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Understanding adoption, non-adoption, and discontinuance of biological control in rice fields of northern Iran

Gholamhossein Abdollahzadeh [a,*], Christos A. Damalas [b,**], Mohammad Sharif Sharifzadeh [a]

[a] Department of Agricultural Extension and Education, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
[b] Department of Agricultural Development, Democritus University of Thrace, GR 682 00 Orestiada, Greece

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ABSTRACT

Biological control of pests can reduce unnecessary pesticide applications in crop production, but research on the adoption of this strategy and the post-adoption status over a long period is limited. In this study, we examined factors affecting adoption, non-adoption, and discontinuance of the use of biological control with *Trichogramma* spp. for the management of the Asiatic rice stem borer [*Chilo suppressalis* (Walker)] in rice (*Oryza sativa* L.) fields of Iran. Information was collected from 415 rice farmers of Golestan Province of northern Iran. A significant proportion of farmers did not adopt biological control, whereas most early adopters dropped it soon after adoption and turned back to the use of pesticides. Attributes of the biological control method and certain perceptions of farmers, such as compatibility of the technology (i.e., consistency with existing values, prior experiences, and needs of farmers), perceived self-efficacy about the method, facilitating conditions (i.e., technical support), perceived usefulness and ease of use of the technology were significant factors for the adoption. Additionally, farmers who perceived benefits of pesticide use, those who were more concerned about safe use of pesticides, those who produced high rice yields, and those who had high annual farm income were less likely to adopt biological control. On the other hand, the likelihood of rejection decreased with increased education level, perceived self-efficacy about the method, increased off-farm income, and information from plant protection staff. The likelihood of discontinuance decreased among farmers with large area under rice cultivation. Policies geared at promoting the biological control in rice fields of the study area should point out its usefulness and ease of use to farmers to guarantee continuous and long-term use after initial adoption. Local stakeholders should monitor the process of biological control adoption and support the initial stages of the process by providing technical support and effective incentives.

1. Introduction

Rice (*Oryza sativa* L.) cultivation has a stable share in the agriculture of the northern provinces of Iran, notably of Guilan, Mazandaran, and Golestan, but production in these areas suffers major yield losses by certain harmful insects. The Asiatic rice stem borer, *Chilo suppressalis* (Walker) (Lepidoptera: Crambidae), is a dominant pest of rice in all rice-producing regions of Iran (Noorhosseini et al., 2010; Abdollahzadeh et al., 2016a). In Asia, this borer is responsible for an average annual yield loss of 5–10% of the rice crop, with occasional localized outbreaks causing losses up to 60% (Pathak and Khan, 1994). In recent years, diverse control methods, including cultural control, chemical control, biological control, and pheromone trapping, have been used as a means to reduce rice stem borer damage (Abdollahzadeh et al., 2016b, c).

Biological control with the release of natural enemies of rice stem borer, i.e., *Trichogramma* spp. (Hymenoptera: Trichogrammatidae), was proposed as a promising pest control method (Noorhosseini et al., 2010), particularly for smallholder farmers who often spend a significant part of their resources on preventing infestation of this pest in their rice fields. The implementation of governmental supportive programs in Iran made biological control readily accessible to farmers, through coverage of parts of cost, free provision of biological agents, farmer field schools, and extension

* Corresponding author.
** Corresponding author.
E-mail addresses: abdollahzade1@gmail.com (G. Abdollahzadeh), chris.damalas@yahoo.gr, cdamalas@agro.duth.gr (C.A. Damalas).

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training (Abdollahzadeh et al., 2016b). Thus, this type of pest control soon gained popularity among rice farmers of Golestan, with production areas treated with *Trichogramma* spp. showing a sharp increase from 2,100 ha in 1996–1997 to 41,930 ha in 2012–2013 (GAJO, 2016).

An integrated pest management (IPM) program focusing on biological control of pests with the use of natural enemies that parasitize the eggs of moths (Lepidoptera), including the Asiatic rice borer, was firstly undertaken in rice fields of Iran in 1990 (Razzaghi-Borkhani et al., 2011). Parasitism and predation of rice borer eggs were important regulating factors of the population so that up to 80% control of this species could be achieved with the release of *Trichogramma* spp. in rice paddies (Rani, 1998). However, barriers such as inadequate support services, inadequate technical facilities, poor skills of farmers, and climate incompatibility with biological control negatively affected farmers' adoption decision (Abdollahzadeh et al., 2015). There are numerous studies on the use of *Trichogramma* for pest control in a number of crops; however, elements such as geographical relevance, ecosystem suitability regarding micro-climatic conditions, target cropping system, target hosts, and alternative hosts, compatibility with other management approaches being implemented within the context of IPM influence effectiveness (Kumar et al., 2013; Wu et al., 2016). Furthermore, the difficult procedure to define an economic threshold, the lack of sufficient technical information (Veisi et al., 2009), the lack of success of some biological control programs, and the high cost also impede farmers' decision for adoption of biological control (Goldberger and Lehrer, 2016).

Informed by common behavioral models such as the Diffusion of Innovation Theory (DIT) (Rogers, 2003), the Theory of Planned Behavior (TPB) (Ajzen, 1991), and also the Technology Acceptance Model (TAM) (Davis, 1989), in the present study we examined three types of behavior in the use of *Trichogramma* spp. as a biological control method of rice stem borer, including initial adoption, rejection, and discontinuance after the initial adoption among rice farmers of Golestan Province of northern Iran. Much of the literature regarding technology acceptance follows the DIT, TPB, and TAM traditions. For example, the DIT explains the diffusion in two ways: first, it considers the innovativeness of the potential user and second, it considers the attributes of the innovation, such as its relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). Yet, only the relative advantage, compatibility, and complexity were consistently related to innovation adoption (Plouffe et al., 2001). The TAM suggests that a decision to accept a technology is determined by two key perceptions, i.e., perceived usefulness (PU) and perceived ease of use (PEOU) (Davis, 1989). TAM and DIT are highly similar in some constructs and they also supplement each other. For example, relative advantage is considered similar to perceived usefulness, whereas complexity is considered similar to perceived ease of use (Wu et al., 2007).

Additionally, farmers' self-efficacy and facilitating conditions will lead to perceived behavior of control towards the adoption of biological control. According to the TPB, perceived behavior of control is defined as the individual's perception of how easy it is to perform a specific action (Ajzen, 1991). This factor is relevant to farmers' use of biological control, because resources, knowledge, and ability to use *Trichogramma* spp. can be measured through farmers' perceptions. To facilitate effective use of biological control, it is essential to have a better understanding about what farmers need and to improve their technical skills with necessary and well-matched resources (including free access to *Trichogramma*, extension agents, training workshops and courses, consultants, and all relevant information) (Abdollahzadeh et al., 2016b). Moreover, self-efficacy of farmers, defined by Bandura (1977) as people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performance, also plays a major role. Self-efficacy is not concerned with the actual skills of an individual, but with judgments of what an individual can do with whatever skills he possesses (Bandura, 1977).

The objective of this study was to examine factors that affect farmers' behavior concerning adoption, rejection, and discontinuance of *Trichogramma* spp. use for the control of rice stem borer in paddy fields of Golestan province, Iran. As data in this area of research are limited, the study is important because it reveals constraints on the adoption and continued use of the biological control technology and also it helps to understand the patterns of abandonment after adoption.

2. Materials and methods

2.1. Study area

The study focuses on rice farmers in the province of Golestan in the northeast of Iran (Fig. 1). Rice cultivation is an integral part of the cropping system, with an area of more than 55,000 ha. This area was also chosen in part because of its prevalence of public sector programs that provide technical and financial assistance to farmers for increasing biological control of rice stem borer in their farms.

2.2. Sample selection

The target population of the study was stratified into 11 counties of Golestan province in northern Iran with experience in biological control programs for rice stem borer control with the use of *Trichogramma* spp. ($N = 1{,}421$). Villages of each county were used as clusters. Two villages with at least some farmers with more than three years of biological control use were randomly selected from each county. Adopters (farmers who were applying *Trichogramma* spp. for the control of rice stem borer), discontinuers (farmers who used *Trichogramma* spp. for the control of control rice stem borer in the past and then dropped it after the cessation of the government incentives), and non-adopters (farmers who did not adopt *Trichogramma* spp. for the control of rice stem borer, but used pesticides) were included in the study. Only villages that had the three groups of farmers were selected. Using the table of Krejcie and Morgan (1970), a sample of 400 rice farmers was randomly and proportionately selected from these 22 villages during 2015–2016. Field reports of the District Agriculture Service Center were used to identify an initial list of rice farmers. Therefore, in the 22 selected villages, lists of farmers were drawn up and prospective participants were grouped according to the three mentioned strata (adopters, discontinuers, non-adopters). From these lists, farmers were selected at random. To ensure access to the required number of questionnaires, the survey included 430 individuals and then 15 questionnaires out of these 430 were dropped due to incomplete or inconsistence response. Finally, 415 questionnaires were selected for analysis. To increase the accuracy and validity, data were collected via farmers' interviews in the local language by trained enumerators.

2.3. Data collection

A structured questionnaire consisting of three parts was used for the interviews. The first part covered farmers' socio-economic data such as gender, age, rice farming experience, education, family size, share of family labor force in rice cultivation, and off-farm income as well as farm characteristics, such as rice cultivation size, rice yield, annual farm income, and use of rice varieties resistant to diseases. The second part covered 28 items under the TAM, DIT, and