Effect of Uncomposted Organic Manures on the Plant Growth and Rhizosphere Microbial Population of Tomato Plants (*Solanum lycopersicum L.*)

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Abstract

Compost is a form of organic fertilizer used in agriculture to promote the optimization of soil pH and nutrient management. Compost application can be used for sustainable agriculture because it has influence on the rhizosphere micro-flora which includes species of bacteria, fungi and other microbes. In this study, the effects of organic compost on the rhizosphere micro flora and the growth of tomato plants was continuously monitored. Three sets of tomato plants were planted under similar growth conditions in three experimental plots with varying soil-compost compositions as follows: soil amended with cow manure, soil amended with leaf litter and non-amended soil. Sample plants were harvested every 2 weeks and the physical characteristics including length of shoot, root and number of leaf were recorded. One gram of soil was removed from the rhizosphere for microbial analysis. The results indicated that plants amended with cow manure germinated faster, however growth rate gradually decreased after three weeks. Plants grown in soil amended with leaf litter compost and those grown in non-amended soil both germinated much later. Growth rate however, continuously increased in plants grown in non-amended soil. Bacterial colonization around the rhizosphere of plants grown in soil amended with both cow and leaf litter manure ranged from 10^5 to 10^7 CFU/g, with highest concentration at week 5 followed by a gradual decrease. Microbial colonization in the rhizosphere of plants grown in non-amended soil also ranged from 10^5 to 10^7 CFU/g, but increased gradually with time.

Keywords: Uncomposted, organic manure, rhizosphere micro-flora, non-amended, tomato plants

Introduction

Composting is the biological decomposition of biodegradable solid waste under controlled aerobic conditions so as to produce a stable organic matter for safe use in agriculture. Compost is the term used to define the stable organic matter derived through composting. The process of composting includes four phases: pre-processing and blending, active composting, curing and post processing (Kokkora et al., 2008). The controlled biological decomposition of organic materials such as leaves, and cow manure can be used to produce compost. Manure compost are known for its high concentrations of nitrogen. The concentration

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of nitrogen varies significantly from type of animal, feeding ration as the type of litter consumed. The essential nutrients present in compost manure include nitrogen, phosphate, potassium, calcium and magnesium (Duong, 2013). Leaf compost is known as an organic amendment to agricultural soils derived from decaying leaves of plants. The main component of leaf compost is organic carbon. The decomposition of leaves increases the organic matter content of the soil increasing simultaneously, the number of beneficial microorganisms (Dighton, 2003).

The use of compost in agriculture has been increasing as both an alternative to landfilling for the management of biodegradable waste, as well as means of increasing or preserving soil organic matter (Kokkora et al., 2008). Composting promotes the optimization of nutrient management and the land application of compost is a way to combat soil organic decline and soil erosion (Van-Camp et al., 2004). By using compost as a soil amendment on agricultural land completes the recycling process of nutrients and the organic matter removed in the harvested produce are replaced back to the soil (Diener et al., 1993). This is a form of maintaining and restoring the quality of soils, thus promoting increase in the rate of plant growth and later increase in crop yield.

The quality of soil is highly dependent on the microbial composition on the rhizosphere of residing plants. The rhizosphere is the area influenced by the physical location of the roots. The rhizosphere micro-flora is highly diversified including different species of bacteria, fungi, nematodes, protozoa, algae among others (Raaijmakers et al., 2009). This year doesn't coincide with what's in the reference Bacterial micro-flora is influenced by variables such as soil structure, soil particle size, mineral composition, geographic location and agricultural practices (Benizri et al., 2007). The micro-flora present in the rhizosphere is important for the execution of specific roles such as plant protection, growth promotion, geochemical cycling of minerals, and production of antibiotics (Kent & Triplett, 2002). Plant-microbe interactions can be summarized into three types which includes microbes responsible for plants nutrition, microbes that indirectly stimulate plant growth by preventing growth or activity of pathogens, and lastly, microorganisms that directly promote growth for example microbes that produce phytohormones (Welbaum et al., 2004). An experiment was conducted to evaluate the effects of two sources of organic matter on the growth and rhizosphere bacterial populations of tomato plants (*Solanum lycopersicum L*) under greenhouse conditions.

Materials and Methods

The effect of organic amended soils on the microbial population and growth of tomato plants (*Solanum lycopersicum*) was determined by planting seeds 1cm deep in seedling trays as follows:

(a) CONTROL- 300g of black loamy soil divided equally in 15 sections of the seedling tray (approximately 20g/section) + 1 tomato seed/section
(b) COW MANURE COMPOST- 150g of black loamy soil + 150g of dried cattle manure (undecomposed) mixed with 100ml water until moist and then equally divided in 15 sections of the seedling tray (approximately 20g/section) + 1 tomato seed/section
(c) LEAF LITTER COMPOST-150g of black loam soil + 150g dried leaf litter grind with a corn grinder mixed with 100ml water until moist and then equally divided in 15 sections of the seedling tray (approximately 20g/section) + 1 tomato seed/section

Seeds were watered daily with 30ml of water and their germination pattern was monitored. Plants were sacrificed every 2 weeks. Shoot length, root length, number of leaves and the bacterial population of rhizosphere soil were recorded from random plants from each treatment. The rhizosphere bacterial population was determined by removing a gram of soil from around the roots of the harvested plant and dislodging the bacteria by adding it to 100ml of water and shaking for 15 minutes. The solution was diluted for using the 10 fold dilution technique and triplicate samples from the 1/100 to 1/100,000 dilution were cultured on Nutrient agar. Cultured samples were incubated at 35°C in a Fisher brand Iso-Temp incubator for a period of 24 hours. After 24 hours, bacteria colonies were counted and microbial concentrations in the stock solution were determined. Bacteria were classified as gram positive or negative using gram staining technique. The data collected were analyzed for correlation and margin of error.

Results and Discussion

Compost amendments to soil can either stimulate or inhibit growth and nutrient uptake of tomato plants. Figure 1 shows the effect of the organic manures on the shoot length of the tomato plants. The results indicated that tomato seeds planted in soil amended with cattle manure germinated faster than those planted with leaf litter compost and control. The growth rate of plants grown in non-augmented soil grew faster after week three than the plants grown in augmented soils. In all three cases a strong correlation was observed between plant growth and time. When soil is amended with cattle manure, it elevates the soil pH to near neutrality and in essence, contributes to the availability of nitrogen, phosphorus, potassium, calcium and magnesium (Whalen et al., 2000). A pH close to neutral is optimum for enhanced germination of seedlings. The composition of leaf litter is mostly organic carbon (Rosberg, 2014), thus the decomposition of carbon is slower making the availability of nutrients limited and delaying the germination process of the tomato seeds.

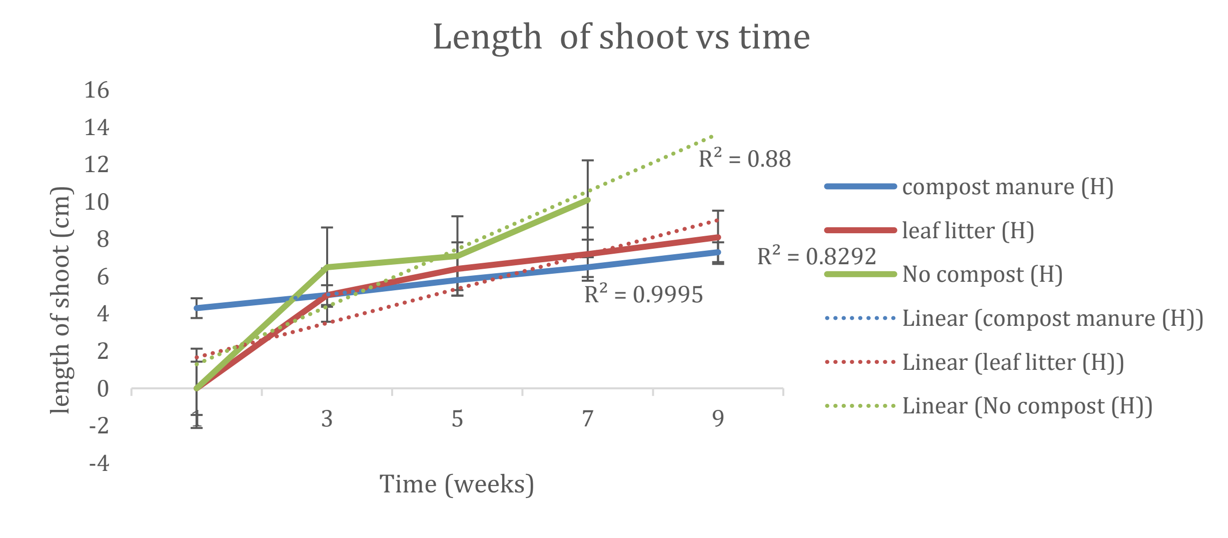

Figure 1. Effect of Organic Manure on the Shoot Growth of Tomato Plants

The effect of the organic manures on the growth of roots of plants showed similar trend. Moderate correlation was observed between the growth of the root over time. The results in Figure 2, indicated that the roots of the plants grown in soil amended with cattle manure had the lowest growth rate indicating the retardation of root growth. This is as result of excess nutrient accumulation leading to toxicity that directly affects plant growth and development. Immature compost is known to have high concentrations of ammonium, hydrogen sulfide and ethylene which are all deleterious to plant growth. The stages of decomposition of the compost could therefore contribute to the slow growth rate of the plants grown in compost amended soil. This decomposition of the compost is accompanied by low oxygen levels and high carbon dioxide levels along with the accumulation of short-chain volatile organic-acids including lactic, propionic and acetic acids. These substances are responsible for poor plant growth. The rapid oxygen depletion in immature compost also depletes the rhizosphere of plants of oxygen, thus affecting the overall health of the root which are highly dependent on oxygen for its development (Brinton, 2001). The plants grown in soil amended with leaf litter showed substantial growth over time. Leaf litter produces organic acids which combined with iron and aluminum ions reduce potential toxicity of plants (Rosberg, 2014). The overall structure and texture of the soil changes due to an increase cation exchange capacity of the soils making nutrients to hold on for longer periods of time among other factors. Plants grown in control soil showed slower initial growth however had sustained growth over the experimental time. Loamy black soil is known for high concentrations of humus which overtime promotes growth substantially (Whalen et al., 2000).

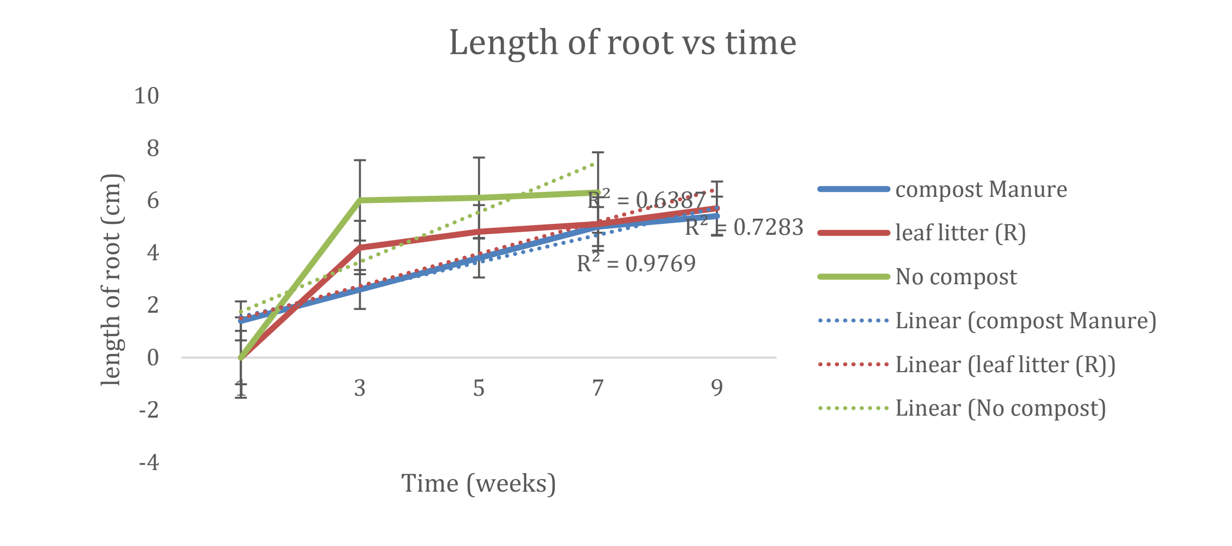

Figure 2. Effect of Organic Manure on the Root Growth of Tomato Plants.

The rate of decomposition of compost is definitely influenced by the level of bacterial colonization on the rhizosphere of plants. Figure 3 illustrates the bacterial colonization of the rhizosphere over time. Bacterial colonization of the rhizosphere in compost manure is relatively slow, this means that degradation process is slow. The biochemical composition of the overall amended soil would determine its susceptibility to microbial degradation. The results indicated that soil amended with dried cattle manure showed a gradual increase in bacterial colonization in the rhizosphere with its peak at week 3 with a concentration of 6.7 x 10^6 cfu/g. It however, gradually decreased to 5.0 x 10^5 cfu/g by the end of week 9. Cattle manure amended soils biochemical composition would include lignocellulose fractions and nitrogenous compounds which are very slowly degraded (Kutzner, 2016).

The concentration of bacteria around the rhizosphere of plants grown in soil amended with leaf litter showed the highest concentration of bacteria among all samples tested. Bacteria colonization peaked at week 5 with a concentration of 6.6 x 10^7 cfu/g but gradually decreased thereafter to 6.0 x 10^5 cfu/g by the end of week 9. The biodegradability of organic matter can be related to the lignin content with the application of a formula derived for lignin anaerobic digestion. The substrate or compost with no lignin composition only achieved a maximum degradability of 83% since, the decomposition of organic substrates such as leaf litter would be coupled with the production of bacterial by-products which would not be readily degradable (Kutzner, 2016).

Bacterial colonization in the rhizosphere of plants grown in non-augmented was 2.5 x 10^7 cfu/g by the end of week 9. This gradual increase indicated that the degradation of the compost influenced the bacterial population. Bacterial by-products produced and the organic molecules present in the leaf litter would support the growth of several successive microbial populations with different nutritional requirements (Kutzner, 2016). This explains the highest peak bacterial colonization observed in soil amended with leaf litter. The spontaneous decrease of bacterial population could be caused by the accumulation of bacterial by-products which are not readily degradable.

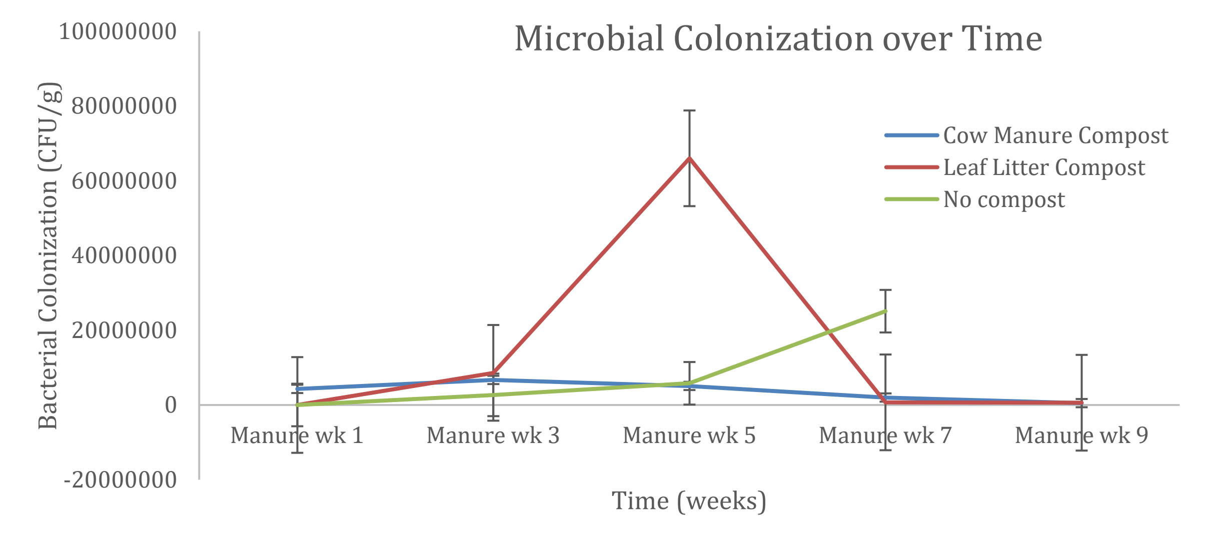

Figure 3. Effect of Organic manures on the Rhizosphere Bacterial Microflora of Tomato Plants

The bacterial colonization can influence the growth rate of the plant. Figure 4 and figure 5 illustrate the relationship between bacteria population of the length of shoot and the length of root respectively. The overall growth of the plants amended with dried cattle manure showed a strong correlation of above 0.9. This confirms the retardation of growth of plants augmented with dried cattle manure due to episodic oxygen depletion and competitive behavior between the rhizosphere and residing microbial communities (Brinton, 2001). The oxygen depletion rate exceeds the rate of natural air diffusion of oxygen into the soil stressing the plant root and the microbial communities. The stress decreases the availability of nutrients responsible for promoting the growth of the shoot (Alvarez et al., 1995). The overall growth of the plants amended with leaf litter showed a strong correlation of 0.7- 0.8. The Leaf litter decomposition promotes the growth of beneficial microorganisms which increase the nutrient availability especially of carbon which is essential for optimal plant growth (Kokkora et al., 2008). Non-augmented soil showed a moderate correlation between bacterial colonization and the overall plant growth rate.

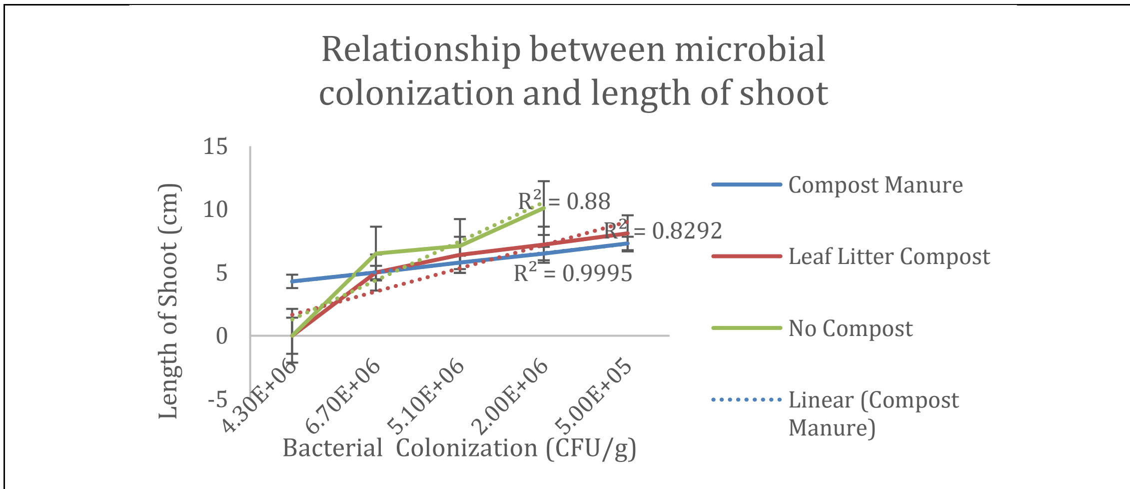

Figure 4. Relationship between Bacterial colonization and Length of Shoot

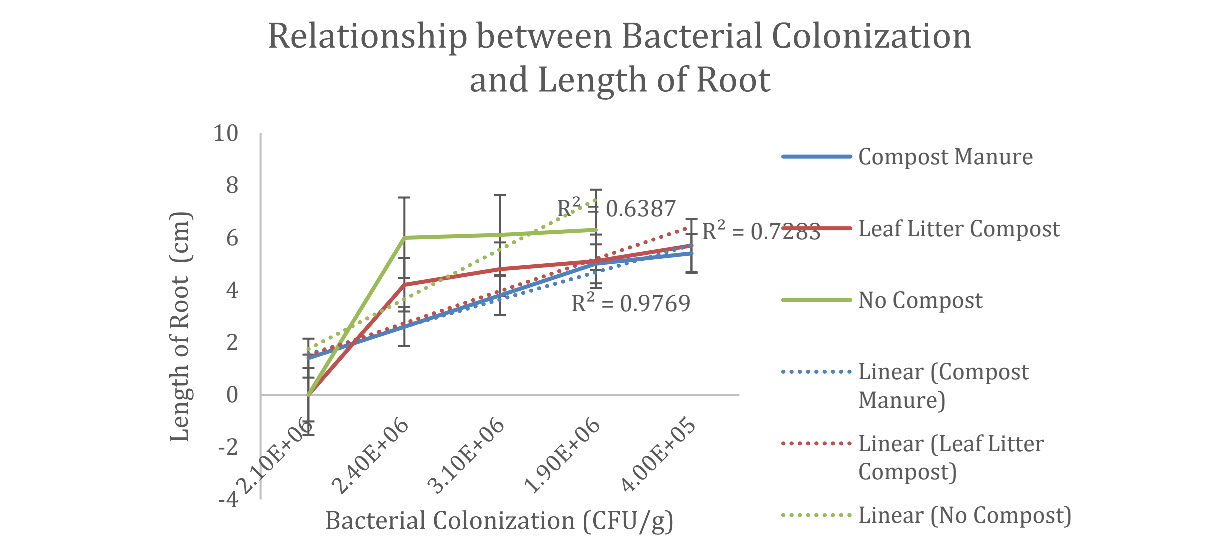

Figure 5. Relationship between the Bacterial colonization and Length of Root

Plant roots actively release substantial amounts of carbon and nitrogen compounds into the rhizosphere. Both bacteria and fungi are attracted to the nutritious environment and use these root exudates for growth and multiplication of the root surface. Antagonistic microorganisms to the plant are also attracted to this nutritious environment as a result plants use chemical signals to suppress microbial growth of certain pathogens. Other microorganisms are known to induce systemic resistance these are plant-associated bacteria as *Pseudomonas* spp. along with other Gram-negative bacteria species such *Bacillus amyloliquefaciens*, *B. subtilis*, *B. pasteurii*, *B. cereus*, *B. pumilus*, *B. mycoides*, and *B. sphaericus* which reduce the incidence or severity of various diseases to which Tomato plants is no exception to. Gram staining analysis done on the bacterial samples collected from the rhizosphere at week 7 is shown in Table 1. The results indicated that all the bacterial colonies from the rhizosphere soil amended with cow manure and the control soil were only gram negative bacilli, whereas the rhizosphere soil from the leaf litter compost had 43% gram positive bacilli and 57% gram negative bacilli.

Table 1. Effect of Organic Manures on the Abundance and Characteristics of Rhizosphere Bacterial Flora of Tomato Plants

Plant Sample harvested at week 7	Bacterial conc. (cfu/g)	Type of Bacteria	Shape
Soil amended with compost manure	2.0×10^6	100% gram negative	bacilli
Soil amended with leaf litter compost	7.0×10^5	43% gram positive and 57% gram negative	bacilli
Non amended soil	2.51×10^7	100% gram negative	bacilli

Conclusion

Compost is a form of organic fertilizer that replenishing nutrients back to the soil thus contributing to various biogeochemical cycles while inorganic fertilizers creates excessive run off of nutrients polluting groundwater, rivers and streams. The effect of compost on plant growth is dependent on the maturity of the compost and as such it may enhance or can be detrimental to the growth rate. Soils should therefore not be amended with any organic material that has not completed the composting process. The application of immature compost material lend intense decomposition accompanied by low oxygen levels, high carbon dioxide levels, accumulation of volatile organic acids resulting in poor plant growth rate. Mature compost on the other hand, elevates nutrient availability, enhance soil texture and structure and is beneficial to the rhizosphere microorganisms. It can be concluded that the amendment of soils with organic debris such as cow manure requires to undergo complete degradation process before application. If uncomposted cow manure is applied, it reduces plant growth and decreases microbial colonization. Dried leaf litter can be added as an organic amendment to soil since, it promotes plant growth and increases microbial colonization as compared to cow manure.

Undecomposed or partially decomposed organic manure is not recommended as an amendment because it does not sustain the growth of the plant over time; however, black loamy soil with certain level of organic matter can sustain the growth of the plants continuously. Bacterial colonization around the rhizosphere of plants grown in soil amended with both cow and leaf litter manure ranged from 10^5 to 10^7 CFU/g, with highest concentration at week 5 followed by a gradual decrease. Microbial colonization in the rhizosphere of plants grown in non-amended soil also ranged from 10^5 to 10^7 CFU/g, but increased gradually with time. The results indicated that there was a strong correlation between microbial colonization and the growth of the shoot.

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