EFFICIENCY OF USING ORGANIC FERTILIZER FROM SEAFOOD SLUDGE AS SUBSTRATE AND HYDROPONIC SOLUTION ON LEAFY VEGETABLE YIELD

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Abstract

The aim of this study was to use organic fertilizer from seafood sludge as substrate and as hydroponic solution. The first experiment was carried out with 4 treatments in net house condition including: (1) control (only soil), (2) Soil+ recommended chemical fertilizer, (3) Soil + 5 tons/ha seafood sludge compost (SSC), and (4) Soil + 5 tons/ha sugarcane cake compost (SCC). The second experiment was conducted with 4 treatments consisting of (1) water (control), (2) extracted solution at ratio of 1:5, (3) extracted solution at ratio of 1:10, and (4) commercial hydroponic solution. Results showed that the yield of green mustard was found in the treatment amended with 5 tons/ha of SS compost five times higher than control treatment. The yield of salad vegetable on hydroponic solution at diluted ratio of 1:10 increased more than 65% compared to the control treatment.

Keywords: *Green mustard, hydroponic, seafood sludge compost, vegetable.*

HIỆU QUẢ SỬ DỤNG PHÂN HỮU CƠ TỪ BÙN THẢI THỦY SẢN LÀM GIÁ THỂ VÀ DUNG DỊCH DINH DƯỠNG THỦY CANH TRÊN ĐẾN NĂNG SUẤT RAU ĂN LÁ

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Tóm tắt

Mục tiêu nghiên cứu là sử dụng phân hữu cơ từ bùn thải thủy sản (BTS) làm giá thể và làm dung dịch dinh dưỡng trồng rau thủy canh. Thí nghiệm 1 được thực hiện với 4 nghiệm thức trong điều kiện nhà lưới gồm: (1) Đất, (2) Đất + NPK khuyến cáo, (3) Đất + 5 tấn phân hữu cơ BTS, và (4) Đất + 5 tấn phân hữu cơ bã bùn mía. Thí nghiệm 2 được thực hiện với 4 nghiệm thức gồm (1) Nước, (2) dung dịch trích tỉ lệ 1:5, (3) dung dịch trích tỉ lệ 1:10, và (4) dung dịch A. Kết quả thí nghiệm cho thấy năng suất cải bẹ xanh khi bón 5 tấn/ha phân hữu cơ BTS cao khác biệt gấp 5 lần so với đối chứng. Năng suất rau xà lách trồng trong dung dịch thủy canh được pha loãng ở tỉ lệ 1:10 tăng 65% so với đối chứng.

Từ khóa: *Cải bẹ xanh, thủy canh, phân hữu cơ bùn thải thủy sản, rau xà lách.*

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1. Introduction

Seafood sludge from wastewater treatment plants of seafood factories was producing more than 313 thousand tons dried solids per year in Vietnam (Võ Phú Đức, 2013). The main components of seafood sludge contain nitrogenous compounds (ammonia, nitrite and nitrate), phosphorus, humic compounds, fulvic acids, aldehydes, and dissolved organic carbon, which cause environmental deterioration at high concentration (Mook et al. 2012). Hence, sludge should be reused whenever possible because it can be seen that the seafood sludge can provide nutrients of N, P, K and organic matter to reduce its environment impact (Feng et al., 2008; Kanagachandran & Jayaratne, 2006; Lê & Trần, 2016; Mook et al., 2012; Olajire, 2012; Parawira et al., 2005; Võ, 2013). Therefore, composting from seafood sludge and using this organic fertilizer as the main source of fertilizer for vegetables are essential to reduce the harmful impact on the environment of the community (Saviozzi et al., 1994; Stocks et al., 2002; Thomas & Rahman, 2006).

Hydroponic culture is a cheap and easy option for organic vegetable production. It is a technique that involves growing plants in water using mineral nutrients without soil (Diver & Rinehart, 2006; Sapkota et al., 2019; Wahome et al., 2011). Easy control of nutrient composition, lack of soil contamination, faster plant growth, shorter crop cycles, high product quality, and good consumer acceptance have made hydroponics an important alternative plant production technique (Benke & Tomkins, 2017; Rothwell et al., 2016).

Even though hydroponic culture can produce optimal plant growth (better yield and quality), its efficiency depends on many factors such as nutrient availability, crop genotype, growing method, and pest management (Sapkota et al., 2019). However, using organic fertilizer as hydroponic solution still faces to some difficulties about suitable diluted concentration for plant growth. Therefore, this paper is conducted with the aim of both producing organic fertilizer from seafood sludge as substrate and nutrient solution.

2. Materials and methods

2.1. Materials

Materials used in two experiments consist of:

- Styrofoam planting boxes (39 cm long, 25 cm wide and 30 cm high) filled with 10 L of substrate. Hydroponic Styrofoam containers (49 cm long, 29 cm wide and 33 cm high) were filled with 20 L of water and mineral fertilizers and plastic cups (height 9 cm and width 4.5 cm).

- Coconut fibre substrate;

- Green mustard and salad vegetable seeds from Trang Nong Co., Ltd.

- Organic fertilizer: seafood organic fertilizer is collected from research result of Nguyễn Thị Phương (2019).

- The hydroponic nutrient solutions were used from Vi Dan Co., Ltd. The contents of major nutrients such as 275 ppm K, 80 ppm Ca, 75 ppm Mg, 110 ppm Fe, 495 ppm NO_3-, 195 ppm $H_2PO_4^-$, 110 ppm Mn, 130 ppm Zn, 10 ppm Bo, 140 ppm Cu, 880 ppm Cl^-, 10 ppm α-NAA; 50 ppm β-Glucose; and 10 ppm EDDHA (red).

- Soil samples: were collected at the biological garden, Dong Thap University. The initial compositions of soil sample and seafood sludge compost (SSC) were showed in Table 1 below.

Table 1. Initial nutrient composition

Materials \ Criteria	NT (%N)	PT (%P_2O_5)	KT (%K_2O)	OM (%)	Nav (%N)	Pav (%P_2O_5)	Kex (%K_2O)
Soil - Control	0.15	0.10	-	3.02	-	-	-
Seafood sludge compost	2.85	6.63	2.11	33.52	0.07	5.46	0.64

Note: N_T: total Nitrogen, P_T: total phosphorus, K_T: total potassium, OM: organic matter, N_{av}: available Nitrogen, P_{av}: available phosphorus, K_{ex}: exchangeable potassium, "-": not data.

2.2. Methodology

2.2.1. Experiment on effect of organic fertilizer from seafood sludge on green mustard growth and yield

a. Experimental design

The experiment was arranged completely randomly with 4 treatments and three replications in net house condition including: (1) control (only soil), (2) Soil+ recommended chemical fertilizer (55 N – 32 P_2O_5 – 46 K_2O kg/ha, approximately 0.19 N – 0.11 P_2O_5 – 0.16 K_2O g/pot), (3) Soil + 5 tons/ha seafood sludge compost (approximately 17.5 g/pot), and (4) Soil + 5 tons/ha sugarcane cake compost (approximately 17.5 g/pot). The amount of dried soil for each pot is 7 kg.

b. Data Collection

Green mustard plants were harvested 30 days after treatment initiation. The response variables measured were plant height, fresh weight, dry weight and number of leaves.

2.2.2. Determinate suitable diluted ratio of seafood sludge compost to make hydroponic solution for salad vegetable growth and yield

a. Experimental design

The experiment was arranged in a completely randomly design with 4 treatments and three replications. Each replication was carried out three plastic cups with three plants for each cup. All treatments were described in Table 2 below.

Table 2. The experimental treatment

No. of treatment	Treatment
T1	Water
T2	Extracted solution at ratio of 1:5
T3	Extracted solution at ratio of 1:10
T4	Commercial hydroponic solution

The solution was made from fresh tap water [electrical conductivity (EC) of 298 µS/cm and pH 7-7.5].

b. Preparation of nutrient solution

Extract solutions from dilution between seafood sludge compost (SSC) and fresh tap water were prepared following methods described by Michitsch et al. (2007). The extracts were prepared by pouring 20 L of fresh tap water through a 2-L volume of SSC or 4-L volume of SSC. The solution was soaked for 24 hours and stirred mixture every 3 hours. After 24 hours, the extracts were filtered through a 1.5-mm screen. These were extracted solution at ratio of 1:5 and extracted solution at ratio of 1:10, respectively. All diluted nutrient solutions were analyzed for chemical criteria such as available nitrogen, available phosphorus and exchangeable potassium. The result showed in Table 3.

Table 3. The content of N_{av}, P_{av}, and K_{ex} in SSC and diluted solution

Treatment	Nav (%N)	Pav (%P_2O_5)	Kex (%K_2O)
Seafood sludge compost	0.07	5.46	0.64
Extracted solution at ratio of 1:5	0.02	0.08	0.02
Extracted solution at ratio of 1:10	0.01	0.04	0.01

Note: Nav: available Nitrogen, Pav: available phosphorus, Kex: exchangeable potassium.

c. Plant condition

Salad vegetable seeds were germinated in seed trays using coconut fibre and transplanted plastic cup filled with coconut fibre after four days germination. Seven-day-old seedlings (two to three true leaves) were transferred to the hydroponic system. After transplanting, the plants were supplied with the nutrient solution weekly. During the culture of salad plants, insect pests were also controlled by mine.

When salad grew from 7 to 15-day-old seedling plant, the amount of hydroponic nutrient solution was 10 ml extracted solution from SSC through a 1-L volume of fresh tap water. From after 15 days planting, the amount of ones was 20 ml extracted solution from SSC through a 1-L volume of fresh tap water.

The pH of the nutrient solution was maintained between 6.5 and 7.5 by adding NaOH or HCl as per need. The pH of the solution was checked three times a week. Furthermore, 2 L of water and nutrient solutions were added to replenish each hydroponic solution 7 days after treatment initiation.

d. Data collection

Salad vegetable plants were harvested 35 days after treatment initiation. The response variables measured were plant height, fresh weight, root weight and number of leaves and length of the longest root.

2.2.3. Statistical analysis

All analyses were carried with three replicates per sample, and mean results per sample used for statistical data treatment. Statistical calculations were carried out using software SPSS version 20.0. Significant differences between all treatments were analyzed by the Duncan when $p<0.05$.

3. Result and Discussion

3.1. Effect of seafood sludge compost on green mustard growth and yield

3.1.1. Plant height

The result showed that the plant height of green mustard were sown on four substrates including of Soil, Soil + NPK, Soil + seafood sludge compost (SSC) and Soil + sugarcane cake compost ranged from 6.33 cm to 18.67 cm (Table 4). Green mustard grown on substrates supplemented with organic fertilizer gave a significantly different plant height higher than controls. There was SSC in this research could be attributed significant ($p < 0.05$) difference in plant height probably to better physical environment in terms of plants grown under different media and nutrient holding capacity. Growing media using SSC gave the highest plant height because SSC provided enough stimulants and mineral contents. Those led to higher water holding capacity and highest plant height growth (Diver & Rinehart, 2006; Michitsch et al., 2007).

Table 4. Effects of different growing substrates on the growth of green mustard

Treatment	Plant height (cm)	Number of leaves	Leaf width (cm)	Fresh weight (g/plant)	Dry weight g/plant)
Control (soil)	6.33^{c}±0.58	4.22^{c}±0.69	2.50^{b}±0.50	7.67^{b}±0.71	3.01^{c}±0.43
Soil + NPK	9.40^{b}±0.56	5.67^{b}±0.58	3.47^{b}±0.46	9.98^{b}±1.42	5.28^{b}±0.23
Soil + SSC	18.23^{a}±1.37	7.33^{a}±1.20	8.17^{a}±0.29	32.57^{a}±2.81	7.24^{a}±0.21
Soil + SCC	18.67^{a}±0.99	6.67^{b}±0.58	7.93^{a}±0.84	35.90^{a}±1.84	7.84^{a}±0.02
CV (%)	**7.09**	**8.95**	**10.09**	**8.61**	**4.53**

Note: Means followed by same letter in columns for each substrate are not significantly different at 5% level, SSC: seafood sludge compost, SCC: sugarcane cake compost.

3.1.2. Fresh weight and dry weight

Green mustard had the greatest fresh weight in the SSC and SCC media followed by soil+NPK and control treatments (Table 4). There was a statistically significant difference between substrates for fresh weight. Interestingly, media of SSC and SCC resulted in full-grown plants of marketable size. The control substrate produced the lowest fresh weight (7.67 g/plant) when compared to the other treatments. Thus, weight variation in green mustard could be attributed to cultivar characteristics and types of media.

Similar to fresh weight, the dry weight of green mustard sown on the substrate amended with organic fertilizer was significant ($P < 0.05$) difference higher than the control and chemical fertilizer treatments. The dry weight of green mustard was the highest when those sown in the SSC and SCC growing media with values of 7.24 g/plant and 7.84 g/plant, respectively (Table 4).

3.1.3. Leaf number and width

Experimental results presented in Table 4 showed that the leaf number ranged from 4.22 to 7.33 leaves. The highest leaf number of green mustard were sown in SSC substrate (7.33 leaves). The number of green mustard leaves got the lowest when it grew in soil media. In general, the leaf number of green mustard increased at nearly 57% SSC growing media compared with the control.

Similar to the results of the leaf number, leaf width was increased for both SSC and SCC growing media. The leaf width of green mustard sown in these media got 8.17 cm and 7.93 cm, respectively. These leaf widths were enhanced by control and recommended fertilizer rate. This result prompted that the organic fertilizer from seafood sludge contain enough nutrients and improve soil quality to help the best green mustard growth (Shinohara et al., 2011; Trần Thị Ba, 2009a; Trần Thị Ba et al., 2009b). This indicated that amending of organic fertilizer is very significant in improving the green mustard growth and yield increase.

3.2. Efficiency of nutrient solution extracted from seafood sludge fertilizer on salad vegetable growth and yield

3.2.1. Overview

Effect of nutrient solution from seafood sludge organic compost on salad vegetable growth and yield were described in Figures 1 and 2. Generally, criteria of plant height, number of leaves and root length of salad vegetable were not significantly different between treatments in the early stage (from 0 to 7-day-old seedling plant).

However, from 10-day sowing to harvest stage, salad vegetable grown in SSC solution gave production criteria higher values than treatments of the control and commercial nutrient solution. When salad vegetable used nutrient solution from extracted SSC got thickest leaf and darkest color, compared to the control.

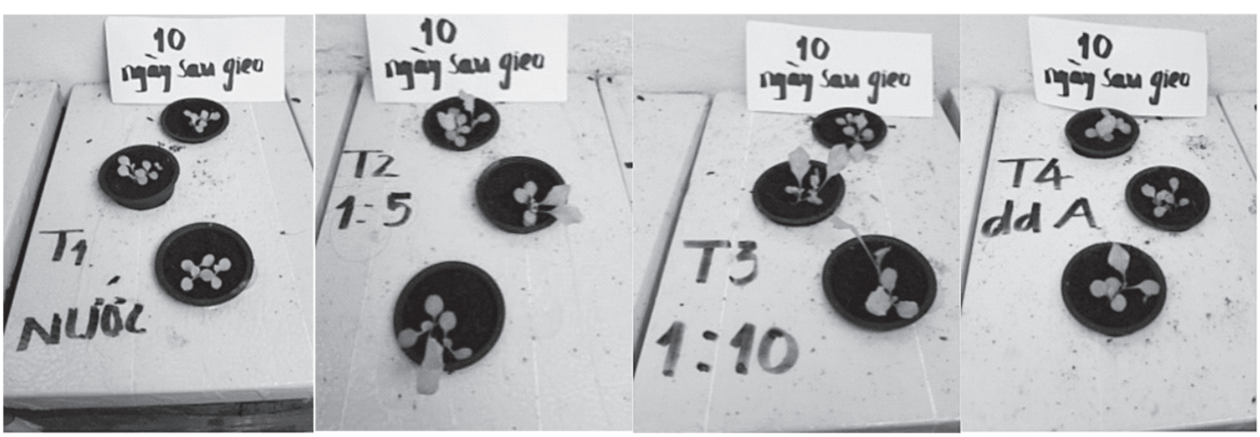

Figure 1. Ability of salad growth in initial period (after 10-day sowing)

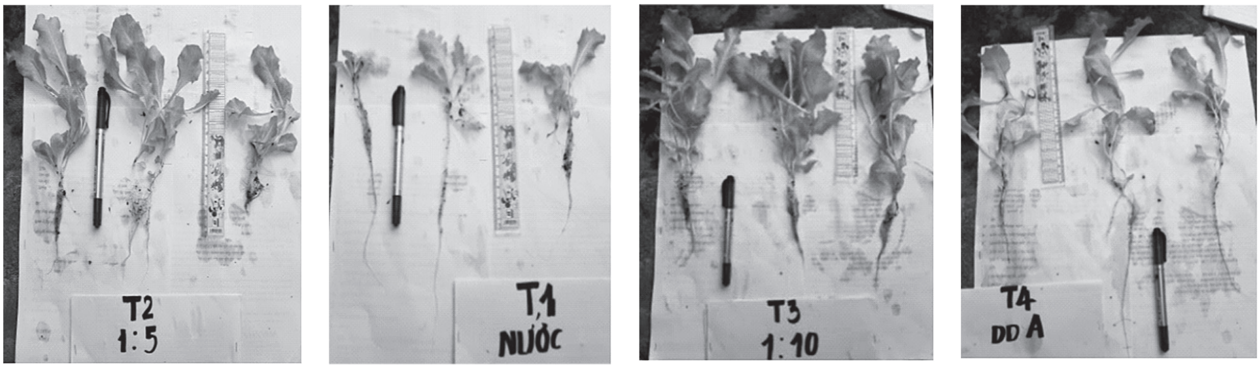

Figure 2. Ability of salad growth in harvest period (after 35-day sowing)

3.2.2. Salad vegetable growth characteristics

a. Number of leaves

Salad vegetable cultivar grown in the T3 nutrient solution generally had a significantly greater number of leaves compared to the other solutions (Figure 3). Differences in the number of leaves per plant could be associated with either solution composition and/or plant characteristics. These findings were slightly different between nutrient solution from SSC and control or commercial hydroponic solution for salad production that could increase the mean number of leaves from 4.1 to 7.33, respectively, after 35 days. However, the result showed that there were no statistically significant differences in leaf number between the T2 and T3 nutrient solutions.

This indicated that it was possible to use diluted organic fertilizers from SSC with water at the ratio of 1:10 for salad cultivation in non-circulating hydroponic system.

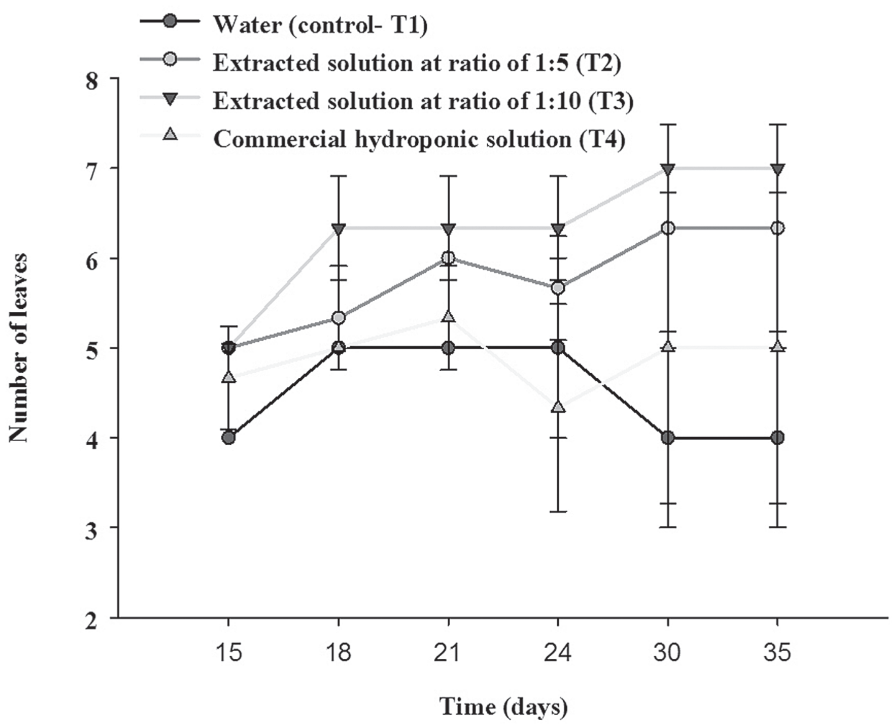

Figure 3. Effects of different hydroponic solution on the number of leaves

Note: The vertical bars represent the standard error.

b. Plant height and root length

The result of plant height was described in Table 4. Throughout the supply in hydroponics culture, the highest plant height (24.2 cm) was obtained when salad vegetable was grown by nutrient solution from diluted SSC with fresh water at ratio of 1:10. There was T3 solution in this investigation which could be attributed to significant ($P < 0.05$) difference in plant height probably better physical environment in terms of plants grown under different solutions. This is in agreement with Shinohara et al. (2011) who asserted that using organic fertilizers to make nutrient solution could provide enough macro-nutrients and micro-nutrients. Through this, the vegetable quality and yield was higher than that of commercial chemical fertilizers as hydroponic solution.

There were significant differences in root length between salad vegetable grown in the different nutrient solutions. The T1 solution generally produced the longest roots (20.5 cm), whereas those grown in T2 had the shortest roots (Table 4). The reason for longer roots could be associated with nutrient condition likely due to lower mineral availability in the solution. For example, available mineral concentration in water solution was low, so roots only grew in root length and nor root width (Figure 2, Table 4). Those lead to low root weight (Fraile-Robayo et al., 2017). Fraile-Robayo et al. (2017) evaluated the growth of vegetable in a hydroponic system and concluded that root size depended on nutrient composition, water availability and temperature. Despite the highest concentrations, the T3 solution produced relatively shorter roots inferring that an overabundance of N, K and Ca was not suitable for salad hydroponic culture. In addition, Shinohara et al. (2011) mentioned that high ammonium nitrogen depressed root metabolism leading to shorter roots.

Table 4. Effect of different hydroponic solutions in salad vegetable growth and yield

Treatment	Plant height (cm)	Root length (cm)	Fresh weight (g/plant)	Root weight (g/root)
T1- Control	$6.20^{c} \pm 2.07$	$20.5^{a} \pm 0.50$	$3.01^{c} \pm 0.68$	$0.17^{d} \pm 0.07$
T2- Extracted solution (1:5)	$16.5^{b} \pm 0.90$	$9.43^{c} \pm 0.81$	$5.76^{b} \pm 0.58$	$0.69^{b} \pm 0.04$
T3- Extracted solution (1:10)	$24.2^{a} \pm 2.25$	$16.8^{b} \pm 0.25$	$8.49^{a} \pm 0.06$	$1.18^{a} \pm 0.06$
T4- Commercial hydroponic solution	$18.4^{b} \pm 0.90$	$18.3^{ab} \pm 2.31$	$6.07^{b} \pm 0.58$	$0.39^{c} \pm 0.13$
CV (%)	**10.14**	**7.73**	**9.17**	**13.73**

Note: Means followed by same letter along columns for each hydroponics solution not significantly different at 5% level.

c. Fresh weight and root weight

Salad vegetable had the greatest fresh weight in the T3 solution followed by N2 and N4 solutions (Table 4). There was a statistically significant difference among treatments for fresh weight. Interestingly, nutrient solutions T2 and T3 resulted in full-grown plants of marketable size with 5.76 g/plant and 8.49 g/plant, respectively. The T1 solution produced the lowest fresh weight compared to the other treatments (Table 4). Thus, weight variation in salad vegetable could be attributed to nutrient concentration in the hydroponic solutions. A previous study by Sapkota et al. (2019) suggested that nutrients are the primary factors that influence plant growth and biomass production in hydroponic culture.

Obtained result was similar for the root weight of salad vegetable. The root weight was highest in T3 solution. There was statistically significant difference at level of 5% between T3 hydroponic solution in comparison with the control and other solution.

Overall, the results indicated that T1 was the proorest nutrient solutions for salad growth. The T1 content of macro-nutrients resulted in lower fresh weight, fewer leaves as well as root weight and root length. Meanwhile, fresh weight and number of leaves as well as root weight and root length were highest in the T3 nutrient solution compared to all other solutions.

4. Conclusions

On green mustard, the amended application of 5 tons/ha of seafood sludge compost was recommended. Throughout this treatment, plant height, fresh weight and dry weight of green mustard reached the highest values with 18.23 cm, 32.57 g/plant and 7.24 g/plant, respectively.

The extracted solution at ratio of 1:10 was chosen for salad cultivation in hydroponic system. However, the further research should be carried on different crops.

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