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RESEARCH ARTICLE

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Nitrogen Gradient Optimization with *Kharif* Legumes on Agronomic Parameters in Zero-till *Rabi* Maize

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ABSTRACT

Background: With the SDG goals of using the generated output of one season on other season for managing the resource potential so to unlock the crop productivity is being the best alternative that need to be looked out in present climate change scenario. So, the present trial is focuses on the lines of residue management of legumes on maize sequence with nitrogen as the driving gradient in 2021-22 and 2022-23.

Methods: The experiment is laid out in split-plot design with 18 treatments consisted of C_1N_1: groundnut$_{100\%\ RDN}$-maize, C_1N_2: groundnut$_{75\%\ RDN}$-maize, C_2N_1: soybean$_{100\%\ RDN}$-maize, C_2N_2: soybean$_{75\%\ RDN}$-maize, C_3N_1: greengram$_{100\%\ RDN}$-maize, C_3N_2: greengram$_{75\%\ RDN}$-maize as main-plots and 3 subplots *viz.*100% RDN, 125% RDN, 150% RDN (*kharif* and *rabi* respectively) during two years of study.

Result: Among the different cropping systems, the preceding *kharif* greengram with 100% RDN on *rabi* zero-till maize showed higher growth parameters *i.e.* plant height, leaf area, leaf chlorophyll content (SPAD reading), dry matter at 30,60,90 DAS and at harvest and yields in both years. However, with respect to nitrogen levels, application of 150% RDN to *rabi* maize showed significantly higher growth and yields followed by 125% RDN and lowest was seen in 100% RDN in *rabi* respectively. On the other hand, the interaction effect was found significant at only 60 DAS in both years.

Key words: Legume-maize sequence, Nitrogen gradient level, RDN, SPAD, Yields.

INTRODUCTION

With the advancement in developing countries, use of cereal-cereal system had reached the threshold levels of production further leading to deteriorating the soil fertility. With the population growth in an exponential way adopting the age-old practises leading to downfall of the production potential (Ammaji *et al.,* 2022). So, in context to maize cropping system demands substantial nitrogen fertilizer inputs, posing challenges for resource-constrained farmers due to high costs and limited accessibility (Sravanthi *et al.,* 2016). The energy-intensive production of nitrogen fertilizers further raises concerns about the sustainability of such farming practices (Yadav *et al*., 2017).

Maize possesses broad adaptability and thrives across varied soil and climatic conditions, making it a prime choice for cultivation alongside different crops within various agricultural settings (Bharathi *et al.,* 2015). Its C_4 nature, coupled with rising demand in livestock and processing industries, further solidifies its status as a viable substitute. Maize [*Zea mays (L.)* Merrill] stands as a versatile crop, holding the third position in terms of importance in India, following rice and wheat. Its cultivation spans over 14.34 lakh hectares, yielding a production of 224.82 lakh tonnes with an average productivity of 2965 kg ha^{-1}. This contributes significantly, constituting 8% of the national food basket (Directorate of Economics and Statistics, Government of India, 2023). In the Telangana State alone, during the 2023-2024 period, maize cultivation covered an area of 4.10 lakh hectares, resulting in a production of 9.95 lakh tonnes, with an impressive productivity rate of 5730 kg ha^{-1}.

Crop rotations, a key aspect of diversified sustainable agriculture, often incorporate legumes for their nitrogen-fixing capacity (Meena *et al*. 2011). These rotations *i.e.* Legume-based cropping systems (LCS) are considered

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instrumental to sustainable intensification in small-holder systems with multiple ecological, social and economic benefits (Monika *et al.,* 2022). Legume crops can fulfil 80%-90% of their N requirements during one crop season from this biological nitrogen fixation and transfer 0%-70% of this biologically fixed N to the succeeding crops (Sikka *et al.,* 2022 and Parihar *et al.,* 2016).

Leftover legume residues in cereal systems provided added benefits to nutrient status and improved plant and soil architecture. The combination of added residues and zero-tillage balanced input credit loads with output productivities, fostering soil microbial fauna (Shukla *et al.,* 2021 and Hailemarian *et al.,* 2021). So, with this knowledge of thought and added source of information we further highlighted our research line with the suitable legume- maize cropping system with added nitrogen gradient levels and residual retention in irrigated conditions.

MATERIALS AND METHODS

The present experiment was carried out at Maize Research Centre, Agricultural Research Institute, P.J.T.S.A.U, Rajendranagar, Hyderabad during *kharif* and *rabi* seasons of two years *i.e.* 2021-22 and 2022-23. The farm is geographically situated at an altitude of 542.3 m above mean sea level at 17°19′ N latitude and 78°23′ E longitude in the Southern Telangana Agro-Climatic Zone of Telangana State and it falls under Semi-Arid Tropics (SAT) according to Troll's classification. Ideal weather conditions prevailed during the crop season for the legume-maize sequence, with temperatures at a normal range (12.60 to 33.20°C), consistent rainfall of 878.54 mm and sufficient sunshine (0.9 to 10 hours day^{-1}) in both years. The experiment was planned in a split-plot design with 6 main-plots and 3 sub-plots which consisted of C_1N_1: groundnut$_{100\%\ RDN}$- maize, C_1N_2: groundnut$_{75\%\ RDN}$- maize, C_2N_1: soybean$_{100\%\ RDN}$- maize, C_2N_2: soybean$_{75\%\ RDN}$- maize, C_3N_1: greengram$_{100\%\ RDN}$- maize, C_3N_2: greengram$_{75\%\ RDN}$- maize cropping systems and sub-plots: F_1: 100% RDN, F_2:125% RDN, F_3:150% RDN in *rabi* respectively during two years.

Kharif legumes *viz.* (groundnut, soybean and greengram) were sown on June 25th with spacing 30 cm × 10 cm and subsequently *rabi* maize was sown on 25th September after harvest of greengram and 23th October in case of soybean and groundnut as sequence crop under zero-tillage conditions with mechanical planter in both the years of 2021-22 and 2022-23. However, the spacing followed for *rabi* maize was 60 cm × 20 cm with recommended doses of 80 P_20_5 and 80 K_20 kg ha^{-1} respectively were applied at basal, along with varied levels of nitrogen as per the treatments in both years. Need based management practices were adopted for both legumes and maize during the crop growth period. The recommended dose of nitrogen applied for groundnut, soybean and greengram during *kharif* are 20, 60, 20 and 240 kg ha^{-1} for *rabi* maize respectively.

Plant height was recorded from 5 randomly selected plants at harvest by measuring from the base of the stem (ground level) to the top most node in Maize. Leaf area from five destructively sampled plants was measured at regular intervals using the LI-COR Model LI-3100 leaf area meter with transparent conveyor belt having electronic digital display and expressed in cm^2. SPAD reading was measured from five tagged plants of the net plot with the instrument CCM-200 plus chlorophyll content meter regular intervals by putting the leaf between the sensors of the instrument. Five plants were selected randomly from second row leaving the border rows were destructively sampled at respective intervals for all the crops for the estimation of drymatter production. The sun dried five cobs were weighed before shelling from each plot and after shelling grain weight was recorded separately. The ratio of grain to total weight of cob was expressed in percentage.

$$\text{Shelling percentage} = \frac{\text{Weight of grains}}{\text{Weight of cob}}$$

From the net plot, cobs were picked, sun dried, threshed and cleaned separately for each treatment. Finally, the yield obtained from net plot was expressed on hectare basis as kg ha^{-1}. Grain yield of five tagged plants assigned for post-harvest observations were also added to the net plot yield. The statistical analysis of the data was performed in Split Plot Design and the representation of growth parameters were done by heat maps using r software.

RESULTS AND DISCUSSION

Plant height (cm)

In both years, zero-tillage maize following *kharif* greengram displayed notably taller plants, with heights ranging from 37.33 to 221.82 cm surpassing soybean and groundnut. Notably, when *rabi* maize applied with 150% RDN showed superiority followed by 125% RDN and 100% RDN. Further, the interaction effect at 60 DAS only was found significant (Table 1a and 1b).

At 60 DAS, significantly higher plant height was noticed in maize grown after greengram with 100% RDN in *kharif* and 150% RDN in *rabi* (129.95 and 131.35 cm) which is on par with 125% RDN in *rabi* (126.74 and 129.42 cm) followed by soybean. The improved plant height was ascribed due to retention of large quantity of greengram residues which favoured for the improved moisture and nutrient mobility status and enhanced decomposition and availability and thus, facilitated overall crop growth. Similar findings were reported by Kumar *et al.* (2015) and Baryal *et al.* (2019).

Leaf area (cm^2)

Leaf area of succeeding zero-till maize was significantly higher when preceded by greengram with 100% RDN, compared to soybean and groundnut. Application of 150% RDN significantly increased leaf area in *rabi* maize across

Table 1: Plant height (cm) of *rabi* maize as influenced by *kharif* legumes and nitrogen fertility levels during 2021-22 and 2022-23.

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
***Kharif* Legumes × nitrogen levels (C × N)**												
C_1N_1: Groundnut$_{100\%\ RDN}$	29.33	28.00	28.67	112.88	109.33	111.11	196.47	195.93	196.20	209.36	197.27	203.32
C_1N_2: Groundnut$_{75\%\ RDN}$	25.33	24.33	24.83	105.78	101.64	103.71	184.21	180.43	182.32	198.44	188.89	193.67
C_2N_1: Soybean$_{100\%\ RDN}$	33.32	32.13	32.73	116.73	119.57	118.15	204.61	198.70	201.66	212.24	211.61	211.93
C_2N_2: Soybean$_{75\%\ RDN}$	31.00	30.33	30.67	110.74	112.59	111.67	195.65	191.40	193.53	210.54	206.18	208.36
C_3N_1: Greengram$_{100\%\ RDN}$	37.33	36.00	36.67	124.15	126.51	125.33	213.37	211.00	212.19	221.82	220.58	221.20
C_3N_2: Greengram$_{75\%\ RDN}$	34.33	32.67	33.50	118.48	123.25	120.87	206.38	203.67	205.03	216.62	213.10	214.86
SEm±	0.31	0.20	-	0.54	0.61	-	0.47	1.37	-	0.56	0.52	-
C.D. (P=0.05)	0.97	0.64	-	1.64	1.92	-	1.47	4.13	-	1.69	1.58	-
***Rabi* maize with varied nitrogen fertility levels (F)**												
F_1: 100% RDN	29.17	27.83	28.50	106.81	107.52	107.17	190.75	187.60	189.18	204.01	199.23	201.62
F_2: 125% RDN	31.67	30.83	31.25	116.64	117.30	116.97	202.11	199.07	200.59	211.94	206.44	209.19
F_3: 150% RDN	34.67	33.17	33.92	120.93	121.88	121.41	207.49	204.40	205.95	218.56	213.14	215.85
SEm±	0.15	0.17	-	0.52	0.23	-	1.36	1.73	-	1.15	1.07	-
C.D. (P=0.05)	0.45	0.51	-	1.53	0.67	-	3.96	5.21	-	3.36	3.13	-
Interaction												
Sub treatments at same level of main treatments F × (C × N)												
SEm±	0.31	0.40		1.39	0.74		3.02	3.23		2.45	2.21	-
C.D. (P=0.05)	NS	NS	-	4.03	2.21	-	NS	NS	-	NS	NS	-
Main treatments at same/different level of sub treatments (C × N) × F												
SEm±	0.38	0.43	-	1.28	0.56	-	3.32	3.46	-	2.82	2.63	-
C.D. (P=0.05)	NS	NS	-	3.74	2.05	-	NS	NS	-	NS	NS	-

Table 1a: Interaction effect of *kharif* legumes and nitrogen fertility levels on plant height (cm) of *rabi* maize at 60 DAS during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	102.00	97.68	110.35	105.75	115.75	109.34	106.81
F_2: 125% RDN	118.25	106.00	117.21	110.5	126.74	121.14	116.64
F_3: 150% RDN	118.39	113.67	122.63	115.97	129.95	124.95	120.96
Mean	112.88	105.78	116.54	111.74	124.14	118.48	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	0.54	0.52		1.28		1.39	
C.D. (P=0.05)	1.64	1.53		3.74		4.03	

Table 1b: Interaction effect of *kharif* legumes and nitrogen fertility levels on plant height (cm) of *rabi* maize at 60 DAS during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	98.00	93.92	112.81	107.62	118.75	114.02	107.52
F_2: 125% RDN	114.00	102.00	118.23	112.16	129.42	126.37	117.03
F_3: 150% RDN	116.00	109.00	127.68	117.99	131.35	129.25	121.88
Mean	109.33	101.64	119.57	112.59	126.51	123.21	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	0.61	0.23		0.56		0.74	
C.D. (P=0.05)	1.92	0.67		2.05		2.21	

various growth stages compared to 125% and 100% RDN levels in both years.

The interaction was found significantly at 60 DAS, higher leaf area was noticed in maize grown after greengram with 100% RDN in *kharif* and 150% RDN in *rabi* (239.62 and 227.14 cm^2) which was on par with 125% RDN in *rabi* (228.35 and 223.50 cm^2) followed by soybean (Table 2a and 2b). This could be attributed due to higher cell division and elongation until vegetative phase, further decline in flowering. Further better synergistic effect of residual decomposition and nitrogen feasibility that supplemented the growth and development of the leaf. The finding was in tune of Singh *et al.* (2015) and Rao *et al.* (2014).

Leaf chlorophyll content

Higher leaf chlorophyll content was observed in maize when grown after greengram with 100% RDN during 2021-22 and in 2022-23 respectively followed by soybean. In sequential *rabi* maize, the F_3 treatment (150% RDN) exhibited significantly higher leaf chlorophyll content compared to F_2 (125% RDN) in both years.

In 2021-22 and 2022-23 at 60 DAS, the interaction effect was found significant when prior greengram residues with 100% RDN in *kharif* and 150% RDN in *rabi* (48.45 and 47.70) which was onpar with 125% RDN (46.32 and 45.76). Lowest was noticed in groundnut with 75% RDN in *kharif* and 100% RDN in *rabi* (Table 3a and 3b). This might be due to the residual influence in collaboration of the nitrogen levels have positively correlated for the effective greenness of the leaves due to the higher photosynthates accumulation that further decreased due to lower doses of nitrogen. Familiar findings by Monika *et al.* (2022).

Dry matter production (kg ha^{-1})

kharif greengram residues showed significantly higher dry matter in 2021-22 (7788 to 21275 kg ha^{-1}) and 2022-23 (7542 to 20443 kg ha^{-1}) over soybean and groundnut. With varied nitrogen levels, significantly higher dry matter production when 150% RDN was applied over other treatments (Table 4). The interaction effect was found to be significantly at 60 DAS only. Thus, the effect of greengram residues @ 100% RDN in *kharif* and 150% RDN on *rabi* maize had significant higher dry matter production (16473 and 16299 kg ha^{-1}) but was onpar with greengram residues @100% RDN in *kharif* and 125% RDN on *rabi* maize (15754 and 15287 kg ha^{-1}) (Table 4a). Enhanced dry matter production in growth stages due to nutrient availability in key developmental phases and lower C:N ratio hasten the decomposition helped for effective accumulation of root-shoot biomass. Similar finding were reported by Mercy *et al.,* 2012 and Onwonga *et al.* (2017).

Shelling percentage (%)

Greengram with 100% RDN had significantly higher shelling percentage in *rabi* maize, followed by soybean and groundnut. Further 150% RDN in *rabi* maize was significantly higher, while 100% RDN showed lowest in two years. Apart, interaction was non-significant. Varied nitrogen fertility, combined with residue retention, reduced nutrient losses, enhancing cob weight and development for improved shelling percentage. Finding were inline with Laxmi *et al.* (2022) (Table 5).

Grain yield (kg ha^{-1})

During 2021-22 and 2022-23, residues of *kharif* greengram with 100% RDN recorded significantly higher grain yield with a tune of 8-9 % than greengram with 75% RDN, 11-14% with 100% and 17-20% with 75% RDN of soybean. Significantly lowest grain yield was recorded with groundnut at 75% RDN with tune of 32-34%. Addition of 150% RDN to *rabi* maize registered significantly higher grain yields followed by 125% RDN with a tune of 6-9% and lowest with 100% RDN with a tune of 18% was represented in Fig 1.

The interaction revealed that, maize grown after *kharif* greengram with 100% RDN followed by 150% RDN in *rabi* maize recorded significantly higher grain yields (9799 and 9704 kg ha ha^{-1}) but was onpar with 125% RDN in *rabi* maize (9386 and 9276 kg ha^{-1}) and significantly lowest kernel yields registered with groundnut at 75% RDN and 100% RDN in maize (6148 and 6001 kg ha^{-1}) respectively in two years.

Enhanced grain yields attributed to increased biomass and quicker decomposition of greengram residues, providing ample nutrients for rabi maize. Under zero-till conditions, minimal soil disturbance and nitrogen immobilization likely contributed to maize's heightened response to higher nitrogen levels, with 250% and 225% levels showcasing superior performance in yield. Similar findings quoted by Ndiso *et al.* (2018) and Monika *et al.* (2022) (Table 5a and 5b).

Stover yield (kg ha^{-1})

During 2021-22 and 2022-23, the greengram residues with 100% RDN in *kharif* recorded significantly higher stover yields than 75% RDN followed by soybean and groundnut in zero-till *rabi* maize sequence. With application of 150% RDN in zero-till maize registered significantly higher stover yields than 125% RDN and 100% RDN in two years of study. However, the interaction effect was found significant. Further stating that maize when grown after *kharif* greengram with 100% RDN followed by 150% RDN in *rabi* maize recorded higher stover yields but was onpar with 125 % RDN.

The preceding greengram residue with 100% RDN contributed to higher dry matter accumulation and exhibited a positive N $\times$ K synergetic effect, enhancing stover biomass during both vegetative and reproductive stages. (Table 5c and 5d). Findling inline with (Shafi *et al.,* 2007 and Hailemariam *et al*., 2021).

Table 2: Leaf area (cm^2) of *rabi* maize as influenced by *kharif* legumes and nitrogen fertility levels during 2021-22 and 2022-23.

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
***Kharif* legumes × nitrogen levels (C × N)**												
C_1N_1: Groundnut$_{100\%\ RDN}$	82.38	75.68	79.03	188.51	183.89	186.20	414.67	411.67	413.17	419.33	422.67	421.00
C_1N_2: Groundnut$_{75\%\ RDN}$	72.01	63.40	67.71	180.34	176.92	178.63	404.00	401.33	402.67	410.33	415.33	412.83
C_2N_1: Soybean$_{100\%\ RDN}$	100.50	97.21	98.86	202.75	197.62	200.19	430.00	427.67	428.84	439.00	443.33	441.17
C_2N_2: Soybean$_{75\%\ RDN}$	92.31	89.22	90.77	191.96	191.59	191.78	422.33	419.33	420.83	430.67	435.67	433.17
C_3N_1: Greengram$_{100\%\ RDN}$	116.75	117.08	116.92	226.55	218.65	222.60	452.67	450.56	451.62	459.67	465.33	462.50
C_3N_2: Greengram$_{75\%\ RDN}$	110.76	107.84	109.30	217.18	209.92	213.55	446.00	444.00	445.00	455.00	460.67	457.84
SEm±	1.62	2.46	-	2.37	1.34	-	1.14	2.07	-	1.34	1.06	-
C.D. (P=0.05)	5.11	7.75	-	7.46	4.21	-	3.43	6.22	-	4.03	3.19	-
***Rabi* maize with varied nitrogen fertility levels (F)**												
F_1: 100% RDN	88.90	85.21	87.06	190.01	184.81	187.41	420.67	417.67	419.17	427.33	431.67	429.50
F_2: 125% RDN	95.48	91.12	93.30	199.79	196.80	198.30	428.50	426.37	427.44	435.67	440.83	438.25
F_3: 150% RDN	102.97	98.88	100.93	213.86	206.02	209.94	435.67	433.24	434.46	444.00	449.00	446.50
SEm±	1.72	1.49	-	1.58	0.74	-	2.41	1.98	-	2.18	2.47	-
C.D. (P=0.05)	5.03	4.35	-	4.63	2.16	-	7.03	5.94	-	6.36	7.20	-
Interaction												
Sub treatments at same level of Main treatments F × (C × N)												
SEm±	4.02	3.53	-	5.23	2.71	-	5.65	5.48	-	5.12	5.97	-
C.D. (P=0.05)	NS	NS	-	15.16	7.86	-	NS	NS	-	NS	NS	-
Main treatments at same/different level of sub treatments (C × N) × F												
SEm±	4.22	3.65	-	3.88	1.81	-	5.90	5.83	-	5.34	6.05	-
C.D. (P=0.05)	NS	NS	-	11.33	5.29	-	NS	NS	-	NS	NS	-

Table 2a: Interaction effect of *kharif* legumes and nitrogen fertility levels on Leaf area (cm^2) of *rabi* maize at 60 DAS during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	175.54	167.44	189.09	182.98	211.71	210.18	190.01
F_2: 125% RDN	190.23	182.23	201.17	186.13	228.35	213.76	199.79
F_3: 150% RDN	199.77	191.36	217.99	206.80	239.62	227.60	213.86
Mean	188.51	180.34	202.75	191.96	226.55	217.18	
Factor	*kharif* legumes × nitrogen levels (C×N)		*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes
SEm±	2.37		1.58		3.88		5.23
C.D. (P=0.05)	7.46		4.63		11.33		15.16

Table 2b: Interaction effect of *kharif* legumes and nitrogen fertility levels on Leaf area (cm^2) of *rabi* maize at 60 DAS during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	172.82	163.24	183.20	180.36	205.32	203.91	184.81
F_2: 125% RDN	183.59	180.01	194.78	191.11	223.50	207.81	196.80
F_3: 150% RDN	195.26	187.50	214.88	203.29	227.14	218.06	207.69
Mean	183.89	176.92	197.62	191.59	218.65	209.92	
Factor	*kharif* legumes × nitrogen levels (C×N)		*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes
SEm±	1.34		0.74		1.81		2.71
C.D. (P=0.05)	4.21		2.16		5.29		7.86

Table 3: SPAD value of *rabi* maize as influenced by *kharif* legumes and nitrogen fertility levels during 2021-22 and 2022-23.

Treatments	30 DAS			60 DAS			90 DAS			Harvest		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
***Kharif* Legumes × nitrogen levels (CXN)**												
C_1N_1: Groundnut$_{100\%\ RDN}$	19.00	18.25	18.63	38.73	38.12	38.43	53.74	50.83	52.29	43.33	40.50	41.92
C_1N_2: Groundnut$_{75\%\ RDN}$	17.65	17.28	17.47	34.47	33.71	34.09	50.29	47.27	48.78	41.36	37.71	39.54
C_2N_1: Soybean$_{100\%\ RDN}$	21.03	20.15	20.59	43.52	42.31	42.92	56.06	54.40	55.23	46.53	45.28	45.91
C_2N_2: Soybean$_{75\%\ RDN}$	19.65	19.16	19.41	39.96	38.94	39.45	54.86	51.93	53.40	44.59	42.85	43.72
C_3N_1: Greengram$_{100\%\ RDN}$	23.33	23.03	23.18	46.04	45.41	45.73	58.69	57.65	58.17	49.42	48.44	48.93
C_3N_2: Greengram$_{75\%\ RDN}$	21.76	21.20	21.48	43.95	43.47	43.71	57.18	55.70	56.44	47.56	46.73	47.15
SEm±	0.20	0.30	-	0.31	0.33	-	0.32	0.32	-	0.32	0.35	-
C.D. (P=0.05)	0.63	0.94	-	0.97	1.01	-	1.02	1.01	-	1.00	1.10	-
***Rabi* maize with varied nitrogen fertility levels (F)**												
F_1: 100% RDN	18.31	17.88	18.10	38.58	37.93	38.26	52.43	50.21	51.32	43.53	41.28	42.41
F_2: 125% RDN	20.60	20.14	20.37	41.00	40.31	40.66	54.99	53.15	54.07	45.18	43.25	44.22
F_3: 150% RDN	22.76	22.41	22.59	43.76	42.74	43.25	57.58	55.83	56.71	47.19	45.72	46.46
SEm±	0.13	0.28	-	0.25	0.71	-	0.46	0.30	-	0.27	0.25	-
C.D. (P=0.05)	0.39	0.82	-	0.73	2.06	-	1.34	0.88	-	0.78	0.73	-
Interaction												
Sub treatments at same level of Main treatments F × (C × N)												
SEm±	0.31	0.49	-	0.98	2.60	-	0.97	0.64	-	0.61	0.57	-
C.D. (P=0.05)	NS	NS	-	2.87	7.56	-	NS	NS	-	NS	NS	-
Main treatments at same/different level of sub treatments (C × N) × F												
SEm±	0.36	0.54	-	0.76	1.81	-	1.12	0.73	-	0.65	0.61	-
C.D. (P=0.05)	NS	NS	-	2.29	5.29	-	NS	NS	-	NS	NS	-

Table 3a: Interaction effect of *kharif* legumes and nitrogen fertility levels on SPAD value of zero-till *rabi* maize at 60 DAS during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	36.08	31.28	41.15	37.31	43.36	42.28	38.58
F_2: 125% RDN	38.45	34.62	43.55	39.64	46.32	43.44	41.00
F_3: 150% RDN	41.67	37.51	45.87	42.93	48.45	46.14	43.76
Mean	38.73	34.47	43.52	39.96	46.04	43.95	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	0.31	0.25		0.76		0.98	
C.D. (P=0.05)	0.97	0.73		2.29		2.87	

Table 3b: Interaction effect of *kharif* legumes and nitrogen fertility levels on SPAD value of zero-till *rabi* maize at 60 DAS during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	35.71	30.45	40.30	36.87	42.78	41.48	37.93
F_2: 125% RDN	37.83	33.89	42.51	38.45	45.76	43.44	40.31
F_3: 150% RDN	40.83	36.79	44.14	41.50	47.70	45.49	42.74
Mean	38.12	33.71	42.31	38.94	45.41	43.47	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	0.33	0.71		1.81		2.60	
C.D. (P=0.05)	1.01	2.06		5.29		7.56	

Table 4: Dry matter production (kg ha^{-1}) of zero-till *rabi* maize as influenced by *kharif* legumes and nitrogen fertility levels during 2021-22 and 2022-23.

Dry matter	30 DAS			60 DAS			90 DAS			Harvest		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
***Kharif* legumes × nitrogen levels (CXN)**												
C_1N_1: Groundnut$_{100\%\ RDN}$	4596	3930	4263	10184	9763	9973	15261	14558	14909	17808	16099	16953
C_1N_2: Groundnut$_{75\%\ RDN}$	3835	3028	3431	9043	8895	8969	12784	12349	12566	15671	15027	15349
C_2N_1: Soybean$_{100\%\ RDN}$	6254	5739	5996	12222	11801	11795	16122	16175	16148	19526	18244	18885
C_2N_2: Soybean$_{75\%\ RDN}$	5401	4827	5114	9871	9302	9586	14379	15362	14870	18628	17170	17899
C_3N_1: Greengram$_{100\%\ RDN}$	7788	7542	7665	14187	13876	14031	18167	17670	17918	21275	20443	20859
C_3N_2: Greengram$_{75\%\ RDN}$	6991	6636	6813	13217	12768	12992	17285	16951	17118	20333	19329	19831
SEm±	229	284	-	81	87	-	281	233	-	257	338	-
C.D. (P=0.05)	723	896	-	256	275	-	846	733	-	809	1066	-
***Rabi* maize with varied nitrogen fertility levels (F)**												
F_1: 100% RDN	5080	4822	4951	9881	9536	9708	14070	13979	14024	16973	16445	16709
F_2: 125% RDN	5948	5658	5803	11416	11032	11224	16027	15596	15811	18675	18263	18469
F_3: 150% RDN	6654	6431	6542	13065	13065	12741	17102	17007	17054	20053	19393	19723
SEm±	175	197	-	63	65	-	185	203	-	171	191	-
C.D. (P=0.05)	513	575	-	183	190	-	540	593	-	499	557	-
Interaction												
Sub treatments at same level of Main treatments F × (C × N)												
SEm±	426	357	-	344	203	-	402	474	-	386	335	-
C.D. (P=0.05)	NS	NS	-	998	589	-	NS	NS	-	NS	NS	-
Main treatments at same/different level of sub treatments (C × N) × F												
SEm±	431	389	-	316	181	-	452	498	-	419	383	-
C.D. (P=0.05)	NS	NS	-	948	529	-	NS	NS	-	NS	NS	-

Table 4a: Interaction effect of *kharif* legumes and nitrogen fertility levels on Dry matter production (kg ha^{-1}) on zero-till *rabi* maize at 60 DAS during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	9246	7659	10370	8695	10335	12985	9881
F_2: 125% RDN	10319	9624	11550	9549	15754	11698	11416
F_3: 150% RDN	10987	9845	14748	11368	16473	14968	13065
Mean	10184	9043	12222	9871	14187	13217	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	81	63		316		344	
C.D. (P=0.05)	256	183		948		998	

Table 4b: Interaction effect of *kharif* legumes and nitrogen fertility levels on Dry matter production (kg ha^{-1}) on zero-till *rabi* maize at 60 DAS during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	9035	7412	10017	8230	10044	12480	9536
F_2: 125% RDN	10010	9260	11099	9287	15287	11250	11032
F_3: 150% RDN	10246	10012	14287	10389	16299	14573	12635
Mean	9763	8895	11801	9302	13876	12768	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	87	65		181		203	
C.D. (P=0.05)	275	190		529		589	

C_1N_1: $Groundnut_{100}$- maize, C_1N_2: $Groundnut_{75}$- maize, C_2N_1: $Soybean_{100}$- maize, C_2N_2: $Soybean_{75}$- maize, C_3N_1: $Greengram_{100}$- maize, C_3N_2: $Greengram_{75}$- maize.

Table 5: Grain, stover yield (kg ha^{-1}), harvest index (%) and shelling percentage (%) of zero-till *rabi* maize as influenced by *kharif* legumes and nitrogen fertility levels during 2021-22 and 2022-23.

Treatments	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})			Shelling percentage (%)		
	2021-22	2022-23	Mean	2021-22	2022-23	Mean	2021-22	2022-23	Mean
***Kharif* legumes × nitrogen levels (C×N)**									
C_1N_1: Groundnut$_{100\%\ RDN}$	7957	7755	7856	9851	9661	9756	60.16	62.76	61.46
C_1N_2: Groundnut$_{75\%\ RDN}$	6963	6804	6884	8707	8486	8596	54.54	57.22	55.88
C_2N_1: Soybean$_{100\%\ RDN}$	8073	8192	8299	10337	10196	10267	69.95	70.49	70.22
C_2N_2: Soybean$_{75\%\ RDN}$	7798	7622	7710	9630	9451	9541	65.31	65.66	65.49
C_3N_1: Greengram$_{100\%\ RDN}$	9193	9089	9141	11250	11073	11173	78.19	79.99	79.09
C_3N_2: Greengram$_{75\%\ RDN}$	8480	8302	8391	10383	10305	10377	73.81	75.1	74.46
SEm±	61	35	-	59	57	-	1.24	1.51	-
C.D. (P=0.05)	191	102	-	192	180	-	3.74	4.56	-
***Rabi* maize with varied nitrogen fertility levels (F)**									
F_1: 100% RDN	7407	7229	7318	9207	9012	9110	67.42	65.63	66.53
F_2: 125% RDN	8059	8054	8140	10116	9974	10067	70.02	68.52	69.27
F_3: 150% RDN	8766	8599	8682	10756	10599	10678	73.70	70.96	72.33
SEm±	39	35	-	32	43	-	0.98	0.89	-
C.D. (P=0.05)	112	101	-	94	124	-	2.81	2.56	-
Interaction									
Sub treatments at same level of Main treatments F × (C × N)									
SEm±	168	156	-	159	172	-	2.12	2.03	-
C.D. (P=0.05)	486	451	-	462	498	-	NS	NS	-
Main treatments at same/different level of sub treatments (C × N) × F									
SEm±	153	143	-	142	160	-	2.40	2.18	-
C.D. (P=0.05)	475	430	-	430	480	-	NS	NS	-

Table 5a: Interaction effect of *kharif* legumes and nitrogen levels on Grain yield (kg ha 1) of zero-till *rabi* maize during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F1: 100% RDN	7451	6148	7818	6905	8394	7727	7407
F2: 125% RDN	7966	6988	7394	7970	9386	8651	8059
F3: 150% RDN	8454	7754	9007	8519	9799	9060	8766
Mean	7957	6963	8073	7798	9193	8480	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	61	39		153		168	
C.D. (P=0.05)	191	112		475		486	

Table 5b: Interaction effect of *kharif* legumes and nitrogen levels on Grain yield (kg ha^{-1}) of zero-till *rabi* maize during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	7246	6001	7576	6742	8287	7519	7229
F_2: 125% RDN	7699	6933	8154	7811	9276	8453	8054
F_3: 150% RDN	8319	7479	8846	8314	9704	8934	8599
Mean	7755	6804	8192	7622	9089	8302	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	35	35		143		156	
C.D. (P=0.05)	102	101		430		451	

Table 5c: Interaction effect of *kharif* legumes and nitrogen fertility levels on stover yield (kg ha^{-1}) of zero-till *rabi* maize during 2021-22.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	9269	7757	9668	8556	10359	9633	9207
F_2: 125% RDN	9859	8741	10313	9851	11481	10451	10116
F_3: 150% RDN	10425	9623	11031	10484	11909	11065	10756
Mean	9851	8707	10337	9630	11250	10383	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	59	32		142		159	
C.D. (P=0.05)	192	94		430		462	

Table 5d: Interaction effect of *kharif* legumes and nitrogen fertility levels on Stover yield (kg ha^{-1}) of zero-till *rabi* maize during 2022-23.

Treatments	*Kharif* legumes × nitrogen levels (C×N)						
Rabi maize with varied nitrogen fertility levels (F)	C_1N_1	C_1N_2	C_2N_1	C_2N_2	C_3N_1	C_3N_2	Mean
F_1: 100% RDN	9007	7537	9517	8378	10168	9468	9012
F_2: 125% RDN	9699	8556	10126	9698	11286	10479	9974
F_3: 150% RDN	10277	9365	10945	10277	11765	10968	10599
Mean	9661	8486	10196	9451	11073	10305	
Factor	*kharif* legumes × nitrogen levels (C×N)	*Rabi* maize with varied nitrogen fertility levels (F)		*kharif* legumes at same level of nitrogen fertility		Nitrogen fertility level at same *kharif* legumes	
SEm±	57	43		160		172	
C.D. (P=0.05)	180	124		480		498	

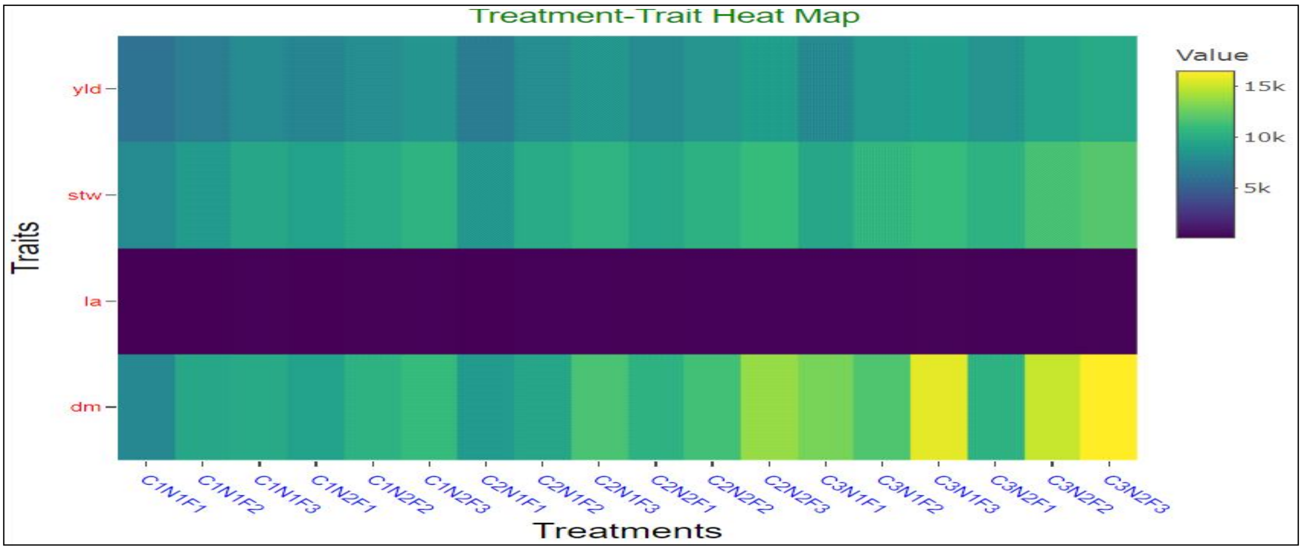

Fig 1: Representation of growth parameters (dry matter, leaf area, grain and straw yield) of zero-till *rabi* maize as influenced by *kharif* legumes by using heat maps in R-software.

CONCLUSION

The study revealed that the cropping sequence of greengram as preceding legume in *kharif* followed by zero-till maize in *rabi* showed significant results in terms of growth parameters and yield. Specifically, nitrogen levels at a recommended dose of 100% in *kharif* and 150% in *rabi* exhibited the superior performance, followed closely by 100%-125% RDN and 75% -150% RDN. This suggests that a balanced approach, with reduced nitrogen in the preceding season but higher doses with legume residue retention, significantly enhances crop growth phenology as well as productivity during the both years.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

REFERENCES

Ali, W., Jan, A., Hassan, A., Abbas, A., Hussain, A., Ali, M., Zuhair, S.A. and Hussain, A. (2015). Residual effect of preceding legumes and nitrogen levels on subsequent maize. International Journal of Agronomy and Agricultural Research. 7(1): 78-85.

Ammaji, P. (2022). Yield and nutrient uptake of maize (*Zea mays* L.) as influenced by legume crops, residue management practices and nitrogen levels in legume- maize sequence. The Pharma Innovation Journal. 11(12): 604-609.

Baryal, M., Rathore, S.S., Mukhtar, A.F. and Kapila, S. (2019). Nitrogen management in maize+soybean intercropping system in semiarid condition of Kandahar, Afghanistan. Annals of Agricultural Research. 40(1): 62-67.

Bharathi, S., Veeraraghavaiah, R., Rao, A.S., Naidu, T.C.M and Lakshmi, G.V. (2015). Productivity and nitrogen requirement of maize (*zea mays* l.) in *rabi* as influenced by *kharif* cropping practices. International Journal of Bio-resource and Stress Management. 6(4): 447-451.

Directorate of Economics and Statistics. Ministry of Agriculture, Government of India (2023). New Delhi. http://eands.dacnet.nic.in/StateData_19-20Year.html.

Hailemariam, M., Yechalew, S, Efrem, A., Abush, T. and Mohammed, A. (2021). Demonstration of maize-soybean [*Glycine max* (L) Merrill] rotations in promotion for sustainable cropping system in Southwest Ethiopia. Journal of Genetic and Environmental Resources Conservation. 9(2): 96-101.

Kumar, R. and Hiremath, S. (2015). Residual effects of maize hybrids, plant population and fertility levels on performance of chickpea in maize-chickpea cropping sequence. Karnataka Journal of Agricultural Sciences. 28(4): 482-485.

Laxmi, Basavanneppa, M.A., Koppalakar, B.G., Vishwanatha, S. and Balanagouda, S.R. (2022). Response of maize (*Zea mays* L.) genotypes to nitrogen levels during rabi under irrigated condition. The Pharma Innovation Journal. 11(8): 1948-1951.

Meena, K.N., Ashok Kumar, Rana, D.S. and Meena, M.C. (2011). Productivity and nutrient uptake of maize (*Zea mays*)-wheat (*Triticum aestivum*) cropping system under different bio-sources and nitrogen levels. Indian Journal of Agronomy. 56(3): 182-188.

Mercy Z., Chandrasekhar, K. and Subbaiah, G. (2012). Response of maize (*Zea mays*) to planting densities and nitrogen levels under late *rabi* conditions. The Andhra Agricultural Journal. 59(4): 517-519.

Monika, S., Sadhu, A.C., Pinal, P., Mevada, K.D. (2022). Effect of inclusion of legumes in cropping system and their residue incorporation on the yield of maize. Legume Research. doi: 10.18805/LR-4868.

Ndiso, J.B., Chemining'wa, G.N., Olubayo, F.M and Saha, H.M. (2018). Effect of cowpea crop residue management on soil moisture content, canopy temperature, growth and yield of maize-cowpea intercrops. International Journal of Agriculture, Environment and Bioresearch. 3(5): 231-250.

Onwonga, R.N., Templer, N.A. and Lelei, J.J. (2017). Soil available nutrients, pH and yield variation in legume-maize systems utilizing two phosphorus sources in Kabete Kenya. International Journal of Research in Agricultural Sciences. 4(1): 2348-3997.

Parihar, C.M., Jat, S.L., Singh, A.K., Kumar, B., Yadvinder Singh, Pardhan, S., Pooniya, V., Dhauja, A., Chaudary, V., Jat, M.L., Jat, R.K and Yadav, O.P. (2016a). Conservation agriculture in irrigated intensive maize-based system of north- western India: Effects on crop yields, water productivity and economic profitability. Field Crops Research. 193: 104-116.

Rao, P.V., Subbaiah, G., Veeraraghavaiah, R., Ashoka Rani, Y. and Srinivasa Rao, V. (2014). Effect of planting densities and nitrogen levels on productivity and economics of rice fallow maize (*Zea mays*) under zero tillage conditions. The Andhra Agricultural Journal. 61(1): 6-12.

Shafi, M., Bakht, J., Jan, M.T. and Shah, Z., (2007). Soil C and N dynamics and maize (*Zea mays* L.) yield as affected by cropping systems and residue management in North-western Pakistan. Soil and Tillage Research. 94(2): 520-529.

Shukla, M., Sadhu, A.C., Mevada, K.D. and Patel, P. (2021). Profitability of legume-maize cropping systems under legume residue management practices. Journal of Food Legumes. 34(1): 38-43.

Sikka R., Kaur Simranpreet, Gupta, R.K. (2022). Effect of phosphorous application on yield and its uptake by soybean (*Glycine max* L.) in different cropping systems. Indian Journal of Agricultural Research. 56(3): 308-312.

Singh, P.K., Kumar, S., Kumar, S. and Kumar, A. (2015). Effect of planting/irrigation techniques and nitrogen levels on growth, total chlorophyll, development, yield and quality of maize (*Zea mays* L.). Indian Journal of Agricultural Sciences. 49(2): 148-153.

Sravanthi, S., Ramana, A.V., Ramana Murthy, K.V. and Jagannadam, J. (2016). Nutrient management in zero till maize for north coastal zone of A.P. The Andhra Agricultural Journal. 63(4): 741-743.

Yadav, M.R., Parihar, C.M., Jat, S.L., Singh, A.K., Kumar Rakesh, R.K. Yadav, Kuri, B.R., Parihar, M.D., Verma, A.P., Jat, M.L. (2017). Long term effect of legume intensified crop rotations and tillage practices on productivity and profitability of maize vis-a-vis soil fertility in North-Western Indo-Gangetic Plains of India. Legume Research. 40(2): 282-290. doi: 10.18805/lr.v0i0.7583.