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Cellulolytic Microbial Activator Influence on Decomposition of Rubber Factory Waste Composting

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***Abstract*—**In this research, an aerobic composting method is studied to reuse organic waste from rubber factory waste as soil fertilizer and to study the effect of cellulolytic microbial activator (CMA) as the activator in the rubber factory waste composting. The performance of the composting process was monitored as a function of carbon and organic matter decomposition rate, temperature and moisture content. The results indicate that the rubber factory waste is best composted with water hyacinth and sludge than composted alone. In addition, the CMA is more affective when mixed with the rubber factory waste, water hyacinth and sludge since a good fertilizer is achieved. When adding CMA into the rubber factory waste composted alone, the finished product does not achieve a standard of fertilizer, especially the C/N ratio.

Finally, the finished products of composting rubber factory waste and water hyacinth and sludge (both CMA and without CMA), can be an environmental friendly alternative to solve the disposal problems of rubber factory waste. Since the C/N ratio, pH, moisture content, temperature, and nutrients of the finished products are acceptable for agriculture use.

***Keywords*—** composting, rubber waste, C/N ratio, sludge, cellulolytic microbial activator

I. Introduction

THE typical production of rubber factory waste (STR 20 – Standard Thai Rubber 20) consists of branch of tree, soil, leaf, and stone which came from the rubber tapping process. In Thailand, it is illegal to discharge such waste outside of the factory area. Generally, it was dump inside the factory area. Composting is an alternative technology for a sustainable solid waste management. It is an environmental friendly technology to treat and to recycle organic wastes. Composting is a controlled biological process that uses natural aerobic process to increase the biological decomposition rate of organic materials [1-2]. Composting is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals and stabilized organic matter. Water and carbon dioxide released into the atmosphere, while minerals and organic matter are converted into a potentially reusable soil-like material called compost [3]. The composting process is consisting of different phases: (i) Initial phase, during which degradable components are decomposed, (ii) Thermophilic phase, during which organic materials are degraded by the high bio-oxidative activity of microorganisms, and (iii) Maturation and stabilization phase, during which organic materials are converted to biologically stable humic substances (a.k.a. finished products). Thus, as long as appropriate measures are taken to eliminate contaminants and impurities from the finished product, it can be used as a soil alteration in a variety of agricultural, horticultural or landscaping applications,

CMA is a group of microorganisms which is highly capable of decomposing agricultural or organic wastes to produce fertilizers in a short period of time. It has been discovered by the Land Development Department of Thailand since 1986. The CMA is a combination of eight microorganisms from bacteria, antinomycetes, and fungi that is able to produce high decomposed cellulose enzyme. The CMA can increase itself very fast in the high organic matter soil preventing other harmful microorganisms to grow. The principle objectives in this research were to reuse organic waste from rubber factory waste as soil fertilizers and to study the effect of cellulolytic microbial activator (CMA) as the activator in the rubber factory waste composting process.

II. Materials and Methods

A. Experimental Raw Materials

Rubber factory wastes were taken from a Standard Thai Rubber 20 (STR20) industry in Pathalung province. The dewatered activated sludge was taken from the wastewater treatment plant of the seafood industry in Songkhla province and the water hyacinth used was collected from the pond at Prince of Songkla University in Songkhla province. The characteristics of raw wastes are shown in Table I. The typical rubber factory waste has a high C/N ratio and low moisture content.

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TABLE I
CHARACTERISTICS OF RAW WASTES FOR COMPOSTING

Materials	pH	Moisture content (%)	Organic carbon (g/kg)	Nitrogen (g/kg)	C/N ratio
Rubber waste	7.7	48.1	26.4	0.1	260
Water hyacinth	5.6	92.0	46.3	2.6	17.8
Sludge from seafood factory	7.2	64.8	1.6	0.3	5.3

TABLE II
PREPARED MIXED MATERIALS FOR COMPOSTING

Reactor	Mixed waste components
1	100% Rubber waste
2	100% Rubber waste + CMA
3	25% Rubber waste + 25% Water hyacinth + 50% Sludge
4	25% Rubber waste + 25% Water hyacinth + 50% Sludge + CMA

B. Experimental Setup

In this research, four aerobic compost reactors were used. The reactor is shown in Fig. 1. Each reactor consists of a cylindrical vessel of 60 litres in volume and a mixer handle for turning compost. The experiments were carried out in a batch test for 60 days. The rubber factory waste, dewatered sludge from the seafood industry, water hyacinth, and CMA were mixed together using the ratio shown in Table II. Each mixture results in approximately 20 kg in weight. The mixed wastes were homogenised by cutting the water hyacinth to approximate 3 to 5 cm in length [4]. A fairly small particle size reduces the depth of oxygen diffusion and microbial advance with the particle, aids the homogenizing of material.

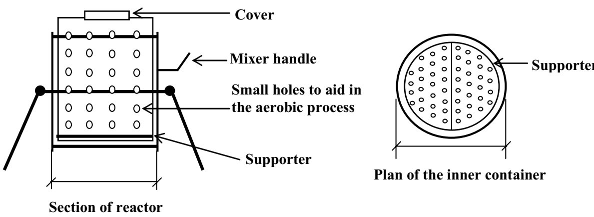

Fig. 1 The aerobic compost reactor

C. Monitoring parameters

Every 4 days, samples from each reactor were taken to analyze. The samples were analyzed to collect the following data: moisture content, pH, nitrogen (digested), TP (digested), and *E. coli* in accordance with Standard Methods [5]. For organic carbon and organic matter were followed by Walkley and Black method and Ca, Mg, and K were analyzed by ICP-OES. Daily temperature was monitored on the reactor. The finished product was taken for analyzing the value of pH, moisture content, nitrogen, TP, organic carbon, organic matter, Ca, Mg, K, and *E. coli*.

III. RESULTS AND DISCUSSIONS

A. Mixed Waste Characteristics

Table III shows the content of mixed wastes in each reactor. The initial moisture content can range from 55% to 70%.

TABLE III
CHARACTERISTICS OF MIXED WASTES FOR COMPOSTING

Parameter	Mixed wastes			
	Reactor 1	Reactor 2	Reactor 3	Reactor 4
pH	7.8	7.5	7.2	7.1
Moisture content (%)	51.5	52.1	65.8	76.9
Organic carbon (g/kg)	36.1	35.3	22.5	30.9
Organic matter (g/kg)	62.2	60.9	38.8	53.3
Nitrogen (g/kg)	0.16	0.12	0.4	1.0
C/N ratio	226	294	55	30
EC (mS/cm)	0.08	0.08	1.1	0.9
Nutrient element (%)				
- Ca	1.18	1.09	0.71	0.51
- Mg	0.06	0.07	0.04	0.04
- K	0.02	0.02	0.12	0.12
- P	0.09	0.08	0.16	0.14
E.Coli (MPN/gm)	ND	ND	>1,100	>1,100

Refer: ND = Not detected

B. Conditions of the Composting Process

Monitoring was mainly focused on temperature, moisture content, pH, C/N ratio, organic carbon and organic matter. However, the control parameters such as moisture content, pH, and C/N ratio can serve as indicators for expected process failure.

Temperature – The temperature change during the composting has a profound effect on the efficiency of the composting process. Heat is generated by decomposing process of the organic matter by microorganisms [6] then the temperature of the compost in reactor is raised a few degree as a result (Fig. 2). The temperature was clearly declined to ambient temperature to about 30^{o}C and later remained stable which is shown as a sign of composting stabilization.

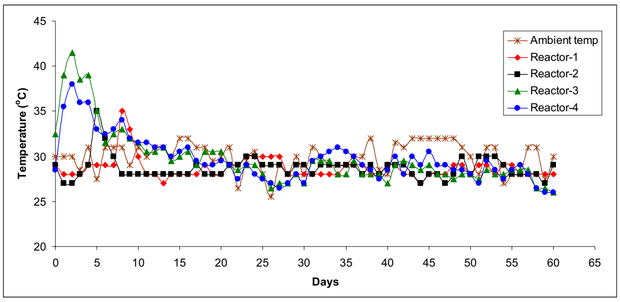

Fig. 2 Variations of temperature during composting

pH - A pH is a parameter which greatly affected the co-composting process. The pH for the initial mixed wastes ranged 7.1 to 7.8, and for the finished product ranged 5.6 to 7.3 (Fig. 3). During the starting period, the pH value rises to 8.0 and 8.5 in the reactor 1 and 2, respectively. This result is due to the decomposition of proteins and the elimination of carbon dioxide. These high pH values are later reduced because the microorganisms produce acids during the decomposition process. However, the pH values at the final stage of the composting will remains constant because the acids are used by the microorganisms once the higher oxygen concentrations are established.

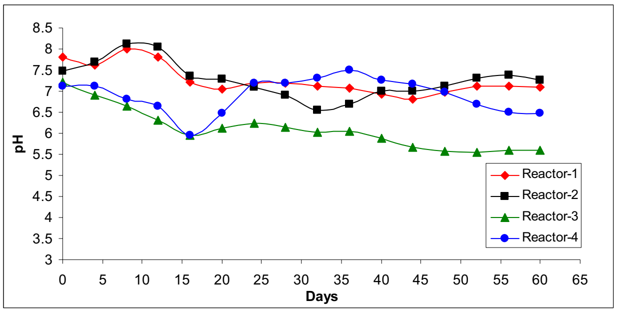

Fig. 3 Variations of pH during composting

Moisture content – Moisture content is an important factor to control because it influences the structural and thermal properties of the material, as well as the rate of degradation and metabolic process of microorganisms. The optimum condition of moisture content needed for microorganism activity is at 60% to 65%. During composting, microorganisms break down the organic matter in mixed materials into carbon dioxide, water, heat, and finished product. Previous results indicated that 1 g of organic matter releases about 25 kJ of heat energy which is sufficient to vaporize 10.2 g of water [7]. Moisture movements of an aeration composting are depended on various factors such as particle size, temperature, and aeration rate etc. The results of these factors are shown in Fig. 4. During the composting, the moisture content must be maintained at above 30% to 35% due to a marked reduction in the microbiological activity. Moisture content can be controlled directly by adding water. However, the moisture content becomes a limiting factor and the rate of decomposition decreases rapidly when the moisture content decreases below 45% to 50%.

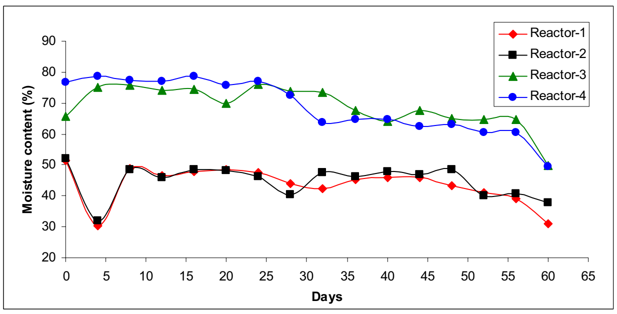

Fig. 4 Variations of moisture content during composting

Particle size – Oxygen is a main factor in controlling the composting process. Decomposition is rapidly near the surface as oxygen diffusion is very high. Particle size affects the retention of moisture content as well as the free air space and the porosity of compost mixture [4]. Aerobic decomposition increases with small particle size. The preferable particle size for composting is 3 mm to 50 mm in diameter. Aeration supply of oxygen is very importance for aerobic decomposition. Turning the reactor provides two benefits: (i) reduce the oxygen diffusion problem and (ii) increase amount of oxygen in the reactor.

Organic matter – During composting process, the organic matter is decomposed by microorganisms, producing carbon dioxide and water. The breakdown of organic matter is a dynamic process achieved by microorganisms, when each group of microorganisms reaching its peak population at the optimum condition for microorganism activity. The organic matter such as protein, cellulose, and hemicelluloses are easily degradable [8] by microorganisms. The microbial biodiversity in the selected microorganisms (i.e., CMA) aids in the breakdown of the organic material. The organic matters are rapidly reduced from a huge volume of decomposable materials to a small volume that continues to decompose slowly (Fig. 5). Then the composting process brings the C/N ratio into a balance.

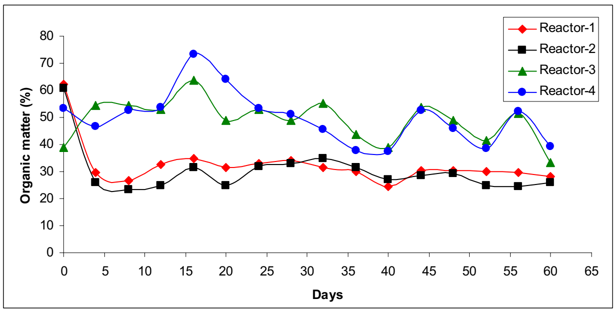

Fig. 5 Variations of organic matter during composting

Organic carbon – Typically, carbon provides the preliminary energy source for the microorganisms growth. Especially, bacteria, actinomycetes, and fungi need both carbon and nitrogen to grow. The organic carbon decreases during decomposition organic matter of microorganisms by changing to carbon dioxide (Fig. 6), escaping to the atmosphere. That is an undesirable odor for aerobic composting [9].

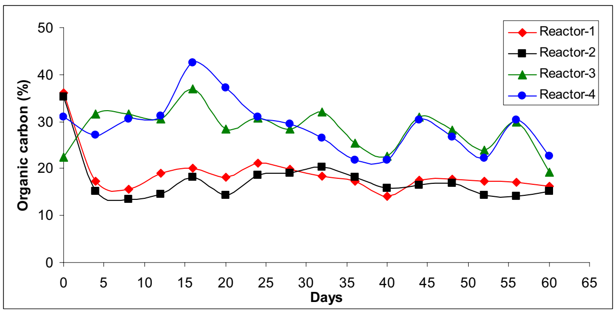

Fig. 6 Variations of organic carbon during composting

Nitrogen – Nitrogen is an important nutrient for composting process since the quantity of nitrogen determines the microorganism population growth. During composting process, microorganisms oxidize organic matters, and release essential minerals for plants such as nitrogen, phosphorus, and sulfur. Therefore, amount of nitrogen increases at the end of the process (Fig. 7). Inorganic nitrogen is usually obtained from the atmosphere.

Under high temperature condition, nitrogen gas is fixed with hydrogen from natural gas to produce ammonia gas. Biological nitrogen fixation process occurs by enzyme nitrogenase. This process converts atmospheric nitrogen, which is not in itself available to plants, into the ammonia form that plants can use. Biological nitrogen fixation is carried out by several organisms, mainly microorganisms, in natural ecosystems. This process consumes tremendous quantities of energy. Inorganic nitrogen in finished products provides a greater amount of immediately available nitrogen to plants and crops, and thus must be applied in a timely manner with stages of plant growth.

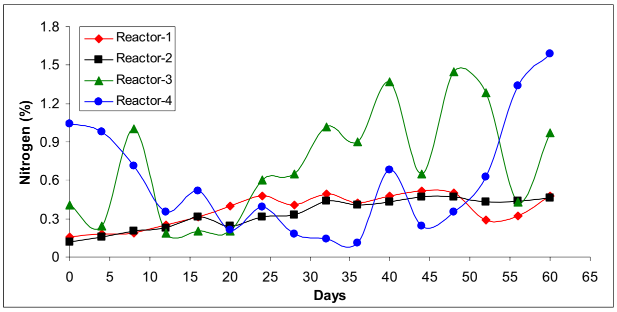

Fig. 7 Variations of nitrogen during composting

C/N ratio – Many research suggested that the composting is successful when the initial C/N ratio of mixed waste is range between 20 and 40 [1][6-7]. However, the results in [9] concluded that the rate of composting decreases when the initial C/N ratio exceeds 30 and the excess nitrogen is converts to ammonia when the initial C/N ratio decreases below 25. This ammonia then releases into the atmosphere and this results in undesirable odor. Even though, the initial C/N ratio in this research is higher than the suggested range (i.e., reactor 1-2 as shown in Fig. 8), the composting process is still occurred successfully.

C. *Evaluation of Maturation Compost*

The most important factor affecting the successful application of compost for agricultural purpose is its degree of stability and maturity [10-11]. The approaches to measure the degree of maturity compost include (i) temperature diminution at the end of composting, (ii) decrease in organic content as analyzed by carbon content and C/N ratio, (iii) absence of obnoxious odor, and (iv) presence of white or gray color due to the growth of actinomycetes [1].

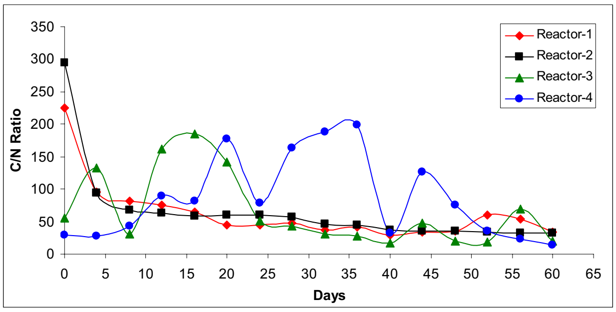

Fig. 8 Variations of C/N ratio during composting

The results show that the composting of rubber factory waste, dewatered sludge from the seafood industry and water hyacinth (i.e., the contents in reactor 3 and 4) increase the moisture content and improve to suitable C/N ratio in mixed waste. It can be concluded that dewatered sludge and water hyacinth increase the overall quality of the mixed waste produced in the reactors. The finished products in all four reactors are organic and inorganic matter, and water. Especially, the finished products in reactor 3 and 4 can be promoted as soil amendment supply nutrients to plants and crops.

TABLE IV
CHARACTERISTICS OF THE FINISHED PRODUCTS

Parameter	Mixed wastes			
	Reactor 1	Reactor 2	Reactor 3	Reactor 4
pH	7.1	7.3	5.6	6.5
Moisture content (%)	31.1	38.0	49.7	49.3
Organic carbon (g/kg)	16.3	15.1	19.3	22.7
Organic matter (g/kg)	28.1	26.0	33.3	39.2
Nitrogen (g/kg)	0.48	0.46	1.0	1.6
C/N ratio	34	33	20	14
EC (mS/cm)	0.10	0.14	4.0	3.9
Nutrient element (%)				
- Ca	1.15	1.11	2.65	3.22
- Mg	0.07	0.06	0.18	0.24
- K	0.02	0.02	0.66	0.68
- P	0.09	0.12	1.17	1.41
E.Coli (MPN/gm)	ND	ND	21	3.6

Refer: ND = Not detected

The finished products in all the reactors turn brown to brownish black color and soil-like texture after the maturation period, especially in reactor 2 and 4 (with adding CMA). Decomposition of organic matter is brought about the microbial that use the carbon as a source of energy and nitrogen for building cell structure. The final C/N ratio of 15 to 20 is expected and the value of higher than 20 may have a negative impact and damage the crop and seed germination. On the basis of the C/N ratio, the final C/N ratio in the reactor 3 and 4 was found to be similar to the recommended values (Table IV). Thus, they can be concluded that the finished product can make a good soil condition (Fig. 9). The result from Fig. 10 to 13 show that P, K, Ca, and Mg content in reactor 3 and 4 gradually increases during the composting process which is enough to denominate as a fertilizer. The amount of Ca and Mg increase due to the decomplexation and denature of essential base ions from microorganisms [12]. However, this process requires an excessive amount of hydrogen ions at low pH.

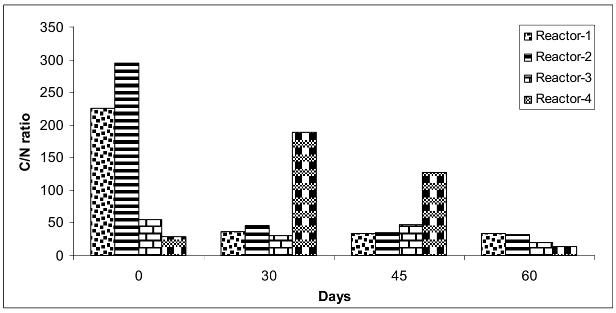

Fig. 9 Variations of C/N ratio during composting

The value of many inorganic components—essential for the growth of plants (i.e., P, K, Ca and Mg) increase during the composting may be caused by (1) the loss of organic fraction or volatile solids as carbon monoxide [13] and (2) the respiration of microorganisms. Carbon dioxide, water, and energy and many minerals are produced in the respiration of microorganisms. Furthermore, Phosphorus is not volatilized during the composting process [14]. Levels of phosphorus along with nitrogen and potassium are important to determine the quality of the finished production. The C/P ratio of 100 to 200 is desirable [15]. It can be seen clearly in Fig. 10-13 that the composting of mixed wastes with adding CMA significantly increases the total amount of the nutrients in the finished products.

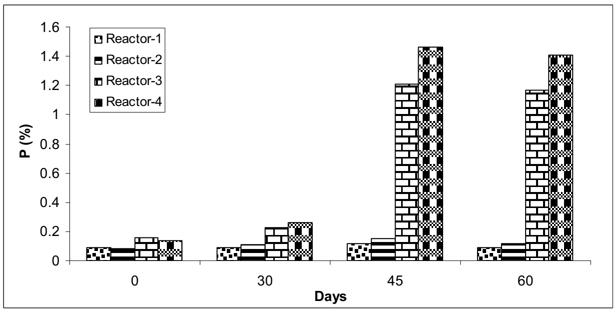

Fig. 10 Variations of Phosphorus content in the composting at various stages

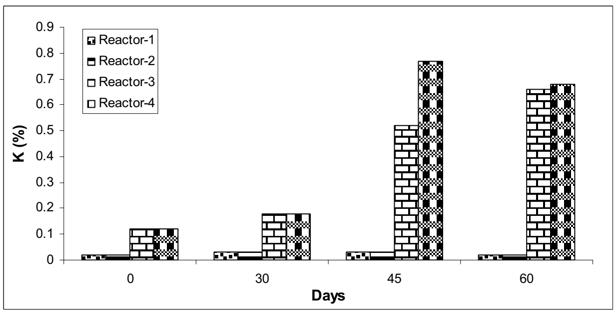

Fig. 11 Variations of Potassium content in the composting at various stages

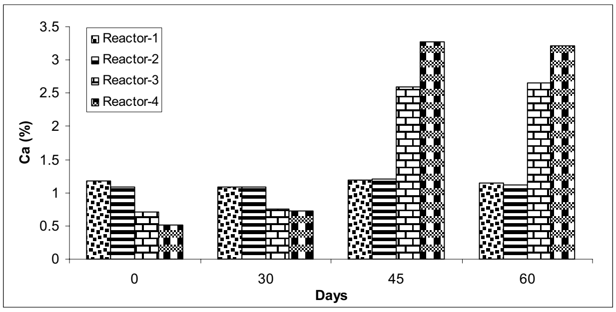

Fig. 12 Variations of Calcium content in the composting at various stages

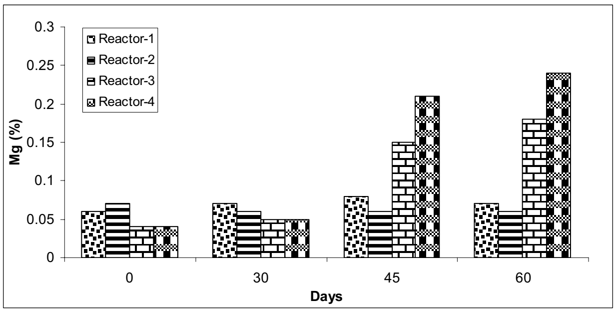

Fig. 13 Variations of Magnesium content in the composting at various stages

IV. CONCLUSION

The finished products in reactor 3 and 4 have a high enough amount of three major nutrient elements (i.e., N, P, K) to be promoted as a fertilizer, while the finished products in reactor 1 and 2 do not achieve such quality. Thus, the result indicates that the rubber factory waste is best composted with water hyacinth and sludge than composted alone.

For the efficiency of CMA, a better fertilizer quality in reactor 4 indicates that the CMA significantly increases the level of three major nutrient elements in the finished product. However, adding the CMA into reactor 2 (i.e., the rubber factory waste composted alone) does not improve the level of the three major nutrient elements than that in reactor 1 (i.e., the rubber factory waste composted alone without CMA). In conclusion, the CMA is more affective when mixed with the rubber factory waste, water hyacinth and sludge since a good fertilizer is achieved (in reactor 4). When adding CMA into the rubber factory waste composted alone, the finished product does not achieve a standard of fertilizer, especially the C/N ratio.

The finished products of composting rubber factory waste and water hyacinth and sludge (both CMA and without CMA), can be an environmental friendly alternative to solve the disposal problems of rubber factory waste. Since the C/N ratio, pH, moisture content, temperature, and nutrients of the finished products are acceptable for agriculture use.

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