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Effect Intercropping with Cowpea and Maize with Organic Manure Application on the Physiological Parameters

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Intercropping involves cultivating two or more crops simultaneously in the same field, optimizing the use of land, water, light, and nutrients for higher yields compared to sole cropping. Organic manures, such as farmyard manure, poultry manure, oilseed cake, vermicompost, and bio-slurry, play a vital role in enhancing soil health by providing essential nutrients and supporting microbial populations. In contrast, excessive use of inorganic fertilizers can lead to environmental degradation. Present study explores the synergistic effects of intercropping and organic manure application on the physiological parameters of maize (*Zea mays)* and cowpea (*Vigna unguiculata*). Agricultural practices like intercropping optimize resource utilization and enhance overall productivity, especially in regions with limited water resources like Mizoram, India. These practices exhibit positive responds when combined with organic manure on soil health and yield attributes on crops. The experiment was laid out in randomized block design (RBD) with ten treatments

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replicated thrice. The result indicate that plants treated with Maize + Cowpea (2:1) + 50% of RDN (Recommended doses of Nitrogen) through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg ha-1), resulted in significantly maximum physiological parameters of the crops.

Keywords: Inter cropping; organic manure; physiological parameters; maize and cowpea.

1. INTRODUCTION

Diverse cropping systems are an essential and vital in today's agricultural scenarios for improved productivity and sustainability [1]. Intercropping, defined as the simultaneous cultivation of two or more crops in the same field [2], is a well-established agricultural practice, particularly in tropical regions. This method maximizes overall productivity per unit area by optimizing the use of land, labor, and growth resources [3,4,5]. Intercropping often leads to higher yields compared to sole cropping systems [6,7], mainly due to the more efficient utilization of resources such as water, light, and nutrients [8].

Fertilizers utilized in agricultural practices provide vital nutrients essential for plant growth, maturation, development of plant parts, and biochemical composition of plants and seed capabilities [9]. Various sources of fertilizers exist, ranging from natural to industrially produce. In the current global context, environmental degradation poses a significant threat, with the extensive use of chemical fertilizers contributing substantially to environmental deterioration through fossil fuel depletion, carbon dioxide generation, and water resource contamination. This contributes to soil fertility loss due to the imbalanced use of fertilizers, negatively impacting agricultural productivity and causing soil degradation. There is a growing acknowledgment that the adoption of ecological and sustainable farming practices is essential to reverse the declining trend in global productivity and environmental protection [9]. The prolonged use of inorganic fertilizers without natural supplements damages the physical, chemical, and biological properties of soil, leading to environmental pollution [10]. Organic manure not only serves as a source of nutrients and organic matter but also enhances the microbial population, biodiversity and activity in the soil [11]. Soils rich in organic matter have been proven to improve the growth and yield of various plants, as well as soil infiltration, compaction, and water retention capacity for seed germination and plant root development [12]. Various sources of organic manures, such as farmyard manure (FYM), poultry manure, oilseed cake, vermicompost and bio-slurry contribute to soil health. Farmyard manure (FYM) is a traditional and important organic source of nutrients, improving the physical, chemical and biological characteristics of the soil [13]. While many vegetable producers opt for inorganic fertilizers due to their ease and rapid availability to plants [14]. Poultry manure is rich organic manure since solid and liquid excreta are excreted together resulting in no urine loss. In fresh poultry excreta uric acid or urate is the most abundant nitrogen compound (40-70 per cent of total N) while urea and ammonium are present in small amounts [15].

Cereal-legume intercropping is a significant practice in subsistence food production, playing a crucial role in both developed and developing countries, particularly in regions with limited water resources [16]. This farming technique, involving simultaneous cultivation of cereal and legume crops, contributes to maintenance and enhancement of soil fertility [17]. Its importance is particularly pronounced in developing countries where farmers facing financial constraints often cannot afford the use of inorganic fertilizers. An essential aspect of cereal-legume intercropping is the nitrogen-fixing ability of legumes. Legumes have the capacity to fix atmospheric nitrogen, a process wherein nitrogen from the air is converted into a form usable by the plants. This nitrogen may be utilized by the legume itself or released from nodules into the soil, becoming accessible to neighboring plants [18]. This symbiotic relationship between cereals and legumes not only supports soil fertility but also presents an economically viable alternative for farmers with limited resources [7]. Legume intercrops have several socioeconomic [19] and biological and ecological [20] advantages compared to sole cropping for small-holder farmers [21]. Keeping in consent the above discussed entities, the present study was conducted with an objective to determine the effect of intercropping with organic manure on the physiological parameters of maize and cowpea.

2. MATERIALS AND METHODS

The experiment was conducted during the kharif seasons of 2020 and 2021 at the organic certified farm of Mr. Lalnuntluanga farm situated at Melriat village, 13 km from the main capital Aizawl city, Mizoram under Tlangnuam RD Block, Aizawl, Mizoram (Fig. 1). The soil of the experimental site is acidic in nature, sandy loam in texture, medium in organic carbon and medium in available nitrogen, low in phosphorus and medium in potassium.

In the course of the experimentation period, the *kharif* crop received 845.8mm rainfall and 1876.6mm rainfall during the year 2020 and 2021, respectively. The mean maximum and minimum temperature during *kharif* season ranged from 25.5 to 30.8^{0}C and 19.8 and 22.1^{0}C during 2020, however during 2021, mean maximum and minimum temperature ranged from 27.3 to 33.4^{0}C and 17.4 and 21.1, respectively. The minimum and maximum mean relative humidity during *kharif* season ranged from 52.6% to 91.9% and 45.7% to 78.4% during 2020 and 2021, respectively. Mean weekly wind speed during *kharif* season of the years 2020 and 2021 ranged from 0.5 to 20.6 km/hr and 0.6 to 1.4 km/hr respectively.

The field experiment was laid out in randomized block design (RBD) with ten treatments replicated thrice (Table 1). "MZM-MB-02" (Mizoram local) cultivar of maize and "MZCP-10" (Mizoram local) cultivar of cowpea are taken as test crop. Farm yard manure was applied as blanket application during land preparation, rock phosphate (150 kg/ha) was applied as basal application and recommended dose of Nitrogen (80 kg/ha) was applied through organic manures. 100% of recommended dose of nitrogen through Farm yard manure (8,600 kg/ha), 100% of recommended dose of nitrogen through poultry manure (4,392 kg/ha), 50% of recommended dose of nitrogen through Farm Yard Manure (4300 kg/ha) + 50% of recommended dose of nitrogen through Poultry Manure (2196 kg/ha), Lime (200 kg/ha) were applied respectively before sowing for different treatments in the selected plots. During the present study, intercropping impacts on physiological parameters of maize and cowpea was assessed by observing different plant growth parameters

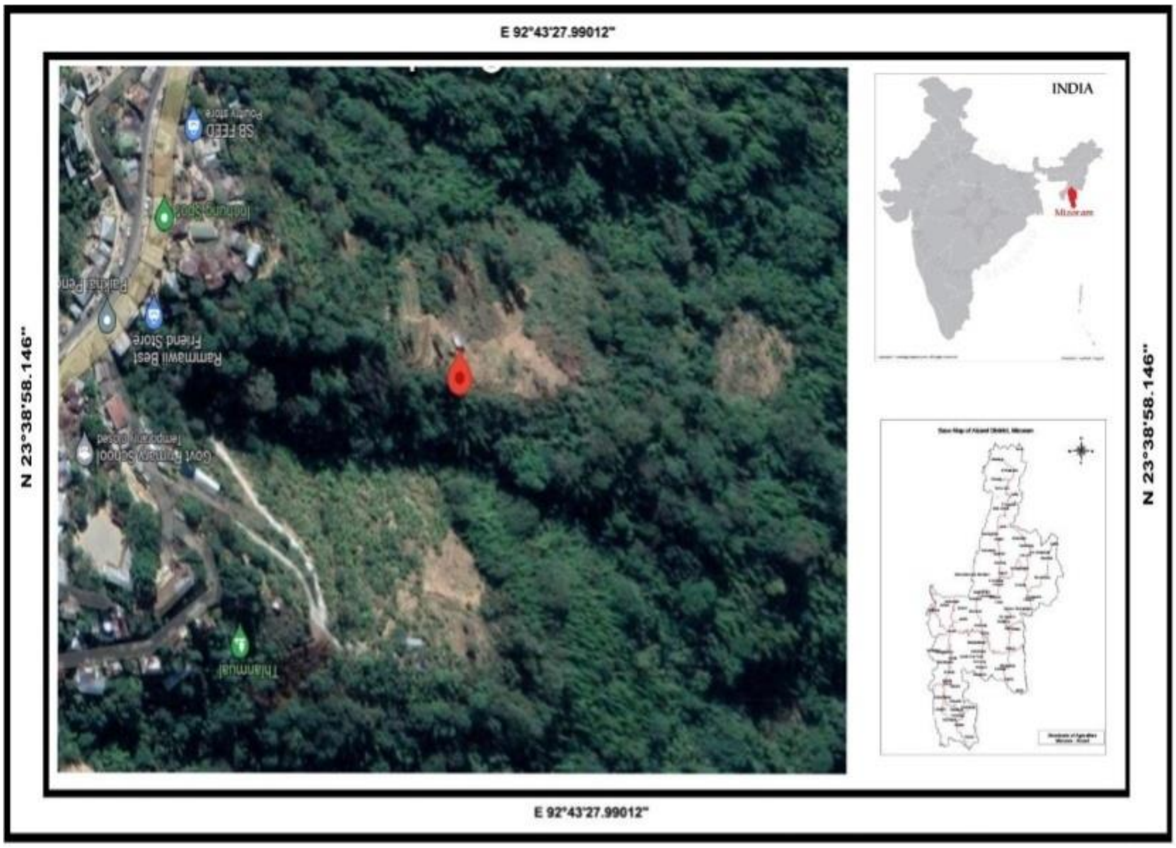

Fig. 1. Experimental Site, Aizawl District Mizoram, India

Table 1. Treatment details of the research experiment

Treatments	Details
T_1	Maize + Farmers' Practice
T_2	Maize + 100% of RDN through Farm Yard Manure
T_3	Maize + 100% of RDN through Poultry Manure
T_4	Maize + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure
T_5	Maize + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha)
T_6	Maize + Cowpea (2:1) + Farmers' Practice
T_7	Maize + Cowpea (2:1) + 100% of RDN through Farm Yard Manure
T_8	Maize + Cowpea (2:1) + 100% of RDN through Poultry Manure
T_9	Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure
T_{10}	Maize+ Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha)

viz. plant height (cm), number of leaf/ plant, leaf area (cm^2), leaf area index, dry matter accumulation (g/m^2), crop growth rate (g/m^2/day), relative growth rate (g/g/day) at different growing stages of the crops. Further, the recorded observed data were statistically analyzed and the critical differences (CD) were worked out at 5% probability level [22]. Thereafter, analysis on correlation was tested for the recorded and calculated data.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Observed plant height in centimeter for the years 2020-21 was averaged and pictorial graph was drawn as shown in Tables 2-3 & Fig. 2 respectively. Averaged plant height of maize and cowpea increased from 30 to 60 DAS rapidly and increased at slower pace up to at harvest stage in all the treatments. Measurements of plant height were not possible for the first five treatments (T_1 to T_5) because the plants were too small for cowpea. Therefore, the readings for plant height began with the sixth treatment (T_6) when the plant heights were presumably tall or more suitable for measurement. Among the treatments, T_{10}: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kgha-1) recorded significantly taller plant in maize at all the stages and which was comparable to T_9: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure at all the stages. The highest plant height of maize and cowpea was noted under T_{10} crops, this might be due to incorporation of cowpea crop as an intercrop which fixes nitrogen and help in soil microbial activity around maize crop favouring higher growth of maize [23]. Nitrogen is a constituent of protein and vitality associated with the activity of all living cells. The maximum plant height was recorded under above mentioned treatments are mainly due to higher crop-intercrop competition i.e., plant attained height owing to less utilization of light and solar radiation [24 and 25]. Therefore, under higher nitrogen availability due to incorporation of pulse crop as intercrop there would have been superior growth of plant due to high rate of protoplasmic protein synthesis leading to taller plants. These constituents increase cell sizes and finally the vertical growth of plants [26]. Organic amendments incorporation helps to provide better environment to enhance growth naturally hence observed significant increase in plant height (Amanulla et al. 2006).

3.2 Number of Leaves Per Plant (Nos.), Leaf Area (cm^2/ plant) & Leaf Area Index (LAI)

Similarly**,** Number of leaves per plant, Leaf area and LAI were observed at 15, 30, 45, 60, and 75 days after sowing (DAS) (Tables 4-9 and Fig. 3 to 5). Measurements of Number of leaves per plant, Leaf area and LAI were not possible for the first five treatments (T_1 to T_5) because the plants were too small for cowpea. Therefore, the readings began with the sixth treatment (T_6). Number of leaves per plant showed a significant increase up to 45 DAS. The treatment T_{10} (Maize + Cowpea 2:1 + 50% RDN through Farm Yard Manure + 50% RDN through Poultry Manure + Lime 200 kg ha-1) resulted in the highest number of leaves per plant, leaf area and leaf area index

(LAI) at 15 DAS, 30 DAS, 45 DAS, and 60 DAS. The lowest number of leaves per plant, leaf area and LAI was observed under T_1 (Maize + Farmers' Practice). The trends and effects of treatments were consistent. The combination of maize and cowpea with specific nutrient management practices, including the use of farm yard manure, poultry manure and lime resulted in a significant increase in the number of leaves per plant, Leaf area and LAI compared to traditional farmer practices (T_1 :Maize + Farmers' Practice). The specific treatment T_{10} showed consistent positive effects across multiple observation periods, while T_8 was particularly effective at 75 DAS. In intercrop cowpea, there was a progressive increase in the number of leaves per plant, Leaf area (cm^2 plant-1) and Leaf area index (LAI) and this trend was observed consistently during the present study. Treatment T_{10} (Maize + Cowpea 2:1 + 50% RDN through Farm Yard Manure + 50% RDN through Poultry Manure + Lime 200 kg ha-1) significantly recorded maximum number of leaves per plant, Leaf area (cm^2 plant-1) and Leaf Area Index (LAI) compared to other treatments. The lowest number of leaves per plant was consistently recorded under T_1 (Maize + Farmers' Practice). The tabulated averaged number of leaves per plant (Nos.), leaf area (cm^2/ plant) & leaf area index (LAI) are shown in Tables 4-9 & Fig. 5 respectively.

The analysis reveals more number of leaves per plant with larger leaf size due to enhancement of cell division and cell expansion by assured supply of vital N in balance form with other nutrients during active crop growing period was probably responsible for this trend. The higher value of the vegetative characteristics of intercropped maize and cowpea together may be due to the efficient use of natural resources like as light, water and nutrients. This echoes the findings of Maitra et al. [27] and [28] that showed that the yield benefit of intercropping results from the efficient conversion of growth resources such as light, water and nutrients into biomass. The higher value of vegetative characteristics of legume and maize intercrop may possibly be attributing to less weed competition, since the majority of the land is covered by crops that inhibit weed growth. This result was also supported by Onunwa et al. [29] where they stated that organic manure resulted in higher number of leaves for maize and cowpea. Similar findings were reported by Okpanachi et al. [30]. Among the organic manures, Composted Poultry

Table 2. Average Plant Height (cm) of Maize during different DAS

Treatments	Days After Sowing (DAS)					
	15DAS	**30DAS**	**45DAS**	**60DAS**	**75DAS**	**90DAS**
T_1	6.11	16.13	46.25	84.08	95.35	152.88
T_2	5.89	21.56	47.61	84.37	100.57	159.72
T_3	6.09	23.62	50.82	89.97	105.3	165.58
T_4	6.41	24.88	53.01	92.57	107.09	168.76
T_5	7.03	31.03	58.24	104.52	113.15	177.97
T_6	5.91	21.71	43.25	86.68	99.78	157.59
T_7	6.3	27.89	55.77	99	106.28	162.32
T_8	6.07	27.65	57.85	103	107.63	166.43
T_9	6.45	32.16	59.99	106.21	115.45	175.55
T_{10}	6.77	36.19	64.81	111.22	117.66	193.78
S.Em.±	0.26	1.42	2.16	3.04	2.38	4.93
C.D.at 5%	0.76	4.21	6.43	9.02	7.07	14.64

Table 3. Plant Height (cm) of Cowpea during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	**30DAS**	**45DAS**	**60DAS**	**75DAS**
T_6	8.17	12.38	24.01	54.81	79.41
T_7	8.24	14.82	26.17	56.25	81.41
T_8	8.17	15.54	27.14	58.49	84.41
T_9	8.1	15.96	27.38	61.88	87.76
T_{10}	8.38	17.95	31.02	63.86	88.65
S.Em.±	0.32	0.41	0.93	1.41	1.56
C.D.at 5%	1.04	1.33	3.03	4.59	5.07

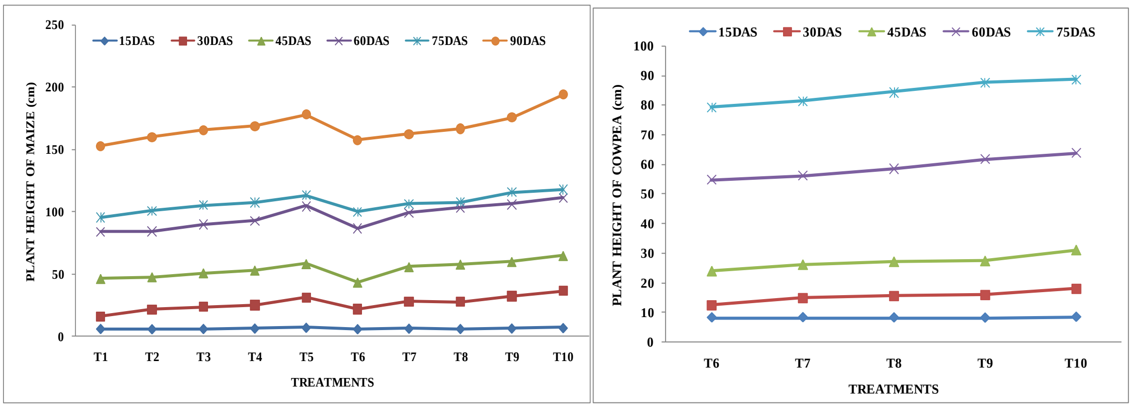

Fig. 2. Plant height (cm) of maize and cowpea

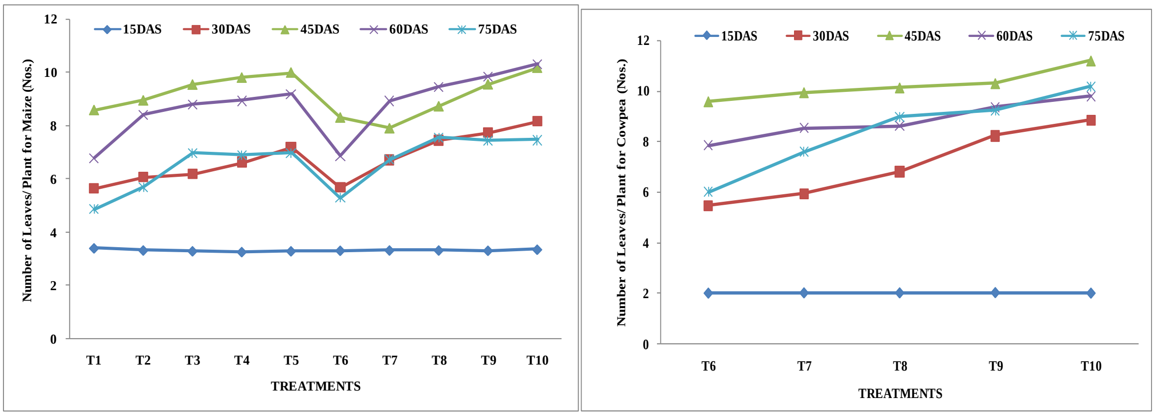

Fig. 3. Number of Leaves per plant for Maize and Cowpea

Table 4. Average leaves per plant (Nos.) for Maize during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	30DAS	45DAS	60DAS	75DAS
T_1	3.41	5.65	8.61	6.8	4.87
T_2	3.33	6.07	8.97	8.42	5.7
T_3	3.3	6.18	9.56	8.82	6.97
T_4	3.27	6.63	9.82	8.96	6.89
T_5	3.3	7.18	10.01	9.22	6.98
T_6	3.32	5.69	8.33	6.88	5.3
T_7	3.33	6.71	7.93	8.95	6.73
T_8	3.33	7.45	8.75	9.49	7.56
T_9	3.32	7.73	9.57	9.86	7.44
T_{10}	3.36	8.16	10.19	10.33	7.47
S.Em.±	0.026	0.614	0.539	0.816	0.678
C.D.at 5%	0.04	0.04	0.04	0.03	0.03

Manure (CPM), either alone or in combination with FYM, produced the highest LAI. This could be because of the higher uptake of nutrients especially N supplied by organic manures and this might have promoted the leaf area and the LAI. Besides, the favorable soil conditions provided either by poultry manure or FYM in addition to supplying plant nutrients might have influenced the leaf area and LAI positively. Such a positive effect was reported byAmanullah et al. [15] in groundnut and in cassava and maize.

Table 5. Average leaves per plant (Nos.) for Cowpea during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	30DAS	45DAS	60DAS	75DAS
T_6	1.99	5.47	9.58	7.85	6.01
T_7	2	5.93	9.94	8.53	7.59
T_8	2	6.81	10.13	8.61	8.98
T_9	2.01	8.23	10.3	9.37	9.23
T_{10}	1.99	8.84	11.2	9.79	10.17
S.Em.±	0.007	1.024	0.428	0.539	1.146
C.D.at 5%	0.07	0.07	0.07	0.09	0.06

Table 6. Average leaf area (cm^2/ plant) for Maize during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	30DAS	45DAS	60DAS	75DAS
T_1	68.25	95.6	128.96	242.77	342.07
T_2	72	105.06	149.19	253.98	354.05
T_3	75	139.62	171.8	280.58	364.54
T_4	78	149.27	196.3	295.46	399.38
T_5	85.5	152.56	205.97	312.7	423.26
T_6	65.25	98.89	138.67	253.86	360.62
T_7	81	106.3	169.47	273.16	374.56
T_8	83.25	125.16	194.7	300.99	388.78
T_9	83.7	168.88	201.79	317.27	436.89
T_{10}	87.75	177.22	224.51	325.23	485.35
S.Em.±	8.78	21.37	22.383	20.634	31.392
C.D.at 5%	26.09	0.76	0.76	0.76	0.76

Table 7. Average leaf area (cm^2/ plant) for Cowpea during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	30DAS	45DAS	60DAS	75DAS
T_6	117.75	61.65	69.09	72.23	119.73
T_7	119.25	71.39	79.68	85.55	142.44
T_8	123.75	83.285	86.58	94.1	150.85
T_9	124.5	90.26	95.69	103.69	163.4
T_{10}	134	98.32	102.09	109.85	172.13
S.Em.±	6.47	10.35	9.2	10.53	14.33
C.D.at 5%	21.09	1.04	1.04	1.04	1.04

Table 8. Average Leaf Area Index (LAI) for Maize during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	30DAS	45DAS	60DAS	75DAS
T_1	0.15	0.27	0.88	1.1	1.1
T_2	0.16	0.28	0.95	1.4	1.3
T_3	0.17	0.3	0.99	1.7	1.7
T_4	0.17	0.31	1.07	1.8	1.8
T_5	0.19	0.33	1.15	1.9	2
T_6	0.15	0.27	0.88	1.2	1.3
T_7	0.18	0.29	0.96	1.6	1.7
T_8	0.19	0.31	1.06	1.9	2
T_9	0.19	0.32	1.14	2.1	2.2
T_{10}	0.19	0.34	1.33	2.2	2.4
S.Em.±	0.02	0.01	0.06	0.3	0.3
C.D.at 5%	0.06	0.04	0.19	0.76	0.76

Table 9. Average Leaf Area Index (LAI) for Cowpea during different DAS

Treatments	Days After Sowing (DAS)				
	15DAS	**30DAS**	**45DAS**	**60DAS**	**75DAS**
T_6	0.26	0.4	0.71	0.63	0.8
T_7	0.27	0.46	0.74	0.81	1.2
T_8	0.28	0.49	0.75	0.9	1.505
T_9	0.29	0.49	0.78	1.08	1.675
T_{10}	0.29	0.54	0.83	1.19	1.945
S.Em.±	0.01	0.01	0.01	0.15	0.312
C.D.at 5%	0.05	0.05	0.04	1.04	1.04

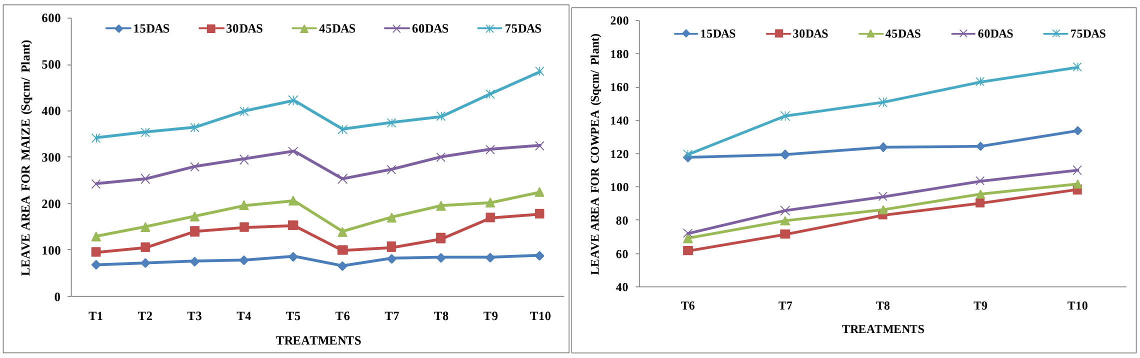

Fig. 4. Leave area in cm²/ Plant for Maize and Cowpea

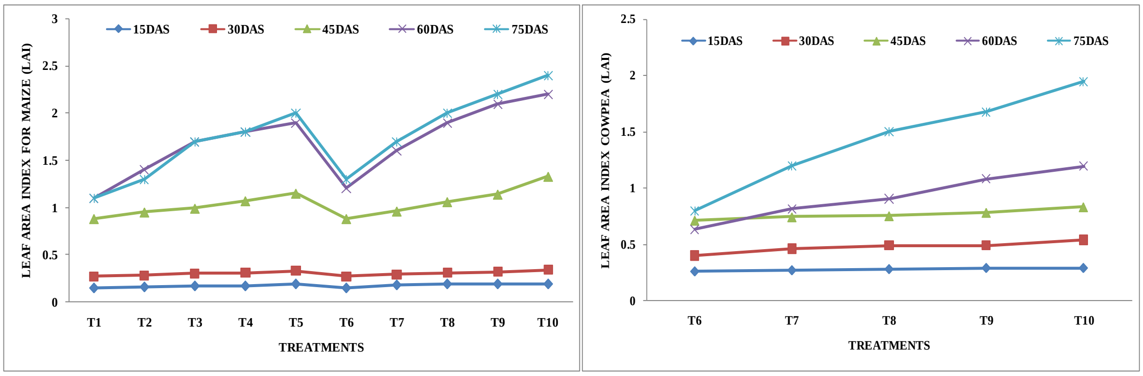

Fig. 5. Leave Area Index (LAI) for maize and cowpea

3.3 Average Dry Matter Accumulation (DMA)

Average dry matter accumulation recorded and it is tabulated in Tables 10 to 11 and Fig. 6. Calculation of Average Dry Matter Accumulation of cowpea was not possible for the first five treatments (T_1 to T_5) because the plants were too small. Therefore, the readings for average dry matter accumulation began with the sixth treatment (T_6). The maximum dry matter accumulation per plant at 30 DAS (103.99 g/m^2), 45 DAS (134.16 g/m^2), 60 DAS (317.50 g/m^2), 75 DAS (934.20 g/m^2) and at 90 DAS (1248.55 g/m^2) respectively, was recorded significantly under treatment T_{10}: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kgha-1), whereas, the lowest dry matter accumulation was recorded under T_1 exhibiting a mean value of 2.94, 68.21, 93.03, 232.71, 766.92 & 977.18 g/ m^2 respectively at 15, 30, 45, 60, 75 & 90 days after sowing (DAS).

In intercrop cowpea, the data on dry matter accumulation per plant of cowpea progressively increased. The results revealed that treatment, T_{10} significantly exhibited maximum dry matter accumulation among rest of the treatments at 15 DAS, 30 DAS, 45 DAS, 60 DAS & 75 DAS respectively. T_9pared with maximum dry matter accumulation treatment at 60 DAS. At 75 DAS, treatments T_7, T_8& T_9 was found to be at par with treatment T_{10}. Intercropping increased the dry matter production and yield compared to sole crops [31,32]. The best indicators of a crop's overall performance and responsiveness are the amount of dry matter produced [33]. Thus in all the treatments, T_{10} can be gauged as satisfyingly exhibiting good growth and productivity in both maize and cowpea when assessed in terms of different plant growth parameters.

3.4 Crop Growth Rate (CGR) and Relative Growth Rate (RGR)

Averaged crop growth rate (CGR) was plotted as shown in Fig. 7 with its data tabulated as shown in Table 12. Measurements of Crop Growth Rate (CGR) and Relative Growth Rate (RGR) were not possible for the first five treatments (T_1 to T_5) because the plants were too small for cowpea. As a result, the readings began with the sixth treatment (T_6). Maximum crop growth rate for Maize was recorded significantly under treatments T_{10} with values 17.55 & 25.77 g/m^2/day during 15-30 DAS & 30-45 DAS respectively; T_5 with value 55.60 g/m^2/day recorded at 45-60 DAS; and T_9 with value 64.45 & 47.25 g/m^2/day during 60-75 DAS & 75-90 DAS.

Whereas, the lowest crop growth rate for maize was found to be 11.22 g/m^2/day during 15-30 DAS under T_1. Since CGR is the change in rate of dry matter production per unit of land area with advancement of crop growth, higher dry matter production per plants at 15-30 DAS, 45- 60 DAS, 60-75 DAS and 75-90 DAS respectively in treatment T_{10} were significantly more when compared with other treatments. In intercrop cowpea, the data on crop growth rate of cowpea at 15-30, 30-45, 45-60 & 75-90 DAS respectively during experimentation have been highlighted in Table 13 and Fig. 7. On mean basis, maximum crop growth rate was observed under T_{10} during the period of 45-60 DAS reaching a value of 3.01 g/m^2/day. The rapid increase in crop growth rate (CGR) during the initial 60

Table 10. Average Dry Matter Accumulation (DMA) for Maize

Treatments	Days After Sowing (DAS)					
	15DAS	30DAS	45DAS	60DAS	75DAS	90DAS
T1	2.94	68.21	93.03	232.71	766.92	977.18
T2	3.86	73.27	95.82	255.76	807.48	1006.45
T3	3.55	76.54	100.26	263.74	817.22	1023.9
T4	3.52	78.17	102.57	275.9	837.2	1039.18
T5	3.36	88.75	114.51	304.73	903.4	1117.07
T6	3.28	70.99	93.82	243.39	800.74	987.38
T7	3.19	82.72	106.98	277.2	868.8	1067.03
T8	3.18	85.86	110.77	287	882.1	1108.89
T9	3.48	94.49	119.56	296.75	916.9	1201.65
T10	3.82	103.99	134.16	317.5	934.2	1248.55
S.Em.±	0.33	2.63	4.31	6.87	4.51	15.95
C.D.at 5%	0.97	7.82	12.81	20.42	13.41	47.38

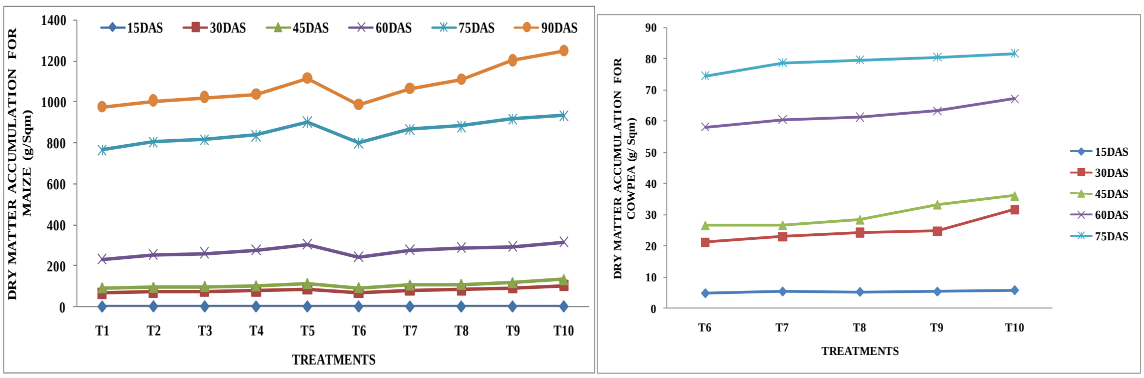

Fig. 6. Dry Matter Accumulation (DMA) for maize and cowpea

Table 11. Average Dry Matter Accumulation (DMA) for Cowpea

Treatments	Days After Sowing (DAS)				
	15DAS	**30DAS**	**45DAS**	**60DAS**	**75DAS**
T6	4.77	21.16	26.58	58.19	74.56
T7	5.3	22.84	26.68	60.61	78.8
T8	5.19	24.29	28.4	61.33	79.77
T9	5.28	24.77	33.26	63.36	80.54
T10	5.72	31.63	36.1	67.22	81.79
S.Em.±	0.18	1.45	0.79	1.52	1
C.D.at 5%	0.6	4.73	2.58	4.95	3.27

Table 12. Average Crop Growth Rate (CRG) in g/m^2/day for Maize

Treatments	Days After Sowing (DAS)				
	15-30DAS	**30-45DAS**	**45-60DAS**	**60-75DAS**	**75-90DAS**
T_1	11.22	24.98	46.93	50.84	37.3
T_2	11.69	24.67	50.96	54.7	38.13
T_3	12.34	24.88	51.65	55.29	39.13
T_4	12.7	24.99	52.85	56.88	38.67
T_5	14.55	25.23	55.6	61.27	42.57
T_6	11.37	24.8	49.28	55.81	35.8
T_7	13.6	25.02	52.53	59.06	40.58
T_8	14.07	25.13	53.59	58.68	44.48
T_9	15.89	25.26	53.29	64.45	47.25
T_{10}	17.55	25.77	54.78	62.95	46.69
S.Em.±	0.51	0.84	1.63	3.02	2.7
C.D.at 5%	1.51	NS	4.84	NS	NS

Table 13. Average Crop Growth Rate (CRG) in g/m^2/ day for Cowpea

Treatments	Days After Sowing (DAS)			
	15-30DAS	**30-45DAS**	**45-60DAS**	**60-75DAS**
T_6	1.61	2.49	2.86	2.59
T_7	1.67	2.47	2.98	2.67
T_8	1.8	2.5	2.95	2.61
T_9	1.79	2.6	2.98	2.55
T10	1.84	2.7	3.01	2.45
S.Em.±	0.07	0.09	0.13	0.17
C.D.at 5%	0.21	0.28	0.38	0.5

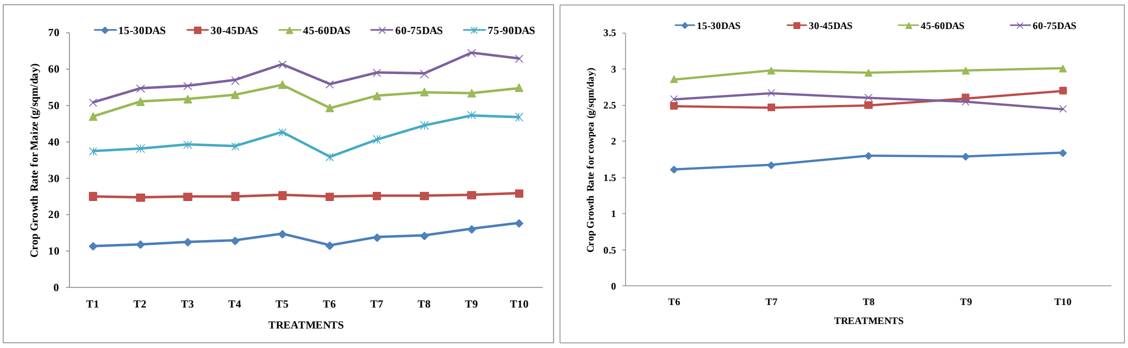

Fig. 7. Crop Growth Rate (CGR) for Maize & Cowpea

DAS can be attributed to optimal conditions for photosynthesis and nutrient uptake, which are critical for early crop development. This finding is consistent with the general understanding of crop growth dynamics [34 and 35]. After 60 DAS, the decline in CGR may be linked to factors such as nutrient depletion, increased competition for resources among plants and possibly environmental stressors. This phase of reduced CGR highlights the importance of proper nutrient management and pest control strategies in sustaining crop growth [36].

Relative Growth Rate (RGR) values computed in g/g/day from total dry matter accumulation obtained at different stages of crop growth in the present study are presented as below in Tables 14-15 and Fig. 8. The data reveal that RGR of maize and cowpea shows decreased trend from sowing rapidly and at slower pace up to at harvest stage. Study of the data reveals that relative growth rate for both the crops influenced significantly at 15-30 DAS. (RGR) is the per day increase in plant dry weight over the already existing dry weight and had a decreasing trend with advancement of crop development. [37]. Pandey and Singh [33] stated that an RGR value in wheat was initially high but with time it decreases and much of the decrease would be attributed to an increase of shading. Crop forage yield and RGR were reduced with intercropping compared with sole crop [38]. Yavas and Unay [39] stated that relative growth rate is a measure used to quantify the speed of crop growth. RGR values are influenced by reproductive stage growth and intercropping. The rate of translocation of photosynthates was probably declined in the plant tissues due to faster drying of cell sap and this was the probable reason for significantly lower RGR in these treatments at last stage of crop. Values for maize significantly reduced with maize aged and the highest values were obtained from intercropping systems. Nooli et al. [40,41,42] also observed similar behaviour of growth rates in maize due to integrated application of various organic and inorganic nutrient sources in maize.

Table 14. Average relative growth rate in g/g/day for Maize

Treatments	Days After Sowing (DAS)				
	15-30DAS	**30-45DAS**	**45-60DAS**	**60-75DAS**	**75-90DAS**
T_1	0.217	0.077	0.055	0.031	0.017
T_2	0.191	0.074	0.058	0.029	0.017
T_3	0.2	0.071	0.057	0.029	0.017
T_4	0.206	0.071	0.058	0.029	0.016
T_5	0.213	0.066	0.058	0.03	0.017
T_6	0.206	0.076	0.057	0.03	0.016
T_7	0.222	0.068	0.057	0.031	0.016
T_8	0.22	0.067	0.057	0.031	0.018
T_9	0.221	0.062	0.055	0.032	0.018
T_{10}	0.222	0.059	0.054	0.031	0.018
S.Em.±	0.01	0.002	0.001	0.001	0.001
C.D.at 5%	NS	0.005	0.004	0.002	0.002

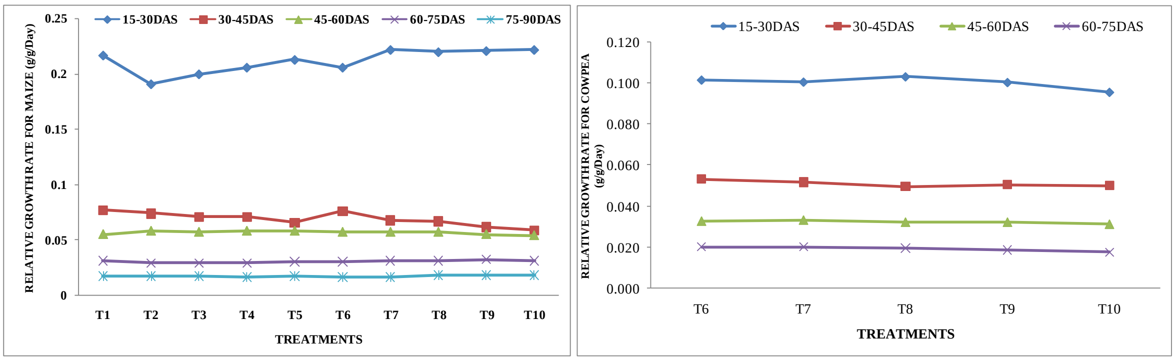

Fig. 8. Relative Growth Rate for Maize & Cowpea (g/g/Day)

Table 15. Average relative growth rate in g/g/day for Cowpea

Treatments	Days After Sowing (DAS)			
	15-30DAS	**30-45DAS**	**45-60DAS**	**60-75DAS**
T_6	0.102	0.053	0.033	0.020
T_7	0.101	0.052	0.033	0.020
T_8	0.103	0.050	0.032	0.020
T_9	0.100	0.051	0.032	0.019
T_{10}	0.096	0.050	0.031	0.018
S.Em.±	0.002	0.001	0.001	0.001
C.D.at 5%	0.005	0.004	0.003	0.002

Table 16. Correlation analysis on plant growth parameters of Maize

Parameters	Plant Height	No. of Leaves	Leave Area	LAI	DMA	CGR	RGR
Plant Height	1.00						
No of Leaves	0.75	1.00					
Leave Area	0.98	0.73	1.00				
LAI	0.91	0.93	0.92	1.00			
DMA	0.91	0.79	0.95	0.94	1.00		
CGR	0.82	0.58	0.86	0.78	0.91	1.00	
RGR	0.61	0.31	0.65	0.52	0.72	0.94	1.00

Table 17. Correlation analysis on plant growth parameters of Cowpea

Parameters	Plant Height	No of Leaves	Leave Area	LAI	DMA	CGR	RGR
Plant Height	1.00						
No of Leaves	0.98	1.00					
Leave Area	0.97	0.92	1.00				
LAI	0.95	0.99	0.86	1.00			
DMA	1.00	0.98	0.97	0.95	1.00		
CGR	0.98	0.96	0.98	0.92	0.98	1.00	
RGR	0.98	0.94	1.00	0.88	0.98	0.99	1.00

Correlation analysis on the different plant growth parameters for both the crops maize & cowpea was calculated as shown below in Tables 16 & 17 respectively. The correlation study shows positive correlation among plant height, no. of leaves, leaf area, LAI, DMA, CGR and RGR. Positive correlations among these parameters imply that as one parameter increases, the other parameters also tend to increase. This suggests that there is a coordinated and synchronized growth pattern in plants, where increases in one aspect of growth are associated with increases in other aspects as well. Similarly [43] also reported the same with positive correlation between whole plant photosynthetic rate on a mass basis and RGR.

4. CONCLUSION

Present study shows that application of intercropping of maize and cowpea in 2:1 ratio and application of 50% of RDN through farm yard manure and poultry manure along with lime @ 200 kg ha^{-1} contributed significantly maximum plant height, number of leaves per plant, leaf area index, dry matter accumulation and crop growth rate among rest of the treatments. The study also emphasizes that the contribution of insights into the potential benefits of integrating intercropping and organic manure application for enhancing the growth and productivity of maize and cowpea. Integrating intercropping and organic manure application are sustainable practices which hold promise for addressing agricultural challenges while promoting soil health and overall environmental sustainability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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