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Management based on POLC framework to promote the adoption and use of beneficial bacterium Bacillus megaterium for growers in Thailand

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Abstract

Empowering the groups of people and organizations involves 1) planning, 2) organizing, 3) leading, and 4) controlling. This four-step process is called POLC framework which will be applied to manage the group of growers in Thailand. There are four main stakeholders, such as target growers, local agricultural staffs, sub-district headmen, and researchers. In this study, there are nine target growers, three local agricultural staffs, two sub-district headmen, and four researchers who have participated in the project to promote the adoption and use of beneficial bacterium Bacillus megaterium in horticultural crops, such as vegetables and fruits, based on POLC management framework in two provinces, Uttaradit and Phetchaburi. A purposive sampling technique was used to select these nine growers. The interview was conducted using in-depth interview and focus group from January to December 2019. The data from the in-depth interview and the focus group were used to score the

relative role of each stakeholder in the project and describe the key activities in which each stakeholder must carry out under POLC framework accordingly. Based on the score of relative role of each stakeholder, the target growers played the most active leading role. The score also corresponded with the number of the key activities. The local agricultural officers are the “change agent”, while the researchers are the catalyst assisting the “change agent”. The sub-district headmen are the facilitator of the project. For a project to succeed, there must be a common understanding of the plan, stakeholder roles, and approach to management of the process.

Author keywords

Bacillus megaterium; fungal diseases in vegetable crops; management; POLC framework

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ISHS

Proceedings of the IX International Scientific and Practical Conference on Biotechnology as an Instrument for Plant Biodiversity Conservation (physiological, biochemical, embryological, genetic and legal aspects)

Editors *K. Thammasiri, P. Kongsawadworakul and H.W. Pritchard*

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Bangkok, Thailand

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Photograph on the front cover*:*
Ascocentrum miniatum (Lindl.) Schltr. is an orchid species, native to Himalayas to Thailand, Malay Peninsular and Java. The miniature plant size and the multiple upright racemes of brilliant yellow-orange flowers have made it the most frequently grown and hybridized with vandaceous orchid genera to create small, bright colored plants that are easy to handle in small areas. It grows well in warm or warm-intermediate temperatures. Courtesy of Kanchit Thammasiri.

IX International Scientific and Practical Conference on Biotechnology as an Instrument for Plant Biodiversity Conservation (physiological, biochemical, embryological, genetic and legal aspects)

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FOREWORD

The IX International Scientific and Practical Conference on Biotechnology as an Instrument for Plant Biodiversity Conservation (physiological, biochemical, embryological, genetic and legal aspects) (Biotech 2021) was successfully held on July 12-13, 2021 in Bangkok, Thailand. The conference was organized as a virtual conference due to COVID-19 pandemic by the Department of Plant Science, Faculty of Science, Mahidol University, under the auspices of the International Society for Horticultural Science (ISHS) and with the support of the Department of Agriculture.

The conference attracted 108 participants which included presenters, staff, researchers, and government agents from 17 countries around the world (Belgium, Brazil, China, Germany, India, Indonesia, Japan, Malaysia, Myanmar, Nepal, Portugal, Russia, Thailand, Turkey, United Kingdom and USA), who shared their knowledge and experiences on a wide range of topics in biotechnology of plant biodiversity conservation.

There were two days (July 12 and 13) of scientific program. The presentations were divided into seven sessions, namely Plant Diversity Conservation, Cryopreservation, Breeding, Micropropagation, Physiology and Production, Plant Molecular Research, and Plant Protection. All oral and poster presentations were of interest to participants, who responded and shared knowledge and experiences with questions, suggestions, and discussion online.

In recognition of the outstanding work of Ph.D. graduate students, two ISHS Young Minds Awards were presented to Mr. João Martins, Ph.D. student at the Center for Functional Ecology, University of Coimbra, Portugal, for the best student oral presentation, entitled "Chemotyping and in vitro conservation of strawberry tree *Arbutus unedo* L., *Ericaceae*" and Mr. Possathorn Nopun, Ph.D. student at the Department of Plant Science, Faculty of Science, Mahidol University, Thailand, for the best student poster presentation, entitled "Micromorphology and histochemistry on lip of *Orchidantha foetida* (*Lowiaceae*)".

I would like to thank the International Society for Horticultural Science for overall help, staffs and students from the Department of Plant Science and Faculty of Science, Mahidol University for all hosted events, co-organizers and committee for their support, keynote speakers and all participants for their valuable contribution, and the Editorial Board for their efforts in producing this volume of *Acta Horticulturae*.

K. Thammasiri
Convener and Editor

PREFACE

The papers contained in this volume of *Acta Horticulturae* report the scientifically reviewed Proceedings of the IX International Scientific and Practical Conference on Biotechnology as an Instrument for Plant Biodiversity Conservation (physiological, biochemical, embryological, genetic and legal aspects). Keynote speakers and authors of selected contributed oral and poster presentations were given the opportunity to submit a manuscript for publication.

The manuscripts were reviewed by the Editors and members of the Editorial Board. Only those papers judged suitable for publication following the authors' consideration of reviewer suggestions appear in this volume of *Acta Horticulturae*.

The ISHS acknowledges and appreciates the contribution of all editors and reviewers. They have made a significant contribution to improving the quality of this publication.

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Management based on POLC framework to promote the adoption and use of beneficial bacterium *Bacillus megaterium* for growers in Thailand

D. Kanjanamaneesathian[1,a] and M. Kanjanamaneesathian[2]

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Abstract

Empowering the groups of people and organizations involves 1) planning, 2) organizing, 3) leading, and 4) controlling. This four-step process is called POLC framework which will be applied to manage the group of growers in Thailand. There are four main stakeholders, such as target growers, local agricultural staffs, sub-district headmen, and researchers. In this study, there are nine target growers, three local agricultural staffs, two sub-district headmen, and four researchers who have participated in the project to promote the adoption and use of beneficial bacterium *Bacillus megaterium* in horticultural crops, such as vegetables and fruits, based on POLC management framework in two provinces, Uttaradit and Phetchaburi. A purposive sampling technique was used to select these nine growers. The interview was conducted using in-depth interview and focus group from January to December 2019. The data from the in-depth interview and the focus group were used to score the relative role of each stakeholder in the project and describe the key activities in which each stakeholder must carry out under POLC framework accordingly. Based on the score of relative role of each stakeholder, the target growers played the most active leading role. The score also corresponded with the number of the key activities. The local agricultural officers are the "change agent", while the researchers are the catalyst assisting the "change agent". The sub-district headmen are the facilitator of the project. For a project to succeed, there must be a common understanding of the plan, stakeholder roles, and approach to management of the process.

Keywords: management, POLC framework, *Bacillus megaterium*, fungal diseases in vegetable crops

INTRODUCTION

Thailand has gained foreign currency from exporting agricultural produce to the countries in the Asean Economic Community (AEC), Japan, People's Republic of China (PRC), the European Union, and USA with a surplus of the trade in agricultural commodity around $ 5 billion dollars. The income from trading agricultural commodity with these partners signifies the importance of agricultural sector for Thailand. Agriculture is also the main source of labor force with around 30% from 6.4 households, working in this sector (Office of Agricultural Economics, 2019). Due to the significance of agriculture, major efforts have been made to improve the quality of production in agriculture.

The Department of Agriculture (DOA) and Department of Agriculture and Extension (DOAE), within the Ministry of Agriculture and Agricultural Cooperatives, are the main government agencies that advocate and introduce standard agricultural practices, such as good agricultural practice (GAP) and organic farming, to farmers in Thailand. GAP, which has been developed by the Food and Agriculture Organization (FAO) and universally adopted by many countries, is the practice that addresses the environmental, economic, and social sustainability of on-farm processes, together with the safety and quality of food and non-food

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agricultural products (FAO, 2010).

One measure, that contributes to produce quality agricultural produces, is to replace hazardous chemical pesticides with beneficial microorganisms. There are several beneficial microorganisms which have the capacity to control plant pests, such as *Beauveria bassiana, Metarhizium anisopliae, Bacillus thuringiensis, Trichoderma harzianum*, and *Bacillus subtilis*. *B. bassiana, M. anisopliae,* and *Bacillus thuringiensis* have been recommended for controlling insect pests in fruits and vegetables (Warburton et al., 2002). *T. harzianum* and *Bacillus subtilis* have been applied to control plant diseases in rice, fruits, and vegetables (Maketon et al., 2008). Thai growers can gain access to the products of these beneficial microorganisms from DOA, DOAE, and the private companies (Maketon et al., 2008).

Bacillus megaterium, an effective antagonistic bacterium against plant diseases caused by fungal pathogens, has been promoted to growers in Uttaradit and Phetchaburi. The growers in these provinces have encountered various pests and they have adopted *B. megaterium* to control plant pests to produce their crops based on GAP. To advocate the growers to continue using this bacterium, the researchers and the local agricultural officers, in conjunction with the sub-district headmen, have adhered to the principles of management to implement the project. Four major functions of management, including planning, organizing, leading, and controlling (the POLC framework) (Carpenter et al., 2012) have been adopted by all stakeholders in both Uttaradit and Phetchaburi.

This study aimed to describe the activities of this project implemented under the POLC framework to manage the adoption and use of beneficial bacterium *B. megaterium* for growers in both provinces.

MATERIALS AND METHODS

The study area

The study was carried out in two provinces, such as Uttaradit and Phetchaburi in Thailand. Uttaradit is situated in the northern region of Thailand, bordering Lao People's Democratic Republic. Sirikit Dam is the main source of water for irrigation. In Uttaradit, the studies were focused in five growers (Table 1) in three Districts, such as Mueang, Pichai, and Thong Saen Khan. Two DOAE agricultural officers, each from Pichai and Thong Saen Khan, were the local staffs who engaged proactively in promoting the adoption and use of beneficial bacterium *B. megaterium* for growers in each district.

Table 1. Location and details of crops in which the growers have used *B. megaterium*.

Location and Province	Number of growers	Number of crops (scientific name)
Mueang, Uttaradit	1	Yardlong bean (*Vigna unguiculata*)
	1	Mango (*Mangifera indica*)
	1	Coriander (*Coriandrum sativum*)
Pichai, Uttaradit	1	Yardlong bean (*V. unguiculata*)
Thong Saen Khan, Uttaradit	1	Yardlong bean (*V. unguiculata*)
Ban Lat, Phetchaburi	1	Water convolvulus (*Ipomoea aquatica*)
		Chinese kale (*Brassica oleracea*)
Cha-Am, Phetchaburi	1	Yardlong bean (*V. unguiculata*)
		Cucumber (*Cucumis sativus*)
Khao Yoi, Phetchaburi	1	Angled loofah (*Luffa acutangula*)
Tha Yang, Phetchaburi	1	Banana [*Musa* (AAA group) "Kluai Hom khiew"]
Total	**9**	**8**

Phetchaburi is located in the western region of Thailand, bordering Myanmar in the west, and the Gulf of Thailand in the east. This province is located in an area where farmers can access irrigation water because of the availability of two dams (the Kaeng Krachan dam and the Phetchaburi dam). In Phetchaburi, the studies were focused on four growers (Table 1) in four districts, such as Ban Lat, Cha-Am, Khao Yoi, and Tha Yang. One agricultural officer

from National Farmers Council (NFC), Phetchaburi office communicated rigorously with these growers in promoting the adoption and use of beneficial bacterium *B. megaterium* for growers in each district.

Sampling, sample size, and stakeholders in POLC

A total of nine growers, who were registered with DOAE (Mueang, Pichai, and Thong Saen Khan, in Uttaradit and Ban Lat, Cha-Am, Khao Yoi, and Tha Yang, in Phetchaburi) in 2019-2020, were subjected to the interview used in this study. A purposive sampling technique was used to select these nine growers. The interview was conducted using in-depth interview and focus group from January to December 2019. There were three local agricultural staffs, two from Uttaradit and one from Phetchaburi, who participated in the project. Two local administrative staffs, one from Mueang, Uttaradit and one from Thong Saen Khan, Uttaradit, assisted in facilitating the meeting among all stakeholders. Four researchers, from Silpakorn University, Phetchaburi IT campus, provided knowledge about the bacterium and supplied the inoculum of *B. megaterium* to the local agricultural offices in Uttaradit and Phetchaburi. These 18 participants, representing four stakeholders, were subjected to the POLC framework of this project.

Data analysis

The primary data from the in-depth interview and the focus group was used to both score the relative role of each stakeholder in the project and describe the key activities in which each stakeholder must carry out under POLC framework accordingly.

Techniques associated with the production of *B. megaterium* to introduce to the participating growers and the local agricultural staffs

The simple technique to produce the fresh cells of *B. megaterium* (Kanjanamaneesathian and Meetum, 2017) is the key element to facilitate the adoption and use of beneficial bacterium *B. megaterium* for growers in this study. *B. megaterium* was recommended to culture in a translucent (20 L) plastic drinking water tank using a common household flavour enhancer (CHFE (Knorr brand, Unilever, Thailand)) as nutrient in a tank containing 10 L of clean drinking water. Ten mL of *B. megaterium*, as bacterial inoculum (1×10^9 CFU g^{-1}) supplied to the local agricultural offices by the researchers, were added to each tank. The culture was aerated using an aquarium air pump and the air tube entered the tank through a cotton wool plug to prevent contamination. The culture was incubated at room temperature (25-32°C) for 3 days until used by the growers.

This fresh cell culture of *B. megaterium*, which had been produced by the growers, was recommended to add to the clean water (v/v at 1:10 proportion) before the bacterial cell suspension was used to either soak the seeds or spray the crops to suppress plant diseases (Kanjanamaneesathian and Meetum, 2019; Kanjanamaneesathian and Nimanong, 2019).

Framework to manage the adoption and use of *B. megaterium* for growers

The POLC (planning, organizing, leading, and controlling) (Carpenter et al., 2012) framework was applied to manage the adoption and use of *B. megaterium* by growers in these two provinces.

Planning includes building proper mission and having a good vision. This step was done by the active discussion among the target growers, local agricultural staffs in each province, and the researchers, as well as the sub-district headmen. This is to ensure that the goals and objectives of the adoption and use of *B. megaterium* are accomplished.

Organizing involves the determination of responsibility among the target growers, local agricultural staffs, the sub-district headmen in each province, and the researchers. It also includes allocating financial resources and other logistics to ensure the accomplishment of objectives in promoting the adoption and use of this bacterium.

Leading involves the establishment of field trials to showcase the efficacy of *B. megaterium* to control plant pests and promote plant growth in the growers' farms. This step is to let the selected target growers to motivate the other neighboring growers to adopt and

use *B. megaterium*.

Controlling involves the activities to ensure that the growers comply with the recommendations given to them by both the local agricultural staffs in each province and the researchers on how to use the bacterium effectively. These growers should be empowered to continue using *B. megaterium* in producing their crops. The learning centers will be established in these farms whose owners will disseminate the knowledge about *B. megaterium* to other growers.

RESULTS AND DISCUSSION

The results of promoting the growers to adopt and use *B. megaterium* based on the POLC framework were presented (Table 2). Based on the score of relative role of each stakeholder, the target growers played the most active leading role in all components of the framework, followed by local agricultural officers, researchers, and sub-district headmen (Table 2). The score of relative role of each stakeholder also corresponded with the number of the key activities in which each stakeholder must carry out (Table 3). For instance, the target growers, who received 3+ in all components of the framework, must be responsible in carrying out at least five key activities for planning (P), organizing (O), and leading (L) and four key activities for controlling (C) (Table 3). This indicates that the target growers are willing to take risks and change their behaviors, by either partially or completely replacing the chemical pesticides with *B. megaterium*. The success of the project can be traced to specific single individuals or group who had an extra-ordinary impact on the project (Boettiger et al., 2017).

Table 2. Score of relative role of each stakeholder in the project to adopt and use *B. megaterium* based on POLC framework.

Stakeholder	Component of framework			
	Planning (P)	Organizing (O)	Leading (L)	Controlling (C)
	Relative role of each stakeholder[a]			
Target growers	+++	+++	+++	+++
Local agricultural officers	+++	+++	++	+++
Sub-district headmen	+	+	+	-
Researchers	+++	+	++	++

[a]+++ indicates the most active leading role, ++ indicates the moderate role and + indicates the least role in each component of framework.

Although, the growers play a major leading role in adopting and using the bacterium, they must receive support from other stakeholders, such as the local agricultural officers, the sub-district headmen, and the researchers. The local agricultural officers, who received 3+ in three components (P,O,C) and 2+ in one component (L), can be identified as the "change agent". They are the staffs who interact actively and regularly with the growers and the growers trust them. As a result, they are capable of assisting the growers to adopt and use the innovation (Boettiger et al., 2017). Without this "change agent" as the stakeholder, it will be very difficult to achieve the goals and objectives of the project.

Likewise, achievement of the key tasks of local agricultural officers shall be attained when they receive collaboration from the other stakeholders, such as the target growers, sub-district headmen, and researchers. Thus, the coordination, collaboration, and commitment among each stakeholder are the key issues in managing the adoption and use of *B. megaterium* in the farms. In addition, commitment from the DOAE and other agricultural agencies is required to ensure that there will be a policy and a practical plan to promote the use of *B. megaterium* in other provinces. With the political and financial support, this kind of project has a high likelihood of being implemented nationwide (Boettiger et al., 2017).

Table 3. Key activities in which each stakeholder must carry out under POLC framework.

Stakeholder	Component of framework			
	Planning (P)	Organizing (O)	Leading (L)	Controlling (C)
Target Growers	• Make a decision to participate in the project • Determine the type of the crops they will use the bacterium to control pests • Determine when they will start growing crop • Determine the size of the field plot used • Determine the number of the growing seasons that they will use the bacterium	• Prepare the fields for producing crops • Prepare propagating materials (seeds/seedlings) • Prepare farm equipment, fertilizers and pesticides • Learn how to prepare and use the bacterium appropriately • Prepare the equipment for applying the bacterium	• Contact the local agricultural offices to acquire the bacterial culture • Prepare the diluted bacterial suspension for use • Apply the prepared bacterial suspension to the crops • Assess the efficacy of the bacterial treatments • Report the efficacy of the bacterial treatment to the local agricultural officers	• Attend the focus group to conclude the project • Volunteer to serve as local expert • Establish the learning center to disseminate the knowledge • Prepare to uptake other knowledge and technologies
Local agricultural officers	• Identify the target growers who will participate in the project • Identify the target crops that will receive the bacterial treatment • Update the junior staffs in the office about the project • Prepare the facility in the office to cope with the production of the bacterial culture for the growers	• Organizing the meeting to train the target growers • Coordinate with the researchers to prepare the bacterial culture for the growers • Coordinate with the growers to determine the efficacy of the bacterial application • Prepare the bacterial cultures for the target growers	• Monitor and advise the growers who have used the bacterium • Collect and send the samples of the treated crops to the researchers for evaluating the efficacy in the laboratory • Prepare the facility in the office to cope with the increased demand of the bacterium	• Facilitate the focus group • Record the data about the growers, crops, how the bacterial suspension was applied and whether this application has any impacts to crops • Compile the data about other growers who have come to receive the bacterial cultures for use but they do not directly participate in the project
Sub-district Headmen	• Facilitate the meeting and encourage the significant of producing crops based on GAP	• Facilitate the meeting among the stakeholders • Facilitate the training session	• Facilitate the meeting to showcase the efficacy of the bacterial application	• None
Researchers	• Layout the goals and the objectives of the project • Prepare the timeline for the activities of the project from the beginning until the end • Prepare the content for training about the application of the bacterium • Coordinate the activities among all stakeholders such as the researchers in the laboratory, the local agricultural staffs and growers • Prepare inoculum of the bacterium to deliver to local agricultural offices	• Monitor the development of the project • Check the purity of the bacterial culture	• Visit the farms to provide technical advice to the growers • Visit the local agricultural to learn about various issues associated with the production of the bacterial cultures for the growers • Arrange the training to showcase the efficacy of the bacterial application	• Discuss with other stakeholders on both positive and negative impacts of the bacterial application to crops • Plan new research topics which address the shortcoming of the recent completed project

The researcher acts as catalyze in assisting the “change agent” both to accelerate the uptake of adoption and to use of the bacterium by the growers. They worked on developing the simple technique to culture the bacterium (Kanjanamaneesathian and Meetum, 2017) at the local agricultural offices. With this simple technique and the liquid inoculum of the

bacterium, the local agricultural officers will produce the bacterial culture at the offices. The target growers will come to collect the bacterial culture and will use it to make the final bacterial cell suspension for use in their farms. The smooth and efficient workflow is another key issue which can impact the implementation of the project. Technically, the liquid bacterial inoculum (produced from the laboratory), the bacterial culture (prepared at the local agricultural offices), and the bacterial cell suspension (prepared by the target growers before use) must not be contaminated during the transportation, preparation, and use. If contamination occurs to the bacterium during these processes, the goals and objectives of the project will be in jeopardy.

Sub-district headmen played the least but significant role in the project. They acted as facilitator to bring together all stakeholders of the project. They may also play a part to bring attention of the officials at the departmental levels in the province to the project. With a role in local administration, they can communicate with other higher administrative levels that should support the project, both in kind and finance.

Finally, there must be a common understanding of the plan, stakeholder roles, and approach to management of the process (Boettiger et al., 2017) for the project to achieve its goal. With the POLC framework as a platform for managing the adoption and use of *B. megaterium*, the policy makers at either departmental or ministerial levels should be able to plan and direct appropriate resources to promote the use of other environmental friendly bioproducts nationwide.

CONCLUSIONS

A change in the behavior of the growers requires management over time. Empowering the groups of people and organizations involves 1) planning, 2) organizing, 3) leading, and 4) controlling. The POLC framework, which has been applied to manage the group of growers in Uttaradit and Phetchaburi, has been found to be satisfactory to manage the adoption and use of beneficial bacterium *B. megaterium* for growers in Thailand.

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