Development of a weed identifier mobile application for Cambodian rice farmers

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Abstract
Cambodian farmers in most areas have shifted their rice planting method towards direct seeding. Yet, direct seeding systems are more prone to weed infestation. Without proper management, weeds can cause seed contamination and yield loss. As weed species in rice fields are diverse, the effective control strategy can be different for each species; being able to identify the weed species that are present is therefore essential. A mobile application (App) may be an effective tool to empower farmers with the information needed to identify and control weeds. A survey regarding weed seed contamination in harvested rice paddy in two provinces was undertaken to determine common weed species of rice in Cambodia. A WeedID prototype App with the ten most common weeds was subsequently designed and developed. The mobile application was evaluated through a survey conducted in Northwest Cambodia. Moreover, more weed species were added to the database to make a total of 30 different weeds. WeedID received interest from enthused Cambodian farmers; it could be an effective information tool to offer better farming decision support and to improve practices to control weeds in rice.

Keywords
Cambodia, rice, weed, mobile application.

Introduction
In 2013, Cambodia exported 1.2 million tonnes of rice (*Oryza sativa* L.) which accounted for 3% of total worldwide rice exports (FAO 2014). Due to water unavailability, diminishing labour supply and increasing labour costs, the predominant rice planting method in Cambodia has shifted from transplanting to direct seeding in Northwest Cambodia (Kamoshita et al. 2009). Although direct seeding requires less labour than transplanting, weed infestation with direct seeding is a primary concern and regardless of planting method the threat of weeds in rice is unavoidable and severe (Matloob et al. 2015). The presence of weeds can significantly influence quantity and quality of rice. Failure in managing weeds at critical periods can result in yield losses of more than 50% (Singh et al. 2005). It is not just the presence of weed plants during cultivation that is a problem; weed seeds can contaminate the rice grain at harvest resulting in a lower rice selling price or even worse, product rejection at rice mills with consequent negative financial impact on farmers. If farmers use their own seed for re-planting, there is an additional risk of increasing the weed seed bank in rice fields. Knowledge of weed control, therefore, has the potential to mitigate financial losses for rice farmers. Different types of weeds require different methods and strategies for effective control so it is important for farmers to identify which weeds are present. Smartphone use in Cambodia has increased significantly over the years and have reached rural populations (Vuthy et al. 2013; Kimchhoy 2015). The aim of this project is to discover whether a mobile application could be a useful medium to transfer the information on weed identification to the Cambodian farmers in order to support them to make better farming decisions and practices for controlling weeds.

Materials and methods
The methodology for this project is divided into four stages and is based on Jason Clarke's innovation model, IDEA which stands for Invent/Imagine, Develop/ Design, Evaluate and Act (ARN 2013).

1) Weed Seed Contamination on Rice Survey (Invent)
   The idea for inventing this App was conceived from a survey of weed seed contamination in harvested rice paddy and rice that had been sun-dried along roadsides in two provinces in Cambodia, namely Battambang and Takeo. 71 samples and 50 samples of harvested paddy rice were collected from five districts in each of Battambang and Takeo provinces respectively; each sample was 500 g. Weed seeds were separated from the sample by hand and inspected with a HOT

S06 digital microscope with magnification up to 200x. For identification, weed seed specimens were compared with a collection of HOT seed images of 186 weed species commonly occurring in Cambodia (R. Martin unpublished). In addition, a logistic regression was used to test for differences in the probability of finding weeds at the province and district level.

2) Mobile App Design and Development
The storyboard and user interface of the mobile App design was created in the form of webpages utilising WordPress. The ten most common weeds in rice paddies according to the survey in Battambang and Takeo provinces were entered into the App database and developed into a mobile App prototype by Nic Barker. The weed data included the photographs of weed seeds, flowers, seedlings, and distinguishing features of immature plants (e.g. leaf base auricles and ligules for grasses), their common name, scientific (binomial) name, family, descriptions/characteristics (from Dr Robert Martin's weed database), habitat, and particular ways to control them. In addition, as this App was tailored for Cambodian farmers, the information in the App was translated into Khmer language by Dr Van Touch.

3) Mobile App User Evaluation
The mobile App prototype was evaluated in a survey as a part of a larger Participatory Rural Appraisal (PRA) survey and was presented to 41 farming households in two provinces in Northwest Cambodia (i.e. Battambang and Banteay Meanchey provinces). It was undertaken in collaboration with Cambodian students from Meanchey University and the University of Battambang. Firstly, farmers were asked to try the App, then they were asked in a semi-structured interview to get their feedback on the usability and usefulness of the App. The interview entailed a series of simple yes/no and open-ended questions, for example, what features or information which they would suggest to add or delete.

4) Further Development of Mobile App (Act)
Based on the diversity of weed species contaminating rice paddy, more weed species were included into the App database to make a total of 30 species.

Results and Discussion

From the weed seed contamination survey in Battambang and Takeo, seeds of 41 different weed species were found in the rice samples. There were 13 plant families represented: Poaceae (10); Cyperaceae (9); Fabaceae (5); Comellinaceae (3); Convolvulaceae (3); Asteraceae (2); Malvaceae (2); Phyllanthaceae (2); Linderniaceae (1); Onagraceae (1); Sphenocleaceae (1); Teliaceae (1); and Xyridaceae (1).

The incidence of seeds of weed species was broadly similar for both provinces. The most common grass species was *I. rugosum*, the most common broadleaved species was *M. corchorifolia* and the most common sedge was *F. miliacea*. *Ischaemum rugosum* was significantly more common in Takeo (occurring in 88% of samples) compared to Battambang (56%). *Echinochloa crus galli* and *A. americana* were common in Battambang but absent or rare in paddy samples from Takeo (Figure 1).

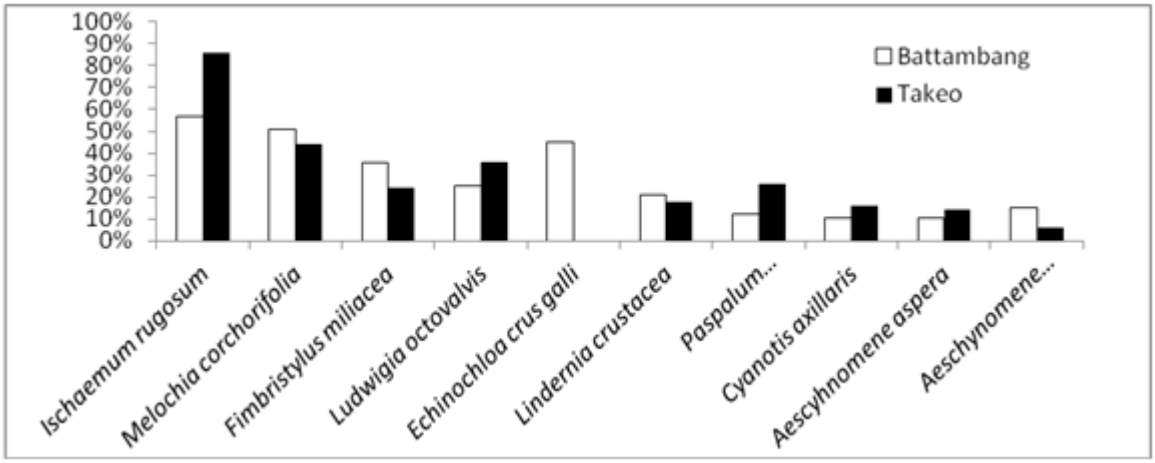

Figure 1. Incidence of the 10 most important weed species for seed contamination in rice paddy in Cambodia (percent presence in samples).

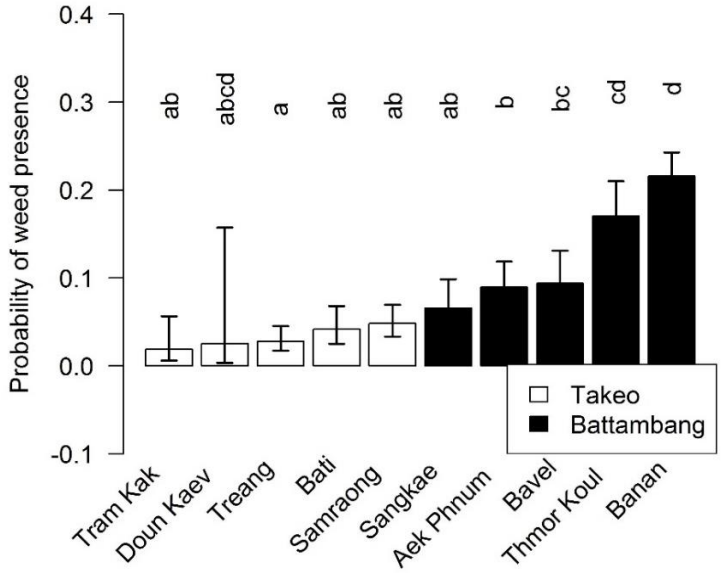

Figure 2. Probability of weed species occurrence as affected by district. Error bars show the 95% confidence intervals and lettering shows the results of pairwise comparison (Tukey HSD) with significance level α = 0.05.

Results of the logistic regression analysis showed that district is a significant predictor of weed presence ($p < 0.05$). Furthermore, there is a significantly higher probability of finding weeds in Thmor Koul and Banan districts in Battambang province (Figure 2). There was a greater number of weed species found in these districts compared with other districts in Battambang and Takeo. The long-standing rice seeding practice in Battambang is aerobic broadcast seeding ahead of the monsoon rains and, where available, irrigation flows. This practice is subject to much higher weed pressure with a broader weed spectrum than flood-irrigated rice (Balasubramanian and Hill 2002). It is suggested that the greater incidence and weed species diversity in Battambang compared with Takeo is the result of a longer history of dry broadcast seeding in Battambang (Nesbitt 1997).

The App was named WeedID and, aside from language translation Apps, this is one of only a few mobile Apps to offer information in Khmer. The interface of the App is straightforward. As the App is run, four options will be given which include seed, seedling, flower, and mature (**Error! Reference source not found.** left). Each option will lead to a gallery of pictures accordingly, for example, if "seed" was chosen, the user would be taken to a gallery of weed seeds (**Error! Reference source not found.** centre) which then provide a weed species information of the chosen image (**Error! Reference source not found.** right).

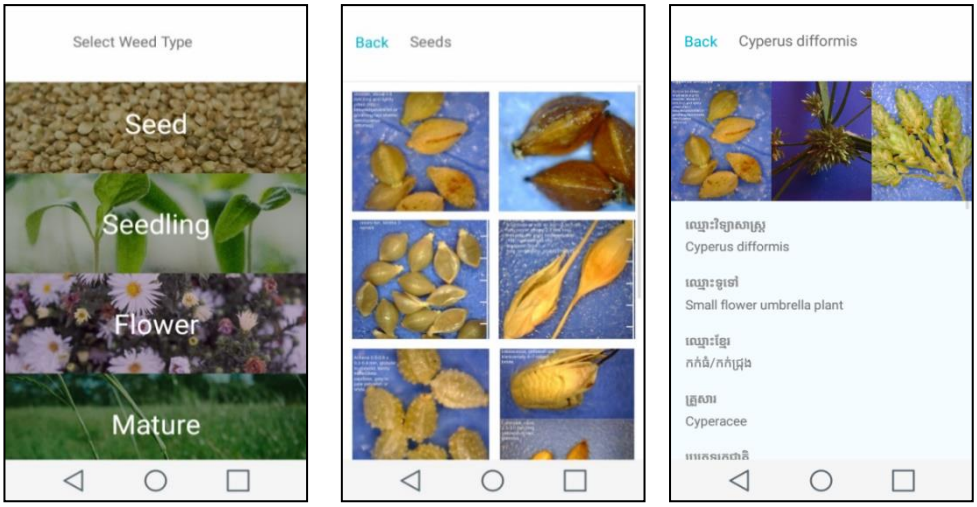

Figure 3. Cambodian Farmers Weed Identification App Screenshots. WeedID homepage (left), A gallery of weed seeds (centre) and information page of specific weed species in Khmer language (right).

An evaluation of the App was performed through the Participatory Rural Appraisal (PRA) survey and the App received positive responses from farmers. Approximately 84% of the 41 respondents claimed to be interested in the App and would use the App beyond the survey. The remaining 16% were not interested as they either did not regard weeds as a significant issue for their paddy field, or they claimed to have been able to manage weeds effectively. Not every farmer owned a smartphone; approximately 30% had their own smartphone, whilst 35% had family members who had smartphones. The remainder did not have a smartphone in the collective household. Nevertheless, from the PRA survey, it was common for farmers to share information with each other. In spite of a proportion of farmers not possessing a smartphone, they are still able access to the mobile App through their neighbours' smartphone.

Conclusions

The WeedID App was positively received by the majority of farmers; additionally, access to a smartphone is common. A mobile application may be construed therefore as an effective medium to transfer information regarding weed identification and management to empower Cambodian farmers to make better farming decisions and practices.

Acknowledgments

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