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MANGO GROWERS' COMPLIANCE WITH PUBLIC GOOD AGRICULTURAL PRACTICES STANDARD: A COMPARATIVE STUDY IN NORTHERN THAILAND

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ABSTRACT
This study investigated the effectiveness of Thailand's public good agricultural practices certification initiative (Q-GAP) in improving export-oriented mango farmers' awareness and practices relating to food safety and quality assurance. Two groups of certified farmers in Northern Thailand (one from Chiang Mai Province and the other from Phitsanulok Province), comprising a total of 96 samples, were surveyed for comparative analysis. Many items of the comparison showed no significant differences between the two groups of farmers (specifically, the use of synthetic pesticides and non-synthetic pest control methods, record-keeping, and agrochemical safety and handling practices). One significant difference worth mentioning was related to the farmers' ability to link the goal of the Q-GAP policy to food safety assurance; when compared to Phitsanulok, approximately 35% more farmers in Chiang Mai demonstrated such an understanding. This contradicted the more experience and days of training on Q-GAP the farmers in Phitsanulok had in comparison to those in Chiang Mai. Moreover, the rates of understanding in both areas were significantly lower than those identified in previous Q-GAP studies of less export-oriented crops. The export-oriented mango farmers might be trained to regard Q-GAP certification as a type of license to export their mango produce, rather than as a tool to improve their food safety and quality assurance.

Contribution/Originality: The originality of this study lies in its examination of export-oriented fruit producers, specifically mango growers, concerning their compliance with Thailand's public good agricultural practices standard (Q-GAP). Its primary contribution relates to the finding that the surveyed certified mango farmers' understanding of the policy goal is much more limited than that of those growing less export-oriented crops.

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1. INTRODUCTION
Since the early 2000s, many member countries of the Association of Southeast Asian Nations (ASEAN) have enacted food safety policies. One of these policies is the introduction of national good agricultural practices (GAP) standards, which are created and administered by the public authorities of the respective countries (except for the private standard "ThaiGAP," which is managed by a private institution and a public university). These public GAP standards were introduced in response to the chronic overuse and misuse of agricultural pesticides in this region

(Schreinemachers et al., 2012) along with associated public concerns about food safety (Wongprawmas, Canavari, & Waisarayutt, 2015).

Despite the common goals of food safety and quality assurance, the public GAP standards of ASEAN nations exhibit significantly different degrees of grower certification. Thailand's Q-GAP is the largest standard in terms of the annual number of certified farms. It accounts for a majority of the farms with certified status in the ASEAN region. Singapore's SingaporeGAP-VF, Myanmar's MyanmarGAP, Cambodia's CamGAP, and Brunei's BruneiGAP each cover fewer than 10 certified farms within each of these nations (see Table A1 in the Appendix). This seems to attest to the Thai government's single-minded quest for quantitative achievements in national GAP certification through extensive behind-the-scenes resource mobilization.

However, the impressive achievements beg the question of whether there is a tradeoff with safety assurance. Generally, there may be a proportional relationship between the level of stringency required to comply with a standard and the required costs of enforcement. Stricter standards require larger enforcement costs because they require larger operating changes on the part of polluters. Conversely, relaxed standards can be achieved with fewer enforcement resources for the opposite reason (Field & Field, 2017). Therefore, the following questions arise: "How limited or satisfactory is the level of Q-GAP compliance required by the enforcing agency and achieved by the growers?" and "Should the degree of farmer participation be sacrificed by increasing the required level of compliance and enforcement?" To solve these broad problems, a series of investigations and verifications must be carried out via several case studies.

Since the formulation of Q-GAP in 2003 and its launch in 2004, there have been three versions of the Q-GAP code of practice: TAS 9001–2004, TAS 9001–2009, and TAS 9001–2013, which were introduced in 2004, 2009, and 2013, respectively (see the details on Q-GAP certification in the Appendix). To date, five policy evaluation studies have been conducted on Q-GAP implementation concerning the enforcement of the standard and producers' compliance with food safety assurance, all of which have focused on agrochemical control. Three of them were based on pre-2013 versions, and two of these did not reveal any significant effect of the growers' participation in Q-GAP on their pesticide use, such as Schreinemachers et al.'s (2012) study on nine fresh fruit and vegetable (FFV) crops in Chiang Mai Province, Northern Thailand, and Amekawa's (2013) study on pomelo growers in Chaiyaphum Province, Northeast Thailand. Meanwhile, Srisopaporn, Jourdain, Perret, and Shivakoti (2015) found that Q-GAP adopters spent significantly less on total fertilizer costs than those who adopted and then disadopted the standards or never-adopters. The study attributed the difference in their findings from the former two studies to the easier nature of rice production for reducing pesticide use compared with FFV production.

However, the findings of the abovementioned case studies are outdated since the bulk of their field research was conducted before 2013. The level of Q-GAP policy implementation (in terms of both enforcement and compliance) could have been improved through the introduction of the 2013 TAS 9001–2013 code of conduct. Therefore, the following two bodies of research were conducted in the post-2013 period: Amekawa, Hongsibsong, Sawarng, Yadoung, and Gebre (2021), having compared 41 Q-GAP-certified and 90 uncertified cabbage farmers in Chiang Mai Province, Northern Thailand, found that the certified farmers' use of insecticides, fungicides, and herbicides, in terms of their adoption rate, frequency of pesticide application, and aggregate pyrethroid residues detected, was significantly lower than that of the uncertified farmers. Amekawa, Bumrungsri, Wayo, Gebre, and Hongsibsong (2022) compared 48 certified and 50 uncertified durian farms in the relatively more market-oriented context of durian farming in Chanthaburi Province with 50 certified and 50 uncertified durian farms in the relatively less market-oriented context of durian farming in Nakhon Si Thammarat Province. The study found that in both areas, certified farmers used more fungicides than their uncertified counterparts, with no significant differences identified in the use of insecticides and herbicides.

The current study revisits the policy evaluation work for TAS 9001–2013 by carrying out the following actions:

First, the study targets mangoes grown in export-oriented production areas (see the agronomic details of mango in the Appendix). While mango production in Thailand includes domestic sales, its degree is limited in the study areas, to the extent that many mango growers are GAP-certified (mostly Q-GAP) for the purpose of export sales. Since GAP certification is a prerequisite for FFV exports, most farmers who grow mangoes for export wish to receive GAP certification. A majority of uncertified mango farmers are not GAP-certified because they either do not have sufficient experience in mango cultivation (i.e., three years or less) or adequate produce quality to be purchased by exporters.

Second, the study adopts a similar approach to the two studies conducted in the post-2013 period to highlight the complex, multidimensional reality of harmony and discord found in the respondent farmers' perceptions, behaviors, practices, and outcomes. Replicating studies with similar methodological approaches in different contexts can contribute to the accumulation of evidence to respond to broad research questions concerning public GAP scholarship.

Third, unlike the previous relevant Q-GAP studies that compared export-oriented Q-GAP-certified and uncertified farmers, this study compares the perceptions and practices of certified farmers in two distant areas. By comparing the certified farmers in two distant areas with potentially dissimilar contexts, we focus on examining whether there are similar or different processes and outcomes in the enforcement of Q-GAP and growers' compliance with it due to geographic and other contextual factors. If similar results are identified in the two areas, it will increase the validity of the findings in the export-oriented mango production context.

2. MATERIALS AND METHODS

Our research team originally sought to conduct a comparative economic study of Q-GAP-certified mango farmers and their GlobalGAP-certified counterparts. However, it was difficult to find respondents among the GlobalGAP-certified mango farmers because the exporters under contract with many such farmers were reluctant to allow us to interview the farmers. Hence, we changed our research agenda to compare the use and handling of pesticides by Q-GAP-certified mango farmers located in two distant provinces. Accordingly, a research team from Chiang Mai University conducted a questionnaire survey of Q-GAP-certified mango farmers in Phitsanulok Province in December 2016 and in Chiang Mai Province in December 2017 (see the map in Figure 1). In 2019, Phitsanulok Province had 50,296 ha and 55,363 tons of mango production (Office of the Permanent Secretary for Ministry of Agriculture and Cooperatives, 2021), whereas Chiang Mai Province had 64,790 ha and 64,711 tons (Chiang Mai Provincial Agriculture and Cooperatives Office, 2022).

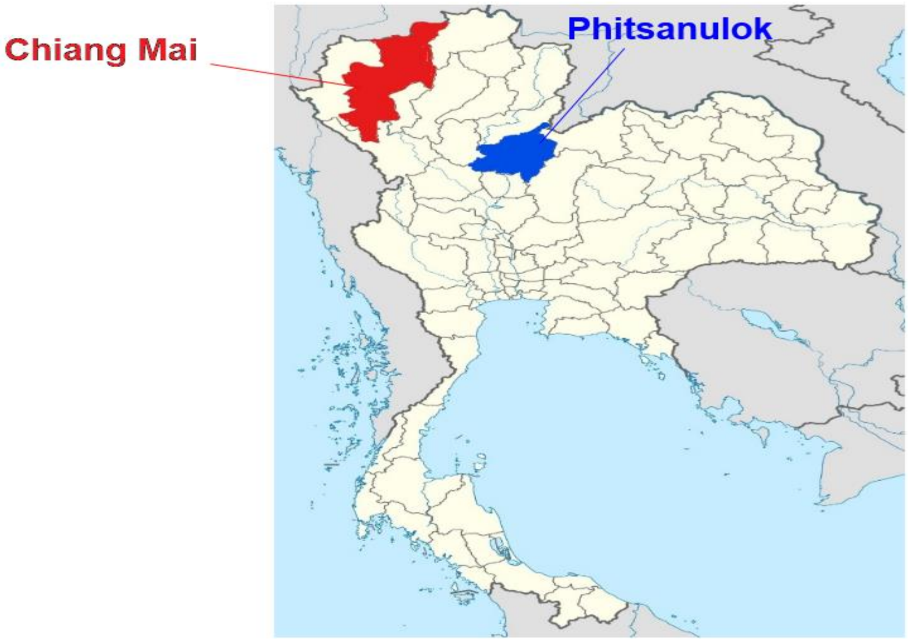

Figure 1. Map of Thailand.

At the time of research, there were a total of 251 Q-GAP-certified mango farmers with a total mango production area of 630 hectares in Phitsanulok Province and 210 certified mango farmers with a total of 425 hectares in Chiang Mai Province. For the survey, we selected farmers from the Noen Maprang and Wang Thong Districts of Phitsanulok Province as they comprised the major mango production areas in the province. Likewise, we chose the Phrao and Mae Taeng Districts of Chiang Mai Province for our random sampling of certified farmers. Accordingly, we interviewed 50 Q-GAP-certified farmers in Phitsanulok Province and 49 certified farmers in Chiang Mai Province. Upon request, the person most knowledgeable about and responsible for mango farming in the household was interviewed. Since the responses of one farmer in Phitsanulok Province and two farmers in Chiang Mai Province were invalid, we removed their data. The final analysis consisted of 49 valid interviews for Phitsanulok Province and 47 for Chiang Mai Province. Additionally, a researcher from Kasetsart University interviewed a group of mango farmers in Wang Thong District, Phitsanulok Province, which included three GlobalGAP-certified farmers. Since the data obtained from the GlobalGAP-certified farmers were not sufficiently complete, they are not referenced in this paper. Each farmer was interviewed for approximately 30–60 minutes using a prepared questionnaire.

The topics included in the questionnaire were as follows: 1) basic farm profile, 2) economic conditions of mango farming, 3) growers' perceptions of Q-GAP and pesticide use, 4) audit experience, 5) training experience, 6) pesticide use and management, and 7) pesticide safety and handling. Questions relating to the farmers' motives, benefits, and reasons associated with their participation or non-participation in Q-GAP were answered on a multiple-choice basis. Regarding pesticide use, the farmers were questioned about whether or not they had adopted a particular type of pesticide (insecticides, fungicides, and herbicides). Additionally, they were questioned about the estimated percentage change in their use of a particular type of pesticide since they had first adopted Q-GAP for mango growing. This approach was employed because several mango growers did not remember or record precisely how many times they had sprayed pesticides or how much pesticide they had sprayed in the past year. The analysis did not involve the full sample because the farmers who did not use a particular pesticide or those who were unsure of the rate were excluded. Similarly, those who did not use a particular farm input were not expected to maintain records for it. Therefore, the record-keeping results excluded those who did not use the input. Regarding the agrochemical safety and handling practices of Q-GAP-certified farmers in the two areas, the first seven items of comparison were derived from the Q-GAP code of conduct in the TAS 9001–2013 version, whereas the latter seven items were derived from the GlobalGAP code of practice in the 5.0 version of Integrated Farm Assurance (i.e., the latest version at the time of the field research). This mixture was used because a comparative study of Q-GAP-certified and GlobalGAP-certified mango farmers was intended at the time of data collection.

Responses were noted on the questionnaire sheet, and conversations were recorded using a voice recorder. Data were analyzed using Stata statistical analysis software. Since the size of each sample set was greater than 30, one-way ANOVA was applied to compare the mean differences for the continuous variables, and a chi-square test was carried out to examine the relationships for the nominal variables. Additionally, frequency distribution was used to present the distributional results of the nominal variables.

3. RESULTS AND DISCUSSION

3.1. Socioeconomic Profile of the Surveyed Mango Farmers

The Q-GAP-certified mango farmers in Chiang Mai were significantly older than those in Phitsanulok ($p < 0.01$) (Table 1). Meanwhile, the farmers in Phitsanulok had a 2.02-times larger total farm size and a 2.47-times larger mango farm size than those in Chiang Mai, and the difference was significant. There was no significant difference in the total number of mango trees in the orchards. However, the farmers in Chiang Mai had 1.86 times more mango trees per ha than those in Phitsanulok, with a significant difference ($p < 0.01$). This suggests that the farmers in Chiang Mai grew mangoes in a significantly more intensive fashion than those in Phitsanulok, regarding the density of tree planting. Both groups of farmers had a high rate of participation in local mango producer groups, with a significant difference in favor of the farmers in Chiang Mai ($p < 0.10$). No significant difference was observed in the level of completed education, gender ratio, or proportion of farmers growing certified crops other than mangoes.

Table 1. Basic profile of the respondent mango farmers.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Gender ratio (man 1: woman 0) (%)	67.3: 32.7	80.9: 19.1	0.132^{NS}
Age (years)	52.06 (11.14)	57.8 (7.22)	0.004***
Primary education Secondary education Vocational/junior college University (%)	67.3 10.2 20.4 6.1	72.3 6.4 14.9 6.4	0.910^{NS}
Total farm size in ha	6.15 (4.22)	3.05 (1.87)	0.005***
Size of mango farmland in ha	6.02 (3.20)	2.44 (1.57)	0.019**
Total number of mango trees	1,345.1 (1,646.1)	1,296.5 (1,738.8)	0.889^{NS}
Number of mango trees per ha	298.5 (283.5)	556.2 (223.0)	0.000***
Farmers belonging to a mango producer group (1 = yes)	93.9%	100.0%	0.085*
Farmers growing certified crops other than mango (1 = yes)	18.4%	28.7%	0.279^{NS}

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$; NS = not significant; standard deviation in parentheses.

Regarding the economic and marketing profiles of the mango farmers in the past year, the mango farmlands of the farmers in Phitsanulok were 2.47 times larger than those of the farmers in Chiang Mai (Table 2). Accordingly, the total annual mango production of the former was 2.22 times larger than that of the latter, and the difference was significant ($p < 0.10$). However, the yield values (kg/ha) were similar, with no significant difference. This seems remarkable considering that the farmers in Chiang Mai had 1.86 times more mango trees per ha than those in Phitsanulok. This suggests that the level of intensification in terms of productivity per tree was significantly higher for the farmers in Phitsanulok than for those in Chiang Mai, although the latter had a higher level of intensification in terms of the number of trees planted per ha. The spatial advantages of the mango farmers in Phitsanulok contributed to tree growth. Nevertheless, the farmers in Chiang Mai had 73% more mango sales per ha than those in Phitsanulok, and the difference was significant ($p < 0.01$). Given the similar yields in the two areas, this suggests that the farmers in Chiang Mai had access to more lucrative market conditions in terms of prices and amount sold. Accordingly, there was no significant difference in the annual total mango sales between the farmers in the two regions. The household-level economic outcomes from mango production (i.e., total annual sales) were similar in the two areas, although the pathways were notably different.

Table 2. Economic and marketing aspects of mango farming.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Total mangoes produced in the past year (kg)	17,679 (33,728) (n = 45)	7,969 (18,357) (n = 45)	0.093*
Yield per hectare (ha) in kg	28,221 (19,508) (n = 45)	28,461 (21,472) (n = 45)	0.956^{NS}
Total mango sales (THB)	308,003 (531,664) (n = 47)	270,652 (410,720) (n = 46)	0.706^{NS}
Mango sales per ha (THB)	66,088 (70,946) (n = 47)	114,612 (11,604) (n = 46)	0.002***

Note: *** $p < 0.01$, * $p < 0.10$, NS = not significant, standard deviation and number of observations n (for items that fall short of the complete sample N) are given in parentheses for continuous variables. One THB was equal to approximately 0.03 USD.

3.2. Farmers' Adoption of Q-GAP

In both areas, the primary motive for certified farmers to apply for Q-GAP was "to sell mangoes in a better way" (28.2% for Phitsanulok and 33.8% for Chiang Mai), which means selling more mangoes, selling at better prices, or both (Figure 2). This was followed by "to sell mangoes for export" (16.9% for Phitsanulok and 24.7% for Chiang Mai). Combined with the relevant motive "to follow the group policy for export" (5.6% for Phitsanulok and 9.1% for Chiang Mai), the motives relating directly to economic purposes accounted for 50.7% in Phitsanulok and 67.6% in Chiang Mai. The relatively high emphasis on economic motives in both areas made sense as the mango sales in these two areas catered primarily to the export markets. Meanwhile, the motives related to product quality/safety assurance accounted for 25.4% in Phitsanulok (15.5% for safety assurance and 9.9% for product quality assurance) and 27.3% in Chiang Mai (16.9% for product quality assurance and 10.4% for safety assurance).

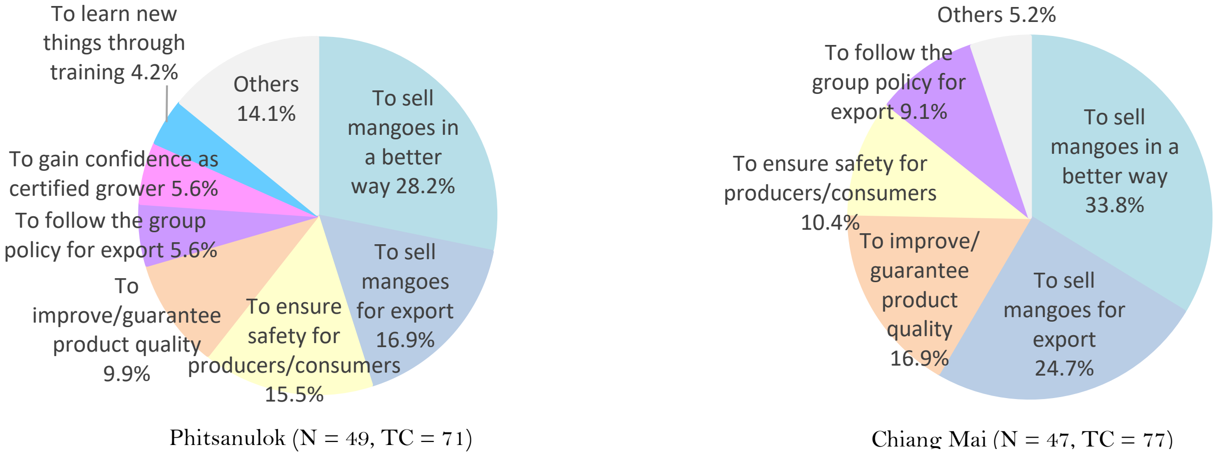

Figure 2. Surveyed farmers' motives to apply for Q-GAP.
Note: N signifies the total number of respondents. TC indicates the total number counted in multiple answers.

The respondent farmers were also asked about the benefits of Q-GAP certification based on their participation in the public food safety program. In both areas, the three most frequently cited benefits were economic, including "access to markets is guaranteed," "can sell mangoes at better prices," and "can sell mangoes to export markets." Collectively, they accounted for 48.7% in Phitsanulok and 57.3% in Chiang Mai (Figure 3). These results appear to be consistent with the economic motivations described above. Another notable result was that "improved agrochemical use," which was not included in the motivation query, was the fourth most frequently cited benefit in both areas (11.5% in Phitsanulok and 10.7% in Chiang Mai). Accordingly, in both areas, the ratios of benefits allocated to the assurance of product quality and safety were lower than in the case of motivation. Additionally, two farmers in Phitsanulok noted they obtained no benefits.

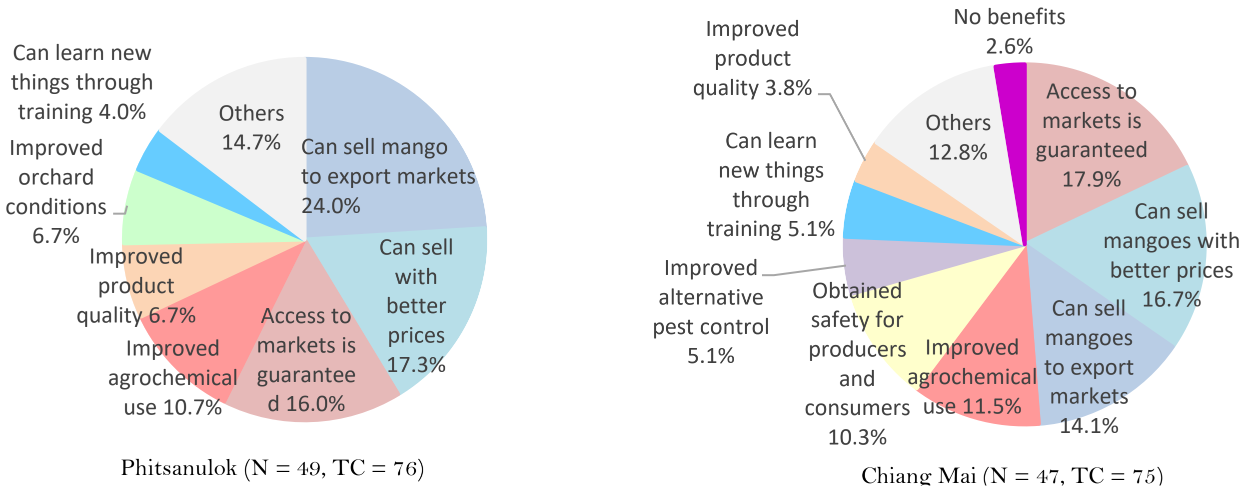

Figure 3. Certified farmers' views about the benefits of Q-GAP certification.
Note: N signifies the total number of respondents. TC indicates the total number counted in multiple answers.

3.3. Farmers' Perceptions of GAP Policy and Pesticide Use

A critical concern regarding the effective implementation of a GAP policy related to the extent to which certified farmers understood the goal of the GAP policy. The proportion of farmers demonstrating such an understanding was significantly lower in Phitsanulok than in Chiang Mai ($p < 0.01$) (Table 3). The farmers' rates of understanding in both areas were remarkably low (59.6% in Chiangmai and 24.5% in Phitsanulok), considering that previous studies on the TAS 9001–2013 version of the Q-GAP code of practice identified understanding levels of approximately 90% among the certified cabbage farmers in Chiang Mai province (Amekawa et al., 2021) and the certified durian farmers in Chanthaburi and Nakhon Si Thammarat (Amekawa et al., 2022). The proportion of farmers who knew of the GlobalGAP standard was significantly higher in Chiang Mai than in Phitsanulok ($p < 0.10$).

Table 3. Farmers' perceptions of Q-GAP policy and pesticide use.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Can relate the goal of Q-GAP policy to food safety assurance (1 = yes)(%)	24.5	59.6	0.000***
Know of GlobalGAP (1 = yes)(%)	20.4	36.2	0.088*
Think that pesticides are not very harmful to users' health when appropriately managed (1 = yes)(%)	61.2	68.1	0.506^{NS}
Think that pesticides are not very harmful to the health of consumers when appropriately managed (1 = yes)(%)	69.4	97.9	0.000***
Think that pesticides are not very harmful to the environment when appropriately managed (1 = yes)(%)	46.9	68.1	0.037**
Think that sufficient assistance has been received from local government agencies to obtain good agricultural technologies and practices (1 = yes)(%)	49.0	31.9	0.091*

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, NS = not significant.

The farmers were also asked about their views on the adverse impact of pesticide use when it was appropriately managed concerning the following three affected objects: users' health, consumers' health, and the environment. The results revealed a significantly more optimistic perspective of farmers in Chiang Mai than of those in Phitsanulok regarding the effects of pesticide use on consumer health and the environment ($p < 0.05$), but no significant difference regarding the impact on the health of pesticide users. Given the very limited understanding of the purpose of the Q-GAP policy in Phitsanulok, the results may imply that farmers in Phitsanulok were not very confident about the effects of their pesticide use but were deliberately cautious about the possible effects. Additionally, a significantly higher proportion of farmers in Phitsanulok compared to those in Chiang Mai felt that they had received sufficient assistance from local government agencies to obtain good agricultural technologies and practices ($p < 0.10$).

3.4. Farmers' Training Experience

There was no significant difference in farmers' experience of public training in pesticide use (Table 4). The proportion of mango farmers with experience was as high as nearly 90% in both sites. Among those who had such experience, the farmers in Phitsanulok had received significantly more training days than those in Chiang Mai ($p < 0.05$). A significantly higher proportion of farmers in Phitsanulok had participated in public GAP training (77.6%) in comparison to those in Chiang Mai (61.7%) ($p < 0.10$), with the former having significantly more training days than the latter ($p < 0.05$). The farmers were also questioned regarding their knowledge and training experience related to IPM and the production and use of organic fertilizers through governmental agencies. No significant differences were observed for these items.

Table 4. Public training experience.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Training experience in pesticide use through governmental agencies (1 = yes)	89.7%	87.2%	0.694^{NS}
Number of training days for pesticide use	2.18 (0.95) ($n = 44$)	1.72 (1.12) ($n = 41$)	0.043**
Training experience in Q-GAP certification through governmental agencies (1 = yes)	77.6%	61.7%	0.091*
Number of training days for Q-GAP certification	1.82 (1.23) ($n = 36$)	1.18 (0.48) ($n = 28$)	0.011**
Knowledge of the term "IPM" (1 = yes)	61.2%	48.9%	0.426^{NS}
Training experience in IPM through governmental agencies (1 = yes)	49.0%	38.3%	0.851^{NS}
Training experience in the production and use of organic fertilizer through governmental agencies (1 = yes)	69.4%	74.5%	0.297^{NS}

Note: ** $p < 0.05$, * $p < 0.10$, NS = not significant, standard deviation and number of observations n (for items that fall short of the complete sample N) are given in parentheses for continuous variables.

3.5. Experiences of Farm Audit

The mean number of Department of Agriculture (DoA) audits that were needed for farmers to receive their most recent Q-GAP certification for mango was slightly over 1.5 in both areas (Table 5). This implies that roughly two out of three applicant farmers failed the first audit. The mean length of the first audit was nearly 15 minutes longer for farmers in Chiang Mai than for those in Phitsanulok, though the difference was not statistically significant.

In the GAP certification in general, farmers are not supposed to receive advance notice of the date of the auditor's visit so they cannot prepare for an audit. However, from the viewpoint of the auditors, visiting farmers without prior notice makes auditing less efficient, for farmers may not be at home at the time of the audit visit. No significant differences were identified regarding the presence or absence of DoA officers' prior contact with the farmers regarding the date of their first visit. Meanwhile, a significantly higher proportion of farmers in Phitsanulok than in Chiang Mai noted that the DoA officers checked their record-keeping documents at the time of the audit ($p < 0.1$).

Table 5. Experiences of farm audit.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Number of DoA audits needed to receive Q-GAP certification	1.57 (0.79)	1.52 (0.81) (*n* = 46)	0.763^{NS}
Length of audit (minutes)	36.25 (34.57) (*n* = 48)	51.14 (69.38) (*n* = 46)	0.188^{NS}
Received prior notice of the date of the first audit (1 = yes)	73.5%	78.3%	0.586^{NS}
Record-keeping of agricultural practices was checked during the audit (1 = yes)	83.7%	68.1%	0.074*
Provided mango for pesticide residue test (1 = yes)	79.6%	93.6%	0.045**
DoA officer picked the mangoes for pesticide residue test (1 = yes)	42.1%	22.7%	0.060*

Note: ** $p < 0.05$, * $p < 0.10$, NS = not significant; standard deviation is given in parentheses for continuous variables. The number of samples is indicated as *n* in parentheses for items that fall short of the complete sample N.

The respondents were asked whether they provided the auditors with mango samples at the time of the audit for pesticide residue analysis, and if they did, who picked the mango samples. In principle, the crop samples should be selected from the field by the auditors themselves, so that the applicant farmers are not in a position to prepare for the selection of the least pesticide-contaminated crop sample for the residue test. A significantly higher proportion of the farmers in Chiang Mai provided mango samples compared to those in Phitsanulok ($p < 0.01$). In Chiang Mai, 77.3% of the farmers picked the mangoes themselves, which was a significant difference from the farmers in Phitsanulok, although nearly 57.9% of the latter farmers also picked the mangoes. These results were significantly higher than those of the previous studies on cabbage in Chiang Mai (9.2%) (Amekawa et al., 2021) and on durian in Chanthaburi (4.0%) and Nakhon Si Thammarat (31.3%) (Amekawa et al., 2022).

3.6. Synthetic Pesticide Use

The adoption of synthetic insecticides was significantly higher among the farmers in Chiang Mai than those in Phitsanulok, although no significant differences were observed for fungicides or herbicides (Table 6). Regarding the percentage change in the amount of pesticides used after certification, the farmers in Phitsanulok reported a larger reduction in the use of all three types of pesticides, but the differences were not statistically significant.

Table 6. Synthetic pesticide use.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Adoption of synthetic insecticides (1 = yes)	91.8%**	100.0%	0.045**
Change in the amount of liquid synthetic insecticides used among the users after certification (percentage)	−18.3% (*n* = 42)	−10.1% (*n* = 42)	0.188^{NS}
Adoption of synthetic fungicides (1 = yes)	91.8%	97.9%	0.183^{NS}
Change in the amount of synthetic fungicides used among the users after certification (percentage)	−15.4% (*n* = 35)	−7.7% (*n* = 42)	0.207^{NS}
Adoption of synthetic herbicides (1 = yes)	83.7%	85.1%	0.847^{NS}
Change in the amount of synthetic herbicides used among the users after certification (percentage)	−11.3% (*n* = 39)	−2.1% (*n* = 33)	0.195^{NS}

Note: ** $p < 0.05$; NS = not significant. The number of samples is indicated as *n* in parentheses for items that fall short of the complete sample N.

3.7. Use of Non-Synthetic Pest Control Methods

No significant difference in the farmers' adoption of non-synthetic pest control methods was identified between the two areas (Table 7). Regarding the comparison of individual methods, of the nine methods identified, a significantly higher proportion of the farmers in Chiang Mai adopted biological insecticide in comparison to those in Phitsanulok ($p < 0.05$). Meanwhile, a significantly higher proportion of the farmers in Phitsanulok were found to mow weeds compared to those in Chiang Mai ($p < 0.10$). No significant differences were found for the other seven methods.

Table 7. Use of non-synthetic pest control methods.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
Adopt at least one non-synthetic pest management method (1 = yes) (%)	57.1	55.3	0.857^{NS}
Adoption of			
Wood vinegar (as botanical insecticide) (1 = yes)(%)	8.2	19.1	0.116^{NS}
Herbal insecticide (1 = yes)(%)	10.2	6.4	0.553^{NS}
Biological insecticide (1 = yes)(%)	22.4	4.3	0.025**
Insect glue trap (1 = yes)(%)	14.3	10.6	0.589^{NS}
Removing insects by hand (1 = yes)(%)	2.0	0.0	0.325^{NS}
Wrapping crops in plastic bags (1 = yes)(%)	2.0	6.4	0.287^{NS}
Smoking (as insect repellent) (1 = yes)(%)	2.0	2.1	0.976^{NS}
EM pesticide (1 = yes)(%)	6.1	8.5	0.653^{NS}
Mowing weeds (1 = yes)(%)	6.1	0.0	0.085*

Note: ** $p < 0.05$, * $p < 0.10$, NS = not significant.

3.8. Record-Keeping

No significant differences between the two areas were identified in the record-keeping of the pest control measures (Table 8). However, it is worth noting that the level of mango farmers' record-keeping of synthetic pesticides in both areas was relatively higher than that of farmers in previous studies; the rates of record-keeping for the equivalent items of certified cabbage farmers in Chiang Mai were 0-64.0% (Amekawa et al., 2021), those of the certified durian farmers in Chanthaburi were 65.2-69.7%, and those in Nakhon Si Thammarat were 2.4-11.1% (Amekawa et al., 2022).

Table 8. Record-keeping.

Variable Description	Phitsanulok	Chiang Mai	p-value
Synthetic insecticide (1 = yes)	84.4% (*n* = 45)	93.6% (*n* = 47)	0.158^{NS}
Synthetic fungicide (1 = yes)	95.7% (*n* = 46)	87.0% (*n* = 46)	0.139^{NS}
Synthetic herbicide (1 = yes)	69.8% (*n* = 42)	80.0% (*n* = 40)	0.284^{NS}
Non-synthetic pest management methods (1 = yes)	62.1% (*n* = 29)	65.4% (*n* = 26)	0.799^{NS}

Note: NS = not significant. The number of samples is indicated as *n* in parentheses for items that fall short of the complete sample N.

3.9. Pesticide Safety and Handling Practices

Regarding the pesticide safety and handling practices in the two regions, Item 10 and Item 13 showed a significant difference, both in favor of farms in Chiang Mai (Table 9). In both areas, Item 9 (documentation of re-entry intervals) and Item 11 (availability of maximum residue limit (MRL) information regarding the destination countries) had less than 50% compliance.

Table 9. Agrochemical safety and handling practices.

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
1. Aware of the chemicals registered under the Hazardous Substances Act and its amendments (1 = yes)	75.5%	68.1%	0.419^{NS}
2. Possession or use of pesticides prohibited under the Hazardous Substances Act and its amendments (1 = yes)	14.3%	17.4% (*n* = 46)	0.678^{NS}
3. Wearing all the protective clothing (mask, gloves, hats, and boots) while working with pesticides (1 = yes)	83.7%	93.6%	0.126^{NS}
4. Storing pesticides in a tidy manner in the specified secure storage to prevent mishandling (1 = yes)	95.9%	100.0%	0.162^{NS}
5. Taking note of the wind direction while spraying to prevent the contamination of the neighborhood farms and environment (1 = yes)	91.8%	97.9%	0.183^{NS}
6. Stopping the application of pesticides before harvest following the withdrawal period indicated on the label of each pesticide or the official recommendations (1 = yes)	93.9%	91.5%	0.653^{NS}
7. Separating the storage of farming equipment, containers, and materials from the storage of pesticides or other chemicals (1 = yes)	89.8%	87.2%	0.694^{NS}
8. Specifying the trade name and active ingredient in the records of pesticide application (1 = yes)	59.2%	74.5%	0.112^{NS}

Variable Description	Phitsanulok (N = 49)	Chiang Mai (N = 47)	p-value
9. Carrying out clearly documented procedures dealing with re-entry intervals on the farm for pesticide application (1 = yes)	26.5%	25.5%	0.911[NS]
10. Possessing the facilities to deal with accidental operator or contamination, which include a source of clean water that is at a distance of no more than 10 meters, a complete first aid kit, and a clear accident procedure with emergency contact telephone numbers (1 = yes)	53.1%	74.5%	0.029**
11. Able to demonstrate that the information regarding the country(ies) of destination's (i.e., market in which the producer intends to trade, including domestic) Maximum Residue Levels (MRLs) is available with a list of MRLs for each country (1 = yes)	40.8%	42.6%	0.863[NS]
12. Rinsing empty containers either via the use of the pressure rinsing device integrated with the pesticide application equipment or at least three times with water (1 = yes)	63.3%	61.7%	0.874[NS]
13. Keeping the pesticide storage facilities secure with a lock and key (1 = yes)	63.3%	78.7%	0.096*
14. Allowing harvest workers access to clean toilets in the vicinity of their farm work (500 meters or 7 minutes) so that they can minimize potential product contamination (1 = yes)	83.0%	83.0%	0.178[NS]

Note: ** $p < 0.05$, * $p < 0.10$, NS = not significant. The number of samples is indicated as *n* in parentheses for items that fall short of the complete sample N.

4. CONCLUSIONS

Several items of the comparison showed no significant difference between the two areas with similar export-oriented mango production contexts. However, one significant difference worth mentioning relates to the farmers' ability to link the goal of the Q-GAP policy to food safety assurance; approximately 35% more farmers in Chiang Mai than in Phitsanulok demonstrated such an understanding. This contradicts the finding that the farmers in Phitsanulok had more experience and days of training on Q-GAP than those in Chiang Mai; the quality of training on Q-GAP is a crucial factor in this regard. Moreover, the rates in both areas were significantly lower than those identified in previous Q-GAP studies of less export-oriented crops. Mango farmers might be inclined to regard Q-GAP certification more as a type of export license for their mango produce rather than as a tool to improve their food safety and quality assurance.

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APPENDIX A.

Table A1. Adoption of national public GAP standards by farmers in ASEAN nations.

Country	Program Name	Year of Formulation	Number of Farmers with Certified Status (Year)	Scheme Owner
Malaysia	MyGAP	2002	664 (2016)	Department of Agriculture
Thailand	Q-GAP	2003	>146,000 (2021)	National Bureau of Agricultural Commodity and Food Standards
Singapore	SingaporeGAP-VF	2004	8 (2020)	Agri-Food and Veterinary Authority
Indonesia	IndoGAP	2004	13,666 (n/a)	National Food Safety Competent Authority
The Philippines	PhilGAP	2005	82 (2016)	Department of Agriculture
Vietnam	VietGAP	2008	1574 (2014)	Ministry of Agriculture and Rural Development
Myanmar	MyanmarGAP	2009	0 (2015)	Department of Agriculture
Laos	LaoGAP	2010	300 (2016)	Department of Agriculture
Cambodia	CamGAP	2010	0 (2017)	Department of Sanitary and Phytosanitary Plants Protection
Brunei	BruneiGAP	2014	4 (2019)	Agriculture and Agrifood Department

Source: MyGAP: obtained via personal contact to the responsible agency in Malaysia; Q-GAP: Department of Agriculture Thailand (2021); SingaporeGAP-VF: Singapore Food Agency (2020); PhilGAP, VietGAP, MyanmarGAP, and LaoGAP: GAP Research Institute (2020); IndoGAP: Food and Agricultural Organization of the United Nations (2016) and GAP Research Institute (2020), LaoGAP: Khoenram (2016) and BruneiGAP: Wasil (2019). n/a not available.

Agronomic overview of mango

Known as the "king of fruits" (Singh, 2016), mangoes (*Mangifera indica Linn.*) originated in the Indo-Myanmar region (Chomchalow & Songkhla, 2018). Mangoes have a cultivation history of 400 years (Chomchalow & Songkhla, 2018). The leading mango-producing nations are India, China, Thailand, Indonesia, and Pakistan (Tiyayon & Paull, 2017). While the mango cultivation in Thailand takes places round the year, the harvesting period rotates from the central to the northeastern to the northern and to southern regions, depending on the longitude and latitude (Sangwanangkul, 2015). As many as 172 cultivars have been documented in Thailand, of which about ten are grown commercially. The major cultivars are "Nam Dok Mai," "Maha Chanok," "Chok Anant," and "Khiao Sawoei" (Chomchalow & Songkhla, 2018). As the third largest mango producer and exporter, Thailand produced 474,111 tons in an area of 549,357 ha in 2020 (Office of Agricultural Economics, 2022a) and exported 116,850 tons with an export value of 3,367 million THB in 2021 (Office of Agricultural Economics, 2022b).

Certification of Q-GAP standard

TAS 9001–2013, the latest Q-GAP protocol, accommodates eight areas of regulation involving 23 "Major Must" control points, 41 "Minor Must" control points, and 52 "Recommended" control points, amounting to a total of 116 control points (see Table A2). The "Major Must" control points require 100% compliance, and the "Minor Must" control points require 60% compliance; however, no compliance is necessary for the recommended control points (National Bureau of Agricultural Commodity and Food Standards, 2013). The requirements of the 2013 version fall short of the more stringent GAP standards. For instance, Malaysia's MyGAP comprises 29 "Major Must" control points (100% compliance required), 77 "Minor Must" control points (90% compliance required) and 57 "Encouraged" control points (no compliance required) of the 163 total control points (Department of Agriculture Malaysia, 2005).

The current protocol involves three years of a valid certification, extended from the two-year period of previous protocols. When a certification is about to expire, a farmer must apply for a new certification 120 days before the expiry date of his/her previous certification to sustain his/her certified status. In order to gain certification, an applicant farmer's farming systems and practices have to be audited by the DoA auditors one to three times within the year of application. Auditors collect samples of growing crops and soils from the farms of the applicant and haul them to a regional center for the laboratory tests on pesticide residue conditions to determine whether and how much residue could be detected. If an excessive amount of pesticide residue is detected, the applicant farmer will fail to pass the application at the time. If the applicant farmer fails to pass all the three instances of an audit, the applicant farmer is not allowed to reapply for a year.

In order for farmers to apply for and obtain certification, it is not mandatory for them to receive a public training on Q-GAP. Hence, farmers can pass the Q-GAP certification without public training, provided that their farming conditions and practices meet the required standards. However, the rate of participation may be influenced by the level of facilitation or encouragement of local DoA/DoAE officers.

Table A2. Control points in the Q-GAP code of practice.

Control Categories	Major Must	Minor Must	Recommended	Subtotal
1. Water	5	2	7	14
2. Planting area	4	4	3	11
3. Pesticides	5	8	8	21
4. Pre-harvest quality management	2	6	11	19
5. Harvest and post-harvest handling	3	6	5	14
6. Holding, moving the produce in the planting plot and storage	0	5	4	9
7. Personal hygiene	1	3	4	8
8. Record-keeping	3	7	10	20
Subtotal:	23	41	52	Total: 116

Source: National Bureau of Agricultural Commodity and Food Standards (2013).