Research article

The Effects of Green Manure on Sustainable Agriculture Soil Conservation under Open Field Conditions

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Abstract Green manure is a type of crop that is used for soil enhancement, both physical and biological. It is enriched with organic matter that provides nutrients to the soil and improves soil fertility. However, improper chemical use by farmers results in soil degradation and adverse effects on beneficial soil microorganisms. To mitigate this problem, farmers need to use fertilizer only as required. The purpose of the current study was to grasp the efficacy of green manure on soil improvement, with consideration of the principles of sustainable agriculture. The research aimed to study the effect of green manure on soil properties including soil pH, soil EC, and available nitrogen. Experiments were carried out in field conditions at the National Meanchey University, Cambodia, from June 25 to July 25, 2022. The experiment was laid out in a randomized complete block design (CRBD) with 4 treatments and 8 replications utilizing green manure produced from different plants. Treatment T0 represented the control, T1 *Glycine max*, T2 *Vigna radiata*, and T3 *Crotalaria Juncea*. The result showed that green manure has a significantly positive effect on soil properties such as pH, electric conductivity, and available nitrogen. T3 produced the highest post-treatment soil pH and reduction in soil electric conductivity (EC), which averaged 7.14 and 0.46, respectively. T2 provided the greatest amount of available nitrogen, while untreated soil was not significantly different among treatments. Therefore, the application of green manure can be a vital choice in soil improvement for sustainable agriculture and increased yield.

Keywords green manure, fertilizer, soil, sustainable agriculture

INTRODUCTION

Soil health is defined as the capacity of the soil to function as a living system, with ecosystem and land use boundaries. It sustains plant and animal productivity, maintains or enhances water and air quality, and promotes plant and animal health. It is based on the interaction, balance, and stability of the physical, chemical, and biological properties of soil, which have direct effects on nutrient cycling, soil structure, water availability, and pests and diseases, ultimately affecting crop health and yield (Patil and Solanki, 2016).

Consequently, fertilization increases efficiency and obtains better quality product recovery in agricultural activities. Fertilizer use has increased by 70%, and pesticide use has increased several-fold (Savci, 2012; Tilman et al., 2002). As a result, fertilization causes the accumulation of heavy metals in soil and plant systems. Long-term unbalanced use of agrochemicals may lead to a community shift of beneficial microorganisms with dangerous consequences for soil physical and chemical structure (Hamidov et al., 2007). Soil structure in agricultural productivity is very important and it is regarded as an indicator. Unconsciously, the fertilizing of soil, just as in the deterioration of the structure is caused by industrial emissions. Especially $NaNO_3$, NH_4NO_3, KCI, K_2SO_4, and NH_4Cl demolish the structure, such as fertilizers, soil, and soil structure, and deterioration is difficult to obtain high-quality and efficient products (Shaviv, 2001). Moreover, soil degradation has strong negative economic impacts since a large part of the population relies on agriculture as a primary source of income (Lal, 2015). More than 500 million hectares of tropical arable land and 33% of the earth's land surface globally face a decline in soil health (Lamb et al., 2005).

Therefore, green manure is considerable for use in soil improvement in terms of sustainable agriculture because it provides numerous benefits to crop production and soil health (Magdoff, 2001). According to Pandey et al., (2008), green manuring helped advance the soil's physical and biochemical anatomy, prevented leaching losses of nutrients, and added water-holding capacity. The approved use of green manuring resulted in high organic matter reserves which added both soil physical and chemical properties if compared to controlled fields. This is because they can help conserve, maintain, or replenish soil resources, including organic matter, nitrogen and other nutrient inputs, and physical and chemical properties (Sarrantonio and Gallandt, 2003). Several studies have investigated cereal-legume intercropping. Legumes are found in natural ecosystems and are key to promoting ecosystem efficiency such as nitrogen fixation, soil microbial health, and ecological network of biodiversity of soil (Duchene et al., 2017; Zhang et al., 2021). Likewise, Ablimit et al. (2022) revealed that microbial phylotypes were grouped into four major ecological clusters. The application of green manure led to significantly increased soil pH, nutrient contents, and enzyme activities, and significantly reduced the relative abundance of potential plant pathogens compared with monocropping, which should ensure high and stable maize yield under long-term continuous cropping (Charron and Sams, 1999).

We conduct research based on sustainable agriculture in an effort to achieve Cambodia’s action plan of Zero Growth on Chemical Fertilizers by 2050. The outcome of the research will be shared with farmers in an effort to maintain the environment and increase food safety.

OBJECTIVE

The research aims to enhance the soil property by inoculation of green manure from different plants, (i) *Glycine max*, (ii) *Vigna radiata*, and (iii) *Crotalaria Juncea*, in an open field at the National Meanchey University, Cambodia.

METHODOLOGY

Experimental Design and Plantation

This research was carried out at National Meanchey University from June 25, 2022, to July 25, 2022. The experiment was carried out by randomized complete block design (RCBD) consisting of four treatments and three replications (Table 1). Each block had a 2 m x 2 m diameter and a length of 0.5 m for a total area of 66.5 m^2. For the plantation, each plant was planted in the experimental field by using different types of plants for comparison. Green manures were plowed into the soil to a depth of 10 cm length after one month of plantation. Each treatment was plowed two times per day after fermentation. Treatment zero was the control, treatment one (T1) used *Glycine max*, treatment two (T2) used *Vigna radiata*, and treatment three (T3) used *Crotalaria Juncea*.

Table 1 Treatment and composition

Treatment	Inoculation
Control	Uninoculated
Treatment 1	*Glycine max*
Treatment 2	*Vigna radiata*
Treatment 3	*Crotalaria Juncea*

Reference: Blomme et al. (2022)

Soil Chemical Analysis

Soil samples were collected before and after plantation in the field experiment of the National Meanchey University. Upon collection, soil samples were sent immediately to the soil laboratory for further analysis including soil pH, soil electrical conductivity (EC), and available nitrogen, which followed the method of Kjeldahl (Cunniff, 1995). Soil pH was determined using the method of Kumar et al. (2014), while EC was analyzed according to the method proposed by Kargas et al. (2022).

Data Analysis

Data were analyzed for analysis of variants (ANOVA) using the R program version (4.0.3). The differences among means were tested by Duncan's multiple range tests at $p \leq 0.05$.

RESULTS AND DISCUSSION

Before planting, soil pH was detected to be the same value for all treatments. This was due to soil experimentation being in the same condition. However, the effect of intercropping on soil pH result displayed that application of green manure enhances soil pH significantly, increasing among treatments (Fig. 1) As a result, treatment 3 (T3) and treatment 4 (T4) provided the highest soil pH values, which ranged from 6 to 7. Our research strongly agreed with Kawu (2020), and found that incorporating green manure crops significantly influenced soil pH at harvest. This phenome is due to a major contribution of soil decomposition by microbial activity when incorporated into the soil (Msimbira and Smith, 2020). Previous studies have reported higher soil organic matter, nitrogen, phosphorus, potassium, calcium, and magnesium contents due to incorporating green manure (Biswas and Mukherjee, 2001; Herrera et al., 2007).

Soil reduction regarding electrical conductivity was examined and was found without significant difference relative to the control, which ranging from 1.20 to 1.44 dSm^{-1}. However, soil EC was found significantly reduced after incorporating green manure into the soil among different treatments (Fig. 2). Moreover, treatment three (T3) resulted in the greatest reduction in soil EC, with a value of 0.49 dSm^{-1}. Similar results, indicating that green manure reduced soil EC, were obtained by Bhayal et al. (2018). This decrease was due to the addition of readily decomposable organic matter in the form of green manure with accumulation of the CO_2 either may be due to the precipitation of Fe^{2+}, Mn^{2+} and consequent adsorption of other cations on the exchange site and decomposition of organic acid (Harish and Devasenapathy, 2010).

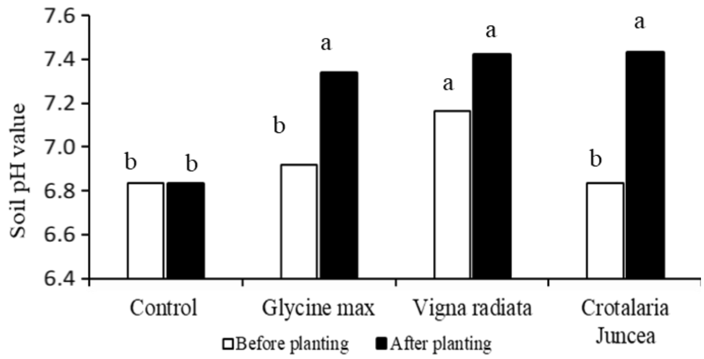

Fig. 1 The effect of green manure on soil pH before and after plantation

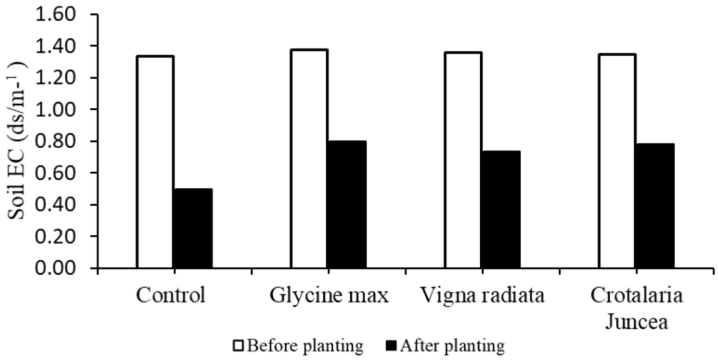

Fig. 2 The effect of green manure on soil electric conductivity

Green manure is usually considered as a cover crop sown to enhance the fertility of the soil between two crops demanding high nitrogen inputs (Sanaullah et al., 2022). After incorporation in soil, the result displayed that green manure had significantly increased the available nitrogen ($P < 0.05$). Barradas et al. (2001), in an experiment with eight species of green manure, observed that white lupine and common vetch were the species that accumulated the highest total N in the whole plant, with amounts of 251.6 and 228.1 kg/ha, respectively. Our result agreed with those of Salahin et al. (2013), finding that green manure has significantly increased soil organic matter, soil health, and crop growth. Moreover, the author found that green manure increased SOM and TN which was obtained from *V. radiata* and *S. aculeata*. There may be a difference in time and species of plant in this result. On the other hand, after incorporation into the soil, the nutrients in the plant biomass were released during the process of decomposition (Piotrowska and Wilczewski, 2012).

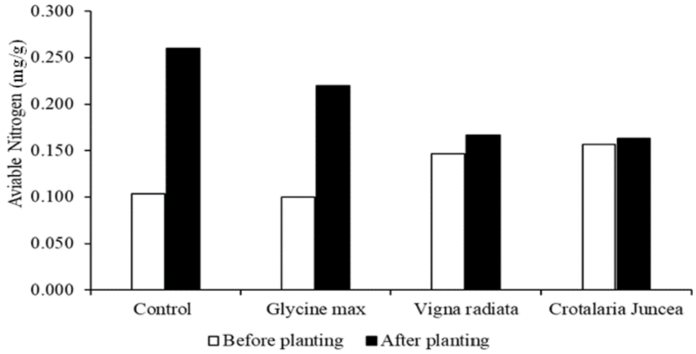

Fig. 3 The effect of green manure on soil available nitrogen

CONCLUSION

The incorporation of *Glycine max*, *Vigna radiata*, and *Crotalaria Juncea* as green manure showed a positive response on soil pH, soil electrical conductivity, and available nitrogen. Therefore, we concluded that treatments 1, 2, and 3 provided a positive result for soil health, but only treatment 2 provided the greatest value of available nitrogen.

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