Effect of Modified Leonardite on Growth and Fruit Yield of Cucumber (*Cucumis sativus* L.)

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***Abstract*—Leonardite is readily available and high in organic matter. It has potentially positive effect on plant growth and yield. The experiment evaluated the effect of modified leonardite on cucumber (*Cucumis sativus* L.). Four treatments including untreated control, modified leonardite at the rate of 15.62 t ha^{-1}, modified leonardite at the rate of 31.25 t ha-1 and modified leonardite at the rate of 46.87 t ha^{-1} were arranged in a randomized completely block design with four replications. Data were recorded for soil properties after application of modified leonardite, plant height, number of leaves and yield at 10, 20, 30 and 40 days after planting. Modified leonardite applied soils led to increase in organic matter and potassium contents in the soil. Cucumber treated with modified leonardite increased plant height. The application with high rate of modified leonardite had the highest number of leaves at 20 and 30 days after planting. Number of fruits and fresh weight of fruits showed significant response to the high rate of modified leonardite compared with other treatments. Therefore, the application of modified leonardite had positive effect on plant growth and improved production of cucumber plants.**

***Index Terms*—cucumber, modified leonardite, growth, yield**

I. Introduction

Cucumber (*Cucumis sativus* L.) is a kind of traditional vegetable worldwide. It is the most popular of Cucurbitaceae family [1]. Its cultivation dated back to over 3,000 years [2]. Cucumber is a primary source of vitamins, minerals, fiber and water content in the fruits, which are necessary for the human diet [3]. Cucumber can be used in fresh and processed forms. The cucumber reaches harvest stage rapidly and is largely eaten in the green fruits or unripe fruits.

The soils, where cucumber is cultivated, requires moderate to high nutrient levels so as to achieve high yields. While, infertile soil causes bitter and abnormal fruits, which are rejected by the consumers. Most soils in Phathumthani province have long been under cultivation and suffered greatly from nutrient depletion. The long term cultivation and continuous application of inorganic fertilizers can affect the productivity of cucumber.

Many studies in various crops have shown significant advantages of applying inorganic fertilizers [4]. However, long term application of inorganic fertilizers especially for ammonium sulphate results in the increase in soil acidity and disturbance of soil structure, which cause yield reduction and low quality of fruits [5].Therefore, the use of external inputs and fertilizers has become imperative. The cucumber cultivation needs significant amounts of high fertilizers to produce high yield and marketable fruits.

Leonardite is rich in inorganic matter, humic acids, fulvic acids and plant nutrients. [6], [7]. Therefore, humic acid and humic compounds stimulate root and shoot development [8], [9]. Moreover, they increase in soil organic matter, plant nutrients and nutrient uptake from the soil included enhance plants resistance to biotic and abiotic stress factors [10]. Therefore, leonardite could be used as a soil amendment because it improved plant growth and yields of tomato, potato [11] and corn [12].

However, the potential of leonardite has not been investigated in cucumber. The objectives of the present study were to evaluate the effect of modified leonardite on growth and yield of cucumber grown in Thailand. The information from this study will be very helpful to the farmers because it will help them in soil organic management for their cucumber production.

II. Materials and Method

A. Location

The experiment was carried out on an upland farmer's field at Phathumthani province, Thailand during April to August 2016. During the growing period, average rainfall was about 4.7 millimeters, average air temperature was about 31.60 ℃ and relative humidity was about 71.80%.

B. Experimental Design

Four treatments applied to the crop consisted of untreated control (T1), modified leonardite at the rate of 15.62 t ha^{-1} (T2), modified leonardite rate at the rate of 31.25 t ha^{-1} (T3) and modified leonardite at the rate of 46.87 t ha^{-1} (T4). The treatments were assigned in a randomized completely block design with four replications. Modified leonardite was ground to fine powder before it was applied to the plots. The plot size was 2 ×1 m and total area was 24 m^2.

C. Plant Material

Three seeds per hill were planted by hand with a spacing of 1 m between rows and 0.8 m between hills within row. The seedlings were later thinned to obtain two plants per hill. Water was applied to the crop based on the conventional schedule. Weed control was carried out by hand depending on weed density in the field.

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Harvest of cucumber was started at 45 days after planting. Inorganic fertilizer (formula 15-15-15) was applied to the plots at the rate of 18.75 t $ha^{-1}$and compost manure was applied at the rate 1 t ha^{-1}. Pesticides and insecticides were applied to control insects and diseases at appropriate growth stages.

D. Modified Leonardite

There are other sources of leonardite in Thailand. Leonardite used for this experiment is a special formula from the company (details of company required). The formula consists of leonardite, dolomite, zeolite, gypsum and guano, and it is referred to as "modified leonardite". All components of the formula were mixed well and fermented for 45 days before it was used in this experiment. The modified leonardite had a pH of 5.33, 21.93% of organic matter, 1.1% of Nitrogen, 0.73 % of P_2O_5, 0.97% of K_2O, 0.2% of Ca, and 6.53 ds/m of electric conductivity (EC).

E. Data Collection

The soil samples for soil analysis were taken at 0-30 cm below the soil surface before planting and after the application of modified leonardite. Data were recorded for pH, organic matter (%), electric conductivity (EC), phosphorus (P), potassium (K), and calcium (Ca). The soil before planting had 2.20% of organic matter, 2,042 mg kg^{-1} of phosphorus, 190 mg kg^{-1} of potassium, 0.51 ds/m of electric conductivity (EC) and pH of 6.60.

Five plants were tagged from the inner rows of each plot for measurement of growth parameters. Plant growth parameters were recorded for plant height (cm) and number of leaves. Cucumber fruits at marketable stage were harvested every day. At harvest times, the number of fruits and weight of fresh fruits (g) in each treatment were recorded.

F. Statistical Analysis

Data were analyzed using analysis of variance (ANOVA) and significant means were separated using Duncan's Multiple Range Test (DMRT) at $P \leqslant 0.05$.

III. Results and Discussion

A. Soil Properties

Soil chemical properties after the application of modified leonardite are shown in Table I. Untreated control (T1) had 1.59% of organic matter, 296 mg kg^{-1} of phosphorus, 190 mg kg^{-1} of potassium, 0.39 ds/m of electric conductivity (EC) and 5.50 of pH. Application of modified leonardite at the rate of 15.62 t ha^{-1} (T2) had 1.24% of organic matter, 316 mg kg^{-1} of phosphorus, 88 mg kg^{-1} of potassium, 0.46 ds/m of electric conductivity (EC) and 5.43 of pH. Application of modified leonardite at the rate of 31.25 t ha^{-1} (T3) had 1.76 % of organic matter, 320 mg kg^{-1} of phosphorus, 99 mg kg^{-1} of potassium, 0.59 ds/m of electric conductivity (EC) and 5.73 of pH. Application of modified leonardite at the rate of 46.87 t ha^{-1} (T4) had 1.65% of organic matter, 362 mg kg^{-1} of phosphorus, 20 mg kg^{-1} of potassium, 0.64 ds/m of electric conductivity (EC) and 5.57 of pH.

The results indicated that application of modified leonardite especially at the high rates increased organic matter, pH, electric conductivity, and phosphorus content in the soil. Similar results were reported by [13] and [14]. However, application of modified leonardite at all rates reduced potassium content in the soil. The variation in soil K levels can be attributed to the uptake of potassium by cucumber during the growing season.

TABLE I. MEANS FOR ORGANIC MATTER (OM), PH, ELECTRICAL CONDUCTIVITY (EC), NITROGEN (N), PHOSPHORUS (P), POTASSIUM (K) AND CALCIUM (CA) IN THE SOIL TREATED WITH DIFFERENT RATES OF SOIL

SOIL	OM (%)	pH	EC (ds/m)	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})
Untreated control	1.59	5.50	0.39	0.08	296	116	4977
15.62 t ha^{-1}	1.24	5.43	0.46	0.06	316	88	4653
31.25 t ha^{-1}	1.76	5.73	0.59	0.09	320	99	4957
46.87 t ha^{-1}	1.65	5.57	0.64	0.08	362	20	4643

B. Soil Properties

Application of modified leonardite at all rates increased plant height compared to untreated control (Fig. 1). All treatments were similar for plant height at 10 and 20 days after planting. The rapid increases in plant height were observed at 30 and 40 days after planting and the applications of modified leonardite at the high rates had taller plants than did the applications at the low rates including untreated control. The results indicated that application of modified leonardite increased soil fertility and available plant nutrient uptake [15]. Thus, leonardite enhanced nutrient uptake and contributed to cell enlargement and growth [16], [17]. Application of modified leonardite strongly affected growth parameters of cucumber.

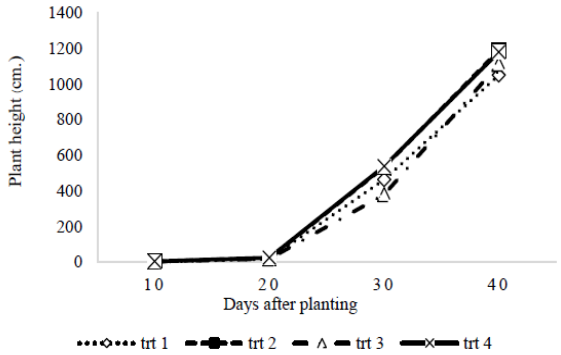

Figure 1. The effect of modified leonardite application on plant height at 10, 20, 30 and 40 days after planting.

C. Soil Properties

Number of cucumber leaves increased after application of modified leonardite (Fig. 2). At 10 days after planting, all treatments had similar number of leaves. Cucumber treated with 46.87 t ha^{-1} of modified leonardite had the highest number of leaves at 20 and 30 days after planting because leonardite increased the number of leaves. The results were in agreement with those reported in corn [12] and snap been [17]. At 40 days after planting, untreated

control had the highest number of leaves but the differences among the treatments were not statistically significant.

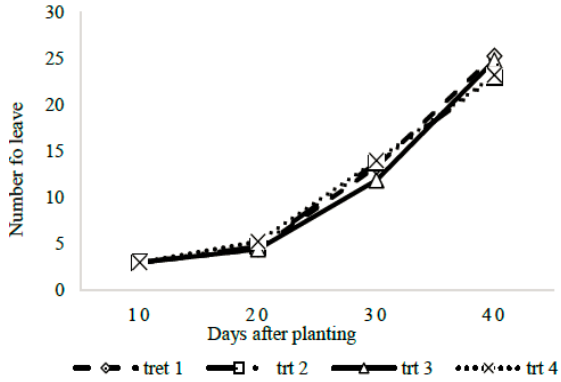

Figure 2. The effect of modified leonardite application on number of leaves at 10, 20, 30 and 40 days after planting.

D. The Number of Fruits per Plant and Fresh Weight

Treatments were significantly different ($P \leq 0.05$) for number of fruits per plant and total fresh weight of fruits per plant (Table II). Numbers of fruits ranging from 13.40 fruits for untreated control to 16.18 fruits for application of modified leonardite at the rate of 46.87 t ha^{-1} were observed among the treatments. However, only application of modified leonardite at the rate of 46.87 t ha^{-1} was significantly higher than untreated control, and it was also significantly higher than application of modified leonardite at the rate of 15.62 t ha^{-1} and application of modified leonardite at the rate of 31.25 t ha^{-1}. In previous study, application of leonardite could increase number fruits of potato [11].

TABLE II. MEANS FOR NUMBER OF FRUITS AND TOTAL FRESH WEIGHT OF CUCUMBER TREATED WITH DIFFERENT RATES OF MODIFIED LEONARDITEL

Modified leonardite	number of fruits (number $plant^{-1}$)	total fresh weight (g $plant^{-1}$)
Untreated control	13.40b	953.83c
15.62 t ha^{-1}	14.03b	1,109.29b
31.25 t ha^{-1}	14.69b	1,128.66b
46.87 t ha^{-1}	16.18a	1,516.55a
t-test	*	*
CV%	16.18	20.9

Notes: Means in the same column with the same letter(s) are not significantly different by Duncan's New Multiple Range Test (DMRT) at 0.05 probability level

Total fresh weights of fruits ranged between 953.83 g per plant for untreated control and 1,516.55 g per plant for application of modified leonardite at the rate of 46.87 t ha^{-1}. All treatments with modified leonardite were significantly higher than untreated control. Application of modified leonardite at the rate of 46.87 t ha^{-1} was highest and it was also significantly higher than application of modified leonardite at the rate of 15.62 t ha^{-1} (1,109.29 g $plant^{-1}$) and application of modified leonardite at the rate of 31.25 t ha^{-1} (1,128.66 g $plant^{-1}$). Yield increase resulting from use of leonardite was also reported in other plants such as climbing bean [18], canola and wheat [19]. In addition, application of modified leonardite at the rate of 46.87 t ha^{-1} would be sufficient to obtain high fruit yield with good quality. It concluded that application of modified leonardite increased number of fruits per plant and total fresh weight.

IV. CONCLUSION

Application of modified leonardite increased soil organic matter and phosphorus content. Application of modified leonardite increased plant height and number of leaves possibly due to higher nutrient uptake of the crop. In addition, application at the higher rates also had higher number of fruits and fresh weight of fruits, indicating that application at the higher rates could increase nutrient uptake nutrient uptake of cucumber. Modified leonardite showed great potential for use in organic agricultures as they can improve plant growth and yield in the long term. In future, further studies on application of modified leonardite to soils are required for more detailed views in different plants.

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