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Quality and benefits of good agricultural practice method on choy sum cultivation in northern Cambodia

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Abstract. Choy sum (*Brassica chinensis* var. *parachinensis*) is one of the important green leafy vegetable crops widely produced and consumed in Cambodia. Most of the farmers practically use chemical inputs to increase their choy sum's yield, yet negatively affecting consumers' health. Accordingly, assuring food safety and higher yield of choy sum are essential for sustainable economic growth and development in Cambodia. In this study, we aimed to investigate the quality and benefits of choy sum cultivation using good agricultural practice (GAP) over the organic farming systems in northern Cambodia; where growth rate, yield and economic efficiency of choy sum crop were assessed. Completely randomized design was employed on three treatments (non-treated control, organic method, and GAP), while classical statistical tests were used to examine the difference of quality and benefits between the treatments. As a result, cultivation technique-GAP method provided a better growth rate, yield, and economic profitability than other treatments. Thus, GAP method's application is recommended for choy sum crop production and other potential green leafy crops. These findings provided more concrete evidence on financial benefits and quality of production of the GAP method on leafy plant growth (choy sum). Therefore, agricultural extension using GAP method would be a good technique to promote agricultural value chain, while improving food safety and livelihoods of Cambodian farmers.

1. Introduction

Choy sum (*Brassica chinensis* var. *parachinensis*) is a commonly cultivated green leafy vegetable crop in Asia [1], and considered as a crucial crop for generating income in rural Cambodia for the reasons of being a short-term duration crop with highly growing demand and exportation to neighbouring countries (e.g. Thailand, Vietnam) [2,3]. However, with limited knowledge on cultivation techniques and market information in rural areas of Cambodia [4], majority of farmers practically use chemical inputs, i.e. pesticides, chemical fertilizers, chemical herbicides to improve their production without correct knowledge on quantity and quality of chemical inputs applied on their respective farms. More often, their decision on applying fertilizers are based on their own assumptions and hearsays which mostly leads to overapplication of chemical inputs, especially on the choy sum crop in order to increase its yield [5]. Consequently, correct application of chemical inputs is critically important to improve agricultural crop production in respect to food safety, public health and livelihoods of Cambodian population [6].

Currently, the main problem faced by Cambodian farmers is decreasing soil fertility leading to low yield on agricultural products, while increasing soil acidity and other factors such as high concentrations



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of various air pollutants, water drainage and low organic matters [7,8]. Cambodia aims to enhance its agricultural sectors, while addressing these challenges through agricultural intensification. Accordingly, standardized application of chemical inputs is the commonly used solution; however, it usually causes negative impacts on human health and harm to soil productivity [2].

Indeed, the utilisation of safe agricultural inputs such as bio-fertilizers and bio-pesticides, instead of toxic chemicals for crop production is nowadays one of the important research portfolios for agronomists and agricultural specialists. Accordingly, good agricultural practice (GAP) and organic agricultural cultivation methods are commonly recommended for farmers to ensure the food safety, profitability and sustainable production of crops [9,10]. Nowadays, besides the purity of the product, consumers increasingly want to be sure that the products were produced without agrochemical inputs and consumers are not exposed to high levels of pollution [11,12]. However, purely organic agriculture applied in our today's farming system results in low yield, particularly Choy sum crop production, and it is prone to pests and insects destroying crops [13]. Compared to GAP methods, more advantages have been shown in various agricultural crop cultivation, while GAP technique enables the fractionalized amount of organic and chemical inputs resulting in better yield, while limiting the overdose of chemical inputs [14]. Therefore, the current study aimed to investigate the growth rate of choy sum in terms of plant height and number of leaves; and evaluate the yield and profitability between the two farming methods (organic and GAP techniques) using benefit-cost.

2. Materials and methods

2.1 Experimental design and data analysis

The experiment was conducted in Siem Reap province (Northern Cambodia) using a completely randomized design (CRD) from March until June 2017. There were three treatments categorized as treatment 1 (T1) for non-treated control treatment, in which no treatment was applied, treatment 2 (T2) for the organic method and treatment 3 (T3) for the GAP method. For each treatment, there were 4 replications that have been applied, while each replication had an individual plot, with the dimension of 6 m in length and 1 m in width, covering the area of 72 m². Each of the replications had 96 choy sum seedlings at a spacing 25 cm × 2.5 cm. In terms of maintenance, all of the treatments were irrigated twice day (at 7 am and 5 pm) until the day before the harvest. Weeds were controlled manually (by hand) once a week for the whole experimental period, except for T1 which was left for control. There were different inputs used for weed control and fertilizers for T2 and T3. These were discussed in detail later on in section 2.2.

2.2. Fertilizer properties and its applications

The organic method (T2) and GAP method (T3) required different types of fertilizers to be applied per plant growth period. The plant growth period was subdivided into the following: 0th stage (pre-planting period); 7th day stage; 14th day stage; and 21st day stage. This implied that the application of fertilizer inputs was on a weekly basis, similar to the usual farming custom of organic farming in Cambodia. The mentioned mixtures of organic fertilizer and bio-pesticide were based on the literature [15]. The fertilizers were applied for T2 including (1) dry cow dung; (2) bio-liquid fertilizer; (3) fish amino acid fertilizer; (4) potassium humate powder; and (5) Ketomium (*Bacteria. Spp*). Whereas, the bio-organic fertilizers were prepared beforehand from the mixture of 200 kg of cow dung; bio-liquid fertilizer (20 cc /10 L); fish amino acid fertilizer (10 g /10 L); potassium humate powder (10 g /10 L); and Ketomium (*Bacteria. Spp*) (10 g/10 L). This was intricately prepared and then applied every 5 days and on the 0th day stage, with 1.5 kg in each replication (6 m²). In terms of pest control, bio insecticide (*Beaveria sp.*) and bio-fungicide were both sprayed at 10 cc /10 L during the 7th, 14th, and 21st day stages.

While for T3, a mixture of 50% bio-organic fertilizer and 50% chemical fertilizer was combined to produce the GAP fertilizer. The bio-organic fertilizer likewise in the GAP fertilizer was produced and tested by the research team. More precisely, the agricultural fertilizer inputs were composed of 50 kg of urea (46-0-0), 50 kg of NPK (15-15-15), and 200 kg of dry cow dung. Additionally, the compound of 30.5% of N from the 100 kg can be generated from NPK and urea. The 30.5% N from the chemical

fertilizers in combination with dry cow dung were able to produce 15-4-4 of GAP fertilizer. The GAP fertilizer was then applied for 0.2 kg per 1 m², with frequency of application based on the 4 stages described above [15]. Accordingly, the insecticides and chemical inputs such as Chlorantraniliprol and Fymetrozine at 20 cc /20 L and fungicide (Tebuconazole and Trifloxystrobin) at 20 cc /20 L, bio-insecticide (*Beauveria Sp*) at 10 cc /10 L, bio-fungicide sp. At 10 cc/10 L were applied. The chemical and organic insecticides and fungicides were used once a week and alternately.

2.3. Plant traits, yield measurement and analysis

Plant traits measured include the plant height (cm) and number of leaves, while for the yield measurement, weight of choy sum in kilograms per hectare was used. For the plant traits, data were collected 3 times: 10th, 20th, and harvest day within the first 3 to 6 days after application [16]. Plant height was measured from the root end to the tip of the major leaf (tallest leaf). This was done for four out of 96 seedlings per replication. The number of measured seedlings is selected by simple random sampling based on the CRD. Likewise, the number of individuals measured, leaves as a plant trait were counted on the same interval (3-time period: 10th, 20th, and harvest day) per replication. On the harvest day period, weight of the 4-choy sum per replicate was measured through a scale.

2.4. Cost-benefit analysis (CBA)

The production cost of each treatment was estimated, and with literatures [17,18] as basis for following the estimation of the price of products [17]. The costs incurred from the establishment, maintenance and harvesting were estimated based on the actual scenario of setting up the experiment. Total yield per treatment was recorded and multiplied by the price of choy sum per kg with price (USD 0.63) if the product is in good quality (shown by T2 and T3), while lower price (USD 0.5) (shown by T1) if it is not in good quality, as depicted by the physical traits. These were obtained based on the local market rate in 2017. The costs of labour and inputs, and the gross margin were computed per month (from the value of 1 cropping season), per hectare. Same cost of labour was used for the three treatments, while the inputs vary. Benefit-cost ratio (BCR) for each treatment was calculated using the formula by Mehmood et al. [18] below:

$$\text{Gross Margin} = \text{Gross return} - \text{total variable cost} \quad (1)$$

$$\text{BCR} = \text{Gross Margin} / \text{Total Cost} \quad (2)$$

2.5. Statistical analysis

Data collected from the experiment were prepared in excel table and then compared through Duncan's Multiple Range Test (DMRT) at P=0.05. Furthermore, the mean values of parameters were statistically analysed in Randomized Design (CRD) using Analysis of Variance (ANOVA) technique in a computer program (Sirichai Statistics 7.0 software).

3. Results and discussion

3.1. Effectiveness of GAP method on choy sum growth

3.1.1. Height of choy sum. The experiment revealed that the GAP method was the most effective method to improve the plant growth with the highest plant height on the 10th day, 20th day, and 25th day stages (with the height of 11.77 cm, 20.47 cm and 32.33 cm respectively) (Table 1). This plant growth was followed by the organic method with value of choy sum's height of 8.50 cm, 18.71 cm and 27.06 cm respectively in accordance to the tree stages (Table 1). More importantly, the non-treated control and organic methods showed lower plant height due to the destroy from insects and pathogens, while the GAP method could effectively withstand and be safeguarded from the equal mixture and safe balance of chemical fertilizers as reported in the literature [15]. For instance, the use of GAP method on rice production showed better plant height compared to the organic methods (106.80 cm vs. 97.80 cm), while the non-treated control was 94.80 cm of plant height [15]. This confirmed that the bioproducts could be used as alternative inputs from chemicals fertilizers [8,19].

Table 1. Variation of mean height of choy sum in cm at different stages of cultivation (day 10th, 20th and 25th)

Treatment	10 th day	20 th day	25 th day
Non-treated control	7.36 ^b	15.87 ^b	22.00 ^c
Organic method	8.50 ^b	18.71 ^b	27.06 ^b
GAP method	11.77 ^a	20.47 ^a	32.33 ^a
CV %	10.49	8.98	5.37

Note: ^a, ^b, ^c denoted the significant difference between different stages (ANOVA, $p < 0.05$).

3.1.2. Number of leaves of choy sum

The result from the experiment showed that the number of leaves at the first 10 days was not significantly different ($P=0.05$) for organic treatment and non-treated control (Table 2), while GAP methods were significantly different compared to organic treatment and non-treated control. There were significant differences in the number of leaves for GAP method, compared to organic method and non-treated control sample as shown in Table 2 at the 20th day. Organic treatment at 25 days did not show a significant difference in the number of leaves compared to non-treated control (9.50 leaves and 8.38 leaves), while the number of leaves produced by GAP method was significantly higher at 25 days than the other methods as shown in Table 2.

Table 2. Variation of the number of leaves of choy sum at different stages of cultivation (Day 10th, 20th and 25th).

Treatment	10 th day	20 th day	25 th day
Non-treated control	4.50 ^b	6.50 ^c	8.38 ^b
Organic method	4.81 ^b	7.69 ^b	9.50 ^b
GAP method	5.69 ^a	9.94 ^a	13.19 ^a
CV%	6.12	7.99	7.53

Note: Letters a, b, c denoted the significant difference between different stages (ANOVA, $p < 0.05$).

Consequently, organic method and GAP method had a better leaf growth compared to the non-treated control. This finding could be implied to various activities such as irrigation, weeding, application of organic fertilizers and organic pesticides, and appropriate crop protection. In addition, it has been shown different effect of fertilizers and pesticides on leaf growth, likewise in other crops such as rice, tomato, and tea [15]. The findings were similar to others previous studies, which showed that GAP (18.00 tiller) and organic methods (13.00 tiller) with agricultural inputs of Ketomium (biological pesticides) gave higher tiller numbers at 60th days compared to the non-treated control (5.50 tiller) [8].

3.1.3. Yield of choy sum. The study showed that organic methods of choy sum gave higher yield than the non-treated control (15.75 tons vs 6.08 tons). The yield of choy sum through GAP method was 26.40 tons significantly different compared to other treatments (Table 3). Likewise, with the other parameters, organic and GAP methods had higher yields compared to non-treated control. Difference in yields (at 95% confidence level) comparing to other treatments with non-treated control, was due to the effectiveness of the fertilizers and organic pesticides in safeguarding the choy sum by providing it with adequate nutrient for higher growing yields and number of leaves. Unlike non-treated control, which were prone to pests, diseases and insufficient nutrients, GAP method provided a better yield. In addition, the significantly different weight between the organic method and GAP method was due to the combined application of chemical fertilizers and pesticides with biological inputs compared to organic method that used solely biological inputs as reported also from rice plant cultivation [8], showing that GAP method gave higher yield than the organic method with the harvest index of 39.44%. Accordingly, the organic method on rice cultivation accounted for 37.93% of harvest index compared to 37.73% and 33.47% for

chemical method and non-treated control respectively [8]. Similarly, a study from tea crops showed a good yield derived from GAP cultivation technique compared to the chemical method, while GAP method gave higher percentage of increasing yields compared to the yield obtained from the non-treated control and the organic cultivation technique [20].

Table 3. Effectiveness of GAP method on choy sum's yield.

Yield	Non-treated control	Organic method	GAP method
Tons	6.08 ^c	15.75 ^b	26.40 ^a

Noted: ^a, ^b, ^c denoted the significant difference between different stages (ANOVA, $p < 0.05$).

3.2. Economic benefits of GAP method on choy sum cultivation

The benefit cost ratio (BCR) computed from the cost incurred in different treatments and the return from the choy sum products showed a significant difference in terms of economic benefits for farmers (Table 4). The results revealed that the BCR value of the GAP method was greater than 1 [21], which means the economic benefit is attained. Whereas organic method and non-treated control were less than 1, that means the cost of production were higher than benefits. Therefore, the organic method and non-treated control were not economically beneficial. The GAP method possessed the highest BCR value (2.13) followed by the organic method (0.79), and the non-treated control (0.25) (Table 4). These results were reported in previous findings from the literatures, wherein the treatment with insecticide applied got the highest BCR of 2.57, calculated at 4 days after the first application (DAFA) intervals [21]. While other literatures mentioned that combination of bio control and chemical gave the highest benefit cost ratio than untreated control and sole one [22,23,24].

In this study, as the GAP method has 50% of chemical fertilizer, the quality of the choy sum was better, and thus has a higher market price. The variation of the acquired BCR values were due to the different cost and type of inputs in each of the three treatments. The prices of different agricultural inputs and choy sum products increased through time due to the production cost from the use of different insecticide, pesticide and fertilizer, with the objectives of increasing the production and protecting vegetables from disease and pests. For this reason, the profitability of different agricultural inputs and price of choy sum varies depending on the season in each year, causing the profitability to either increase or decrease. Being aware of these economic benefits and the quality of products from the GAP method brought by training on food safety practices were likely to have a higher adoption of the GAP system, as proved by a study of Sriwichailamphan et al. [25].

Table 4. Benefit cost ratio analysis of choy sum crop with different cultivation methods.

Particulars	Non-treated control	Organic method	GAP method
Income (USD)	237.50	984.38	1,650.00
Total cost (USD)	190.00	550.00	527.00
Gross margin	47.50	434.38	1123.00
BCR	0.25	0.79	2.13

4. Conclusions

The GAP method was an appropriate method for choy sum crop production, which provided high quality crop, safety for vegetable consumption and economic efficiency. Compared to organic methods and non-treated control, the GAP method showed better profitability and safe production with only 50% chemical inputs. Consequently, growth rates, number of leaves, and stem weight of the treatments were significantly different due to the effectiveness of the GAP method in controlling pests and diseases. More importantly, it helps to maintain an environment, food safety and consumer's health. Hence, this finding was informed to consumers on safety and quality of choy sum using GAP cultivation techniques, while suggesting to the government to encourage farmers to implement the GAP method in their farming systems. This will enable the development of the agricultural sectors ensuring the welfare of the farmers

by fixing the problems of price fluctuation, regular supply of input at reasonable price, monitoring the activities of middlemen, and etc. in order to maximize the benefit of farmers and consumers. This paper was a pathway for future research on marketing of other crops produced through the GAP method.

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