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Research Article

Enhancing bare land soil quality using electric induction apparatus in combination with rabbit urine liquid fertilizer application to support garlic (*Allium sativum*) production

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Abstract: The new approach in this study was using electric induction technique to enhance soil fertility of bare land in a combination of rabbit urine application in the form of liquid fertilizer. This approach had been exaggerating soil microbial activities and modifying the exchange capacity of anions and cations in soil. This study aimed to find out the best combination of different duration of electricity induction and rabbit urine liquid fertilizer at different levels of their application. Randomized factorial block design with two factors was used for this study. The first factor was the duration of the electric induction at the rates of 0, 30, 45, and 60 minutes, while the application of rabbit urine as liquid organic fertilizer was at the rates of 0, 100, 150, and 200 mL/L. Plant height, number of leaves and stem diameter, fresh and dry weight of garlic bulb were measured within 3 months. The observations were carried out using destructive and non-destructively approached with intervals of 7 days. The best treatment that gave the highest plant height, number of leaves, stem diameter, tuber diameter, fresh and dry garlic bulb and garlic production was found under the combination of 60 minute of electricity induction and 200 mL/L of urine rabbit application ($P<0.05$). Also, this treatment was successfully to give garlic production of 8.56 t/ha.

Keywords: *environmental degradation, organic fertilizer, soil fertility*

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Introduction

The area of bare land in Indonesia was reached 12.4 million ha according to the agricultural census in 2004 (BPS, 2004) and it continued to increase for the next following year, in which was approximately 1/3 from the existing degraded dryland area. These lands usually were dominated by grasses, *Imperata*, or even shrubs which were uncultivated for ages. At the same time, the use of this land for improving crop productivity was becoming short term government policy so far, instead of expanding cultivation by re-opening a new site which mainly still covered by native vegetation (Mulyani and Agus, 2006). In order to reuse bare land for the area of cultivation is quite challenging, since their soil properties were not in ideal condition to support crop growth, resulting in a degraded condition. Degraded soil is becoming a major issue in the tropical region. (Dairah and Heryani, 2014). Soil chemical under bare land status has been reported to have low C, N content and C/N ratio, high soil pH, and low in P and K (Tian et al., 2017). In term of soil physical properties, the soil moisture was low with high bulk density since dominated by clay and sandy particle (Lelisa and Abebaw, 2016). However, research on improving bare land into fertile soil are limited, so far rehabilitation of bare lands was relying on revegetation processes (Lelisa and Abebaw, 2016).

Garlic *(Allium sativum)* production in Indonesia needs to be increased as the demand for this commodity remaining high. Chemical fertilizers are generally used excessively by farmers to enhance that production while organic material was less used. The accumulation of chemical fertilizer which causes soil degradation affects soil nutrient uptake. Long-term use of chemical fertilizers and pesticides will reduce the potential for land production and increase the toxic effects on crop yield. A massive degraded soil such as bare land needs to be revitalized using various approaches such as the adoption of electric induction in combination with organic fertilizer since this material had lower nutrient content compared to chemical ones.

The new approaches on reusing bare for cultivation land using electric induction were adopted in this study. This technique was hypothesized to enhance soil fertility by exaggerating soil microbial activities to decompose complex organic compounds and increasing exchange capacity of anions and cations of soil. The electrification process is effective and efficient when it is performed under wet condition or at the level of water sufficiently in soil. The water availability is needed because it becomes a conductor to perform electricity process for mobilizing the inductions (Oliver et al., 2013). Electric induction carried out on agricultural land can help for neutralizing soil pH, exaggerating the exchange ions and cations from soil mineral to soil solutions, and releasing nutrients which then absorbing by colloidal soils or directly by crop (Sugiarto et al., 2013). Implementation of electricity induction technology on organic material is rarely used, for example, to animal waste, including rabbit urine in the form of liquid fertilizer.

Rabbits can release faeces and urine in considerable amounts, but they are not widely used as biofertilizer. Faeces and urine of rabbits better processed into organic fertilizer rather than wasted. Rabbit urine dominantly consists of nitrogen. Wandita et al. (2016) reported that 100 mL/day of urine could be produced by rabbit, and it can be used as liquid organic fertilizer (LOF) through a fermentation process. The biofertilizer could fulfil nutrients crop demand if it applied properly to the soil in combination with other soil amendments (Arfarita et al., 2019a; 2020). The use of rabbit urine as an organic liquid fertilizer is to improve soil fertility and also to reduce farming costs; even it can save environmental problems. It has been used to improved yield of tomato (Sembiring et al., 2017), melon (Lestari et al., 2019) and packcoy (Susilo, 2019). However, the nutrient content is limited and need to be enhanced with electric induction for maximizing crop nutrient uptake. The application of electric induction techniques to rabbit urine as a liquid organic fertilizer (LOF) to the soil is expected to improve soil chemical and biological properties, as the new alternative way to revitalize the bare land area. Since the uptake of nutrients from the soil into crop can be improved, the effectiveness of liquid fertilizer as main sources of nutrients can be enhanced.

The aim of this study was to find out the best treatment under the combination of different duration of electricity induction under the application of rabbit urine liquid fertilizer at varying levels of application to a local garlic variety.

Materials and Methods

Study location

The study was conducted for five months, starting on February 25 to June 29, 2019. The research was performed at loamy-alluvial soil of Malang with the geographic position at 7°54'43.82" S and 112°34'53.70" E. The experimental field is located at an altitude of 567 m above sea level; the daily average temperature is 24°C, and rainfall is 2,000-3,000 mm/year. Soil N before treatments ranged between 0.16 to 18%, while soil P and K ranged from 3.26 to 7.74 mg/kg and 0.71 to 0.87 me/100 g, respectively. The initial soil pH was about 5.1.

Land preparation

The experimental plot was cleared, ploughed and harrowed using a hand hoe to pulverize soil for making a bed with the size of 1 m x 1 m for each treatment. The height of the bed was 40 cm with the inter-row spacing of 40 cm. Garlic seed of "Lumbu Hijau" variety was placed in the depth of 2-3 cm from the soil surface with the growing point was positioned upward before lightly covered with soils. Goat manure that was used as basal organic fertilizer was applied three days before planting at the rate of 10 t/ha or 1 kg per bed. The Phonska (N, P, and K compound fertilizer) containing N: 15%, P: 15%, K: 15% and S: 10% was applied at the rate of 50 g per plot or in which it was equal to that application at the rate of 500 kg/ha.

Materials

Rabbit urine was prepared by fermenting this material using EM4 and under the addition of molasses. All ingredients were mixed in a large plastic container (25 kg), and they were mixed until uniform. Fermentation was performed to reduce ammonia concentration and to guarantee that the nitrate decomposition process was complete. This material was sprayed to the bottom side of garlic leaves, which then it was poured into the soil before the electric induction in garlic plants was applied ten times with intervals of application of 7 days. The rabbit urine contains nutrients such as (N = 4%, P_2O_5 = 2.8%, and K_2O = 2% (Hamamoto and Uchida, 2015). Rabbit urine fertilizer has C/N ratio of about 10-12 and pH of 6.47-7.52 (Campitelli et al., 2012). The use of this material to improve crop performance, however, is limited. On the other hand, the goat manure is recognized to have nutrients as follow: N (1.15%), P_2O_5 (1.10%), K_2O (2.79%), Ca (1,56%), Mg (0.42%), S (2,050 ppm), Fe (7,214 ppm), Mn (512 ppm), and Zn (924 ppm) (Sunaryo et al., 2018).

The negative and positive cables were installed in the beds of each treatment. Negative cables were buried in the ground while positive cables were placed on the soil surface. When it was connected to electricity and the power is turned on, the LED indicator would be displayed. This induction equipment was controlled by measuring the rate of electric current using an Avometer which within the ranges of 10 to 14 milliampere (mA). The electric current was stabilized after the instrument being working for 15 minutes. Previously, the soil needs to be saturated with water as it becomes a good conductor for anion and cation become evenly distributed in the soil as it expected to be absorbed by the crop.

Research design

Treatments tested in this study were combinations of electric induction duration (I) and the application of liquid organic fertilizer (LOF) of rabbit urine (U). The electric induction duration (I) consisted of four levels, i.e. I_0 = electric induction 0 minutes, i_1 = electric induction 30 minutes, i_2 = electric induction 45 minutes, and i_3 = electric induction 60 minutes. The application of liquid organic fertilizer (LOF) of rabbit urine (U) consisted of four levels, i.e. U_0 = LOF rabbit urine 0 mL/L, U_1 = LOF rabbit urine 100 mL/L, U_2 = LOF rabbit urine 150 mL /L, U_3 = LOF rabbit urine 200 mL /L. The sixteen treatments were arranged in a factorial randomized block design with three replications. Data obtained were subjected to Analysis of Variance (ANOVA) using Genstat ver 18.00 destructive and non-destructive methods to measure garlic growth parameters such as garlic height, number of leaves, stem diameter tuber diameter, fresh weight and dry weight of biomass. Multivariate Biplot (Kaisermann et al., 2018) was employed to determine the relationship amongst variables and mechanism of garlic yield improvement.

Results and Discussion

Soil quality (soil chemical properties)

After treatments, there was a significantly increased ($p<0.05$) on soil chemical properties. Soil N reached 0.17 to 0.19%, slightly increase by 0.02% compared to before treated with rabbit urine liquid fertilizer. Moreover, the increment of soil P was detected almost eight times higher to about 40.43 to 46.31 mg/kg. A similar pattern was found for soil K, which raised to 1.27 to 1.28 me/100 g. Soil pH increased to 6.75 to 6.95. It was clear that the use of fermented rabbit urine using EM_4 successfully improved soil quality under the use of an electric induction apparatus.

Vegetative phase

The results of ANOVA showed that there was a significant interaction between electric induction duration and the application of rabbit urine to various garlic parameters (garlic height, number of leaves, and stem diameter) (Table 1). The duration of electric induction and application of rabbits urine of I_3U_3 (electric induction 60 minutes + rabbits urine: 200 mL) was significantly different to all parameters compared to other treatments. The crop height of the I_3U_3 treatment was about 58.3 cm, which was the highest amount of the treatments, but it was not significantly different from I_3U_2 and I_3U_1 treatments. The number of leaves was recorded at about 5.50 with an average value of stem diameter at about 0.84 cm. This was presumably because the I_3U_3 treatment contains higher macro and micronutrients from fermented additional fertilization in the form urine rabbit which has already decomposed during fermentation processes. This micronutrients act as activators of enzyme and biochemical reaction for supporting plant growth. Likewise, sufficient macronutrient content available for plant needs can increase panicle length and be able to increase crop production (Sitompul et al., 2014).

Rekha et al. (2017) reported that livestock urine is more easily utilized by plants because the elements are easily decomposed, and the amount is not too much so that the benefits are more quickly seen in plant growth. Plant growth in the form of plant length, number of leaves, and stem diameter is influenced by the content of organic matter (organic carbon). The higher the organic material, the plant growth will also increase. Hidayati et al. (2011) reported that rabbit urine contains macro and micronutrients consisting of N P K on average (N) 2.72%, (P) 1.1% and (K) 0.5%. Rabbit urine application was also observed by Simamora et al. (2014) and Djafar et al. (2013) on tomato plants. They reported that rabbit urine was also able to support vegetative growth, namely tomato plant height. This shows that the urine nutrient content of rabbits is only able to support vegetative growth of plants, but is not able to change the difference in tomato yields, because the soil media is sufficiently available in the nutrients. The application of organic fertilizer was a significant difference in the fresh weight of bulbs and bulb diameter. The application of rabbit manure produced a fresh weight of bulbs and bulbs diameter on shallot which not significantly different with the treatment of cajeput waste compost + rabbit manure (Parwi et al., 2019)

Table 1. Effect of electric induction duration treatment and rabbit urine LOF application on garlic growth parameters.

Treatment	Plant length (cm)		Number of leaves		Stem Diameter (cm)		Chlorophyll content (mg/mL)	
	Age of 79 days after planting							
I_0U_0	46.50	a	4.00	a	0.55	a	9.39	a
I_0U_1	47.78	ab	4.13	a	0.59	a	11.18	c
I_0U_2	48.00	ab	4.21	a	0.60	b	11.34	cd
I_0U_3	49.20	bc	4.39	b	0.63	b	11.47	f
I_1U_0	47.44	ab	4.11	a	0.56	a	10.60	b
I_1U_1	50.57	de	4.32	b	0.63	b	10.72	c
I_1U_2	51.67	de	4.33	b	0.63	b	11.57	f
I_1U_3	52.23	de	4.42	b	0.66	c	11.74	f
I_2U_0	47.46	ab	4.17	a	0.58	a	10.35	b
I_2U_1	52.47	ef	4.61	c	0.64	c	12.04	g
I_2U_2	52.93	ef	4.62	c	0.68	d	12.22	h
I_2U_3	54.16	fg	5.00	d	0.73	e	12.43	h
I_3U_0	49.33	cd	4.21	a	0.58	a	11.67	d
I_3U_1	55.28	gh	5.07	e	0.67	c	14.07	i
I_3U_2	56.80	gh	5.11	e	0.70	d	14.73	j
I_3U_3	58.30	h	5.50	f	0.84	f	14.14	k
LSD 5%	3.60		0.27		0.04		0.38	

Remarks: The number accompanied by the same letter in the same column shows Not significantly different in the Least Significant Different (LSD) test 5%. I_0 = electric induction 0 minutes, I_1 = electric induction 30 minutes, I_2 = electric induction 45 minutes, I_3 = electric induction 60 minutes, U_0 = LOF rabbit urine 0 mL/L, U_1 = LOF rabbit urine 100 mL/L, U_2 = LOF rabbit urine 150 mL /L, U_3 = LOF rabbit urine 200 mL /L.

In this study, the growth rate in the garlic plant was also influenced by electrical induction. Relevant to a study reported by Darsiah et al. (2018), the application of electric induction significantly affected the height of ground kale plant by 11.40 cm and the number of leaves of 4.25 strands at the age of 13 days after planting (DAP). Electric induction for 60 minutes is the best timing in conducting land management applications that cover all aspects. Sugiarto et al. (2013) described that electrical induction techniques could utilize the existing local potential and maintain the stability of soil ecosystems which are interactions between soil and water resources with biotic components in the form of plants and microorganisms in the soil. Arfarita et al. (2016; 2017; 2019b) reported that some microbe plays an important role to enhance nutrient availability to support crop growth. The stability of the soil ecosystem can make the processes in the soil run well, especially those related to the supply of nutrients and energy flow. The application of electric induction on agricultural land has many important roles. One of them is to help activate the ion and cation exchange in the soil so that plants can absorb nutrients properly. Cation exchange causes cations that have been absorbed by soil colloids to be hard to be washed away by gravitation water but can be replaced by other cations. Since the cation exchange capacity of soil after treatments were not measured, this mechanism can be detected using chlorophyll content which raised almost in all treatment compared to control. Moreover, this study was more focused on soil macronutrients (N, P and K) increments, as these were the main nutrients for supporting plant growth. The availability of soil N uptake by crop not only can be detected from its vegetative performance but also from their chlorophyll content. There was a significant effect

($P<0.05$) of treatment on N uptake represented by chlorophyll value, as the major component of this is constructed using N on their chemical composition. In addition, electric induction can help the formation of cellular networks that will support plants to be weighted. This is because the application of electricity induction in wetlands can increase the availability of nutrients in the soil.

Generative phase

The results of the analysis of variance showed that there was a significant interaction between the duration of electric induction treatment and rabbit urine application on generative phase parameters such as stem diameter, fresh weight, dry weight and production of garlic (Table 2 and Figure 1). The I_3U_3 treatment (60 minutes electric induction + rabbit urine 200 mL) was significantly different ($p<0.05$) from other treatments. However, the tuber diameter that was about 2.93 cm and total fresh weight of plant of about 12.83 g were not significantly different from those of the treatments of I_3U_2 and I_3U_1. The total dry weight of plant of about 10.12 g was not significantly different from I_3U_2 treatment, but the garlic production of about 8.56 t/ha was significantly greater than that of all other treatments. This is probably because the contents of nitrogen, auxin and gibberellin hormones in rabbit urine can stimulate the growth and development of plant organs so that that nutrient and hormones can form cloves that will eventually become the bulbs of the garlic plants. This is consistent with the statement from Sarwono (2002) who reported that rabbit urine is widely used as a liquid fertilizer for cut flowers and vegetables, and is thought to contain growth-supporting hormones, such as auxin or gibberellin. In line with the results of research Nugraheni and Paiman (2011), showed that rabbit urine concentration significantly affected plant fresh weight, plant dry weight, leaf dry weight, stem dry weight, and root dry weight. Frequency of rabbit urine application affects plant dry weight, leaf dry weight, stem dry weight and tomato root dry weight. Hayward (1961) has investigated the content of elements found in rabbit urine which reportedly contains ammonia (0.05%), sulfate (0.18%), phosphate (0.12%), chloride (0.6%), magnesium (0.01%), calcium (0.015%), potassium (0.6%), sodium (0.1%), creatinine (0.1%), uric acid (0.03%), urea (2%), water (95%) and the rest are hormones, toxins and abnormal substances. The nutrient content of rabbit urine includes high nitrogen which is important in synthesizing protein and distributed to the tubers of garlic (Sumiati and Gunawan, 2007). While the electric induction in garlic fields that have been applied by LOF caused the exchange of ions and cations in the soil, soil that received a measurable electric induction would activate all electrically charged compounds or objects in the soil and plants. This is very useful in chemical processes in the soil. During the electrical induction process, another thing that can be improved is the acidity of the soil.

Table 2. Effect of electric induction duration treatment and application of rabbit urine LOF on garlic production parameters.

Treatment	Tuber diameter (cm)		Fresh Weight (g)		Dry Weight (g)		Production (t/ha)	
I_0U_0	1.74	a	8.67	a	6.39	a	5.78	a
I_0U_1	2.18	c	8.81	a	7.00	b	5.87	a
I_0U_2	2.16	c	9.87	b	7.03	b	6.58	b
I_0U_3	2.31	d	10.29	bc	7.11	c	6.86	bc
I_1U_0	1.99	b	9.77	b	7.17	b	6.51	b
I_1U_1	2.45	de	10.70	c	7.32	cd	7.13	c
I_1U_2	2.43	de	11.67	d	8.10	cd	7.78	d
I_1U_3	2.51	e	11.83	d	8.37	cd	7.89	d
I_2U_0	2.00	b	9.87	b	8.42	b	6.58	b
I_2U_1	2.55	e	12.27	de	8.48	de	8.18	dc
I_2U_2	2.51	e	12.07	d	8.57	de	8.04	d
I_2U_3	2.68	fg	12.08	d	8.62	ef	8.05	dc
I_3U_0	2.10	bc	10.42	bc	8.94	b	6.95	bc
I_3U_1	2.59	f	12.18	de	9.33	f	8.12	dc
I_3U_2	2.93	g	12.33	de	9.83	g	8.22	dc
I_3U_3	2.93	h	12.83	e	10.12	g	8.56	e
LSD 5%	2.04		0.76		0.43		0.52	

Remarks: The number accompanied by the same letter in the same column shows Not significantly different in the Least Significant Different (LSD) test 5%. I_0 = electric induction 0 minutes, I_1 = electric induction 30 minutes, I_2 = electric induction 45 minutes, I_3 = electric induction 60 minutes, U_0 = LOF rabbit urine 0 mL/L, U_1 = LOF rabbit urine 100 mL/L, U_2 = LOF rabbit urine 150 mL /L, U_3 = LOF rabbit urine 200 mL/L.

Figure 2. Bulbs of garlic plant in each treatment.

Provision of electric current flow on agricultural land can neutralize and increase soil pH. The neutral soil acidity conditions make macro and micronutrients available quite perfectly. Under neutral pH conditions, the P content is usually also in high criteria, because the ion exchange complex is dominated by base cations due to a neutral pH atmosphere, so that nutrient exchange is quite effective because, at neutral pH, nutrient availability is optimal (Bouksila et al., 2012). According to Kato et al. (1995), P is generally absorbed by plants in $H_2PO_4^-$ and HPO_4^{2-} anions while the source can be in the form of P-organic or P-inorganic. P-organic is usually in the form of phytase and its derivative, phosphor lipid. At a soil depth of 0-20 cm from the surface, the P-inorganic content becomes smaller, because it is bound by Ca, Fe or Al compounds. Conversely, in a deeper position, the inorganic P is more soluble and leached. Therefore, with the presence of electrical induction, P is increasingly available to plants.

A dose of 200 mL/L given at 7-day intervals during growth has been shown to increase garlic production. Electrical induction testing on plants was also carried out by Fadli et al. (2018), which proved that the application of electricity at intervals of 5 days gave the best economic weight results in lettuce (*Lactuca sativa* L.) compared to controls. Cahya et al. (2018) showed a significant interaction between the duration of electric induction of 60 minutes and spraying of gibberellins of 500 mg/20,000 litres gave the best results on I1G2 of I1 dragon fruit production per hectare. Grading results showed that all crops (with treatment) were entered at grade A 100% and were significantly different from control. The relationships amongst variables are presented in Figure 3. It can be seen that there was a significant correlation between chlorophyll content (mg/mL) and dry weight (g/bulb) (R^2 = 0.73), tuber diameter (cm) and garlic production (t/ha) (R^2 = 0.81), plant height (cm) and tuber diameter (cm) (R^2 = 0.91) and number of leaves and tuber diameter (cm) (R^2 = 0.87). The mechanism of enhancing crop yield can be described using multivariate Biplot (Figure 4). It can be seen that chlorophyll content had a similar magnitude and direction with the number of leaves and dry weight (Figure 4). A similar pattern was observed on tuber and stem diameter, which had a close relationship with garlic production (upper middle). Multivariate analysis Biplot could reach up to 97.58% of the variance, in which it was contributed from Principle Component-1 (95.21%) and Principle Component-2 (2.37%). Vectors situated closely together represent variables that are highly correlated, while orthogonal vectors represent variables that are uncorrelated (Dawes and Goonetetilleke, 2006). This Biplot analysis commonly used to determining soil properties and nutrient in corresponds to a land-use change of different location of sampling (Keisermann et al., 2018).

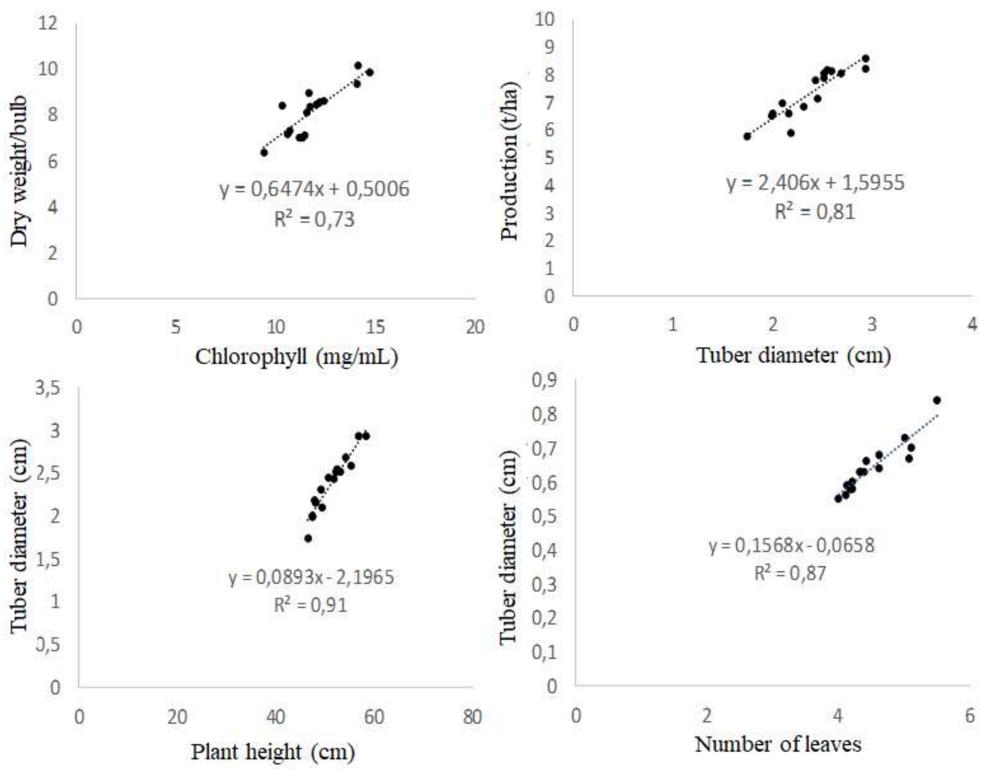

Figure 3. The relationship amongst variables to examine the effect of treatments.

Conclusion

The treatment of electric induction and application of rabbit urine application showed there was an interaction in various crop parameter. The best treatment was observed under the treatment of I_3U_3 (60 minutes induction duration and rabbit urine application of 200 mL/L). There was a significant effect of that treatment on the parameters of plant height, number of leaves, stem diameter, tuber diameter, fresh weight, dry weight, and production. This indicates that the application of electric induction and application of rabbit urine is potential to increase the production of garlic. Further study needed to explore those effect on soil microbial structure and dynamic. There was a significant correlation amongst variable detected using correlation and multivariate analysis (Biplot) determined the mechanism of garlic yield improvement.

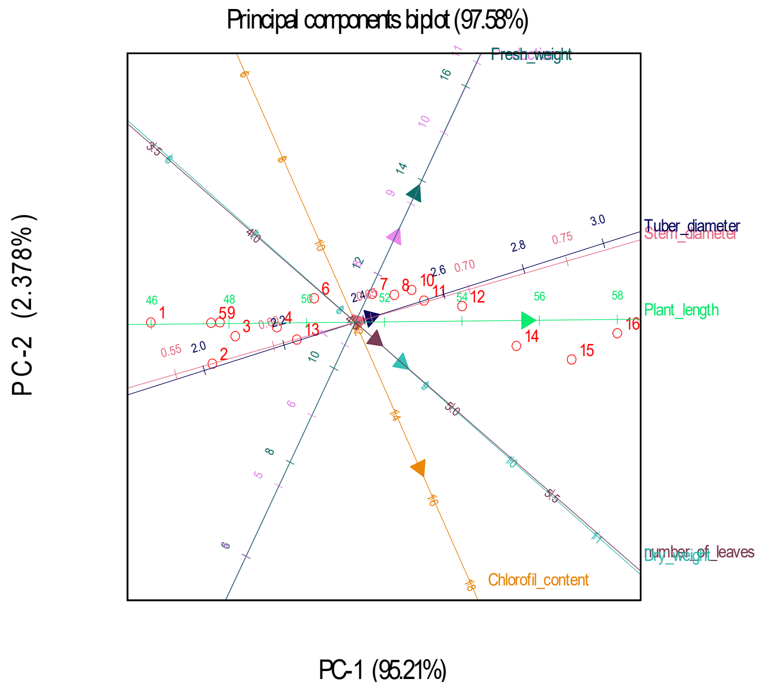

Figure 4. The multivariate analysis to examine the continuation and segregation of variable.

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