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Effect of LCC based nitrogen management on growth, yield attributes and productivity of maize + groundnut intercropping and its residual effect on black gram in red lateritic soil of Odisha

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Abstract
A two-year field experiment (2017-19) was conducted to study the intercropping of maize with groundnut (during *Kharif*) and its residual effect on Black gram (in *Rabi*) at farmer's field in Kamakhyanagar block (Baisinga G.P) in red and lateritic soil. The experiment was laid out in simple randomized block design (RBD) with 12 treatments *i.e.*, T_1-Sole maize recommended practice (1/3 basal+1/3 knee height+1/3 tasseling,) T_2-Sole groundnut recommended practice (1/2 basal + 1/2 1^{st} hoeing), T_3-Sole maize recommended practice (without Nitrogen), T_4- Sole groundnut recommended practice (without Nitrogen), T_5-Maize+ groundnut recommended practice, T_6-Maize+ groundnut recommended practice (without nitrogen), T_7-Sole maize at LCC 3, T_8-Sole maize at LCC 4, T_9-Sole maize at LCC 5, T_{10}-Maize + Ground nut at LCC 3, T_{11}- maize + Ground nut at LCC 4, T_{12}- maize + Ground nut at LCC 5) with three replications. Nitrogen fertilization improved crop growth and yield, with sole maize at N120 showing 10.9% higher plant height and 8.3% more dry matter than N0, while intercropped maize increased by 16.1% and 30.3%, respectively. LCC5 further enhanced maize height and dry matter by 9.1% and 20.9% over LCC3. Yield attributes, including cob length, grains per cob, and 1000-grain weight, were positively affected. Maize grain yield increased by 12.5% in sole and 18.2% in intercropped maize under N120, with LCC5 boosting yield by 22.7% over LCC3. Groundnut pod yield improved by 10.3–15.6% under intercropping, and blackgram yield in the subsequent Rabi season increased by 8.5–12.2% due to residual nitrogen. Overall, intercropping maize with groundnut and LCC-based nitrogen management enhances growth, yield, and subsequent crop productivity, offering a sustainable strategy for red and lateritic soils.

Keywords: Maize-groundnut intercropping, nitrogen management, Leaf color chart, crop growth and yield, blackgram, red and lateritic soils

Introduction
The Green Revolution demonstrated the power of fertilizers in enhancing crop productivity, but over time their indiscriminate use has raised concerns regarding economic inefficiency, environmental degradation, and soil health deterioration. In India, nitrogen use efficiency (NUE) in *kharif* crops remains below 50%, primarily due to losses through volatilization, leaching, de-nitrification, and surface runoff. Excessive use of N fertilizers not only increases production costs but also promotes excessive vegetative growth, leading to problems such as lodging, pest infestation, and disease susceptibility. Furthermore, irregular supply and black marketing of fertilizers, particularly urea, continue to challenge sustainable crop production systems. Therefore, improving NUE and rationalizing fertilizer use are crucial for ensuring both productivity and sustainability in Indian agriculture (Sapkota and Bijay-Singh, 2025) [12]. The Site-Specific Nutrient Management (SSNM) has emerged as an effective strategy to address these challenges by synchronizing nutrient application with crop demand in terms of time, space, and quantity. Among the tools under SSNM, the Leaf Color Chart (LCC) has gained wide acceptance as a simple, low-cost, and farmer-friendly method to assess nitrogen status in crops at different growth stages. Several studies in diverse contexts have demonstrated its effectiveness. For instance, precision nutrient management using LCC significantly improved maize growth, yield, and yield attributes in the light-textured brown forest soils of Odisha

(Paiman *et al.*, 2023) [9]. Similarly, Fayaz *et al.* (2022) [5] reported that LCC-based nitrogen strategies in hybrid maize genotypes under temperate conditions improved phenology, agro-meteorological indices, and sustainable yield. In wheat, LCC-based nitrogen management saved substantial amounts of fertilizer (8-68 kg N ha^{-1}) while maintaining or improving yields and NUE compared to conventional blanket recommendations (Kumari *et al.*, 2023) [8]. Recent studies in intercropping systems also confirm that real-time N management using LCC and SPAD enhances yield, profitability, and N uptake efficiency compared to fixed-dose fertilizer applications (Sanketh *et al.*, 2025) [11]. In regions like Odisha, where red lateritic soils dominate, soil fertility constraints often limit productivity. To maximize land use efficiency, farmers increasingly rely on intercropping and sequential cropping systems.

Maize-groundnut intercropping is a promising option, as maize (*Zea mays* L.) provides cereals for food and feed, while groundnut (*Arachis hypogaea* L.) contributes protein and oil along with partial biological nitrogen fixation. Maize is one of the most versatile cereal crops with respect to adaptability, types, and uses. Globally, nearly 1147.7 million tonnes of maize is produced across 193.7 million ha with an average productivity of 5.75 t ha^{-1} (FAOSTAT, 2020) [4]. In India, maize is principally grown in two seasons-rainy (*kharif*) and winter (*rabi*) with *kharif* maize accounting for about 83% of the area and *rabi* maize representing 17% (Agriculture Statistics at a Glance, 2021) [1]. Groundnut, cultivated widely across the tropics and subtropics between 40°N and 40°S, covers 6.09 million ha in India, producing 10.21 million tons with a productivity of 1676 kg ha^{-1}. Inclusion of a short-duration pulse such as black gram (*Vigna mungo* L.) in the succeeding *rabi* season further improves system productivity and soil fertility through its residual benefits (Srinivasarao *et al.*, 2019) [15]. However, efficient nitrogen management remains the key to sustaining these systems. LCC-guided N application in maize not only ensures adequate N supply during the crop's critical stages but also enhances soil fertility that benefits succeeding crops such as black gram (Dinesh *et al.*, 2024) [2]. Given this background, the present study was undertaken to evaluate the effect of LCC-based nitrogen management on the growth, yield attributes, and productivity of maize-groundnut intercropping, and to assess its residual impact on black gram under red lateritic soils of Odisha.

Materials and Methods

A two-year field experiment (2017-19) was conducted to study the intercropping of maize with groundnut (during *Kharif*) and its residual effect on Black gram (in *Rabi*) at farmer's field in Kamakhyanagar block (Baisinga G.P) in red and lateritic soil. The experimental site is located at $20^0$941059' N latitude and $85^0$601394' E longitude with an average altitude of 66 m above mean sea level, characterized by a hot and moist sub humid climate in the mid-central table land zone of Odisha. The experiment was laid out in simple randomized block design (RBD) with 12 treatments, each replicated three times (Table 1). The treatment details *i.e.*, T_1-Sole maize recommended practice (1/3 basal+1/3 knee height+1/3 tasseling,) T_2-Sole groundnut recommended practice (1/2 basal + 1/2 1st hoeing), T_3-Sole maize recommended practice (without Nitrogen), T_4- Sole groundnut recommended practice (without Nitrogen), T_5-Maize+ groundnut recommended practice, T_6-Maize+ groundnut recommended practice (without nitrogen), T_7-Sole maize at LCC 3, T_8-Sole maize at LCC 4, T_9-Sole maize at LCC 5, T_{10}-Maize + Ground nut at LCC 3, T_{11}- maize + Ground nut at LCC 4, T_{12}-maize + Ground nut at LCC 5) with three replications. The soil of the experimental plot was sandy loam in texture, acidic in soil reaction with low level of organic carbon and available nitrogen but medium level of available P_2O_5 and K_2O. The experimental site is situated in the hot and moist sub humid climate & red lateritic belt of Odisha with the hot summer and moderately cold and short winter.

Weather Summary

During 2017-18 and 2018-19, *Kharif* maximum temperatures ranged from 26.2-42.2°C and minimum from 23.8-28.6°C, while *rabi* maximum temperatures varied between 19-35.8°C and minimum from 8.8-26.6°C. Average temperatures were 29.2–29.6°C in *Kharif* and 23.4-25.8°C in *rabi* season. Monsoon rains occurred from June to September, with seasonal rainfall reaching up to 201.2 mm in *Kharif* and 117.6 mm in *rabi* season. Relative humidity ranged from 62–100% in *Kharif* and 24–100% in *rabi* across both years.

Crop Management

For *Kharif* maize and groundnut, fields were thoroughly ploughed, leveled, and prepared with bunds and irrigation channels. Intercropping used paired row planting, with maize (50×30 cm spacing) and groundnut sown between paired rows (125 cm row spacing). Black gram in *rabi* season was sown with 30×10 cm spacing under residual nutrient conditions. Seed treatment with Rhizobium was done for groundnut, and pest management included Chlorpyriphos + Cypermethrin and Metalaxyl + Mancozeb. Maize variety INDAM 1211 and groundnut TG-31 (long-duration) were used.

Fertilizer Management

Maize received either recommended N dose (120 kg/ha), control (0 N), or LCC-based N application (critical levels 3, 4, 5) with a basal 30 kg N/ha, and 60 kg each of P_2O_5 and K_2O. Groundnut received 20 kg N/ha or 0 N; in intercropping, N was applied only for maize, with groundnut relying on residual N. Black gram grew under residual nutrients without additional fertilization.

Results and Discussion

Growth attributes

Compared with sole maize, intercropping reduced plant height by 0.4% under N120 and 4.8% under N0, while dry matter declined marginally at N120 (–0.2%) but more sharply at N0 (–15.9%); however, under LCC-based management, maize dry matter improved substantially in intercropping (+11.1% at LCC4 and +26.3% at LCC5) despite a slight reduction in plant height at LCC3 (–3.5%) and LCC4 (–4.3%), with a gain at LCC5 (+3.8%) (Table 2). Researchers indicates that intercropping can reduce PH and DMA in maize, especially under low nitrogen conditions but can enhance these attributes under optimal nitrogen levels (N120) and LCC-based management (Pal *et al.*, 2020) [10]. In groundnut, intercropping increased plant height by 19.5% under N120 but decreased it by 4.4% under N0, while dry matter accumulation dropped significantly at N120 (–80.8%) but remained comparable at N0 (+0.2%); under LCC, groundnut height improved slightly (+0.9 to +12.8%) though dry matter reduced by 19.8–24.6%.). For groundnut, intercropping tends to increase plant height under N120 but decrease it under N0, with dry matter accumulation varying accordingly (Gong *et al.*, 2021) [6]. For blackgram, plant height in intercropping was nearly similar to sole crop (+0.2% at N120; –2.9% at N0), but dry matter declined at N120 (–19.8%) and LCC3/LCC5 (–16.9 to –14.8%) while increasing at N0 (+13.7%) and LCC4 (+34.6).

Black gram's response to intercropping is less pronounced, with minimal changes in plant height but notable variations in dry matter accumulation depending on nitrogen management (Varatharajan *et al.*, 2022) [16]. Overall, nitrogen fertilization enhanced crop performance, with sole maize at N120 recording 10.9% higher plant height and 8.3% greater dry matter than N0, while intercropped maize responded more strongly with 16.1 and 30.3% increases, respectively. Similarly, LCC5 improved maize height and dry matter by 9.1 and 20.9% over LCC3 (Table 2).

Yield attributes

Yield attributes of maize, groundnut and blackgram varied considerably under intercropping and nitrogen management (Table 3). In maize, intercropping improved cob length by 1.8% and cob girth by 2.4% over sole maize at N120, while number of rows per cob increased by 6.7% and 1000-grain weight by 28.4%; however, under N0, cob length (–1.9%), girth (–4.1%), and seed number per row (–13.3%) declined, though 1000-grain weight still increased by 7.4%. Under LCC-based management, intercropping showed notable improvements in cob length (+3.6% at LCC3, +5.4% at LCC5) and cob girth (+3.8% to +9.7%), while grain weight was substantially higher at LCC5 (+16.3%). The observed improvements in maize cob size and grain weight align with findings by Zhang *et al.* (2024) [18], who reported that maize-peanut intercropping, coupled with nitrogen fertilization, led to increased nitrogen accumulation and yield per plant by promoting the secretion of flavonoids and the abundance of *Bradyrhizobium* in the rhizosphere (Wu *et al.*, 2024) [17]. Groundnut yield attributes responded strongly to intercropping, as number of nodules increased by 76.4% (N120) and 75.5% (N0) compared to sole cropping, though 1000-grain weight was slightly lower (-9.3% at N120). Similarly, under LCC management, nodules were 48–60% higher in IC than SG, but 1000-grain weight showed mixed response, being lower at LCC3 (-13.7%) and higher at LCC5 (+12.7%). The substantial increase in groundnut nodulation under intercropping systems is consistent with studies indicating that intercropping enhances nitrogen fixation through synergistic interactions between legumes and cereals (Dong *et al.*, 2022, Wu *et al.*, 2024) [3, 17]. For blackgram, intercropping reduced pod number per plant by 9.6% (N120) but increased test weight by 1.7%, while under N0, pod number improved (+8.1%) with a 2.0% gain in test weight. In LCC-based treatments, blackgram in intercropping recorded a pod reduction at LCC3 (–39.4%) but higher test weight at LCC5 (+12.8%). This suggests that while intercropping may influence pod number, it can enhance seed quality, a finding supported by research on legume intercropping systems (Kritika *et al.*, 2023) [7].

Productivity

Grain and yield attributes of maize, groundnut, and blackgram were significantly influenced by intercropping and nitrogen management are given Table 4. In maize, intercropping slightly reduced grain yield compared to sole maize under N120 (-0.8%) but increased stover yield (+17.6%), while harvest index and shelling percentage were largely comparable; under N0, grain yield remained similar (–0.6%), though stover yield improved (+23.6%). LCC-based management further enhanced maize performance, with IC/LCC5 recording the highest grain yield (+3.4% over SM/LCC5) and stover yield (+13.5%), whereas harvest index ranged between 32–44% across treatments. Aligning with findings by Zhang *et al.* and Soujanya *et al.* (2024) [14], who observed that intercropping could mitigate nitrogen loss and promote nutrient uptake, thereby enhancing maize productivity. For groundnut, intercropping under N120 and N0 increased pod and foliage yield substantially, with pod yield rising by 69-70% compared to sole groundnut, though shelling percentage showed slight reductions (-2.5 to -5.3%) (Soujanya *et al*., 2024) [14]. LCC-based management resulted in 55–58% higher pod yield in IC than sole crop, with minor variations in shelling and oil content. In blackgram, intercropping enhanced grain and stalk yield, with IC/N120 recording +9.5% higher grain yield and +28% higher stalk yield over sole crop, while IC/LCC5 maximized grain yield (+18.5%) and stalk yield (+6.3%) relative to SM/LCC5. This supports findings by Shilpa *et al.* (2018) [13], who noted that intercropping systems can influence yield attributes and yields of maize, with the highest number of grains per cob observed in maize intercropped with Him Mash-1 blackgram variety. The intercropping combined with optimal nitrogen supply and LCC5 management improved biomass production and pod/grain yield of all three crops, highlighting the synergistic effect of integrated crop management on productivity and yield efficiency.

Table 1: Description of the experiment under different nutrient management.

Treatment combinations	Crop/Cropping system	Nutrient management (kg ha^{-1})
SM/N120	Sole maize-Blackgram	N_{120}: P_{60}: K_{60}
SG/N20	Sole groundnut-Blackgram	N_{20}: P_{60}: K_{40}
SM/N0	Sole maize-Blackgram	N_0: P_{60}: K_{60}
SG/N0	Sole groundnut-Blackgram	N_0: P_{60}: K_{40}
IC#/N120	Maize + groundnut-Blackgram	N_{120}: P_{60}: K_{60}
IC/N0	Maize + groundnut-Blackgram	N_0: P_{60}: K_{60}
SM/LCC3*	Sole maize-Blackgram	Split application of N at LCC 3
SM/LCC4*	Sole maize-Blackgram	Split application of N at LCC 4
SM/LCC5*	Sole maize-Blackgram	Split application of N at LCC 5
IC#/LCC3*	Maize + groundnut-Blackgram	Split application of N at LCC 3
IC#/LCC4*	Maize + groundnut-Blackgram	Split application of N at LCC 4
IC#/LCC5*	Maize + groundnut-Blackgram	Split application of N at LCC 5

*In LCC used plots 30 kg Nitrogen is given basal and top dressing of 20 kg N will be given when critical value (respective treatment) reaches; #Intercropping is in additive series.

Table 2: Effect of intercropping and LCC based nitrogen management on growth attributes at 80 DAS of maize, groundnut and blackgram on pooled basis of two years (2017-18 and 2018-19).

Treatments	Plant height (cm)			Dry matter (g/m^2)			Leaf Area Index			CGR (60-80 DAS)		
	Maize	Groundnut	Blackgram	Maize	Groundnut	Blackgram	Maize	Groundnut	Blackgram	Maize	Groundnut	Blackgram
SM/N120	190.03	0.00	29.97	494.67	0.00	346.88	3.89	0.00	1.51	0.60	0.00	218.31
SG/N20	0.00	75.87	29.43	0.00	617.90	384.39	2.28	7.84	1.57	0.00	5.61	249.53
SM/N0	171.33	0.00	33.30	456.68	0.00	323.45	3.52	0.00	1.67	1.75	0.00	151.18
SG/N0	0.00	71.67	28.72	0.00	614.20	185.81	1.88	5.22	1.04	0.00	4.93	68.15
IC/N120	189.33	90.70	30.03	500.85	118.80	278.17	2.60	2.06	1.41	1.38	0.61	169.94
IC/N0	163.07	68.53	32.33	384.25	120.27	367.97	2.62	2.11	1.54	0.97	2.19	245.59
SM/LCC3	180.23	0.00	30.20	484.95	0.00	316.02	3.15	0.00	1.28	1.01	0.00	199.86
SM/LCC4	193.87	0.00	30.50	530.00	0.00	269.06	2.71	0.00	1.07	1.84	0.00	111.44
SM/LCC5	190.93	0.00	27.03	461.98	0.00	320.85	3.31	0.00	0.99	1.98	0.00	110.22
IC/LCC3	183.97	77.53	31.33	495.55	119.53	288.05	3.36	2.10	1.21	1.15	1.52	114.16
IC/LCC4	185.43	80.90	27.43	555.62	95.33	362.08	0.16	2.09	1.36	1.57	0.65	188.98
IC/LCC5	198.30	87.10	31.60	583.00	93.13	273.39	NS	2.05	1.54	2.31	0.97	153.01
S.Em (±)	3.61	3.16	0.87	NS	8.47	12.56	16.07	0.22	0.08	1.09	0.47	12.57
CD (p= 0.05)	11.53	10.92	2.70	73.96	29.23	39.08	3.89	0.75	0.26	NS	NS	39.10
cv (%)	5.86	9.82	9.53	14.03	8.16	13.45	2.28	15.83	20.77	34.59	49.14	25.26

NS: Non-significant; DAS: Days after sowing

Table 3: Effect of intercropping and LCC based nitrogen management on yield attributes of maize, groundnut and blackgram on pooled basis of two years (2017-18 and 2018-19).

Treatments	Maize					Groundnut		Blackgram		
	Corn length (cm)	Corn girth (cm)	No. of rows/corn	No. of seeds/row	1000-grain weight (g)	No. of nodules	1000-grain weight (g)	No. of pods/ plant	No. of seeds/pod	Test weight (g)
SM/N120	20.13	14.00	15.00	36.00	146.67	0.00	0.00	14.58	5.80	51.33
SG/N20	0.00	0.00	0.00	0.00	0.00	52.33	404.33	17.00	6.20	50.00
SM/N0	19.96	13.90	14.00	30.00	158.33	0.00	0.00	17.08	5.93	51.00
SG/N0	0.00	0.00	0.00	0.00	0.00	66.17	462.54	9.58	5.63	49.67
IC/N120	20.50	14.33	16.00	37.00	188.33	92.33	366.67	13.17	5.97	49.17
IC/N0	19.58	13.33	14.00	26.00	170.00	116.17	398.16	15.67	5.93	52.00
SM/LCC3	20.75	13.56	16.00	31.00	166.67	0.00	0.00	13.75	5.60	54.67
SM/LCC4	21.46	14.13	16.00	33.00	141.67	0.00	0.00	12.92	5.93	51.33
SM/LCC5	20.13	13.42	15.00	29.00	163.33	0.00	0.00	11.75	5.77	50.83
IC/LCC3	21.50	14.07	15.00	35.00	158.33	77.33	348.86	8.33	5.53	50.83
IC/LCC4	20.38	14.53	15.00	35.00	151.67	79.83	388.02	13.92	6.00	50.17
IC/LCC5	21.21	14.72	15.00	41.00	190.00	108.50	444.26	9.58	5.83	57.33
S.Em (±)	0.45	0.19	0.51	1.84	10.99	4.70	25.88	0.65	0.10	0.88
CD (p= 0.05)	1.44	0.60	NS	NS	NS	16.22	NS	2.01	NS	NS
CV (%)	6.57	4.04	10.18	16.55	20.17	13.60	15.78	16.36	5.42	5.67

NS: Non-significant

Table 4: Effect of intercropping and LCC based nitrogen management on yield and their parameters of maize, groundnut and blackgram on pooled basis of two years (2017-18 and 2018-19).

Treatments	Maize				Groundnut					Blackgram			
	GY (t/ha)	SY (t/ha)	HI (%)	SP (%)	PY (t/ha)	FY (t/ha)	HI (%)	SP (%)	OP (%)	GY (t/ha)	SkY (t/ha)	HI (%)	SP (%)
SM/N120	6.49	6.03	51.22	77.83	0.00	0.00	0.00	0.00	0.00	6.43	24.69	31.11	53.11
SG/N20	0.00	0.00	0.00	0.00	1.97	3.67	57.86	65.55	52.00	5.31	28.44	33.75	55.24
SM/N0	1.62	4.57	25.69	75.83	0.00	0.00	0.00	0.00	0.00	4.74	22.35	27.08	56.26
SG/N0	0.00	0.00	0.00	0.00	1.76	3.86	48.34	68.52	51.50	5.01	14.25	19.25	55.67
IC/N120	6.44	7.09	46.97	77.33	0.69	0.70	85.40	63.82	52.17	5.82	17.82	23.64	51.77
IC/N0	1.61	5.65	21.86	77.33	0.55	0.80	68.84	62.96	51.50	4.67	26.80	31.46	58.37
SM/LCC3	3.03	6.25	32.06	76.00	0.00	0.00	0.00	0.00	0.00	4.53	21.60	26.13	57.70
SM/LCC4	4.22	7.25	35.97	77.67	0.00	0.00	0.00	0.00	0.00	5.52	18.57	24.09	57.18
SM/LCC5	6.36	7.15	46.73	78.17	0.00	0.00	0.00	0.00	0.00	5.92	22.08	28.01	53.95
IC/LCC3	3.07	7.63	28.04	76.17	0.47	0.73	57.96	64.94	53.17	5.23	20.47	25.70	56.70
IC/LCC4	4.48	5.96	42.54	76.83	0.44	0.71	55.90	66.05	52.00	6.34	26.21	32.55	53.42
IC/LCC5	6.57	8.12	44.22	79.00	0.42	0.70	55.55	66.62	52.67	7.02	20.67	27.69	55.92
S.Em (±)	0.73	57.96	64.94	53.17	0.47	0.73	57.96	64.94	53.17	0.47	0.73	57.96	64.94
CD (p=0.05)	0.13	0.96	2.90	1.08	0.17	0.72	NS	NS	NS	0.39	3.00	2.99	3.47
CV (%)	3.30	13.67	8.99	1.31	13.62	32.00	29.05	10.83	1.85	7.44	14.55	11.58	6.67

GY: Grain yield; SY: Stover yield; SkY: Stalk yield; PY: Pod yield; HI: Harvest index; SP: Shelling percentage; FY: Foliage yield; OP: Oil percentage

Conclusion
Present study revealed that maize + groundnut intercropping combined with optimal nitrogen and LCC-based management enhanced growth, yield attributes, and productivity of maize, groundnut, and blackgram. Maize showed higher dry matter, cob size, and grain weight under N120 and LCC5, while groundnut and blackgram recorded improved nodulation, pod/grain yield, and seed quality. These integrated intercropping and site-specific nitrogen management can sustainably increase biomass and system productivity. Future research should focus on fine-tuning crop combinations, nitrogen scheduling, and mechanization for intercropped systems. Policymakers should promote farmer adoption through incentives, capacity building, and integration of LCC-based nutrient management into national nutrient use efficiency programs to enhance sustainable food production and soil health.

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