Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2023, Volume 36, Issue 1, Page 212-218

Effect of integrated nutrient management on growth and yield of Soybean - Maize sequence and soil health in acidic soil of Mizoram

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ARTICLE INFO

Article history:
Received: 14 September, 2022
Revision: 24 April, 2023
Accepted: 25 April, 2023

Key words: *Hill terrace, soil health, soybean-maize sequence, soil enzyme activity, yield*

DOI: 10.56678/iahf-2023.36.01.27

ABSTRACT

Proper integration of nutrient is beneficial for soil health and plant growth and yield characteristics. Two-year experiment was conducted in acidic terrace soils of ICAR RC NEH Region farm, Mizoram Centre where *kharif* soybean is followed by *rabi* maize. Agricultural lime and chemical fertilizer integrated with vermicompost and FYM were used as treatment combinations. Results suggested that growth and yield parameters of soybean and maize such as plant height, no of branches per plant, no of pods per plant, cob length and girth of maize, and grain yield were significantly increased due to the application of lime and higher dose of chemical fertilizers, and integration with organic manures. Soil pH, available N, P and K were increased due to liming. Liming and fertilizer integrated with manures also increased the dehydrogenase and acid phosphatase enzyme activity of soil. The experiment suggests that liming material and integration of chemical fertilizer with organic manures are important to increase the soil health, plant growth and yield in acidic terrace soils of Mizoram.

1. Introduction

Appropriate integration of chemical fertilizers and organic manures and knowledge transfer to the farmers is one of the key principles of integrated nutrient management (INM; Gruhn et al. 2000). Balanced utilization of organic sources of nutrients such as farm yard manures (FYM) and other manures along with mineral fertilizers is vital for maximizing crop yields with the goal to retain environmental and ecological balance. Intensification of agriculture by injudicious use of fertilizers alone deteriorates soil health, intensify environmental pollution, and even biodiversity and human health (Campiglia et al. 1999). Incorporation of balanced and recommended dose of nutrients application from organic and inorganic sources is prerequisite for higher yield and reducing production cost (Shukla et al. 2022).

Soils in the north-eastern region of India are acidic in nature where approximately 65 per cent of the area has soil pH below 5.5 (Sharma and Singh 2002). Soil acidity induce phosphorus (P) deficiency, low base saturation and aluminium (Al) and iron (Fe) toxicity (Patiram 1991, Manoj-Kumar et al. 2012). The situation is further aggravated by sloppy terrain where soil erosion and land degradation induced soil carbon loss have a negative impact on sustainable farming systems and crop production (Saha et al. 2012). Liming increased soil pH thereby improving the availability of plant nutrients, uptake and biological activity and lowers toxicity of elements like Al^{3+}, vital for achieving optimum crop yields in acid soils (Reddy and Subramanian 2016). Hence, an integrated approach, incorporation of liming, fertilizer and manure application along with adoption of suitable cropping sequences is a good strategy for enhancing crop growth under acidic soils (Manoj-Kumar et al. 2012). Soil organic carbon (SOC) constitutes the interface between soil biological activity and nutrients for soil microbes, and plant uptake. Thus, soil biochemical activities like dehydrogenase and acid phosphatase enzyme activity mediates the soil functioning and acts as an indicator of soil quality (Lungmuana et al. 2019).

The cropping intensity in the NEH region is low (134%) and one reason may be due to the prevalence of rainfed mono-cropping system. Thus, a proper cropping sequence with the inclusion of suitable legume is required for sustaining and increasing the agricultural production of the region. Maize is the second largest cereal crop grown as rainfed in Mizoram next to rice which covers an area of 6353 hectares with production of 11568 MT during 2019-2020 (Anonymous 2020). Cultivation of *rabi* cereals like maize

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with additional irrigation is one option to increase the cropping intensity and system productivity. Therefore, an experiment was conducted where soybean followed by *rabi* maize was conducted for two years with an objective to study impact of different combination of liming and fertilizer on growth and yield characters of soybean followed by maize and also the effect of treatments on soil health in acidic degraded terrace soils of Mizoram.

2. Materials and Methods

Study environment: A field experiment was carried out during the *kharif* and *rabi* season of 2016 and 2017 at the research farm of ICAR Research Complex for North Eastern Hill Region, Mizoram Centre, Kolasib, Mizoram having an elevation of 630 m MSL. The climate of location is subtropical humid receiving an average annual rainfall of 2600 mm. The initial soil was clay loam texture (*Alfisol*) having soil pH (1:2.5 soil water suspension): 5.41, organic carbon (Walkley─Black): 0.88%, available N (alkaline $KMnO_4$─N): 78.4 mg kg^{-1}, available P (Bray─1): 13.15 mg kg^{-1}, available K (1 N NH_4─acetate): 170.5 mg kg^{-1}, available S ($CaCl_2$ extractable): 25.92 mg kg^{-1}, exchangeable Ca and Mg (1 N NH_4─acetate): 2.5 and 1.45 Meq 100^{-1} g soil.

Experimental layout: The experiment was laid out in a two way randomize complete block design (RCBD) with three replications in upland terrace. The treatments comprised two dose of hydrated lime (L_1-0 and L_1-1000 kg/ha) and five dose nutrient treatment (T_1-0, T_2-half the recommended dose of fertilizer (RDF), T_3-Full dose RDF, T_4-Half RDF+FYM @ 3 tonnes/ha and T_5-Half RDF+Vermicompost @ 3 tonnes/ha. The RDF followed for soybean was 20:60:40 kg ha^{-1} N, P and K and maize was 80:60:40 kg ha^{-1} N, P and K. Lime was applied in the form of calcium hydroxide and N, P and K as urea, SSP and MOP. Lime was applied seven days before the sowing and subsequently after sowing, fertilizer application was carried out where half N was applied as basal dose while the other two portions were top dressed in an interval of 30 days after the first application. Soybean (var. JS-335) was sown during the month of August (35cm x 15cm spacing) followed by maize (var. RCM-75) during November (70cm x 35cm spacing). Standard cultural practices were followed during the entire crop growth period. Soybean growth attributes such as plant height, number of branches, number of pods per plant were recorded from five randomly selected plants from each plot whereas for maize cob length, cob girth and grain yield were recorded at the time of final harvest.

Soil sampling: Soils attached to the roots of maize plant were collected after the completion of two season sequence and passed through 2 mm sieve. Fresh soil samples were preserved at 4ºC for biological analysis and remaining portion were air dried in shade to determine the physico-chemical soil parameters. Soil moisture was determined by oven drying of the fresh samples at 105ºC till constant weight. Acid phosphatase (ACP) activity was determined by the method of Eivazi and Tabatabai (1977) where one g of fresh soil with the substrate (0.025 N *p*─nitrophenyl phosphate pH 6.5 was incubated at 37°C. The activity was determined in terms of *p*-nitrophenol (PN) produced during 1 hour of incubation as µg PN/g (dry weight) soil/h). Dehydrogenase activity (DHY) was determined by the method of (Casida et al. 1964) expressed as µg (TPF)/g (dry weight) soil/h after incubating soil sample with 2,3,5─triphenyl tetrazolium chloride (TTC) at 37°C for 24 hours.

Data analysis: Two-way analysis of variance (ANOVA) for RCBD was used for comparing the effect of lime and fertilizer treatments and interactions. All main effects means were subjected to post hoc tests (LSD) to identify the homogeneous means at ($P<0.05$) level of significance. Multivariate analysis principle component analysis (PCA) was done and scattered plots were drawn considering PC 1 and PC 2 as X and Y axis to observe the relative position of the treatment combinations. All the statistical analysis was carried out using statistical software SAS version 9.3 (SAS Institute, Chicago).

3. Results and Discussion

Crop growth and yield: The experimental data on crop growth of soybean and maize revealed that liming applied @ 1000 kg/ha significantly increased the plant height (59.08 cm), number of branches (7.68), number of pods per plant (51.75) and grain yield (2.01 t/ha against no lime 1.67 t/ha) of soybean (Table 1). Similarly plant height (184.38 cm), cob length (18.81 cm), cob girth (15.23 cm) and grain yield of maize (3.23 t/ha) was also improved significantly against no lime (167.17 cm, 17.25 cm, 14.47 cm and 2.81 t/ha, respectively; Table 2). The combine application of half dose of fertilizer with FYM and vermicompost (59.54 and 62.16 cm) exerted taller plant height of soybean while the number of pods per plant was significantly increased by half NPK with FYM (51.43), with vermicompost (50.84) and full NPK (49.87) compared to control (42.65) respectively. Similarly, half NPK with FYM, vermicompost and full NPK significantly increased the plant height; cob length and cob girth of maize against the control treatment (154.06, 16.74 cm and 13.94 cm). The grain yield of soybean was significantly increased by half NPK with FYM (2.02 t/ha), vermicompost (2.14 t/ha) and full NPK (1.82 t/ha) compared to half NPK (1.6 t/ha) and control (1.62 t/ha; Table 1). Half NPK with vermicompost (3.21 t/ha), FYM (3.15 t/ha) and Full NPK (3.1 t/ha), half NPK (2.94 t/ha) significantly increase the grain yield of maize over control (2.69 t/ha).

Table 1. Effect of lime and nutrient management on growth and yield parameters of Soybean

Treatments	P. Height (Cm)	No. branches	No. pods per plant	Grain yield ($t\ ha^{-1}$)
No Lime	53.39^{b}	7.22^{b}	45.39^{b}	1.67^{b}
Lime	59.08^{a}	7.68^{a}	51.75^{a}	2.01^{a}
Lime (F Value)	18.45**	5.02*	47.29**	31.03**
Control	46.24^{c}	6.91^{b}	42.65^{c}	1.62^{cd}
½ NPK	55.56^{b}	7.49^{ab}	48.08^{b}	1.60^{d}
Full NPK	57.66^{b}	7.51^{ab}	49.87^{ab}	1.82^{bc}
½ NPK FYM	59.54^{ab}	7.63^{a}	51.43^{a}	2.02^{ab}
½ NPK Vermi	62.16^{a}	7.71^{a}	50.84^{ab}	2.14^{a}
Fert (F Value)	16.89**	1.93^{ns}	11.77**	12.25**
*Lime*Fert*	0.31^{ns}	0.21^{ns}	0.7^{ns}	0.66^{ns}

Note: * *p*-level < 0.05; ** *p*-level < 0.01. The data represents pooled data (2016 and 2017). Means in columns with the same letter are not significantly different for each factor (Lime and fertilizer).

The experimental soil was acidic (Soil pH 5.4) and liming induced increased soil pH and nutrient availability have increased the plant growth and yield characters. Liming can reduce aluminium toxicity and improved plant growth and similar findings of plant growth and yield improvement due to lime application were reported by Manoj-Kumar et al. (2012). The higher growth and grain yield under application of lime and amendments (NPK with vermicompost and FYM) was attributed to good soil health due to application of available nutrients and organic manures which was observed to increased soil biological and chemical properties (Bhatt et al. 2004). Lime application has led to 20% grain yield over control while INM with vermicompost and FYM has led to increase of 32% and 25% grain yield of soybean over control. Similarly, 15% increment in grain yield of maize was observed due to lime application and INM with vermicompost and FYM has led to increase of 19% and 17% grain yield of maize over control. Combined application of organic and inorganic sources controls the release of nutrients in the soil through mineralization of organic substances which facilitated better crop growth (Acharya et al. 2012, Shahid et al. 2013). On contrary, lowest grain yield in absolute unfertilized control plot was probably associated with decrease in soil organic carbon pool and reduction in nutrient supply (Baishya et al. 2015).

Table 2. Effect of lime and nutrient management on growth and yield parameters of Maize

Treatments	P. Height (Cm)	Cob length (Cm)	Cob girth (Cm)	Grain yield ($t\ ha^{-1}$)
No Lime	167.17^{b}	17.25^{b}	14.47^{b}	2.81^{b}
Lime	184.38^{a}	18.81^{a}	15.23^{a}	3.23^{a}
Lime (F Value)	14.9**	20.21*	10.97**	55.48**
Control	154.06^{c}	16.74^{c}	13.94^{c}	2.69^{c}
½ NPK	179.27^{ab}	17.80^{bc}	14.78^{b}	2.94^{b}
Full NPK	181.65^{ab}	18.14^{ab}	14.72^{b}	3.10^{ab}
½ NPK FYM	172.48^{b}	18.30^{ab}	14.99^{b}	3.15^{a}
½ NPK Vermi	191.42^{a}	19.19^{a}	15.81^{a}	3.21^{a}
Fert (F Value)	7.79**	5.29**	6.8**	11.15**
*Lime*Fert*	2.38^{ns}	2.63^{ns}	0.78^{ns}	5.69**

Note: * *p*-level < 0.05; ** *p*-level < 0.01. The data represents pooled data (2016 and 2017). Means in columns with the same letter are not significantly different for each factor (Lime and fertilizer).

Soil properties: Effect of liming profoundly increased various soil properties (Table 3). Addition of lime showed significant effect on soil pH (5.56) against without lime (5.4) while the fertilizer treatments have no significant effect on the soil pH. The soil organic carbon was not significantly affected by lime whereas significant increase in the SOC was observed with half dose of NPK with FYM (0.98%) and vermicompost (1%) against control (0.76%). Liming has significantly increased the status of available N (101.06 mg/kg), P (14.89 mg/kg), K (199.57 mg/kg), exchangeable Ca (3.18 Meq/100g) and Mg (1.99 Meq/100g) against no lime (88.2, 12.96 and 182.97 mg/kg: N, P, K) and 2.43, 1.63 Meq/100g exchangeable Ca and Mg respectively. However, there was no significant effect on the status of available N, P and exchangeable Ca by the fertilizer treatments, but the available K was higher in all the fertilizer treatments (Half NPK with vermicompost, FYM, Full NPK, Half NPK: 203.59, 203.42, 194.51, 183.41 mg/kg) against the control (171.42 mg/kg). Similarly, the exchangeable Mg was slightly higher in all the fertilizer treatments (Half NPK with vermicompost, FYM, Full NPK, Half NPK: 1.95, 1.98, 2.02, 1.7 Meq/100g) against the control (1.4 Meq/100g) respectively. Liming increased the enzyme activity of dehydrogenase (8.83 µg TPF/g/h) and acid phosphatase (316.6 µg PN/g/h) against no lime (6.56 µg TPF/g/h and 285.57 µg PN/g/h). The dehydrogenase activity was significantly increased by half dose NPK with vermicompost (9.09 µg TPF/g/h) compared to all the treatments, the acid phosphatase enzyme activity was significantly increased by half dose NPK with vermicompost and FYM (336.68 µg PN/g/h) against full dose NPK (283.69 µg PN/g/h), half NPK (284.84 µg PN/g/h) and control (273.07 µg PN/g/h) respectively.

Integrated nutrient management has led to improvement in the chemical and biological properties of soil along with the attribution of lime incorporation in the studied cropping sequence. Omission of lime in the NPK graded dose and organic amendments does not indicate any positive response on soil acidity suggesting that liming play an important role in acidic soil for soil health improvement. The findings are in line with Saha et al. (2010) where addition of organic manure in the form of FYM and Vermicompost and lime addition with chemical fertilizers in an integrated manner showed significant improvement in soil health. This positive effect of balanced nutrition on soil health through integrated nutrient management over absolute unfertilized and controlled treatment might be attributed to better crop growth and root biomass and better return of surface plant residues (Christensen 1988).

Soil enzyme activity is an indicator of soil health and respond to soil and land management quickly (Lungmuana et al. 2019). Application of lime increase the soil pH thereby increases decomposition and mineralization of soil OM to increase soil enzyme activity (Acosta–Martinez and Tabatabai 2000). Organic manures increase microbial activity to improve soil health and it can be observed that the DHY and ACP were significantly increased in the manure integrated treatments compared to full and half dose of NPK. Ramdas et al. (2017) and Mandal et al. (2018) have also reported similar results of increased DHY and ACP activity by INM treatments. Table 4: Effect of lime and nutrient management on growth and yield parameters of Soybean

Treatments	**pH**	**SOC (%)**	**N (mg kg^{-1})**	**P (mg kg^{-1})**	**K (mg kg^{-1})**	**Ca (Meq 100 g^{-1})**	**Mg**	**DHY (µg TPF g^{-1}h^{-1})**	**ACP (µg PNg^{-1}h^{-1})**
No Lime	5.40^{b}	0.86^{a}	88.20^{b}	12.96^{b}	182.97^{b}	2.43^{b}	1.63^{b}	6.56^{b}	285.57^{b}
Lime	5.56^{a}	0.95^{a}	101.06^{a}	14.89^{a}	199.57^{a}	3.18^{a}	1.99^{a}	8.83^{a}	316.6^{a}
Lime (F Value)	20.1**	1.39^{ns}	10.68**	9.15**	16.13**	21.97**	10.5**	67.29**	7.99*
Control	5.44^{b}	0.76^{b}	88.90^{a}	12.25^{b}	171.42^{c}	2.77^{a}	1.40^{b}	6.26^{b}	273.07^{b}
½ NPK	5.56^{a}	0.86^{ab}	90.03^{a}	13.76^{ab}	183.41^{bc}	2.60^{a}	1.70^{ab}	7.10^{b}	284.84^{b}
Full NPK	5.49^{ab}	0.94^{ab}	100.08^{a}	14.47^{a}	194.51^{ab}	2.72^{a}	2.02^{a}	7.06^{b}	283.69^{b}
½ NPK FYM	5.41^{b}	0.98^{ab}	97.35^{a}	14.54^{a}	203.42^{a}	3.03^{a}	1.98^{a}	8.96^{a}	336.68^{a}
½ NPK Vermi	5.49^{ab}	1.00^{a}	96.78^{a}	14.62^{a}	203.59^{a}	2.92^{a}	1.95^{a}	9.09^{a}	336.68^{a}
Fert (F Value)	2.05^{ns}	1.44^{ns}	1.24^{ns}	1.97^{ns}	8.97**	0.91 ^{ns}	4.26*	16.7**	5.48**
*Lime*Fert*	0.66^{ns}	1.41^{ns}	0.06^{ns}	0.83^{ns}	1^{ns}	0.91^{ns}	1.66^{ns}	1.25^{ns}	0.39^{ns}

Parameters	PC 1	PC 2
S. Plant height	0.937	-0.113
S. No branches	0.928	-0.199
S. No pods	0.915	0.003
S. Grain yield	0.952	-0.045
M. Plant height	0.909	-0.144
M. Cob length	0.865	0.265
M. Cob girth	0.950	0.008
M. Grain yield	0.906	0.014
N	0.960	-0.025
P	0.888	0.122
K	0.957	0.054
Ca	0.874	-0.151
Mg	0.774	0.154
DHY	0.889	0.046
pH	0.937	-0.113
SOC	0.573	0.805
Acid phosphatase	0.786	-0.392
Eigenvalue	13.38	1.02
Proportion	78.7%	6.05%
Cumulative	78.7%	84.77%

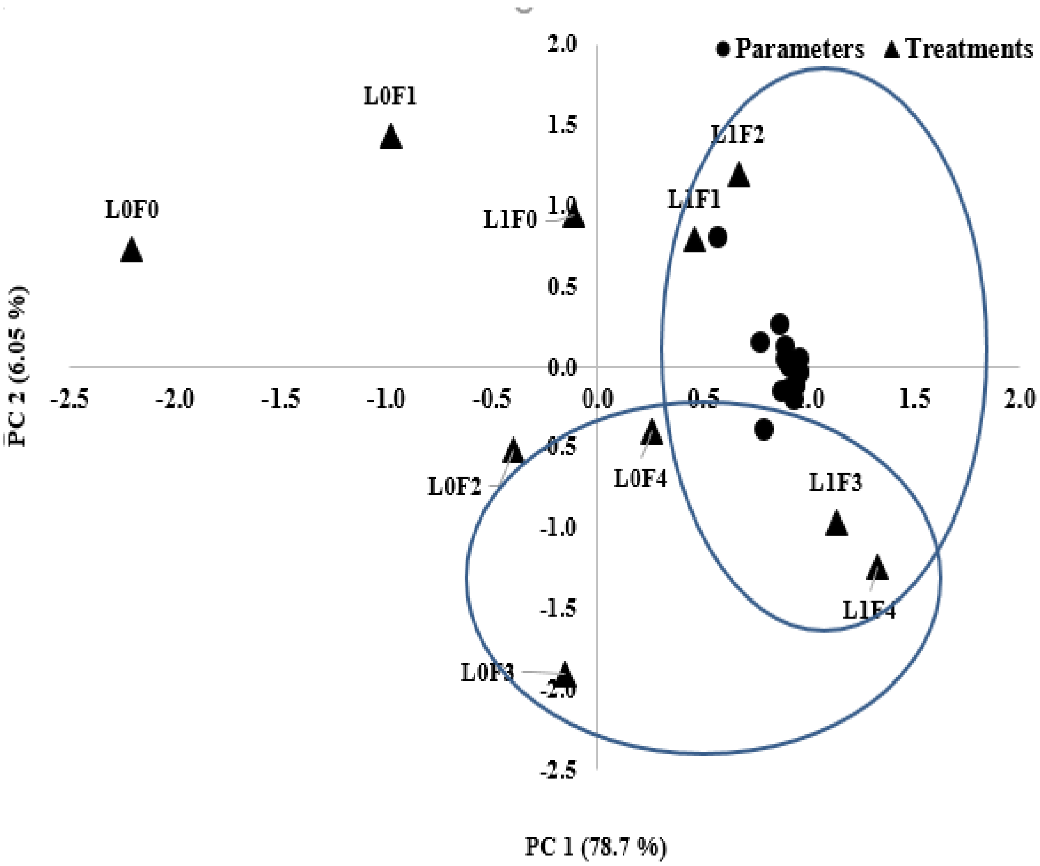

Figure 1. Scattered diagram of principal component analysis (PCA)

Relationship between the studied parameters and principal component analysis (PCA): Principal component analysis (PCA) verified the first two components accounted for 84.77% of the total variance into variables (PC1: 78.7%, PC2: 6.05%) across all the studied parameters (Table 4). PC1 showed positive loadings on all the studied parameters and PC2 had negative loadings on plant height, no of branches, grain yield of soybean and plant height of maize and available N, exchangeable Ca and soil pH respectively. The spatial variability of treatments and studied parameters was presented in Figure 1 respectively. The PCA generated two distinct clusters where lime treatment was located in the +ve side of PC 1 and fertilizer treatments comprising of integration with manures separately suggesting that lime application and integration of fertilizer with organic manure is responsible for the studied plant growth, yield and soil properties.

4. Conclusion

An integrated approach of soil acidity management through application of liming and fertilizers with manures was found to be beneficial for improving the soil health, chemical properties and its enzyme activities thereby enhancing the growth and productivity in soybean and maize-based cropping sequence. Crop rotation with soybean which is a leguminous crop benefitted the soil nutrients status and supply of nutrients to the succeeding crop. From results of present study, it may be concluded that application of half dose of recommended dose of fertilizers (NPK) coupled with organic sources of nutrients through vermicompost was found to be most beneficial for optimizing the growth and yield of soybean and maize, and thereby increasing soil biological and chemical properties. Overall liming and sustainable intensification of nutrients through INM showed a significant advantage in the crop productivity and soil health management of soybean-maize cropping sequence in the acidic soils of Mizoram.

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