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Effect of Organic Nutrient Management and Intercropping of maize on the Soil Health of Acidic Soils of Mizoram

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ABSTRACT

The present investigation was conducted during the kharif seasons of 2020 and 2021 at the certified organic farm of Mr. Lalnuntluanga farm situated at Melriat village, Aizawl, Mizoram. The experiment was laid out in randomized block design (RBD) with ten treatments replicated thrice. These treatments were randomly arranged in each replication, divided into thirty plots. The treatments comprised of intercropping and organic nutrient management of maize on soil chemical and microbial properties. Soil pH, EC, OC, available N,P,K at pre experiment and post-harvest are analyzed. Standard methods of observation, analysis of soil and plant samples, and appropriate statistical methods for the analysis of data were used. Soil pH, EC values were significant at T_{10} at pre-experiment and recorded maximum at treatment T10, and organic carbon at T6 treatment. Soil available N, P, Kare recorded maximum at treatment T_{10} in pre experiment and post-harvest.

Key words : *Organic nutrient management, Soil health, Intercropping*

Introduction

Maize (*Zea mays* L.), also locally known as Vaimim is the 2nd most important cereal crop after rice in Mizoram and is grown in varied agro ecosystems as sole crop or in combination with other crops and trees. About 6,353 ha land (Statistical Handbook Mizoram, 2020) is reported to have been brought under maize cultivation in the state of Mizoram during the year 2019-2020 with the production of 11,568 metric tonne. Granged *et al*. (2011) reported that, pH is found to be generally acidic (4.5-5.0) in nature especially in northeast hilly region which could be due to the formation of humic acid because of organic matter decomposition. Mizoram is a hilly terrain where high rainfall is received every year. Shifting cultivation is a common practice and people mostly depend on the production of shifting cultivation sites for their livelihood. But it leads to rapid degradation of land because of leaching and runoff losses of top soil (Wapongnungsang *et al*., 2018). Grogan *et al*. (2012) reported that this has caused widespread concern about land degradation, declines in soil fertility, crop yields, food security, and ecological balance in Mizoram state. Soil acidity is common in regions where precipitation is high enough to leach significant amounts of exchangeable bases from the surface layers of soils. The high precipitation leaches appreciable amounts of exchangeable bases from the surface layers of the soils so that the exchange complex is dominated by H ions. Acid soils, therefore, occurs widely in humid regions and affects the growth of plants markedly (Brady and Nyle, 1974).

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In Mizoram, over the past ten years, the area planted to maize has grown dramatically, from 7,500 to 11,700 acres. Due to an increase in area (23,000 tonnes), production has grown, but productivity has decreased over that time, going from 2,093 to 1,940 kg/ha (ICAR-IIMR Annual Report, 2020). The level of production is somewhat moderate in Mizoram and it needs to be substantially increased to meet the growing demand for human food, animal and poultry feed. Maize is grown either sole cropping under *jhum* or with mixed cropping successfully intercropped with paddy, turmeric, ginger, other vegetables, pulses and oilseeds (Kumar *et al*., 2019). Organic farming is a socially acceptable and environmentally sound food production system for the fragile hill ecosystem. Farmers in the region have been practicing such cultivation for the centuries, though with low productivity and income. Soil enzyme activity is an indicator of soil health and respond to soil and land management quickly (Lungmuana *et al.,* 2019).

Keeping in view organic farming has a role in ensuring sufficient and nutritious food supply in the future and, high yield can be obtained by organic farmer, the present experiment and titled "Effect of organic nutrient management and intercropping of maize on the soil health of acidic soils of Mizoram" was planned have the following objectives:

1. To study the effect of organic nutrient management on soil properties.
2. To study the effect of intercropping on soil properties.
3. Effect of intercropping on economics of treatment combination.

Review of Literature

The present status and future prospect regarding the "Effect of organic nutrient management and intercropping of maize on the soil health of acidic soils of Mizoram" are reviewed under following heads:

To study the effect of organic nutrient management on soil properties

Tasung *et al.* (2019) stated from their observation at Arunachal Pradesh that intercropping of leguminous crops between maize increases the soil nitrogen content and beneficial microorganism. Economically, it is profitable as it provides additional income to the farmers. Application of FYM, vermin-compost, poultry litters, pig litter, bone meal, ash etc. not only increases the soil fertility status but also improves the soil physical condition.

Borase *et al.* (2020) conducted a long-term experiment in fluvisol (World Reference Base soil classification) from 2003 -2011 (8 years) and integrated from 2011-2016 (5 years) at the research farm of ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India, Their study aimed to assess the long-term impact of four crop rotations [rice-wheat, rice-wheat-mungbean, rice-chickpea, rice-wheat-rice-chickpea (2- year rotation)] each consisted of three nutrient treatments [control, integrated nutrient management (INM), and chemical fertilizers (RDF)] on soil carbon pools, soil microbial and biochemical properties. Therefore, they concluded that cropping intensification/diversification of Rice-Wheat rotation with grain legume inclusion along with INM could improve soil organic carbon, microbial activity, and enzymes activities and thereby improved the crop productivity.

To study the effect of intercropping on soil properties

Singh and Srivastava (2018) during their research at Birsa Agricultural University Farm, Kanke, Ranchi during *kharif* season revealed that farmers practicing intercropping of maize and pigeon pea made 81% profit more than those farmers who are involved in maize and pigeon pea monocropping. The profit of the farmers involved in the intercrops was possible due to the reduction in the cost of production as an economic advantage of intercropping.

Singh *et al.* (2019) during the research of Diversity of Landraces Maize in Mizoram: Prospect, Challenges and Opportunities reported that Maize (*Zea mays* L.) (locally known as Vaimim) is the 2nd most important cereal crop after rice in Mizoram and because of its divergent types, it can be grown over a wide range of climatic conditions and can be grown over a wide variety of soil but adapted to well drained mildly alkaline at a soil pH range of 7.5 to 8.5.

Effect of intercropping on economics of treatment combination

Laltlanmawia and Lalsiamliana (2019) reported from Serchhip district of Mizoram that due to the introductions of maize- based cropping system in jhum land during *kharif* season, farmers get dual benefits and doubling their income by selling of maize as well as soybean with a reasonable price.

Biruk *et al.* (2021) carried out a field experiment during 2017 to 2018 cropping season at Kako, Bena-Ttsemay woreda, South Omo zone, Southern Ethiopia to determine the effect of intercropping of maize and cowpea on the yield, land use efficiency and profitability of both crops. Their findings revealed that the land use efficiency improved by 55.8 % when intercropping of one row maize to one row cowpea and intercropping of one row maize to two-row cowpea was by 27.9%, which indicated that when intercropped, the productivity was higher than the sole.

Materials and Methods

The materials, methodology and techniques adopted during the experiment conducted in season of 2020 and 2021, investigation entitled "Effect of organic nutrient management and intercropping of maize on the soil health of acidic soils of Mizoram".

Experimental Site

The experiment was conducted during the kharif seasons of 2020 and 2021 at the certified organic farm of Mr. Lalnuntluanga farm situated at Melriat village, 13 km from the main capital Aizawl city Mizoram under Tlangnuam RD Block, Aizawl, Mizoram.

Climate and Weather

During rains, the climate in lower hills and river gorges are highly humid and exhausting for people, whereas it is cool and pleasant in the higher hills even during the hot season.

Data showed that during experimentation, the *kharif* crop received 845.8 mm rainfall and 1876.6 mm rainfall during the year 2020 and 2021, respectively. Therefore, the amount of rainfall received was conducive for satisfactory growth of maize. 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.

Soil Characteristics

Soils are generally fertile and responsive to fertilizer application. It is rich in organic carbon content but low in available phosphorus and medium in nitrogen and potassium content. However, the area is suitable for agricultural and horticultural cultivation and allied activities such as sericulture and forest plantation etc for sustainable management of land resources. The soil was sandy loam in texture, medium inorganic carbon and medium in available nitrogen, low in phosphorus and medium in potassium.

Experimental Details

Experimental Design

The experiment was laid out in randomized block design (RBD) with ten treatments replicated thrice. The treatments comprised of cowpea intercropping and organic nutrient management. There were 10 treatments and each replicated thrice. These treatments were randomly arranged in each replication, divided into thirty plots. The treatments tested, specifications of the layout, etc. are given below.

"MZCP-10" (Mizoram local) Cultivar of cowpea was taken as test crop.

Soil Properties

Soil biological analysis

Microbial biomass carbon (MBC) was determined

Table 1. Chemical analysis of soil at pre-experimental stage

Sl No	Parameter	Unit	Methodology	Reference
1	Available N	Kg ha^{-1}	Kjeldahl method	Johan Kjeldahl,1883
2	Available P	Kg ha^{-1}	Bray's No 1Method	Bray and Kurtz,1945
3	Available K	Kg ha^{-1}	Extraction with Ammoniumacetate solution (Jackson, 1973)	Flame photometer(ESICO-1382, India)
4	Organic Carbon	%	$K_2Cr_2O_7$ wet OxidationMethod	Walkey and Black,1934
5	pH		1:2.5 soil water suspension	WPH-10,Wensar, India
6	EC	dS m^{-1}	Electrical conductivity meter	Method No. 4USDA. Hand Book No. 16 (Richards, 1954)

by chloroform fumigation extraction method where fresh soil was extracted with 0.5 M K_2SO_4 (Jenkinson, 1988). Carbon content in the extract was determined by $K_2Cr_2O_7$ wet-oxidation method and total N by Kjeldahl method (Bremner and Mulvaney, 1982). The difference between fumigated and un-fumigated samples was determined and calculation of MBC and MBN were done using conversion factors (KEC = 0.38; Vance *et al.,* 1987 and KEN = 0.5). The microbial quotient was calculated as the ratio of MBC to SOC and expressed in percentage (Anderson and Domsch, 1989).

Acid (ACP) and alkaline phosphatase activities (ALK) were estimated using modified universal buffer (MUB, pH 6.5 and 11) and p–nitrophenyl phosphate disodium salt (0.025 M) as a substrate (Tabatabai and Bremmer, 1969).

Soil dehydrogenase activity (DHY) was estimated by the reduction of triphenyl tetrazolium chloride (TTC) to triphenyl formazan (TPF) during soil incubation of 37 °C for 24 h and expressed as $\mu g\ g^{-1}$ (dw) Casida Jr. *et al*., 1964.

Economic analysis

Cost of cultivation, gross return, net return and benefit cost ratio was worked out to evaluate the economics of each treatment, based on existing market price of inputs and output according to the treatment and different parameters.

Cost of cultivation (ha^{-1}): It is a supplementary index to indicate the amount of capital resources needed for raising a particular crop. In preparing the cost of cultivation, expenditure incurred on items such as labour (including family labour), seeds, organic manures, plant protection and power (tractor, power tiller and pumping water). The cost of cultivation for each treatment was worked out separately; taking into consideration all the cultural practices followed and costs of inputs used.

Gross return (`ha^{-1}) - It is the total monetary value of the economic produce (such as grains, tubers, bulbs, fruits, etc.) and by-products (such as straw, fodder, fuel, etc.) obtained from the crop. It is calculated by multiplying the yield (of both main and by-product) with the prevailing market price and is expressed asha^{-1}. The gross return from each treatment was calculated.

Gross return **(₹ha^{-1})** = Income from the sale of grain and Stover.

Net return (₹ha^{-1}) -The net profit from each treatment was calculated separately, by using the following formula.

Net return (**INR** ha^{-1}) = Gross return (**INR** ha^{-1}) - Cost of cultivation (**INR** ha^{-1})

Benefit cost ratio (B:C ratio)-This index provides an estimate of the expenditure incurred in adopting a particular crop. It is calculated by the following formula:

Statistical Analysis

Randomized block design was used in the experiment. The data recorded during investigation were subjected to statistical analysis as per method of "Analysis of variance technique" (Skeleton). The significance and non-significance of the treatment effect were judged with the help of 'F' variance ratio test. Calculated 'F' value (variance ratio) was compared with the table value of 'F' at 5% level of significance. If calculated value exceeded the tabular value, the effect was considered to be significant. Skeleton for analysis of variance has been given in the Table 2.

Results and Discussion

Soil analysis

Available N, P and K in soil (kg ha^{-1}) at pre-experiment

Among all treatments, significantly highest available

Table 2. Skeleton of ANOVA for Randomized Block Design

Source of variation	d.f.(degree offreedom)	S.S.(Sum of square)	M.S.S(Mean sum of Square)	F cal	F Tab at 5%
Due to Replication	(r-1)	S.S.	R.S. S	T.S.S.	
Due to Treatment	(t-1)	S.S.	T.S. S	E.S.S.	
Due to Error	(r-1) (t-1)	S.S.	E.S. S		
Total	(rt-1)	T.S.S.			

where,
T.S. S = Total sum of square, E.S. S = Sum of square due to error, R.S. S= Root sum of square

nitrogen (N), content in the soil was recorded under treatment T_{10} during 2020 (290.14 kg ha^{-1}), two-year mean data analysis (302.90kg ha^{-1}). However, it was found statistically similar toT_4, T_5, T_7, T_8 and T_9 respectively. The lowest available nitrogen (N) content on two-year mean analysis was found with the treatments T_6. In Phosphorus, among all treatments, significantly highest available phosphorus (P) content in the soil was found under treatment T_{10} during 2020 (10.51 kg ha^{-1}), 2021 (12.18kg ha^{-1}) and two-year mean data analysis (11.35 kg ha^{-1}). However, it was found statistically similar to T_5 and T_9. Meanwhile, the lowest available P content during both the year and on mean basis in soil was observed under T_1. The data on soil available potassium (K) values were significant in different treatments. Significantly highest available potassium(K) content in the soil during 2020 (267.57 kg ha^{-1}), 2021 (274.10 kg ha^{-1}) and on mean value (270.84 kg ha^{-1}) were found under treatment T_{10} which was followed by T_5, T_9, T_4, T_8, T_3 and T_7 respectively. The lowest available K content during both the year and on mean value in soil was observed under T_1.

Available N, P and K in soil (kgha^{-1}) at post-harvest

Among all treatments, significantly highest available nitrogen (N), content in the soil was recorded under treatment T_{10} during 2020 (315.95kgha^{-1}), 2021 (342.91 kg ha^{-1}) two-year mean data analysis (329.43 kgha^{-1}). However, it was found statistically similar to T_5, T_8; T_9. While during year 2021, significantly highest available nitrogen (N) content in the soil was recorded under treatment T_6, which was followed by treatment T_7 and T_9. In Phosphorus, among all treatments, significantly highest available phosphorus(P) content in the soil was found under treatment T_{10} during 2020 (12.14 kgha^{-1}), 2021 (13.96kg ha^{-1}) and two- year mean data analysis (13.05kg ha^{-1}). However, it was found statistically similar to T_5 T_8; T_9. On the other hand, lowest available P content during both the year and on mean value in soil was observed under T_1.

The data revealed that the soil available potassium (K) values were affected significantly due to different treatments. Significantly highest available potassium (K) content in the soil during 2020 (273.82 kg ha^{-1}), 2021 (281.15 kg ha^{-1}) and on mean (277.49 kg ha^{-1}) were found under treatment T_{10}which was followed by T_4; T_5,T_8; T_9. On the other hand, lowest available potassium (K) content during both the year and on mean value in soil was observed under treat-

Table 3. Effect of intercropping and organic nutrient management on N, P and K of pre-experiment and post-harvest of crop.

Treatment	Available N (kg ha^{-1})						Available P (kg ha^{-1})						Available K (kg ha^{-1})					
	Pre-experiment			Post-Harvest			Pre-experiment			Post-Harvest			Pre-experiment			Post-Harvest		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
T_1	208.03	219.55	213.79	220.02	227.80	223.91	3.26	3.95	3.60	3.92	4.73	4.32	119.44	124.05	121.75	123.85	128.82	126.34
T_2	253.37	276.00	264.69	276.46	302.22	289.34	5.41	6.59	6.00	6.56	7.81	7.19	222.07	227.61	224.84	227.32	233.86	230.59
T_3	268.97	287.49	278.23	287.69	309.63	298.66	6.56	7.84	7.20	7.78	9.20	8.49	245.91	251.82	248.87	251.57	257.93	254.75
T_4	265.67	282.82	274.25	283.11	302.34	292.73	6.47	7.69	7.08	7.61	8.97	8.29	246.89	252.90	249.90	252.34	259.05	255.70
T_5	253.66	269.29	261.48	269.75	286.54	278.15	6.35	7.67	7.01	7.51	8.89	8.20	253.06	258.63	255.85	258.28	264.74	261.51
T_6	238.65	251.90	245.28	252.25	267.53	259.89	6.12	7.61	6.87	7.62	9.13	8.38	256.37	262.36	259.36	262.05	268.58	265.31
T_7	238.99	260.54	249.77	260.69	284.17	272.43	7.22	8.45	7.83	8.37	9.81	9.09	253.07	259.45	256.26	258.58	265.47	262.02
T_8	234.20	252.31	243.26	252.64	272.53	262.59	7.49	9.05	8.27	8.90	10.53	9.72	262.18	268.44	265.31	268.06	274.66	271.36
T_9	280.63	299.88	290.26	300.14	320.43	310.29	7.21	8.48	7.84	8.43	9.78	9.10	263.44	269.70	266.57	269.33	276.03	272.68
T_{10}	290.14	315.66	302.90	315.95	342.91	329.43	10.51	12.18	11.35	12.14	13.96	13.05	267.57	274.10	270.84	273.82	281.15	277.49
S.Em. ±	2.43	2.48	2.40	2.48	2.44	3.04	0.21	0.22	0.21	0.18	0.20	0.17	1.50	1.50	0.16	1.47	0.90	1.59
C.D. at 5 %	7.24	7.36	7.14	7.38	7.25	9.05	0.63	0.66	0.64	0.54	0.61	0.51	4.46	4.45	0.48	4.37	2.67	4.73
F-Test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

ment T_1. The increase in N content of soil may be the effect of incorporation of organic manure along with lime in soil this may be attributed to the mineralization of soil nutrients available to plants naturally. Similar results were also reported by Onunwa *et al*. (2021). The root borne phosphatase is more effective at hydrolyzing organic phosphorus because the root excretes more protons (malate, malonate, and citrate) and carbohydrates. The phosphate-solubilizing bacteria like *Pseudomonas*, which are reported to be more prevalent in intercropped soils and are associated with higher nitrogen and phosphorus content in soil, are enhanced by the hydrolysis of the organic phosphorus. The built up of available phosphorus was higher in the organic manure treated plots that might be due to release of organic acid during microbial decomposition of organic matter which might have helped in the solubility of native phosphates thus increasing available phosphorus pool in the soil.

Effect on biological properties of soil MBC, APA and DHA at post-harvest

The data pertaining to soil MBC (microbial biomass carbon (mg kg^{-1}); APA, (acid phosphatase activity (mg PNP g^{-1} h^{-1}); DHA, (dehydrogenase activity (mg TPF g^{-1} 24 h^{-1}) was analyzed and tabulated in Table 4.1. The effect of intercropping and organic nutrient management on MBC was significant. Application of treatment T_{10} increased contribute more microbial biomass carbon (MBC) and the significantly maximum MBC was recorded during 2020 (356.77 Ugg^{-1}), 2021 (372.31 Ugg^{-1}) and two-year mean (364.54 Ugg^{-1}) over other treatments except it was found statistically similar to treatments T_5 on mean analysis, T_8 and T_9 during 2020.

The microbial biomass is an essential component of nutrient cycling in the agro-ecosystems. Soil management practices strongly affect the size of the microbial biomass pool. The study of soil floral or faunal activity and soil microbial function, such as MBC, SMBN, and soil enzyme, is known as soil biological health Liu *et al.* (2010). In the current study, an increase in the activity of soil enzymes indicated that pulse crops could enhance the health of the soil.

In acid phosphatase activity (APA), among all treatments, significantly highest acid phosphatase activity (APA) in the soil was found under treatment T_{10} during 2020 (776.45Ug g^{-1}), 2021(724.24Ug g^{-1}) and two-year mean data analysis (750.34Ug g^{-1}). However, it was found statistically similar to T_5 and T_9 on mean analysis. On the other hand, lowest available acid phosphatase activity (APA) during both the year and mean value in soil was observed under T_1.

Phosphatases are important, because they provide P for plant uptake by releasing PO_4 from immobile organic P. The findings are in consistent with Ebhin Masto *et al*. (2006) who reported that phosphatase activity was strongly influenced by soil pH. Both acid and alkali phosphatase activities were higher under manure-amended plots and lower in the control.

The data revealed that the soil dehydrogenase activity (DHA) values were affected significantly due to different treatments. Significantly highest DHA in the soil during 2020 (6.19), 2021 (6.21) and on mean (6.20) (Ug g^{-1} h^{-1}) were found under treatment T_{10} which was followed by T_4; T_5, T_8; T_9. On the other hand, lowest dehydrogenase activity (DHA) values during both the year and on mean in soil was observed under treatment T_1.

The legume-intercropped treatment was shown to have higher dehydrogenase activity. When compared to the monoculture, the soil that had been supplemented with legumes had a greater dehydrogenase level. An ecosystem with higher organic matter input normally tends to have higher microbial biomass Wapongnungsang and Tripathi (2018) thus, contributing to greater recovery of soil fertility status and enzymatic activity increased like acid phosphatase, dehydrogenase etc.

Effect on biological properties of soil microbial status at post-harvest

The data revealed that the population of bacteria, fungi and actinomycetes was influenced significantly among treatments. Maximum influence on bacteria was significantly recorded with T_{10} (60.07, 62.44 and 61.25(cfu $\times 10^5$ g^{-1} soil) during both the years and on mean basis which is significantly at par with treatments T_4, T_5, T_7, T_8 and T_9 respectively.

Maximum influence on Fungi was significantly recorded with T_{10} (26.92, 26.80 and 26.86 (cfu $\times 10^4$ g^{-1} soil) during both the years and on mean basis which is significantly at par with the rest of the treatments except T_1 respectively.

Significant influence on actinomycetes was recorded with T_{10} (35.82, 34.66 and 35.24 (cfu $\times 10^4$ g^{-1} soil) during both the years and on mean basis which is significantly at par with the rest of the treatments except T_1 and T_2respectively. The lowest bacteria, fungi and actinomycetes population on both year and two-year mean analysis were observed with the treatment T_1 (53.95, 23.74, 32.13cfu $\times 10^4$ g $^{-1}$ soil).

The result revealed that the interaction between maize and cowpea increased the abundance of some bacteria, fungi and actinomycetes in intercropping as compared to sole maize. Soil microorganism play a key role in soil nutrient cycling and crop nutrient uptake. Similar findings are also reported by Chaudhary *et al.* (2023); that soil microbes are an important part of soil ecosystem, and their community composition and quantity changes reflect soil quality and health to a certain extent, and are also the key factors to overcome continuous

Soil fungi decompose organic matter in crop residues. The result is consistent with the findings of Zhao *et al.* (2022), they reported from their observation that the diversity and richness of the fungal community increased in intercropping maize and peanut, consistent with the promotion of fungal community growth under intercropping. Further, they observed that saprotrophic fungi were concentrated in rhizosphere soil as a dominant functional group and obtained nutrients by dead host cells. Actinomycetes have been known to secrete a wide array of hydrolytic enzymes in natural conditions as a dominant member of saprophytic community.

Conomical Studies

Cost of cultivation (₹ha^{-1}**) -** Cost of cultivation of different treatments was worked out by summation of cost of cultivation of component crops during both year 2020, 2021 and their mean. Among the various treatments, highest cost of cultivation (46,852ha^{-1} in 2020),(49,195ha^{-1} in 2021) and (48,023.5 ha^{-1} in two years mean) were involved in treatments T_8 respectively. The lowest cost of cultivation of (20,500ha^{-1} in 2020, (21,525ha^{-1} in 2021 and (21,012.05ha^{-1} in two years mean) were calculated for treatment T_1 and T_6 respectively (Table 4.2).

Gross return (`ha^{-1}**) -** Gross return for the different treatments was obtained by addition of returns obtained from all the commercials part of both the crop during both year 2020, 2021 and their mean (Table 4.2). The maximum gross return was computed under treatment T_{10} during 2020, 2021 and their mean (70,368.34ha^{-1}, 72,458.23 ha^{-1} and 71,413.285ha^{-1}, respectively. The lowest gross return (21,141.2322,645.34 and 21,893.285ha^{-1}) was noted by treatment T_1 during both the year and two years mean.

Net return (`ha^{-1}**) -** Net return of the various inter-

Table 4. Effect of intercropping and organic nutrient management on economics:

Treatments	Gross return (₹/ha)			Cost of cultivation (₹/ha)			Net Return (₹/ha)			B: C Ratio		
	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean	2020	2021	Mean
T_1	21,141.23	22,645.34	21,893.285	20,500	21,525	21,012.05	641.23	1,120.34	880.785	1.03	1.05	1.04
T_2	36,854.12	39,200.64	38,027.38	33,400	35,027	34,213.5	3,454.12	4,173.64	3813.88	1.10	1.12	1.11
T_3	53,373.30	56,632.05	55,002.675	46,852	49,195	48,023.5	6,521.30	7,437.05	6979.175	1.14	1.15	1.14
T_4	49,191.28	53,415.28	51,303.28	40,126	42,153	41,139.5	9,065.28	11,262.28	10,163.78	1.23	1.27	1.25
T_5	55,955.37	60,194.70	58,075.035	42,596	44,747	43,671.5	13,359.37	15,447.70	14,403.53	1.31	1.35	1.33
T_6	21,296.76	22,527.02	21,911.83	20,500	21,525	21,012.5	796.76	1,002.02	899.39	1.04	1.05	1.04
T_7	37,367.23	41,742.12	39,579.675	33,400	35,113	34,256.5	3,967.23	6,629.12	5,298.175	1.12	1.19	1.15
T_8	59,435.87	62,886.45	61,161.160	46,852	49,195	48,023.5	12,583.87	13,691.45	13,137.66	1.27	1.28	1.3
T_9	59,346.22	60,373.77	59,859.99	40,126	42,154	41,140.0	19,220.22	18,219.77	18,719.99	1.48	1.43	1.45
T_{10}	70,368.34	72,458.23	71,413.285	42,596	44,748	43,672.0	27,772.34	27,710.23	25,241.285	1.65	1.62	1.63

cropping systems was workout to evaluate the profitability of the different treatments and presented in Table 4.2. Maximum net return in the year 2020 27,772.34 ha^{-1} and in the year 2021,27,710.23ha^{-1} and their mean 25,241.285 ha^{-1} was recorded in treatment T_{10}. However, the lowest net return (641.23,1,120.34 and 880.785 ha^{-1}) was noted by treatment T_1 during both the year and two years mean.

Benefit: Cost ratio - Maximum benefit: cost ratio, 1.65 in 2020, 1.62 in 2021 and 1.63 on mean basis was recorded with treatment T_{10}. Whereas, treatment T_1 gave B:C ratio of 1.03 during 2020 and 1.05 during 2021 and their mean 1.04 and T_6 gave lowest benefit: cost ratio of 1.04 during 2020, 1.05 in 2021 and 1.04 respectively on mean basis during the years of investigation (Table 4.2).

All intercropping treatments resulted in more profit in term of monetary returns as compared to sole crops. The higher economic returns were obviously due to higher seed and stover yield production of component crops. This could be attributed to higher yield advantage under intercropping of maize with cowpea. In agreement with these results, higher net monetary return was also reported Sonam *et al.* (2014). Hence, it was concluded that intercrop of maize with cowpea is biological and economically sustainable intercropping system.

Summary and Conclusion

To assess the effect of intercropping and organic nutrient management on soil properties

Nutrient status of soil samples of both the years were analyzed, soil status viz., maximum soil pH, EC (Electrical conductivity), organic carbon (%) at pre- experiment and post-harvest, soil microbial status at post-harvest of crop viz., bacteria (cfu $\times 10^5$ g $^{-1}$ soil), fungi (cfu $\times 10^4$ g $^{-1}$ soil), actinomycetes (cfu $\times 10^4$ g $^{-1}$ soil) showed significant result due to different treatments, while in soil samples, significantly maximum soil nutrient content was observed with available N, P and K (kg/ha) at pre-experiment and post- harvest as well as available MBC (mg kg^{-1}), APA (mg TPF g^{-1} 24 h^{-1}), DHA (mg PNP g^{-1} h^{-1}) after crop harvest with treatment T_{10}: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha) due to the effect of cowpea intercropping and nutrient management on maize which is followed by treatment T_5: Maize + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha) respectively.

To work out the economics of treatment combinations

Maximum cost of cultivation was recorded in T_3: Maize + 100% of RDN through Poultry Manure and T_8: Maize + Cowpea (2:1) + 100% of RDN through Poultry Manure and lowest at T_1 and T_6 while maximum gross and net return was observed in treatment T_{10}: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha). Moreover, it was observed from data that maximum B:C ratio was recorded with treatment T_{10}: Maize + Cowpea (2:1) + 50% of RDN through Farm Yard Manure + 50% of RDN through Poultry Manure + Lime (200 kg/ha) amongst the rest of the treatment whereas the lowest B:C ratio was recorded with T_1 and T_6 respectively.

Conclusion

From the experimental findings, it is therefore, being concluded that for more productive cultivation among the various treatments, the quantity of organic matter incorporated into soil helps to improve the available NPK. The application of balanced amounts of nutrients and manures also improve the organic matter and MBC, APA and DHA status of soils, which corresponded with higher enzyme activity. The role of cereal+legume intercropping systems for improving the productivity and profitability and sustaining the soil health through improving physical, chemical, and biological soil parameters is observed from the experiment. Therefore, this treatment may be adopted to harness maize production and profitability under the marginal and degraded land especially in light of the changing climate and ecological parameters of Mizoram.

Conflict of Interest- None

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