Research article

Characteristics of an Agricultural Innovation and Incentives for Adoption: Rhizobium in Cambodia

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Abstract In this paper we consider whether the processes of farm-level change and adoption of new technologies in Cambodia can be related to the adoptability characteristics of a technology. The literature posits that technologies can be assessed in terms of relative advantage, compatibility, complexity, trialability and observability. Other socio-economic factors may also be important in the adoption process. We test these propositions among commercial upland farmers in north-west Cambodia for rhizobium inoculation of legume seeds to increase crop yields. In promoting this technology the objective is to increase farm income and help to reduce poverty and improve food security. We surveyed farmers who have been involved in a project testing and demonstrating rhizobium inoculation (along with other technologies) and statistically analyzed the results. We found that, with respect to their rhizobium-adoption intentions, relative advantage (incentive) is the predominant characteristic, with observability also being important. Other socio-economic characteristics in their adoption, intentions included whether they grew legumes, the source of first contact, the period since the technology was introduced, and the size of farm. That the innovation demonstrated high relative advantage was confirmed by separate economic analysis of the likely return on investment for rhizobium in these upland farming systems. Using an approach of assessing adoptability characteristics prior to release provides a basis for developing and screening technologies for successful adoption, rather than trying to adapt ill-suited (in terms of these characteristics) technologies after the event. Such an approach is likely to be more efficient for project sponsors to achieve desirable change.

Keywords new technology, adoptability, relative advantage, rhizobium, Cambodia

INTRODUCTION

There are many constraints to improved crop production for upland farmers in Cambodia (Farquharson et al., 2006). Overcoming such constraints by development and adoption of new technologies or improved farm management techniques can lead to increased farm income to alleviate poverty and improve food security.

Typical economic and social constraints in these upland regions can include small farm sizes and lack of suitable facilities and machinery (i.e. economies of scale are not available and cost of production relatively high), availability of technologies or improved management techniques, levels of education and management or technical expertise, availability and cost of credit, availability of farm inputs of assured quality, marketing and transport options for farm products, adverse prices of inputs and outputs and options or incentives for adding value on farms (e.g. through on-farm storage). And poverty itself may be a trap in poor countries (Sachs, 2005) where natural, built and human capital can be very low.

Because any improvement must be considered in a farming systems context (McConnell and Dillon 1997), where many constraints may be limiting, it may be difficult for a farmer to observe the full expression from any particular change. However, the fertility of soil, and thus the nutrient level available to plants, is an important constraint to crop growth anywhere in the world. In north-west Cambodia many soils have recently been cleared of forest and are still relatively fertile for agricultural use. However, continued cropping without replacement of soil nutrients is unsustainable (e.g. for Cambodia see Martin et al., 2012); and long-term soil fertility decline has been observed in other places (e.g. for Australia see Dalal and Mayer, 1986).

Martin et al. (2012) report activity of farm-level trials, extension activities and farmer adoption intentions for rhizobium in Cambodian upland regions. In this paper we investigate rhizobium inoculum of legume seeds as an innovation or technology by considering adoptability characteristics.

UPLAND CROPPING SYSTEMS IN CAMBODIA

Production of rain fed crops such as maize and soybean has rapidly expanded in north-western Cambodia after reintegration of the former Khmer Rouge began in 1996 (Anonymous, 2004), although soybean production has declined since 2005. The area is mountainous and most of the cultivated areas have rich soil of volcanic or limestone origin. However, in the space of 10 years, crop yields are now declining and soils are being eroded and degraded by excessive cultivation and burning. The main crops grown in the upland areas of Battambang/Pailin, according to area sown, are maize (red corn), soybean, mungbean, sesame and cassava.

There was a rapid expansion in the area sown to maize in Battambang/Pailin between 2005 and 2009 but since 2009 the area of maize has declined and the area of cassava has correspondingly increased. The area sown to soybean, mungbean and sesame has also declined. This is indicative of a trend towards an over-reliance on production of maize and (more recently) cassava with the potential to lead to soil degradation and fertility decline.

Unlike Cambodian lowland rice producers, who are often at subsistence levels in their operations, the upland farmers in the regions studied by Martin et al. (2012) are primarily commercial as indicated by surveys conducted within the project. This has implications for their farm objectives and response to innovations. The regions studied were those of Martin et al. (2012).

OPTIONS TO INCREASE CROP YIELD

Options to increase crop yields include better varieties, certified seed, improved agronomic practices, reduced tillage, better weed and pest control, fertilizer application and legume crop rotations. Biological nitrogen (N) fixation by crop legumes is a key process in agriculture and inoculation of legume seeds with rhizobia can increase the effectiveness of legume growth and the N-supplying capacity of the soil (Herridge, 2005).

Pin et al. (2009) demonstrated that rhizobial inoculation can replace N fertilizer for mungbean, peanut and soybean at a much reduced cost and reduced environmental impact. The results were comparable to those obtained in other countries. Significant increases in grain yields of mungbean (7%), peanut (15%) and soybean (12%) were obtained by rhizoidal inoculation and the response was equal to (soybean) or better than (mungbean, peanut) application of 40 kg N/ha. Inoculation increased the number of nodules per plant by 23% for mungbean, 39% for peanut and 66% for soybean. Rhizoidal inoculation was included in on‐farm demonstrations of improved technologies in collaboration with Provincial Department of Agriculture staff as well as non‐government organizations. Early results indicate that farmers are interested in inoculation but lack of understanding, access to rhizobium and the ability to adopt the technology. The purpose of this demonstration was to give farmers 'hands‐on' experience and practice in rhizobial inoculation.

ON-FARM RESEARCH AND EXTENSION

On-farm experiments and demonstrations with rhizobium inoculation were carried out at Samlout district in Battambang Province, north-west Cambodia between 2008 and 2010. In 2010, twelve on−farm rhizobium inoculation demonstrations of soybean and sixteen demonstrations of rhizobium inoculation for peanut were held. The objectives were to implement on‐farm demonstrations of rhizobium inoculation of peanut and soybean; to measure the effect of inoculation on nodulation, growth and seed yield of the crops; and to determine the impact of inoculation on farmer's cash income through gross margin (GM) and partial budget analysis.

In 2010, rhizobium inoculation increased the average soybean kernel yield by 15% from 2.944 to 3.379 t/ha. Peanut kernel yield was increased by 12% from 3.493 to 3.920 t/ha. Rhizobium inoculation increased the crop gross margin (GM) for soybean by 4% from US$884 to US$916/ha. For peanut, the GM increased by 15% from US$1,869 to US$2,148/ha.

From the farmer's point of view the economically important measure is the return on investment for funds used in a new technology (CIMMYT, 1988). How does the likely return compare to the opportunity cost of funds? Economic analyses by Farquharson et al. (2006), Farquharson et al. (2008)and (Scott, 2008) have shown relatively high returns on investment for rhizobium, depending on the price at which inoculums can be delivered to the farm gate.

ADOPTABILITY OF TECHNOLOGOES AND RESEARCH QUESTION

Rogers (2003) distinguished and gives the effort of studying the characteristics of adopters and the properties of an innovation influencing the rate of adoption. He developed a classification scheme describing the perceived attributes of innovations. Five different attributes were proposed by Rogers (2003): relative advantage (the degree to which an innovation is perceived as being better than the idea (or practice) it supersedes); compatibility (the degree to which an innovation is perceived as consistent with existing values, past experiences and needs of potential adopters); complexity (the degree to which an innovation is perceived as relatively difficult to understand and use); trialability (the degree to which an innovation may be experimented with on a limited basis); and observability (the degree to which the results of an innovation are visible to others).

Pannell et al. (2006) discussed adoption of innovations through a cross-disciplinary lens, where a dynamic learning process is related to the achievement by the farmer of landholder personal goals. They considered that innovations are more likely to be adopted if they have a high relative advantage and are readily trialable. The research question addressed in the Cambodian study was how rhizobium as an innovation is assessed by potential innovators in terms of Rogers' five attributes. The hypothesis tested was that adoption intentions were related to these innovation attributes and other factors and, if so, which innovation attributes were most important.

METHODOLOGY

A survey questionnaire was developed for individual farmer interviews asking about their personal circumstances (e.g. age, farm size, crops grown, and farming experience), their previous exposure to rhizobium (i.e. workshops attended, village trials) and whether they would adopt rhizobium. Their responses to Rogers' (2003) five attributes, were assessed in categorical forms (i.e. Yes/No/Undecided). The survey was conducted in four villages of Samlout district in June 2011 by researchers from the Cambodian Agricultural Research and Development Institute (CARDI). The survey questions were translated and recorded in Khmer.

A logistic model (e.g. see Askar et al., 2006) was developed to test statistically the determinants of adoptability of a technology such as rhizobium. The data were also analyzed with log-linear models that examined whether the responses of farmers were independent of their personal circumstances and experience of rhizobium. Logistic regression analysis was used to analyze adoption intentions and the importance of innovation attributes.

RESULTS

The total number of farmers interviewed was 59, out of which 57 were deemed suitable (Table 1). Of these, 46 indicated that they would and 11 that they would not adopt rhizobium. Results for the significance of innovation characteristics are shown in Tables 2 and 3.

Table 1 Farmer interview numbers by villages, June 2011 Samlaut

Village	Kantout	Sre reach	Beong Run	Kampong Touk	Total
Interviews	14	16	11	16	57

Table 2 Statistical importance of rhizobium innovation characteristics

Decision to adopt rhizobium by farmers according to	Statistical significance
Relative advantage	**
Compatibility	NS
Complexity	NS
Trialability	NS
Observability	*

*Significance: <0.001 '***', <0.01 '**', <0.05 '*', <0.10 '.', >0.10 'Not Significant (NS)'*

Relative advantage was highly significant and observability moderately significant, whereas the other characteristics were not significant (Table 2) in the adoption intention decision. For other factors influencing adoption intentions, the source of first contact and whether farmers grew legumes were highly significant, the period since rhizobium was introduced and size of farm was moderately significant, a farm workshop was not very significant.

DISCUSSION

When donors fund integrated farm-level projects there is an opportunity to conduct activities including agronomic trials; on-farm demonstrations and field days; economic analysis of technologies, management changes and farming systems; and social analysis of farmer characteristics interacting with difficult and dynamic learning and change processes. In this paper we report on work which considered the characteristics of innovations as perceived by farmers after they had experienced such project activities where the technology was introduced and demonstrated. These activities provided a basis for an objective consideration of the adoption decision.

In terms of innovation characteristics, relative advantage was most important and observability was also highly significant. With respect to relative advantage Pannell et al. (2006, p.1415) noted that 'among those farmers with a focus on profit, the farm-level economics of a proposed practice will be important'. The ability to observe the new technology perform in real-farm situations is also highly important. Thus relative advantage and observability were found to be most important to these commercial farmers.

Of the other socio-economic factors influencing adoption the farmers responses indicated that a trusted source of information and (for rhizobium inoculation) whether they grew legumes were important. The size of farm and period of time to consider the technology were also important, but not gender or age of these farmers.

Table 3 Statistical importance of other factors

Decision to adopt rhizobium by farmers according to	Statistical significance
Gender of farmer	.
Period since rhizobium was introduced	*
Source of first contact	**
Observing locally	NS
Attended a rhizobium workshop	NS
Age of respondent	NS
Size of farm	*
Presence of off-farm work	NS
Grow legumes	**
Attended farm demonstrations	NS
Attended farm workshops	.
Years of experience farming in Samlout	NS

*Significance: <0.001 '***', <0.01 '**', <0.05 '*', <0.10 '.', >0.10 'Not Significant (NS)'*

If adoptability is important in generating successful farm-level outcomes (and successful project outcomes) then a process of assessing the characteristics of technologies or innovations prior to their promotion to the farming community may be valuable to project funders and sponsors. The innovation attributes assessed in this paper have been incorporated into a screening process (called the ADOPT tool) for this purpose (see Kuehne et al. (2011). More widespread use of such a tool could be advantageous to research funders and sponsors.

CONCLUSION

The Cambodian upland farmers exposed to the rhizobium inoculation technology for legume seeds assessed this technology in terms of five important characteristics suggested by the literature for successful innovations. A survey and statistical analysis showed that relative advantage was the most important trait for adoptability. An existing tool (ADOPT) to predict outcomes according to these traits is available. Perhaps project funders who do not already do so, could consider testing such a tool to augment project development processes and improve the probability of project success.

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