Effects of microbial organic fertilizer on glycoalkaloid content and yield of *Solanum procumbens* Lour.

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ABSTRACT

Solanum procumbens Lour. is a traditional medicinal plant known for its rich glycoalkaloid content. This research aimed to determine the suitable types and application rates of microbial organic fertilizers to enhance yield and glycoalkaloid content in *Solanum procumbens* Lour. A two-factor experiment was conducted using a Split-Plot Design (SPD) with three replications. The main plots included four types of microbial organic fertilizers (HD301, HD302, Komix-BL2, and HCMK7), while the sub-plots involved three application rates (2, 4, and 6 tonnes/ha per crop). Various parameters were measured, including fresh and dry biomass per plant, fresh and dry yield per ha, glycoalkaloid content, and glycoalkaloid yield across two cropping cycles. The results indicated that applying HCMK7 at a rate of 6 tonnes/ha per crop produced the highest outcomes: in the initial crop, a fresh weight of 255.2 g and dry weight of 111.1 g per plant, fresh yield of 15.77 tonnes/ha, dry yield of 6.99 tonnes/ha, glycoalkaloid content of 0.70%, and glycoalkaloid yield of 48.97 kg/ha. In the ratoon crop, the same application rate yielded a fresh weight of 282.5 g and dry weight of 134.6 g/plant, fresh yield of 17.62 tonnes/ha, dry yield of 9.21 tonnes/ha, glycoalkaloid content of 0.76%, and glycoalkaloid yield of 70.39 kg/ha. The highest average glycoalkaloid content (0.73%) and total glycoalkaloid yield (119.36 kg/ha) across both crops were also recorded at this application rate.

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1. Introduction

Solanum procumbens Lour. is a traditional medicinal plant in Vietnam, known for its rich content of glycoalkaloids and other secondary metabolites, including cholesterol, β-sitosterol, lanosterol, dihydrolanosterol, and solasodine, which offer various health benefits. This plant has been shown to have properties that prevent cirrhosis, reduce inflammation, and protect the liver (Nguyen, 2002; Huynh et al., 2021). *Solanum procumbens* Lour. thrives in areas with adequate sunlight (Do, 2004), making the Southeast of Southern Vietnam an ideal region for its cultivation, where it also shows an increase in glycoalkaloid content.

In agricultural production, chemical fertilizers are commonly used due to their ability to quickly increase productivity at a low cost. However, the use of chemical fertilizers in long term can lead to imbalances soil pH, reduced bacterial diversity and major changes in the composition of the bacterial population (Wu et al., 2020). On the other hand, microbial organic fertilizers improve soil fertility by increasing humus and organic matter content, and by optimizing the function of soil microbial populations (Zhu et al., 2021). For grey degraded soils, which have lower clay and organic matter content, microbial organic fertilizers should be added to improve soil fertility and physical properties. Research has shown that microbial organic fertilizers can increase herb yield, seed weight, and essential oil content in medicinal plants, while also enhancing their resistance to diseases and pests (Wang et al., 2019; Huang et al., 2022). Furthermore, these fertilizers have been demonstrated to boost the synthesis and accumulation of active secondary metabolites such as organic acids, saponins, alkaloids, sesquiterpenes, and lactones (Waqas et al., 2015). Therefore, the application of microbial organic fertilizers could positively impact the yield and glycoalkaloid content of *Solanum procumbens* Lour.

2. Materials and Methods

2.1. Materials

Solanum procumbens Lour. seeds (sample code QN9) were collected from Duc Pho district, Quang Ngai province, Vietnam, and subsequently planted at the Agronomy Research Station of Nong Lam University, Ho Chi Minh City, Vietnam. The seeds were sown in a nursery using a growth medium composed of 60% grey soil, 29% cow manure, 1% superphosphate, and 10% rice husk ash, and were allowed to grow for 60 days. Once the seedlings reached a height of 5 - 6 cm, developed 5 - 6 leaves, and were observed to be free of diseases and pests, they were transplanted into the field.

The microbial organic fertilizers used in this experiment were as follows:

HD301: Containing 0.5% nitrogen, 0.5% P_2O_5, 0.5% K_2O, 15% organic matter, and *Trichoderma* sp. at a density of 1.2 x 10^6 CFU/g.

HD302: Containing 1% nitrogen, 1% P_2O_5, 1% K_2O, ≥ 15% organic matter, and *Hirsutella* sp. at a density of 10^6 CFU/g.

Komix-BL2: Containing 1% nitrogen, 3% P_2O_5, 1% K_2O, 1% Mg, 100 ppm Zn, 200 ppm Mn, 16% organic matter, 30% humidity, and phosphate-solubilizing microorganisms at a density of ≥ 1 x 10^6 CFU/g.

HCMK7: Containing 18% organic matter, 2% nitrogen, 2% P_2O_5, 1% K_2O, trace elements (CaO, MgO, B, Cu, Zn), and *Trichoderma* sp. at a density of 10^6 CFU/g.

Solasodine: made by Chengdu Biopurify Phytochemicals Ltd.

2.2. Experiment design

A two-factor experiment was conducted using a Split-Plot Design (SPD) with three replications. The main plots were assigned four types of microbial organic fertilizers (HD301, HD302, Komix-BL2, HCMK 7), while the subplots consisted of three fertilizer doses (2 tonnes/ha per crop, 4 tonnes/ha per crop, and 6 tonnes/ha per crop). The experiment was carried out over two cropping cycles, with the same fertilizer doses applied in both cycles. *Solanum procumbens* Lour. planted at a spacing of 40 cm × 30 cm, resulting in a plant density of 83,333 plants/ha. Each treatment was applied to a plot size of 9.0 m² (6.0 m × 1.5 m). Microbial organic fertilizers were applied 3 days before planting for the initial crop and 7 days after harvesting for the initial crop.

The experiment was conducted at Agronomy Research Station in Nong Lam University, Ho Chi Minh City, Vietnam from June 2021 to March 2022

Solanum procumbens Lour. were transplanted during the rainy season in 2021, a period favorable for the growth and development of the plant. However, the high rainfall during the harvesting period posed challenges for drying the fresh herbs. The ratoon crop was cultivated during the sunny season, from November 2021 to March 2022. During this period, irrigation was necessary to support the plants' growth, reproduction, and fruiting.

The data in Table 1 showed that cultivated soil was a silty clay, moderately acidic, low organic matter and total nitrogen but high total phophorus and potassium (Rayment & Lyons, 2011). Available P_2O_5 and K_2O were low.

Table 1. Physical and chemical properties of the experimental soil

Texture (%)			pH_{KCl}	Organic matter (%)	Total N (%)	Total P_2O_5 (%)	Total K_2O (%)
Clay	Silt	Sand					
36.98	12.88	50.14	5.78	0.81	0.065	0.059	0.058

Source: Research Institute for Biotechnology and Environment, Nong Lam University (2021).

2.3. Data collection and statistical analysis

Fresh herb weight (g/plant): The fresh weight of the herb was measured as the average stems, leaves, flowers and fruits of 5 target plants at 135 days after transplantation for the initial crop and 124 days after cutting for the ratoon crop.

Dried herb weight (g): The dried weight of the herb (g/plant) was calculated the average stems, leaves, flowers and fruits of 5 target plants after drying at 70°C until weight stability was achieved.

Actual fresh yield (tonnes/ha): This was calculated using the formula: Actual fresh yield (tonnes/ha) = The fresh herb weight of each base plot (kg) x 10^{-3} × 10,000]/Area of the base plot (m²).

Actual dry yield (tonnes/ha): This was calculated at 8% herb moisture content using the formula: Actual dry yield (tonnes/ha) = The dry herb weight of each base plot (kg) x 10^{-3} × 10,000]/ Area of the base plot (m²) (was calculated at the moisture content of herbs 8%).

For the analysis of th glycoalkaloid content of *Solanum procumbens*: 2 g herbal powder in each treatment was extracted with 50 mL methanol-acetic acid solution 5% in 3 h. Filtering and drying residue at 50°C. Dissolving residue with methanol, filtering and transfering to a 10 mL graduated cylinder, adding methanol in enough to make 10 mL of solution. This was test solution.

Table 2. Chemicals and amount of chemicals in samples

Reagents	Standard sample	Test sampsle	White sample
Buffer solution pH8	5.0	5.0	5.0
Bromothymol blue solution 2%	0.5	0.5	0.5
Standard solasodine solution (0.5 mg/mL)	0.5	0.0	0.0
Test solution	0.0	0.5	0.0
Methanol	0.0	0.0	0.5
Chloroform	10.0	10.0	10.0

To shake for 5 min

To transfer chloroform into other tube after 30 min

To shake chloroform with 10 mL NaOH 0.05 N solution

To transfer blue solution into other tube after 30 min

To measure the absorbance of blue solution at a wavelength of 616 nm

Glycoalkaloid content was calculated using the following formula:

X (%) = [DT x 50]/[Dc x a x (100 - A]

Where:

Dc: absorbance value of the standard sample at a wavelength of 616 nm

DT: absorbance value of the test sample at a wavelength of 616 nm

a: dried herb weight

A: Herb moisture content (Nguyen & Pham, 2000)

Glycoalkaloid yield (kg/ha): This was calculated using the formula:

The glycoalkaloid yield (kg/ha) = Actual harvested dried yield (tonnes/ha) x glycoalkaloid content (%)] x 1000/100

The total glycoalkaloid yield (kg/ha) was calculated as the sum of the glycoalkaloid yields from both the initial crop and the ratoon crop.

Economic analysis:

+ Total cost (VND/ha per crop): This was calculated by summing general costs (seeds, labor, other materials) and microbial organic fertilizer costs.

+ Production cost (VND/kg glycoalkaloid): This was calculated using the formula:Production cost (VND/kg glycoalkaloid) = The glycoalkaloid yield (kg/ha)/Total cost (VND/ha per crop)

Data analysis: Data were analyzed using DSAASTAT software. Differences between treatments were tested using Duncan's Multiple Range Test at a significance level of 0.05 or 0.01.

3. Results and Discussion

3.1. Effect of microbial organic fertilizers on yield components, herb yield, glycoalkaloid content, and glycoalkaloid yield of *Solanum procumbens* Lour.

The types of microbial organic fertilizers applied had a statistically significant effect on the fresh herb (Table 3). When HCMK7 was used in the initial crop, the fresh herb weight of *Solanum procumbens* was highest, showing a statistically significant difference compared to the fresh herb weight when HD301 and HD302 ($P < 0.01$) applications. In the ratoon crop, the differences in fresh herb weight between treatments were not statistically significant ($P > 0.05$).

Regarding the amount of microbial organic fertilizer applied, both cropping cycles showed that applying 6 tonnes/ ha per crop resulted in a statistically significantly higher fresh herb weight compared to the 2 and 4 tonnes/ha per crop treatments ($P < 0.01$). The HCMK7 fertilizer, which contains 2% nitrogen, positively impacted the growth of *Solanum procumbens* Lour. and enhanced fresh herb weight. This finding aligns with results from Pham et al. (2019) and Le et al. (2020), who reported that the fresh herb weight of *Solanum procumbens* Lour. was highest with the application of 250 kg N/ha per year or 125 kg N/ha per crop. It is also consistent with Hoang et al. (2016), who observed increased fresh herb weight in *Solanum procumbens* Lour. with the application of 250 kg N + 200 kg P_2O_5 + 150 kg K_2O compared to other fertilizer rates.

Significant differences in dried herb weight were also observed between treatments in both the initial and ratoon crops. The highest dried herb weight was noted with HCMK7 application in the initial crop ($P < 0.05$), while higher dried herb weights were found with Komix-BL2 and HCMK7 application in the ratoon crop ($P < 0.05$). Additionally, the highest dried herb weight was achieved with the highest dose of microbial organic fertilizer (6 tonnes/ha per crop, $P < 0.01$).

The microbial organic fertilizers contain organic matter, N, P_2O_5, K_2O, and effective microorganisms. These fertilizers supply essential nutrients and beneficial microorganisms that enhance soil health and crop growth (Wei et al., 2024). Therefore, applying microbial organic fertilizers with higher nutrient content and in larger amounts increased the fresh and dried herb weight of *Solanum procumbens* Lour.

Data in Table 4 showed that the actual fresh yields in both the initial and ratoon crops were significantly influenced by the amounts of microbial organic fertilizers applied, with statistically significant differences observed. The highest actual fresh yields were obtained with the application of 6 tonnes/ha per crop, reaching 13.88 tonnes/ha in the initial crop and 16.48 tonnes/ha in the ratoon crop. The differences in the effects of the types of microbial organic fertilizers on actual fresh yield in the ratoon crop were not statistically significant. Both the type and amount of microbial organic fertilizers applied had a significant impact on the actual dry yield in both cropping cycles. The highest actual dry yield was achieved with the application of HCMK7 fertilizer, yielding 5.98 tonnes/ha in the initial crop and 7.72 tonnes/ha in the ratoon crop. Significant differences in actual dry yield were also observed across different fertilizer application rates. The application of 6 tonnes/ha per crop resulted in the highest actual dry yield, with 6.06 tonnes/ha in the initial crop and 8.27 tonnes/ha in the ratoon crop, both of which were statistically significant ($P < 0.01$). In contrast, the application of 2 and 4 tonnes/ha per crop resulted in lower actual dry yields in both crops

Table 3. Effect of types and amounts of microbial organic fertilizers application on fresh herb weight (g/plant) of *Solanum procumbens* Lour.

Parameters	Dose (tonnes/ha) (L)	Types of microbial organic fertilizers (P)				Average (L)
		HD301	HD302	Komix-BL2	HCMK7	
Fresh herb weight (g/plant) in initial crop	2	170.1	187.9	200.3	202.3	190.2^{c}
	4	180.9	201.5	226.7	233.8	210.7^{b}
	6	199.2	211.1	249.9	255.2	228.8^{a}
	Average (P)	183.4^{c}	200.2^{bc}	225.7^{ab}	230.4^{a}	
	CV (%) = 6.91; F_P =18.22**; F_L = 21.32**; F_{P*L} = 0.84^{ns}					
Fresh herb weight (g/plant) in ratoon crops	2	185.5	162.8	162.5	189.4	175.0^{c}
	4	205.0	189.8	225.0	232.5	213.1^{b}
	6	242.0	238.7	247.3	282.5	252.6^{a}
	Average (P)	210.8	197.1	211.6	234.8	
	CV (%) = 6.00; F_P =4.62^{ns}; F_L = 110.12**; F_{P*L} = 2.37^{ns}					
Dried herb weight (g/plant) in plant crop	2	70.3	79.0	77.6	85.3	78.1^{c}
	4	81.4	84.0	95.1	90.7	87.8^{b}
	6	86.7	90.3	108.7	111.1	99.2^{a}
	Average (P)	79.4^{b}	84.4^{ab}	93.8^{ab}	95.7^{a}	
	CV (%) = 7.73; F_P = 9.81**; F_L = 28.80**; F_{P*L} = 1.75^{ns}					
Dried herb weight (g/plant) in ratoon crop	2	79.3	67.2	75.4	91.5	78.3^{c}
	4	90.6	84.1	101.7	109.3	96.4^{b}
	6	104.0	114.8	114.2	134.6	116.9^{a}
	Average (P)	91.3^{b}	88.7^{b}	97.1^{ab}	111.8^{a}	
	CV (%) = 8.52; F_P = 10.76**; F_L = 65.10**; F_{P*L} = 1.58^{ns}					

*Values within the same group followed by the same letters are not significantly different at P ≤ 0.05 according to the Duncan's multiple range test; * and ** are significantly different at the 5% and 1% levels, respectively.*

Table 4. Effect of types and amounts of microbial organic fertilizers application on actual herb yield (tonnes/ha) of *Solanum procumbens* Lour.

Parameters	Dose (tonnes/ha) (L)	Types of microbial organic fertilizers (P)				Avesrage (L)
		HD301	HD302	Komix-BL2	HCMK7	
Actual fresh yield (tonnes/ha) in initial crop	2	9.89	10.56	11.83	11.82	11.03^{c}
	4	10.35	11.93	13.48	14.29	12.51^{b}
	6	11.79	12.94	15.06	15.73	13.88^{a}
	Average (P)	10.68^{c}	11.81^{bc}	13.46^{ab}	13.95^{a}	
	CV (%) = 7.70; F_P = 16.34**; F_L = 26.52**; F_{P*L} = 0.84^{nss}					
Actual fresh yield (tonnes/ha) in ratoon crop	2	11.48	11.09	11.84	12.95	11.84^{c}
	4	12.95	12.83	15.03	14.69	13.88^{b}
	6	15.49	15.84	16.97	17.62	16.48^{a}
	Average (P)	13.31	13.25	14.62	15.09	
	CV (%) = 4.68; FP = 4.49^{ns}; F_L = 149.93**; F_{P*L} = 1.23^{ns}					
Actual dry yield (tonnes/ha) in initial crop	2	4.11	4.87	5.05	5.07	4.78^{c}
	4	4.65	5.03	5.93	5.86	5.37^{b}
	6	5.30	5.67	6.28	6.99	6.06^{a}
	Average (P)	4.69^{c}	5.19^{bc}	5.75^{ab}	5.98^{a}	
	CV (%) = 7.30; F_P = 18.46**; F_L = 31.90**; F_{P*L} = 1.37^{ns}					
Actual dry yield (tonnes/ha) in ratoon crop	2	5.46	5.09	5.82	6.62	5.75^{c}
	4	6.09	6.19	7.21	7.33	6.70^{b}
	6	7.61	7.98	8.26	9.21	8.27^{a}
	Average (P)	6.39^{b}	6.42^{b}	7.0^{ab}	7.72^{a}	
	CV (%) = 4.56; F_P = 14.07**; F_L = 136.26**; F_{P*L} = 1.28^{ns}					

*Values within the same group followed by the same letters are not significantly different at P ≤ 0.05 according to the Duncan's multiple range test; * and ** are significantly different at the 5% and 1% levels, respectively.*

The experiment results demonstrated that the amounts of microbial organic fertilizers had a strong impact on the glycoalkaloid content in the plants. As the amount of microbial organic fertilizer increased, the glycoalkaloid content also improved. With a fertilizer rate of 6 tonnes/ha per crop, glycoalkaloid contents reached 0.70% and 0.72% in the initial and ratoon crops, respectively. These were statistically significant differences compared to the 4 tonnes/ha per crop and 2 tonnes/ha per crop application ($P < 0.05$ in initial crop and $P < 0.01$ in ratoon crop) . Regarding the effect of different types of microbial organic fertilizers, there were no statistically significant differences in glycoalkaloid content among the applications of HD301, HD302, Komix-BL2, and HCMK7 in the initial crop. However, the highest glycoalkaloid content (0.73%) was obtained with the application of HCMK7 in the ratoon crop (Table 5). The average glycoalkaloid content was influenced by the types and amounts of microbial organic fertilizers, as well as their interaction. Higher glycoalkaloid content was observed with increased microbial organic fertilizer application. The application of 6 tonnes/ha per crop significantly enhanced the glycoalkaloid content of *Solanum procumbens* Lour. In contrast, the average glycoalkaloid content was lower when HD301 fertilizer was applied. The application of 6 tonnes/ha per crop of HD302, Komix-BL2, and HCMK7 fertilizers resulted in higher average glycoalkaloid contents and showed significant differences compared to average glycoalkaloid contents in other treatments.

Table 5. Effect of types and amounts of microbial organic fertilizers application on glycoalkaloid content (%) of *Solanum procumbens* Lour.

Parameters	Dose (tonnes/ha) (L)	Types of microbial organic fertilizers (P)				Average (L)
		HD301	HD302	Komix-BL2	HCMK7	
Glycoalkaloid content (%) in initial crop	2	0.53	0.57	0.54	0.60	0.56^{c}
	4	0.56	0.61	0.72	0.66	0.64^{b}
	6	0.64	0.74	0.73	0.70	0.70^{a}
	Average (P)	0.58	0.64	0.67	0.65	
	CV (%) = 6.81; $F_P = 3.99^{ns}$; $F_L = 33.17^{*}$; $F_{P*L} = 2.38^{ns}$					
Glycoalkaloid content (%) in ratoon crop	2	0.61	0.60	0.64	0.68	0.63^{c}
	4	0.61	0.66	0.69	0.73	0.67^{b}
	6	0.69	0.70	0.72	0.76	0.72^{a}
	Average (P)	0.64^{B}	$0,65^{B}$	$0,68^{AB}$	0.73^{A}	
	CV (%) = 3.24; FP = 21.35^{**}; $F_L = 45.33^{**}$; $F_{P*L} = 1.61^{ns}$					
Average glycoalkaloid content (%)	2	0.57^{d}	0.58^{d}	0.59^{d}	$0.64c^{d}$	0.60^{c}
	4	0.58^{d}	0.64^{c}	0.70^{ab}	0.69^{ab}	0.65^{b}
	6	0.67^{bc}	0.72^{a}	0.73^{a}	0.73^{a}	0.71^{a}
	Average (P)	0.61^{b}	0.65^{ab}	0.67^{a}	0.69^{a}	
	CV (%) = 3.26; $F_P = 18.74^{*}$; $F_L = 85.83^{**}$; $F_{P*L} = 3.63^{*}$					

*Values within the same group followed by the same letters are not significantly different at P ≤ 0.05 according to the Duncan's multiple range test; * and ** are significantly different at the 5% and 1% levels, respectively.*

As shown in Table 6, among the four types of fertilizers, the lowest glycoalkaloid yield (27.30 kg/ha) was observed with the application of HD301, which had statistically significant differences compared to glycoalkaloid yield in treatments using Komix-BL2 (38.77 kg/ha) or HCMK7 (39.28 kg/ha) fertilizers, though the difference was not statistically significant when compared to glycoalkaloid yield when applied HD302 (33.51 kg/ha) in the initial crop. However, in the ratoon crop, HCMK7 produced the highest glycoalkaloid yield (56.37 kg/ha) compared to glycoalkaloid yield in other treatments. In both cropping cycles, the application of 6 tonnes/ha per crop resulted in the highest glycoalkaloid yield, with 47.25 kg/ha in the initial crop and 59.56 kg/ha in the ratoon crop. Conversely, the lowest glycoalkaloid yields were observed with the application of 2 tonnes/ha per crop of microbial organic fertilizer, at 26.89 kg/ha and 36.60 kg/ha, respectively.

The total glycoalkaloid yield reached its highest value with the application of 6 tonnes/ha per crop of microbial organic fertilizer, showing statistically significant differences compared to the lower rate applications ($P < 0.01$). While the application of Komix-BL2 and HCMK7 fertilizers clearly improved the glycoalkaloid yield of *Solanum procumbens*, the applications of HD301 and HD302 did not result in significant enhancement. The experiment also demonstrated that the application of HCMK7 fertilizer at 6 tonnes/ha per crop resulted in a total glycoalkaloid yield of 119.36 kg/ha across both the initial and ratoon crops, significantly higher than the yields achieved with other types and amounts of fertilizer.

The application of organic fertilizers had beneficial effects on crop growth and yield by improving the biological and physical properties of the soil (Zheljazkov & Warman, 2004). Organic fertilizers and microbial organic fertilizers have been proven to increase the yield of *Solanum procumbens* Lour. and other species in the *Solanum* genus (Nguyen et al., 2018; Nguyen & Ha, 2019). Additionally, the application of organic or microbial organic fertilizers has been reported to enhance secondary metabolite contents in the Solanaceae family. For instance, the use of organic fertilizers has been shown to increase polyphenols, phenols, flavonoids, t-ferulic acid, cyanidin, and caffeic acid contents in eggplants, tomatoes, and peppers (Faller & Fialho, 2010; Basay et al., 2021). The partial or complete replacement of chemical fertilizers with organic or microbial organic fertilizers has been observed to increase vitamin A, vitamin C, lipids, acidity, nitrogen, total sucrose content, brix, phenolics, and antioxidants in tomatoes (Oliveira et al., 2013; Dabire et al., 2016). In our study, the application of microbial organic fertilizers was confirmed to improve the yield and glycoalkaloid content of *Solanum procumbens*, and the experimental results are consistent with previous reports.

Economic efficiency analysis

The economic analysis revealed that the application of 6 tonnes/ha per crop of microbial organic fertilizer resulted in the highest total cost, whereas the applications at 4 and 2 tonnes/ha per crop were the least expensive (Table 7). Despite the higher total cost, the production cost per unit of glycoalkaloid yield was lowest with the 6 tonnes/ha per crop application, owning to the significant improvement in glycoalkaloid yield. Among the different fertilizers, HCMK7 achieved the lowest production cost compared to production cost wthen used of HD301, HD302, and Komix-BL2.

Table 6. Effect of types and amounts of microbial organic fertilizers application on glycoalkaloid yield (kg/ha) of *Solanum procumbens* Lour.

Parameters	Dose (tonnes/ha) (L)	Types of microbial organic fertilizers (P)				Average (L)
		HD301	HD302	Komix-BL2	HCMK7	
Glycoalkaloid yield (kg/ha) in initial crop	2	21.94	27.69	27.57	30.35	26.89^{c}
	4	25.99	30.87	42.64	38.52	34.51^{b}
	6	33.96	41.98	46.09	48.97	42.75^{a}
	Average (P)	27.30^{b}	33.51^{ab}	38.77^{a}	39.28^{a}	
	CV (%) = 10.88; F_P = 10.49**; F_L = 52.92**; F_{P*L} = 1.92^{ns}					
Glycoalkaloid yield (kg/ha) in ratoon crop	2	33.55	30.40	37.21	45.23	36.60^{c}
	4	37.17	41.00	49.46	53.50	45.28^{b}
	6	52.26	56.14	59.45	70.39	59.56^{a}
	Average (P)	40.99^{c}	42.51^{c}	48.70^{b}	56.37^{a}	
	CV (%) = 6.11; FP = 41.25**; F_L = 166.16**; F_{P*L} = 1.72^{ns}					
Total glycoalkaloid yield (kg/ha)	2	55.48^{f}	58.10^{f}	64.78^{ef}	75.57^{de}	
	4	63.15^{ef}	71.86^{e}	92.10^{c}	92.02^{c}	
	6	86.23^{cd}	98.12^{bc}	105.53^{b}	119.36^{a}	
	Average (P)	68.29^{c}	76.03^{bc}	87.47^{ab}	95.65^{a}	
	CV (%) = 6.08; F_P = 26.59**; F_L = 183.90**; F_{P*L} = 2.81*					

*Values within the same group followed by the same letters are not significantly different at P ≤ 0.05 according to the Duncan's multiple range test; * and ** are significantly different at the 5% and 1% levels, respectively.*

Table 7. Economic efficiency of *Solanum procumbens* Lour. crop

Parameters	Dose (tonnes/ha) (L)	Types of microbial organic fertilizers (P)			
		HD301	HD302	Komix-BL2	HCMK7
Total cost (VND/ha per 2 crops)	2	233,171,159	233,421,283	243,216,715	244,193,814
	4	274,888,814	276,182,270	295,522,888	295,934,246
	6	318,432,579	319,755,974	346,648,011	347,822,270
Production cost (VND per kg of glycoalkaloid)	2	4,202,497	4,017,832	3,754,717	3,231,200
	4	4,352,625	3,843,169	3,208,546	3,216,007
	6	3,692,920	3,258,956	3,284,768	2,913,965

4. Conclusions

The application of HCMK7 fertilizer at a rate of 6 tonnes/ha per crop on *Solanum procumbens* Lour. grown in grey soils of Ho Chi Minh City resulted in notable outcomes. The fresh herb weights achieved were 255.2 g/plant and 282.5 g/plant, and the dried herb weights were 134.6 g/plant and 111.1 g/plant, in the initial and ratoon crops, respectively. The actual fresh yields were 15.73 tonnes/ha per crop and 17.62 tonnes/ha per crop, while the actual dry yields were 6.99 tonnes/ha per crop and 9.21 tonnes/ha per crop. The glycoalkaloid content was 0.70% and 0.76%, and the glycoalkaloid yields were 48.97 kg/ha and 70.39 kg/ha, respectively, in the initial and ratoon crops.

The experiment also noted the highest average glycoalkaloid content (0.73%) and total glycoalkaloid yield (119.36 kg/ha) when HCMK7 fertilizer was applied at 6 tonnes/ha per crop. This application also resulted in the lowest production cost of 2,913,965 VND/kg of glycoalkaloid.

Conflicts of interest

All authors declare no conflict of interest.

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