Improving maize yield and soil productivity through N management practices in maize-legume Intercropping

Abstract

A field experiment was conducted to investigate the effects of maize intercropping and nitrogen management on crop productivity. The study comprised two factors: maize intercropping with five treatments (sole maize, skipped row maize, and maize intercropped with greengram, blackgram, or cluster bean) and nitrogen management with three treatments (100%, 75%, and 50% of the recommended nitrogen dose). The results showed that sole maize at 60 x 20 cm spacing and maize intercropped with cluster bean, blackgram, or greengram significantly outyielded sole maize in skipped rows. Nitrogen application at 100% of the recommended dose resulted in higher maize yields, while intercropping with cluster bean showed the highest maize grain equivalent yield and land equivalent ratio. The study highlights the potential of maize intercropping and optimized nitrogen management to enhance crop productivity, reduce soil nutrient depletion, and promote sustainable agriculture practices.

Keywords: maize intercropping, nitrogen management, crop productivity, sustainable agriculture.

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Introduction

The sustainable productivity level of crops is the need of hour in the present Indian farming. Hence, we must examine every possibility for crop intensification with sustainable nutrition for achieving the sustainability. Maize (*Zea mays* L.) is the third most important cereal crop after wheat and rice in the world, and India is the seventh largest producer of maize. Due to its multidimensional uses, high production potential and adaptability to wide range of environment, we can expect maize to assume a proportionally large and more important role in the food production in coming years. Under crop intensification intercropping with maize is gaining popularity during recent past in southern agro climatic zone of Andhra Pradesh. Hybrid maize being an exhaustive crop, requires high quantity of nutrients particularly nitrogen. The recent maize hybrids are responding to more than 240 kg N ha^{-1}. But, the prohibitive cost of fertilizer nitrogen limits the farmers for its liberal application. In the present day's concern about environmental degradation coupled with high cost of nitrogen, there is a need to find out supplemental alternative sources. Legumes, if associated with maize can reduce nitrogen requirement to some extent, besides maintaining soil health. Though considerable quantum of research has been carried out in maize nutrition, much of them was resource exploitive type, but not conserving type and they were unable to answer, proportionate fertilizer nitrogen saving to hybrid maize when legumes are associated Traditionally, nitrogen recommendations for maize-based intercropping systems have been determined by the response of individual crops, rather than considering the intercropping system as a whole. This approach can lead to suboptimal nitrogen management, resulting in reduced economic returns. By adopting a rational agronomic approach of uniform plant population of both base and inter crop, the production potential and economic viability of maize + legume inter cropping system depends upon nature and type of associated legume and quantity of fertilizer applied. Hence, the present study was designed with following objectives to explore the possibilities of intercropping of short duration legumes under variable doses of nitrogen to maize and intercropping sequence under different crop geometry.

Material and Methods:

The experiment was conducted at the Agricultural Research Farm, Sri CB Singh Memorial Shikshan Sansthan, Jhinjhak, Kanpur Dehat, U.P., India, during the Kharif season of 2022-23. The farm is situated in the Indo-Gangetic Plains, between 26.35° N latitude and 80.09° E longitude, with an elevation of 130.00 m above mean sea level.A randomized block design with a factorial concept was employed, with three replications. The treatments consisted of two factors: maize intercropping systems and nitrogen management. The maize intercropping systems included five treatments: sole maize at 60 x 20 cm spacing, skipped row maize, maize + greengram intercropping, maize + blackgram intercropping, and maize + cluster bean intercropping.The nitrogen management factor consisted of three treatments: recommended dose of nitrogen (240 kg ha-1), 75% recommended dose of nitrogen (180 kg ha-1), and 50% recommended dose of nitrogen (120 kg ha-1). Sole crops of greengram, blackgram, and cluster bean were raised separately at 30 x 10 cm spacing outside the experimental layout.The plot size was 6.0 x 5.4 m (gross) and 4.0 x 3.6 m (net). Intercrops were sown at a spacing of 60 x 5 cm. A uniform dose of 60 kg P2O5 ha-1 and 50 kg K2O ha-1 was applied as basal to maize in all plots. Nitrogen was applied in three equal splits, viz., basal, knee stage, and tasseling stage. For the intercrops, 20, 50, and 40 kg N, P2O5, and K2O ha-1, respectively, were applied as basal application at sowing.

Results and Discussion

The results of the study revealed that maize intercropping and nitrogen management significantly influenced the growth parameters, yield attributes, and yield of maize. The growth parameters, such as plant height, leaf area index, and dry matter production, were significantly higher in sole maize at 60 x 20 cm spacing, which was at par with maize + cluster bean, maize + blackgram, and maize + greengram intercropping.The yield attributes, such as cob length and girth, number of grains cob-1, and 100 grain weight, were higher in sole maize at 60 x 20 cm planting, closely followed by maize + cluster bean, maize + blackgram, and maize + greengram intercropping. The grain and stover yield of maize was highest in sole maize at 60 x 20 cm, which was at par with the yields of maize + cluster bean, maize + blackgram, and maize + greengram intercropping. The application of 100% recommended dose of nitrogen to maize resulted in significant higher yield attributes and grain and stover yield, while application of 50% recommended dose of nitrogen resulted in significantly lower yield attributes and grain and stover yield.

Table 1: Plant height (cm) of maize as influenced by maize + legume intercropping and nitrogen management

Treatment	25 DAS	50 DAS	75 DAS
Maize intercropping			
T_1: Maize 60 x 20 cm	52.6	126.9	164.9
T_2: Maize skipped row	48.3	109.8	142.6
T_3: T_2 + Greengram	48.2	121.6	158.0
T_4: T_2 + Blackgram	48.6	124.8	158.4
T_5: T_2 + Cluster bean	52.1	125.1	161.6

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SEm ±	2.36	3.61	4.02
CD (P=0.05)	NS	10.3	11.5
Nitrogen management			
N_1: 100 % Rec. N to maize	52.4	124.2	164.6
N_2: 75 % Rec. N to maize	50.3	119.2	153.9
N_3: 50 % Rec. N to maize	48.0	105.3	141.6
SEm ±	1.83	4.01	4.23
CD (P=0.05)	NS	11.5	12.1

Table 2 : Leaf area index of maize as influenced by maize + legume intercropping and nitrogen management

Treatment	25 DAS	50 DAS	75 DAS	Harvest
Maize intercropping				
T_1: Maize 60 x 20 cm	0.212	2.50	1.49	1.28
T_2: Maize skipped row	0.181	1.94	1.20	1.20
T_3: T_2 + Greengram	0.199	2.36	1.36	1.25
T_4: T_2 + Blackgram	0.206	2.39	1.39	1.26
T_5: T_2 + Cluster bean	0.212	2.41	1.42	1.28
SEm ±	0.07	0.14	0.048	0.014
CD (P=0.05)	NS	0.40	0.14	0.04
Nitrogen management				
N_1: 100 % Rec. N to maize	0.217	2.38	1.36	1.11
N_2: 75 % Rec. N to maize	0.201	2.36	1.29	1.09
N_3: 50 % Rec. N to maize	0.179	2.01	1.14	0.99
SEm ±	0.006	0.108	0.037	0.010
CD (P=0.05)	0.017	0.31	0.11	0.03

Table 3 : Dry matter production (kg ha^{-1}) of maize as influenced by maize + legume intercropping

and nitrogen management

Treatment	25 DAS	50 DAS	75 DAS	Harvest
Maize intercropping				
T_1: Maize 60 x 20 cm	421.7	4311	7257	9174
T_2: Maize skipped row	408.0	4004	6655	8763
T_3: T_2 + Greengram	412.8	4296	6987	8917
T_4: T_2 + Blackgram	417.6	4298	7056	9003
T_5: T_2 + Cluster bean	419.6	4303	7240	9103
SEm ±	4.8	90.9	112.0	104.2
CD (P=0.05)	NS	262	323	301
Nitrogen management				
N_1: 100 % Rec. N to maize	420.1	4199	6987	9314
N_2: 75 % Rec. N to maize	418.8	4109	6763	9074
N_3: 50 % Rec. N to maize	404.2	3802	6213	8517
SEm ±	3.61	102.5	86.7	90.2
CD (P=0.05)	10.6	297	251	260

Table 4 : Yield attributes of maize as influenced by maize + legume intercropping and nitrogen management

Treatment	Cob length (cm)	Cob girth (cm)	No. of grains per cob	100 grain weight (g)
Maize intercropping				
T_1: Maize 60 x 20 cm	14.4	14.7	333	28.8
T_2: Maize skipped row	12.1	12.9	252	23.8

T_3: T_2 + Greengram	13.7	13.4	297	26.4
T_4: T_2 + Blackgram	13.9	14.4	299	27.5
T_5: T_2 + Cluster bean	14.4	14.6	324	27.7
SEm ±	0.74	0.54	26.83	1.15
CD (P=0.05)	2.1	1.6	77	3.3
Nitrogen management				
N_1: 100 % Rec. N to maize	14.8	14.6	333	28.1
N_2: 75 % Rec. N to maize	14.5	14.3	324	27.7
N_3: 50 % Rec. N to maize	12.3	13.0	245	24.7
SEm ±	0.57	0.42	20.78	0.88
CD (P=0.05)	1.6	1.2	60	2.5

Table 5 : Grain yield, stover yield and harvest index of maize as influenced by maize + legume intercropping and nitrogen management

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
Maize intercropping			
T_1: Maize 60 x 20 cm	4009	5921	40.4
T_2: Maize skipped row	3071	4277	41.8
T_3: T_2 + Greengram	3791	5685	40.0
T_4: T_2 + Blackgram	3864	5771	40.1
T_5: T_2 + Cluster bean	3905	5825	40.1
SEm ±	86.5	93.7	1.23
CD (P=0.05)	250	271	NS

Nitrogen management			
N_1: 100 % Rec. N to maize	3838	5809	39.7
N_2: 75 % Rec. N to maize	3791	5694	40.0
N_3: 50 % Rec. N to maize	3055	4984	38.0
SEm ±	79.2	83.4	1.01
CD (P=0.05)	229	241	NS

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Table 6 : Biometric observations of greengram as influenced by maize + legume intercropping and nitrogen management

Treatment	Plant height (cm)			Leaf area index			Dry matter production (kg ha^{-1})		
	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest
(Maize + greengram) + N_1	10.3	59.4	59.6	0.32	2.89	2.02	110	2401	2492
(Maize + greengram) + N_2	10.4	59.1	59.1	0.30	2.80	1.98	96	2398	2413
(Maize + greengram) + N_3	10.3	59.0	59.0	0.30	2.80	1.96	96	2346	2409
Sole greengram	10.5	60.2	59.6	0.33	3.02	2.63	114	2462	2562

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N_1, N_2 and N_3 are 100, 75 and 50 % recommended doses of nitrogen to maize respectively.

Table 7 : Yield attributes and yield of greengram as influenced by maize + legume intercropping and nitrogen management

Treatment	Yield attributes				Yield	
	No. of clusters per plant	No. of pods per cluster	No. of seeds per pod	1000 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
(Maize + greengram) + N_1	11.0	5.3	5.5	37.5	418	860
(Maize + greengram) + N_2	10.8	4.9	5.2	37.1	394	854

(Maize + greengram) + N_3	9.6	5.4	4.9	36.1	384	851
Sole greengram	11.6	5.5	5.4	38.0	425	860

N_1, N_2 and N_3 are 100, 75 and 50 % recommended doses of nitrogen to maize, respectively

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Table 8 : Biometric observations of blackgram as influenced by maize + legume intercropping and nitrogen management

Treatment	Plant height (cm)			Leaf area index			Dry matter production (kg ha^{-1})		
	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest
(Maize + blackgram) + N_1	11.2	45.2	49.8	0.32	3.01	2.19	360	2280	2436
(Maize + blackgram) + N_2	11.0	45.3	48.1	0.29	2.98	2.78	354	2200	2380
(Maize + blackgram) + N_3	11.0	45.3	47.1	0.30	2.98	2.11	350	2196	2300
Sole blackgram	12.2	47.4	50.1	0.32	3.21	3.01	375	2460	2502

N_1, N_2 and N_3 are 100, 75 and 50 % recommended doses of nitrogen to maize, respectively.

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Table 9 : Yield attributes and yield of blackgram as influenced by maize + legume intercropping and nitrogen management

Treatment	Yield attributes				Yield	
	No. of clusters per plant	No. of pods per cluster	No. of seeds per pod	1000 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
(Maize + blackgram) + N_1	6.2	12.6	3.6	46.6	378	609
(Maize + blackgram) + N_2	5.3	12.3	4.3	46.0	362	538
(Maize + blackgram) + N_3	5.2	12.0	4.1	45.7	358	514
Sole blackgram	6.4	13.3	4.2	48.1	421	713

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N_1, N_2 and N_3 are 100, 75 and 50 % recommended doses of nitrogen to maize, respectively.

Table 10:Biometric observations of cluster bean as influenced by maize + legume intercropping and nitrogen management

Treatment	Plant height (cm)			Leaf area index			Dry matter production (kg ha^{-1})		
	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest	25 DAS	50 DAS	Harvest
(Maize + cluster bean) +N_1	9.9	54.6	70.3	0.7	2.9	1.7	124.8	1286	4402
(Maize + cluster bean) +N_2	8.8	51.4	70.2	0.6	2.6	1.6	117.0	1050	4208
(Maize + cluster bean) +N_3	8.3	43.3	69.1	0.5	2.5	1.4	109.8	1072	3891
Sole cluster bean	10.9	55.6	72.0	0.7	3.1	1.9	128.4	1352	4580

The study revealed that maize + legume intercropping and nitrogen management had a significant impact on yield attributes, yield, and soil fertility. The treatment with 100% recommended dose of nitrogen (N1) in maize + cluster bean intercropping system showed improved yield attributes and yield, resulting in 5.0 clusters per plant, 16.8 pods per cluster, 5.9 seeds per pod, 42.9g 1000 seed weight, and 1063 kg/ha seed yield. Additionally, the haulm yield was recorded at 2900 kg/ha. The highest maize grain equivalent yield (5790 kg/ha) and land equivalent ratio (1.938) were recorded in the treatment where maize was intercropped with cluster bean (T5). Nitrogen management also had a significant impact on maize grain equivalent yield and land equivalent ratio. The highest nitrogen uptake (105.0 kg/ha) was recorded in the treatment where maize was grown alone (T1), while intercropping maize with greengram (T3) and blackgram (T4) resulted in similar nitrogen uptake (97.1 kg/ha). Nitrogen management significantly influenced the nutrient uptake of greengram, blackgram, and cluster bean, with the highest nitrogen uptake recorded in cluster bean (34.0 kg/ha) when 100% recommended nitrogen (N1) was applied. The highest soil available nitrogen (177 kg/ha) was recorded in the treatment where 100% recommended nitrogen (N1) was applied to maize, while intercropping maize with greengram (T3) also resulted in higher soil available nitrogen (176 kg/ha). The highest computed nitrogen balance (125 kg/ha) was recorded in the treatment where maize was intercropped with greengram (T3) and cluster bean (T5) with 100% recommended nitrogen (N1). The growth parameters, yield attributes, and yield of the intercrops, viz., greengram, blackgram, and cluster bean, were higher in their respective sole crops, followed by application of 100%, 75%, and 50% recommended dose of nitrogen to maize.The maize grain equivalent yield and land equivalent ratio were higher in maize + cluster bean intercropping, followed by maize + greengram and maize + blackgram. The application of 100% recommended dose of nitrogen to maize resulted in significant superiority of maize grain equivalent yield and land equivalent ratio.The nutrient uptake by maize was influenced by maize intercropping and nitrogen management. The highest value of nitrogen and phosphorus uptake by maize was associated with 60 x 20 cm planting, which was comparable with that of maize + greengram and maize + blackgram intercrops.The post-harvest soil status of available nitrogen, phosphorus, and potassium was influenced by maize intercropping and nitrogen management. The post-harvest soil status of available nitrogen was highest in maize + greengram, closely followed by maize + blackgram and maize + cluster bean intercropping.

Conclusion

The study investigated the effects of maize intercropping and nitrogen management on maize growth, yield, and economic returns. The results showed that maize intercropping and nitrogen management significantly influenced maize growth, yield attributes, and yield. Sole maize at 60 x 20 cm spacing and maize + cluster bean intercropping resulted in higher growth parameters, yield attributes, and yield.The application of 100% recommended dose of nitrogen to maize resulted in significant higher yield attributes and grain and stover yield. The growth parameters, yield attributes, and yield of the intercrops were higher in their respective sole crops, followed by application of 100%, 75%, and 50% recommended dose of nitrogen to maize. In conclusion, the study suggests that maize intercropping with cluster bean and application of 100% recommended dose of nitrogen to maize can result in higher growth parameters, yield attributes, and yield, as well as higher economic returns. Optimizing nitrogen management in maize-based intercropping systems is crucial to achieve higher yields.

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