33	1.80	1.75
CD (P=0.05)	3.66	5.13	5.74	0.65	0.65	0.81	0.96	5.26	5.10
Residues management (B)									
No residues (NR)	46.4	41.4	87.9	5.62	4.48	10.1	11.1	38.1	49.2
Crop residues (CR)	59.7	56.4	116.1	6.82	6.00	12.8	14.0	51.3	65.3
Leucaena twigs (LT)	61.9	59.2	121.1	7.21	6.31	13.5	14.6	53.9	68.5
SEm±	1.26	1.76	1.97	0.22	0.22	0.28	0.33	1.80	1.75
CD (P=0.05)	3.66	5.13	5.74	0.65	0.65	0.81	0.96	5.26	5.10
Interaction (A x B)									
W – NR	47.5	32.5	79.9	5.75	3.58	9.3	11.3	29.9	41.2
W – CR	63.9	46.8	110.7	7.66	5.02	12.7	15.0	42.9	58.0
W – LT	69.3	38.9	108.2	8.16	4.22	12.4	16.3	35.9	52.2
CP – NR	51.4	37.0	88.3	6.51	3.85	10.4	12.3	33.7	46.0
CP – CR	63.5	56.6	120.1	7.09	5.86	12.9	15.0	50.3	65.2
CP – LT	62.9	79.8	142.7	7.59	8.32	15.9	15.0	71.9	86.9
M – NR	40.4	54.9	95.3	4.59	6.01	10.6	9.7	50.7	60.4
M – CR	51.6	65.8	117.4	5.73	7.13	12.9	12.0	60.6	72.6
M – LT	53.5	59.0	112.5	5.87	6.40	12.3	12.6	54.0	66.5
SEm±	2.17	3.04	3.41	0.39	0.39	0.48	0.57	3.12	3.02
CD (P=0.05)	NS	8.89	9.95	NS	1.13	1.41	NS	9.11	8.83

Interaction effect of preceding crop and residue management was significant only with NPK uptake in stover and total uptake of N and P. Higher NPK uptake in stover and N and P uptake in total after chickpea and mustard as preceding crops with *Leucaena* twigs and crop residues were noticed. Moreover, the magnitude of total nutrient uptake by clusterbean in 2011 was about 25% lesser than 2010 and that was due to its less yields. The increased uptake of NPK under residues application could be attributed to higher green-pod and stover yield because of availability of soil nutrients from residues and conserved moisture due to residues application. The overall improvement on growth of clusterbean due to residual effect of residues applied to previous legumes like chickpea and with *Leucaena* twigs could be ascribed to their pivotal role in several physiological and bio-chemical processes viz. root development, photosynthesis, energy transformation (ATP and ADP) and symbiotic biological N_2 fixation processes and in protein synthesis (Tisdale *et al*., 1995). Working in clusterbean- based cropping system, several workers reported higher uptake of NPK by clusterbean under the previous legumes or oil seed crops than the cereal crop both with and without residues application (Buttar *et al.,* 2009).

Economics

Economic performance of clusterbean as influenced by residue management and preceding crops suggested that cost of cultivation was relatively high in 2011 than 2010 and gross and net returns were comparatively same in both years (Table 6 and 7).

Table 6: Effect of crop residues and *Leucaena* twigs on economics of clusterbean in 2010

Treatment	Cost of cultivation (x10^3 IRs ha^{-1})	Gross returns (x10^3 IRs ha^{-1})	Net returns (x10^3 IRs ha^{-1})	Net returns/ IRs invested
No residue	9.81	40.23	30.42	3.10
Crop residues	12.76	43.57	30.82	2.42
Leucaena twigs	11.31	52.80	41.49	3.67

The increase in production cost in 2011 was due to increase in labour wages (33% more than that of 2010) and in input costs. Though the prices of output were high in 2011, it recorded comparatively equal net returns due to less yield of green-pod in 2011. Cop residue has some economic values, and their market prices were added to the production costs, but *Leucaena* twigs were freely available and only application costs were incurred on it. The economic analysis exhibited highest gross returns (52.80 x 10^3 IRs ha^{-1}), net returns (41.49 x 10^3 IRs ha^{-1}), and net returns/ IRs invested (3.67) under *Leucaena* twigs in 2010. Similarly, higher gross returns (61.79 x 10^3 IRs ha^{-1}) net returns (46.49 x 10^3 IRs ha^{-1}), and net returns/ IRs invested (3.04) under wheat with *Leucaena* twigs was overlooked in 2011. The highest net returns under clusterbean-mustard systems were reported by Saxena *et al.* (1998).

Table 7: Effect of crop residues and *Leucaena* twigs on economics of clusterbean after winter-season crops in 2011

Treatment	Cost of cultivation (x10^3 IRs ha^{-1})	Gross returns (x10^3 IRs ha^{-1})	Net returns (x10^3 IRs ha^{-1})	Net returns/ IRs invested
Wheat - no residue	13.30	42.49	29.19	2.19
Wheat - crop residues	16.90	57.74	40.84	2.42
Wheat - *Leucaena* twigs	15.30	61.79	46.49	3.04
Chickpea - no residue	13.30	45.84	32.54	2.45
Chickpea - crop residues	16.90	57.60	40.70	2.41
Chickpea - *Leucaena* twigs	15.30	58.25	42.95	2.81
Mustard - no residue	13.30	36.93	23.63	1.78
Mustard - crop residues	16.90	46.70	29.80	1.76
Mustard - *Leucaena* twigs	15.30	48.43	33.13	2.17

CONCLUSION

Growth and yield attributes, weed density and dry biomass, yield performance, NPK uptake and economics of clusterbean were influenced by residue management and the preceding winter-season crops. *Leucaena* twigs retention was found better during both years. Wheat and chickpea as preceding crops both with *Leucaena* twigs followed by crop residue exerted higher gross and net returns, and net returns/ IRs invested. Therefore, it was concluded that clusterbean after chickpea and wheat with *Leucaena* twigs mulching could be high yielding and economically feasible under semi-arid dry land condition.

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