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Effectiveness of the Vietnamese Good Agricultural Practice (VietGAP) on Plant Growth and Quality of Choy Sum (*Brassica rapa* var. parachinensis) in Northern Vietnam

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Abstract - In response to the recent concerns about human health, ecosystem sustainability and thus demands for food safety, production of clean produce, particularly daily-consumed vegetables, is essential. The study was carried out in Thai Nguyen city (northern Vietnam) during August – November 2011 to evaluate impacts of a VietGAP guideline on plant growth and quality of Choy Sum, one of the major vegetables in the research area. The experiment comprised two treatments, a control (local farmers' conventional practice) and an experimental treatment (plants grown according to the VietGAP guideline). Plant samples of the latter treatment were collected for quality test at the end of the experiment. Results showed that the experimental plants had significant higher growth parameters with regards to leaf areas (7.13 dm^2) and average top plant weight (3.33 kg m^{-2}), while those of the control treatment were 5.80 dm^2 and 2.77 kg m^{-2}, respectively. Lab test results showed the experimental plant samples met the national quality standards to be certified as a clean product. The participatory on-field experiment would facilitate critical reflections, transformative learning and readiness for adoption of eco-friendly production practices by the local farmers.

Keywords: Choy Sum; Clean vegetables; Food safety; Quality; Plant growth; Production practices; VietGAP

Introduction

Dissemination of the Vietnamese Good Agricultural Practices (VietGAP) in agricultural production would be considered as a "conversion period" toward organic production (Ha, 2014a) to address the increasing food safety concerns (Ha and Nguyen, 2013; Ha, 2011, 2014a, 2014d; Van Hoi *et al.*, 2009) and therefore market demands in Vietnam (Dung and Ngan, 2012; Ha, 2011, 2014b, 2014c; Simmons, 2008).

As the daily consumed produce at every household, vegetables are amongst the most concerned agricultural products. High demands by export markets for clean vegetables have been reported by various authors (e.g. Ha and Nguyen, 2013; Ha, 2011, 2014a, 2014b, 2014c; Scott, 2006; Simmons and Scott, 2008). Likewise, domestic demands for safe vegetables are recently of particular interests by the Vietnamese middle class and foreigners staying in Vietnam (Nicetic *et al.*, 2010).

In responding to the consumers' needs and pressure for change in production practices due to public concerns (Ha, 2014a, 2014b, 2014c, 2014d), a safe vegetable program had commenced since the early 1990s in Hanoi and Ho Chi Minh city and then been disseminated to other provinces under the support of the Ministry of Agriculture and Rural Development (MARD) (Nicetic *et al.*, 2010). However, only until early 2008, the complete national VietGAP guideline for production of fresh fruits and vegetables was developed (Ha, 2014b, 2014c; MARD, 2008). Since then the VietGAP has been widely disseminated and adopted by smallholder farmers and cooperatives in various production regions of Vietnam (Ha, 2014b; Nicetic *et al.*, 2010). Although there are some impediments to broad scale adoption of VietGAP, as reported by Ha (2014b), which need to be addressed in a coordinated manner, the immediate and long-term benefits for vegetable growers are obvious due to higher product prices received from adoption of the eco-friendly practices (QUACERT, 2013). In addition, healthy crop growth and qualified quality for certification of "safe" and/or clean produce have been reported by Ha (2011), Ha (2014c) and Ha (2014b).

The peri-urban areas of Thai Nguyen city (northern Vietnam) are the main production zone of fresh vegetables for the whole province. However, the current poor quality produce and limited number of clean vegetable selling points have been stated (Ha and Nguyen, 2013; Ha, 2011). To promote large scale production of clean vegetables in Thai Nguyen, besides other measures as asserted by Ha (2014b), participatory on-field trials of VietGAP should also be required to prove the adoptability of the improved production guidelines for vegetables, while these activities would help change local farmers' mindsets, raise awareness and thus adoption.

This study was conducted on Choy Sum (*Brassica rapa* var. *parachinensis*), one of the major vegetable crops in Thai Nguyen (Ha, 2011), to evaluate impacts of the VietGAP adoption on growth and quality of the crop during August – November 2011 in Thai Nguyen city. The aim of this study were to 1) compare the growth parameters between an experimental treatment (crops grown according to the VietGAP guideline) and a control treatment (farmers' conventional practice) and 2) evaluate the quality of the experimental Choy Sum grown according to the VietGAP guideline.

Materials and Methods

Experimental design

The experiment comprised two treatments, a control and/or conventional farmers' practice (T1) and an experimental treatment (T2) that applied the VietGAP guideline. For better comparison of growth parameters between the two treatments, the experimental plot was divided into two subplots for the control and experimental treatments, respectively. Within each subplot, 3 soil-beds were used. Since the experiment was conducted on a relative small and flat land area with a similar soil type, a Randomized Complete Block (RCB) design was applied, where each soil bed was considered as one block, to reduce the experimental errors. In each sub-plot, nine single replicate plants were chosen for measuring growth parameters (Figure 1).

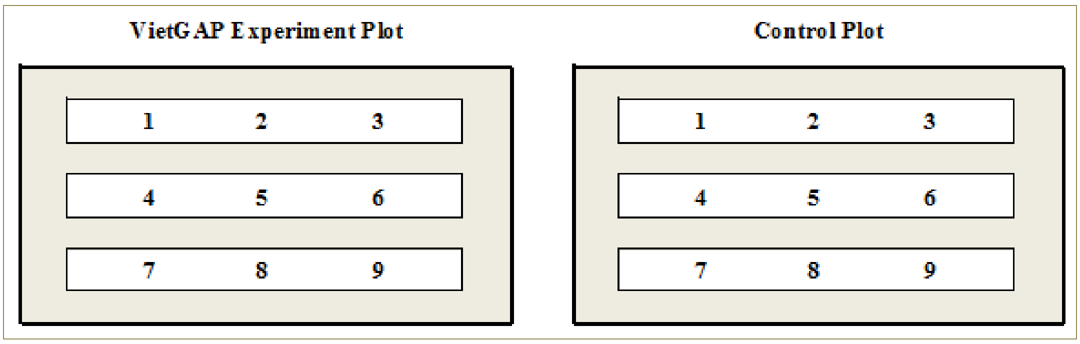

Figure 1. Experimental design for two treatments in two separate subplots. *There are 3 soil-beds per each subplot. The numbers indicate the single replicate plants selected for measuring the growth parameters.*

Production guidelines applied for each treatment

+ Control treatment (T1): the cultivation was applied according to the local farmers' traditional practice. The researcher and farmers together took note of all details from the beginning of the whole production cycle, including fertilizer amount, types, quantity of pesticides used and cultivation techniques applied. The cultivation practice is described in Table 1 below. Seeds in the control treatment were densely sown by the farmers with a purpose of harvesting twice. The first time was harvested at week 3 after sowing as a way to reduce plant density. The plants harvested at this stage were sizable for sales. In the second time (one month after sowing), all the remaining plants were harvested. Watering was carried out on daily basis or every 2-3 days, depending on growth stages and weather conditions. Weeding and chipping were done regularly.

The pesticide BP Dygan 3.6 EC (active element: Abamectin 3.6%) was applied at day 11 after sowing. + Experimental (VietGAP) treatment (T2): Ploughing and removal of crop residues were conducted early prior to sowing. Soil pH was initially tested with a value of 4.51 ± 0.04. The low level of pH was reported to negatively influence the nutrient absorbability of plant roots and mobility of mineral nutrients (Cao *et al.*, 2011; Tran *et al.*, 2012). The formula of soil pH adjustment by Lester (2010) was applied to raise the pH value to 6.0, which is suitable for the experimental crop.

At 20 days prior to sowing, formalin solution (2.0%) was prepared and applied to the soil with an amount of 5.0 L m^{-2} to saturate it up to a depth of 20 cm. The drench area was then covered by polyethylene sheets. After 15 days, the cover was removed and soil-beds were raised for sowing seeds (Tewari, 2009).

Fertilization and tending of Choy Sum were adapted from the production guideline of Tran (2009). Plants were watered on daily basis or every 2-3 days, depending on growth stages and weather conditions. Pest scouting was regularly carried out and damage levels were evaluated according to the national technical regulation on surveillance methods of plant pests (MARD, 2010) to make decisions.

After basal fertilizers were applied according to the guideline, soil samples were collected for electrical conductivity (EC) test. The EC value was 1.06 ± 0.07 mS cm^{-2}, which is regarded as suitable for the experimental crop (Lester, 2010).

Table 1. Production guidelines applied for the two treatments:

Guideline	VietGAP (T2) (adapted from Tran, 2009)	Farmers' practice (Control) (T1)
Planting distance	10 x 15cm	Seeds were densely sowed.
- Total chemical fertilizers applied (per one hectare):	Bio-organic fertilizer (organic matter > 15%; NPK: 1:1:1): 3.0 tons/ha. Chemical fertilizers: 60kg Urea (46.0% N) + 135kg Superphosphate (16.5% P_2O_5) + 40kg Potassium Chloride (60.0% K_2O).	Manure (chicken & pig dung): 2.10 tons/ha. N.P.K-S (5: 10: 3 - 8): 416.67 kg/ha + Urea (46.0% N): 154.16 kg/ha.
Basal fertilizing	All organic fertilizers + all Superphosphate + 50% Urea + 50% Potassium.	100% manure + 100% N.P.K-S
Topdressing	7 days after planting: 50% urea + 50% potassium.	1^{st} time (18 days after sowing): 83.33kg Urea/ha; 2^{nd} time (day 25 from sowing): 70.83kg Urea/ha
Plant care	Watering daily or every 2-3 days, depending on growth stages and weather conditions; Regular weeding and chipping.	Watering daily or every 2-3 days, depending on growth stages and weather conditions; Regular weeding and chipping.
Pest control	Regular check, identification of pests, damage levels and making decision.	Used chemical pesticides when the pests were identified.

Data collection

The following parameters at harvest time were recorded to compare between growth parameters of the nine replicates of the experimental and control treatments:

- Plant height (taken from the stem base to the highest point);
- Leaf number; damaged leaves caused by pests and diseases and levels of damage were evaluated according to the national technical regulation (MARD, 2010);
- Average leaf surface area: measured according to the method of Holtzclaw (2007); and
- Weight per one square meter.

Soil, water and vegetable sample tests

Soil sampling was carried out at the beginning of land selection to check the contents of heavy metals. Since the experiment plot was small and flat, soil sampling was conducted by selecting five diagonal points (Modified from Le, 2011; MOST, 2005; Peters *et al.*, 2007). At each point, a soil sample was taken from surface to 20 cm deep. The samples were then put into plastic

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bags and sealed before sending for lab tests. Since well water was used for irrigation, three random samples were selected to test heavy metal contents. For plant samples, three samples were selected randomly from each subplot for quality test in terms of nitrate, heavy metal contents, microbial and pesticide residues in the laboratory of soil and agricultural product quality analyses, Northern Mountainous Agriculture & Forestry Science Institute.

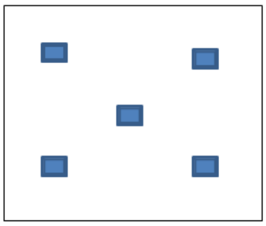

Figure 2. Five diagonal point sampling method for soil (Ha, 2014c).

Data analysis

Data obtained were subjected to analysis of variance using General Linear Model procedure in Minitab® Statistical Package (Release 15; Minitab® Inc., PA, USA) with the least significant differences (LSD) calculated at 5% level of significance. GraphPad Prism (Release 6, GraphPad Software Inc., La Jolla, CA 92037, USA) was used to illustrate the differences of plant growth parameters between the two treatments.

Results and Discussion

Evaluation of crop growth

Similar to other experiments on mustard greens (Ha, 2014c) and leafy radish (Ha, 2014b), plant heights of Choy Sum between the two treatments were not statistically different (Table 2). However, leaf numbers between two treatments of the crop were not significant (Table 2) though the planning density of T2 was much lower compared to that of the control treatment (T1). This might be due to the genetic character of the crop.

The VietGAP plants (T2) had significantly higher average leaf area (7.13dm^2) and top plant weight (3.33kg m^{-2}) compared to those of the control (T1) with respectively 5.80 dm^2 and 2.77 kg m^{-2} (Table 2, Figure 3). As a leafy vegetable, the increased leaf area and weight would affect consumers' choices and "willingness to pay" (Bonti-Ankomah & Yiridoe, 2006; Ha, 2014b, 2014c). Moreover, it is interesting to note that despite the dense planting by the farmers, total weight per one square meter in the control was even lower than that of the experimental treatment. The results would serve as clear evidence of the VietGAP's effectiveness that would help raise awareness and trigger transformational learning of the local producers to get away from the traditional perception of "the more the better". The conventional perception implies their inclination to apply high level of chemical inputs (e.g. fertilizers, pesticides, and high density planting) to expect high yields with less level of pest damages. Compared to other experimental vegetables, for instance, mustard greens (*Brassica juncea* L.) and leaf radish (*Raphanus sativus* L.) (Ha, 2011, 2014b, 2014c), Choy Sum had much lesser pest damage level. There were two types of pests, namely leaf-miner (*Liriomyza sativae* Blanchard) and diamondback moth (*Plutella xylostella* Linnaeus), which occurred during the production period in both T1 and T2.

In the experimental subplot (T2), since most of the diamondback moths identified during pest scouting were killed manually, thus only a few damage symptoms were presented (Figure 4), except for leaf-miners due to their active movement. However, the occurrence levels of these pests were not significant compared to the action thresholds (Leaf-miner: 30% leaves affected; Diamondback moths: 30 moths m^{-2}) as stipulated by MARD (2010 pp. 17-18).

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Table 2. Plant growth of Choy Sum in the two treatments

Treatment	Plant height (cm)	Leaf number	Average leaf area (dm^2)	Weight ($kg\ m^{-2}$)
VietGAP (T2)	30.33	7.8	7.13 (a)	3.33 (a)
Control (T1)	29.28	7.4	5.80 (b)	2.77 (b)
P-value	*n.s*	*n.s*	**	*

Notes: The growth parameters were measured upon harvest (30 days from planting). Values followed by different letters within a column are significantly different according to Tukey test. n.s.: not significant, * P<0.05, **P<0.01, ***P<0.001.

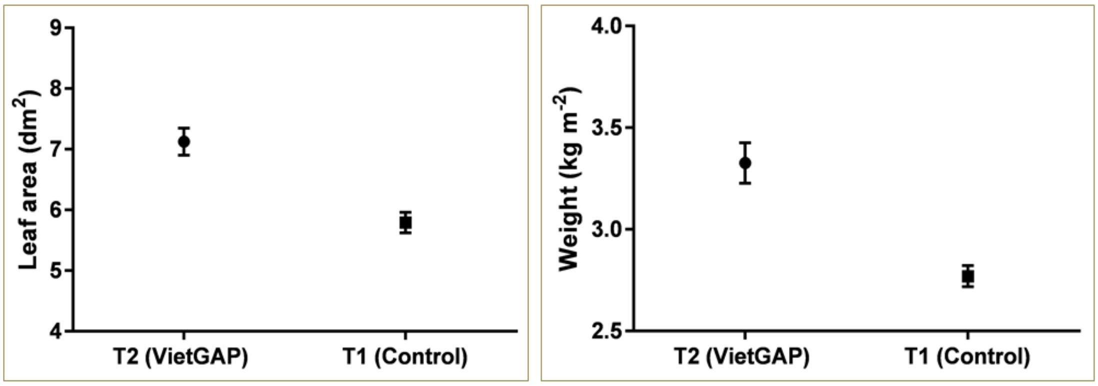
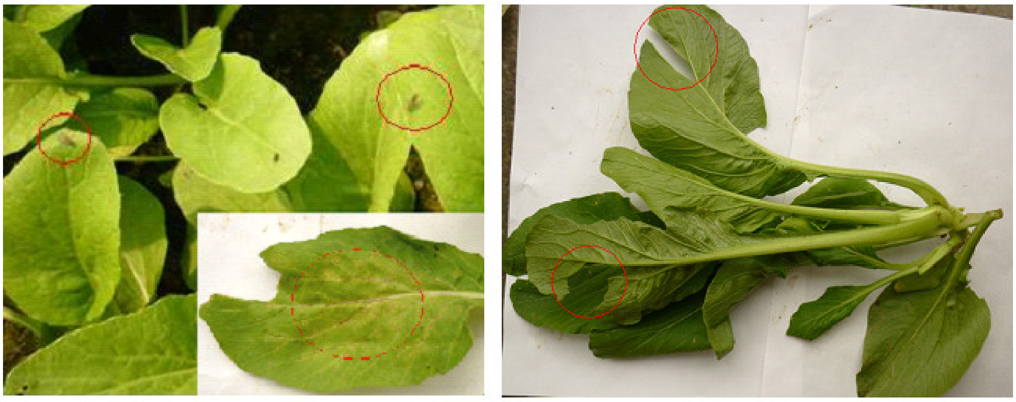


Figure 3. Comparing average leaf areas (left figure) and top plant weights (right figure) between the two treatments of Choy Sum. *Vertical bars represent standard errors of means (S.E).*



(A). Leaf-miners & damages on Choy Sum leaves. (B). Damage caused by diamondback moths

Figure 4. Pests and their damage symptoms on Choy Sum (red circles).

(A). White mould appeared on the bed surface (B). Root rot symptom

Figure 5. Disease symptoms on Choy Sum plants of the control treatment.

As one of the common problems in the control treatment, spotted white mould was found on the bed surface, resulting to an average of 8.3 (± 0.33) plants per one square meter affected with root rot (Figure 5). This would be a reason for reduced plant weights in the control treatment. Improper treatment of farmyard manure and high density planting were reported as the major causes (Ha, 2011, 2014b, 2014c). Moreover, imbalanced fertilization with excessive amount of chemical fertilizers together with late topdressing of urea (5 days before harvest) (Table 1) would induce unhealthy plant growth and possible high level of nitrate content remained in the products upon harvest.

Evaluation of product quality of Choy Sum grown according to the VietGAP guideline

The quality parameters according to VietGAP standards include Nitrate (NO_3-) level, microbial content (*Salmonella, Coliforms, Escherichia coli*), heavy metals (As, Pb, Hg and Cd) and pesticide residues in plant samples. Results of quality analyses were compared with the current national standards. Results in Table 3 show that the contents of nitrate, microorganisms and heavy metals were in the safe thresholds. The test results of pesticide residues in plant samples were compared with the maximum residue limits (MRLs) as stipulated in by the Ministry of Health (Decision No. 46/2007/QD-BYT, dated on 19 December 2007). Results in Table 4 show that the levels of chemical residues are below the MRLs. Based on the above quality test results, the Choy Sum grown according to the VietGAP guideline in Thai Nguyen met the quality standards as a clean produce.

Table 3. Analyses of Nitrate, microbial and heavy metal contents in Choy Sum samples

Parameters	NO_3- (mg/kg)	Microbial content (CFU/g)			Heavy metal content (mg/kg)			
		Salmonella	*Coliforms*	*Escherichia coli*	As	Pb	Hg	Cd
Average value	271.22	0	111.67	3.00	0.073	0.017	< 0.0001	0.007
S.E	0.59	0.00	2.03	0.58	0.009	0.007	-	0.000

Note: National standards applied for each parameter: TCVN 5247:1990 for Nitrate; TCVN 4829:2005 for Salmonella; TCVN 6848:2007 for Coliforms; TCVN 6846:2007 for Escherichia coli; TCVN 7601:2007 for As.; TCVN 7602:2007 for Pb.; TCVN 7604:2007 for Hg; and TCVN 7603:2007 for Cd. S.E - Standard Errors. CFU – Colony Forming Units.

Table 4. Test results for pesticide residues in the experimental Choy Sum samples

Parameters	Residue contents in plant samples (mg/kg)			Average (mg/kg)
	Sample 1	Sample 2	Sample 3	
Methyl Parathion	0.023	0.023	0.024	0.023 ± 0.0003
Fenvalerate	0.001	< 0.001	0.001	-
Imidacloprid	< 0.001	< 0.001	0.001	-
Diazinon	0.042	0.045	0.044	0.044 ± 0.0009
Tebufenozide	0.082	0.077	0.082	0.080 ± 0.0017

Conclusions

The study has shown positive impacts of applying the VietGAP protocol on plant growth and quality of Choy Sum in Thai Nguyen city. The increased leaf areas and average weight per one square meter in the experimental subplot are the indicators of healthy plant growth and thus ease of sales. In contrast, the conventional cultivation practice showed its limitations by poor plant growth, occurrence of white mould and high ratio of root rot. Choy Sum grown according to the VietGAP guideline in Thai Nguyen met the national quality standards to be certified as a clean produce. The research served as a case study and a demo-plot for local farmers to reflect on their current cultivation practices for a possible change. In addition, the participatory on-field trial was also necessary to build capacity for local farmers, trigger transformational learning, and enhance confidence and positive attitude toward application of the improved production practice.

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