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Physiological growth parameters, yield and quality of maize (*Zea mays* L.) as influenced by integrated nutrient management in intercropping system with green gram (*Vigna radiata* L.) under Island Ecosystem, A & N Islands

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Abstract
An experiment was conducted during Rabi season of dry months (January to April) of 2016 and 2017 at Field Crop Experimental Research Farm, Bloomsdale, Chouldhari, ICAR- CIARI, Port Blair, Andaman and Nicobar Islands to study the physiological growth parameters, yield and quality of maize (*Zea mays* L.) as influenced by integrated nutrient management in intercropping system with green gram (*Vigna radiata* L.) under island ecosystem of A & N Islands. The experiment was laid out in randomized block design (RBD) with three replications each consisting of two intercropping 1:1 and 2:2 ratio and eight nutrient sources. The main plot treatments include maize, green gram inter cropping ratio with 8 nutrient applications. Among the integrated nutrient management treatments, during the successive stages in pooled analysis the maximum (145.41,2.01,10.65,3.42 and 97.73) were recorded in application of N_1 [100% RDF (Recommended Dose of Fertilizers)], followed by N_8[25% RDN through Urea + 50% through PM + 25% *Gliricidia* + *Azotobacter*] was [144.85,1.88,10.56,3.38 and97.04], however the maximum crop growth rate and relative growth rate was recorded in N_8[25% RDN through Urea + 50% through PM + 25% *Gliricidia* + *Azotobacter*]. Among the cropping system S_1 registered significant and maximum Total yield (48.32 q/ha), which was superior to maize intercropped with greengram. Among the nutrient source treatments N_1 (100% RDF (Recommended Dose of Fertilizers) recorded significant and maximum total yield (60.49 q/ha), which was superior to rest of the treatments.

Keywords: INM, maize-green gram intercropping, CGR, RGR, growth and yield

1. Introduction

In India, maize (*Zea mays* L.) is the third most produced cereal crop after wheat and rice. It is a significant crop. It is a plant that is a member of the Poaceae family of grasses. China comes in second and the USA top in terms of output. With a global production of 1162 million tons and a productivity of 5754.7 kg/ha, it is grown on about 201 million hectares and has a greater diversity of soil, temperature, biodiversity, and management techniques. With a productivity of 3196.9 kg/ha, India produced 31.65 million tonnes on 9.9 million hectares in 2021(Anonymous, 2023) [1]. Approximately 21% of the world's crop production between 2000 and 2021 came from sugarcane. Even though in 2000 all three crops made up 10% of the total, maize production increased three times faster than either wheat or rice during that time, overtaking rice in 2001 to become the second most produced crop globally. The biggest obstacle to increasing maize production is nutrient availability. Due to its extensive use, maize has a high nutrient requirement, and a system for managing nutrients is crucial to its production. Alternatives need to be reconsidered in light of the current energy crisis, high fertilizer costs, and the farming community's limited purchasing power. Through the provision of an improved physical, chemical, and microbiological environment, they increase crop yield per unit of applied nutrients. (Madakemohekar *et al*., 2013) [6].

Additionally, he stated that persistent use of chemical fertilizers can alter the pH of the soil, disrupt ecosystems of helpful microorganisms, increase pests, and even contribute to the emission of greenhouse gases. Thus, it seems that the best course of action is to make the most use of organic waste and combine it with chemical and biological fertilizers to create integrated manure. According to Gundlur *et al*. (2015) [5], applying inorganic fertilizers in various ratios along with various sources of organic manures plays a major role in maintaining the nutritional status of the soil, improving plant uptake of nutrients, and increasing crop output in maize-based cropping systems. But in addition to differing for diverse cropping systems across the nation, the package of methods also needs to be adjusted to each farmer's unique demands in order to maximize profit and productivity. In order to achieve optimal plant growth and nutrient delivery to realize yield potential, balanced fertilization with organic and inorganic fertilizers is critical to the sustainability of maize production. There are several ways to provide plant nutrients, including chemical fertilizers, crop wastes, organic manures, and biofertilizers. The greatest strategy for increasing resource efficiency and producing crops at a lower cost is integrated nutrient management. With this method, every potential source of nutrients is used, taking into account economic factors, and chemical fertilizers are used to provide the crop with the necessary balance. Integrated nutrient management including application of organic and inorganic fertilizers, and bio fertilizers are warranted for sustainable food production and maintaining soil health (Patil *et al*. 1992) [9]. According to De *et al*. (1986) [12], maize + green gram intercropping system utilized nitrogen more than maize as a single crop. Nanda *et al*. (1995) [15] found that the combination of 75 kg N/ha and azosprillium seed inoculation resulted in the highest green fodder yield and benefit: cost ratio.

These crops' nutrient requirements will differ from their sole crop requirements, especially in an intercropping system. A balanced nutritional intake is necessary for the system's upkeep and/or increased productivity. According to a review of the academic literature, the Andaman and Nicobar Islands' intercropping system's nutritional features are not well documented. Field research on the nutritional features of the maize + mung bean intercropping system was therefore judged necessary. The productivity and fertility of the soil will be significantly impacted by the intercropping of maize and green gram (Dahmardeh *et al*., 2010) [3]. To maintain soil fertility and long-term productivity for sustainable agriculture, integrated nutrient management—which combines several nutrient sources and management techniques that are complementary to intercropping systems—is essential.

2. Materials and Methods

In January through April of 2016 and 2017, a field experiment was carried out at the Field Crop Experimental Research Farm, Bloomsdale, Chouldhari, ICAR-CIARI, Port Blair, Andaman and Nicobar Islands, India. The experiment laid out in randomized block design (RBD with three replications each consisting two intercropping 1:1 and 2:2 ratios and eight nutrient sources. The main plots treatments include maize, green gram, with 8 nutrient applications The treatments details are as T_1 Maize + Green gram (1:1) recommended dose of fertilizer (100%), T_2 Maize + Green gram (1:1) 100% recommended dose of fertilizer through organic manure (33% FYM +33% Vermicompost +33% Poultry Manure), T_3 Maize + Green gram (1:1) + 50% RDN through Urea + 50% N through Farm Yard Manure, T_4 Maize + Green gram (1:1) + 50% RDN through Urea + 50% N through Vermicompost, T_5 Maize + Green gram (1:1) + 50% RDN through Urea + 50% N through Poultry Manure, T_6 Maize + Green gram (1:1) + 25% RDN through Urea + 50% N through Farm Yard Manure + 25% *Gliricidia*+ *Azotobactor*, T_7 Maize + Green gram (1:1) + 25% RDN through Urea + 50% N through Vermicompost +25% Gliricidia+ *Azotobactor*, T_8 Maize + Green gram (1:1) + 25% RDN through Urea + 50% N through Poultry Manure+ 25% Gliricidia+ *Azotobactor* also same combination was used (2:2) plot. At the experimental site, the soil type was Entisol, with a bulk density of 1.42 mg m3 and a sandy clay loam texture. The soils had 3.7 g kg-1 of organic carbon, 163 kg ha-1 of accessible N, 14.8 kg ha-1 P, and 256 kg ha-1 of ammonium acetate K. They are also non-saline (EC 0.02 dS m-1) and had a pH of 6.0. The land received pre-sowing irritation and was ploughed. Following the preliminary tillage, there were 54 distinct plots in the field, each measuring 4.20 m by 2.5 m. The pre-treated maize cv. Vivek 27 seed was seeded by the dibbling method in a dry season and interplanted with green gram (var. CARI Mung1) under rainfed conditions. A modest amount of supplemental irrigation was provided throughout important crop growth phases. RDF: The recommended fertilizer dosage (for maize, 120:80:60 NPK). The remaining dose of N was administered as topdressing in two splits at the knee high stage and the pre-teaselling stage. The basal dose of N was provided by RDN (recommended dose of N), FYM (farm yard manure), VC (vermicompost), and PM (poultry manure). The dosage of FYM, phosphorus-solubilizing bacteria, vermin-compost, and Azotobacter was administered according to treatment. Hand hoeing kept the field clear of weeds. The same methods of providing irrigations as needed and plant protection measures were applied to each treatment. Just prior to crop harvest, parameters related to yield qualities were recorded. On May 10, 2017, the crop was harvested and the grains were wrapped into bundles with labels after around 80% of the cobs turned yellowish. The weight of the bundles after sun drying was noted. Using a hand-operated maize sheller, the cobs were taken out of the plants and dried and threshed. Each plot's grain yield was so noted.

3. Results and Discussion

3.1 Physiological growth characters

Plant growth characteristics such plant height, stem diameter, number of leaves/plant, leaf area index/plant, dry weight (g), crop growth rate, and relative growth rate of maize crop were shown to be non-significant under the conditions of maize-green gram intercropping caused by cropping systems. In the case of maize-green gram, the results of this study showed that various integrated nutrients management treatments had a significant impact on plant growth parameters, including plant height, stem diameter, number of leaves/plant, leaf area index, plant dry weight (g), crop growth rate, and relative growth rate of maize crop (table 1). During the various stages of the pooled analysis, the application of N1 [100% RDF (Recommended Dose of Fertilizers)] produced the highest crop growth rates (145.41,2.01,10.65,3.42 and 97.73), followed by N8 [25% RDN through Urea + 50% through PM + 25% Gliricidia + Azotobacter] with the following results: 144.85,1.88,10.56,3.38 and 97.04. On the other hand, the maximum crop growth rate and relative growth rate were recorded in N8 [25% RDN through Urea + 50% through PM + 25% Gliricidia + Azotobacter].

The reason for the higher growth parameter values can be explained by the fact that the crop grown under these treatments was relatively easier to extract and had more nutrients available for plants in the field than under other treatments. This led to better crop growth in terms of plant population, plant height, number of leaves, stem girth, leaf area, leaf area index, dry weight, crop growth rate, and relative growth rate, all of which were measured during the investigation and pooled analysis of the maize crop at all growth phases. The data in Tables 1 demonstrated that intercropping with green gram increased plant height, number of leaves, and stem diameter when compared to solo maize. As the stages progressed, maize plant height, leaf count, and stem diameter all increased in correlation with green gram. This might be explained by the synergistic effect of the relationship between component crops and maize. The capacity of green gram and cluster beans to fix atmospheric nitrogen in the soil and make it available to plant roots may be the cause of this (Chen *et al*., 2004) [2]. Furthermore, through mycorrhizal links, root exudates, or the decay of roots and nodules, legumes can directly fix nitrogen (N) to non-legumes. Alternatively, during the spring, the legume can indirectly fix atmospheric nitrogen (N2), reducing competition for soil NO3 with non-legumes. It is anticipated that each of these changes will have a compounding effect on the crop's ability to absorb applied and naturally occurring nutrients. The results of this investigation reflect it. These growth indicators demonstrated progress throughout. These results are consistent with those reported by Mobasser *et al*. (2014) [14] and Jat *et al*. (2014) [7].

3.2 Yield Parameters
3.2.1 Yield (q/ha)
Following statistical analysis, the data on maize yield (q/ha) were recorded and are shown in table 2. Throughout the trial years as well as in the pooled analysis, cropping systems, nutrient sources, and their interactions all had an impact on the total yield (q/ha). Greengram-intercropped maize yielded less than S1's noteworthy and greatest Total yield (48.32 q/ha) among the cropping systems. N1 (100% RDF) (Recommended Dose of Fertilizers) was the nutrient source treatment that produced the highest and most notable overall yield (60.49 q/ha), outperforming the other treatments. N8 was discovered to be statistically equivalent to N1, nevertheless. The harvest index and biological yield showed the same pattern. According to Haymes and Lee (1999) [13] and Latati *et al*. (2013) [8], increased nitrogen fixation by component crops likely contributed to the rise in yield attributes. This in turn led to increased N intake of linked maize.

3.2.2 Biological yield (q/ha)
After statistical analysis, the data on maize's Stover Yield/Biological (q/ha) were compiled and displayed in Table 2. Cropping systems and nutrient sources affected the Stover Yield/Biological (q/ha) in both the experiment and pooled study years. S1 cropping system recorded the highest and most significant Stover Yield/Biological (159.97 q/ha), outperforming maize intercropped with greengram. The Stover Yield/Biological (q/ha) was considerably affected by the various Nutrient Source application treatments in both the years and the pooled study. Nt1 (100% RDF) (Recommended Dose of Fertilizers) was the Nutrient Source treatment that produced the highest and most notable Stover Yield/Biological (166.69 q/ha), outperforming the other treatments. But no treatment was discovered to be statistically equivalent.

3.2.3 Harvest index (%)
Table 2 presents the statistical analysis of the data made on the Harvest index (%) of maize. Cropping systems, fertilizer sources, and their interactions caused variations in the Harvest index (%) in both the trial and pooled study years. S2 cropping system recorded the highest and most significant Harvest index (30.21%) compared to maize intercropped with greengram. The Harvest index (%) was greatly impacted by the various approaches to Nutrient Source application in both the years and the pooled analysis. Nt1 (100% RDF) (Recommended Dose of Fertilizers) was the Nutrient Source treatment that produced the highest and most significant Stover Harvest index (36.34%) compared to the other treatments. But no treatment was discovered to be statistically equivalent.

3.3 Production Efficiency Indices
3.3.1 Land Equivalent Ratio
Tables 2 display the results of several competing functions, including aggressiveness and the land equivalent ratio (LER). The relative land area needed for solitary crops to yield the amount produced in the intercropping system is known as the LER. To get the combined LER, the LERs of legumes and maize were computed and combined. The combination LER for maize and green gram (1:1) was the highest of all the intercropping combinations. The LER value was nearly at the greatest value in a few other combinations. A versatile crop, maize grows slowly in the beginning. Furthermore, there was plenty of room for the beans to grow because the maize was planted in paired rows. Eventually, these assisted in communicating to the crops the high LER and advantages of the maize legume intercropping system.

Intercropping of maize and green gram under various nutrient management strategies resulted in considerable variations in the land equivalent ratio (LER), with intercropping being much better than either of the solo crops. Lower LER (1.31, 1.35, and 1.33) was recorded in maize and green gram solo crops, whereas application of Nt1 [100% RDF (Recommended Dose of Fertilizers)] for maize and green gram intercropping system recorded significantly higher LER (2.00) in both the year and pooled analysis. The land equivalent ratio (LER) can be used as an indirect indicator of how well growth resources are used in an intercropping system. Due to the intercropping system's superior utilization of growth resources, the LER with 100% RDF (Recommended Dose of Fertilizers) for maize and green gram was higher than for a single crop, as reported by Muyayabantu *et al* (2013).

3.3.2 Aggressivity Index
A review of Table 2's data revealed that, at each row ratio, maize intercropping with greengrams was more aggressive in S2 (0.041 to 0.076) than in S1 (0.008 to 0.025). Out of all the intercropping treatments, maize with greengram intercropping in a 2:2 row ratio exhibited the highest rating of aggressivity. Additionally, maize exhibited greater aggressiveness under the row ratio of 1:1 compared to the other treatments. The fact that maize aggressivity showed positive values across all intercropping treatments suggested that it functions as a dominant element in both intercropping systems. On the other hand, the intercrops' low competitiveness when cultivated alongside maize was indicated by their negative aggressivity ratings. When compared to greengram intercropping in different row ratios (-0.043 to -0.426), the aggressiveness of maize-based intercropping ranged from (0.042 to -0.787). When compared to green gram treatments, the aggressively intercropping row proportions with greater negative values showed reduced dominance of green gram over maize. When aggression has a negative value, the species is dominated; conversely, when

aggression has a positive value, the species is dominating. Except when maize intercropped with greengram (2:2), maize demonstrated positive values in the current study.

3.4 Quality parameters

3.4.1 Carbohydrate (%)

Table 2 displays the results of a statistical analysis of the observations made on the percentage of carbohydrates in maize. The farming systems, nutrient sources, and their interactions all had an impact on the percentage of carbohydrates. S1 cropping system had non-significant and maximum carbohydrate (0.30%), which was higher than greengram-intercropped maize. The various Nutrient Source application procedures had a substantial impact on the carbohydrate (%) had. N1 (100% RDF) (Recommended Dose of Fertilizers) was the nutrient source treatment that produced the highest and most significant carbohydrate (%) compared to the other treatments. But no treatment was discovered to be statistically equivalent.

3.4.2 Protein content (%)

Table 2 presents the statistical analysis of the findings made about the protein content (%) of maize. Cropping systems and nutrient sources caused variations in the protein content (%). S1 cropping system had a maximum protein content of 10.57 percent, which was higher than that of maize intercropped with greengram. The protein content (%) was greatly impacted by the various nutrient source application procedures. N1 (100% RDF) (Recommended Dose of Fertilizers) was the nutrition source treatment that had the highest and most significant protein content (%) compared to the other treatments. But no treatment was discovered to be statistically equivalent.

Furthermore, when compared to only maize, intercrops of legumes with maize can significantly improve the quality and reduce the need for protein supplements. Furthermore, it is assumed that legumes improve soil quality by fixing atmospheric nitrogen and transforming it into forms that plants can absorb. Nitrogen fertilization can be partially or completely replaced by biological fixation of atmospheric nitrogen. The findings are consistent with Dwivedi *et al*. (2015) [4] and Prasanthi and Venkateswaralu (2014) [11].

Table 1: Effect of cropping system and Integrated nutrient management on growth attributes parameters in maize (*Zea mays* L.) as influenced by intercropping with green gram (*Vigna radiata* L.).

Factors	Dose	Plant height (cm)	Stem Diameter	No of Leaves	Leaf area index/plant	Dry Weight	CGR (g/m^2/day)	RGR (g/g/day)
Method of intercropping								
S_1	Maize + Green gram (1:1)	140.3	1.63	9.54	3.05	67.27	197.74	0.254
S_2	Maize + Green gram (2:2)	140.19	1.63	9.48	2.98	65.31	191.34	0.256
F-test		NS	NS	NS	S	S	NS	NS
S. Ed. (±)		0.723	0.121	0.132	0.149	0.471	4.583	0.008
C. D. (P = 0.05)		1.477	0.061	0.261	0.295	0.961	9.359	0.017
Nutrient management practices								
N_1	100% RDF (Recommended Dose of Fertilizers)	145.41	2.01	10.65	3.42	97.73	293.24	0.302
N_2	100% RDN (Recommended Dose of Nitrogen)through Organic manure (33% Farm Yard Manure (FYM) +33% Vermicompost +33% Poultry Manure)	132.81	1.27	8.27	3.22	34.2	91.72	0.203
N_3	50% RDN through Urea + 50% N through Farm Yard Manure (FYM)	136.03	1.32	8.62	2.83	38.11	108.2	0.212
N_4	50% RDN through Urea + 50% N through Vermicompost (VC)	138.31	1.51	8.87	2.8	45.98	120.53	0.237
N_5	50% RDN through Urea + 50% N through Poultry Manure (PM)	139.1	1.61	9.2	3.02	60.24	176.16	0.25
N_6	25% RDN through Urea +50% N through FYM + 25% *Gliricidia* + *Azotobacter*	140.07	1.67	9.59	2.37	64.34	180.37	0.259
N_7	25% RDN through Urea + 50% N through Vermicompost + 25% *Gliricidia* + *Azotobacter*	142.24	1.76	10.36	3.08	92.69	290.67	0.275
N_8	25% RDN through Urea + 50% through PM + 25% *Gliricidia* + *Azotobacter*	144.85	1.88	10.56	3.38	97.04	295.45	0.305
F-test		S	S	S	NS	S	S	S
S. Ed. (±)		0.892	0.048	0.076	0.277	0.235	2.292	0.004
C. D. (P = 0.05)		1.766	0.095	0.15	0.548	0.481	4.679	0.008

Table 2: Effect of cropping system and Integrated nutrient management on yield parameters, Production Efficiency Indices and Quality Parameters in maize (*Zea mays* L.) as influenced by intercropping with green gram (*Vigna radiata* L.).

Factors	Dose	Yield Parameters			Production Efficiency Indices		Quality Parameters	
		Yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Land Equivalent Ratio	Aggressivity Index	Carbohydrate (%)	Protein content (%)
Method of intercropping								
S_1	Maize + Green gram (1:1)	48.32	159.97	30.13	1.7	-0.196	56.47	10.72
S_2	Maize + Green gram (2:2)	45.58	150.66	30.21	1.65	-0.277	55.70	9.95
F-test		S	S	S	S	S	NS	S
S. Ed. (±)		0.62	0.748	2.613	0.013	0.025	0.015	0.071
C. D. (P = 0.05)		1.265	1.527	5.335	0.026	0.052	0.030	0.145
Nutrient management practices								
N_1	100% RDF (Recommended Dose of Fertilizers)	60.49	166.69	36.34	2.00	0.000	60.17	11.66
N_2	100% RDN (Recommended Dose of Nitrogen)through Organic manure (33% Farm Yard Manure (FYM) +33% Vermicompost +33% Poultry Manure)	31.15	156.83	19.78	1.33	-0.591	52.61	9.76
N_3	50% RDN through Urea + 50% N through Farm Yard Manure (FYM)	34.06	156.49	21.73	1.41	-0.553	51.25	9.96
N_4	50% RDN through Urea + 50% N through Vermicompost (VC)	40.67	151.38	26.86	1.52	-0.354	55.89	10.34
N_5	50% RDN through Urea + 50% N through Poultry Manure (PM)	44.22	139.08	31.81	1.6	-0.274	56.53	10.16
N_6	25% RDN through Urea +50% N through FYM + 25% *Gliricidia* + *Azotobacter*	48.42	152.88	31.70	1.7	-0.195	56.07	9.91
N_7	25% RDN through Urea + 50% N through Vermicompost + 25% *Gliricidia* + *Azotobacter*	56.36	159.59	35.17	1.85	0.024	57.43	10.06
N_8	25% RDN through Urea + 50% through PM + 25% *Gliricidia* + *Azotobacter*	60.22	163.49	38.00	1.96	0.050	58.71	10.81
F-test		S	S	S	S	S	S	S
S. Ed. (±)		0.31	0.374	1.306	0.006	0.013	0.029	0.142
C. D. (P = 0.05)		0.633	0.764	2.668	0.013	0.026	0.060	0.290

Conclusion
In conclusion, the study investigated the physiological growth characteristics, yield parameters, production efficiency indices, and quality parameters of maize-green gram intercropping under various nutrient management strategies. The results revealed significant impacts of integrated nutrient management treatments on plant growth parameters, with treatments such as N1 showing the highest crop growth rates. Intercropping with green gram positively influenced plant height, leaf count, and stem diameter of maize, likely due to nitrogen fixation abilities. Yield parameters, including total yield, biological yield, and harvest index, were also influenced by cropping systems and nutrient sources, with N1 consistently outperforming other treatments. Production efficiency indices like Land Equivalent Ratio (LER) indicated the superiority of intercropping over solo crops, particularly when managed with 100% RDF. Maize demonstrated aggressiveness in intercropping systems, with positive values indicating dominance. Quality parameters such as carbohydrate and protein content were significantly influenced by cropping systems and nutrient sources, with N1 showing the highest values. Intercropping of legumes with maize showed potential to enhance quality and reduce the need for external protein supplements, aligning with findings from previous studies. Overall, the study underscores the potential of integrated nutrient management and intercropping strategies to optimize maize production, improve resource utilization, and enhance crop quality.

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Competing interests
Authors have declared that no competing interests exist.

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