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Effects of Different Proportional Composts of Cattle Manure and Corn Straw on Greenhouse Cucumber

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Abstract:

Agricultural waste composts as a soil amendment in intensive farming are a feasible practice to improve soil fertility, productivity and resources utilization. However, the best ratio and impact of cattle manure (CM) and corn straw (CS) composting on soil fertility and cucumber growth and yield in greenhouse remain elusive. Using "Jinwang 607" cucumber as test materials, this study compared the effects of seven volume ratios (0:6, 1:5, 2:4, 3:3, 4:2, 5:1, 6:0) composts of CM and CS on soil nutrient content, cucumber growth and yield in greenhouse. The results showed that, seven composts all increased the contents of soil organic matter, total nitrogen, total phosphorus, total potassium, alkali-hydrolyzed nitrogen, available phosphorus, available potassium, plant aboveground dry matter accumulation and yield. And the increase in above-mentioned parameters was more prominent in the 4:2 ratio compost treatment compared to other treatments. This treatment effectively reduced risk of soil salinization and acidification, increased soil nutrients content, promoted plant photosynthesis, accumulated more organic matter to transfer to fruits, increased fruit number, and then obtained the highest yield, which was 52213 kg/ha increased by 51.8% compared with the control. Therefore, this suggests that the best volume ratio of CM and CS composting could be 4:2 for improving soil fertility and plant productivity to greenhouse cucumber.

Keywords: *Cattle manure, Corn straw, Compost, Cucumber, Greenhouse.*

I. INTRODUCTION

As a large agricultural country, the amount of agricultural waste is increasing with the development of agricultural industry in China[1]. Limited by traditional concept and technology condition, the efficiency of harmless treatment and resource utilization of

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agricultural waste is low. It is estimated that annual amount of livestock and poultry waste is 3.8 billion tons, and the comprehensive utilization rate is less than 60%. Nearly 900 million tons of straw are produced and about 200 million tons are unused in China. These agricultural wastes, which have not been treated or utilized, are often discarded or burned at will, causing adverse effects on the urban and rural ecological environment[2-4]. Greenhouse farming refers to a production mode of crop cultivation under a changed environment caused by various technical facilities. It could break through the restriction of external environmental factors such as low temperature, strong light or heavy rain on the growth of plant, extend the planting time, and improve the yield and quality of crop[5]. In recent years, with the rapid development of greenhouse farming, the soil problems caused by high-intensity production in greenhouse have become more and more serious. The soil nutrient imbalance, soil hardening, acidification, secondary salinization and monocropping obstacle are caused by the perennial closed environment, single cultivation, blind application of large amounts of chemical fertilizer, unsuitable fertilizer types and so on in greenhouse. This has brought adverse influence to land resources and surrounding environment, and directly threatens the development of greenhouse farming[6,7]. Therefore, how to treat and utilize agricultural waste efficiently, and how to improve the soil environment in the greenhouse have become important problems for agricultural sustainable development in China.

Composting is a process where organic wastes are decomposed by microorganisms under aerobic conditions[8]. Previous studies have found that most agricultural waste contains lots of organic matter and nutrient elements such as nitrogen (N), phosphorus (P) and potassium (K). The application of agricultural waste compost has been recognized as one of the most promising approaches for preserving soil quality and crop production[9,10]. Cattle manure (CM) and corn straw (CS) are common agricultural wastes. Das et al. reported that CM compost amendment significantly increased soil pH, nutrient availability, microbial biomass, aboveground plant biomass and grain yield in a submerged rice paddy[11]. Zhang et al. found that CS compost could effectively improve soil organic matter and structure and enhance soil fertility[12]. Liu et al. concluded that CS has higher C/N ratio, its compost would take N from the soil when applied into soil, resulting in “N starvation” and poor crop growth. CM has lower C/N ratio, when its compost applied into soil, the microbial propagation would be inhibited due to lack of energy, resulting in slow and incomplete decomposition of compost, which also is adverse to the crop growth. Therefore it is considered that neither CM nor CS is suitable for composting alone[13]. Zhao et al. and Xu et al. found that co composting of CM and CS could shorten the maturity time and increase the yield and quality of compost[14,15]. However, at present it is not very clear what proportion of CM and CS composting is the best for soil fertility and plant productivity. The experiment was conducted to study the effects of different volume ratios of CM and CS compost on soil nutrients content, cucumber growth and yield in

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greenhouse. The aim is to determine the optimum composting ratio of CM and CS, thus providing reference for improving greenhouse cucumber cultivation technology and utilization efficiency of agricultural waste.

II. MATERIALS AND METHODS

The experiment was performed in Dongyang Comprehensive Experimental Base at Yuci, Shanxi Province, China (112°40′33″E, 37°30′10″N) from October 2018 to August 2019. The columnless greenhouse is a steel frame with a span of 8.4 m, a length of 60 m and a ridge height of 3.2 m. The soil is mild sandy loam, pH 8.46, organic matter content 20.94 g/kg, total N content 1.43 g/kg, total P content 0.79 g/kg, total K content 26.10 g/kg, alkali-hydrolyzable N content 70.81 mg/kg, available P content 34.47 mg/kg and available P content 271.98 mg/kg. The tested cucumber variety is “Jinwang 607”, which was purchased from Tianjin Chaoyan Seedling Technology Co., Ltd. They were sent to the miniature high-quality seedling base of Shanxi Jinzhong Honglinyuan Agricultural Technology Co., Ltd. for seedling cultivation on March 8, 2019, and grafted on March 30. The selected rootstock varieties were the excellent Hesheng No.3 pumpkin seedlings provided by Qingdao Jinma Agricultural Science and Technology Co., Ltd. CM and CS were purchased from Dongyang Comprehensive Experimental Base.

2.1 Experimental Design

In October 2018, the prepared CM and crushed CS were fully and evenly mixed in different volume proportions for composting. The artificial pile-turning was used to ventilate and supply oxygen every three days, and the maturity time was 65 days. After maturity, all ratios fertilizers were wrapped in plastic sheet and store in a cool place for later use.

A randomized block design was used with 8 treatments and 3 replicates. The area of each plot was 10 m^2. With no base fertilizer as control, 7 ratios compost were used as 7 fertilizer treatments. The amount and proportion of CM and CS in different treatments were shown in Table I. Each treatment fertilizer was applied as base fertilizer at one time when the plot was divided, and 0.24 m^3 was applied in each plot. The different plots were separated by double-layer plastic sheet with buried depth of 1 m.

On April 25, when cultured to one leaf and one bud, cucumber plantlets of uniform height were selected and transplanted according to 4 rows per plot, 13 plants per row and 52 plants per plot. On July 31, when most of cucumber plants under all treatments died, the experiment ended. Soil moisture was maintained at 70% - 90% of field capacity by drip irrigation under

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mulch during cucumber growth period. Other management measures were carried out according to the conventional greenhouse cucumber cultivation methods.

2.2 Measure Index

2.2.1 Determination of yield traits of cucumber

Five plants selected randomly from each plot were labeled for yield traits determination. Plot yield and fruit number were recorded at each harvest, and the yield and fruit number per treatment were calculated. Then the yield and fruit number per unit area were calculated according to the planting density. Use electronic balance to weigh, use ruler and vernier caliper to measure the length and diameter of fruit.

TABLE I. Amount and ratio of CM and CS in different compost treatments

TREATMENTS	CM (m^3)	CS (m^3)	VOLUME RATIO
CK	0	0	0
T1	0	0.72	0:6
T2	0.12	0.60	1:5
T3	0.24	0.48	2:4
T4	0.36	0.36	3:3
T5	0.48	0.24	4:2
T6	0.60	0.12	5:1
T7	0.72	0	6:0

2.2.2 Determination of growth indexes of cucumber

On the 50, 60, 70, 81 and 96 days after transplanting, 8 plants were randomly selected from each treatment and divided into stems and leaves. Fresh weight was measured by electronic balance after washing and drying. Leaf area was determined by leaf area scanner. Then the stems and leaves were placed in the oven at 105°C for 15 min, and dried at 80°C until constant weight for measuring dry weight and NPK content. The total N content was determined by Kjeldahl nitrogen analyzer. The total P content was determined by molybdenum antimony colorimetric method. The total K content was determined by flame photometric method. Aboveground biomass is the sum of dry weight of leaves and stems of cucumber plants.

2.2.3 Determination of soil indicators

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After cucumber seedlings pulled, the surface soil samples of 0 - 15 cm were taken using the five-point cross method in each plot. After natural air drying, the soil samples were crushed and mixed by a grinder for index determination. Soil pH was determined by pH meter (1/5 soil-water ratio, w/v), salt content was determined by drying method, organic matter content was determined by potassium dichromate method, total N content was determined by Kjeldahl nitrogen analyzer, alkali-hydrolyzable N content was determined by alkali-hydrolysis diffusion method, total P content and available P content were determined by molybdenum antimony colorimetric method, total K content and available K content were determined by flame photometric method.

2.3 Statistical Analysis

Use Microsoft Excel 2010 software for data processing and graphics rendering. SPSS Statistics 22 software was used for variance analysis and Duncan significance test ($P < 0.05$).

III. RESULTS

3.1 Effects of Different Ratios Compost on Soil Properties in Greenhouse

Soil pH is the basic chemical property of soil, which has great influence on soil fertility and crop growth. Table II showed that different ratios compost had different effects on soil pH value. The value among eight treatments was T4 > T5 > T3 > T2 > CK > T1 > T6 > T7. Compared with CK, T4, T5, T3 and T2 treatments significantly increased soil pH, among which T4 and T5 treatments increased the most. T1, T6 and T7 treatments reduced soil pH, and T7 treatment decreased the most. It indicated that under different proportions compost treatment, CM and CS composting with ratios of 3:3 and 4:2 had the best effect on improving soil pH value, which would reduce the risk of soil acidification.

Soil salinity is the percentage of soil salt quality in dry soil quality. Too high or too low of its value is not conducive to the normal growth and development of crops. Table II showed that among all treatments, soil salinity was the highest under T7 treatment (0.44%) and the lowest under T4 and T5 treatment (0.10%). The value was T7 > T6 > T1 > T2 > CK > T3 > T4 = T5, indicating that compared with CK, the four treatments of T7, T6, T1 and T2 increased soil salt content, while the three treatments of T3, T4 and T5 decreased soil salt content by 16.7% – 44.4%. It suggested that in different treatments, high ratio of CM or CS in compost would lead to the increase of soil salinity, thereby increasing the possibility of soil salinization and was not conducive to the improvement of soil fertility. When CM and CS were composted at the ratio

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of 3:3 or 4:2, the soil salinity would be decreased and the risk of salinization would be reduced.

Soil organic matter content and NPK content are important indicators of soil fertility and soil quality. Compared with CK, the seven treatments from T1 to T7 significantly increased the contents of soil organic matter, total N and alkali-hydrolyzable N, and showed a trend of increasing first and then decreasing. Among them, the contents of organic matter, total N and alkali-hydrolyzable N under T5 treatment were the highest, which were 30.89 g/kg, 1.96 g/kg and 92.23 mg/kg, respectively, and were 52.3%, 41.0% and 131.3% higher than those under CK. The results showed that the application of different proportions of CM and CS compost would increase the contents of organic matter, total N and alkali-hydrolyzable N in soil. T5 treatment, that is CM and CS composted with a ratio of 4:2, had the best effect. Compared with CK, different proportions of compost also significantly increased the contents of total P, total K, available P and available K in the soil. With the increase of the proportion of CM in compost, the contents of total P, total K, available P and available K showed an upward trend.

TABLE II. Effects of different treatments on soil properties in greenhouse

TREATMENTS	PH	SOIL SALT CONTENT (%)	ORGANIC MATTER (g/kg)	TOTAL N (g/kg)	TOTAL P (g/kg)	TOTAL K (g/kg)	ALKALI-HYDROLYZED N (mg/kg)	AVAILABLE P (mg/kg)	AVAILABLE K (mg/kg)
CK	8.77c	0.18e	20.28g	1.39e	0.71d	22.31d	39.87e	37.67g	275.17e
T1	8.70d	0.21c	21.89f	1.45e	0.83c	23.97c	66.05d	46.60ef	337.11e
T2	8.87b	0.19d	22.25f	1.54d	0.81c	24.35bc	69.02cd	44.97f	329.13e
T3	8.88b	0.15f	22.91e	1.52d	0.83c	24.53bc	72.0bcd	53.02e	471.61d
T4	9.00a	0.10g	28.91b	1.89b	0.87b	25.65ab	76.16b	65.66d	504.04cd
T5	8.96a	0.10g	30.89a	1.96a	0.88b	26.15a	92.23a	96.23c	600.00c
T6	8.69d	0.30b	24.52d	1.71c	0.86b	25.06abc	69.02cd	103.71b	710.58b
T7	8.35e	0.44a	26.65c	1.53d	0.92a	26.38a	74.97bc	165.16a	863.96a

Notes: The different lowercase letters in a column indicate significant differences among treatments at $P<0.05$.

3.2 Effects of Different Ratios Compost on Cucumber Growth in Greenhouse

Leaf is an important place for plant photosynthesis. Leaf area index and leaf number per

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plant directly affect plant photosynthesis area, thereby affecting plant growth. Fig 1 and 2 showed that, the leaf area index and leaf number per plant of cucumber under all treatments decreased first and then increased. The decrease was mainly due to the vine pruning on the 59 days after transplanting, which removed a large number of leaves. After 81 days, the growth trend of leaf area index and leaf number under different treatments slowed down, and some treatments showed a downward trend. Among eight treatments, the leaf area index and leaf number per plant of the seven treatments from T1 to T7 were significantly higher than those of CK, indicating that the application of different ratios compost would improve the leaf area index and leaf number per plant, thereby increasing the photosynthetic area of plants. The leaf area index and leaf number per plant under T5 treatment were always the highest, suggesting that T5 treatment had the best effect on plant photosynthetic area increase, and the plant would maintain this larger photosynthetic area for a longer time.

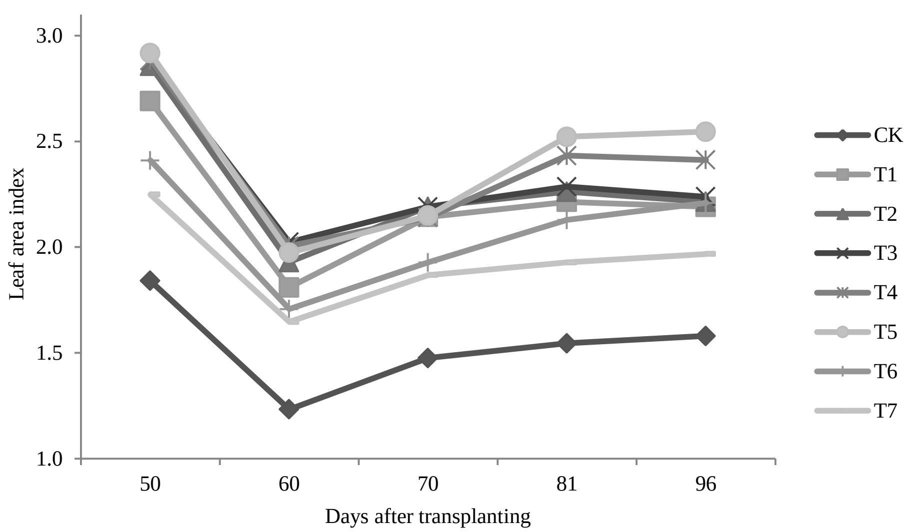

Fig 1: leaf area index of cucumber plants under different treatments and transplanting days

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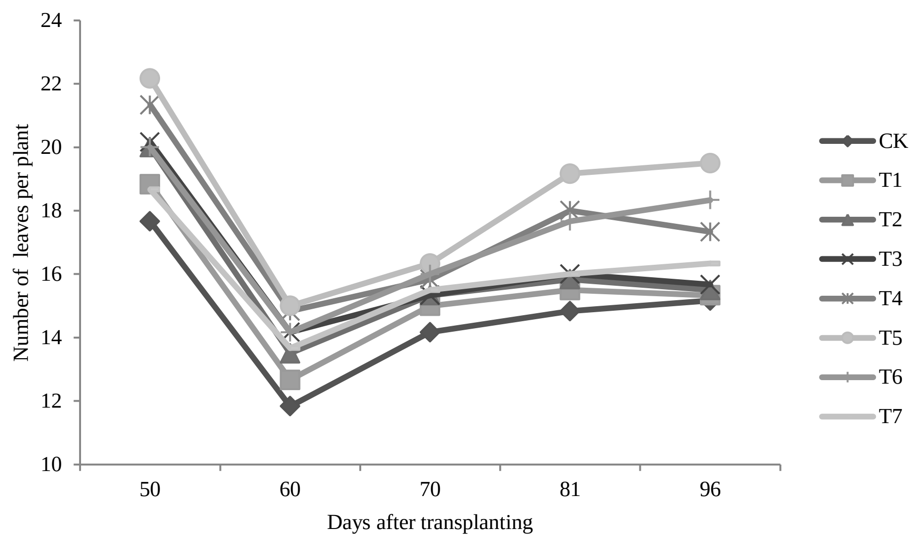

Fig 2: number of leaves per plant of cucumber under different treatments and different transplanting days

N is an important part of chlorophyll. The N content in leaves directly affects the chlorophyll content, thus affecting the photosynthetic rate. It also affects leaf life, and then affects photosynthesis time. From Fig 3, it can be seen that the N content in cucumber leaves under different treatments showed a trend of increasing first and then decreasing with the increase of days after transplanting. This indicated that N was mainly accumulated in leaves before 70 days after transplanting, and then gradually transferred to fruit after 70 days. In all treatments, the leaf N content under CK treatment was the lowest, and that under T4 and T5 treatments were higher. This suggested that the application of different ratios compost could increase the N content in leaves, thereby increasing the photosynthetic rate of plants and prolonging the photosynthetic time, among which T4 and T5 treatments had better effects. P is an indispensable element in the formation of nuclear protein and lecithin, which could accelerate cell division and promote growth of roots and shoots. K could increase the intensity of photosynthesis, promote formation of sugar, and enhance plant stress resistance and disease resistance. As can be seen from Fig 4 and 5, the contents of P and K in cucumber leaves under all treatments also showed a trend of increasing at first and then decreasing. The P content began to decrease at about 81 days after transplanting, and the K content decreased at about 70 days after transplanting, which was consistent with the change trend of N content. It indicated that N and K in leaves were transferred to fruits before P. Among eight treatments, the P and K contents in leaves under CK treatment were the lowest, while those under T5 and T7 treatments were relatively higher. The results suggested that T5 and T7 treatments were more beneficial to

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plant uptake of P and K.

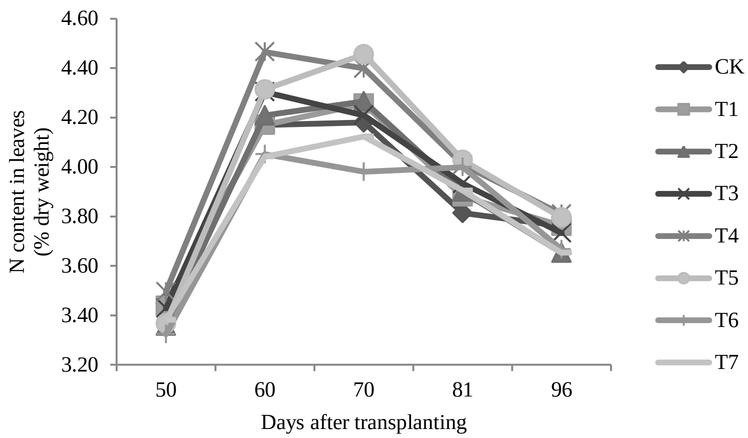

Fig 3: N content in cucumber leaves under different treatments and different transplanting days

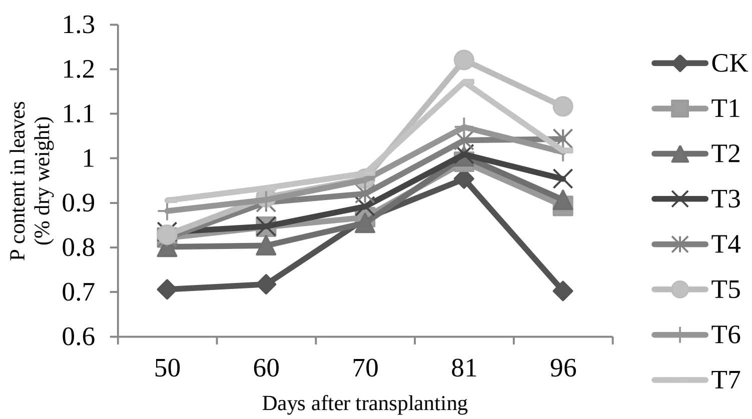

Fig 4: P content in cucumber leaves under different treatments and different transplanting days

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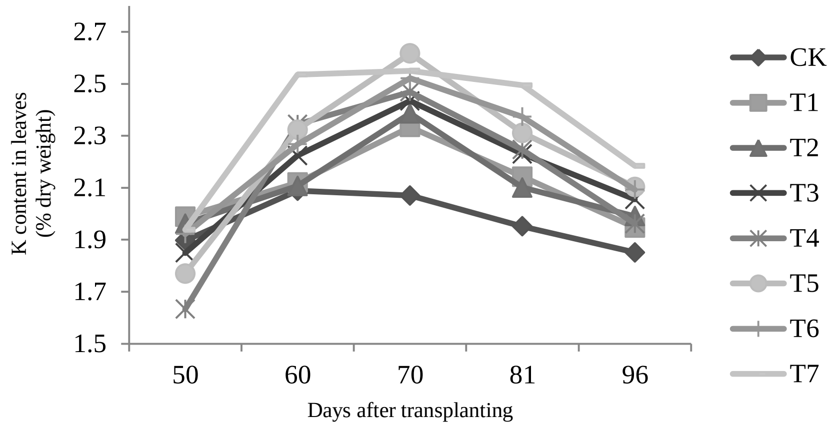

Fig 5: K content in cucumber leaves under different treatments and different transplanting days

Aboveground biomass is an important parameter reflecting plant growth. As can be seen from Fig 6, regardless of the effect of vine pruning on all cucumber plants, the plant aboveground biomass under T1 to T7 treatments showed a slow growth trend, while there was no obvious change under CK treatment. It may be due to that after cucumber began to bear fruit, the organic matter synthesized by photosynthesis were more transferred to the fruit, so the growth of plant aboveground part slowed down. The organic matter under CK treatment almost all transferred to the fruit, so the aboveground biomass changed little. In all treatments, the plant aboveground biomass under T5 treatment remained the highest during the fruiting period, indicating that cucumber plants under T5 treatment grew best and accumulated more dry matter. This trend was consistent with the results of Fig 1-5.

3.3 Effects of Different Ratios Compost on Cucumber Yield Traits in Greenhouse

Fig 7 showed that cucumber fruit number under eight treatments was significantly different. The number under T5 treatment was the most, followed by T4 treatment. There was no significant difference between it under T2, T3, T6 and T7. Under CK treatment the number was the least. It indicated that the application of different ratios compost would significantly increase the number of cucumber fruits, and the improvement of T5 treatment was the best. There was no significant difference in fruit length and diameter under different treatments, suggesting that different compost had no significant effect on fruit length and diameter (Fig 8).

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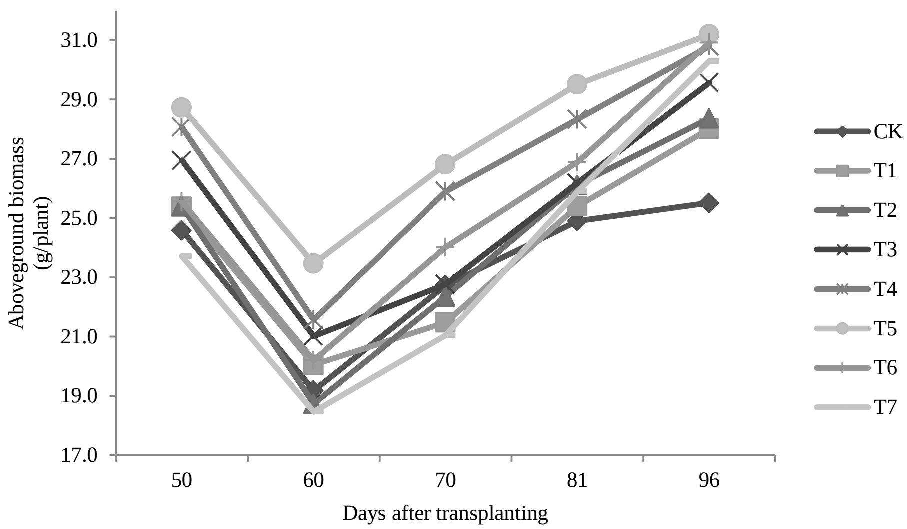

Fig 6: aboveground biomass of cucumber plants under different treatments and transplanting days

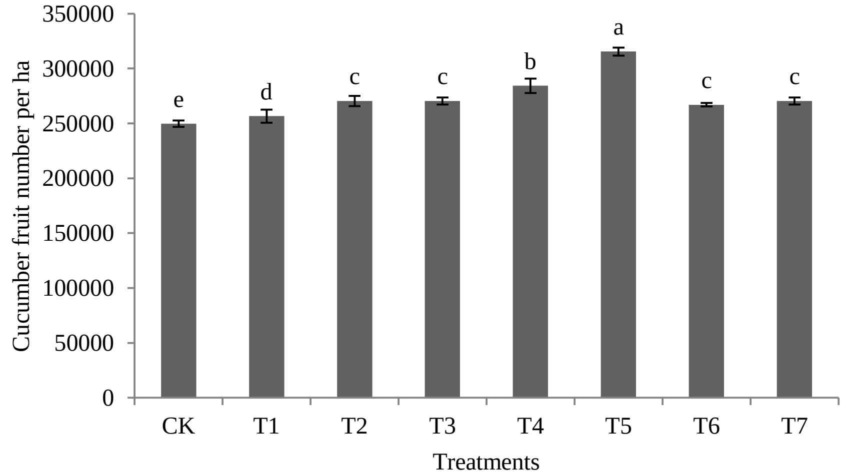

Fig 7: effects of different treatments on the number of cucumber fruit

The effect of different ratios compost on cucumber yield was significant. Fig 9A showed that the yield was T5 > T4 > T3 > T2 > T6 > T1 > T7 > CK. Under T5 treatment, the yield was the highest, which was 52213 kg/ha, and it increased by 51.8% compared with CK treatment. With the increase of days after transplanting, the yield under different treatments showed a decreasing trend, but it under T5 treatment remained at a higher level in different periods (Fig

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9B).

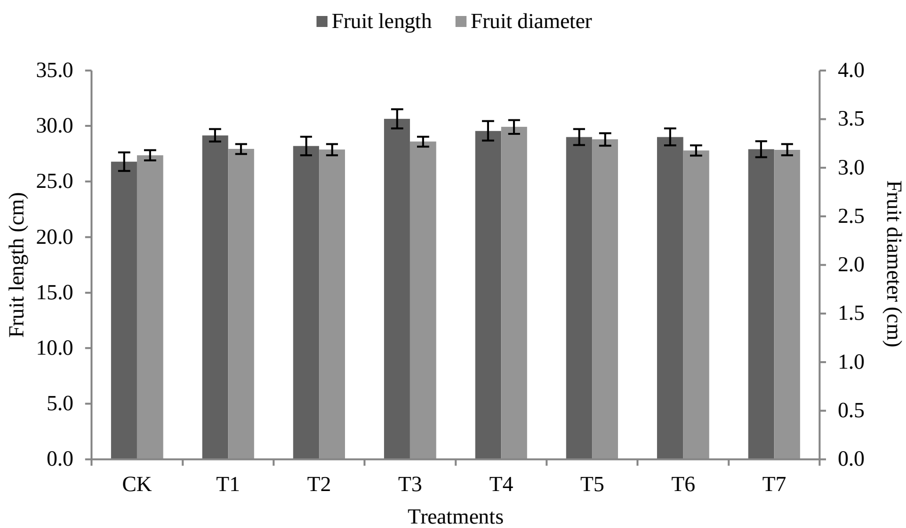
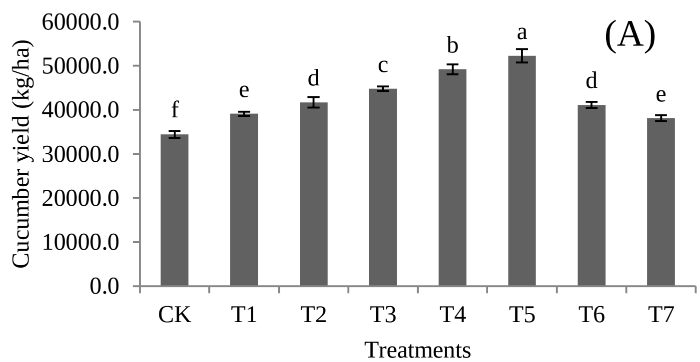


Fig 8: effects of different treatments on the length and diameter of cucumber fruit



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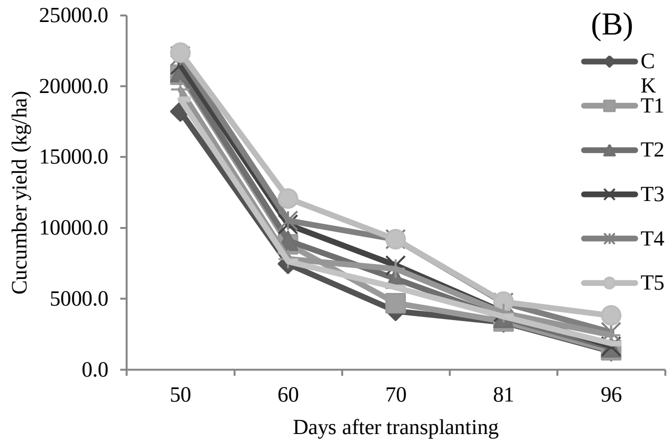

Fig 9: effect of different treatments on the cucumber total yield (A) and yield change with days after transplanting (B)

IV. DISCUSSION AND CONCLUSION

Cucumber is one of the main crops in greenhouse vegetable cultivation, which requires high soil quality. It is very important to improve cucumber rhizosphere environment for its growth and yield. Previous studies have found that organic fertilizer application in greenhouse could increase soil pH, decrease salt accumulation, avoid soil acidification, slow soil salinization, improve soil fertility and increase vegetable yield[16,17]. The results of this experiment were almost consistent with these studies, but there were differences in the effects of different proportions compost. In this experiment, the application of 4:2 ratio of CM and CS compost had the best effect on the increase of soil pH and the decrease of salt content. With the increase of the proportion of CM or CS in the compost, the soil pH decreased and the salt accumulation increased gradually. This may be because with the increase in the amount of CM or CS, the minerals brought in increased and then soil salt content increased. 7 ratios compost significantly increased the contents of organic matter, total N, total P, total K, alkali-hydrolyzed N, available P and available K. Among them, the effect of 4:2 composting of CM and CS was the best. This may be because this ratio is conducive to the promotion of compost maturity, so inorganic matter would be transformed into organic matter more efficiency, thereby facilitating crop absorption.

Under different treatments, cucumber growth and yield were significantly different. Among seven ratios compost treatment, cucumber leaf area index, leaf number, leaf N content and aboveground biomass were significantly higher than the control, indicating that the application of compost could improve the efficiency of photosynthesis rate, area and time, thereby plants could accumulate more organic matter to transferred to fruit. The cucumber yield and fruit number under compost treatments were significantly higher than those under control, and there was no significant difference in fruit length and diameter, indicating that the increase of yield was mainly achieved by increasing fruit number rather than increasing the single fruit length or fruit diameter. Compared with other treatments, plant yield under CM and CS 4:2 compost was the highest, which was mainly due to that this ratio would best improve plant photosynthetic rate, increase photosynthetic area, prolong leaf life, increase photosynthetic time, so as to accumulate more organic matter, more fruit, and then obtain the highest yield.

In summary, the application of different proportions of CM and CS compost could improve soil environment, increase soil fertility, and promote the growth and yield of greenhouse cucumber. The application of compost at 4:2 ratios had the best effect on yield increase, mainly because it would increase soil pH, reduce salt content, increase the nutrient content, increase the absorption of nutrient elements by plant, promote photosynthesis ability, accumulate more organic matter, and increase the number of fruits. However, the test results are greatly affected by soil fertilizer and water content in greenhouse. In the future, different facility environments need to be selected for further research.

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