Co-composting of Chinese milk vetch with rice straw and using the compost as a peat substitute of seeding substrate of vegetables

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Abstract: Chinese milk vetch (*Astragalussinicus* L.) is an environment-friendly green manure used for rice with low carbon/nitrogen (C/N) ratio and high moisture. To improve the added values of milk vetch, the feasibility of co-composting of milk vetch with rice straw was evaluated. The probability of using the milk vetch-based compost as a peat substitute in seeding substrate of vegetable was further tested. The changes in physicochemical properties during co-composting of milk vetch and rice straw were evaluated, depending on three treatments: (1) milk vetch alone (MV), (2) co-composting of milk vetch and rice straws with 4:1 ration (w/w) (MV+S) and (3) MV+S with the addition of 3% (w/w) microbial inoculation (MV+S+M). The entire composting durations were 15 d, 24 d, and 24 d in MV, MV+S, MV+S+M composts. Compare to MV compost, both the MV+S, MV+S+M composts increased the temperature, pH, organic C, total nitrogen (N), total potassium (K) and the germination index (GI) (over 100) during the cooling/mature phase, and decreased total N loss, and generally, the improvements or reductions were greater in the MV+S+M compost than in the MV+S compost. Additionally, the MV+S+M compost was added at a peat substitute rates of 0%, 20%, 40%, 80% and 100% in a pot experiment to testify the utilization of milk vetch-based compost in substrates. The results showed that the substrate with 40% substitute rate increased the cabbage seeding growth, and that the electrical conductivity was the limiting factor of preventing the substitute rate increase. Another pot experiment demonstrated that the substrate with 40% peat substitute increased the cucumber growth as compared to the substrate without compost. In conclusion, the co-composting milk vetch with rice straw was feasible and quick, and microbial inoculation accelerated the composting process and improved the compost quality. The milk vetch-based composts were nutrient-rich and safe, and thus, can replace part of peat in vegetable seeding substrate.

Keywords: Chinese milk vetch (*Astragalussinicus* L.), compost, peat, seeding substrate
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1 Introduction

Chinese milk vetch (MV, *Astragalussinicus* L.), an nitrogen-fixing leguminous plants with high biomass (2.25-3.75 t/hm^2), is considered as the most popular green manure in rice fields of China, Japan and Korea[1,2]. Usually, milk vetch is sown in late autumn and harvested in the next spring, and then incorporated into the soil before the early or middle rice cultivation. ,Milk vetch not only increases the rice yields, but also improves soil physicochemical properties and some biological characteristics[3,4]. Besides, milk vetch increases carbon (C) sequestration[5], minimizes the greenhouse gases emission[2],and can be also used as forage and even the source of honey[6] .

To date, animal manure is the most widely used raw material for aerobic composting. Similar to animal manure, milk vetch is nitrogen (N)-rich material with lower carbon/nitrogen (C/N) ration and higher moisture and nutrition[2,7]. Moreover, milk vetch is more environment-friendly, as compared with animal manure, because it almost contains no heavy metals, pathogens, odor, antibiotic residues and weed seeds. Therefore, milk vetch can be a potentially excellent raw material for composting.

Many factors affect the composting process, such as C/N ration, pH, particle size, porosity, moisture and the management practices that control O_2 concentration, temperature and water content[7]. Microbial inoculates, such as effective microorganisms (EMs), play an important role in composting management. A majority of investigators believed that microbial inoculates can accelerate composting process, increase the nutrient and reduce the pathogen in compost[8,9]. However, other scientists argued that it is unnecessary to add the allochthonous microorganisms because the autochthonous microorganisms are adequate in compost[9,10]. Thus, the effects of adding microorganisms to composting process need to be further evaluated. In this study, we investigated the effects of microbial inoculates on composting process and compost quality.

Peat is used extensively for seeding substrates in vegetation production. However, as a natural, non-renewable resource, its utilization would be limited[11]. Since composts have the physicochemical properties similar to those of peat[12], many composts have been used peat as the substitutes in the recent years. These compost products are generated generally based on

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agricultural and/or industrial wastes, such as animal manure composts[13], green waste composts[11,14], and municipal solid waste- and sewage sludge-based composts[15]. However, to our knowledge, there have been no reports about use of the milk vetch-based composts as a component to replace part of peat in vegetation production.

Milk vetch, as a high quality N source, had been incorporated into the soil and they can improve the soil fertility. However, this way of utilizing them has low economic benefit. Aerobic co-composting of milk vetch with other C-rich materials, such as crop straw, could extend the green manure industry chain, and improve the economic value of milk vetch. The objectives of this study were to: (1) evaluate the feasibility of co-composting of milk vetch with rice straw; (2) to examine the function of microbial inoculates during milk vetch composting process; and (3) to search the optimum proportion of using milk vetch-based compost as a peat substitute of seeding substrate of vegetables.

2 Materials and methods

2.1 Co-composting of Chinese milk vetch with rice straw experiment

2.1.1 Materials

Milk vetch and rice straws were collected from the fields of Chibi city of Hubei province, China, and used as the raw materials for composting. Their characteristics were listed in Table 1. Prior to composting, the fresh milk vetches were hand-squeezed 5 cm and air dried to about 80% moisture content. Rice straws were squeezed mechanically below 1 cm and dried to below 15% moisture content. The powdery microbial inoculates were obtained from the Institute of Plant Protection and Soil Fertilizer, Hubei Academy of Agricultural Sciences, Wuhan, Hubei, China, which included *bacillus subtilis*, *candida tropicalis*, *aspergillusoryzae* and *trichodermaviride*, and the efficacious living-cells exceed 0.5×10^9 cfu/g.

Table 1 Characteristics of Chinese milk vetch and rice straw

Materials	pH	Moisture /%	Organic C /g·kg^{-1}	Total N /g·kg^{-1}	Total P /g·kg^{-1}	Total K /g·kg^{-1}	C/N ratio
Chinese milk vetch	8.4	81.2	483.1	22.9	8.0	31.0	21.1
Rice straw	8.2	12.0	551.0	5.4	1.5	25.3	102.5

Note: C, carbon; N, nitrogen; P, phosphorus; K, potassium.

2.1.2 Experimental procedure

Three treatments with 3 replicates were conducted: (1) composting milk vetch alone (MV); (2) co-composting of milk vetch and rice straws with 4:1(w/w) (MV + S); and (3) MV + S with the addition of 3% (w/w) microbial inoculates (MV + S + M). The fermentation vessel was nine plastic buckets whose height, bottom diameter and bung diameter were 70 cm, 42 cm and 52 cm respectively. The composting process lasted from 16 April 2016 to 10 May 2016, where day 0 was16 April, 2016. All of the composts were turned firstly at day 1, and then turned manually every two days to maintain an adequate O_2 level and the homogeneity of the materials.

2.1.3 Compost analysis

The core temperature of composts was monitored every 1 h within the first 12 h of each feedstock at the depth of 30 cm, with a thermometer by hand. Subsequently, the temperature was measured daily at 9:00 and 16:00, and the mean value was taken as the daily temperature. The ambient temperature was recorded with the same method.

Samples of composts were collected at days 1, 4, 8, 12, 16, 20 and 24, respectively, randomly, from 5 points at the around 30 cm depth. After being mixed homogenously, the pH, organic carbon (C), total nitrogen (N) and phosphorus (P) and potassium (K) were measured as described previously by Bao[16]. The pH of compost samples was detected with a pH meter in a 1:2.5 (w/v) water-soluble extract. Organic C was measured by the dichromate redox titration method. The contents of total N, P and K were determined by Nesslercolorimetry, vanadim-molybdate-yellow colorimetry and flame photomete, digested with H_2SO_4-H_2O_2. Loss of organic matter and total N was calculated as follows: organic matter or total N loss (% of initial) = (initial organic matter or total N - final organic matter or total N)/(initial organic matter or total N) ×100[17].

Germination index (GI) was obtained as described by Li and Peng[10]. The mixture of compost and distilled water (1:10, w/v) was fully oscillated, and then centrifuged for 20 min at 3000 r/min. The supernatant fraction was collected as the compost extract. Five milliliter of the compost extract or 100% deionized water (as the control) was added into a petri dish (diameter 9 cm) with double-layer filter papers laid previously. Ten seeds of cucumber (*Cucumissativus* L.) were spread on the filter paper. All the petri dishes were placed in a climate chamber with controlled conditions (22℃) for 48 h. The percentage of germinated seeds and root length were recorded. The GI was calculated as follows: GI (%) = (A1 ×A2)/(B1 ×B2) ×100%, where A1 and A2 were the percentage and the average root length of germinated seeds of the treatments, B1 and B2 were the percentages of germinated seeds and the average root length of the Control. The GIs of day 24 samples were measured with triplicates.

2.2 Pot experiment 1

Two pot experiments were performed at the greenhouse of Hubei Academy of Agricultural Sciences, Wuhan, Hubei, China. The first experiment was conducted to select suitable proportions of the milk vetch-based compost as peat substitution. The substrates consisted of MV + S + M compost, vermiculite and peat, and their characteristics were presented in Table 2. The vermiculite always account for 30% (v/v) of substrate, and the rest was the mixture of peat and composts at different peat substitute ratios of 0%, 20%, 40%, 60%, 80%, and 100% (v/v). Thirty five (35) seeds of cabbage (*Brassica campestris* L.) were sown in a pot with the height of 9.5 cm and bung diameter of 11 cm. Each treatment included six pots, and one pot was regarded as a replicate. The pots were regularly irrigated and managed.

The selected physicochemical properties, including pH, total N, total P, total K, bulk density, total porosity (TP), water-holding porosity(WHC) and electrical conductivity (EC) were measured. The pH, total N, total P, total K were measured with the same methods used in the samples of composts. The bulk density, TP, WHC and EC were evaluated according to trade standard of plug seeding substrate of vegetables (NY/T 2118-2012)[18] in China. Bulk density was determined by dividing the oven-dried weight of each substrate by its bulk volume (100 mL). To measure the growing media TP and WHC, 100 cm^3 of each substrate was saturated with water for 24 h and placed in a funnel to monitor the changes in water content (water content per unit of medium, w:w). Then the TP and WHC were calculated according to the method described in NY/T 2118-2012[18]. EC was measured using an EC meter (substrate: distilled water ratio of 1:10). The germination rate and above-ground biomass were measured at the 7th and 14th day after sowing, respectively.

Table 2 Characteristics of materials used as seeding substrates

Materials	pH	Moisture /%	OM /g·kg^{-1}	Total N /g·kg^{-1}	Total P /g·kg^{-1}	Total K /g·kg^{-1}	Bulk density /g·cm^{-3}	Electrical conductivity /ms·cm^{-1}
Peat	4.8	31.8	530	10.9	11.3	25	0.26	0.59
Vermiculite	6.7	25.7	21	0.4	6.7	168	0.30	0.13
MV+S+M Compost	8.7	30.0	722	23.5	7.7	41	N. D.	N. D.

Note: OM, organic matter; N, nitrogen; P, phosphorus; K, potassium; MV+S+M Compost, the compost that was made from Chinese milk vetch, rice straws and microbial inoculation; N.D., not determined.

2.3 Pot experiment 2

The pot experiment 2 was conducted to validate the effect of the substrate selected from pot experiment 1 on vegetable seeding growth. A peat-vermiculite mix (peat/vermiculite = 7:3, v/v) was used as Control. Cucumber (*Cucumissativus Linn*) seeds were sown in polystyrene plug trays (32 cells per tray) with the selected substrate and Control, respectively. Each treatment included 4 trays, and one tray was regarded as a replicate. Prior to sowing, the seeds were soaked for 6 hours with water. Five days after sowing, the germination rate of cucumber was measured. Fifteen days after sowing, the seedling height, length and width of leaves and above-ground biomass were measured.

2.4 Statistical analysis

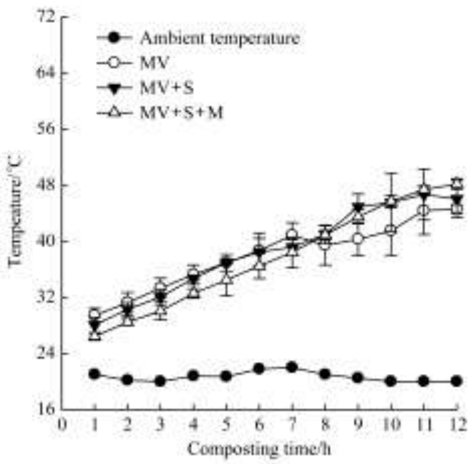
One-way analysis of variance (ANVOA) were used to compare the differences of the physicochemical parameters, organic C and total N loss and GI among MV, MV+S and MV+S+M composts, and of the selected characteristics of substrates with different peat substitution rates as well as the cabbage growth rate in pot experiment 1. The Duncan's multiple comparison was performed to compare the means. A *t*-test was used to compare the differences in cucumber seeding growth rate between selected substrate and the Control in pot experiment 2. For data that did not satisfy the assumption of equal variance, $\lg(x+1)$, square root transformation or $1/x$ was used prior to analysis. If the data were still not homogenous, Tamhane's T2 multiple comparison was used. All the statistical analyses were conducted with SPSS 11.5 (SPSS Inc., Chicago, IL) and the significant level is $p<0.05$.

3 Results and discussion

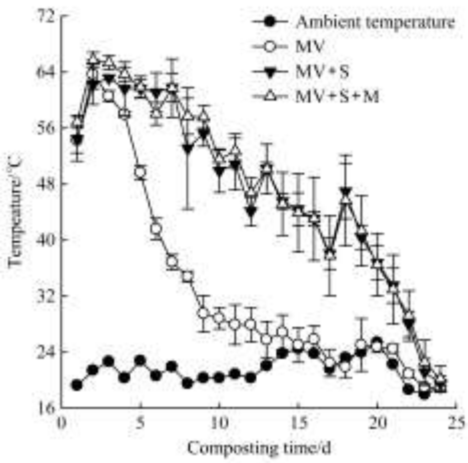
3.1 Changes in physicochemical properties during co-composting of milk vetch and rice straw

3.1.1 Changes in temperature

Generally, the compost process can be categorized in the typical temperature-related compost phases, i.e. mesophilic (up to 40°C), thermophilic (over 40°C) and cooling/maturation phase (up to 40°C)[19]. Temperatures profile of the three composts followed the typical pattern (Figure 1). During the mesophilic phase, the temperatures of the three composts increased sharply upto 40°C within 7 hours(Figure 1a), which was much faster than animal manures compost[7] and sewage sludge compost[20] that generally lasting for 1-3 d and approximate 10 d, respectively. The rapid rise in temperature might be due to milk vetch, which has more hemi-cellulose and labile C[10] for bacterial decomposition as compared to animal manure and sewage sludge. In addition, the temperatures during mesophilic phase were ranked in the order of MV > MV + S > MV + S + M, which was opposite to the general rule[7,21]. The reason might be due to the allochthonous straw and inoculate that did not stimulate the bacterial decomposition in such a short time. With the development of fermentation process, the temperatures were ranked in the order of MV+S+M>MV+S> MV (Figure 1b) during thermophilic and cooling/maturation phases, indicating that the co-composting increases the microbial activity and the improvements are greater with the addition of microbial inoculate. The entire composting durations were 15 d, 24 d, and 24 d in MV, MV+S, MV+S+M composts, which were shorter than those of animal manures and sledge composts[7,20]. The result referred the composting process based on milk vetch was quietly quick. Besides, the composting time was much shorter in the MV compost than in the other two composts. This observation maybe brought out by the labile nature of carbon in MV compost.



a. Temperature change within the first 12 h



b. Temperature change within 24 d

Note: MV, composting milk vetch alone; MV + S, co-composting of milk vetch and rice straws; MV + S + M, co-composting of milk vetch and rice straws with the addition of microbial inoculates.

Figure 1 Changes in temperature within the first 12 h and 24 d during composting

3.1.2 Changes in pH, organic C, C/N ration, and nutrients

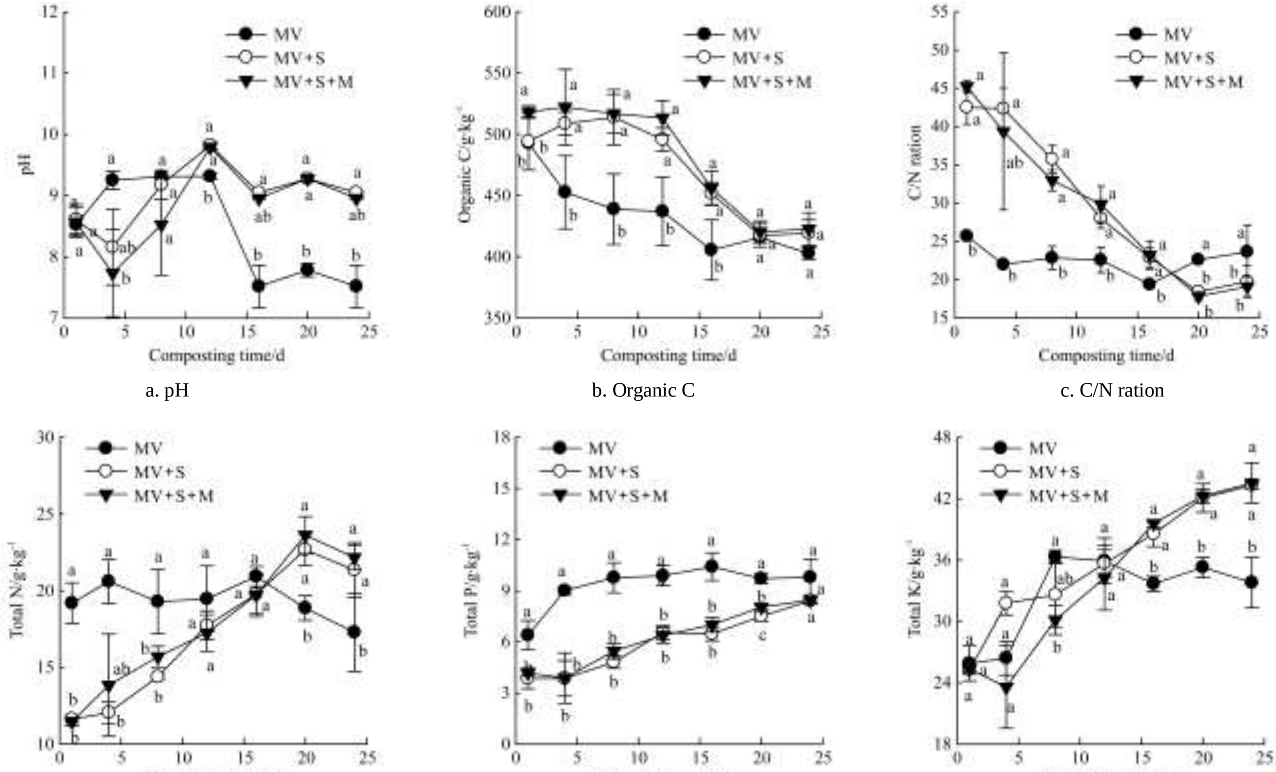
Since the composting process in the MV compost was not synchronized with those of MV+ S and MV + S + M composts, the changes in pH, organic C, C/N ration, and nutrients were different between the MV compost and other two composts (Figure 2). The pH in MV compost increased rapidly in the initial 4 days, and then tended to be stable at 9.25-9.32 from the 4th to 12th day, and finally stabled at 7.52-7.78 from the 16th to 24th day (Figure 2a). The pH values in MV+S and MV+S+M composts reached the lowest at the 4th day, and then increased fast and reached the peak values at the 12th day (max pH = 9.79 in MV + S compost and max pH=9.82 in MV+S+M compost). Finally, the pH value became stable at 9.28-8.96, which were higher than that of MV compost. The pH variation profiles of declining, rising and stabilizing in MV + S and MV + S + M compost were similar to that of co-composting of sewage sludge with food waste[20], possibly due to the changes in acidic type compounds, such as small molecular organic acid[21] and the mineralization of N-containing materials, such as proteins, amino acids and peptides[20]. In addition, the pH value was lower in the MV+S compost than in the MV+S+M compost over the entire composting process, reflecting that the microbial inoculate may accelerate the mineralization of N-containing materials. Similar results were observed by Jusoh et al[22].

Organic C of the three composts were detected to decrease gradually during the composting process (Figure 2b), which agreed with the review of Bernal et al.[7] The organic C was ranked in the order of MV+S+M > MV+S > MV, which might be due to the reason that rice straw brings a lot of C and the microbial inoculate increases the humus process.

C/N ratio in MV compost fluctuated within the range of 19.7-25.7 during composting (Figure 2c). This observation was not consistent with the general C/N ratio variation which decline gradually below 20[7]. This may be due to the reason that the initial C/N ration of MV compost was low and just within the adequate C/N ratio range of 25-35[7]. The C/N ratio in MV+S and MV+S+M composts dropped gradually and down to below 20, indicating that the compost are matured[7]. The C/N ration was lower slightly in MV+S+M compost than in the MV+S compost, which was similar to the effect of EM[22].

The concentration of total N in the three composts increased at the thermophilic phase and then decreased at the cooling/maturation phase (Figure 2d). This observation did not agree with the general observation that total N will increase as the dry mass losses[7], this might be due to the high level of pH value, which was over 7.5 during the thermophilic and cooling/maturation phase and promoted the NH_3-volatilisation. The final total N contents in MV+S and MV+S+M composts exceeded the level of MV compost, indicating that co-composting increases the compost quality. Microbial inoculate increased the concentration of total N, which was similar to the effects of EM[22,23], possibly due to the increase in the microbial biomass N[22].

Total P contents in the MV+S and MV+S+M composts increased gradually (Figure 2e) and agreed with the general observation that the concentration of mineral elements increases as the dry weight losses of the material during composting[9]. Among the three composts, the total P contents were ranked in the order of MV > MV+S+M > MV+S, possibly due to the reason that more P in the soluble organic matter[22] was leached in the MV+S + M and MV+S composts than in the MV compost. Microbial inoculate increased the concentration of total P, the same with the effect of inoculate on total N, probably attributable to the reason that inoculate increases the microbial biomass P. The decrease after 12d sampling in MV treatment was due to the available P in the soluble organic matter will be leached more and more as time goes during the cooling/mature stage.



a. pH b. Organic C c. C/N ration

d. Total N e. Total P f. Total K

Note: MV, composting milk vetch alone; MV + S, co-composting of milk vetch and rice straws; MV + S + M, co-composting of milk vetch and rice straws with the addition of microbial inoculation.

Figure 2 Changes in physicochemical parameters during composting

Similar to total P content, total K contents in the MV+S and MV+S+M composts increased gradually during the composting time (Figure 2f). The total K content in the MV + S + M compost was lower than that of MV + S compost during the thermophilic phase, and then gradually caught up and even exceeded the level of MV + S compost., probably due to the reason that the inoculate uses the K during the later period of composting. Similar results were reported by Jusoh et al.[22]. The change trend of total K in the MV treatment were similar to that of total P.

The nutrient content (the sum of total N, total P and total K) of final MV, MV+S, MV+S+M compost were 60.9 g/kg, 73.1 g/kg, and 74.2 g/kg, respectively, which exceeded the China Trade Standard (5%) of Organic Fertilizer (NY525-2012)[24]. Therefore, the three composts had good fertility.

3.1.3 Organic matter and total N loss

No significant differences in organic matter loss were observed among the three composts (Table 3) and the organic matter losses in MV, MV+S, and MV+S+M composts were 56.1%, 59.7%, and 58.7% , respectively, which were within the range of 40%-70% as reported previously in other studies[17,25,26]. The total N losses in MV, MV+S, MV+S+M composts were 57.2%, 24.4% and 21.4%, which also were within the range of 19%-60% observed in other previous reports[17,25,26]. Co-composing of milk vetch and rice straw decreased significantly the N loss. This effect might be resulted from the initial higher C/N ration of MV+S, MV+S+M composts[7]. Microbial inoculate decreased the N loss, probably due to the reason that microorganisms increase the N immobilization and/or reduce the NH_3 volatilization[27]. EM caused the similar effects on N loss[27].

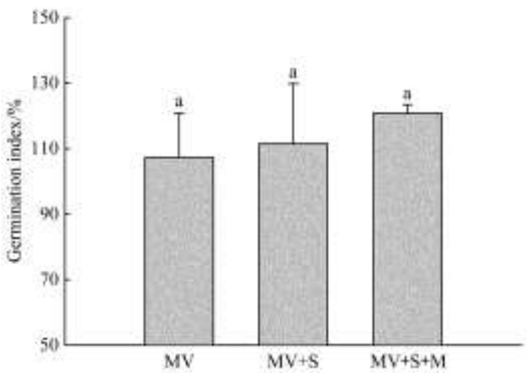
Table 3 Effects of different composts on the loss of organic matter and total nitrogen

Treatments	Samples of day 0			Samples of day 24			OM loss /% of initial OM	Total N Loss /% of initial total N
	Weight/kg	OM/%	Total N/%	Weight/kg	OM/%	Total N/%		
MV	5.7±0.2 b	83.3	2.3	3.0±0.1 b	69.4±0.8 a	1.7±0.3 b	56.1±0.5 a	57.2±0.6 a
MV+S	9.9±0.5 a	89.3	1.4	4.9±0.2 a	72.3±1.9 a	2.1±0.2 a	59.7±4.4 a	24.4±4.9 b
MV+S+M	9.8±0.6 a	89.3	1.4	4.9±0.3 a	72.9±2.3 a	2.2±0.1 a	58.7±4.7 a	21.4±10.1 b

Note: OM, organic matter; N, nitrogen; P, phosphorus; K, potassium. MV + S, co-composting of milk vetch and rice straws; MV + S + M, co-composting of milk vetch and rice straws with the addition of microbial inoculation. Values within a column followed by different letters are significantly different at $p<0.05$. No analysis of variance for OM and total N in the sampling of day 0.

3.1.4 Germination index

The GI indicates the phytotoxicity of composts to plants[28], and its value over 85% means no phytotoxicity[10]. Figure 3 showed the GI values of the three composts were over 100% during the cooling/maturation, signaling no phytotoxicity problem in the three composts. The GI values in this study were higher than those of composts using animal manures and vegetable wastes[7,24,28], due to the reason that milk vetch and rice straw have fewer pathogens, antibiotics and heavy metals than animal manures and vegetables do. Although the GI values among the three composts were not significantly different, a trend of MV+S+M > MV + S > MV was obviously observed. This means microbial inoculate improved the safety of compost, which agreed with the review of Ab Muttalib[8].



Note: MV, composting milk vetch alone; MV + S, co-composting of milk vetch and rice straws; MV + S + M, co-composting of milk vetch and rice straws with the addition of microbial inoculates.

Figure 3 Effects of different composts on germination index of day 24 sampling

3.2 Characteristics of substrates with different peat substitution rates and the effects of substrates on cabbage seeding growth

The selected physicochemical characteristics of substrates were listed in Table 4. The pH, total N, P and K of each substrate increased gradually as the peat substitution rate increased, particularly the pH exceeded the optimal range of 5.5-7.5[29] when the substitute rate reached 100%. There were no significant difference in organic matter among six substrates, due to the organic matter contents of peat and CMV+S+M compost were similar (Table 2). In addition, the organic matter contents of studied substrates were near the ideal range (over 350 g/kg)[29]. Similar result was observed in bulk density. TP and WHC decreased gradually as the peat substitution rate increased from 20% to 100%, and their values were within the accepted range[29]. EC is a limiting factor for substrates[15]. In the present study, EC increased linearly within the substitute rate range of 20%-100%, and exceeded the accepted range[30] when the substitute rate was over 60%, referring that the utilization of milk vetch-based composts for peat substitution should be restricted to a certain extent.

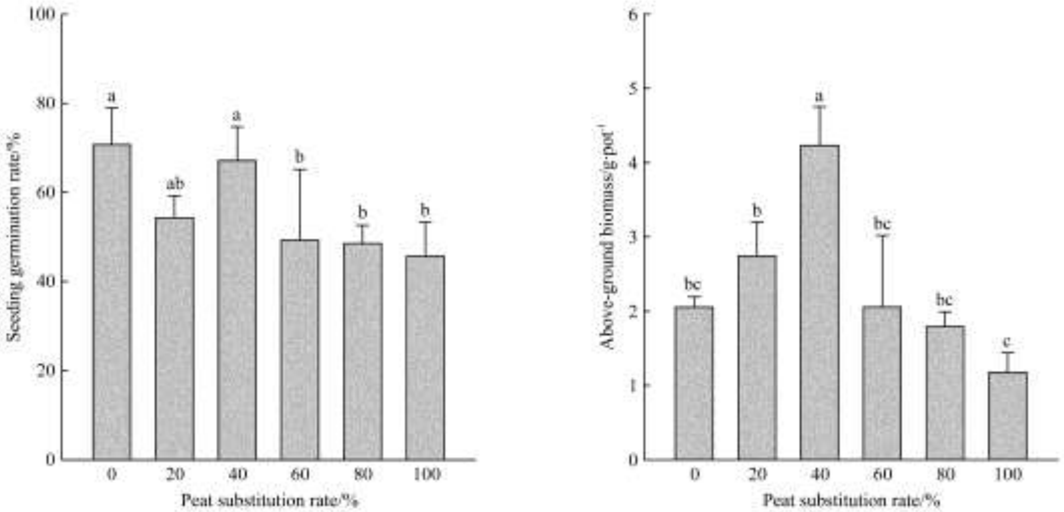
The highest cabbage germination rate (70.7%) was found in peat-based substrate (0% peat substitute), followed by substrate with 40% substitution rate (Figure 4a). Within the range of 40%-100% substitution rate, the germination rates were significantly lower than that of peat-based substrate, and the reduction increased as substitution rate increased. The above-ground biomass of cabbage was significantly higher in the substrate with 40% substitution rate than in the peat-based substrate, and decreased as substitution rate increased with the range of 40%-100% (Figure 4b).

The characteristics of substrates and the effects of substrates on cabbage seeding growth indicated that the highest peat substitution rate was 40%. Other investigators obtained similar results. For instance, Ostos et al.[15] found that the sewage sludge-based compost could replace 40% peat; Tian et al.[29] found that the mushroom residue- and garden waste-based composts could replace 50% peat.

Table 4 Characteristics of the selected substrates with different peat substitution rates

Peat substitution rate/%	pH	OM /g·kg^{-1}	Total N /g·kg^{-1}	Total P /g·kg^{-1}	Total K /g·kg^{-1}	Bulk density /g·cm^{-3}	Total porosity /%	Water-holding porosity/%	Electrical conductivity /mS·cm^{-1}
0	4.4±0.2 f	368±29.8 a	6.1±0.4 f	8.6±1.3 d	77±0.0 e	0.26±(< 0.01) e	64.4±2.9 a	54.1±0.9 a	1.00±0.03 f
20	5.6±0.2 e	371±14.4 a	7.0±0.3 e	10.0±0.8 cd	91±2.5 d	0.34±(< 0.01) a	59.2±0.4 b	49.9±0.9 b	0.83±0.06 e
40	6.5±0.0 d	361±6.6 a	8.9±0.0 d	13.4±1.0 c	114±3.8 c	0.30±(< 0.01) b	63.2±3.6 ab	52.7±0.5 ab	1.26±0.04 d
60	7.1±0.1 c	353±4.4 a	9.5±0.4 c	21.1±1.0 b	119±3.8 c	0.27±(< 0.01) c	60.4±1.1 ab	51.0±1.0 ab	1.73±0.11 c
80	7.6±0.2 b	349±2.1 a	12.1±0.5 b	26.2±4.6 a	146±1.7 b	0.27±(< 0.01) cd	60.9±1.5 ab	50.8±2.7 ab	2.24±0.06 b
100	8.4±0.1 a	345±4.8 a	13.2±0.1 a	28.5±1.9 a	173±4.4 a	0.26±(< 0.01) d	61.1±1.7 ab	50.7±0.1 b	2.69±0.06 a
Accepted range	5.5-7.5[29]	>350[29]				0.20-0.60[29]	>60[29]	>45[29]	0.75-1.99[30]

Note: OM, organic matter; N, nitrogen; P, phosphorus; K, potassium. Values within a column followed by different letters are significantly different at p<0.05.



a. Seeding germination rate

b. Above-ground biomass

Figure 4 Effects of substrates with different peat substitution rates on cabbage seeding germination index and above-ground biomass

3.3 Effects of selected substrates on cucumber growth

The results from the pot experiment 1 indicated that CMV+S+M compost could replace 40% peat. Table 4 showed that the selected substrates significantly increased the cucumber growth, due to the content of nutrients in the selected substrate, which was significantly higher than in the substrate without CMV+S+M compost (Table 5). The effects of milk vetch-based compost on crop growth were similar to those of substrates based on cattle manure compost[13], spent mushroom compost[11], municipal solid waste- and sewage sludge-based composts[15].

Table 5 Effects of selected substrates on cucumber seeding growth

Substrate	Seeding germination rate/%	Plant height /cm	Leaf length /cm	Leaf width /cm	Above-ground biomass /g·plant^{-1}
Control	85.2±10.3	6.3±0.4	4.1±0.1	4.7±0.2	0.9±0.1
Selected substrate	87.5±9.2	9.1±0.6	6.7±0.4	7.7±0.5	2.1±0.2
Significance	NS	*	*	*	*

Note: NS means no significant and the asterisk means significant at p<0.05.

4 Conclusions

The present study showed that milk vetch, as an N-rich material, could be easily composted alone or with rice straw, and that the co-composting had more composting time and nutrients, and lower C/N ration and less N loss. Microbial inoculate accelerated the composting process and improved the compost quality. All milk vetch-based composts were safe because the raw materials are harmless. The utilization of milk vetch-based composts for peat substitution can be a useful procedure to obtain suitable substrates for vegetable, and the optimal peat substitute rate was found to be 40%. EC limited the increase of peat substitute rate.

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