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Preceding Rainy-Season Crops and Residue Management Practices on Root: Shoot Characteristics, Productivity and Profitability of Chickpea under Zero-Till Semi-Arid Ecosystem

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ABSTRACT

To identify suitable chickpea-based cropping system, field experiment was conducted for two years (2010-2011 and 2011-2012) with three preceding rainy-season crops: pearl millet, cluster bean and green gram along with three treatments viz. no residue, crop residue and Leucaena twigs mulching. The rainy season crops and chickpea were grown under rainfed condition with zero-tillage. Chickpea showed higher root length density (RLD), root surface area (RSA), root volume density (RVD) and average root diameter under crop residues, followed by Leucaena twigs. The pooled analysis of data showed significant yearly variations on seed yield of chickpea. Pearl millet as preceding crop resulted in significantly higher yield of chickpea (1.31 t ha^{-1} in 2010-2011 and 1.06 t ha^{-1} in 2011-2012), followed by green gram and cluster bean. Pearl millet with Leucaena twigs showed significantly higher chickpea yield (1.68 t ha^{-1}), highest gross returns (37.72 × 10^3 IRs ha^{-1}), net returns (25.52 × 10^3 IRs ha^{-1}) and net returns/IRS invested (2.09) in 2010-2011. However, higher chickpea yield (1.46 t ha^{-1}), the highest gross returns (44.02 × 10^3 IRs ha^{-1}), net returns (25.87 × 10^3 IRs ha^{-1}) and net returns/IRs invested (1.42) were received after pearl millet with crop residues in 2011-2012. The same trend was followed for nutrient uptake. Chickpea after pearl millet with crop residues or Leucaena twigs resulted high-yield and profitable cropping system under zero-till semi-arid condition.

Keywords: Chickpea, Preceding rainy-season crops, Productivity, Profitability, Root: Shoot characteristics, Semi-arid rainfed, Residue management, Zero-till

INTRODUCTION

Zero tillage is trending as a changing way to the sustainability of intensive production systems under both irrigated and rainfed conditions which leads to management of water and soil for agricultural activities without disturbing the soil. Zero till improves the soil health as well as facilitates the timely sown crops to utilize the residual soil moisture [1]. Zero tillage improves the quality of soil by returning crop organic residues and influencing favorable effects on physio-chemical properties of soil. Furthermore, zero tillage leads to decrease weed infestation owing to favorable soil environment which are responsible for better crop growth and higher yield.

Mulching increases soil porosity which has direct effect on soil aeration, enhance root growth and crop development [2,3]. Also, mulching has favorable effect on soil organic carbon, water retention, temperature and increases water stable aggregates on surface layer [4,5]. Application of mulch of *Leucaena leucocephala* and other legume species in standing crops helps in conservation of soil moisture for proper growth and development [6-8].

Inclusion of legumes under cropping system fixes nitrogen to soil through atmosphere and adds soil fertility [9]. Pearl millet, cluster bean and green gram are grown as short duration crops during rainy season followed by long

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duration and drought hardy winter crop such as chickpea on preserved soil moisture [10].

This study was conducted for understanding the effects of preceding rainy-season crops and residue management practices on growth, productivity, nutrient uptake and profitability of chickpea under zero-till semi-arid rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted to study the effect of residue management and preceding rainy-season crops on growth, productivity, nutrient uptake and profitability of chickpea-based cropping systems. The cropping systems involved combinations of three crops (pearl millet, cluster bean and green gram) in rainy season followed by chickpea under zero-till rainfed condition. The experiment was laid out in Randomized Block Design with four replications and three treatments of surface cover management, viz. control (no-residue), crop residues @ 5 t ha^{-1} and Leucaena twigs @ 10 t ha^{-1}.

Root samples were taken at flowering stage (60 DAS) in rainy and winter-season crops (80-90 DAS) with the help of root auger. Cleanliness and other procedures for root scanning were accomplished as per standard protocol [9]. The root parameters like root length density, surface area, root volume and diameter of different thickness of roots were recorded for all six crops. Scanning and image analysis using RHIZO system was operated in a computer mounted with the scanner of RHIZO system. Growth analysis like Leaf area index (LAI), net assimilation rate (NAR), relative growth rate (RGR) were calculated. Yield attributes viz. plant population at maturity, number of pods per plant, number of seeds per plot, test weight, stover yield and harvest index were recorded. Pooled analysis of seed yield was done for evaluation of year and treatment interaction effect. Economic analysis was done and expressed as cost of cultivation, gross and net returns and B:C ratio. The biometric data on ancillary and yield parameters were analyzed by standard statistical techniques and regression and correlation analysis for major yield attributes and seed yield was done [11].

RESULTS AND DISCUSSION

Root: Shoot growth and soil moisture

Root morphological parameters, viz. root length density (RLD), surface area density (RSD), root volume density (RVD) and average diameter of roots (AD) taken at flowering stages of chickpea during 2010-2011 and 2011-2012 are presented in **Table 1**. The residue management practices influenced root parameters of chickpea. The higher root morphological parameters of chickpea were recorded with crop residue, followed by Leucaena twigs and the least with no-residue. Chickpea showed higher root morphological parameters in 2010-2011 due to their vigorous growth in congenial environment under uniform application of residues.

Table 1. Effect of residue management and preceding rainy-season crops on root parameters of chickpea at flowering stages.

Treatment	2010-2011				2011-2012			
	PM	**CB**	**GG**	**Mean**	**PM**	**CB**	**GG**	**Mean**
	Root length density (cm cm^{-3})				**Root length density (cm cm^{-3})**			
No residue	0.465	0.448	0.318	0.411 ± 0.080	0.171	0.182	0.129	0.161 ± 0.028
Crop residue	0.820	0.531	0.659	0.670 ± 0.145	0.439	0.235	0.334	0.336 ± 0.012
Leucaena twigs	0.536	0.614	0.542	0.564 ± 0.043	0.355	0.370	0.178	0.301 ± 0.017
Mean	0.607	0.531	0.506		0.322	0.262	0.214	
	Surface area density (cm^2 cm^{-3})				**Surface area density (cm^2 cm^{-3})**			
No residue	0.147	0.186	0.251	0.194 ± 0.053	0.134	0.119	0.094	0.116 ± 0.020
Crop residue	0.577	0.331	0.594	0.501 ± 0.147	0.157	0.143	0.145	0.148 ± 0.007
Leucaena twigs	0.311	0.397	0.453	0.387 ± 0.071	0.169	0.155	0.119	0.148 ± 0.026
Mean	0.345	0.305	0.432		0.153	0.139	0.120	
	Root volume density (cm^3 cm^{-3})				**Root volume density (cm^3 cm^{-3})**			
No residue	0.005	0.006	0.008	0.007 ± 0.002	0.006	0.004	0.004	0.005 ± 0.001
Crop residue	0.032	0.019	0.027	0.026 ± 0.007	0.006	0.010	0.006	0.007 ± 0.002

Leucaena twigs	0.013	0.027	0.021	0.021 ± 0.007	0.008	0.006	0.009	0.008 ± 0.001
Mean	0.017	0.017	0.019		0.007	0.007	0.006	
	Average diameter of root (mm)				**Average diameter of root (mm)**			
No residue	1.97	2.41	3.07	2.48 ± 0.55	1.68	1.13	1.67	1.49 ± 0.31
Crop residue	4.33	5.85	4.46	4.88 ± 0.84	2.08	2.49	1.69	2.09 ± 0.40
Leucaena twigs	3.23	2.38	3.19	2.93 ± 0.48	2.27	1.67	2.93	2.29 ± 0.63
Mean	3.18	3.55	3.57		2.01	1.76	2.10	

Root is a vital component of plant system. To ensure normal plant growth and proper root development, the soil must have enough air, water and nutrients [12]. Root penetration to a greater depth is necessary for anchorage and uptake of water and nutrients from soil. It is the finer roots with larger length density (RLD) and surface area, which contribute to more water and nutrient uptake from surface as well as sub-surface than the thicker roots, which remained confined to upper surface layers especially under zero-tillage [13].

Tables 2 and 3 showed that crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were higher in chickpea after pearl millet and green gram as preceding crops under crop residues mulching, followed by Leucaena twigs and no-residue from 0-30 DAS and 30-60 DAS in 2010-2011 and from 60-90 DAS and 90-120 DAS in 2011-2012.

Table 2. Effect of crop residues and Leucaena twigs on crop growth indices of chickpea after rainy-season crops in 2010-2011.

Treatment	CGR (g day^{-1} m^{-2})				RGR (g g^{-1} day^{-1})			NAR (mg day^{-1} m^{-2})	
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	30-60 DAS	60-90 DAS	90-120 DAS	30-60 DAS	60-90 DAS
PM-NR	4.29	2.86	1.63	1.20	0.064	0.056	0.052	1.040	0.705
PM-CR	5.77	2.39	1.96	1.38	0.069	0.063	0.064	0.876	0.595
PM-LT	4.86	3.88	2.52	2.81	0.062	0.059	0.054	1.073	0.645
CB-NR	2.95	2.13	2.67	0.98	0.060	0.063	0.049	0.792	0.551
CB-CR	4.25	3.56	2.00	2.68	0.063	0.063	0.059	1.050	0.456
CB-LT	4.05	2.53	2.62	2.01	0.068	0.059	0.063	1.020	0.479
GG-NR	2.73	3.14	2.37	1.17	0.066	0.062	0.051	1.042	0.700
GG-CR	3.28	5.41	3.11	1.21	0.075	0.066	0.060	0.651	0.900
GG-LT	3.46	5.98	3.14	2.17	0.074	0.066	0.052	0.751	1.249

Table 3. Effect of crop residues and Leucaena twigs on crop growth indices of chickpea after rainy-season crops in 2011-2012.

Treatment	CGR (g day^{-1} m^{-2})				RGR (g $g^{-1}day^{-1}$)			NAR (mg day^{-1} m^{-2})	
	0-30 DAS	30-60 DAS	60-90 DAS	90-120 DAS	30-60 DAS	60-90 DAS	90-120 DAS	30-60 DAS	60-90 DAS
PM-NR	1.73	0.99	0.80	6.16	0.049	0.046	0.076	1.180	0.619
PM-CR	2.87	0.72	0.20	9.58	0.057	0.030	0.077	1.484	1.402
PM-LT	1.73	1.71	0.27	6.67	0.044	0.026	0.082	1.182	0.333
CB-NR	0.86	1.09	2.12	2.30	0.050	0.060	0.061	2.035	0.129
CB-CR	1.51	1.02	5.34	4.26	0.046	0.063	0.073	2.017	0.102
CB-LT	1.27	0.81	2.58	5.20	0.050	0.073	0.070	1.847	0.089
GG-NR	1.33	0.35	2.84	3.35	0.034	0.064	0.067	1.164	0.166
GG-CR	1.77	0.15	5.53	4.42	0.030	0.071	0.070	0.979	0.098
GG-LT	1.56	0.26	4.38	4.27	0.022	0.074	0.071	0.905	0.089

Chickpea grown under rainfed did not follow definite growth pattern. The CGR was governed according to the pattern of profile soil moisture as given in **Figure 1**. The growth rate increases only after the availability of soil moisture through rainfall. Application of crop residues in chickpea after pearl millet and green gram and Leucaena twigs after cluster bean provided comparatively higher CGR, RGR and NAR than with and without residues. There was comparatively higher CGR during the period from 0-30 DAS in 2010-2011. The significant effect of retention of residues in moisture conservation was responsible for optimizing crop growth. Retaining crop residues and Leucaena twigs and following cluster bean and green gram as preceding crops increased crop growth indices in both years and that was due to favorable soil environment created by legume crops.

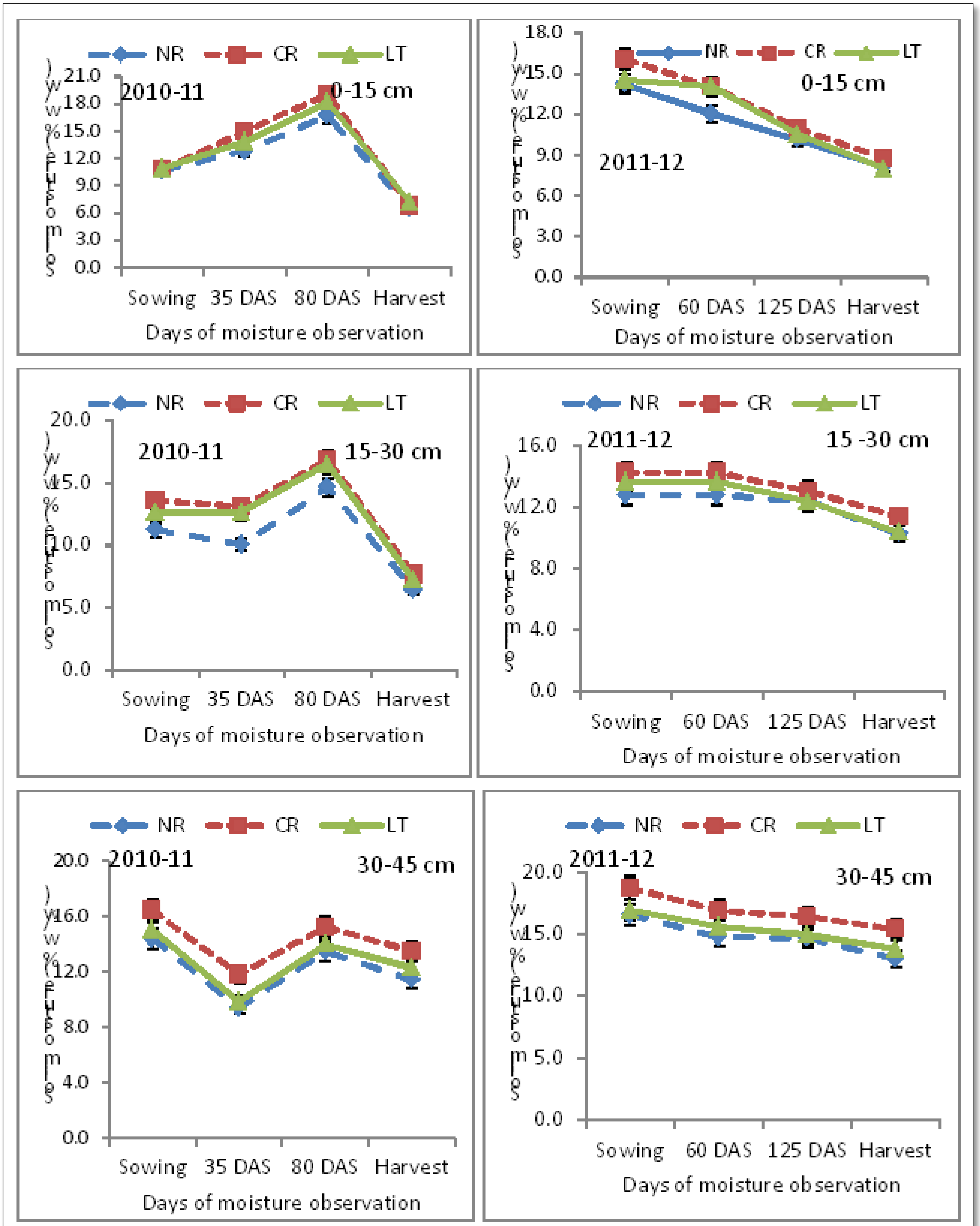

Figure 1. Influence of residue retention practices on profile soil moisture (w/w %) in chickpea field.

Higher CGR and RGR with crop residues under legume-based systems was reported [6,14]. Legumes can absorb more water from their deep root system, as a result, showed better performance even under rainfed condition [9]. More availability of soil moisture after legumes and crop residues mulching might be due to greater shoot and root biomass production owing to deep-rooted system and addition of more organic matter through leaf fall of legumes and helped to conserve more soil moisture, resulting in higher growth parameters. Residue retention ensured more water availability to the crop from the effective root-zone due to improving infiltration, less runoff and checking evaporation loss [15].

Yield performance

Preceding rainy-season crops and residue management showed significant influence on the seed, Stover and biological yield of chickpea **(Figure 2)**. Leucaena twigs after pearl millet recorded significantly higher seed yield (1.68 t ha^{-1}) than other treatments in 2010-11. The seed yield was significantly higher (1.46 t ha^{-1}) with crop residues after pearl millet in 2011-2012.

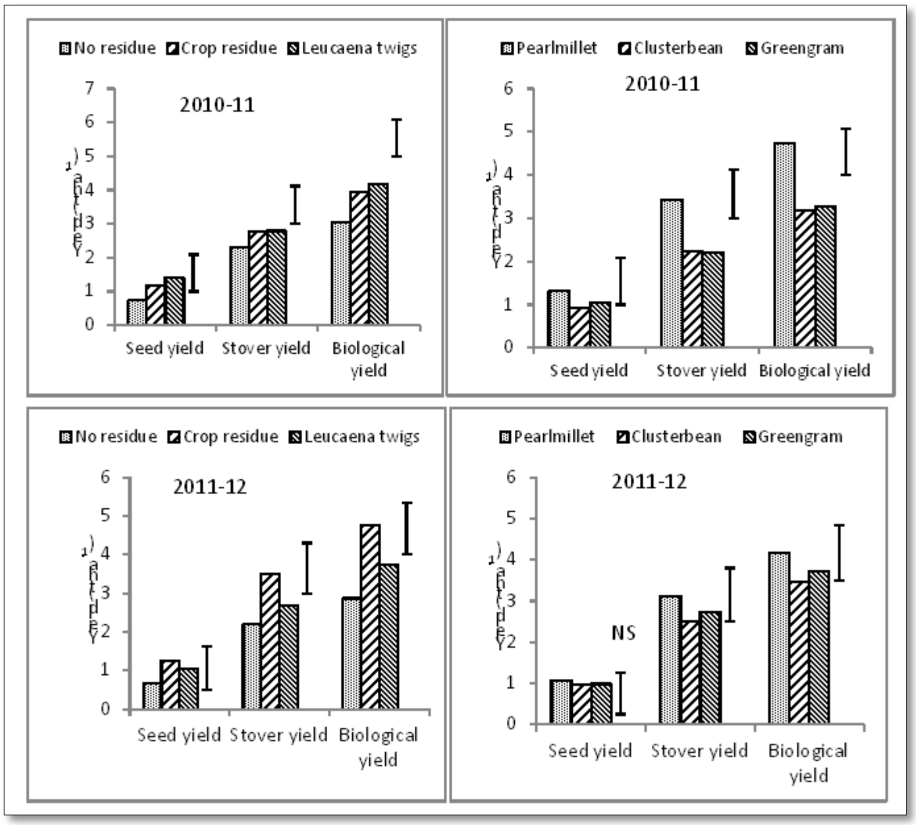

Figure 2. Yield performance of chickpea as influenced by residue management and preceding rain season crops.

Pearl millet extracted more surface soil moisture, wherein, the sub-surface soil moisture was utilized better by deep rooted and hardy chickpea crop, leading to better productivity under pearl millet-chickpea system. Crop residues having high C:N ratio took more time to decompose, which in the first season did not add to soil fertility, but helped positively in absorbing moisture obtained either from rainfall or dew, resulting higher yield in second year. Addition of nitrogen through Leucaena twigs might result higher yields under Leucaena twigs over no-residue. Rapid decomposition of Leucaena twigs helped in quick release of nutrients, which increased growth and yield attributes, resulting in higher yield performance. Residue application improved the soil moisture, physico-chemical and biological environment of the soil through the addition of nutrients and enhanced microbial activity aiding the cropping system to be more productive [16]. Pearl millet-chickpea system was also found to be high yielding in Rajasthan [17].

Pooled analysis on data on economic yield of chickpea **(Table 4)** as affected by years, preceding crops and residue management showed a significant influence. The chickpea yield in first year was 9% higher than second year. The evenly distributed rainfall throughout the winter season during the first year (2010-2011) was beneficial to chickpea because of coincidence of rain with their flowering and fruiting period. The uniform distribution of 20 mm rainfall during 2012 was beneficial for pod filling. Conservation of soil moisture and increased fertility status after decomposition helped to increase the yield under crop residues in later years over Leucaena twigs and no-residue.

Table 4. Pooled analysis on seed yield of chickpea (t ha^{-1}) as affected by year, preceding crops and residue management.

Treatment	2010-2011				2011-2012				Overall mean
	NR	CR	LR	Mean	NR	CR	LR	Mean	
Pearl millet	0.89	1.38	1.68	1.31	0.71	1.47	1.00	1.06	1.12
Cluster bean	0.59	1.00	1.21	0.93	0.64	0.99	1.24	0.96	0.89
Green gram	0.70	1.13	1.31	1.05	0.69	1.34	0.94	0.99	0.90
Mean	0.73	1.17	1.40		0.68	1.27	1.06		
	Year (A)	Preceding Crop (B)		Residues (C)		A × B	A × C	B × C	A × B × C
SEM ±	0.019	0.024		0.024		0.033	0.033	0.043	0.059
CD (P=0.05)	0.057	0.069		0.069		0.098	0.098	0.121	0.171

Regression analysis between yield and yield attributes of chickpea **(Figure 3)** showed highly significant positive correlation with plants m^{-2} in 2011-2012. Significant positive correlation with plants m^{-2} in 2010-2011 and number of pods $plant^{-1}$ was observed in both years.

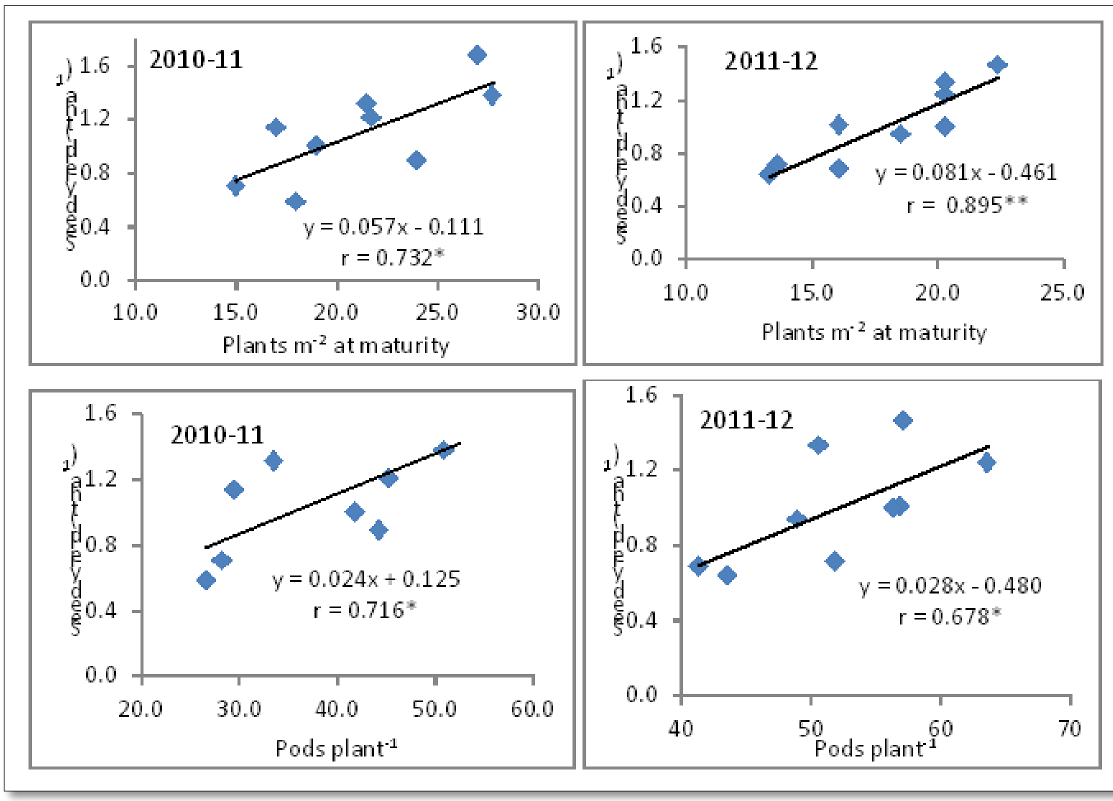

Figure 3. Regression and correlation of chickpea yield (y) with major yield attributes (x).

Nutrient uptake

Tables 5 and 6 shows the nutrient uptake by chickpea for 2010-2011 and 2011-2012.

Table 5. Effect of crop residues and Leucaena twigs on nutrient uptake (kg ha^{-1}) in chickpea after rainy-season crops in 2010-2011.

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
Preceding crops (A)									
Pearl millet (PM)	41.1	30.4	71.4	3.26	3.61	6.87	6.34	45.0	51.4
Cluster bean (CB)	30.0	21.1	51.1	2.47	2.43	4.90	4.71	28.6	33.3
Green gram (GG)	33.8	21.4	55.1	2.69	2.39	5.08	5.18	28.6	33.8
CD (P=0.05)	2.65	2.45	3.13	0.26	0.30	0.36	0.52	3.17	3.04
Residues management (B)									
No residue (NR)	23.1	21.3	44.4	1.92	2.51	4.43	3.67	30.1	33.7
Crop residues (CR)	37.1	25.3	62.4	2.96	2.91	5.87	5.69	36.0	41.7
Leucaena twigs (LT)	44.6	26.2	70.8	3.54	3.01	6.55	6.87	36.2	43.0
CD (P=0.05)	2.65	2.45	3.13	0.26	0.30	0.36	0.52	3.17	3.04
Interaction (A × B)									
PM-NR	27.8	28.9	56.6	2.31	3.49	5.79	4.49	42.3	46.8
PM-CR	42.7	31.8	74.5	3.35	3.69	7.04	6.56	48.0	54.6
PM-LT	52.7	30.4	83.1	4.13	3.66	7.79	7.95	44.7	52.7
CB-NR	19.0	16.1	35.0	1.59	1.86	3.45	3.05	22.2	25.3
CB-CR	32.0	21.1	53.1	2.62	2.46	5.07	5.05	28.6	33.7
CB-LT	38.9	26.2	65.1	3.19	2.97	6.16	6.02	34.8	40.9
GG-NR	22.6	18.9	41.5	1.86	2.17	4.03	3.45	25.6	29.1
GG-CR	36.5	23.1	59.7	2.90	2.60	5.50	5.45	31.2	36.7
GG-LT	42.2	22.1	64.3	3.31	2.40	5.71	6.63	28.9	35.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	5.48	3.04

Table 6. Effect of crop residues and Leucaena twigs on nutrient uptake (kg ha^{-1}) of chickpea after rainy-season crops in 2011-2012.

Treatment	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
Preceding crops (A)									
Pearl millet (PM)	33.5	28.3	61.8	2.70	3.44	6.14	5.39	41.9	47.2
Cluster bean (CB)	31.0	24.3	55.4	2.56	2.80	5.36	5.10	32.7	37.8
Green gram (GG)	32.0	26.5	58.5	2.57	3.11	5.68	5.07	36.0	41.0
CD (P=0.05)	NS	3.15	5.07	NS	0.44	NS	NS	4.22	4.44
Residues management (B)									
No residue (NR)	21.9	21.0	42.9	1.81	2.47	4.28	3.59	29.0	32.6
Crop residues (CR)	40.5	33.0	73.4	3.27	3.89	7.15	6.46	46.2	52.7
Leucaena twigs (LT)	34.1	25.2	59.3	2.75	3.00	5.75	5.50	35.4	40.9
CD (P=0.05)	3.63	3.15	5.07	0.35	0.44	0.62	0.71	4.22	4.44
Interaction (A × B)									
PM-NR	22.6	22.0	44.56	1.87	2.68	4.54	3.79	31.9	35.74
PM-CR	46.0	40.3	86.27	3.69	4.89	8.57	7.33	60.1	67.44
PM-LT	31.8	22.7	54.54	2.55	2.75	5.29	5.03	33.5	38.56
CB-NR	20.8	21.0	41.81	1.73	2.35	4.08	3.46	27.7	31.19
CB-CR	32.3	24.8	57.12	2.65	2.85	5.50	5.32	33.3	38.59
CB-LT	39.9	27.3	67.27	3.29	3.17	6.46	6.53	37.0	43.55
GG-NR	22.4	20.2	42.53	1.82	2.37	4.19	3.52	27.3	30.85
GG-CR	43.2	33.8	77.00	3.47	3.86	7.33	6.73	44.9	51.60
GG-LT	30.4	25.5	55.97	2.42	3.04	5.46	4.95	35.5	40.50
CD (P=0.05)	6.29	5.45	8.78	0.60	0.76	1.08	1.23	7.31	7.70

Significant result was found on interaction effect of preceding crop and residue management on nutrient uptake, and followed the same trend as that on seed and Stover yield. The higher uptake of N, P and K in seed and Stover after pearl millet as preceding crop was noticed in both years. Similarly, crop residues retention also showed significant variation in nutrient uptake in both years with maximum uptake under crop residues in 2011-2012. The result for NPK uptake under crop residues and Leucaena twigs in 2010-2011 was statistically at par.

The increased uptake of NPK under residue retention could be attributed due to greater availability of conserved soil moisture to the plants. Significantly higher seed and Stover yield with crop residues and Lecuaena twigs was due to higher nutrient uptake. Their crop growth was poor under no-residue; and, therefore NPK uptake was also less. Pearl millet as preceding crop gave higher dry mater yield and nutrient uptake of chickpea [9,18].

Economics

The economics of chickpea resulted in the higher returns with pearl millet and Leucaena twigs in first year and with crop residues in second year **(Table 7)**.

Table 7. Effect of crop residues and Leucaena twigs on economics of chickpea after different rainy-season crops.

Treatment	Cost of cultivation ($\times 10^3$ IRs ha^{-1})		Gross returns ($\times 10^3$ IRs ha^{-1})		Net returns ($\times 10^3$ IRs ha^{-1})		Net returns/IRs invested	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
Pearl millet - No residue	10.71	15.05	20.75	21.76	10.04	6.71	0.94	0.45
Pearl millet - Crop residue	13.16	18.15	31.38	44.02	18.23	25.87	1.39	1.42
Pearl millet - Leucaena twigs	12.21	17.05	37.72	30.22	25.52	13.17	2.09	0.77
Cluster bean - No residue	10.71	15.05	13.45	19.64	2.74	4.58	0.26	0.30
Cluster bean - Crop residue	13.16	18.15	22.63	29.71	9.47	11.56	0.72	0.64
Cluster bean - Leucaena twigs	12.21	17.05	27.32	36.87	15.12	19.82	1.24	1.16
Green gram - No residue	10.71	15.05	16.05	20.74	5.34	5.69	0.50	0.38
Green gram - Crop residue	13.16	18.15	25.55	39.74	12.39	21.59	0.94	1.19
Green gram - Leucaena twigs	12.21	17.05	29.33	28.38	17.13	11.33	1.40	0.66

The cost of cultivation was relatively higher in 2011-2012 than 2010-2011, while the gross and net returns showed almost consistent trend in both years. The increase in production cost in 2011-2012 was due to increase in labor wages (33% more compared with 2010-2011) and other input costs. Crop residues themselves have economic value and addition of their market price in the production costs increased the total cost of cultivation in second year. Leucaena twigs which were freely available around the farm periphery and only application costs were incurred.

The price of chickpea was increased by 32% in 2011-2012 which recorded comparatively higher net returns. The economic analysis exhibited the highest gross returns (37.72 $\times 10^3$ IRs ha^{-1}), net returns (25.52 $\times 10^3$ IRs ha^{-1}) and net returns/IRs invested (2.09) under pearl millet with Leucaena twigs treatment in 2010-2011. Similarly, the highest gross returns (44.02 $\times 10^3$ IRs ha^{-1}), net returns (25.87 $\times 10^3$ IRs ha^{-1}) and net returns/IRs invested (1.42) were recorded under pearl millet with crop residues in 2011-2012. Our findings are in conformity with those of other workers in pearl millet-based systems [19].

CONCLUSION

Pearl millet as preceding crops resulted in better growth, yields and nutrient uptake in chickpea over cluster bean and green gram. Both Leucaena twigs and crop residue after pearl millet led to higher returns and net returns/IRs invested in chickpea. Therefore, it was recommended to grow chickpea after pearl millet with crop residues or Leucaena twigs for higher productivity and profitability under zero-till semi-arid condition.

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REFERENCES

1. Duiker SW, Lal R (1999) Crop residues and tillage effects on carbon sequestration in a Luvisol in Central Ohio. Soil Tillage Res 52: 73-81.
2. Sharma AR, Singh R, Dhyani SK, Dube RK (2010) Moisture conservation and nitrogen recycle through legume mulching in rainfed maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system. Nutrient Cycling in Agro-ecosystems 87: 187-197.
3. Masood A (2002) Role of pulses in soil health and sustainable crop production. Indian J Pulse Res 15: 107-117.
4. Sharma PK, Acharya CL (2000) Carry-over of residual soil moisture with mulching and conservation tillage practices for sowing of rainfed wheat (*Triticum aestivum*) in north-west India. Soil Tillage Res 57: 43-52.
5. Sharma AR, Behera UK (2009) Nitrogen contribution through Sesbania green manure and dual-purpose legumes in maize-wheat cropping system: Agronomic and economic considerations. Plant Soil 325: 289-304.
6. Gomez KA, Gomez AA (1984) Statistical procedures for agricultural research. John Wiley and Sons, NY.
7. Box JE, Bruce RR, Agassi M (1996) The effect of surface cover on infiltration and soil erosion. In “Soil Erosion Conservation and Rehabilitation” (Agassi M, ed.). Dekker: New York, pp: 107-123.
8. Rathore AL, Pal AR, Sahu KK (1998) Tillage and mulching effects on water use, root growth and yield of rainfed mustard and chickpea grown after lowland rice. J Sci Food Agric 78: 149-161.
9. Aggarwal P, Choudhary KK, Singh AK, Chakraborty D (2006) Variation in soil strength and rooting characteristics of wheat in relation to soil management. Geoderma 136: 353-363.
10. Singh R (2008) Effect of preceding crops and nutrient management on productivity of wheat (*Triticum aestivum*) based cropping system in arid region. Indian J Agronomy 53: 267-272.
11. Singh G, Marwaha TS, Kumar D (2009) Effect of resource-conservation techniques on soil-microbiological parameters under long-term maize (*Zea mays*)–wheat (*Triticum aestivum*) crop rotation. Indian J Agric Sci 79: 94-100.
12. Husnjak S, Filipovic D, Kosutic S (2002) Influence of different tillage systems on soil physical properties and crop yield. Rostlinna Vyroba 48: 249-254.
13. Meena SL (2009) Productivity of cluster bean (*Cyamopsis tetragonoloba*) and sesame (*Sesamum indicum*) intercropping system under different row ratio and nutrient management in arid region. Indian J Agric Sci 79: 901-905.
14. Gill MS, Ahlawat IPS (2006) Crop diversification - Its role towards sustainability and profitability. Indian J Fert 2: 125-138.
15. Sugiyanto Y (1986) Soil physical properties affecting the roots distribution of mature rubber on Rod-Yello Podosolic soil, North Sumaatra (Indonesia). Bulletin Perkaretan (Indonesia) 4: 82-88.
16. Vaidya VB (1995) Estimation of thermal efficiency and apparent reflectivity of mulches using soil temperature. Journal of Maharashtra Agricultural Universities 20: 341-344.
17. Oliviera MT, Merwin K (2001) Soil physical conditions in a New York orchard after eight years under different ground cover management systems Plant Soil 234: 233-237.
18. Singh BP (2003) Productivity, stability and economics of various cropping systems in semi-arid ecosystem. Crop Res (Hisar) 25: 472-477.
19. Narain P, Singh RK (1999) Erosion control and productivity through sun hemp mulching and green manuring. In: Annual Report. Central Soil and Water Conservation Research and Training Institute, Deharadun, pp: 40-41.