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Growth and Productivity of Maize (*Zea mays* L.) as Influenced by Precision Nutrient Management and Intercropping Cowpea (*Vigna unguiculata* L.) under Hot and Sub-humid Region of Odisha

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ABSTRACT

Background: Cereal-legume intercropping is an age-old practice in most of the countries. Among the major cereals, maize is a better choice to include in legume intercropping due to its morphology and wider row spacing. Therefore, legume intercropping in consort with proper nutrient management can enhance overall productivity of the system, further improving crop diversification, nutritional security and agriculture sustainability. Considering these aspects, the present study was performed to examine the growth and productivity of maize as influenced by precision nutrient management and cowpea intercropping.

Methods: The present study was carried out during *rabi* season of 2022-23 at P. G. Research Farm of M.S. Swaminathan School of Agriculture, Odisha, India. The experiment was laid out in split-plot design with five intercropping combinations and five nutrient management treatments. All the treatments were replicated thrice. The plot size maintained was 5.0 m × 4.8 m. In case of maize and cowpea, high yielding hybrid 'JKMH 4510' and 'KBC 9' variety were taken for the study, respectively.

Result: The results revealed that the growth parameters were significantly affected by intercropping ratios and nutrient management treatments. Although the yield attributes of maize were differed non significantly among the intercropping treatments but were significantly influenced by the nutrient treatments. In case of grain yield of maize, the Green Seeker-based nutrient management gave highest value with cowpea intercropping ratio of 1:1 and 2:2. LER and ATER were greater than unity, which indicated that the intercropping was advantageous. However, the maximum LER and Area Time Equivalent Ratio (ATER) were obtained from C_3 (M+C 1:2) with 140:70:70 kg N, P_2O_5, K_2O/ha, respectively. The study concluded that intercropping of maize + cowpea in 1:2 row ratio with Green Seeker-based nutrient management were advantageous over pure stand of maize fertilised with conventional nutrient management.

Key words: Competition functions, Cowpea, Green seeker, Maize, Nutrient management, Yield.

INTRODUCTION

In the present scenario of rapid global urbanisation, shrinkage of agricultural land, degradation of resources and ill effects of climate change are major concerns for agricultural sustainability (Noorunnahar *et al*., 2023; Sairam *et al*., 2023a). To meet the future need of foodgrains for ever-increasing population, there is urgent need for proper crop planning and intensification with efficient use of available resources (Maitra and Gitari, 2020; Maitra, 2020). In this aspect, intercropping can be an ideal choice in which multiple crops are cultivated over the same area at a given time (Sahoo *et al*., 2023). In countries like India, cereal based cropping system is widely adopted. Among the major cereals, maize is considered next to rice and wheat. Maize cultivation is increasing day by day in India due to its stable market price and versatile usage such as food, feed and fodder and its wider adaptability under diverse agroclimatic conditions (El-Mehy *et al*., 2023; Zalac *et al*., 2023). Intercropping of pulses in cereals is an age-old practice to ensure diversity in the food-basket for smallholders. Maize is cultivated in wide row spacing that offers suitable companion crops to grow under the mixed stand (Maitra *et al*., 2019). In maize-legume intercropping system, further space can be created by arranging paired row seeding

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where higher population of legumes can be seeded in an additive series to ensure more grain and biomass yield from unit area (Manasa *et al*., 2018; Maitra *et al*., 2020).

Maize-legume intercropping system can ensure crop diversification, enhanced resource use efficiency, higher gross productivity, natural insurance against adverse conditions and improvement of soil health (Baishya *et al*., 2021; Ndayisaba *et al*., 2021). Moreover, legumes share a portion of biologically fixed nitrogen to nonlegumes grown in the mixed stand and positively influence soil chemical and biological properties (Maitra *et al*., 2021; Singh *et al*., 2023). Among different legumes, cowpea is one of the most suitable pulses, which can perform in various agroclimatic conditions and cropping systems. There are suitable short duration and partial shade tolerant cultivars of cowpea, which can perform well in an intercropping system with taller cereals like maize as row intercropping (Nandi *et al*., 2022). The nitrogen requirement of legumes is less; however, maize is a high nutrient demanding crop. Therefore, when maize is considered as a cereal component with cowpea, required primary nutrients are to be provided to maize for its optimum yield. Among the primary nutrients, since nitrogen is subjected to various losses; hence, an optimization of nitrogen for maize is essential for increasing its productivity as well as nitrogen use efficiency (Nduwimana *et al*., 2020; Sairam *et al*., 2023b). In this regard, various precision tools developed for nitrogen management in cereals can be considered. The GreenSeeker is such a precision nitrogen management tool which is a hand-held optical sensor used for the real time nitrogen requirement of cereals at different growth stages through a non-destructive sampling of leaves (Ali *et al*., 2018). During recent time, the GreenSeeker-based nitrogen management is becoming popular (Kumar *et al*., 2022).

Considering these above facts, the present study was conducted to assess the effect of precision nutrient management in maize and intercropping cowpea on growth, productivity and competitive ability of maize under hot and sub-humid region of Odisha.

MATERIALS AND METHODS

The present study was carried out during rabi season of 2022-23 (25th November 2022 to 30th March 2023) at P. G. Research Farm of M.S. Swaminathan School of Agriculture, Odisha, India (23°39′ North latitude and 87°42′ East longitude). The meteorological data showed that the maximum and minimum temperature during the crop period varied from 29-35°C and 15-21°C respectively (Fig 1). The maximum relative humidity ranged between 79-91% and the minimum relative humidity varied from 37-68%. The total rainfall during the crop period was 71.8 mm and the average sunshine hours varied between 7-9 hours/day. The experimental soil was sandy loam in texture with a pH of 6.6. The electrical conductivity of the soil was 0.24 dS/m. The soil was lower in organic carbon (0.46%) and the initial nutrient status of nitrogen, phosphorous and potassium, are found to be 246, 12.6 and 143 kg/ha respectively. The experiment was laid out in split-plot design with five cropping systems in main plot and five nutrient management treatments in sub plot (Table 1) with three replications. Further, a reference plot of sole cowpea was laid out beside the experimental area.

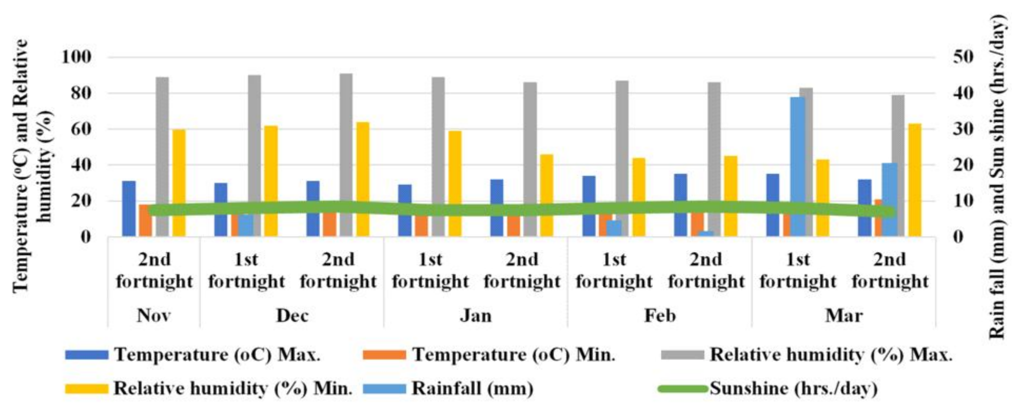
During the experiment, standard package of practices was considered for maize-legume intercropping system. In case of maize, hybrid 'JKMH 4510' and cowpea variety 'KBC 9' was considered for the study. The plot size maintained was 5 m × 4.8 m and maize uniform row and paired rows were sown with a row spacing of 60 cm and 90/30 cm respectively. The plant to plant spacing of maize adopted was 25 cm in both the row proportions. In between the inter row spacing of maize, one, two and three rows of cowpea was planted as per the treatment specifications. The plant-to-plant distance of cowpea were 10cm and in reference plot (sole cowpea) 30 cm × 10 cm spacing was adopted. The nutrients like nitrogen, phosphorous and potassium were applied through urea, single super phosphate and muriate of potash as per the nutrient treatments at different stages (Table 1). Five irrigations were provided to maize. To maintain the plots weed free, two hand weedings at 20 DAS and 50 DAS were performed. Emamectin benzoate 5% SG @ 250 g/ha was sprayed at 30 DAS to protect the crop from fall army worm (*Spodoptera frugiperda)*.

The growth and yield attributes of maize and yield of both the crops were recorded by adopting the standard procedures. The competitive functions such as land equivalent ratio, area time equivalent ratio, monetary advantage and maize equivalent yield were calculated by considering the concept and formulas given by Willey and Osiru (1972), Hiebsch (1978), Willey (1979) and De Wit (1960) respectively. The statistical analysis of the experimental data was processed by considering the concept of Gomez and Gomez (1984). The analysis of variance (ANOVA), the standard error of means (SEm±) and critical difference (CD) at 5% probability level of significance was analysed through Excel software, Microsoft Inc., Redmond, Washington, USA.

RESULTS AND DISCUSSION

Effect of intercropping system and nutrient management on growth parameters of maize

The results revealed that intercropping systems did not influence plant height significantly, however, it significantly impacted on dry matter accumulation and leaf area of maize (Table 2). Similar results were observed by Ogedegbe *et al*. (2017), because there was no competition for light due to morphological difference between the crops. Among cropping systems, C_1 (sole maize), C_2 (M+C 1:1) and C_4 (M+C 2:2) remained statistically at par in dry matter accumulation of maize and they were significantly superior to C_3 (M+C 1:2) and C_5 (M+C 2:3). Probable reasons may be no inter-species competition in C_1 and complementary effect in C_2 and C_4. C_3 and C_5 showed inferior values of dry matter accumulation due to higher interspecies competition as



Source: Agro-Meteorological Observatory, Centurion University of Technology and Management, Paralakhemundi, Odisha, India.

Fig 1: Agrometeorological observations during the crop period (Nov 2022 to Mar 2023).

Table 1: Details of the treatment.

Main plot (Intercropping system)							
C_1		Sole maize					
C_2		Maize uniform row (UR) + cowpea (1:1)					
C_3		Maize uniform row (UR) + cowpea (1:2)					
C_4		Maize paired row (PR) + cowpea (2:2)					
C_5		Maize paired row (PR) + cowpea (2:3)					
Sub plot (nutrient level in kg N, P_2O_5, K_2O/ha)		Nitrogen splits (kg/ha)					
		Basal	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
N_1	Control (0: 0: 0)	-	-	-	-	-	-
N_2	120: 60: 60	40	-	40	-	-	40
N_3	140: 70: 70	46.6	-	46.6	-	-	46.6
N_4	160: 80: 80	53.3	-	53.3	-	-	53.3
N_5	Green seeker (164: 60: 60)	40	10.2	18.4	24	40.8	30.6

Table 2: Effect of intercropping system and nutrient management on plant height, leaf area and dry matter accumulation of *rabi* maize.

Treatment	Plant height at harvest (cm)	Dry matter accumulation at harvest (g/m²)	Leaf area at 60 DAS (cm²/plant)
		Intercropping systems	
C_1	236	5079	1449
C_2	238	5187	1484
C_3	229	4762	1353
C_4	233	5016	1445
C_5	228	4716	1356
SEm±	4.9	46.6	23.2
CD (P=0.05)	NS	150.6	76.3
		Nutrient management	
N_1	174	3687	881
N_2	211	4189	1250
N_3	238	4772	1444
N_4	266	5779	1690
N_5	274	6271	1807
SEm±	3.1	68.9	33.1
CD (P=0.05)	8.9	197.1	94.7
		Interaction (C × N)	
SEm ±	7.8	145.6	70.2
CD (P=0.05)	NS	422.0	NS

cowpea population was more (Moriri *et al*., 2010; Prasanthi and Venkateswaralu, 2014). The treatments C_1 (5079 cm^2) and C_2 (5187cm^2) being statistically at par with each other recorded significantly higher maize leaf area/plant than rest of the cropping systems. Sole maize (C_1) did not fetch any interspecies competition; hence, utilized the resources full-fledgedly and expressed higher leaf area along with dry matter accumulation. The treatment M+C (2:2) recorded moderately higher leaf area of maize than rest of the treatments probably because of paired row arrangement of planting, which created enough space for cowpea. In case of C_3 and C_5, cowpea competed with maize due to its planting geometry and density respectively. The results are in conformity with the findings of Yavas and Unay (2016) and Gaikwad *et al*. (2022).

Nutrient management influenced plant height significantly, where the GreenSeeker-based treatment resulted in the highest plant height (277 cm) which was statistically at par with N_4 (266 cm). Further, the treatment N_3 increased plant height of maize and it remained significantly superior to N_2 (211 cm) and N_1 (174 cm). Such differences were obtained probably due to variation in nutrient doses and their split application. In the Green Seeker-based treatment, nitrogen was applied for six times which might increase N-use efficiency (Pooniya *et al*., 2015; Kumar *et al*., 2022). As expected, N_1 produced significantly the lowest plant height than remaining treatments because of no exogenous application of nutrients. Almost a similar trend was observed in leaf area/plant in maize as influenced by nutrient management. However, N_5 showed its supremacy over rest of the treatments. The second-best treatment was N_4, which was significantly superior to N_3 and its lower doses. The results clearly support the importance of nutrient needs as well as split application of nitrogen in maize (Pooniya *et al*., 2015; Kumar *et al*., 2022; Singh *et al*., 2015). The dry matter accumulation/m^2 followed exactly a same trend as leaf area/ plant of maize in which the GreenSeeker-based recommendation produced significantly higher value than other treatments. The trend was like C_5<C_4<C_3<C_2<C_1. The higher leaf area led to increase in the photosynthetic capacity which increased dry matter accumulation in maize (Parihar *et al*., 2017; Shivashankar *et al*., 2023).

Effect of intercropping system and nutrient management on yield attributes of maize

Yield attributes of maize were not affected by the different intercropping ratios (Table 3). Marginally higher number of cobs/plant and number of grains/cob were recorded with C_2 (M+C 1:2). Ogedegbe *et al*. (2017) and Nandi *et al*. (2022) also reported nonsignificant effect of intercropping systems on these yield attributes. Although, nutrient level N_5 led to the highest number of cobs/plant (1.83), which was found at par with N_4 (160: 80: 80 kg N,P_2O_5,K_2O/ha). The treatment N_3 (160: 80: 80 kg N, P_2O_5, K_2O/ha) increased the number of cobs/plant and it remained significantly superior to N_2 (1.45) and N_1 (1.12). Similar results were also obtained for number of grains/cob. However, N_5 (GreenSeeker-based nutrient management) showed its superiority over other treatments. The treatment N_3 (218) was significantly inferior to N_4 (160: 80: 80 kg N, P_2O_5, K_2O/ha) (282) in production of number of grains/cob. The 1000 grain weight of maize as affected by nutrient doses varied from 233g for N_5 to 210g for N_1. Treatment N_5 and N_4 were at par with each other while other treatments were at par with N_1. The result

Table 3: Effect of intercropping system and nutrient management on yield parameters of *rabi* maize.

Treatment	Cobs/plant	Grains/cob	1000 grain weight (g)	Grain yield of maize (kg/ha)	Grain yield of cowpea (kg/ha)
			Intercropping system		
C_1	1.58	240	223	5374	-
C_2	1.60	246	224	5488	477
C_3	1.54	228	220	5027	867
C_4	1.58	237	221	5323	489
C_5	1.54	223	220	4843	768
SEm ±	0.045	5.6	4.1	86.7	13.1
CD (P=0.05)	NS	NS	NS	282.7	45.2
			Nutrient management		
N_1	1.12	168	210	2154	275
N_2	1.45	196	217	4636	674
N_3	1.66	218	220	5602	784
N_4	1.77	282	229	6593	828
N_5	1.83	311	233	7070	690
SEm ±	0.054	4.2	3.5	81.7	14.8
CD (P=0.05)	0.255	12.2	10.0	233.5	42.6
			Interaction (C × N)		
SEm ±	0.152	10.2	8.1	185	29.6
CD (P=0.05)	NS	NS	NS	545.0	83.4

demonstrated the importance of nutrient management in attaining better yield attributes. Precision nutrient management with GreenSeeker probably helped in increasing the nutrient use efficiency; thus resulting in higher values of yield attributes as recorded by (Sinha, 2016) and Vikram *et al*., 2015).

Effect of intercropping system and nutrient management on grain yield of maize and cowpea

The treatment C_2 (M+C 1:1) (5488 kg/ha) being at par with C_1 (5374 kg/ha) and C_4 (5323 kg/ha) produced the highest grain yield of maize (Table 3). C_3 (M+C 1:2) contributed significantly lower grain yield than other treatments and was at par with C_5 (M+C 2:3). Superiority of C_2, C_1 and C_4 was probably due to higher dry matter accumulation, better crop geometry and less inter species competition respectively. Overcrowding in C_3 and C_5 probably led to lower yield (Kim *et al*., 2018; Talukdar *et al*., 2023). Cowpea yield was also significantly affected as C_3 gave the highest yield followed by C_5. C_4 yielded significantly lower than C_5 due to reduction in plant population but it was at par with C_2 because of same population of cowpea in both the treatments. Similar findings were also found by (Ogedegbe *et al*., 2017).

The GreenSeeker treatment with split application of nitrogen produced the highest yield (7070 kg/ha) followed by N_4 (160: 80: 80 kg N, P_2O_5, K_2O/ha) with a yield of 6593kg/ha (Table 3). The trend was like $N_5>N_4>N_3>N_2>N_1$. The increased leaf area and dry matter accumulation in maize led to increased yield and precision nutrient management showed its positive impact on yield (Shekhawat *et al*., 2021; Jain and Maliwal, 2022; Kumar *et al*., 2022 and Salama *et al*., 2022). The highest yield of cowpea grain was obtained under N_4 (828 kg/ha) followed by N_3 (784 kg/ha) treatment. N_5 (Green Seeker-based) treatment was inferior to the above treatments and it was at par with N_2 (120: 60: 60 kg N, P_2O_5, K_2O/ha), which yielded 690 kg/ha and 674 kg/ha respectively. The reduced grain yield of cowpea in Green Seeker-based treatment was probably because of the growth habit cowpea which did not require excess nitrogen at the later stage.

Effect of intercropping system and nutrient management on intercropping competition functions

The highest LER-total (1.84) was obtained in the treatment C_3N_3 (M+C 1:2) with 140:70:70 kg N, P_2O_5, K_2O/ha (Table 4). LER-total value was more than one for all the intercropping ratios, which indicated the advantage of additive series. Increase in the nutrient doses increased LER for a particular intercropping ratio which suggested that nutrient helped in attaining better yield and land utilisation efficiency by crops in the mixed stand. Similar results were observed by Salama *et al*. (2022); Akter Suhi *et al*. (2022) and Nandi *et al*. (2022). The treatment C_3N_3 (M+C 1:2) with 140:70:70 kg N, P_2O_5, K_2O/ha registered the highest ATER of 1.62, which denoted that it had highest land and time utilisation among the other intercropping systems. In contrast, M+C 1:2 with no application of fertilisers gave the lowest ATER. The findings were in line with the results of Nandi *et al*. (2022) and Jan *et al*. (2016). The maize equivalent yield (MEY) was highest for

Table 4: Effect of intercropping systems and nutrient management on intercropping competition functions.

Treatments	Land equivalent ratio (LER)			Area time equivalent ratio (ATER)	Maize equivalent yield (kg/ha) (MEY)	Monetary advantage (Rs/ha) (MA)
	Maize	Cowpea	Total			
C_2N_1	1.01	0.19	1.20	1.15	1120	10394
C_2N_2	0.99	0.39	1.37	1.28	2305	38641
C_2N_3	1.01	0.43	1.44	1.33	2530	50795
C_2N_4	1.04	0.48	1.51	1.39	2820	67339
C_2N_5	1.04	0.41	1.45	1.35	2398	62482
C_3N_1	1.06	0.24	1.30	1.24	1443	16414
C_3N_2	0.96	0.71	1.67	1.49	4183	70593
C_3N_3	0.97	0.87	1.84	1.62	5162	98361
C_3N_4	0.90	0.88	1.78	1.56	5223	100076
C_3N_5	0.89	0.72	1.62	1.44	4291	83161
C_4N_1	1.13	0.20	1.33	1.28	1190	17122
C_4N_2	0.97	0.40	1.37	1.27	2370	37863
C_4N_3	0.96	0.45	1.41	1.30	2647	47889
C_4N_4	0.99	0.48	1.47	1.35	2867	61705
C_4N_5	0.99	0.40	1.40	1.30	2389	55160
C_5N_1	1.18	0.24	1.41	1.35	1396	21878
C_5N_2	0.87	0.64	1.50	1.34	3771	53422
C_5N_3	0.89	0.73	1.63	1.45	4352	73691
C_5N_4	0.88	0.78	1.66	1.47	4614	84989
C_5N_5	0.87	0.65	1.52	1.36	3851	70411

the treatment C_3N_4 (5223 kg/ha) closely followed by treatment C_3N_3 (5162 kg/ha) and lowest for treatment C_2N_1(1120). Difference in the MEY was due to difference in the yield and price of the individual crops. The results were in conformity with the findings of Jan *et al*. (2016) and Akter Suhi *et al*. (2022). Monetary advantage obtained for intercropping was highest for C_3N_4 (Rs.100076/ha) followed by C_3N_3 (Rs.98361/ha). However, the lowest monetary advantage was observed for treatment C_2N_1 (Rs.10394/ha). C_3N_4 and C_3N_3 both having the same population gave different monetary advantage because of difference in nutrient doses in each. Optimum crop geometry in C_3 makes it highly profitable in economic terms. The results are in conformity with findings of Alla *et al*. (2015) and Abou-Keriasha *et al*. (2011).

CONCLUSION

Significantly higher maize equivalent yield was observed for maize + cowpea 1:2 row arrangement with application of 160:80:80 kg N, P_2O_5, K_2O/ha and it was closely followed by Green seeker based N management along with optimum application of phosphorous and potassium. Keeping in the view of nutrient optimization and obtaining optimum yields, the experiment may conclude that the planting of maize and cowpea in intercropping with 1:1 and 2:2 row proportion along with the GreenSeeker-based nutrient recommendation was found to be more remunerative to obtain higher system productivity and economic return over sole cropping of maize in hot and sub-humid region of Odisha.

Conflict of interest

All authors declared that there is no conflict of interest.

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