Combination of vermicompost and mineral fertilizer on growth and yield of romaine lettuce (*Lactuca sativa* var. *longifolia* Lam)

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Abstract

Romaine lettuce (*Lactuca sativa* var. *longifolia* Lam) is a leafy vegetable that is commercially produced worldwide. Nitrogen (N) is one of the most important elements among plant nutrients. Its effects are related to the growth and yield of the crops; however, excessive synthetic fertilizer application can have adverse environmental effects and additional economic costs. Organic fertilizers like manure and compost release nutrients slowly for plant growth and enhance soil fertility. The aim of this study was to evaluate the combined rates of mineral nitrogen and vermicompost application on growth and yield of romaine lettuce (*Lactuca sativa* var. *longifolia* Lam.). The experiment was conducted at the crop station of the Royal University of Agriculture, Phnom Penh, Cambodia. The experiment consisted of five treatments with three replications, and treatments were: (i) 100% N fertilizer + 0% vermicompost (control), (ii) N fertilizer 75% + Vermicompost 25%, (iii) 50% N fertilizer + 50% vermicompost, (iv) 25% N fertilizer + 75% Vermicompost, and (v) 0% N fertilizer + 100% Vermicompost. Plants samples were taken from five random plants and analysed for plant height (cm), leaf number (No.), leaf area (cm^2), weight per plant (g), estimated non-marketable yield (t/ha), estimated marketable yield (t/ha) and estimated total yield (t/ha). Soil samples were collected at 0-20 cm depths and analysed for soil pH, SOM (%), total nitrogen (%), soil hardness (kg/cm2), situResp@ (Abs) and POXC (mg kg^{-1}). In general, the combined treatment of 50% of N fertilizer and 50% of vermicompost showed the best performance on growth and yield of romaine lettuce; including high leaf area, fresh weight per plant, estimated marketable yield and estimated total yield. Furthermore, POXC was also the highest among treatments. In conclusion, the combination of the organic and inorganic fertilizers (N50% + V50%) showed the best results when compared with full application of N fertilizer.

Keywords: growth, lettuce, mineral fertilizer, vermicompost, yield.

Introduction

Lettuce is produced commercially in many countries worldwide and is also widely grown as a vegetable in home gardens (Abu-Rayyan et al. 2004). It is a very popular vegetable due to its highest consumption rate and economic importance (Coelho et al. 2005). The romaine lettuce (*Lactuca sativa var. longifolia*) is commonly eaten raw in salads, but also can be cooked (Katz and Weaver, 2003). To enhance the growth and yield of the crop, farmers use various mineral fertilizers.

Low soil fertility such as poor physical, chemical and biological properties are a major problem in vegetable production. Chemical fertilizers have made substantial contributions to increased crop yields and food nutrition (Fageria 2009). However, excessive fertilizer application can have adverse environmental effects on water quality from nitrate leaching and phosphorus in runoff (Heckman 2007; Heckman et al. 2003). Therefore, it is important to determine fertilizer application rates that maximize yields while minimizing environmental pollution (Heckman et al. 2003).

Nitrogen (N) is an important element among other plant nutrients that enhance crop growth and yield. Its effects are related to the growth of leaf area and photosynthetic rate (Pinheiro Henriques and Marcellis 2000; Pons and Westbeek 2004). Optimal fertilizer management and efficient use of N are necessary to improve yield and quality, and may reduce production costs (Fageria 2009). Although inorganic fertilization is very important for healthy plant growth and development, the organic source of nutrients may have advantages such as slow release of nutrients, maintaining ideal carbon:nitrogen (C:N) ratio, improving water holding capacity and soil microbial biomass with fewer adverse effects (Kiros et al. 2018; Yadav et al. 2010). Mineral fertilizers must be used efficiently because they are highly soluble. The combination of mineral fertilizers and organic fertilizers may be the best strategy for soil fertility management.

Sustainable soil management concerns exist with the use of mineral fertilizers, because of their rapid solubility and sometimes excessive use, which can lead to environmental concerns such as decreased water quality from leaching and runoff (Heckman, 2007; Heckman et al. 2003; Manotti et al. 1994; Sims, Simard and Joern 1998). Moreover, when the sand content increases, the N use efficiency decreases. The efficiency of mineral fertilizers is generally highly variable and profitability is low (Seng et al. 2001). Such adverse effects are reported particularly for the case of highly weathered sandy soils with low N and organic matter contents. A combination of mineral and organic fertilizers may be a management practices that reduces N loss in weathered sandy soils and increase N-use efficiency.

However, some studies have shown that organic source N materials had a higher N-use efficiency then urea-N. This finding indicates that it could be of interest to include organic amendment combined with mineral fertilizer. On the other hand, it is important to address the locally-available organic manures to improve the soil fertility, especially in the areas with a high sand fraction and high cost of mineral fertilizers (Ro 2016).

Farm yard manure, particularly cow manure, is commonly used by farmers. However, vermicompost may have some advantages over cow manure, and vermicompost has been promoted as one of the viable alternative options for soil amendment. Its beneficial effects are reported as increased moisture-holding characteristics, enhanced nutrient uptake and plant hormone-like activity (Galli et al. 1990; Tomati et al. 1988). Additionaly, human pathogens maybe reduced through by earthworms during vermicompost production (Contreras-Ramos et al. 2004). Moreover, the vermicompost contain nutrients that are easily available for plant uptake (Suthar 2010).

Despite its benefits, sole use of vermicompost is not economical, but could be used in combination with mineral fertilizer. The combination of vermicompost and mineral fertilizers could help stabilize yield through providing micronutrients, improving nutrient retention and providing favorable soil physical conditions (Gill and Walia, 2014). There have been many reports on the benefits of combined use of mineral fertilizer and vermicompost on various crops (Singh and Wasnik 2013; Getaneh and Mezgebu 2019; Reddy et al. 1998; Desai et al. 1999; Jeyabal and Kuppusamy 2001; Canellas et al. 2002; Kabir 1998; Azad 2000; Suthar and Singh 2008).

Therefore, sustainable nutrient management with the combination of vermicompost and mineral fertilizer amendment are crucial to improving crop growth and yield of romaine lettuce without harming the environment. Additionally, this combination may also build up the nutrient balance and increase soil fertility. The aim of this study is to evaluate the combined rates of N mineral fertilizer and vermicompost application on growth and yield of romaine lettuce (*Lactuca sativa* var. *longifolia* Lam).

Methods

Experimental site and design

This experiment was conducted on a sandy loam soil at the crop station at the Royal University of Agriculture, Phnom Penh, Cambodia, from February 1st, 2020, to March 27th, 2020. The experiment was designed in Randomize Complete Block Design (RCBD) which consisted of five treatments and three replications: Treatment 1 ($N_{100\%}V_{0\%}$): 100% N fertilizer + 0% Vermicompost, Treatment 2 ($N_{75\%}V_{25\%}$): 75% N fertilizer + 25% of Vermicompost, Treatment 3 ($N_{50\%}V_{50\%}$): 50% N fertilizer + 50% of Vermicompost, Treatment 4 ($N_{25\%}V_{75\%}$): 25% N fertilizer + 75% of Vermicompost, Treatment 5 ($N_{0\%}V_{100\%}$): 0% N fertilizer + 100% of Vermicompost.

The soil characteristics of the experimental field was a soil pH 6.31 (H_2O, 1:2.5), Total N 0.08% (Kjeldahl digestion), SOM 0.46% (Walkley & Black wet composition), CEC 13.3 cmolc/kg (Ammonium acetate pH 7.0), sand 60%, silt 21.90%, and clay 18.10%.

The nutrient composition of the vermicompost was total N 0.56% (Kjeldahl digestion), total P_2O_5 0.85% (Olsen method), Total K 0.69% (Flamephotometer), organic matter 82% (Ignition loss), C:N 85.8 and moisture 6.66%.

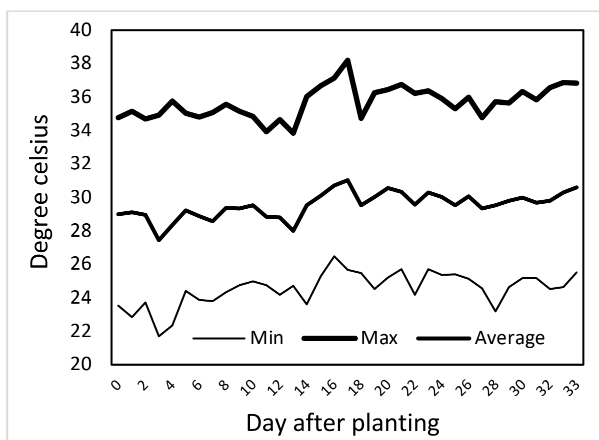

Fig. 1: Temperature during the whole crop cycle. Source: Weather station in crop station of Faculty of Agronomy, Royal University of Agriculture.

Plot preparation

The study included a total of 15 plots with a size of 1 m X 2 m per plot. Each plot contained four rows in which there were nine hills (one plant per hill), for a total of 45 plants per plot with 20 cm by 20 cm hill spacing. The plots were 0.5 m apart and were raised to height of 15 cm.

Fertilizer application

Phosphorus and potassium in the form of single super phosphate (SSP) and potassium chloride (KCL), respectively, were uniformly applied in all experimental plots at the rate of 30 kg P_2O_5 ha^{-1} and 130 kg K_2O ha^{-1} (Hochmuth and Maynard, 1996). Nitrogen application in the form of urea was split applied three times: 50% of N was applied pre-plant and the remaining N was applied at 30 days and 45 days after sowing (Smith, et al., 2011). Nitrogen was applied 5 cm to the side and 5 cm below the seed. Vermicompost was incorporated into the soil one week before sowing (Sharma et al., 2017). It was thoroughly mixed into the top 15 cm. The 100% rate of mineral N and vermicompost were 120 Kg ha^{-1} (Stivers et al. 1993) and 10 t ha^{-1}, respectively (Reddy et al. 1998; Singh and Wasnik 2013).

Plant materials and seed preparation

Romaine lettuce variety was Romanila F1 (RTU) developed by the Agriance Company. The romaine lettuce (*Lactuca sativa* var. *longifolia* Lam) seeds were sown into plastic trays for 20 days, and grown for additional for 35 days.

Growth and yield parameters

Growth and yield parameters such as plant height (cm), leaf number per plant, leaf area index, fresh weight per plant (g/plant), and estimated marketable yield (t/ha), estimated non-marketable yield (t/ha), and estimated total yield (t/ha) of romaine lettuce were measured and analyzed. Plant sample were randomly collected in a zigzag pattern, and five plants samples were collected for each treatment and replication.

Soil analysis

The soil sampling was performed pre-planting and post-harvest by sampling each plot at a 0-20 cm depth. Soils samples were air-dried, passed through a 2mm-sieve, and analyzed for pH (H_2O, 1:2.5), soil organic matter (Walkley & Black wet composition) and total Kjeldahl N (Kjeldahl digestion). Permanganate oxidizable carbon was determined using a 0.02 M KMnO4 solution as developed by Culman et al. (2012) and Weil et al. (2003).

Statistical analysis

The data were analysed using analysis of variance (ANOVA) in Statistix 8 (Analytical Software, Version 8). Comparisons between treatment means were done through the least significant difference (LSD) test at $P < 0.05$ probability level.

Results

The leaf area and weight per plant were significantly different among treatments (table 1), but there was no significant difference in plant height (22.3 - 24.3 cm for all treatments) and leaf number per plant (27.7 - 31.7 for all treatments; Table 1). The highest leaf area was found when high mineral N was applied between 50-100% (212.5 – 215.4 cm^2 leaf area). The combination of less mineral N and more vermicompost showed lower plant leaf area (187.05 cm^2 and 189.58 cm^2 for $N_{25\%} + V_{75\%}$ and $N_{0\%} + V_{100\%}$; respectively). Sole use of either mineral N or vermicompost showed low weight per plant, with only 189 g per plant for $N_{0\%} + V_{100\%}$ and 193 g per plant for $N_{100\%}+V_{0\%}$. The combination of mineral N and vermicompost produced high weight per plant, and the combined mineral N at 50% and vermicompost at 50% treatment had the highest weight per plant.

Table 1. Effect of a combined different rates of mineral N and vermicompost on plant height (cm), leaf number (No.), leaf area (cm^2) and weight per plant (g).

Treatment	Plant Height (cm)	Leaf Number (No.)	Leaf Area (cm^2)	Weight per Plant (g)
$N_{100\%}+V_{0\%}$	22.66	27.73	212.47 a	192.87 bc
$N_{75\%} + V_{25\%}$	24.26	31.66	208.41 ab	221.67 ab
$N_{50\%} + V_{50\%}$	24.30	31.46	215.38 a	251.07 a
$N_{25\%} + V_{75\%}$	23.13	31.20	187.05 b	204.47 bc
$N_{0\%} + V_{100\%}$	22.30	30.13	189.58 b	189.00 c
F-test	ns	ns	*	**
CV (%)	4.61	7.99	5.70	7.70

$N_{xx\%}$ represents percentage of nitrogen use at 120 kg ha^{-1} while $V_{xx\%}$ represents percentage of vermicompost use at 10 t ha^{-}, Different letters in a column denotes significant difference at P < 0.05 by Least Significant Different (LSD), The critical values are used for mean comparison by LSD at alpha = 0.05.

Table 2. The effect of different rates of vermicompost on pH, soil organic matter (SOM), total nitrogen (TN), and POXC.

Treatment	pH	SOM (%)	Total N (%)	POXC (mg kg^{-1})
$N_{100\%}+V_{0\%}$	6.26	0.73	0.04	218.60 c
$N_{75\%} + V_{25\%}$	6.14	1.16	0.03	300.78 b
$N_{50\%} + V_{50\%}$	6.37	1.37	0.03	403.42 a
$N_{25\%} + V_{75\%}$	6.19	0.87	0.03	376.51a
$N_{0\%} + V_{100\%}$	6.49	1.08	0.03	354.81 ab
F-test	ns	ns	ns	**
CV (%)	3.46	25.83	19.68	10.99

$N_{xx\%}$ represents percentage of nitrogen use at 120 kg ha^{-1} while $V_{xx\%}$ represents percentage of vermicompost use at 10 t ha^{-1}. Different letters in a column denotes significant difference at P < 0.05 by Least Significant Different (LSD). The critical values are used for mean comparison by LSD at alpha = 0.05.

Soil related parameters measured after harvest were shown in Table 2. The measured soil pH, SOM and Total N were not statistically different among treatments. The range of soil pH and SOM were between 6.19-6.49 and 0.73-1.37 % respectively for all treatments. The approximate total N was 0.03% for most of the treatments. POXC was found to be significantly different among the treatments. The increasing amount of vermicompost produced higher POXC levels. The sole use of mineral N without addition of vermicompost showed the lowest POXC amounts.

Discussion

Application of either sole or combination of mineral N fertilizer and vermicompost had no effect on plant height and leaf number. The highest leaf area was observed when 50% mineral N fertilizer and 50% vermicompost, compared to sole mineral nitrogen use. Similar studies found that the application of compost significantly increased the leaf area and number of leaves in a lettuce crop (Stancheva and Mitova 2002). A combination of vermicompost and mineral-N fertilizer significantly influenced some growth parameters in Cabbage plant (Canellas et al. 2002). Some morphological attributes such as plant height and leaf area were improved by application of vermicompost leachate in strawberry (Singh et al. 2010). The 50% mineral-N fertilizer and 50% vermicompost treatment had the highest leaf area, which may have been the result of a synergetic effect of the readily available N from the mineral-N fertilizer and the growth promoting hormones from humic acid in the vermicompost (Atarzadeh et al. 2013). Nitrogen influences plant growth and crop yield of leafy vegetables (Brintha and Seran 2009) by its associated effects on leaf growth and photosynthetic rate (Pinheiro Henriques and Marcellis 2000; Pons and Westbeek 2004). Hence, a combination of nitrogen and vermicompost enhanced the leaf area of romaine lettuce (*Lactuca sativa* var. *longifolia* Lam), which was greater compared to sole use of mineral nitrogen. A comparison of weight per plant among the treatments showed significant difference at 99% probability level. Combined application of 50% mineral-N fertilizer and 50% vermicompost produced greater weight per plant compared to 100% mineral N fertilizer treatment. The positive effects of vermicompost on plant growth and yield may not be due to the slow rate of nutrient release, but the results of the plant growth promoters and humic acids produced by microbes that are stimulated by earthworm activity (Atiyeh et al. 2002). The marketable yield and total yield of romaine lettuce (*Lactuca sativa* var. *longifolia* Lam) were influenced by a combination of mineral fertilizers and vermicompost. Chaoui (2003) reported that the vermicompost has the ability to release nutrients slowly and effectively, thus it increases nutrient use efficiency for crop production. Additionally, the combined use of vermicompost and mineral fertilizers help in maintaining yield stability by correcting micronutrient deficiencies, improving effectiveness of connected supplements, and providing favourable soil physical conditions (Gill and Walia 2014).

Permanagnate-oxidizable carbon (POXC) is also known as active carbon. POXC is one of the total organic carbon fractions. It is also a carbon energy source for microorganism, and its transformation is very rapid. Thus, it is always used as a tool to assess the carbon change in the soil. In this short-term experiment, the increase in applied vermicompost resulted in an increase in POXC.

Conclusion

Combined levels of vermicompost and mineral-N fertiilizer affected romaine lettuce growth and yield (*Lactuca sativa* var. *longifolia* Lam). The results indicated that the combination of 50% mineral-N fertilizer and 50% vermicompost significantly increased the leaf area, fresh weight per plant, estimated marketable yield and estimated total yield. The application of N alone produced lower weight per plant and growth of the romaine lettuce. Furthermore, the combination of the vermicompost and mineral-N fertilizer ($N_{50\%} + V_{50\%}$) had greater amount of POXC. Therefore, this study concludes that there was a benefit of using vermicompost along with mineral-N on the romaine lettuce production.

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